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BEFORE THE BOARD OF ENVIRONMENTAL REVIEW
OF THE STATE OF MONTANA

IN THE MATTER OF: **APPEAL AMENDMENT AM4,** **WESTERN ENERGY COMPANY,** **ROSEBUD STRIP MINE AREA B** **PERMIT NO. C198400B**	**CASE NO. BER 2016-03 SM** **AFFIDAVIT OF ALEXIS BONOGOFSKY IN SUPPORT OF PLAINTIFF'S MOTION FOR SUMMARY JUDGMENT**

I, Alexis Bonogofsky, hereby declare:

1. I am over eighteen (18) years old, I am competent to testify, and have personal knowledge of the matters set forth herein.
2. I am a fourth generation Montanan and I live at 2020 Tired Man Road, south of Billings, MT on the Yellowstone River on my family's farm and ranch. My partner and I operate Blue Creek Boers, a meat operation. My family has farmed and ranched since they homesteaded in Montana over 100 years ago. In addition, I am a fellow with the Lannan Foundation. In this capacity, I write about politics and energy issues mostly centered around southeastern Montana and document eastern Montana landscapes with photography. Previously, I was the Tribal Lands Program Manager for the National Wildlife Federation. In that capacity, I worked with Tribes on issues ranging from energy issues such as coal, oil and gas, to bison restoration on tribal lands. I continue to work with the Northern Cheyenne tribal community on climate change issues and on environmental issues including water and air pollution related to energy production and development. In addition, I also work with ranchers in southeast Montana on these same issues. Because of my work and personal relationships with the tribe and ranchers, I travel frequently, sometimes up to once or twice a week, to the Colstrip and Lame Deer areas. I am also a big game and upland bird hunter. I do the majority of big game hunting at the L&L Ranch, approximately 17 miles south Colstrip. This is the place where I shot my first mule deer and for over three years I have pursued elk, mule deer, and antelope on this ranch and plan to do so every year that

conditions allow in the future. Hunting is a way of life for me, as I grew up hunting with my mother and father. Hunting provides food for my partner and myself throughout the year. The L&L Ranch is an amazing place for high quality hunting opportunities and provides us with a unique experience that you cannot find anywhere else in Montana. You cannot step a foot in any direction without seeing amazing natural beauty and history of the American West. We are planning to hunt on the L& L this coming fall.

3. I have been a member of the MEIC since October 2012, and currently serve on the Board of Directors. MEIC is a nonprofit corporation founded in 1973 by Montanans concerned about protecting and restoring Montana's natural environment. MEIC has worked extensively on addressing the impacts of air pollution in Montana. I have also been a member of the Sierra Club since 2009. The Sierra Club is the nation's oldest grassroots conservation organization, founded in 1892. The Sierra Club is waging a national campaign to both hold polluters in the coal industry accountable and to speed the nations transition to cleaner fuels. These efforts extend to Montana.
4. As a hunter, I spend on average 3 to 5 days pursuing big game on the L&L. I spend at least 60 additional days a year in and around Colstrip and Lame Deer, Montana. During my trips to the Colstrip area, I have occasionally seen from a distance the mining operations occurring at the Rosebud mine. This is concerning for me, as I'm aware of the impacts of coal strip mining to the ecology and water quality of southeastern Montana.

5. Growing up on the ranch on the Yellowstone River, I was taught that the land provides for us and we, in turn, need to protect the land. I grew up eating almost exclusively wild game that my family hunted and vegetables that we grew on our farm. Recently, an Exxon oil pipeline ruptured underneath the Yellowstone River and our land was flooded with oil. That disaster has impacted our land greatly and has shown me what pollution can do to the wildlife, plants and livestock that we raise and my own health. It has been devastating to our operation. I am on the Board of the national organization Pipeline Safety Trust. I grew up living around three oil refineries and a coal fired power plant in Billings. The air pollution from these sources impacts the air quality in our region and water quality in the Yellowstone River. I personally have been impacted by environmental pollution my whole life, and now work to protect other people and wildlife from the effects of pollution.
6. I am deeply concerned about the water pollution from the Rosebud Coal mine and its potential impacts on the health of the land and the wildlife that I hunt on the L&L ranch. I believe that the pollution from the Rosebud Coal mine is the major source of water pollution directly north of the area where I annually hunt. I'm aware that the segment of East Fork Armells Creek that flows north from Colstrip is considered an impaired water body by the Montana Department of Environmental Quality. This impairment is due to elevated levels nitrate plus nitrite, electrical conductivity, total dissolved solids, and total Kjehldahl nitrogen. The DEQ has listed coal mining as a probable source of impairment.

7. The L&L Ranch is characterized by large sandstone rock formations flanked by shortgrass prairie and large buttes dominated by pine forests. Besides Rosebud Creek, which is the eastern boundary of the ranch, there is little surface water on the property.
8. Southeastern Montana is a semi-arid climate and therefore existing streams, creeks and wetland areas are extremely important to wildlife that live in the area. Any surface water is an extremely valuable resource in southeastern Montana and necessary to sustain the high quality hunting opportunities that southeast Montana offers. Any impacts to water, whether it is a spring drying up or the discharge of pollution, impacts the wildlife resource.
9. I am concerned and worried that the deer, antelope and elk that I hunt on the L&L are exposed to pollution from the Rosebud mine when they drink out of East Fork Armell's Creek and Rosebud Creek, which is just north and northeast of the ranch that I hunt on, and that pollution impacts their health and, in turn, my health. I am also concerned that they suffer from degraded habitat caused by the strip mine.
10. I am extremely concerned about the toxins being exposed to the wildlife that I eat. We know that wildlife pick up toxins from pollution in the water, and to my knowledge, there have not been studies conducted on the wildlife that live in and around the Rosebud mine.
11. Improving the water quality in the region I work and hunt in will have a positive impact on my health, my family's health, my work, my hunting

opportunities, and my ability to view the scenic vistas and landscapes in southeastern Montana.

12. I declare under penalty of perjury that the foregoing is true and correct.

5-4-16
Date

Alexis Bonogofsky
Alexis Bonogofsky

Subscribed and sworn before me this 4th day of May, 2016.

Carole Carranco
Notary Public for the State of Montana
Residing at Billings
My Commission Expires: 11-16-2019

CAROLE CARRANCO NOTARIAL SEAL STATE OF MONTANA

CAROLE CARRANCO
NOTARY PUBLIC for the
State of Montana
Residing at Billings, Montana
My Commission Expires
November 16, 2019

"Healthy environment, healthy people"

Montana Department of
ENVIRONMENTAL QUALITY

Steve Bullock, Governor
Tracy Stone-Manning, Director

P. O. Box 200901 • Helena, MT 59620-0901 • (406) 444-2544 • Website: www.deq.mt.gov

January 15, 2014

Ms. Dicki Peterson
Western Energy Company
Rosebud Coal Mine Area B, C1984003B
P.O. Box 99
138 Rosebud Lane
Colstrip, MT 59323-0099

Permit ID: C1984003B
Revision Type: Amendment
Permitting Action: Deficiency
Subject: AM4, Sixth Round Acceptability Deficiency

Dear Dicki:

The Department of Environmental Quality (DEQ) has completed its acceptability review regarding Western Energy Company's application for Amendment AM4. The following deficiencies must be adequately addressed before DEQ can determine the application acceptable:

ARM 17.24.314(3):

Please provide more detail on the surface water model used to create tables G-1, G-2, G-3, and G-5. Specifically, state the inputs to the model that were used and how they were calculated. A map or a reference to an exhibit in the permit is also needed as it is unclear how many sub-basins were used, how the streams for the model were calculated or which streams were used, and how the model was constructed. An example can be provided upon request.

The explanation as to why Areas A, B, and C can be analyzed separately from Areas E and D should be included in the text of the PHC.

P. 36 Section 4.2.4.1 General Water Quality Evaluation: A statement was added to the revised PHC determination that states: "A sample is considered to represent baseline conditions if it was collected before mining approached within 0.5 miles. There were no samples meeting this criterion for overburden, interburden and sub-McKay wells, as mining started in 1975." Although not numerous, there are water quality samples for these units that were collected and analyzed prior to encroachment of mining within a half-mile. Please check to confirm the statement in the PHC is accurate.

Figure 23A, Simulated Potentiometric Heads, Pre-Mine Conditions still has the proposed Area F permit outline on it. The data may be used, but the permit outline must be deleted.

As a suggestion for future documents, a list of acronyms or introduction of the terms an acronym represents (e.g. PHC, TDS) during its first use in a document would be helpful to a reader

unfamiliar with commonly used permit acronyms. The acronym "PHC" appears to be used to represent the probable hydrologic consequences *determination* as well as probable hydrologic consequences of mining and causes confusion. In future documents please use "PHC" to represent the probable hydrologic consequences determination, as that is the most common use of the acronym.

Upon receipt of satisfactory responses to these deficiencies, DEQ will determine the application to be acceptable.

Please feel free to contact Robert D. Smith at 406-444-7444 with questions regarding this letter.

Sincerely,

Chris Yde, Supervisor
Coal and Uranium Program
Industrial and Energy Minerals Bureau
Phone: 406-444-4967
Fax: 406-444-4988
Email: CYde@mt.gov

C: Jeff Fleischman, Office of Surface Mining
Gene Hay, Office of Surface Mining

FC: 620.112 (AM4)

May 3, 2013

Ms. Dicki Peterson
Western Energy Company
Rosebud Coal Mine Area B
P.O. Box 99
138 Rosebud Lane
Colstrip, MT 59323-0099

Permit ID: C1984003B
Subject: PHC for AM4 (Amendment Application 184)

Dear Dicki :

Per your request, this letter summarizes the outcome of our phone conversation Tuesday morning (April 30, 2013) between DEQ staff, Western Energy staff, and your hydrology consultant, Michael Nicklin, regarding the PHC necessary to complete review of AM4 (Amendment Application 184).

The PHC needs to comprehensive for areas A, B, and C. The PHC should include analysis of potential hydrologic impacts for all permitted mining in Rosebud Mine areas A, B, and C, as well as the proposed cuts in Area B (AM4). There is no need to complete PHC's for individual areas, as the Rosebud Mine as a whole needs to have a single comprehensive analysis for all surface water and groundwater impacts. The proposed cuts associated with currently unapproved minor revisions for Area A should not be included.

Any deficiencies identified after review in the PHC will be included in the next AM4 response letter.

Please feel free to contact me if questions remain or if I failed to consider some aspect of our conversation.

Sincerely,

Chris Yde, Supervisor
Coal and Uranium Program
Industrial and Energy Minerals Bureau
Phone: 406-444-4967
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Email: CYde@mt.gov

FC: 620.112 (AM4)

Exhibit 17

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MONTANA BOARD OF ENVIRONMENTAL REVIEW

IN THE MATTER OF: **APPEAL AMENDMENT AM4 WESTERN ENERGY COMPANY ROSEBUD STRIP MINE AREA B, PERMIT NO. C1984003B**	Case No.: BER 2016-03 SM RESPONDENT'S RESPONSES TO PETITIONER'S SECOND SET OF REQUESTS FOR ADMISSION, INTERROGATORIES AND REQUESTS FOR PRODUCTION

Respondent, Department of Environmental Quality ("DEQ") responds to PETITIONER'S SECOND SET OF REQUESTS FOR ADMISSION, INTERROGATORIES AND REQUESTS FOR PRODUCTION as follows:

DISCOVERY REQUESTS

REQUEST FOR ADMISSION NO. 44: You are requested to admit that proposed Area F operations will impact water quality and water quantity in the Rosebud Coal seam. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ objects to this discovery request as argumentative to the extent that it requires the assumption that the deficiencies identified by DEQ in WECO's Area F application

Exhibit 16

will be resolved and that Area F operations will proceed as proposed. DEQ further objects to this discovery request on the grounds of relevance. This discovery request seeks information not relevant to the subject matter of this appeal and not reasonably calculated to lead to the discovery of admissible evidence. DEQ has already stated in response to Petitioner's First Set of Discovery Requests, Interrogatory No. 13, that DEQ justified its decision not to include Area F within the CHIA because "[t]he proposed action was determined to have no impacts to mine Area C making it unnecessary to include Area F," and cited to those specific portions of the CHIA that support its conclusion (See DEQ's Answer to Interrogatory No. 13). Without waiving its objections, DEQ admits that if WECo's Area F permit application is approved and operations proceed in Area F as proposed, proposed Area F operations will have an impact on water quality and quantity in the Rosebud Coal seam, but consideration of these impacts were not relevant to preparation of the CHIA for Amendment AM4.

REQUEST FOR ADMISSION NO. 45: You are requested to admit that the Rosebud Coal seam in Area F is saturated and functions as an aquifer. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ objects to this discovery request on the grounds of relevance. This discovery request seeks information not relevant to the subject matter of this appeal and not reasonably calculated to lead to the discovery of admissible evidence. DEQ has already stated in response to Petitioner's First Set of Discovery Requests, Interrogatory No. 13, that DEQ justified its decision not to include Area F within the CHIA because "[t]he proposed action was determined to have no impacts to mine Area C making it unnecessary to include Area F," and cited to those specific portions of the CHIA that support its conclusion (See DEQ's Answer to Interrogatory No. 13). Without waiving its objections, DEQ admits that the Rosebud coal seam

Exhibit 16

in Area F varies from completely unsaturated to completely saturated. Based on the definition of "aquifer" contained in § 82-4-203(5), MCA, the Rosebud coal seam would be considered an aquifer in some parts of Area F and not an aquifer in other parts of Area F.

REQUEST FOR ADMISSION NO. 46: You are requested to admit that ground water in the Rosebud Coal aquifer generally flows from the west towards the east. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: Admit in part, deny in part. For those portions of the Rosebud Coal seam that meet the definition of "aquifer" contained in § 82-4-203(5), MCA, flow directions vary from location to location. However, DEQ admits that in general groundwater in the Rosebud Coal seam flows in an easterly direction. (See CHIA page 8-7: "Lateral up gradient flow of saturated Rosebud coal is generally from the west at the Rosebud Mine…").

REQUEST FOR ADMISSION NO. 47: You are requested to admit that portions of the Rosebud Coal seam in Area F are up gradient of portions of the Rosebud Coal seam or the spoils aquifers in Area B. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: Deny. As described in the CHIA, page 8-6 "A sizeable stock pond is coincident with the groundwater mound between the west end of Rosebud Mine Area B and south part of Area C." This groundwater mound just west of Area B forms a groundwater divide which separates groundwater in Area B from groundwater in Area F. No groundwater from Area F is predicted to flow to or through Area B.

REQUEST FOR ADMISSION NO. 48: You are requested to admit that there is a hydrologic connection between portions of the Rosebud Coal seam in Area F and downgradient

Exhibit 16

portions of the Rosebud Coal seam or spoils in Area B. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: Deny. See Answer to RFA No. 47. Area B is not downgradient from Area F.

REQUEST FOR ADMISSION NO. 49: You are requested to admit that proposed mining operations in Area F may affect the quantity or quality of surface water or groundwater in downgradient areas of the Rosebud Coal seam or spoils. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ objects to this discovery request as unreasonably duplicative of the information requested in RFA No. 44. DEQ further objects to this discovery request as it is argumentative to the extent that it requires the assumption that the deficiencies identified by DEQ in WECo's Area F application will be resolved and that Area F operations will proceed as proposed. DEQ further objects to this discovery request on the grounds of relevance. This discovery request seeks information not relevant to the subject matter of this appeal and not reasonably calculated to lead to the discovery of admissible evidence. DEQ has already stated in response to Petitioner's First Set of Discovery Requests, Interrogatory No. 13, that DEQ justified its decision not to include Area F within the CHIA because "[t]he proposed action was determined to have no impacts to mine Area C making it unnecessary to include Area F," and cited to those specific portions of the CHIA that support its conclusion (See DEQ's Answer to Interrogatory No. 13). Additionally, as indicated in DEQ's ANSWER to RFA 47-48, Area B is not downgradient from Area F and there is no hydrologic connection between Area B and Area F. Without waiving its objections, DEQ admits that if operations in Area F are approved and proceed as proposed, they may affect the quantity or quality of surface water or groundwater in downgradient areas of the Rosebud Coal seam or spoils, but consideration of these impacts were

not relevant to preparation of the CHIA for Amendment AM4 because Area B is not downgradient from Area F. (See DEQ's Answers to RFA Nos. 44, 47 and 48).

REQUEST FOR ADMISSION NO. 50: You are requested to admit that proposed mining operations in Area F may affect the quantity or quality of water in downgradient areas of the Rosebud Coal seam or spoils in Area B. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ respectfully refers to and reiterates its objections and answer to RFA No. 49.

REQUEST FOR ADMISSION NO. 51: You are requested to admit the Rosebud Coal seam aquifer contributes recharge to the alluvium of East Fork Armells Creek. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ admits that the portion of the Rosebud Coal seam that comes in contact with the alluvium of East Fork Armells Creek (EFAC) is an aquifer and contributes recharge to the alluvium of EFAC.

REQUEST FOR ADMISSION NO. 52: You are requested to admit that the proposed mining operations in Area F may affect recharge of portions of the alluvium of East Fork Armells Creek. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ objects to this discovery request as argumentative to the extent that it requires the assumption that the deficiencies identified by DEQ in WECo's Area F application will be resolved and that Area F operations will proceed as proposed. DEQ further objects to this discovery request on the grounds of relevance. This discovery request seeks information not relevant to the subject matter of this appeal and not reasonably calculated to lead to the discovery

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of admissible evidence. DEQ has already stated in response to Petitioner's First Set of Discovery Requests, Interrogatory No. 13, that DEQ justified its decision not to include Area F within the CHIA because "[t]he proposed action was determined to have no impacts to mine Area C making it unnecessary to include Area F," and cited to those specific portions of the CHIA that support its conclusion (See DEQ's Answer to Interrogatory No. 13). Without waiving its objections, DEQ answers this request as follows: Even if WECo's Area F permit application is approved and operations proceed in Area F as proposed, DEQ denies that the proposed mining operations in Area F may affect recharge of portions of the alluvium of EFAC. As indicated in DEQ's Answers to RFA Nos. 47-50, the groundwater mound described in DEQ's Answer to RFA No. 47 forms a groundwater divide between Area F and EFAC. Area B and EFAC are not downgradient from Area F. Accordingly, no groundwater from Area F is predicted to flow to or through EFAC alluvium.

REQUEST FOR ADMISSION NO. 53: You are requested to admit that proposed mining operations in Area F may affect recovery of ground water levels in the Rosebud Coal spoils downgradient of mining operations. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ objects to this discovery request as vague and ambiguous. There are no Rosebud Coal spoils. DEQ also respectfully refers to and reiterates its answers to RFA Nos. 47-50 and 52. Without waiving its objections, DEQ answers this request as follows: If WECo's Area F permit application is approved and operations proceed in Area F as proposed, DEQ admits that the proposed mining operations in Area F may affect groundwater levels in the Rosebud Coal seam and spoils downgradient of the proposed mining operations in Area F. The Area F Permit application Appendix O – PHC, Section 3.2.1, page 16 states that "[b]ased on the

results of the groundwater model, the drawdown (Rosebud and McKay coal) within a one mile radius of the Area F permit boundary is predicted to be less than five feet during the mine phase." (See Area F Permit Application, Appendix O, p. 16 and Appendix I-B, Figure I-7). However DEQ denies that Area B and EFAC are downgradient of the proposed mining operations in Area F.

REQUEST FOR ADMISSION NO. 54: You are requested to admit that proposed mining operations in Area F may affect recovery of ground water levels in the Rosebud Coal spoils in portions of Area B. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ respectfully refers to and reiterates its objections and answer to RFA No. 53. Without waiving its objections, DEQ answers this request as follows: For the reasons stated in DEQ's answer to RFA No. 53, DEQ denies this request.

REQUEST FOR ADMISSION NO. 55: You are requested to admit that removal of downgradient portions of the Rosebud Coal seam will decrease the buffering capacity of the coal seam on water quality as spoils water moves down gradient. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ objects to this discovery request on the grounds that it is vague, ambiguous and unintelligible. Accordingly, DEQ cannot truthfully admit or deny the request.

REQUEST FOR ADMISSION NO. 56: You are requested to admit that removal of coal in Area B will decrease the buffering capacity of the coal seam on water quality as spoil water from up gradient portions of the mine moves downgradient. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ respectfully refers to and reiterates its objections and answer to RFA No. 55.

REQUEST FOR ADMISSION NO. 57: You are requested to admit that removal of coal in Area B may decrease the buffering capacity of the coal seam on water quality as spoil water from Area F moves downgradient. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ respectfully refers to and reiterates its objections and answer to RFA Nos. 55-56.

INTERROGATORY NO. 32: Please state whether mining operations in Area F may have any impact on water quality or water quantity on surface or groundwater, including potential impacts to recovery of ground water levels, in any portion of Area B. If you answer is anything other than an unqualified "Yes," please set for in detail and with specificity the basis for your answer and any facts that support your answer.

ANSWER: DEQ objects to this discovery request on the grounds that is compound and that Petitioner has already propounded the maximum number of 50 interrogatories, including subparts, allowed under Rule 33, Mont. R. Civ. P. DEQ respectfully refers to and reiterates its objections and answers to RFA Nos. 47-50. Without waiving its objections, DEQ answers this request as follows: If WECo's Area F permit application is approved and operations proceed in Area F as proposed, DEQ denies that may have any impact on water quality or water quantity on surface or groundwater, including potential impacts to recovery of ground water levels, in any portion of Area B because Area B is not downgradient from Area F. (See DEQ's Answers to RFA Nos. 44, 47 and 48). Additionally, as indicated in DEQ's answer to RFA No. 53, any drawdown from Area F is not expected to reach Area B.

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REQUEST FOR PRODUCTION NO. 13:

Please produce any and all documents, including emails, computer files, or hand written notes, related to the phone conversation between WECO staff, DEQ staff, including Chris Yde, and consultant Michael Nicklin, that occurred on Tuesday, April 30, 2013.

ANSWER: DEQ objects to this discovery request to the extent that it seeks to discover privileged information. Without waiving its objections, DEQ does not have a record of a phone conversation occurring between WECO staff and DEQ staff , including Chris Yde, and consultant Michael Nicklin, on Tuesday April 30, 2013 related to the Rosebud Mine. However, DEQ does have a record of a conference call that took place between WECO staff and DEQ staff, including Chris Yde, and consultant Michael Nicklin, on May 16, 2013, to discuss the Area B PHC. Notes from this conference call taken by Chris Yde, and a summary of discussion points submitted by Michael Nicklin prior to the call are attached hereto as Exhibits 44-45, respectively.

REQUEST FOR PRODUCTION NO. 14: Please produce any maps or figures in DEQ's possession or control that depict the potentiometric surface or potentiometric head in the Rosebud coal seam and/or spoil that include Area F.

ANSWER: DEQ objects to this discovery request as overly broad and burdensome, as the requested documents are publicly available online, and as such, can be obtained by Petitioners with no more burden than DEQ. DEQ further objects to this discovery request on the grounds of relevance. Without waiving its objections, DEQ answers this discovery request as follows: DEQ and WECO have already produced responsive, non-privileged documents which are contained within WECO's Area F application PHC Report in their production of documents, and these documents, including the relevant maps and figures are also publically available online. (See Area F Application, Appendix I-A, Plate GM-B1; Figure GM-13; Figure GM-17, page 2 and

Area B AM4 CHIA Figure 8-5 (includes eastern half of Area F)), attached hereto as Exhibits 46-49, respectively.

REQUEST FOR PRODUCTION NO. 15: Please produce any probable hydrologic consequences reports or determinations or ground water models in DEQ's possession or control for proposed mining operations in Area F.

ANSWER: DEQ respectfully refers to and reiterates its objections and answer to RFP No. 14, and asserts that PHC reports, determinations or ground water models for proposed Area F mining operations are not relevant to the Area B AM4 CHIA . Without waiving its objections, DEQ answers this discovery request as follows: DEQ and WECo have already produced responsive, non-privileged documents which are contained within WECo's Area F application PHC Report (Appendix O) The requested groundwater models are included in the Area F application as Appendix I-A and I-B. These documents are also publically available online.

REQUEST FOR PRODUCTION NO. 16: Please produce any and all documents in DEQ' s possession or control in which DEQ employees state, determine, or explain that analysis of impacts from operations of Area F did not have to be considered in the CHIA.

ANSWER: None Exist.

INTERROGATORY NO. 33: If you contend that the CHIA adequately assessed whether the cumulative hydrologic impacts of mining and reclamation activities within the cumulative hydrologic impact area would cause violation of electrical conductivity standards in Spring Creek, Pony Creek, Cow Creek, South Fork Cow Creek, Emilee Coulee, or Lee Coulee, please describe and explain in detail every fact or expert opinion that supports your contention.

ANSWER: DEQ objects to this discovery request on the grounds that is compound and that Petitioner has already propounded the maximum number of 50 interrogatories, including

subparts, allowed under Rule 33, Mont. R. Civ. P. DEQ further objects to this discovery request as overly burdensome and oppressive to the extent that it requires DEQ to describe and explain in detail each fact set forth in the CHIA that it relied on in making this assessment. DEQ further objects to this discovery request to the extent that it seeks premature disclosure of expert opinions. DEQ has not decided on which, if any expert witnesses may be called during a hearing in this matter. DEQ reserves the right to identify experts and to disclose expert opinions in accordance with any scheduling order. Without waving its objections, DEQ answers this discovery request as follows: The CHIA documented that the numeric EC standards for tributaries of Rosebud Creek were one of the criteria used to evaluate impacts to surface waters (On page 2-4 the CHIA states "[s]tandards for electrical conductivity (EC) and sodium adsorption ratio (SAR) set forth by ARM 17.30.670(4) apply to tributaries of Rosebud Creek."). Additionally, the CHIA concluded for each of the drainages listed that the proposed action in Area B would have no impacts (On page 9-6 the CHIA states "[t]he proposed action will not affect the Cow Creek drainage basin." On page 9-13 the CHIA states "[t]he proposed expansion of mining in Rosebud Area B in AM 4 will not affect the water quality in the Lee Coulee drainage. Spoil water from Area B AM 4 cuts will not contribute to surface flow." On page 9-14 the CHIA states "because the proposed mining in AM4 will not contribute water to Miller Coulee, the proposed action is designed to prevent material damage." Also on page 9-14 the CHIA states "The proposed mining in AM4 will not contribute water to Pony Creek, therefore the proposed action is designed to prevent material damage." On page 9-16 the CHIA states "[t]he proposed mining with AM4 will not affect the Spring Creek drainage, and therefore the proposed action is designed to prevent material damage."). It is reasonable to conclude that if there are no impacts the EC standard will not be violated.

Exhibit 16

REQUEST FOR ADMISSION NO. 58: You are requested to admit that there are wadeable streams within the cumulative hydrologic impact area identified in the CHIA. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ admits that Rosebud Creek is a wadeable stream within the CIA identified in the CHIA, and that there are additional stream reaches that are wadeable, but not entire streams other than Rosebud Creek.

INTERROGATORY NO. 34: Please identify any and all streams or stream segments within in the cumulative hydrologic impact area that are wadeable.

ANSWER: DEQ objects to this discovery request on the grounds that is compound and that Petitioner has already propounded the maximum number of 50 interrogatories, including subparts, allowed under Rule 33, Mont. R. Civ. P. DEQ further objects to this discovery request as overly burdensome and oppressive to the extent that it requires DEQ to compile a list or summarize information provided in the CHIA. Without waving its objections, DEQ answers this discovery request as follows: West Fork Armells Creek, Stocker Creek, East Fork Armells Creek, unnamed tributaries of East Fork Armells Creek, Spring Creek, Cow Creek, Hay Coulee, Emile Coulee, Lee Coulee, and Rosebud Creek may contain perennial or intermittent reaches which are wadeable streams. Only Rosebud Creek is wadeable for its entire reach. The remaining streams listed are mostly non-wadeable, with short intermittent/perennial reaches that are wadeable.

REQUEST FOR ADMISSION NO. 59: You are requested to admit that East Fork Armells Creek upstream of Colstrip is impaired and not meeting water quality standards. If your

Exhibit 16

answer is anything other than an unqualified admission, please state specifically and in detail the basis for your answer.

ANSWER: DEQ admits that DEQ's 2014 Water Quality Standards Attainment Record for East Fork Armells Creek (segment MT42K002_170) lists 'Aquatic Life' as impaired due to 'alteration in stream-side or littoral vegetative covers' with 'Surface Mining' listed as an unconfirmed source. However, the aquatic life impairment information contained in the 2014 Water Quality Standards Attainment Record was derived from a 2006 DEQ impairment determination that was based on erroneous information. The conclusion that aquatic life was impaired in 2006 was based upon evidence of habitat impairment that was incorrect. No aquatic life survey was done at that time to support the aquatic life impairment determination. Since the 2006 assessment there has been extensive data collected, including aquatic life surveys for EFAC, which can be used to conduct an updated aquatic life use support determination.

INTERROGATORY NO. 35:

A. Please identify each person from DEQ who, in development of the CHIA, reviewed the Memorandum from Penny Hunter and Jason Vogel of Arcadis U.S. Inc. to WECo, dated December 14, 2014.

B. For each person identified in part A., please identify the professional qualifications of that person.

ANSWER: DEQ objects to this discovery request on the grounds that it contains multiple subparts and that Petitioner has already propounded the maximum number of 50 interrogatories, including subparts, allowed under Rule 33, Mont. R. Civ. P. DEQ further objects to this discovery request on the grounds of relevance. This discovery request seeks information not relevant to the subject matter of this appeal and not reasonably calculated to lead to the discovery

Exhibit 16

of admissible evidence. DEQ further objects to this discovery request to the extent that it seeks premature disclosure of expert identities, qualifications, and opinions. DEQ has not decided on which, if any expert witnesses may be called during a hearing in this matter. DEQ reserves the right to identify experts and to disclose expert opinions in accordance with any scheduling order. Without waving its objections, DEQ answers this discovery request as follows:

A. DEQ cannot be reasonably expected to know all of the individuals at DEQ that may have reviewed the Memorandum from Penny Hunter and Jason Vogel of Arcadis U.S. Inc. to WECo, dated December 14, 2014. To the best of DEQ's knowledge, the following DEQ staff may have reviewed the memorandum: Emily Hinz, Angela McDannel and Pete Schade.

B. DEQ will disclose the professional qualifications of expert witnesses identified in this matter in accordance with the scheduling order.

REQUEST FOR ADMISSION NO. 60: You are requested to admit that DEQ representatives from WECo met with staff from DEQ on or about September 13, 2015, regarding results from an aquatic life survey of East Fork Armells Creek. If you answer is anything other than an unqualified admission, state in detail the basis for your answer.

ANSWER: Deny. DEQ has no record of any such meeting occurring on or about September 13, 2015, which was a Sunday. DEQ admits that there is a record that a meeting apparently occurred on or about September 21, 2015.

REQUEST FOR PRODUCTION NO. 17: Please produce any and all documents in DEQ's possession or control, including but not limited to electronic documents, hand-written notes, emails, meeting agendas, and meeting summaries, related to the meeting between DEQ personnel and personnel or representatives of WECo on September 13, 2015.

Exhibit 16

ANSWER: See the email from Dicki Peterson to Chris Yde, forwarded to Emily Hinz, Melissa Sjolund, and Pete Schade dated September 23, 2015, regarding "Aquatic life presentation", attached hereto as Exhibit 50.

REQUEST FOR ADMISSION NO. 61: You are requested to admit that the summary presented to DEQ by Penny Hunter on or about September 13 of the survey of aquatic life in East Fork Armells Creek conducted by Arcadis in 2014 stated that East Fork Armells Creek did not meet aquatic life criteria. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ objects to this discovery request on the grounds of relevance. This discovery request seeks information not relevant to the subject matter of this appeal and not reasonably calculated to lead to the discovery of admissible evidence. Without waving its objections, DEQ answers this discovery request as follows: DEQ admits that Penny Hunter's presentation stated as follows:

"Conclusions and Recommendations

The large amount of variability inherent within ephemeral systems, and the low quality of habitat and benthic communities, would not provide a strong indicator of water quality impacts due to mining activity.

- Flow and natural levels of organic matter are more likely to drive aquatic community dynamic than other factors

Although EFAC supports aquatic life, aquatic life criteria are not met.

- Baseline conditions are a better indicator of existing use
- Criteria are based on different organisms not present in EFAC

Aquatic life monitoring will likely demonstrate natural variability; unlikely to demonstrate impacts from mining"

However, Penney Hunter's conclusion that "aquatic life criteria are not met" is based on data from the 1970s and therefore is not relevant to today's conditions. In order to determine whether aquatic life criteria are currently met, DEQ should conduct an evaluation using the most recent data as well as the most recent methodologies for evaluating this data.

REQUEST FOR ADMISSION NO. 62: You are requested to admit that operations of the Rosebud Mine are contributing to the impairment of East Fork Armells Creek. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ objects to this discovery request as vague and ambiguous. DEQ further objects to this discovery request as unreasonably duplicative of the information requested in RFA No. 24. Without waving its objections, DEQ respectfully refers to and reiterates its answer to RFA No. 24.

INTERROGATORY NO. 36: Your response to INTERROGATORY NO. 28(B) states that "concerns were raised that potential inputs of additional salinity, sulfate, and chloride to EFAC from the Rosebud Mine may cause material damage to the protected beneficial use of aquatic life support for C-3 waters." Please state whether DEQ employees believed that these pollutants were contemporaneously causing material damage in East Fork Armells Creek.

ANSWER: DEQ objects to this discovery request on the grounds that Petitioner has already propounded the maximum number of 50 interrogatories, including subparts, allowed under Rule 33, Mont. R. Civ. P. Without waving its objections, DEQ answers this discovery request as follows: Any concerns that were identified in DEQ's answer to INTERROGATORY NO. 28(A)-(C) were adequately addressed by WECo, and DEQ ultimately concluded, as stated in the CHIA, that there would be no material damage to EFAC as a result of the Area B AM4 mining operations.

Exhibit 16

REQUEST FOR ADMISSION NO. 63: You are requested to admit that the beneficial use of aquatic life support in East Fork Armells Creek may be impaired even if some aquatic life can be detected in the water body. If you answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ objects to this discovery request to the extent that it calls for a legal conclusion, requires speculation, and is irrelevant. This discovery request seeks information not relevant to the subject matter of this appeal and not reasonably calculated to lead to the discovery of admissible evidence. Additionally, DEQ is without sufficient knowledge or information to affirmatively admit or deny the request as the request calls for a speculative admission or a hypothetical question. Without waving its objections, DEQ answers this discovery request as follows: Aquatic Life Beneficial-Use determinations are based on data and information collected for that specific purpose, and are conducted by the Water Quality Monitoring Section of the DEQ's Water Quality Bureau. How aquatic life assemblages are used in making Beneficial Use determinations are documented in the Water Quality Monitoring Section's SOPs and Methodologies.

INTERROGATORY NO. 37: Please summarize the meeting between John North and Dana David and John Martin representing WECo in May 2014 regarding the Rosebud Mine.

ANSWER: DEQ objects to this discovery request on the grounds that Petitioner has already propounded the maximum number of 50 interrogatories, including subparts, allowed under Rule 33, Mont. R. Civ. P. DEQ further objects to this discovery request to the extent that it seeks to discover privileged information and/or the mental impressions and/or legal strategies of counsel for DEQ and WECo. Without waiving its objections, DEQ has no recollection of any meeting occurring between counsel for DEQ and counsel for WECo in May 2014.

REQUEST FOR ADMISSION NO. 64: You are requested to admit that in their May 2014 meeting with John Martin, John North and Dana David raised concerns about material damage occurring to East Fork Armells Creek from sulfate, salinity, and chloride from the Rosebud Mine. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ respectfully refers to and reiterates its objections and answer to INT No. 37. Without waving its objections, DEQ denies that a meeting occurring between counsel for DEQ and counsel for WECo in May 2014.

REQUEST FOR PRODUCTION NO. 18: Please produce any documents, including but not limited to memos, handwritten notes, or emails, in your possession or control that summarize the May 2014 meeting between John North and Dana David of DEQ and John Martin representing WECo.

ANSWER: DEQ respectfully refers to and reiterates its objections and answers to INT No. 37 and RFA No. 64. Without waving its objections, DEQ responds to this discovery request as follows: None exist.

INTERROGATORY NO. 38: Please identify any mitigation measures that DEQ requested or required WECo to undertake to address concerns about material damage from sulfate, chloride, or salinity in East Fork Armells Creek.

ANSWER: DEQ objects to this discovery request on the grounds that Petitioner has already propounded the maximum number of 50 interrogatories, including subparts, allowed under Rule 33, Mont. R. Civ. P. Without waving its objections, in a Deficiency letter "AM4, Seventh Round Acceptability Deficiency" dated June 3, 2014, DEQ requested additional information from WECo, including an aquatic life survey, to address any concerns DEQ staff

regarding the potential for material damage to EFAC from sulfate, chloride, or salinity. After DEQ reviewed the additional information provided by WECo in the ABC PHC Addendum to Appendix M of the Area B AM4 permit application, no mitigation was required as no material damage was indicated, as described in the CHIA. However, the Written Findings for the amended permit (Amendment AM4) contains stipulations for continued aquatic life monitoring in all intermittent reaches.

REQUEST FOR PRODUCTION NO. 19: Please produce any and all documents that describe the process or procedure by which DEQ determines whether a waterbody meets applicable water quality standards.

ANSWER: DEQ objects to this discovery request on the grounds that it is overly broad and burdensome and the documents requested are publicly available online, and as such, can be obtained by Petitioners with no more burden than DEQ. DEQ further objects to this discovery request on the grounds of relevance. This discovery request seeks information not relevant to the subject matter of this appeal and not reasonably calculated to lead to the discovery of admissible evidence, as the Coal Section evaluates whether mining operations are causing violations of WQ standards, but does not conduct waterbody standards or beneficial use evaluations. These determinations are made by another division within DEQ. Without waving its objections, DEQ responds to this discovery request as follows: The Water Quality Monitoring Section of the DEQ's Water Quality Bureau routinely conducts assessments of Montana's streams and evaluates data to determine whether streams are meeting their beneficial uses and reports this information every two years to the EPA in Montana's Water Quality Integrated Report. See http://deq.mt.gov/Water/WQPB/cwaic . Assessment methodologies used to determine whether a waterbody meets applicable water quality standards consist of a variety of SOPs and

methodology guidance developed by the DEQ specifically for this purpose. Relevant documents can be found at http://deq.mt.gov/Water/WQPB/qaprogram/sops and include (hyperlinks below):

- WQPBWQM-001 - Water Quality Assessment Method
- Nutrient Assessment Method
- Metals Assessment Method
- Sediment Assessment Method
- Historic Water Quality Assessment Method (2000-2008).

As indicated above, these documents may be downloaded by Petitioners directly from DEQ's website.

REQUEST FOR PRODUCTION NO. 20: Please produce any and all documents in DEQ's possession or control regarding communications between DEQ personnel and WECo personnel or representatives that discuss or address DEQ's concerns about material damage in East Fork Armells Creek due to salinity, sulfates, or chloride.

ANSWER: DEQ objects to this discovery request to the extent that it seeks to discover privileged information. Without waiving its objections, DEQ has already produced responsive, non-privileged documents in response to Petitioner's First Set of Discovery Requests.

REQUEST FOR ADMISSION NO. 65: You are requested to admit that DEQ's CHIA does not consider future impacts of all mining operations on water quality in Rosebud Creek. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ denies that the CHIA does not consider future impacts of all mining operations on water quality in Rosebud Creek. DEQ considered the entire area within which impacts to the hydrologic balance resulting from the proposed operation may interact with the impacts of all previous, existing and anticipated mining in the Rosebud Creek drainage on surface and ground water systems.

REQUEST FOR ADMISSION NO. 66: You are requested to admit that the evidence before DEQ at the time it issued its CHIA did not affirmatively demonstrate that the cumulative hydrologic impacts of all mining operations in Lee Coulee, Miller Coulee, Cow Creek, Pony Creek, Hay Coulee, and Spring Creek will not contribute to Rosebud Creek's gaining of salts downstream of Lee Coulee. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ objects to this discovery request as argumentative to the extent that it requires the assumption that the law requires WECO's application to affirmatively demonstrate that the cumulative hydrologic impacts of all mining operations will not contribute to Rosebud Creek's gaining of salts downstream of Lee Coulee. DEQ further objects to this discovery request on the grounds of relevance. This discovery request seeks information not relevant to the subject matter of this appeal and not reasonably calculated to lead to the discovery of admissible evidence. DEQ further objects to this discovery request to the extent it requires DEQ to characterize the CHIA, a document which speaks for itself. Without waiving its objections, DEQ denies that it is required to affirmatively demonstrate that the cumulative hydrologic impacts of all mining operations . . . will not contribute to Rosebud Creek's gaining of salts downstream of Lee Coulee. Pursuant to § 82-4-227(3)(a), WECo is required to affirmatively demonstrate through its permit application, that "the assessment of the probable cumulative impact of all anticipated mining in the area on the hydrologic balance has been made by the department and the proposed operation of the mining operation has been designed to prevent material damage to the hydrologic balance outside the permit area;" WECo's application affirmatively demonstrates and DEQ's CHIA confirms that the proposed operation is designed to prevent material damage to Rosebud Creek.

Exhibit 16

REQUEST FOR ADMISSION NO. 67: You are requested to admit that the evidence before DEQ at the time it issued its CHIA did not affirmatively demonstrate that the cumulative hydrologic impacts of all mining operations in Lee Coulee, Miller Coulee, Cow Creek, Pony Creek, Hay Coulee, and Spring Creek will not contribute to exceedances of water quality standards for specific conductance in Rosebud Creek downstream of Lee Coulee. If your answer is anything other than an unqualified admission, please state in detail the basis for your answer.

ANSWER: DEQ respectfully refers to and reiterates its objections and answer to RFA No. 66. Without waiving its objections, DEQ denies that it is required to affirmatively demonstrate that the cumulative hydrologic impacts of all mining operations . . . will not contribute to exceedances of water quality standards for specific conductance in Rosebud Creek downstream of Lee Coulee. Pursuant to § 82-4-227(3)(a), WECo is required to affirmatively demonstrate through its permit application, that "the assessment of the probable cumulative impact of all anticipated mining in the area on the hydrologic balance has been made by the department and the proposed operation of the mining operation has been designed to prevent material damage to the hydrologic balance outside the permit area;" WECO's application affirmatively demonstrates and DEQ's CHIA confirms that the proposed operation is designed to prevent material damage to Rosebud Creek.

INTERROGATORY NO. 39: If you contend that there is a hydrological connection between clinker deposits in the area between Area B of the Rosebud Mine and the Big Sky Mine and the Rosebud coal seam, please describe and explain in detail every fact or expert opinion that supports your contention.

ANSWER: DEQ objects to this discovery request on the grounds that is compound and that Petitioner has already propounded the maximum number of 50 interrogatories, including

subparts, allowed under Rule 33, Mont. R. Civ. P. DEQ further objects to this discovery request as overly burdensome and oppressive to the extent that it requires DEQ to describe and explain in detail each fact set forth in the CHIA that it relied on in making this assessment. DEQ further objects to this discovery request to the extent that it seeks premature disclosure of expert opinions. DEQ has not decided on which, if any expert witnesses may be called during a hearing in this matter. DEQ reserves the right to identify experts and to disclose expert opinions in accordance with the scheduling order. Without waiving its objections, DEQ refers Petitioners to the following relevant sections of the CHIA: Page 8-6 "An apparent recharge area also is visible in the higher elevations at the northeast part of Big Sky Mine Area A...." "Fractured clinker permits greater infiltration of precipitation and surface flow and locally may be a source of recharge. "Page 8-11 "As in all of the shallow, local bedrock aquifers, the main source of recharge originates from uplands west of active mining in the Rosebud Mine and north of mining in Big Sky Mine...." Page 9-59 "Due to a large deposit of clinker throughout much of the area between the two mines, enhanced aquifer recharge will serve to dilute spoil water quality impacts in this area."

INTERROGATORY NO. 40: Please identify every document that DEQ considered in preparing its CHIA that provides evidence of a hydrological connection between clinker deposits in the area between Area B of the Rosebud Mine and the Big Sky mine and the Rosebud coal seam.

ANSWER: DEQ objects to this discovery request on the grounds that Petitioner has already propounded the maximum number of 50 interrogatories, including subparts, allowed under Rule 33, Mont. R. Civ. P. Without waiving its objections, DEQ refers Petitioners to the PHC and model report in Appendix M of the AM4 permit application.

Exhibit 16

REQUEST FOR PRODUCTION NO. 21: Please produce the documents identified in your answer to INTERROGATORY NO. 42.

ANSWER: DEQ objects to this discovery request as vague, ambiguous, unintelligible and overly burdensome. DEQ has not been asked to identify any documents in response to INTERROGATORY NO. 42, and as such, is not able to provide an answer to this request.

REQUEST FOR PRODUCTION NO. 22:

Please produce the following cumulative hydrologic impact assessments:

A. Rosebud Area D Application 115, November 1985;

B. Rosebud Mine Area A Application 107, June 1984;

C. Rosebud Mine Area B Second Extension, June 1983;

D. Big Sky Mine Area B Application 180, June 2007;

E. Big Sky Mine Area B 1988, New Permit, November 1988;

F. Big Sky Mine Area A Snider's Amendment, April 1987.

ANSWER: DEQ objects to this discovery request on the grounds of relevance. This discovery request seeks information not relevant to the subject matter of this appeal and not reasonably calculated to lead to the discovery of admissible evidence. DEQ further objects to this discovery request on the grounds that it is overly broad and burdensome. Without waving its objections, copies of the requested documents are attached hereto as Exhibits 51-56, respectively.

INTERROGATORY NO. 41: Please identify all documents that DEQ personnel reviewed in preparing the CHIA.

ANSWER: DEQ objects to this discovery request on the grounds that Petitioner has already propounded the maximum number of 50 interrogatories, including subparts, allowed

under Rule 33, Mont. R. Civ. P. Without waiving its objections, DEQ refers Petitioners to all documents cited in the CHIA and all permit application materials for Amendment AM4.

INTERROGATORY NO. 42: Please identify all property owners, including surface and sub-surface owners, of the properties on which impoundments of coal combustion resides are located in and around Colstrip, Montana.

ANSWER: DEQ objects to this discovery request on the grounds that Petitioner has already propounded the maximum number of 50 interrogatories, including subparts, allowed under Rule 33, Mont. R. Civ. P. DEQ further objects to this discovery request on the grounds of relevance. This discovery request seeks information not relevant to the subject matter of this appeal and not reasonably calculated to lead to the discovery of admissible evidence. DEQ further objects to this discovery request on the grounds that it is overly broad and burdensome.

INTERROGATORY NO. 43: Please identify any agreements between WECo and any owners or operators of the Colstrip Generating Station regarding use, placement, or disposal of coal combustion residues at the Rosebud Mine.

ANSWER: DEQ respectfully refers to and reiterates its objections and answer to INTERROGATORY NO. 42. DEQ further objects to this discovery request to the extent that Petitioners seek information not within the possession or control of DEQ, and outside of the personal knowledge of DEQ.

INTERROGATORY NO. 44: Please state whether DEQ has ever approved use, placement, or disposal of coal combustion residue at the Rosebud Mine or the Big Sky Mine. If your answer is anything other than an unqualified "No," please set forth the following information specifically and in detail:

A. Identify all such approvals;

Exhibit 16

B. Describe when, where, and for how long coal combustion residue has been used, placed, or disposed of at the Rosebud or Big Sky Mine.

ANSWER: DEQ objects to this discovery request on the grounds that it is compound and Petitioner has already propounded the maximum number of 50 interrogatories, including subparts, allowed under Rule 33, Mont. R. Civ. P. DEQ further objects to this discovery request on the grounds of relevance. This discovery request seeks information not relevant to the subject matter of this appeal and not reasonably calculated to lead to the discovery of admissible evidence. DEQ further objects to this discovery request on the grounds that it is overly broad, burdensome and intended to create an undue burden on DEQ, as it would require DEQ to compile and summarize information contained in the Rosebud Mine annual reports and applicable permits. Without waving its objections, DEQ has approved the use of bottom ash at the Rosebud Mine "as a tank or culvert bedding material and a road and parking facilities sanding material." DEQ will make applicable Rosebud Mine annual reports and permit documents available for Petitioner's review upon reasonable request.

REQUEST FOR PRODUCTION NO. 23: Please produce any and all documents in DEQ's possession or control that you identified in your answer to INTERROGATORY NO. 43.

ANSWER: DEQ respectfully refers to and reiterates its objections and answer to INTERROGATORY NO. 43. Without waiving its objections, DEQ answers this discovery request as follows: None exist.

INTERROGATORY NO. 45: Please identify when, where, and for how long coal combustion residues have been used, placed, or disposed of at the Rosebud Mine or the Big Sky Mine.

ANSWER: DEQ respectfully refers to and reiterates its objections and answer to INTERROGATORY NO. 44.

INTERROGATORY NO. 46:

A. Please identify each and every conference call or in-person meeting between the persons identified in INTERROGATORY NO. 1, INTERROGATORY NO. 3, or INTERROGATORY NO. 4 and employees or representatives of WECo regarding WECo's application for Amendment AM4;

B. Please state in detail the subject matter of each and every conference call or in-person meeting between persons identified in INTERROGATORY NO. 1, INTERROGATORY NO. 3, or INTERROGATORY NO. 4 and employees or representatives of WECo regarding Wesco's application for Amendment AM4;

C. Please identify every meeting or call agenda or meeting or call summary from each and every conference call or in-person meeting between persons identified in INTERROGATORY NO. 1, INTERROGATORY NO. 3, or INTERROGATORY NO. 4 and employees or representatives of WECO regarding WECo's application for Amendment AM4.

ANSWER: DEQ objects to this discovery request on the grounds that it is compound and Petitioner has already propounded the maximum number of 50 interrogatories, including subparts, allowed under Rule 33, Mont. R. Civ. P. DEQ further objects to this discovery request on the grounds of relevance. This discovery request seeks information not relevant to the subject matter of this appeal and not reasonably calculated to lead to the discovery of admissible evidence. DEQ further objects to this discovery request on the grounds that it is overly broad, burdensome and intended to create an undue burden on DEQ.

REQUEST FOR PRODUCTION NO. 24:

Please produce every document identified in INTERROGATORY NO. 46.C.

ANSWER: DEQ respectfully refers to and reiterates its objections and answer to INTERROGATORY NO. 46.

VERIFICATION FOR INTERROGATORIES AND REQUESTS FOR PRODUCTION

STATE OF MONTANA)

ss.

County of Lewis & Clark)

I, Chris A. Yde, being first duly sworn, state that I am the supervisor of the Coal and Opencut Mining Bureau, Coal Section, Montana Department of Environmental Quality, and I am authorized to answer the foregoing discovery requests and to make this verification. I have read the foregoing Answers to Requests for Admission, Interrogatories and Requests for Production, and the information provided in them is true and correct to the best of my knowledge and belief.

Chris A. Yde

Subscribed and sworn to before me by Chris Yde, this 11th day of April, 2016.

HILLARY HOULE
NOTARY PUBLIC for the
State of Montana
Residing at Helena, Montana
My Commission Expires
May 19, 2019

Signature of Notary

As the attorney for the Department of Environmental Quality, I am signing these Answers to Requests for Admission, Interrogatories, and Requests for Production and certify this response in accordance with M. R. Civ. P. Rule 26(g)(1).

STATE OF MONTANA,
DEPARTMENT OF
ENVIRONMENTAL QUALITY

Rebecca Convery
Special Assistant Attorney General

Exhibit 16

CERTIFICATE OF SERVICE

The undersigned certifies that on April 11, 2016, she caused the original or a copy of the foregoing DEQ Responses to Petitioner's Second Discovery Requests to be delivered or transmitted to the person named below as follows:

Original by first class and copy by electronic mail:

Shiloh Hernandez
Western Environmental Law Center
103 Reeder's Alley
Helena, MT 59601
(406) 204-4861

hernandez@westernlaw.org

By:

Exhibit 16

Attachment 1: WECO B Amendment CHIA; Surface Water

Proposed WECO Area B Amendment

Proposed disturbance in Western Energy's Area B Amendment mine plan would lie primarily within the East Fork Armells Creek (EFAC) drainage basin, above Colstrip, with a portion extending over the divide into the Lee Coulee drainage, a tributary of Rosebud Creek (see Map 1). The Area B mine plan amendment would increase surface disturbance by 2102 acres, as a result of extending the pits approximately 4.5 miles to the west.

Combined surface disturbance from the proposed mine plan amendment and the existing Area B permit would total 4878 acres, with east-west pits extending up to 8.5 miles along slopes north of the drainage divide between EFAC and Rosebud Creek. A small portion of total surface disturbance in Area B would occur in upper northwest tributaries of Lee Coulee (214 acres; see Map 1). Here, final pits and highwall reduction would cross south over approximately 1.5 miles of the Rosebud drainage divide into Lee Coulee along the south-central portion of the amendment area (sections 14 and 15, T1N R40E).

Existing and Proposed Mining Disturbance - Colstrip Region

Mining disturbance in the EFAC drainage basin currently totals approximately 8306 acres (WECO mine areas A, B, C, D and E, including ~209 acres prelaw mining; Table 1). The proposed Area B amendment and other permitted life-of-mine plans would increase life-of-mine surface disturbance in the EFAC drainage to about 16,605 acres (25.9 $mi.^2$; see Map 1, Table 2).

Mining disturbance in the Rosebud Creek drainage basin currently totals approximately 5782 acres (WECO mine areas D, E and Pit 6, Big Sky Coal Company (BSCC) mine areas A and B, including ~1076 acres prelaw mining). The Area B amendment and other permitted life-of-mine plans would increase life-of-mine surface disturbance in the Rosebud drainage to about 9371 acres (14.6 $mi.^2$).

Additional mining disturbance has been permitted, but not yet begun, in the upper West Fork Armells Creek (WFAC) drainage basin (WECO Area C; see Map 1). The Area C permit would bring life-of-mine surface disturbance in the WFAC drainage to approximately 1645 acres. Combined life-of-mine disturbance in Armells Creek (both East and West Forks) would total about 18,250 acres (28.5 $mi.^2$). Cumulative life-of-mine disturbance for the entire Colstrip region (both Armells and Rosebud Creek drainages) would total about 27,621 acres (43.2 $mi.^2$).

Because mining operations and reclamation proceed simultaneously, a complex pattern of disturbance conditions occur at any one time during mining, and evolve toward completed reclamation over proposed life-of-mine periods (e.g. WECO B: 20 years, WECO C: 38 years). Principal mining-related surface disturbances include: soil removal, storage and redistribution; active pits, backfilled pits and regraded overburden (incl. boxcut spoils and highwall reduction); revegetation; access and haulroads, facilities, and sediment ponds.

Cumulative Mining Disturbance

Taken alone, life-of-mine operations and reclamation proposed for WECO Area B would disturb about 16% of the 48 $mi.^2$ EFAC drainage basin above Stocker Creek, about 5% of the total 148 $mi.^2$ EFAC drainage, or about 2% of the entire 370 $mi.^2$ Armells Creek drainage (Table 3). Only about 2% of the 20.6 $mi.^2$ Lee Coulee drainage, or less than 0.1% of 799 $mi.^2$ of adjacent Rosebud Creek drainage would be disturbed by proposed WECO Area B mining and reclamation.

Cumulative surface mining operations and reclamation proposed for all Colstrip area mines would disturb nearly 40% of the EFAC drainage basin above Stocker Creek, about 16% of the total EFAC drainage, or about 8% of the entire Armells Creek drainage. With the addition of BSCC's Area B mining, a total of 25% of the Lee Coulee drainage, or less than 1% of the adjacent Rosebud Creek drainage would be disturbed by cumulative surface mining and reclamation proposals.

Surface water systems nearest to mined areas would have the greatest potential for mining-related impacts, both during mining operations and after reclamation. Further downstream, particularly where the disturbed watersheds join larger drainages, measurable and expected impacts would diminish in significance (e.g. lower Armells Creek, Rosebud Creek and Yellowstone River reference sites; see Map 2; Table 3).

Cumulative mining-related impacts to surface water systems in the Colstrip area would potentially be measurable in EFAC below Colstrip to its junction with WFAC. Measurable impacts in WFAC would be limited to the upper portion of the drainage, due to the limited disturbance proposed (see Table 3, Map 2). In the Rosebud Creek drainage, cumulative mining impacts to surface water would potentially be measurable in Lee Coulee, Miller Coulee, and Cow Creek below mining to their junctions with Rosebud Creek. Measurable impacts in other mined tributaries of Rosebud Creek would be limited to the upper portions of those drainages (see Table 3, Map 2).

Operational Impacts of Surface Mining

Operational impacts to offsite surface water systems are related primarily to storage and discharge of storm and snowmelt runoff (and pumped pit water) from runoff and sediment control systems. WECO Sediment ponds are required to retain runoff from storms up to 2.4" (10-year, 24 hour recurrence), and three years of projected sediment loss from disturbed drainages above them. Pond design requirements result in at least temporary interception of all but the larger storm or snowmelt runoff events. In practice, snowmelt runoff (usually in February or March) and successive spring storms (heaviest from April through June) result in more frequent pond discharges. Periodic use of some ponds for storage and discharge of pumped pit water, and as water sources for haulroad dust suppression complicates any general pattern of pond operations.

Seepage losses and surface discharges of stored runoff or pit water from perimeter sediment ponds can affect flows in downgradient alluvial aquifers and streams. The effects of individual sediment ponds would generally be limited to adjacent streams and their alluvial aquifers, unless pond contributions are significant relative to those of the receiving channel or aquifer. For example, an intermittent flow reach has been created in an ephemeral reach of Lee Coulee below BSCC's pond B-9, which has discharged nearly continuously from 11/89 to 11/91, and from 4/93 to 10/94.

Sediment pond discharge samples usually meet MPDES effluent limitations (regulated by Montana Dept. of Health and Environmental Sciences). Most of the local MPDES exceedances are of total suspended solids limits: 35 mg/L (30-day avg.), or 70 mg/L (daily max.). Most pond discharges are similar or lower in suspended solids than storm and snowmelt runoff from local undisturbed drainages, which are highly variable (e.g. WECO sites SW-9A, SW-09 and SW-60 north of the amendment area on EFAC; see Figure 1). In pond discharges with large amounts of groundwater (from pit pumping), dissolved solids are usually higher than in ephemeral runoff from local undisturbed drainages, which are often under 100 mg/L TDS (e.g. WECO site SW-60 on EFAC, north of the proposed amendment area; see Figure 2).

The effects of multiple active sediment ponds in a drainage with significant mining activity (like EFAC) are potentially significant, but would depend on several variables, including the number of active ponds, level of mining activity, amount of pit pumping, and the timing and magnitude of storm and

snowmelt runoff. The cumulative effects of WECO sediment ponds on EFAC surface flow and chemistry are further complicated by MPC power plant and municipal water uses within and adjacent to Colstrip (see text below).

Pit dewatering and drawdown of coal, overburden or adjacent alluvial aquifer water levels could reduce or eliminate intermittent streamflow or ponding during mining operations. In EFAC, mining in Area B (and in adjacent WECO mines) could temporarily dewater alluvial (or other) aquifers contributing baseflow to any connected intermittent flow reaches (e.g. described above) or stockponds (e.g. ponds PO-929 and PO-937). In Lee Coulee, both WECO Area B and BSCC Area B mining would similarly dewater intermittent flowing and ponded reaches during mining operations; drawdowns have already occurred in the Lee Coulee wet reach adjacent to BSCC Area B. Mining-induced dewatering of stream baseflow should taper-off as pits move farther away from the affected stream reach, and backfilled spoil material saturates. However, in Lee Coulee where BSCC has proposed to mine through the intermittent stream reach, special mitigations would be required to reconnect upgradient recharge to approximate premining streamflow conditions.

Postmining Impacts of WECO Area B Mining

Postmining impacts to surface water systems in Area B would depend primarily on reclamation success in approximating premine topography, drainage geomorphology, and distribution of soil, water, and vegetation resources. Vegetative cover data from reclaimed fields in Area B give some evidence of potential recovery of premining hydrologic conditions (see Table 4). Sampling of nine reclaimed fields in Area B show total vegetative cover ranging from 63 to 99% (average 77%; 1993 data). Area B revegetation began in 1977 and continued through 1987; mining disturbance has not advanced since 1986. The youngest revegetated fields in Area B were 6-7 years old in 1993, the oldest 16-17 years; a total of 719 acres has been revegetated (of 1951 acres disturbed).

Topography/Geomorphology

Area B mining and reclamation would result in reclaimed topography that approximates premine topography with a simplified reconfiguration of principal drainage divides, channels, and slopes. The more highly dissected landforms (e.g. upper tributaries and ridgeline areas) would be regraded to a more uniform postmine topography with reduced drainage densities and slope diversity than before mining (see Maps 3 and 4). There would be no disturbance of the EFAC channel immediately north of Area B disturbance limits, but there would be some disturbance of adjacent alluvial terraces.

Because most Area B tributaries would remain undisturbed in at least some portion of their upper and lower reaches, blending of reclaimed and undisturbed topography along upper and lower disturbance limits would tend to result in average slopes being roughly similar between premine and postmine topography (see Maps 3 and 4). However, steeper premine slopes in Area B (e.g. 50-70% with some steeper outcrops) would be much flatter in reclaimed topography (approximately 20-30%). This flattening of steeper features is typical for mined land reclamation, and is due in part to regulatory limits, except in areas where steeper postmine features (e.g. bluff extensions, thin breaks) are allowed. No steeper features are proposed for Area B. Reclaimed topography proposed for the flatter, low elevation areas in Area B would be similar or a little steeper than the premine areas (1-2% slopes).

Some repositioning of channels and drainage boundaries would occur in EFAC and Lee Coulee tributaries within Area B due to displacement of backfilled overburden, regrading and final highwall reduction. Changes in drainage area would be most significant in WECO drainages 021-1, 020, 026, 011, 139, 012 and 127 (see Figure 4, Maps 3 and 4). Adjacent premine drainages 021-1 (781 acres) and 020 (501 acres) would be reconfigured into much larger (1226 acres)

and smaller (58 acres) postmine tributaries, respectively. The reverse would be true for adjacent premine drainages 026 (403 acres) and 139 (57 acres) which would be reconfigured into two more similarly sized drainages (202 and 289 acres, respectively). The change in adjacent drainages would result in much larger peakflows in the lower reach of postmine drainage 021-1, which would be somewhat offset by runoff storage in proposed permanent pond PO-21B. Where proposed changes to premine drainage area and potential runoff are more significant, some channel adjustments could be expected in undisturbed lower reaches of mined drainages, with at least short-term instabilities.

Surface Water Resources

Annual precipitation in the Colstrip area has ranged from 5.84 inches (1979) to 22.12 inches (1978) for the 1948 to 1992 period; the annual average for the period was 14.51 inches (see Figure 3; NCDC 1993). Average monthly precipitation in Colstrip ranges from a low of 0.52 inches (February) to 2.63 inches (June), with the wettest months occurring during spring storms (April through June). Monthly extremes for the period of record have ranged from 0.0 to 9.27 inches (May 1978). Rainfall predominates from May through October, snowfall is common from November to April and contributes approximately one third of the average annual precipitation.

Stream channels in Area B are ephemeral tributaries of EFAC and Lee Coulee with bedrock and structural controls. Most tributary and main channels are incised and vegetated with limited alluvial material in the upper reaches, increasing downchannel. Streamflow in Area B channels generally occurs in response to storm and snowmelt runoff; some limited intermittent flow may also occur in short reaches below springs (see below). Two adjacent intermittent flow reaches have been described in EFAC, beginning near the west end of the amendment area (NW¼ section 17, T1N, R40E) and continuing about two miles downstream to SE¼ section 10 (T1N, R40E). An intermittent/perennial wet reach also occurs in the mainstem Lee Coulee channel within the BSCC Area B permit area. Both of these flowing stream reaches appear to be related to groundwater discharges from adjacent overburden, coal and alluvial aquifers.

Storm runoff in ephemeral channels usually occurs after short intense storms, long duration storms, or after frequent wetting from smaller consecutive rain events. Snowmelt runoff usually occurs in February or March. Runoff duration in ephemeral channels is limited after storms in smaller tributaries, but may persist for weeks during snowmelt periods, especially in larger drainages. The intermittent reaches in EFAC are reported to have baseflow (up to 30 gpm) for much of the year. Intermittent streamflow at a monitoring site in Lee Coulee was common during snowmelt, spring, early summer and fall periods (baseflow up to ~100-200 gpm); individual baseflow periods ranged from over a week to approximately six months in length during the 1985-1993 monitoring period [BSCC flume BRTFL, NE¼ section 25 (near section 30 line; T1N, R40E) in Lee Coulee about two miles below proposed WECO B mining disturbance].

Following backfilling and regrading of mined drainages, runoff from unreclaimed mine spoils above sediment ponds are more flashy than in undisturbed drainages, with higher peakflows and suspended solids concentrations, due to limited infiltration and lack of a vegetative cover. After resoiling and seeding of regraded areas some vegetative stabilization of slopes and channels is initiated, and greater infiltration is promoted. Some rilling and gullying usually occurs as drainage systems stabilize, but this tends to diminish with increasing vegetative cover. Infiltration characteristics are expected to recover gradually toward premining conditions with increased vegetative cover and redevelopment of soil profiles.

Runoff characteristics of reclaimed drainages are expected to approximate those of premining drainages where soil, vegetation and geomorphic conditions are similar. However, because postmine drainages are generally reclaimed to simpler systems with less drainage density, overland flow distances would be somewhat longer, slowing times of runoff concentration, resulting in somewhat

lower runoff peaks of longer duration. These changes in peakflow character would be compounded where postmining slopes are flatter than in premine topography. Water chemistry in stable reclaimed areas is expected to be similar to premining conditions, with variable suspended solids concentrations (depending primarily on runoff magnitude) and low dissolved solids concentrations.

Only two springs have been mapped within the existing and proposed Area B permit boundary (SP-28 and SP-79). SP-28 in WECO drainage 019 has been mined-out, and SP-79 near the upper mining disturbance limit in the upper portion of WECO drainage 129-3 is not proposed to be "removed", but may be temporarily disturbed during mining. Similar, but indirect disturbance may also occur at SP-78, 1000 ft. SSE of SP-79 in a Lee Coulee tributary. Most springs in the area are used primarily by stock and wildlife; limited flow and chemistry data are available (see Table 5).

Five stockponds have been mapped within the existing and proposed Area B permit boundary (PO-911, PO-988, PO-989, PO-990 and PO-129D; see Table 6). Pond PO-911 in WECO drainage 015 was mined-out in 1983, the others would be removed by mining disturbance in the proposed amendment area. WECO proposes to leave five permanent ponds in Area B (see Table 7). Pond PO-21B in WECO drainage 021-1 would be left in the existing Area B; ponds PO-026, PO-129, PO-129B and PO-192B would be left in the proposed amendment area, located in drainages currently holding stock ponds. Stockponds in the area are also used primarily by stock and wildlife, and have limited water level and chemistry data available (see Table 6).

Offsite Disturbances (Non-Mining Activities)

In addition to surface mining disturbance, several important offsite activities also occur in the Colstrip area (see Map 1), including:
- Montana Power Company's power plants, fly ash ponds, and process water ponds (EFAC and Cow Creek);
- Castle Rock Reservoir - a 112-acre surge storage pond for power plant and municipal uses (pumped from the Yellowstone River to an EFAC tributary near Colstrip);
- Colstrip sewage treatment plant discharges and municipal runoff (EFAC);
- roads and railways; and
- the Rosebud County Landfill.

The combined effect of surface mining and Colstrip area offsite disturbances on local hydrology are not fully understood, but some general observations are possible. In addition to effects from upstream mining, changes to the local water balance and chemistry of EFAC are significantly influenced by these offsite disturbances.

Approximately 8000 to 8500 AF/year of Yellowstone River water is pumped via a 29-mile pipeline to the 2250 acre-feet surge storage pond (Castle Rock Reservoir) to supply MPC power plant and Colstrip municipal uses. The MPC power plant complex uses about 7,700 AF/yr (90-95%) of the annual surge pond storage, with 85% of that lost to evaporation through cooling processes and pond surfaces (MDSL/OSM 1983). The remainder of MPC's annual surge pond use is primarily for dust suppression (~400 AF/yr, most lost to evaporation), and seepage to local aquifers (e.g. overburden, coal or spoil aquifers and alluvium in EFAC and Cow Creek).

Total municipal use of surge pond water was estimated at 630 AF/yr (for 1980 population of 3,258). A large part of municipal use was for household and community irrigation, with losses to evapotranspiration, infiltration and urban runoff (MDSL/OSM 1983). Discharge of Colstrip sewage treatment plant effluent totaled 210 AF in 1980, including discharges to EFAC, and adjacent sewage effluent holding ponds (7-23 AF/month; or 130-170 gpm). Recent discharge reports of Colstrip sewage treatment plant effluent are higher,

ranging from 326-393 AF/yr (22-42 AF/month, or 160-340 gpm; 9/89 to 9/94 data (MDHES 1994)).

Seepage from the surge pond northwest of Colstrip to downgradient EFAC alluvium (~1/2 mile) has been estimated at 180 AF/yr (110 gpm; MDSL/OSM 1983). A consistent streamflow increase is apparent between two flume sites located on an adjacent reach of EFAC [between MPC's South flume (AR-2, upstream) adjacent to the sewage effluent holding ponds and North flume (AR-1, downstream) below the surge pond tributary (Hydrometrics 1993)]. Streamflow at MPC's South flume ranged from ~0.2 to 1.2 cfs (~120-520 gpm), while flows at the North flume ranged from ~0.4 to 2.8 cfs (~200-1200 gpm; 1981-1992 data). These increases in baseflow apparently reflect contributions from sewage treatment plant effluent and surge pond seepage. About 6 miles downstream, flow measurements at an EFAC site north of Colstrip ranged from 0 to 169 cfs, exhibiting storm and snowmelt runoff peaks (mean instantaneous flow 3.98 cfs; ~monthly USGS data from 10/74 to 9/85 - see Figure 5).

Water samples from EFAC in the immediate Colstrip area have a wide range of dissolved solids concentrations (e.g. station SW-01: ~1400-7000 mg/L TDS; Figure 2). Yellowstone River water supplied to the surge pond is significantly lower in dissolved solids than EFAC samples (e.g. Yellowstone at Miles City: ~200-600 mg/L TDS, Slagel and others, 1983). MPC's plant process water ponds and effluent holding ponds (fly ash ponds) have very high dissolved solids concentrations (e.g. ranging from about 5,000 to 50,000 mg/L TDS; MPC 1994). However, seepage from ponds at the plant site into EFAC alluvium is estimated to be small compared to alluvial flow above Colstrip (estimated at 340 gpm) and therefore significantly diluted (Hydrometrics 1993). Effluent from Colstrip's sewage treatment plant is apparently lower in dissolved solids than adjacent EFAC water, presumably due to its Yellowstone River source. During a one-day sampling of six EFAC monitoring sites in the Colstrip area, sewage treatment plant effluent measured 1320 mg/L TDS (6/15/93 sample, Hydrometrics 1993). Some dilution of dissolved solids is evident in EFAC below the sewage effluent ponds and the surge pond, due to inflow of lower TDS water.

Conclusions

The proposed amendment to WECO's Area B mine would increase overall mining disturbance in the Colstrip area by 3.6 $mi.^2$, roughly doubling the permitted mining disturbance for Area B.

Proposed Area B amendment disturbance in EFAC (3.3 $mi.^2$) would amount to 18% of total mining disturbance proposed above Stocker Creek (18.1 $mi.^2$), 13% of total mining disturbance in EFAC (25.9 $mi.^2$, adding disturbance in Stocker Creek), or 12% of total mining disturbance for the entire Armells Creek drainage (28.5 $mi.^2$, adding disturbance in WFAC; see Table 3). Proposed Area B amendment disturbance in Lee Coulee (0.33 $mi.^2$) would only amount to about 6% of total surface mining disturbance proposed in Lee Coulee (5.2 $mi.^2$), and only about 2% of total mining disturbance proposed for the entire Rosebud Creek drainage (14.6 $mi.^2$, adding disturbance in Miller and Hay Coulees, and Cow, Pony and Spring Creeks).

Proposed Area B mining in the EFAC drainage is obviously of much greater significance than in Lee Coulee. Disturbance in the proposed amendment alone is also of some significance in EFAC, particularly above Stocker Creek. However, as vegetative reclamation in Area B progresses from the initial bare cover to vegetative conditions similar to premining, only localized hydrologic responses are expected in surface water systems. Although the proposed WECO Area B amendment would place some additional burden on the cumulative surface water impacts of Colstrip area mining, it does not appear that premine surface water uses would be prevented after the proposed reclamation is completed. The Department therefore finds that no material damage to surface water systems would result with the proposed mining and reclamation in WECO's Area B amendment.

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Table 1. Existing mining disturbance in Colstrip area drainages within and adjacent to Area B (acres). Drainage boundaries are based on proposed postmine topography where shifts from premining divides occur (e.g. due to pit or major regrading disturbance). Redisturbed NP spoils (prelaw) are included as WECo disturbance. Differences between disturbance totals calculated here and those listed in permits or annual reports reflect minor differences in measurement techniques.

	EF Armells Cr. above Stocker	Stocker Creek	WF Armells Creek	Cow Cr. mainstem	South Fk. Cow Cr.	Spring Creek	Pony Creek	Lee Coulee	Miller Coulee	Hay Coulee	Total
WECo A	2165	529									2694
WECo B	1965							0			1965
WECo C	1152	1474	0								2626
WECo D	476			691		0	135				1302
WECo E	336			734	165						1235
WECo Pit 6					378					136	514
NP (WECo D)	1			139							140
NP (WECo E)				31	28						59
NP (WECo Pit 6)					<1						0
NP (adjacent)	208			176	536					34	954
Big Sky A									1656	13	1669
Big Sky B								749	15		764
BS (adjacent prelaw)									166		166
sum WECo	6094	2003	0	1425	543	0	135	0	--	136	10336
sum prelaw (NP,BS)	209	--	--	346	564	--	--	--	166	34	1319
sum Big Sky	--	--	--	--	--	--	--	749	1671	13	2433
Total	6303	2003	0	1771	1107	0	135	749	1837	183	14088

Table 2. Proposed life-of-mine disturbance in Colstrip area drainages within and adjacent to Area B (acres). Drainage boundaries are based on proposed postmine topography where shifts from premining divides occur (e.g. due to pit or major regrading disturbance). Redisturbed NP spoils (prelaw) are included as WECo disturbance. Differences between disturbance totals calculated here and those listed in permits or annual reports reflect minor differences in measurement techniques.

	EF Armells Cr. above Stocker	Stocker Creek	WF Armells Creek	Cow Cr. mainstem	South Fk. Cow Cr.	Spring Creek	Pony Creek	Lee Coulee	Miller Coulee	Hay Coulee	Total
WECo A	2733	813									3546
WECo B	4943							214			5157
WECo C	2254	4184	1645								8083
WECo D	1134			901		555	403				2993
WECo E	336			735	182						1253
WECo Pit 6					378					136	514
NP (WECo D)	0			104							104
NP (WECo E)				31	28						59
NP (WECo Pit 6)					<1						0
NP (adjacent)	208			176	536					34	954
Big Sky A									1657	13	1670
Big Sky B								3084	38		3122
BS (adj. prelaw)									166		166
sum WECo	11400	4997	1645	1636	560	555	403	214	--	136	21546
sum prelaw (NP,BS)	208	--	--	311	564	--	--	--	0	34	1117
sum Big Sky	--	--	--	--	--	--	--	3084	1695	13	4792
Total	11608	4997	1645	1947	1124	555	403	3298	1861	183	27621

Exhibit 15

Table 3. Drainage basins within and adjacent to permitted mining disturbance in the Colstrip area. Life-of-mine surface disturbance [(mi.^{2}), and % of drainage area (%DA)] is given for each drainage affected. Drainage/subdrainage relationships are indicated by indentation, in downstream order.

Drainage Basin	Drainage Area (DA)	Total Mining Disturbance Colstrip area*		WECO B Mining Disturbance		Elevation Range
	(mi.^{2})	(mi.^{2})	(%DA)	(mi.^{2})	(%DA)	(ft. AMSL)
Armells Creek:						
E. Fk. Armells above Stocker Cr.	48.2	18.14	(37.6)	7.72	(16.0)	3120-4780
Stocker Creek	26.3	7.81	(29.7)			3120-3940
East Fork Armells Cr. nr. Colstrip**	97.3	25.95	(26.7)	7.72	(7.9)	3030-4780
East Fork Armells Cr.	158	25.95	(16.4)	7.72	(4.9)	2780-4780
West Fork Armells Cr.	148	2.57	(1.7)			2780-4807
Armells Creek nr. Forsyth** (mouth)	370	28.52	(7.7)	7.72	(2.1)	2560-4807
Yellowstone River at Forsyth**	40,339	28.52	(0.1)	7.72	(<0.1)	2505-12799
Rosebud Creek:						
Lee Coulee	20.6	5.15	(25.0)	.33	(1.6)	3010-3720
Rosebud Creek nr. Colstrip**	799	5.15	(0.6)	.33	(<0.1)	3000-5217
Miller Coulee	13.2	2.91	(22.0)			2980-3653
Hay Coulee	6.2	.29	(4.7)			2940-3639
Cow Creek mainstem	17.0	3.04	(17.9)			2940-3580
South Fork Cow Creek	10.3	1.76	(17.1)			2940-3648
Cow Creek	32.0	4.80	(15.0)			2850-3648
Pony Creek	14.2	.63	(4.4)			2820-3560
Spring Creek	22.3	.87	(3.9)			2760-3580
Rosebud Creek at mouth, nr. Rosebud**	1302	14.64	(1.1)	.33	(<0.1)	2480-5217
Yellowstone River at Miles City**	48,253	43.16	(0.1)	8.06	(<0.1)	2333-12799

* Disturbance above Yellowstone River sites does not include mining outside of the Colstrip area.
** USGS streamflow measurement sites

Table 4. Historical disturbance and revegetation summary for WECO Area B, including: cumulative total disturbance and revegetation (acres), and total vegetative cover (% - average and range for fields sampled; data from Annual reports). Some permit area changes affect cumulative area totals (e.g. bond release).

Annual Report Period	Total Disturbance	Total Revegetation	Total Vegetation Cover	
	(acres)	(acres)	average (%)	range (%)
1976	203	0	-	-
1977	446	15	-	-
1978	440	49	-	-
1979	582	158	-	-
1980				
1981	701	208	78	-
1982	823	232	77	-
1983	1100	412	75	-
1984	1658	519	86	-
1985	1850	561	66	-
1986	1952	692	-	-
1987	1952	721	59	-
1988	1952	721	-	-
1989	1949	718	-	-
1990	1949	718	33	21-47
1991	1951	719	-	-
1992	1951	719	74	51-104 n=13
1993	1951	719	77	63-99 n=9

Exhibit 15

Table 5. Springs within and adjacent to Western Energy's Area B.

Spring	Mine	Drainage	Location (T, R, S)	Source	Water samples
SP-06	WECO A mined-out	EFAC trib. (013)	1N 41E 4abad	spoils	1/13/81: TDS 2810; TSS 3
SP-11		Richard Coulee	1N 40E 19dccd	overburden	5/1/86: TDS 1770; TSS 14 (~5 gpm)
SP-28	WECO B mined-out	EFAC trib. (019)	1N 41E 8aab	overburden	11/79: (~5-10 gpm)
SP-67		WFAC trib.	1N 39E 11bbda	overburden	8/4/83: TDS 2530
SP-77		Richard Coulee	1N 40E 20dadb	overburden	5/1/86: TDS 1290; TSS 4 (~1 gpm)
SP-78		Lee Coulee trib. (upper)	1N 40E 22bbbb	overburden	5/16/86: TDS 17,400; TSS 20 (~4 gpm)
SP-79	WECO B amend.	EFAC trib. (129-3)	1N 40E 16ddac	overburden	5/20/86: TDS 12,600; TSS 96 (~4 gpm)

Table 6. Stock ponds within and adjacent to Western Energy's Area B.

Pond	Mine	Drainage	Location (T, R, S)	Water samples	Water level (5/86)
PO-911	WECO B	EFAC trib. (015)	1N 41E 9abac	3/12/81 - 1/7/83 (n=7): TDS 100-7490, mean 1875; TSS 29-216, mean 79	mined-out 1/83
PO-920	WECO A	EFAC trib. (013)	1N 41E 5abbb	8/16/82 - 1/7/86 (n=6): TDS 142-1510, mean 795; TSS 2-3280, mean 612	mined-out '79; 9/86 = PO-13A
PO-929		EFAC	1N 40E 15babc	5/28/86: TDS 3580, TSS 8	half full
PO-937		EFAC	1N 40E 8ddac		dry
PO-982		Lee Coulee trib. (Randy Thomas)	1N 40E 24aacd	5/13/86: TDS 96, TSS 10	little water
PO-983	BSCC B	Lee Coulee trib. (Marmot Mound)	1N 41E 19cadb		dry
PO-984	BSCC B	Lee Coulee (below Marmot trib.)	1N 41E 29ccca	5/14/86: TDS 1700, TSS 22	little water; dike out
PO-985	BSCC B	Lee Coulee (above Bad Bob Gulch)	1N 41E 33bdcc	5/14/86: TDS 1340, TSS 26	little water
PO-986		Lee Coulee (upper)	1N 40E 22bbcd	5/15/86: TDS 282, TSS 84	part full
PO-987	BSCC B	Lee Coulee trib. (Gamble's well)	1N 40E 24cacb		dry
PO-988	WECO B amend.	EFAC trib. (129-3/129-7)	1N 40E 16acda		dry
PO-989	WECO B amend.	EFAC trib. (129-3)	1N 40E 16daca		dry
PO-990	WECO B amend.	EFAC trib. (026)	1N 40E 13abba		dry
PO-129D	WECO B amend.	EFAC trib. (129-5)	1N 40E 17dadb		dry

Exhibit 15

Table 7. Proposed permanent ponds in Western Energy's Area B reclamation plan.

Pond	WECO Mine	WECO Drainage	Drainage Area (acres)	Elevation Range (ft. AMSL)	Location (T, R, S)
PO-21B	B	021-1	780	3340-3660	1N 41E 8bc
PO-026	B amend.	026	190	3370-3565	1N 40E 12da
PO-129	B amend.	129	1130	3460-3745	1N 40E 15ab
PO-129B	B amend.	129-3	860	3500-3745	1N 40E 16ad
PO-129D	B amend.	129-5	420	3580-3745	1N 40E 17da

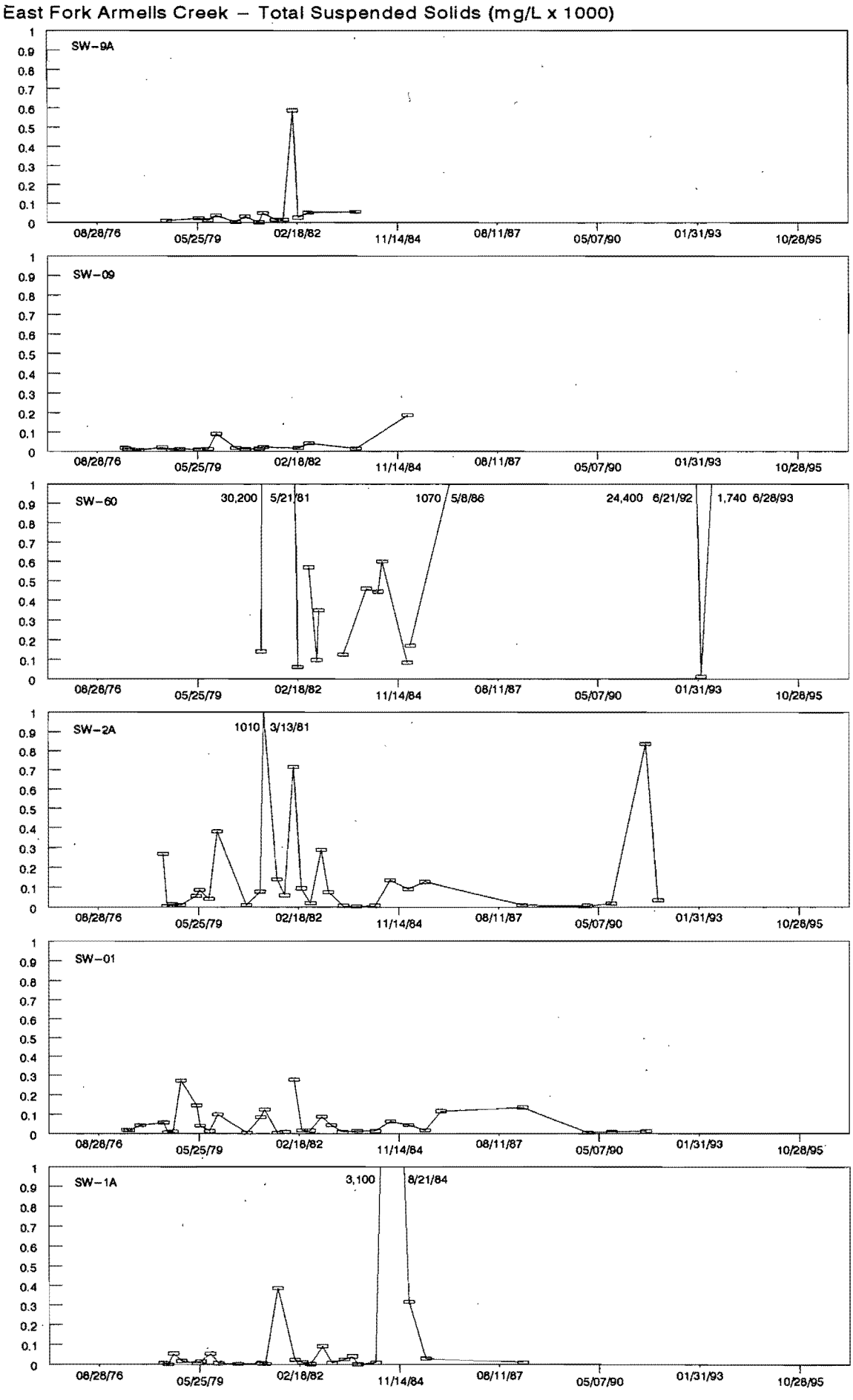

Figure 1. Total suspended solids (mg/L) in streamflow samples from East Fork Armells Creek monitoring sites (downstream order; WECo data).

Exhibit 15

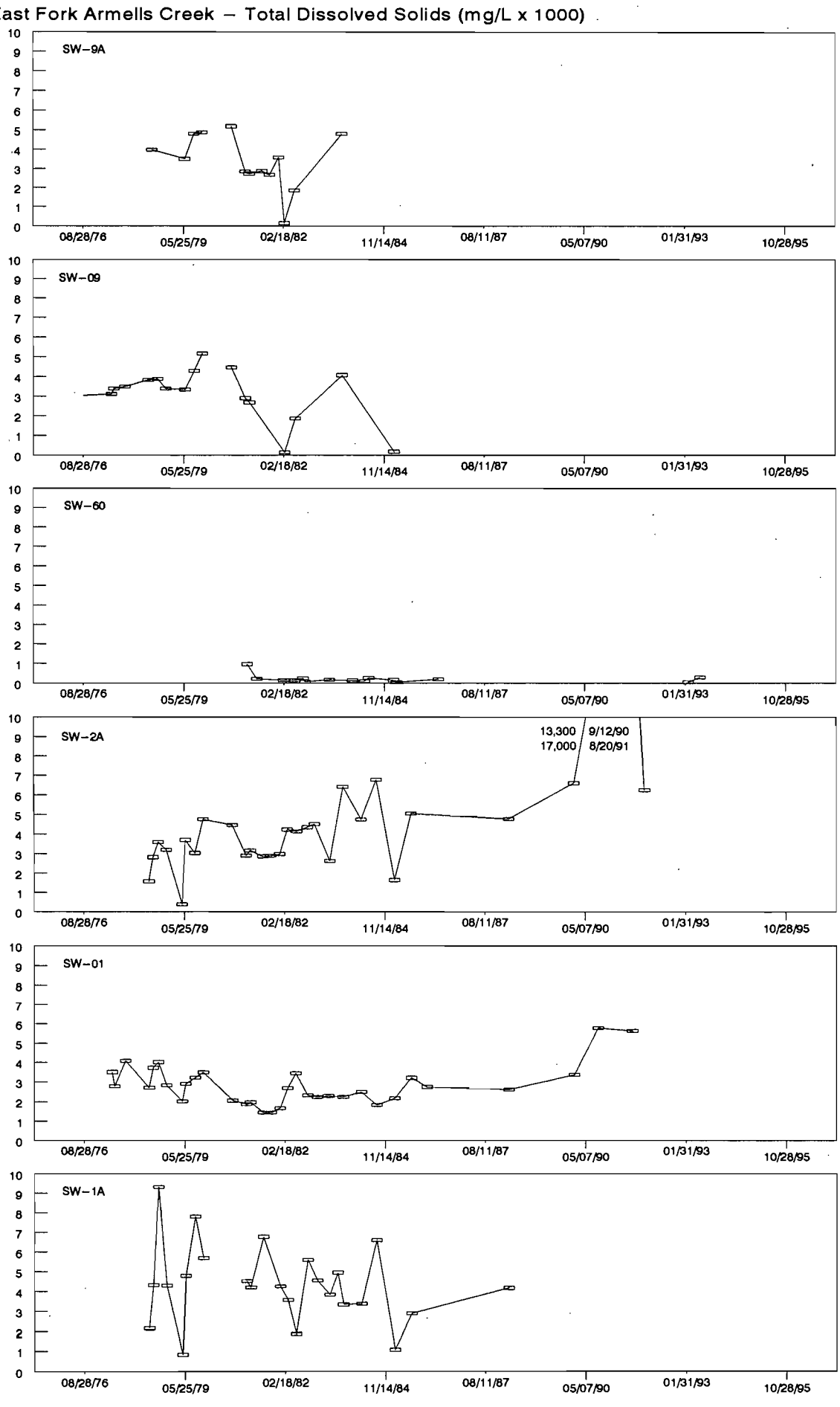

Figure 2. Total dissolved solids (mg/L) in streamflow samples from East Fork Armells Creek monitoring sites (downstream order; WECo data).

Exhibit 15

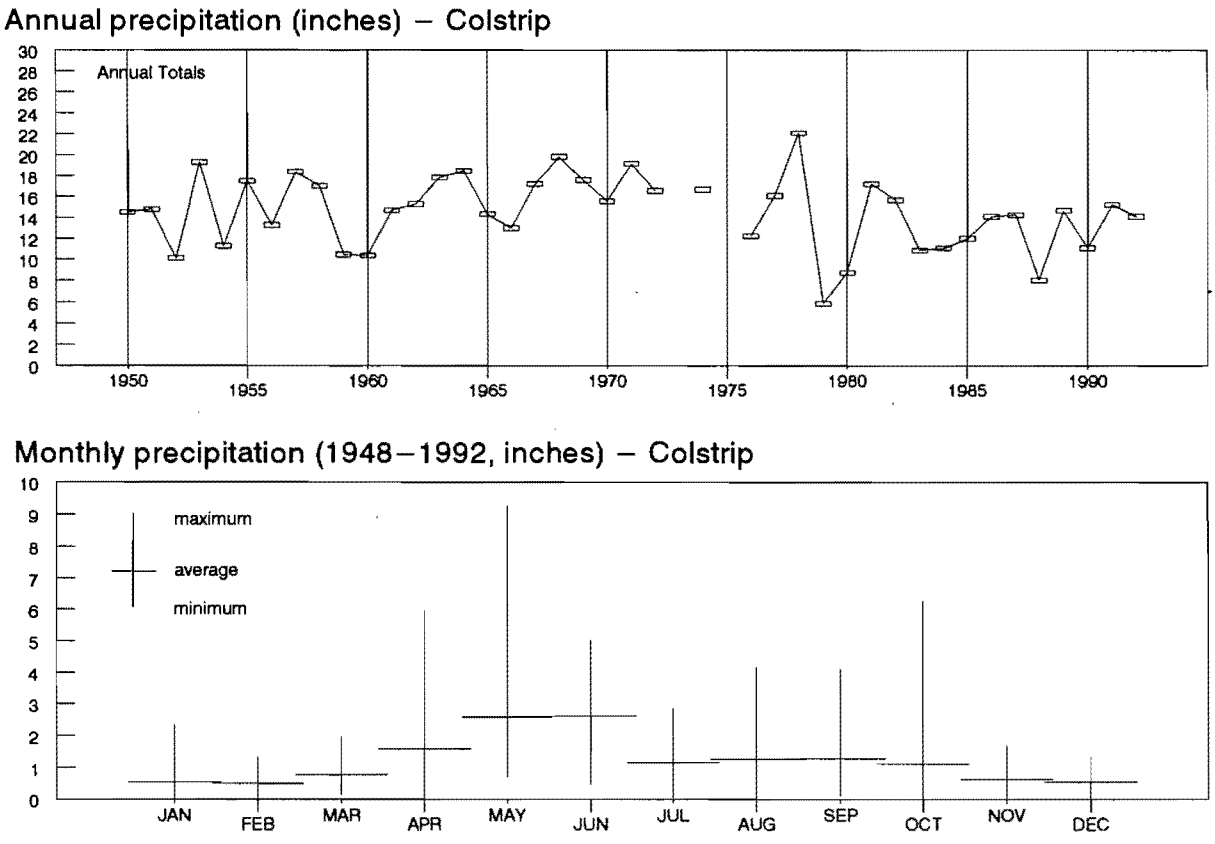

Figure 3. Annual and monthly precipitation in Colstrip, Montana, for the 1948 to 1992 period (missing data in 1948, 1973, 1974, 1975, 1976, 1980 and 1981).

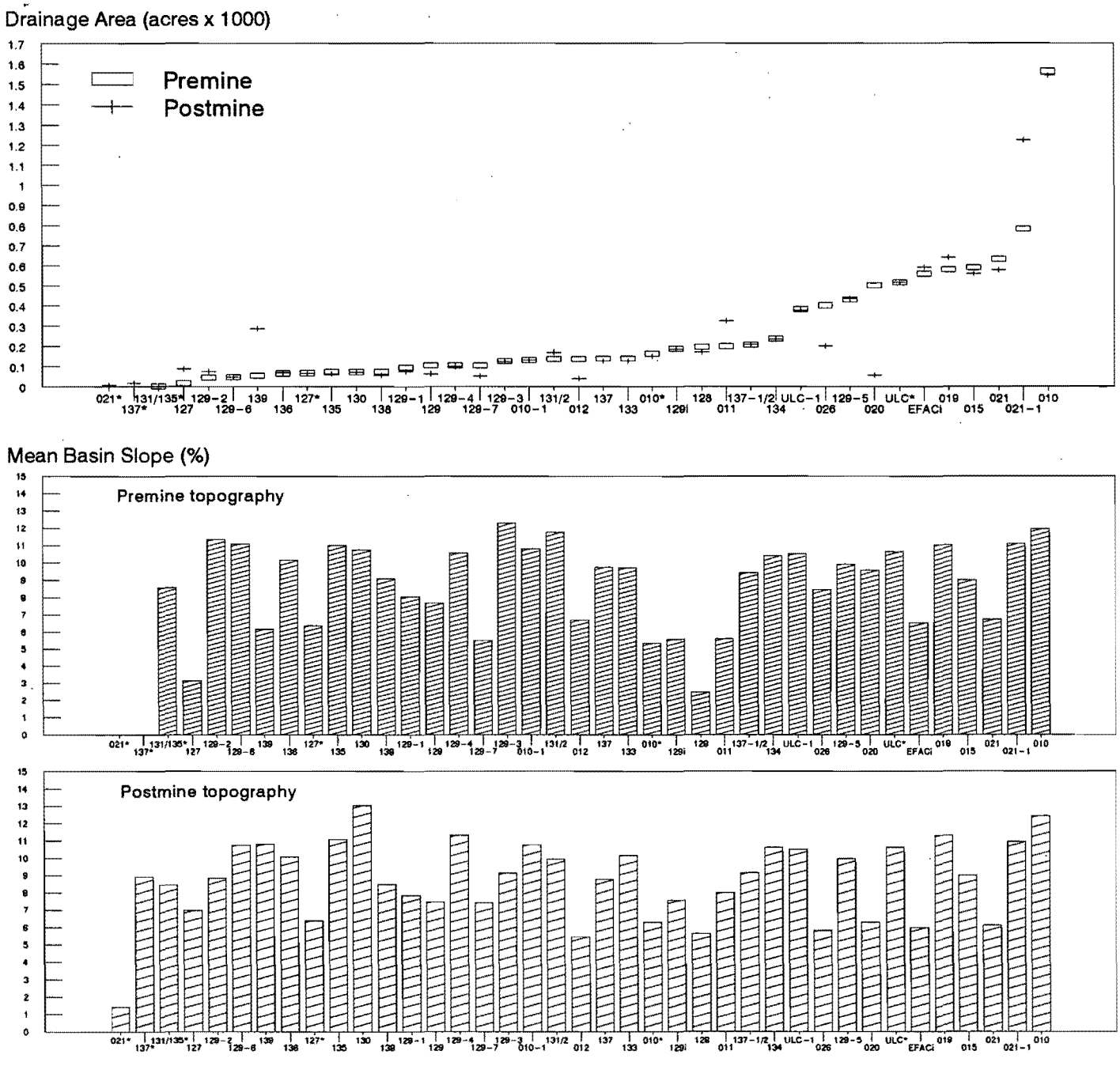

Figure 4. Comparison of premining and postmining drainage basins (area, mean basin slope) for East Fork Armells and Lee Coulee tributaries disturbed by existing and proposed WECo Area B mining.

Exhibit 15

East Fork Armells Cr. nr. Colstrip (6.7 mi. north; USGS site)

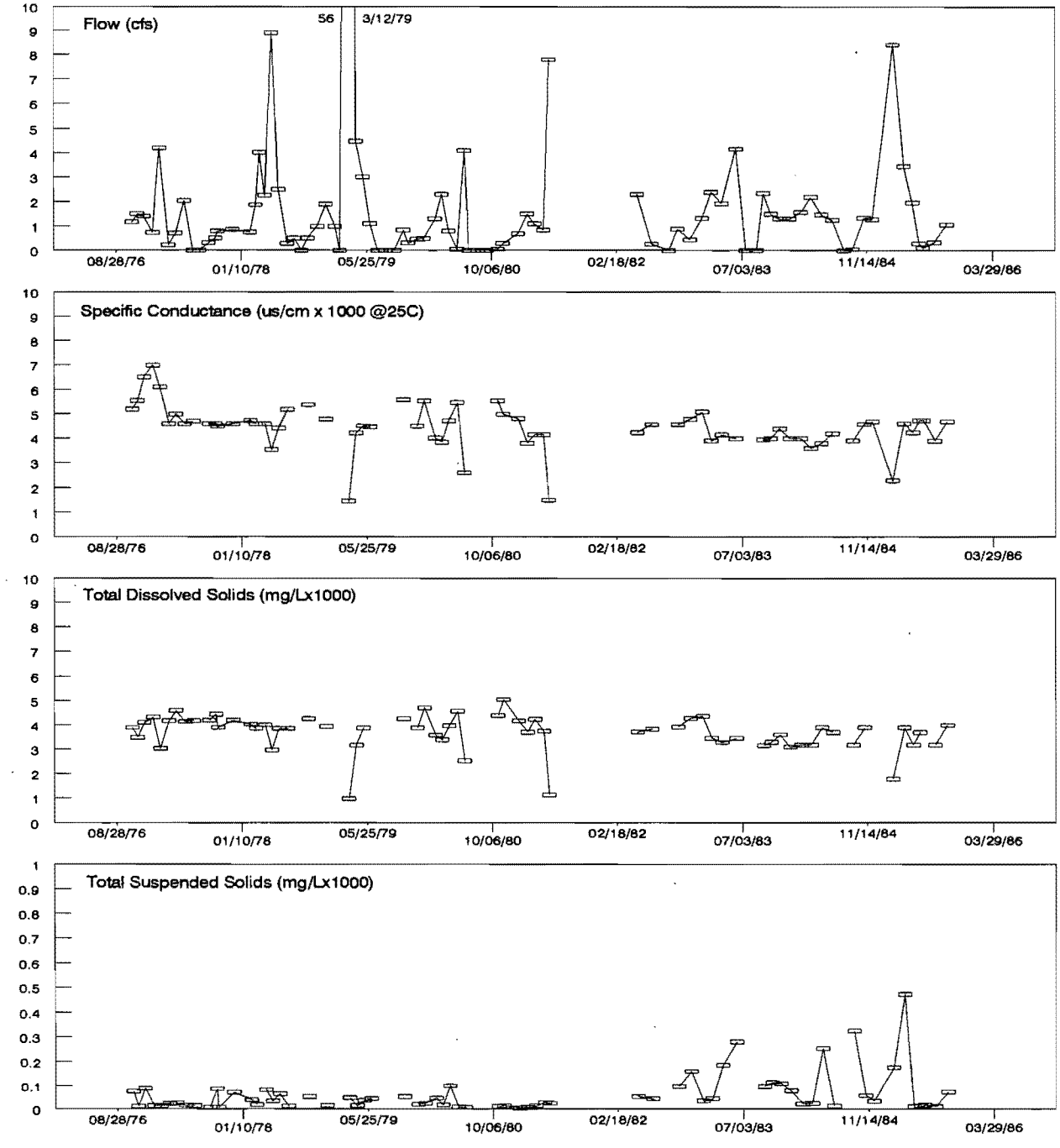

Figure 5. Streamflow and chemistry for East Fork Armells Creek near Colstrip [6.7 mi. north; approx. monthly measurements/samples (USGS site, same location as WECo's SW−1A)].

Exhibit 15

26.4.314 PLAN FOR PROTECTION OF THE HYDROLOGICAL BALANCE

This section describes the plan for protection of the hydrologic balance at the Rosebud Mine. Components of the premining hydrologic balance are described and detailed descriptions of protective measures to be taken during and after proposed mining activities are presented. This section also includes a description of the monitoring plan to determine probable hydrological consequences of the proposed strip mining operation on the mine plan area and the adjacent area.

Premining Hydrologic Balance: The hydrologic balance describes the relationships between all aspects of surface and groundwater quantity and quality including precipitation, runoff, evaporation, and changes in ground and surface water storage. Major components in the hydrologic balance are:

1. precipitation as rainfall and snow;
2. evaporation from open water surfaces and soils;
3. transpiration from plants;
4. interception of precipitation by vegetation;
5. infiltration of water into the soil and percolation to groundwater;
6. runoff both as overland and channelized flow;
7. storage of moisture in the soil and in ponds and reservoirs; and
8. recharge, discharge, and storage of water in groundwater systems.

Mining has the potential to change the hydrologic balance through possible changes in evapotranspiration, infiltration, runoff, soil moisture, or groundwater. Sedimentation ponds, diversion ditches, water treatment ponds, postmining recontouring, top soil replacement and revegetation are specifically designed to protect the hydrologic balance.

Exhibit 14

WCCPROD00001522

Hydrological Systems Components: Water input to the hydrologic system comes in the form of precipitation, including rain, snow, sleet, and hail. A portion of the precipitation is intercepted by vegetation. Some precipitation runs off or goes into storage in ponds, depressions, etc. Overland flow enters drainage channels and becomes streamflow. A portion of precipitation infiltrates into the soil, most of which provides water for plants, but some percolates downward recharging underlying groundwater systems. The majority of the precipitation is returned to the atmosphere by evapotranspiration which includes evaporation from water bodies and soil surfaces and transpiration from plants. Of the water that percolates downward to groundwater systems, some enters regional groundwater systems, some is held in the unsaturated zone between the soil surface and the water table, and some enters into local groundwater systems. Surface water flows commonly are sources of recharge to groundwater, particularly to alluvium underlying stream channels. Local and regional groundwater systems discharge to springs or to streams providing baseflow.

Precipitation: Precipitation has been measured at Colstrip from 1941 to the present. The long-term average annual precipitation at Colstrip for the period 1941 to 1985 is 15.5 inches. April, May, and June normally are the wettest months averaging 1.9, 2.5 and 3.3 inches, respectively. January and February are the driest months averaging 0.6 inches each (U.S. Department of Commerce, 1973). Extremes in precipitation since 1970 were 22.12 inches in 1978 and 7.66 inches in 1980. The wettest individual month during the 1970 to 1979 period was May, 1978 during which 9.3 inches of rainfall occurred. (U.S. Department of Commerce, 1979), average monthly (1941 - 1985) precipitation for Colstrip is

Exhibit 14
WCCPROD00001523

shown in Table 27, page 186. Precipitation Data for Colstrip are updated annually with the Annual Hydrology Report (HRDV I, Surface Water FLow Data). Precipitation data are collected by Western Energy at surface water sites using wedge-type gages.

From November to April, precipitation occurs predominantly in the form of snow which contributes approximately one-third of the total annual precipitation for the Colstrip area. Due to prevailing westerly winds, snow typically accumulates on leeward slopes of the north-south oriented drainages which are predominant in Area B.

Interception: Interception occurs when precipitation is caught by the vegetative cover and redistributed as throughfall, stemflow, and evaporation. Interception loss is the part of rainfall that is retained by the aerial portion of the vegetation and is either absorbed by the vegetation or is returned to the atmosphere through evaporation. Major factors in interception are vegetation type, density, form, and age. Water intercepted by vegetation is not available for infiltration. No site-specific data are available for interception losses for native vegetation in the Colstrip area. Horton (1919), however, developed a general relationship for clover and meadow grasses as follows:

$$I = 0.00042H + 0.00026HP$$

where I is interception in millimeters (mm)

H is the grass height in mm

P is precipitation in mm for an individual event

Horton's equation must be used with individual storm events; thus, it is difficult to apply to the Colstrip area on an average basis. To obtain an idea of magnitude of interception, assuming ten storms of equal duration in the

Exhibit 14
WCCPROD00001524

months of May and June, and five storms per month in July through October, and using a gross height of 150 millimeters (six inches) results in interception losses shown in Table 26, page 149. These values are less than, but agree reasonably well with empirical results published by the U. S. Soil Conservation Service (Dunne & Leopold, 1978) for interception losses in cropped areas of oats or wheat during the growing season (see Table 26).

Exhibit 14
WCCPROD00001525

TABLE 26

Calculated Interception Losses at Colstrip, Montana

Interception in Inches

	J	F	M	A	M	J	J	A	S	O	N	D
Horton	--	--	--	--	.12	.15	.06	.07	.07	.05	--	--
SCS*	--	--	--	--	.24	.33	.12	.14	.14	.10	--	--

* Reference: Dunne & Leopold, 1978

Exhibit 14

WCCPROD00001526

Evapotranspiration: Evapotranspiration includes both evaporation from water and soil surfaces and the transpiration or use of water by plants. It is the principal path by which precipitation returns to the atmosphere. Quantitative measurements of evapotranspiration are very difficult to make, thus numerous indirect techniques have been developed to calculate evapotranspiration rates. There are several factors involved in evaporation and transpiration including temperature, wind, total heat input, vegetation type, and season. A widely used technique for calculating evapotranspiration is the Blaney-Criddle formula (SCS, 1970) which states:

$$E_t = (0.142\ T_a + 1.095)\ (T_a + 1.78)kd$$

where; E_t = potential evapotranspiration (cm/month)

T_a = average air temperature ($^\circ$C) (when T_a is less than 3°C, the first term in parenthesis is equal to 1.38)

k = empirical crop factor that varies with crop type and stage of growth

d = monthly fraction of annual hours of daylight.

Potential evapotranspiration (E_t) as calculated by this formula is defined as that evapotranspiration that would occur if the availability of water were not a limiting factor. Evapotranspiration values using the Blaney-Criddle formula are shown in Table 27, page 186.

Another common method for estimating evapotranspiration is the use of Class A pan evaporation data. Class A evaporation stations consist of a standard 4 foot diameter pan partially filled with water. Each day the amount of water

Exhibit 14
WCCPROD00001527

loss from the pan is determined and the water replaced. Pan evaporation data are relatively easy to obtain and pan data are widely available for estimations of evaporation.

Montana State University has collected land pan evaporation data at Peabody Coal Company's Big Sky Mine near Colstrip and Western Energy Company has collected pan evaporation data at the Rosebud Mine; results are in Table 28, page 187. Also, included in this table are U. S. Weather Service pan data from the Yellowtail Dam and the Huntley Project stations. Gray (1970) recommends applying a factor of 0.68 to pan evaporation data to estimate actual evapotranspiration. With a pan evaporation of 53 inches per year at Colstrip, and a pan factor of 0.68, actual evapotranspiration is estimated to be 36 inches per year. This compares reasonably well with evapotranspiration of 28 inches calculated by the Blaney-Criddle method. Dr. D. Dollhopf of Montana State University suggests a pan factor of 0.85 for the Colstrip area which results in a potential evapotranspiration value of 45 inches (Dollhopf, pers. comm., 1981).

Potential evaporation or evapotranspiration at Colstrip is large compared to precipitation. This condition is common and typical of semiarid areas with warm summers. Implications of these data are that loss of moisture by evaporation and evapotranspiration is a major factor in the hydrologic balance for any area of this type.

Another factor contributing to loss of moisture in an area is sublimation. Sublimation is a direct conversion of ice or snow to water vapor without passing through a water phase. Chow (1964) estimates sublimation losses in the middle latitudes during the winter season to be about 0.5 inches of water per month of snow cover. Snow normally occurs in the Colstrip area from November through March and accounts for approximately one-third of the total annual precipitation

Exhibit 14
WCCPROD00001528

for the Colstrip area. Thus, during this period sublimation could transfer about half of the precipitation (2.5 inches) occurring from November through March back into the atmosphere.

Infiltration: Infiltration is the movement of water through the soil/air interface. It involves three independent processes: entry through the soil surface, storage within the soil profile, and transmission through the soil. Infiltration of water into soils is affected by the soil type, antecedent moisture, organic matter, vegetative cover, subsurface permeability, watershed slope, and soil temperature.

A detailed soil survey was conducted in Area B in accordance with the standards of the National Cooperative Soil Survey (26.4.304(13)). Results of this survey were used to estimate infiltration rates in Area B. Most soils in the proposed mining area are derived from fine grained materials and are categorized into U.S. Soil Conservation Service Hydrologic Soil Group B. Infiltration rates for this group range from slow (0.06 in/hr) to moderately rapid (6 in/hr) and are shown in Table 29, page 188. A weighted average for the permit area is moderate (2.3 in/hr).

Due to the semiarid nature of this area, total depth of infiltration generally is not high. In areas where water accumulates, such as small depressions, ponds or channel bottoms, sufficient water is present to allow significant infiltration into the subsurface. The average infiltration rate of 2.3 in/hr for soils in Area B substantially reduces the amount of runoff in the basin. Most precipitation events in this area have intensities that are less than 2 inches per hour (5 cm/hr), thereby allowing infiltration to be a major

Exhibit 14
WCCPROD00001529

mechanism influencing runoff. This value of 2.3 in/hr compares with a value of 3.8 in/hr (average of 213 determinations at 18 sites on the Rosebud Mine determined using ring infiltrometers.

Runoff: When the rainfall or snowmelt rate exceeds the infiltration rate of the soil, water collects and flows overland to drainage channels. Area B primarily is drained by small ephemeral tributaries to East Fork Armells and Rosebud Creeks. Approximately 1907 acres or 91 percent of the disturbed area drains to East Fork Armells Creek, and 195 acres or 9 percent of Area B Extension drains to Rosebud Creek. Normally, no flow occurs in the ephemeral drainages within the permit area except during periods of intense rainfall or rapid snowmelt.

Two cutthroat flumes, one instrumented culvert, and five crest gages are currently utilized to measure streamflow in East Fork Armells Creek and ephemeral tributaries in Area B. Locations and installation descriptions are included in HRDV I (Surface Water Station Descriptions). Flow data are found in HRDV I (Surface Water Flow Data). An average annual water yield of 0.0185 acre-feet per acre has been estimated for Area B (26.4.308(8)(e) utilizing data from three U.S.G.S. gaging stations near Colstrip having similar drainage basin characteristics. Applying this value to the proposed disturbance area results in an average of 39 acre-feet or 0.2 inches of runoff per year from the 2102 acres. This estimated annual runoff is substantially higher than has been observed in the Colstrip area since Western Energy began monitoring surface water flows in 1979.

Sediment ponds in Area B (assuming all were in place at one time) might impound 0.8 percent of the average annual runoff for Armells Creek near Forsyth.

Exhibit 14

WCCPROD00001530

Estimated reduction in annual runoff for various other locations and tributaries are: 6.2 percent for Armells Creek above the mouth of Stocker Creek; 8 percent for Armells Creek at the highway near the eastern edge of Area B; 1.5 percent for Lee Coulee above Rosebud Creek; and 0.02 percent for Rosebud Creek above the Yellowstone River. This assessment is based on relative drainage areas only and neglects such factors as sediment pond discharges which are difficult or impossible to predict.

Soil Moisture: Soils can absorb significant quantities of water which infiltrate into the subsurface. Water moving into an idealized isotropic soil will satisfy the water holding or field capacity of the surface horizons before moving downward in response to gravity. After removal of the gravitational water, water still remains in the soils due to capillary and surface forces. The amount of water that the soils can hold after gravitational drainage is termed "field capacity". For soils in Area B, field capacities range from 0.06 inches/inch to greater than 0.13 inches/inch and average about 0.1 inches/inch as shown in Table 29, page 188. Assuming a layer of soil approximately 4 feet thick, the total amount of water that can be held in the soil is 4.8 inches. From this, it can be seen that the soils can be a major factor in water storage. This water is available for transfer to the atmosphere by evaporation or by transpiration through plants. Moisture is also held by soil and regolith materials at depths greater than four feet but above the water table where interaction with plants and the surface are less likely.

Soil moisture fluctuates in response to long-term climatic changes and shows annual fluctuations. Soils commonly are at their highest moisture content during spring and early summer when snowmelt and precipitation are maximum.

Exhibit 14
WCCPROD00001531

They become driest during the late summer when evaporation and transpiration have had their maximum effect. During the fall, soils tend to gain some water from precipitation. Methods for measuring soil moisture include laboratory analysis of samples collected from test borings, neutron scatter technique, and gypsum blocks; all of which have been used at the Rosebud Mine.

Soil moisture studies have been or are being conducted by Western Energy Company in Areas A, B, and C and by MSU at several locations in the Colstrip area to provide information on a variety of soil, vegetation and geomorphic situations. In Areas A, B, and C, a total of 18 sites, all on East Fork Armells Creek alluvium, were monitored monthly to depths of 8 to 12 feet (Hydrometrics, 1980). Results of this testing show that during the exceptionally dry period from June to October, 1980, soil moisture variations were small except in the upper few feet of the soil. The zone showing the most significant moisture fluctuations was the upper foot of the profile; soil moisture was lowest during the summer and increased slightly in the late fall.

Soil moisture readings for the 1981 growing season (June to October) along East Fork Armells Creek were compared to the 1980 data for the same period. Within the top three feet of the soil profile there were significant moisture variations due to precipitation events. However, below three feet, soil moisture for both years at specific depths were very similar, and varied at a maximum by five percent throughout the growing season. Some general trends were apparent in 1980 and 1981. Surface moisture to 3.0 feet declined from June to August or September, increasing in September or October with fall precipitation. Monthly variations in soil moisture below 3.0 feet were very small in most cases, fluctuating by one to three percent generally, and up to five percent in

Exhibit 14
WCCPROD00001532

one instance. The heavy rains at Colstrip during spring 1981 and early summer did not seem to affect subsurface moisture below 3.0 feet.

Soil moisture is also being evaluated at sites in Areas A and B in a continuation of Western Energy Company's infiltration study mentioned under Infiltration, Rule 26.4.304(5), and documented in HRRV V (Western Energy Co., 1982 and Western Energy Co., 1983). Gypsum blocks, evaporation pans, and precipitation gages were installed during the summer of 1984 at an undisturbed site in Area A and a reclaimed site in Area B. Mirco watersheds at each site were isolated with metal edging and equipped with catchment buckets. Preliminary analysis of data from this study, although not conclusive, seems to support the findings mentioned above.

Groundwater: Groundwater is present in shallow bedrock aquifers including coal seams, localized sandstone lenses and in unconsolidated alluvium present in large drainages in the area. In Area B, a number of groundwater observation wells have been constructed to observe water level fluctuations in the various aquifers and to determine the hydraulic properties of water-bearing zones (HRDV I, Groundwater Stations and Level Data, and HRDV III, Groundwater Hydrographs). Data obtained from these observation wells and detailed discussion of groundwater characteristics are in 26.4.304(5).

Groundwater Recharge: Groundwater recharge can potentially occur in the permit area through three mechanisms: 1) area wide infiltration and recharge, 2) lateral inflow from topographically high areas such as the Little Wolf Mountains, 3) infiltration and recharge in topographic low areas such as stream channels and depressions. The relative importance of these three mechanisms probably varies from mine area to mine area and probably also within mine areas,

Exhibit 14
WCCPROD00001533

particularly an area as large as Area B. Area wide infiltration and recharge could occur as a result of precipitation during late fall before the ground freezes--or in the spring as a result of snow melt, runoff, or precipitation after the ground has thawed. An annual infiltration of 0.06 inches could supply a potential outflow of approximately two gallons per minute from a one square mile area. Potentiometric surface maps suggest both regional recharge from the Little Wolf Mountains and area wide infiltration (HRRV I, Annual Report). Topographic lows, such as depressions and stream channels concentrate moisture and could become local point and line sources of recharge to underlying groundwater systems. Quantitatively, the contribution of such sites are unknown, difficult or impossible to quantify accurately, and vary from year to year. Overall, groundwater recharge from such sites is probably small, but may be locally significant.

Groundwater Discharge: A list of springs, their contributing aquifers and flows are presented in 26.4.304(8)(b), Table 1, page 58 and shown on the Surface Water Sites, Ponds, Springs, and Private Wells Map (HRDV I, Monitoring Schedule and Site Location Map). Evidence of discharge to surface water includes intermittent flow in East Fork Armells Creek and a number of springs or seeps in the headwaters of the Armells Creek drainage. During runoff, alluvium along the ephemeral streams may become saturated. These saturated sediments slowly drain and supply a short period of baseflow to these streams. East Fork Armells Creek contains two short segments which have continuous base flow during much of the year ranging from no flow to about 30 gpm (within Sections 8 and 15, T1N, R40E). The source of these discharges is believed to be alluvium, with contribution from Rosebud coal in Section 15. Above Section 15 (T.1N.,R.40E.), alluvium may

Exhibit 14
WCCPROD00001534

discharge to the Rosebud coal and/or overburden. The absence of larger and more numerous perennial segments of these streams suggests groundwater discharge to streams is not significant.

Groundwater Storage: The change in the amount of groundwater storage can be determined by assessing annual fluctuations in water levels and by determining the areal extent of aquifers underlying the area. Results of groundwater monitoring in the entire upper East Fork Armells Creek shows there is little fluctuation in groundwater levels in bedrock aquifers (HRDV II, Groundwater Hydrographs). However, alluvial aquifers tend to have a distinct seasonal fluctuation in response to the annual precipitation cycle.

Water bearing zones of interest in the permit area are the Rosebud overburden and Rosebud coal. The alluvial aquifer associated with East Fork Armells Creek will be disturbed by mining along the middle and upper terraces parallel to East Fork Armells Creek in Sections 11, 14, 15, 16, and 17 (T1N,R40E). Major changes in groundwater storage in the East Fork Armells Creek alluvium, however, are not expected and will not be considered here. During mining and reclamation, infiltration and discharge from sedimentation ponds and mine pits should mitigate the disruption of the headwater drainages.

Average annual water level fluctuations for Rosebud overburden and the Rosebud coal wells are approximately 1.1 and 0.8 feet, respectively (HRDV II, Groundwater Hydrographs). Multiplying these fluctuations by the areal extent of the aquifers and by the storage coefficient yields the change in groundwater storage. Storage coefficients for overburden and Rosebud coal are estimated to be 0.004 (see discussion under Rule 26.4.305(5)).

Exhibit 14
WCCPROD00001535

Using an average storage coefficient for both aquifers, changes in storage are estimated to be the equivalent of .05 and .04 inches of water for the Rosebud overburden and Rosebud coal seam respectively, for the mine permit area.

Rosebud Overburden

DS = DWL x Area x S

= 1.1 x 9490 acres x 0.004

= 41 acre/ft. or .05 inches

Rosebud Coal

DS = DWL x Area x S

= 0.8 x 9490 acres x .004

= 30 acre/ft. or .04 inches

DS = change in groundwater storage (acre-ft.)

DWL = change water level elevation (ft.)

Area = Area of aquifer (acres)

S = Storage coefficient

Neither the overburden nor the Rosebud coal underlie the entire permit area, so these estimates are high. These results indicate that changes in groundwater storage are relatively insignificant in the overall hydrologic balance.

Summary: From an evaluation of the components of the hydrological cycle, several important conclusions can be made:

1. Precipitation in the form of rainfall is the major input to the hydrological system and the period of major precipitation occurs during late spring and early summer which also is a period of high evapotranspiration.
2. Interception and subsequent evaporation result in about 0.5 to 1.0 inches of precipitation loss per year.

Exhibit 14
WCCPROD00001536

3. Evapotranspiration is the major mechanism for return of water to the atmosphere and is far more important than any other component of the hydrological cycle for transfer of water; calculated potential evapotranspiration is two to three times the average annual precipitation.
4. Sublimation of snow is an important mechanism for transfer of water to the atmosphere during late fall, winter, and early spring.
5. The infiltration capacity of soils in the proposed mining area is large compared to precipitation intensities in the area. This means that infiltration is an important mechanism for transfer of a significant percentage of precipitation into the soil, and surface runoff will occur only during significant precipitation events or following rapid snowmelt.
6. Soil moisture is an important but difficult to quantify component of the hydrological cycle; however, significant quantities of water are stored in the soil and subsequently removed by evaporation and transpiration.
7. Runoff to streams, groundwater recharge, and changes in groundwater storage are a small fraction of the precipitation input into the hydrological cycle.
8. Groundwater discharge contributes very little to the transfer of water from one component to another component or other components of the hydrologic cycle.

Exhibit 14

WCCPROD00001537

Exhibit 14

26.4.314 (1) (a): Mining in Area B will be done by dragline excavation. Pit orientation is shown on Exhibit A. Spoils will be regraded with crawler tractors. The general mining plan includes salvage of soil material from the mining area in advance of each pass. Average depth of topsoil salvage will be one foot. After topsoil is removed, subsoil will be removed by an average depth of about one foot. Scrapers and other mobile equipment will salvage, transport and deposit the soil materials on graded areas or in soil storage areas. Overburden stripping will be done with a dragline.

Mining impacts of hydrological importance that can occur are destruction of horizontal continuity in the overburden strata and mixture of the overburden strata in the backfilled pits creating a more isotropic media. During this process, some geological materials that were saturated are intermixed with unsaturated materials. In addition, a variety of lithologies are mixed including siltstones, sandstones and shales. The mining process substantially increases the surface area of excavated materials exposed to air and water. During the mining process, soil structure is altered, vegetation is removed, and the replaced subsoil and topsoil probably has a slightly increased bulk density.

The dragline removes overburden material by pulling the bucket upward from near the base of the cut toward the top. This material is then "cast" into spoil ridges in the preceding cut. As the stripped overburden material is cast, it is spread over a relatively large area, as much as perhaps 150 meters by 50 meters horizontally and 20 by 30 meters vertically. During this process, the materials are thoroughly mixed, and blocks of geologic materials tumble down steep spoil pile slopes and form a "rubble layer" at the base of the replaced spoils.

Exhibit 14
WCCPROD00001539

Moran et al (1979) conclude that the rubble zone is probably thin but has a substantially higher permeability than the original materials. Backfilled spoils have a higher porosity than the original strata and these spoils probably have a higher vertical percolation rate since the materials when backfilled are more isotropic. Most sedimentary materials exhibit a strong preferential horizontal permeability. At the ground surface, infiltration of precipitation has been shown to be comparable in reclaimed and undistrubed lands (HRRV V; Western Energy Co., 1982; Western Energy Co., 1983). This means that runoff will be similar to premining conditions.

Postmine spoils water quality has been estimated from overburden chemistry using the regression presented in Western Energy Company's 1983, Annual Hydrology Report (HRRV I, Annual Report). Average total dissolved solids concentration for Area B spoils is predicted to be about 3,000 mg/l, ranging from approximately 2,500 to 5,200 mg/l, as shown on Exhibit R. Overburden E.C's from 1,000 ft. grid holes were krigged to predict E.C's for 300 ft. blocks, and the regression was applied to the results. Premine TDS values for observation wells in Rosebud coal and overburden and private wells are tabulated in Table 30, page 189. Average spoils water TDS levels will be within the range found for private wells in Area B Extension and where sufficient quantities of suitable quality water are not available from spoils, adequate water supplies can be obtained from deeper horizons.

Measures will be taken to mitigate or eliminate all adverse impacts on water quality. If toxic or acid-forming overburden or mine wastes are present, they will be segregated during burial to avoid contact with groundwaters in accordance with 26.4.641. The excavation of pits will create a spoil ridge which will be regraded to its approximate original contour using bulldozers and

Exhibit 14
WCCPROD00001540

scrapers. Subsoil will be placed on regraded spoils to a uniform depth of about 1.3 feet. The subsoil will be overlayed with approximately 1.1 feet of topsoil. Treesoils will be placed to a uniform depth of 1.5 feet. During regrading and soil distribution, the drainages will be reconstructed to approximate the pre-mining drainage pattern and contour. Regrading and reclamation of mined areas will begin within a maximum of two spoils ridges of the pit. Following topsoil placement, and at the proper season, a seed bed will be prepared using a chisel plow and a farm tractor. Straw mulch will be incorporated into the soil on slopes steeper than 5:1. Fertilizer will be applied at a rate based on soil analyses. The prepared soil will then be seeded with appropriate seed mixtures (see also Sections 26.4.308 and 26.4.313).

As described in 26.4.315, all runoff from disturbed lands will be treated in sediment ponds. These ponds will be constructed in accordance with DSL and other applicable state and federal rules. Water discharged from these ponds will meet water quality standards and effluent limitations of the State of Montana and OSM. As described in detail in 26.4.633, a valid MPDES permit (Montana Pollutant Discharge Elimination System) will be obtained for all discharges from the proposed mining areas to public waters. This will assure protection of water quality in receiving waters in East Fork Armells and Rosebud Creeks.

26.4.314(1)(b) As described in 26.4.304(5)(b) there is no current use of the surface water in the proposed permit area except stock watering. Stock watering use of East Fork Armells Creek and Lee Coulee adjacent to and downstream from the mining area will not be significantly affected by the proposed mining activities. Downstream of the mine area changes in water quantity and quality are expected to have little effect on existing water uses.

Exhibit 14

WCCPROD00001541

Groundwater use in and adjacent to the proposed permit area has been described in Sections 26.4.304(5)(b), and 26.4.314(1)(a). Two wells, one of which is currently used for stock watering, will be removed by mining and seven other wells may be impacted as discussed in 26.4.304(5). During reclamation, replacement wells will be drilled that will provide water of adequate quantity and quality for intended postmining use as discussed under 26.4.304(5)(b) and 26.4.314(1)(a).

26.4.314(1)(c): Mining and reclamation plans for Area B presented in this permit application are designed to minimize impacts to both surface water and groundwaters. Reclamation of disturbed lands to approximate topography, vegetation, and soil conditions as described in the operations plan above are the principal procedures to be used to maintain premining runoff volumes from small ephemeral watersheds in Area B. Also, premining channel morphology and gradient are documented by longitudinal and cross-sectional channel profiles (Appendix D). This documentation will be used to reclaim channels to their approximate premining conditions. Temporary impacts of sediment ponds are addressed under 26.4.304(5) and 26.4.314(1)(a).

Aquifer properties of the postmine spoils aquifer are similar to those of the Rosebud Coal and Overburden (HRDV III, Aquifer Test Data). Infiltration rates for reclaimed surfaces have also been shown to be similar to infiltration rates for undisturbed areas (HRRV V, Western Energy Company, 1983), see also 26.4.304(5). Therefore, the quantity of groundwater available after mining will be similar to premine conditions.

Exhibit 14

WCCPROD00001542

Changes in groundwater quantity will be minimized by restoring recharge capacity as described in section 26.4.314(2)(c). Spoils will be backfilled as soon as possible in a manner designed to maintain the premining hydrologic balance. The alluvial aquifer associated with East Fork Armells Creek will be disturbed by mining activities along 12,600 feet of the middle and upper terraces parallel to East Fork Armells Creek.

Because the postmine topography will approximate the premine topography and recharge capacity will be restored, the net postmine ground and surface water flux will approximate premine conditions. Alluvial gravels are dry or only partially saturated throughout much of the 12,600 feet of alluvium that will be mined through. In this reach (Section 17 and the western 3/4 of Section 16) a reduction in cross-sectional flow area of the alluvium will not significantly alter alluvial flow rates. To the east (Section 15 and downstream) where the alluvial gravels are fully saturated (or nearly so), a reduction in cross-sectional flow area of the alluvium will result in a decrease in alluvial groundwater flow, an increase in surface water flow, and a possible increase in the eastward component of spoils water flow as compared with premine Rosebud coal and overburden flow.

To preserve the hydrologic balance, compacted clayey spoils will be placed against saturated gravels exposed in mine pits if premine alluvial water levels are higher than premine Rosebud coal water levels. Where the Rosebud coal now discharges to alluvium, the hydrologic connection will be maintained by simply spoiling directly against the gravel. When the spoils resaturate following mining and reclamation, flow in the alluvium will be maintained by inflow of spoils water. Downstream from Section 15, flows in undisturbed alluvium will be

Exhibit 14
WCCPROD00001543

essentially the same as premine flows. A reduction in alluvium ground water flow in Section 15 will be compensated for downstream by increased infiltration through the channel bottom from increased surface water flows. Past mining in Areas A and B has had no noticeable effect on vegetation along East Fork Armells Creek or on surface flow downstream from surface water station SW-55.

Where saturated gravels are to be mined, wells will be installed along the boxcut to dewater the alluvium which will be mined. Water will be pumped to East Fork Armells Creek at approximately E28,500 where it will be discharged to the channel and will ultimately return to the alluvial ground water system by infiltration through the channel bottom. Suspended sediment loads of ground water are normally less than 30 mg/1 so treatment should not be necessary to meet MPDES requirements.

Water levels in spoils wells in Areas A, B, and Pit 6 suggest that ground water levels and flow will fully recover within 10 to 20 years of final reclamation. A computer simulation done for the Final Comprehensive Environmental Impact study predicted that recovery would take hundreds of years, but recharge from sources such as sediment ponds, run off temporarily stored in mine pits, and area wide infiltration were not accounted for.

Mining cuts adjacent to alluvium will temporarily reduce ground water flow from bedrocks units to the alluvium. However, this reduction in recharge to the alluvium will have only a small effect on down stream alluvial flows (26.4.304(5)).

Exhibit 14
WCCPROD00001544

26.4.314(2)(a): Treatment and water control facilities for the proposed permit area are shown in Exhibit D. Treatment facilities are planned to impound drainage from all areas where soil has been salvaged, unless otherwise approved by the Department. There will be 15 sedimentation ponds with spillways in the proposed mining area and 97 sediment traps (seepage/evaporation ponds without spillways; see Figure 4, page 191). All impoundments are designed to contain the 10-year, 24-hour runoff volume. Spillways associated with sediment ponds will be designed to carry the peak discharge from the 25-year, 24-hour precipitation event.

Sedimentation ponds in series or parallel will be used in Drainage 129 and 136. These ponds will be installed sequentially as mining progresses. Sediment production and runoff records from the first pond may be used in developing final design for the remaining ponds. Sediment production will be monitored by comparing detailed surveys of initial impoundment dimensions with resurveyed bathometric contours, by core sampling to determine sediment volumes, or by other approved methods. Typical cross sections of proposed ponds are shown in Figures 5 and 6, pages 192 and 193.

At all times during mining, sedimentation pond volumes will be adequate to retain the 10-year, 24-hour runoff from disturbed lands above the ponds.

During mining, runoff from undisturbed land above the pit will be intercepted by the pit or by temporary impoundments or traps in the drainages above the pit. Very large runoff events will be intercepted by the pit. Interception by the pit insures that runoff will not cause water quality problems in East Fork Armells Creek and Rosebud Creek.

A system of ditches and traps proposed for the perimeter haul road is shown in Exhibit D. Ditches along the haul road direct runoff to either sedimentation ponds or sediment traps. In areas where the haul road crosses the ephemeral drainages, sediment traps will be provided to collect runoff from the road embankment. Ditches will roughly parallel access roads to intercept all runoff from disturbed lands. Through use of this containment system, Western Energy will prevent any sediment or untreated runoff from leaving the permit area.

Imported Pit Water:

Pit water from Big Sky Mine will sometimes be pumped to an inactive pit in Area B (MR03-03-03B). Exhibit A shows the approximate location of the pipeline and pit. Portions of this water will be used for dust suppression. The water may be directed to other pits within Area B and other permit areas within the Rosebud Mine depending upon operational needs. It is expected that using inactive pit areas for water storage will aid in the resaturation of the adjacent spoils. The water in the pit will not be allowed to rise above an elevation of 3393 feet and will be measured quarterly and reported in the Annual Hydrology Report. Two spoil wells will be installed during 2003 to monitor the resaturation of the spoils. The location of the wells will be determined in consultation with the Department.

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Groundwater: Groundwater drainage to the pit will come from Rosebud overburden, Rosebud coal, and from alluvium/colluvium associated with ephemeral drainages. Western's mining plan will disturb a portion of the middle and upper terraces of the alluvial aquifer underlying East Fork Armells Creek. Groundwater flow in Rosebud coal and overburden through the area to be mined is small, probably on the order of 5 - 10 gallons per minute (26.4.304(5)). Potential flow from tributary alluvium/colluvium is also expected to be small. Groundwater inflow to the pit may periodically be pumped to sedimentation ponds. Some of this water will be used for dust suppression. When necessary, excess water will be discharged in accordance with Western's MPDES discharge permits.

Groundwater Inflow: Inflows from aquifers cut by the pits will be a combination of water released from storage and groundwater flow from the aquifer in response to natural hydraulic gradients. The inflow of groundwater released from storage in aquifers can be estimated analytically. A commonly used method is the line-sink equation (Walton, 1970). This equation assumes laminar flow, instantaneous release of water from storage, and isotropic conditions none of which are fully met by drainage from natural groundwater systems in rapidly excavated mine cuts. The very large flow rates implied by line-sink formula for initial inflows are incorrect. Due to convergence of flow at the free face, initial inflows will be lower than predicted; consequently, these inflow estimates should be regarded as maximums. The Darcy equation can be used to predict the "steady state" groundwater inflow from the aquifer system. The "steady state" groundwater inflow is

the continuous groundwater flow in the aquifer prior to mining in the sector cut by mining.

A significant complication in prediction of pit flows is the backfilling of pits with spoils. Spoils will be backfilled by the dragline after the coal is removed creating a temporary groundwater sink (until they resaturate) which will act as a partial barrier to groundwater inflow to the next successive cut. Actual pit inflows from storage also will depend greatly on the rate of vertical excavation into the aquifer and the time that elapses between cuts. There is no methodology that will accurately predict groundwater inflow from the complex cut and backfill mining proposed in this operation.

Results of pit and boxcut inflow calculations are presented below. Aquifer hydraulic coefficients and groundwater gradients are summarized in 26.4.304(5). Storativity is assumed to be .04 for alluvium and .004 for bedrock aquifers and transmissivities are 1,480 gpd/ft for alluvium, 276 gpd/ft for overburden, and 56 gpd/ft for Rosebud coal. A major simplifying assumption used in calculation of pit inflow is that during mining of successive blocks, groundwater drainage from previously mined blocks will not enter the new block. The rate of groundwater drainage from storage in each block decreases rapidly with time and the residual drainage from previous cuts would be small in comparison with water from a new cut. Each new cut is assumed to have full groundwater storage, that is, it has not been partially drained by a previous cut. It is assumed that each cut is opened instantaneously and that residual drainage entering previous cuts does not flow into new cuts. Thus, the first assumption leads to a slight underestimate of inflow and the others to a significant (possibly an order of magnitude) overestimate. Experience at the Rosebud Mine suggests that the inflow estimates are high.

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Western's Area B Extension mining plan includes cutting through approximately 12,600 feet of alluvium adjacent to East Fork Armells Creek along the middle and upper terrace levels in Sections 15, 16, and 17 (T1N,R40E). Alluvium here consists of about 25 feet of silt overlying 5 - 10 feet of sandy gravels. Estimated inflow into the boxcut from exposed alluvium, overburden, and Rosebud coal would be approximately 2,990, 543, and 382 gpm at 1, 30, and 60 days, respectively. Boxcut inflow calculations assume that the entire boxcut is opened instantaneously. Because it will actually take several months to open the boxcut, this assumption may introduce an order of magnitude error in the calculations. Other than inflow from storage in East Fork Armells Creek alluvium over the short period the pit is open, little long-term inflow from this alluvial aquifer is expected and impacts on the alluvial system will be minor as discussed earlier in this section.

Flows from tributary gravels into the boxcut in the vicinity of East Fork Armells Creek are expected to be minor. Assuming a transmissivity of 250 gpd/ft, inflow from a combination of tributary alluvium, overburden, and Rosebud coal are about 0.017, 0.0031, and 0.0022 gpm/ft of cut (one face) for periods of 1, 30, and 60 days, respectively. The tributary alluvium is assumed to have a saturated thickness of five feet; however, alluvium often is dry in tributary channels throughout the Colstrip area. For a tributary alluvial channel 100 feet wide, inflow to a boxcut is estimated to be 1.7, 0.3, and 0.2 gpm at 1, 30, and 60 days, respectively.

Exhibit 14

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2. (b) Sedimentation ponds will be designed for total containment of discharges of the 10-year, 24-hour precipitation event from disturbed areas in the proposed mine area. Locations of sedimentation ponds and associated diversion ditches are shown on the Drainage Plan, Exhibit D and are described in 26.4.314(2)(a). All discharges will be in accordance with 26.4.633 and will be discussed in further detail in Western's application for a MPDES permit associated with Area B Extension outfall sites.

2. (c) As part of the mining reclamation plan, overburden will be replaced in the excavations, regraded to approximate original contour, and covered with subsoil and topsoil. Because existing materials are replaced in the pits and existing subsoils and topsoils are salvaged for replacement on the regraded surface, spoils and postmine soils will be similar in lithology to existing materials. The vegetative cover will be reestablished on the reclaimed topography. Soils in the portions of Area B to be mined are nearly all silt loams, sandy loams, and loams. There will be about 2.4 feet of topsoil and subsoil replaced over the spoils in the reclaimed areas. The replaced soils will be similar in texture to the premining soils but the soil structure will be altered. Infiltration rates for undisturbed and reclaimed areas near Colstrip have been evaluated by Western Energy Co., in 1982, and 1983 (HRRV V) as discussed in 26.4.304(5), and 26.4.314. Infiltration into these soils (that is, movement of water through the soil air interface into the soil), is a function of soil texture, structure, vegetative cover and slope. These four factors will be similar in the postmining soils and the overall infiltration capacity of these soils will be similar to premining infiltration capacity as shown by the above mentioned studies. The downward movement or percolation of water through

Exhibit 14
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the soils is, in part, controlled by the field capacity of the soils. Much, if not all, of the initial infiltration will be retained by the topsoil. These soils have a field capacity of 0.06 to 0.13 in/in (Table 29, page 188) which means they can hold three to six inches of water before any deep percolation will occur. Such large accumulations of water will seldom occur in these soils. Spoils material placed beneath the topsoil will be a variety of lithologies but will dominantly be silt. In the process of strip mining, the individual strata are intermixed and the porosity is increased. In most geological materials, the horizontal permeability is many times greater than the vertical permeability. After strip mining, however, the soils will become more isotropic; that is, permeability will be similar in all directions including the vertical direction. This indicates that percolation rates through the spoils potentially could be higher than in premining conditions. The amount of water that percolates into the spoils, however, will be controlled by the movement of water through the topsoil. Much of the water moving into the topsoil will subsequently be removed by evapotranspiration and will not be available for percolation. It is expected that the potential rate of percolation will be much greater than the availability of water and that evapotranspiration out of the topsoils will be a controlling process in recharge capacity of the reclaimed mine land. Regraded spoils will be scarified prior to placement of topsoils. This will insure that there is no impermeable barrier at the soil-spoils interface.

The overall impact of mining on recharge capacity in Area B has both regional and local aspects. Regional impacts to lands and water from mining near Colstrip were assessed in a Comprehensive Environmental Impact Study (DSL and OSM, 1983). Locally, in and adjacent to these lands, the general lithology, vegetative cover and topography will be similar to premining conditions. There probably is a

Exhibit 14
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small amount of groundwater recharge to bedrock aquifers in the area to be disturbed by mining in Area B, and the location of all regional sources of recharge are not completely known (see section 26.4.314(1)). Recharge areas probably will function after mining as they did before mining; however, in groundwater systems with very low flows, accurate determination of recharge locations and volumes is difficult. Reclamation of mined lands to approximate premining conditions particularly along the principal stream courses, will do much to mitigate the effects of mining on recharge capacity.

Transmissivity of the spoils in reclaimed land near Colstrip has been measured by Western Energy Company (HRDV III, Aquifer Test Data) and the Montana Bureau of Mines and Geology (Van Voast, Hedges, and McDermott (1977)). MBMG spoils transmissivity data range from 0.7 to 479 gpd/ft with a lognormal mean of 33 gpd/ft for 11 observation holes compared with a range of 10 to 12,715 gpd/ft and a lognormal mean of 109 gpd/ft for the Rosebud coal. Aquifer test data collected by Western Energy Company for ten spoils wells show transmissivities ranging from 28 to 2955 gpd/ft with a lognormal mean of 253 gpd/ft. Aquifer test data collected by Western Energy Company show a range of 3.4 to 4,500 gpd/ft for 15 overburden wells with a lognormal mean transmissivity of 103 and a range of 0.5 to 1,650 gpd/ft for 29 Rosebud coal wells with a lognormal mean transmissivity of 31 gpd/ft. These data suggest that the transmissivity of the spoils will be higher than transmissivities in undisturbed bedrock units (Rosebud coal and Rosebud overburden). Spoils transmissivity is low, however, and overall groundwater movement in the spoils probably will be similar in magnitude to that in the existing bedrock units.

Exhibit 14
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The overall impact of mining in Area B to recharge capacity is expected to be small and relatively short-term. The reclaimed lands should function hydrologically in a similar manner to the existing system. East Fork Armells Creek alluvium is the most important aquifer in the area in terms of flow and significant changes in water quality or quantity in the alluvial system that would affect present uses are not expected to result from the proposed mining.

Drawdown effects of mining in the Colstrip area were predicted with a three-dimensional computer model (DSL and OSM, 1983). Results indicate drawdowns of several tens of feet within a mile of active pits. While results of the model are not exact, they do indicate that total recovery to premining water levels may take several hundred years. Allowing a small amount of area wide infiltration (even less than .5 in./yr.) would significantly increase the rate of recovery. Water level data for Pit 6 suggest 10 to 20 years for recovery.

Total dissolved solids concentrations in the spoils aquifer will increase over premining concentrations in the Rosebud coal and Rosebud overburden. Although total dissolved solids concentrations will increase, water quality will still be acceptable for stock watering, the primary premining use.

2. (d) The hydrology monitoring program for Western Energy's Colstrip operations, including Area B, consists of periodic collection of surface water quality and quantity data, groundwater quality and groundwater water level information as shown in the Monitoring Schedule (HRDV I, Monitoring Schedule and Site Location Map). It should be recognized that representative measurement of surface water characteristics in the ephemeral drainages within the proposed permit area, is logistically and technically difficult.

Exhibit 14
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Western Energy's annual reports summarize data collected in each year and the projected hydrological monitoring program for the next year. The location of all surface water and groundwater monitoring sites are shown on the hydrologic monitoring sites map (HRDV I). Details of the monitoring plan specific to this proposed mining plan in Area B are contained in Sections 26.4.645 and 26.4.646.

Probable hydrologic consequences of mining on surface water are discussed in 26.4.304(9), 26.4.314, 26.4.314(1)(a), 26.4.314(1)(b), 26.4.314(1)(c), and 26.4.314(2)(a). Probable hydrologic consequences of mining on groundwater are discussed in 26.4.304(5), 26.4.304(5)(b), 26.4.304(9), 26.4.314, 26.4.314(1)(a), 26.4.314(1)(b), 26.4.314(1)(2), 26.4.314(2)(a), and 26.4.314(2)(c).

In addition to the material presented elsewhere in the permit and referenced above, Western Energy Company analyzed impacts to the water quality of the alluvial groundwater systems adjacent to the Rosebud Mine using a computer model. The model was used in the Area C, Block II permit application to evaluate the impacts of mining as proposed in Western Energy Company's application on the alluvial water quality of East Fork Armells Creek and spring along West Fork Armells Creek and East Fork Armells Creek and to evaluate the impacts of mining with and without a 500 foot buffer zone between the East Fork Armells Creek and the boxcut. This model uses a flow net analysis and postmine water quality predicted from overburden E.C. to estimate postmine water quality changes to alluvial aquifer systems. Overburden E.C.'s on 1,000 ft. centers were krigged to estimate E.C.'s for 300 ft. blocks and the krigged values were run through a

Exhibit 14

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regression equation relating overburden E.C. to spoils water quality (Exhibit R). Existing aquifer test and water quality data for the area modeled were used when available. Where data were not available, values interpolated from nearby data points were used. Water levels used in the model are presented in HRDV II (Groundwater Stations and Level Data). Water quality data are presented in HRDV III (Groundwater Quality Data), aquifer properties are found in HRDV III (Aquifer Test Data) and the potentiometric surface for the Rosebud coal is presented in HRDV 1 (Annual Report). Cross sections for East Fork Armells Creek, Stocker Creek, West Fork Armells Creek, Cow Creek, and South Fork Cow Creek alluvium at locations where aquifer properties are known have been drawn. Cross-sections were not drawn for Lee Coulee or Miller Coulee. A cross-section prepared by Dollhopf, et al (1981) and aquifer data provided by Peabody Coal Co. (Koffler, 1986, and Wheaton, 1986) were used for those watersheds. The cross-sections are assigned locations based on the distance up-stream along an imaginary alluvial flow path. Cross-section locations with mile designations and assumed flow paths are shown on Exhibit S. Alluvial aquifer data for each section was input to the computer on two or more data lines (first data page for each analysis, Appendix F). The first line contains the gradient, average premine total dissolved solids, mile designation, and the number of wells in the cross-section. The second and subsequent lines contain the permeability and cross-sectional flow area for each well. Cross-sections are presented for each stream following the alluvial aquifer input data.

Exhibit 14

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A flow-net (Exhibit S) was constructed for the bedrock aquifer using the potentiometric surface for the Rosebud coal as presented in HRRV I augmented by data from Dollhopf, et al (1981). Input data to the program for the bedrock aquifers (second and subsequent data pages for each analysis, Appendix F), consist of a data line with the number of cells or elements in each flow path and the mile point along the assumed alluvial aquifer flow path, followed by data lines for each element or cell consisting of a line containing the width and length of the element; a line containing the Rosebud coal transmissivity, gradient, premine total dissolved solids; a line containing overburden transmissivity, gradient, premine total dissolved solids; and the estimated postmine total dissolved solids on the last line. If an element will not be mined, a flow weighted average of overburden and Rosebud coal TDS values was input for the postmine TDS. Input data are presented in Appendix F. Output from the model consists of plots of TDS versus time for the various alluvial cross-sections under consideration. These are presented in Appendix F following the input data. In most cases estimated impacts to alluvial groundwater quality for most of the drainages under consideration are very small because the flow rates through the bedrock aquifers and estimated flow rates through the spoils are very small in comparison to flow rates through the alluvium.

In its present form, the model routes dissolved solids along a single alluvial flow path; so for this analysis, tributaries were handled by ignoring the tributary alluvium and assuming that the bedrock flows enter the main stem alluvium at the confluence with the tributary. This will not introduce appreciable error because the alluvial flow times are short relative to the length of the analysis. For some areas to be mined, it is known that no direct connection exists with the alluvial aquifer associated with the stream draining the area.

Exhibit 14
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It was assumed that these areas would not impact alluvial groundwater quality. Areas where the degree of alluvial connection was unknown were assumed to impact alluvium, even though in some cases a direct connection is extremely unlikely (i.e. Cow Creek tributatries draining the northeast quarter of Section 25, T2N,R41E; and the northwest quarter of Section 30, T2N,R42E; or Stocker Creek tributaries draining Sections 2 and 3, T1N,R40E.

The relatively large impacts predicted for alluvial sections at miles 1.1 and 1.7 on East Fork Armells Creek result primarily from the small alluvial flows for those cross-sections of 13 and 23 gpm respectively. The estimated alluvial groundwater flow for the cross-section at 3.3 miles is 63 gpm. This significant reduction in alluvial groundwater flow coupled with total dissolved solids inputs from Areas A and D, the power plants, and the ash pond combine to produce an estimated 2.5 fold increase in TDS at 1.1 miles. The several hundred thousand gallons per day of relatively low TDS (about 1,200 mg/l) water from the sewage treatment plant was not accounted for in this analysis because it is not known how much actually enters the groundwater system. A small percentage of sewage treatment plant effluent entering the alluvial groundwater system would result in a significant reduction in predicted impacts.

Power plant impacts were factored into the analysis by assuming that 1,000,000 gallons of water per year with a TDS of 15,000 mg/l might enter the alluvial groundwater system. Montana Power Company's ash pond in Section 29, T2N,R41E, was simulated by setting the post-disturbance TDS of a bedrock flow element equal to 15,000 mg/l. Impacts of the plants represent about 300 mg/l at 1.7 miles and the ash pond represents about 50 mg/l at 1.1 miles.

Exhibit 14

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Impacts of mining in Area C Amendment, on East Fork Armells Creek were evaluated in detail in that permit (pages 383 through 383d). Input data for that analysis were updated with new information and was incorporated into this analysis. Impacts of mining on springs along West Fork Armells Creek were also evaluated in the Area C Amendment permit (pages 383d through 383f). Because the alluvium is not continuous below Springs SP-36 and SP-37, impacts to the springs will not affect alluvium downstream. Therefore, that analysis was not incorporated into this effort. Impacts of mining in Area D on Spring SP-24 are found on pages 42 through 42d of that permit (SMP 86003-D). Because Pony Creek alluvium is not continuous below SP-24, mining in Area D is not expected to impact alluvial groundwater quality downstream.

Predicted impacts to Lee Coulee and Miller Coulee are signigicant for the first 20 years after mining. Predicted increases in total dissolved solids concentrations (4,200 mg/l for Lee Coulee and 1,700 mg/l for Miller Coulee) in alluvial groundwater near Rosebud Creek are higher than expected because Western Energy Company does not know the mining sequence at the Big Sky Mine. So, mine blocks assumed for the model were large which would tend to compress the time period over which impacts occur and increase the peak change. Little is known about alluvial aquifer properties and cross-sections for either drainage, so input parameters had to be estimated from data reported by Dollhopf, et al (1981) and Peabody Coal Company (Koffler, 1986, and Wheaton, 1986). Bedrock aquifer properties and gradients were estimated from information provided by Peabody Coal Co. (Koffler, 1986, and Wheaton, 1986) and reported by Dollhopf, et al (1981). Because Western Energy Company did not have access to actual potentiometric surface maps for the Big Sky Mine area, the potentiometric surface was approximated using data presented by Dollhopf, et al (1981). Because

Exhibit 14
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of time contraints and uncertainties about the flow system, the flow net was drawn assuming as a worst case that all mining at Big Sky would contribute groundwater flow to either Lee or Miller Coulee. As a result of this assumption, the flow patterns do not fit the potentiometric contours precisely, but the results will give a conservative estimate of impacts to the alluvial system.

Impacts to Rosebud Creek were computed by summing the maximum increase in mass transport for Miller Coulee, Lee Coulee, South Fork Cow Creek, and Cow Creek (5.1×10^8 mg/day) and comparing that figure to the average mass transport for Rosebud Creek near Colstrip (USGS station 0695250, mass transport = 1.2 x 10" mg/day). Maximum impacts for all four streams were assumed to reach Rosebud Creek simulataneously and, because Western Energy Company has no information on groundwater flow rates or water quality for Rosebud Creek alluvium, the entire change in mass transport predictd by the model was assumed to impact surface water quality. Under these assumptions the predicted change in total dissolved solids under average flow conditions would be about 0.4 percent or from about 950 mg/l to 954 mg/l.

Exhibit 14
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Exhibit 14

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Exhibit 14

WCCPROD00001563

TABLE 27

Monthly Precipitation and Potential
Evapotranspiration (Et) at Colstrip, Montana

Month	Average Temperature(1) °C	Precipitation(1) (in.)	E_t(2) (in.)	Net Gain or Loss (in.)
January	-6.1	.56	.20	+ .36
February	-3.0	.56	.29	+ .27
March	0.1	.74	.58	+ .16
April	7.1	1.86	1.59	+ .27
May	12.4	2.47	3.17	- .70
June	17.1	3.31	4.69	- 1.38
July	21.9	1.18	6.44	- 5.26
August	21.2	1.39	5.61	- 4.22
September	15.0	1.38	3.05	- 1.67
October	9.2	1.04	1.53	- .49
November	1.3	0.67	.44	+ .23
December	-3.5	0.63	.27	+ .36
		+15.79	-27.86	-12.07

(1) U. S. Dept. of Comm., Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1941-1970 #81, August, 1973.

(2) Calculated Blaney-Criddle formula values.

Exhibit 14

WCCPROD00001564

TABLE 28

Class A Pan Evaporation Data for
Colstrip, Montana and Nearby Areas, 1979

Evaporation in Inches

Month	J	F	M	A	M	J	J	A	S	O	N	D
Location												
Colstrip												
Big Sky Mine	-	-	2.98	3.38	8.06	9.00	11.89	10.02	7.85	-	-	-
Rosebud Mine	-	-	-	2.70	9.22	11.70	17.64	27.90	18.07	-	-	-
*Yellowtail Dam	-	-	-	-	7.34	8.77	9.68	7.38	6.13	-	-	-
*Huntley Project	-	-	-	-	-	9.27	10.50	9.60	8.20	-	-	-

Source: Big Sky Mine data from Montana State University taken at Peabody Coal Company's Big Sky Mine, 1979; Rosebud Mine data collected by Western Energy Co., 1977 to 1983, Air Quality Resource Monitoring Reports; Yellowtail Dam and Huntley Project data from NOAA Climatologic Data, Annual Summary for Montana, 1975-79.

* 1975 - 1979 Average

Exhibit 14

WCCPROD00001565

TABLE 29

Infiltration Data for Soils in the Vicinity of Area B

Map Symbol	Mapping	Acres[1]	Infiltration Rate (inch/hour	Water Holding Capacity (inch/inch)
7E	Ustic Torriorthents, 15 to 35% SLOPES	75.1	0.2 - 2.0	>0.13
13C	Busby fine sandy loam, 2 to 8% slopes	163.2	2.0 - 6.0	0.08 - 0.13
13D	Busby fine sandy loam, 9 to 15% slopes	166.1	2.0 - 6.0	0.08 - 0.13
16A	Kremlin loam, 0 to 2% slopes	12.7	0.6 - 2.0	>0.13
16C	Kremlin loam, 2 to 8% slopes	115.7	0.6 - 2.0	>0.13
27C	Flower silt loam	93.3	0.6 - 2.0	0.18 - 0.22
37A	Lonna silt loam, 0 to 2% slopes	161.4	0.2 - 0.6	>0.13
37C	Lonna silt loam, 2 to 8% slopes	26.1	0.2 - 0.6	>0.13
44C	Savage silty clay loam, 2 to 8% slopes	41.7	0.06 - 0.2	>0.13
49A	Yamac loam, 0 to 2% slopes	4.3	0.6 - 2.0	>0.13
49C	Yamac loam, 2 to 8% slopes	166.6	0.6 - 2.0	>0.13
49D	Yamac loam, 8 to 15% slopes	287.7	0.6 - 2.0	>0.13
59A	Kobar silty clay loam, 0 to 2% slopes	40.8	0.2 - 0.6	>0.13
59C	Kobar silty clam loam	45.5	0.2 - 0.6	0.14 - 0.18
59D	Kobar silty clay loam, 8 to 15% slopes	1.1	0.2 - 0.6	>0.13
72B	Vanstel silt loam, 0 to 2% slopes	48.3	0.2 - 2.0	>0.13
84D	Cabbart loam, 4 to 15% slopes	14.4	0.2 - 0.6	0.06 - 0.08
92D	Delpoint loam, 8 to 20% slopes	28.9	0.6 - 2.0	0.08 - 0.13
131E	Busby-Yetell-Rock Outcrop Complex, 8 to25% slopes	12.4	0.6 - 2.0	0.08 - 0.13
132E	Busby-Riedel Complex, 8 to 25% slopes	191.2	2.0 - 6.0	0.06 - 0.08
184F	Cabbart-Yawdim-Rock Outcrop Complex, 15 to 70% slopes	24.2	0.06 - 0.6	0.06 - 0.08
188E	Delpoint-Cabbart loams, 15 to 25% slopes	18.9	0.2 - 2.0	0.06 - 0.13
311	Havre Loam, occasionally flooded, 0 to2% slopes	18.3	0.6 - 2.0	>0.13
498E	Delpoint-Cabbart-Yamac Complex, 8 to 25% slopes	183.5	0.6 - 2.0	0.06->0.13
	Rock outcrop	16.0	--	--
	TOTAL	1,958*	Ave = 2.3	Ave = 0.10

[1] Actual Disturbance
* Total does not include 144 acres of soil storage

TABLE 30

Premine Total Dissolved Solids Concentrations for Observation Wells in Rosebud Coal, Overburden and Existing Private Wells - Area B Extension

Rosebud Coal		Overburden		Private Wells (1)	
Well	TDS (mg/l)	Well	TDS (mg/l)	Well	TDS (mg/l)
WR-100	418	WO-101	345	PW-34	Dry
WR-124	1,311	WO-162	1,461	PW-94	1,442
WR-162	993	WO-166	1,746		
WR-164	1,580	WO-173	3,260		
WR-173	1,436				
P-07	1,135	Mean	1,703		
P-08	2,499				
P-09	2,585				
P-10	1,410				
S-24	1,907				
Mean	1,527				

Exhibit 14

WCCPROD00001567

Written Findings

Prepared by:

Montana Department of State Lands

for

Big Sky Mine
Lee Coulee, Area B

Peabody Coal Company

Rosebud County, Montana

Pursuant to Montana's

Strip and Underground Mine Reclamation Act

November 1988

Exhibit 13

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Exhibit 13

Peabody Lee Coulee

Written Findings

I. Introduction

A. Introductory Table

1. Name of Applicant:	Peabody Coal Company
2. Name of Mine:	Big Sky Mine
3. MSHA Number:	24-00108
4. Type of Mine:	Area Strip Mine
5. Type of Application:	New Permit
6: Affected Area:	
Disturbed Life of Mine	3,200 acres
Permit Area Life of Mine	5,435.8 acres
Disturbed First Permit Term	924.6 acres
7. Anticipated Annual Coal Production:	2.8 million tons
8. Maximum Annual Coal Production	4 million tons

B. Chronology of Events:

DATE	EVENT
December 20, 1985	Original application received
February 24, 1986	Deficiency letter sent (first part)
March 1986	Draft AVF Decision Document sent to OSMRE
April 17, 1986	Deficiency letter sent (second part)
May 1, 1986	Notice of Intent to Publish EIS published
July 1, 1987	AVF Decision Document sent to Peabody
October 7, 1987	Totally revised application submitted
November 3, 1987	Additional information to accompany October 7 submittal received
January 5, 1988	Notice of Completeness sent to Peabody
May 3, 1988	Deficiency letter sent
July 10 and 20, 1988 and September 27, 1988	Deficiency responses submitted
July 27, 1988	Draft EIS issued for public comment
August 16, 1988	Cultural Resources Data Recovery Plan submitted
August 25, 1988	Responses submitted regarding additional written and verbally communicated deficiencies
September 20, 1988	Responses submitted regarding additional written and verbally communicated deficiencies
September 23, 1988	Responses submitted regarding additional written and verbally communicated deficiencies
September 39, 1988	Responses submitted regarding additional written deficiencies
October 26, 1988	Responses submitted regarding additional written deficiencies
November 1, 1988	Final EIS Issued

Exhibit 13

II. Environmental Setting

Peabody has applied to the Department of State Lands (DSL) and the Office of Surface Mining Reclamation and Enforcement for a new mining and reclamation permit in Lee Coulee (Area B). The new permitted acreage would be 5,435.8 acres, of which 3,200 acres are proposed to be disturbed.

Several environmental assessments have been prepared by the Department and the federal government for Peabody's previous permits, proposed mining operations, or actions associated therewith. These include:

Montana Department of State Lands. November, 1973. Draft Environmental Impact Statement, Peabody Coal Company, Big Sky Mine.

U.S. Geological Survey and Montana Department of State Lands. September 1979. Final Environmental Statement, Proposed Expansion of Mining and Reclamation Plan, Peabody Coal Company, Big Sky Mine, Rosebud County, Montana.

U.S. Geological Survey and Montana Department of State Lands. 1980. Environmental Statement, Regional Analysis, Northern Powder River Basin Coal, Montana.

Montana Department of State Lands. September 1983. Technical and Environmental Assessment for Repermitting and Revision, Peabody Coal Company, Big Sky Mine, Rosebud County, Montana.

Montana Department of State Lands. March 1986. Preliminary Environmental Review, Peabody Coal Company's Big Sky Mine, Area B Proposal, Rosebud County, Montana.

Montana Department of State Lands and U.S. Office of Surface Mining Reclamation and Enforcement. April 1987. Preliminary Environmental Review, Snider's Amendment, Peabody Coal Company, Big Sky Mine, Area A.

Montana Department of State Lands and U.S. Office of Surface Mining Reclamation and Enforcement. July 1988. Draft Environmental Impact Statement, Peabody Coal Company, Big Sky Mine, Area B, Rosebud County, Montana.

The final EIS for Area B is in preparation.

Montana Department of State Lands and U.S. Office of Surface Mining Reclamation and Enforcement. November 1988. Final Environmental Impact Statement, Peabody Coal Company, Big Sky Mine, Area B, Rosebud County, Montana.

III. Evaluation of Compliance

This section will evaluate for compliance the mining and reclamation plan that Peabody has proposed in its application.

A. Mine Plan and Coal Conservation

Peabody would mine only the Rosebud coal seam using the conventional form of single-seam mining called area mining. The permit application and the draft EIS (DSL and OSMRE, 1988) describe the mining method and the sequencing in great detail. The McKay coal seam is not proposed to be mined at this time. This is due to Peabody's customer not wanting the McKay coal because of its high sulfur content and the resulting air quality concerns with respect to sulfur dioxide. Therefore, the McKay coal seam is considered unmarketable at this time by Peabody. DSL concurs with this position.

Another concern is the avoidance of a minable coal reserve of state-owned coal located in the northeastern corner of Section 36, T1N, R40E. The total amount of affected coal is 541,200 tons. The coal conservation directives of the regulations require the state to maximize the recovery of economically minable coal within logical mining units. Due to leasing terms, the state is unable to grant a lease at this time. Therefore, Peabody has committed in its permit application to pursue obtaining a coal lease and submit an amendment application once an appropriate time frame is reached to satisfy all concerns.

The DSL has determined that Peabody's mine and coal conservation plans are in compliance with all rules and regulations of Montana's permanent program.

B. Reclamation Plan

Reclamation would concentrate on returning the area to the historic land uses of native rangeland for livestock grazing and wildlife habitat. Livestock grazing may be enhanced by better distribution of water after mining. Areas of concentrated shrub and tree plantings would be established to promote habitat diversity. Two bluff extensions are proposed around Marmot Peak. These bluff extension plans include a contingency plan demonstrating highwall reduction and backfilling if further slope stability analyses prove to demonstrate instability.

The DSL has determined that Peabody's reclamation plan is consistent with the rules and regulations.

C. Overburden Handling

After mining is completed, bulldozers and scrapers would be used for final grading to move spoil material to achieve the desired land form. Rough backfilling and grading would be completed within 180 days following coal removal. Prior to applying soil, the spoils would be ripped to a depth of 12 to 24 inches.

The overburden within the proposed permit area consists primarily of sandstone with some occurrence of siltstone and shale. Overburden analyses

revealed that the majority of the strata proposed for disturbance are of suitable quality. However, any unsuitable or marginally suitable overburden encountered would be adequately mitigated by either dilution, blending, or selective handling (if necessary). Some textural problems were noted as a few strata were high in either sand or clay. These particular strata would be effectively mixed in the process of mining.

D. Soils, Vegetation and Land Use

Soil material would be salvaged utilizing a two-lift salvage technique. Soil salvage depths for soil mapping units within the permit area range from 0 to 3 feet, depending on limitations (i.e., depth to bedrock, rock fragment content, texture, or other parameters) as indicated in the pre-mine soil survey. Soil material would be replaced over regraded spoil to a depth of approximately 1.5 feet. Some special handling of "tree soil" (coarse textured soils with greater than 35 percent rock fragments) would be required in order to promote the successful establishment of Ponderosa pine in the post-mining phase.

In general, soil handling would be performed in a manner which is consistent with the act and regulations.

Revegetation would be conducted in accordance with DSL rules and approved procedures by seeding or planting a variety of predominantly native species of grasses, forbs, trees and shrubs to return the area to native rangeland for the historic land uses of livestock grazing and wildlife habitat.

E. Hydrology

1. Surface Water

Protection of the hydrologic balance during mining and reclamation activities would be provided by an approved drainage and sediment control system and continuation of the hydrologic monitoring program as approved by DSL.

Post-mine impacts to drainages would be minimized by the development of approximate original topography and concave longitudinal stream profiles with some changes in channel gradients, sinuosities, and drainage densities in the reclamation plan. The potential for erosion and instability from the increases in runoff and peak flow volumes predicted for some reclaimed channels would be minimized by establishment of a native vegetation cover and stable channels designed to pass the runoff from a 100-year, 24-hour precipitation event.

Post-mine increases predicted for dissolved solids (e.g., TDS, sulfate) in surface waters impacted by mining are expected to be small, with improvement as the vegetative cover is established and as spoils aquifer quality improves gradually.

Removal of three seasonal upland ponds would be mitigated for by the addition of a well with a livestock tank and a "wildlife watering facility", a protected overflow pond designed to provide water for species that can't use

the livestock tank and aquatic and riparian habitat. To mitigate for the loss of five wells to be removed by mining and as a parital mitigation for loss of surface water in the coulee bottom, five wells with livestock and wildlife watering faciliites would be established on the proposed permit area after mining. The replacement wells would be distributed to complement livestock and wildlife usage. Peabody has also committed to consulting with DSL where monitoring indicates the potential for opportunistic development of permanent surface water sources (e.g., final cut impoundments, the reestablished Marmot Peak tributary, leaving sediment ponds or spring development).

A stream buffer study zone has been proposed for the upper "wet reach" of Lee Coulee to remain undisturbed for the first five years of mining. Peabody would conduct hydrologic and biologic monitoring during that period to determine the extent and characteristic of the aquatic habitat. Peabody would then propose either mine plan changes or specific mitigation for mining all or part of the "wet reach" based on the monitoring results. In either case, Peabody has committed to protecting the "Turtle Pond area" from mining disturbance for the life of operations, and proposes enhancement of this area as a general mitigation for surface water impacts.

Details of these and less significant hydrologic impacts are described in the Lee Coulee permit application and in the Draft Environmental Impact Statement.

2. Groundwater

The proposed mining would physically disrupt the upper three aquifers in Lee Coulee; the alluvial (silt, sand and gravel) aquifers, the overburden (siltstone, sandstone and shale) aquifers, and the Rosebud coal aquifer. Connections may exist between these upper aquifers and underlying aquifers; if so, disruption of the upper aquifers may affect the pressure of the deeper aquifers by increasing the permeability of the confining layer.

The Rosebud coal aquifer is generally under semi-confined conditions in the mine area, but becomes unconfined where the Lee Coulee channel has eroded into it. In the upper part of the Lee Coulee drainage, it appears that shale underlying the Rosebud coal creates a mounding of groundwater that then discharges through the unconfined coal and overburden aquifers to the alluvium. This increases storage in the alluvial aquifer and results in several perennial pools of surface water in the ephemeral drainages. The reach of this type in the Lee Coulee drainage is referred to as the "wet reach" in the permit application. Disruption of the coal and overburden aquifers adjacent to the wet reach may have the effect of diminishing the extent of surface water. As mitigation, the operator has committed to increasing surface water resources downgradient of the affected part of the wet reach, opportunistic development of surface water resources and establishment of "wildlife watering facilities" in the form of stock tank overflows.

During mining the open pit would act as a groundwater sink causing local drawdown. The operator has committed to replacing water supplies affected by the mine. The operation would remove five stock wells; these would be replaced during reclamation with deeper wells.

Mining is expected to degrade groundwater quality due to the exposure of fresh mineral surfaces in the spoil to groundwater. The water can then solubilize these minerals resulting in an increase in salts. Previous mining in the drainages adjacent to the north, in Area A, has caused an average increase in total dissolved solids (TDS) of approximately 150 percent; however, a few Area A monitoring wells have shown water quality degraded to a greater degree. Most spoil groundwater in Area A, although degraded in quality, still meets the applicable beneficial use criteria for livestock grazing and wildlife. Similar post-mine water quality is expected in the Lee Coulee drainage. The operator has agreed, at DSL's request, to commit some of the spoil monitoring wells to monitoring conditions which may contribute to elevated TDS levels, such as the anomalously high levels found in some wells in Area A. Monitoring wells would be installed in an area with potential for upward leakage from underlying aquifers and in an area used for timber disposal (to attempt to determine if gaseous by-products of organic decomposition are increasing chemical reactions in the spoil).

F. Wildlife

Wildlife-related issues of concern for mining in Area B are: sharp-tailed grouse dancing ground removal, raptor nest site disturbance, surface water source removal, aquatic habitat destruction, and sandstone outcrop elimination.

One active sharp-tailed grouse dancing ground (Arena B-1), located along Lee Coulee, would be removed by mining. The combination of 1) availability of existing leks within proximity to Arena B-1, 2) revegetation plans designed to reestablish the topographic and vegetative characteristics of Arena B-1, and 3) the DNR Sharp-tailed Grouse Mitigation Plan, should mitigate impacts to regional sharp-tailed grouse populations and maximize the potential to reestablish Arena B-1 after mining.

A golden eagle nest (NW¼NE¼, Section 30, T1N, R41E) and a prairie falcon aerie (NW¼SW¼, Section 24, T1N, R40E) are located immediately adjacent to proposed disturbance areas. The U.S. Fish and Wildlife Service believes that mining can proceed without adversely impacting the eagle nest if a buffer zone with a one-half mile radius is established around the nest. Should mine-induced disturbance to the eagle pair be documented (i.e., two consecutive years of nest non-use while mining within the one-half mile buffer zone), Peabody Coal Company would construct artificial nests at suitable, known perching sites. Disturbance to the prairie falcon eyrie is not anticipated. Peabody Coal Company has agreed to monitor this nest site for nesting and territorial activities and to create or enhance additional eyrie sites in adjacent sandstone bluffs before mining begins in Area B.

Lee Coulee is one of the few reliable sources of surface water for wildlife in the permit area. Peabody Coal Company is committed to replacing any surface water sources that may be lost to mining. Planned mitigation includes enhancement of the Turtle Pond area, which will not be disturbed for the life-of-mine, and opportunistic development of water enhancement features such as final cut impoundments, sediment ponds or springs. Peabody Coal Company also proposes to install six wells with stock tanks, each of which will be equipped

with wildlife escape ramps and an overflow to a catchment basin or pond. The overflow areas would be protected from livestock and enhanced to partially mitigate for loss of coulee bottom habitat. Since this is a human-maintained source of water, it cannot be guaranteed to provide water for wildlife beyond the life of the mine. Specific plans would be developed during consultation between Peabody Coal Company and the Department prior to implementation of any of the above surface water replacement mitigation plans.

Lee Coulee may support a "biological community" which could preclude mining. Peabody Coal Company has established a stream buffer study zone around Turtle Pond and the "wet reach" of Lee Coulee (see Surface Water section).

Mining would eliminate some sandstone outcrops and natural bluffs. To mitigate for the resultant loss of wildlife habitat, Marmot Peak would not be removed. To mitigate for the loss of any potential eyries and to encourage nesting by golden eagles and prairie falcons, one or two eyries would be created in each of the two bluff extensions left on Marmot Peak, depending on the bluff's size and other physical characteristics. Eyries would also be developed in an existing bluff that is currently used as a nesting site for prairie falcons just northwest of the proposed permit area.

G. Cultural Resources

With the redefinition of sites 24RB1163 and 1164, Peabody has made the necessary eligibility determinations for all eight sites identified within the proposed permit area. Mitigation plans had already been submitted and approved for all sites. With the revised plan for the redefined 24RB1164, Peabody has also met the mitigation plan requirement for all eight sites. This completes the company's pre-permit obligations.

Peabody would have to complete the approved mitigation measures, including submitting a satisfactory final report, for each site prior to receiving approval to disturb the site; this will be stipulated (see section V). The company has also committed to protecting the sites from vandalism, etc. in the interim.

Requests were made to the Northern Cheyenne and Crow Tribes for any information they might have on culturally or religiously significant sites in the proposed permit area and immediately adjacent areas. The Crow Tribal Council replied that no significant resources of this nature were present in these areas. No response was received from the Northern Cheyenne Tribal Office.

H. Bonding

Bonding levels proposed by Peabody for Area B have been reviewed and found adequate for the initial five-year permit term. The bonding analysis identifies the worst-case scenario during the permit term and calculates an adequate reclamation cost estimate. The total bond amount required is $3,469,987.00. Peabody will be submitting this amount just prior to permit issuance.

IV. Findings

1. The Montana Department of State Lands has determined that the permit application submitted in 16 volumes, submitted on October 7, 1987, and revised through October 1988, is complete and accurate and the applicant has complied with Montana's permanent regulatory program (82-4-222, MCA), subject to the proposed stipulations described in Section V.

2. The applicant has demonstrated that reclamation, as required by the Montana Strip and Underground Mine Reclamation Act and regulations, can be accomplished under the reclamation plan contained in Volumes 12 through 16 of the permit package, and as subsequently revised (82-4-227(1), MCA), subject to appropriate stipulations referenced above.

3. The Department has determined that the new permit application known as Area B for the Big Sky Mine is:
   a. Not within an area under study or administrative proceedings under a petition to have an area designated as unsuitable for strip or underground coal mining operations (82-4-227(9), MCA).
   b. Not included in an area designated unsuitable for strip or underground coal mining operations pursuant to 82-4-227(9), MCA.
   c. Not on any lands subject to the prohibitions or limitations of 82-4-227, MCA, to include national parks, refuges, forests, etc.; nor where adverse impacts to publicly owned parks of places included in the National Register of Historic Places, public roads and buildings, occupied dwellings and cemeteries would occur.
   d. Not mining on any lands within 100 feet, horizontally, of the outside right-of-way line of any public road.
   e. Not mining within 300 feet, horizontally, of any occupied dwelling.
   f. Not mining within 300 feet, horizontally, of any public building, church, school, community or institutional building, or public park.
   g. Not mining within 100 feet, horizontally, of a cemetery where human bodies are interred.

4. Peabody has acquired all surface and mineral rights necessary to conduct operations for all areas proposed to be permitted and bonded.

5. The Department has made an assessment of the probable cumulative impacts of all anticipated coal mining on the hydrologic balance of the cumulative impact area. This includes: previous and existing mining in Peabody's Big Sky Mine (Area A), Western Energy Areas A, B, C, D, E, Pit 6 and Northern Pacific's pre-law mining, and proposed mining (Peabody Coal Company - Lee Coulee (Area B) and Western Energy Company's Area C Amendment). The assessment does not include mining previously alluded to by Peabody for Richard Coulee to the south of Area B, since that plan is uncertain and no details have been submitted. A Preliminary Environmental Review including an assessment of probable cumulative hydrologic impacts would be undertaken with submission of an application for mining in Richard Coulee.

   It has been determined that the proposed plan has been designed to prevent material damage to the hydrologic balance outside the permit area (82-4-

227(3)(a), MCA). The following is a summary of the Department's assessment:

The proposed mining is contained entirely within the Lee Coulee drainage, a minor tributary (20.61 square miles or about 1.6 percent) of Rosebud Creek (1302 square miles). Peabody's Big Sky Mine (Area A) to the northeast of Lee Coulee will include 1699 acres of disturbance by the upcoming completion of permitted mining (see SMP 83004CR). Total permitted area for the Lee Coulee (Area B) proposal would be 5436 acres, of which 3247 would be disturbed by mining (including the mined area, the area upon which spoil is to be deposited and graded, and where final highwalls will be reduced; see Exhibits 12-2, 20-2 and Figure 20-2, Peabody Coal Company Area B Application, 1988). The proposed disturbance represents 33 percent of the upper Lee Coulee drainage (9849 acres above Schmidt's Ditch, the lower limit of mining) and 25 percent of the total Lee Coulee drainage area. The probable hydrologic impacts to the surface water system within the permit area are summarized above (Evaluation of Compliance). Minor impacts are predicted for the surface water system outside the permit area (DEIS, MDSL/OSMRE 1988). This includes an approximate 2 percent increase in TDS at the mouth of Rosebud Creek (based on average annual flow) which could be somewhat higher during low flow months or years.

Impacts are expected to the coal, overburden and alluvial aquifers within the permit area. Average TDS increase in the spoil aquifer is predicted to be 2.3 times the pre-mine values, at a maximum, for the disturbed aquifers. The impact to the Rosebud Creek alluvial aquifer outside the permit area is predicted to be an 11 percent rise in TDS (Draft EIS MDSL/OSMRE, 1988). This increase in TDS may affect land management practices, or cause impacts outside the permit area where the local water table is very near to the surface; existing subirrigated areas consist largely of deep-rooted alfalfa and for this reason, impacts to existing beneficial uses are expected to be minimal.

The upper Rosebud Creek drainage, above the USGS gauge near Colstrip (one mile below the mouth of Lee Coulee), contains approximately 799 square miles (511,360 acres). Of this, approximately 9,800 acres will eventually be disturbed as a result of previous, existing and proposed mining plans. This includes: Peabody Areas A (1699 acres) and B (3247 acres); Western Energy (WECO) Area B Extension (195 acres on the upper Lee Coulee/East Fork Armells Creek divide), part of Area D West and all of Area D East (approximately 2530 acres), Areas E and E Extension (1086 acres), and Pit 6 (approximately 700 acres). The total disturbed area represents approximately 1.2 percent of the total Rosebud drainage, and the Lee Coulee disturbance represents about 0.6 percent of the upper Rosebud Creek drainage.

6. No structures currently exist in Area B. Peabody will construct minor facilities, i.e., mine office and fuel storage to help facilitate the operation. Other mine facilities are contained in Area A, which is under permit and in compliance with 82-4-222(2)(i), MCA, and pursuant regulations. The facilities in Area A will be used to support mining operations in Area B.

7. Peabody has paid all reclamation fees from previous and existing operations as required by 30 CFR Chapter VII, Subchapter R (OSMRE Applicant Violators System, November 10, 1988).

8. The following special categories of mining are not applicable to the proposed mining operation: special bituminous mining (30 CFR 785.12(c)), experimental practices mining (30 CFR 785.13(d), mountain top removal mining (30 CFR 785.14(c)), steep slope mining (82-4-232(2), MCA), prime farmlands (82-4-227(5), MCA), variance for delay in contemporaneous reclamation requirements (30 CFR 785.18(c)), areas in or adjacent to alluvial valley floors (82-4-227(3)(b), MCA), augering (ARM 26.4.326), coal processing plants or support facilities not located within the permit area (ARM 26.4.327), and in-situ processing activities (ARM 26.4.904).

   There is no designated prime farmland located within the permit area because the permit area does not contain a developed and dependable irrigation water supply.

   Pursuant to 82-4-232(7), the applicant has proposed alternate reclamation with respect to the leaving of bluff extensions around Marmot Peak (See B. Reclamation Plan). This constitutes a variance from AOC as currently defined. The Department has determined that the applicable rules have been met with this proposal.

   An alluvial valley floor is not present in Area B because the Department has determined that Lee Coulee and its tributaries meet the definition of upland areas, and therefore, do not satisfy the geologic criteria of an alluvial valley floor (see AVF Decision Document for Lee Coulee, MDSL, June 1987).

9. There is no proposal for an intensive agricultural post-mining land use within the proposed permit area.

10. The proposed operation would not affect the continued existence of threatened or endangered species or result in the destruction or adverse modification of their critical habitats, as determined under the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.) (Memo from Acting State Supervisor, Mt. State Office, USFWS to Chief, Federal Lands Branch, OSMRE, August 2, 1988).

11. There are no private family burial grounds within the permit area (personal communication with Reg Hoff, Peabody Coal Company on October 3, 1988), 82-4-227(7), MCA).

12. According to the records of the Montana Department of State Lands, no outstanding violations exist on the current operation. Further, no strip or underground coal mining and reclamation operation owned or controlled by Peabody Coal Company or related entities is currently in violation of the Montana Strip and Underground Mining Act or any federal law, rule or regulation pertaining to air or water environmental protection that has not

been or is not in the process of being resolved (82-4-227(11), MCA). (AVS check of November 10, 1988; filed in application file No. 00132.

13. Records of the Montana Department of State Lands and OSMRE show that the applicant does not control and has not controlled strip or underground coal mining and reclamation operations with a demonstrated pattern of willful violations of the Act of such nature, duration, and with such resulting irreparable damage to the environment that would indicate an intent not to comply with the provisions of the Act (82-4-227(12), MCA). (AVS check of November 10, 1988; filed in application file No. 00132).

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V. Stipulations

26.4.1131

Peabody Coal Company shall complete the approved mitigation measures, including submittal of a satisfactory final report, for each of the cultural/historical sites that are eligible for listing on the National Register of Historic Places and that will be disturbed, before approval is granted to disturb these sites.

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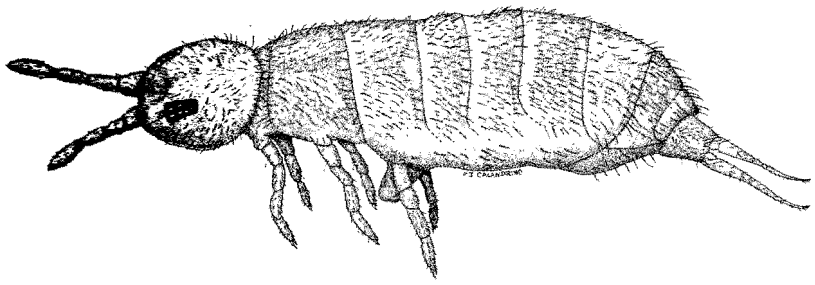
Vol. 20, No. 1 Spring 1987

THE GREAT LAKES ENTOMOLOGIST



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Isotoma nympha Snider and Calandrino (Collembola: Isotomidae). Drawing by Frank J. Calandrino, Michigan State University.

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AN ANNOTATED LIST AND NEW SPECIES DESCRIPTIONS OF COLLEMBOLA FOUND IN THE PROJECT ELF STUDY AREA OF MICHIGAN [1]

Richard J. Snider and Frank J. Calandrino [2]

ABSTRACT

An annotated list of 80 collembolan species taken from the ELF Project area in Dickinson County, Michigan, is presented. Two new species are described, a new record for the United States is established, and new records for Michigan's Upper Peninsula are reported. Specimens were obtained using pitfall traps and extraction of litter and soil cores taken from deciduous forest.

The United States Navy Electronic Systems Command during 1981 was directed by the President to proceed with completion of an ELF (Extremely Low Frequency) communications system for submarines. This entailed the construction of a 58-mile-long antenna in Michigan's Upper Peninsula. Since 1982, our research team has been monitoring the deciduous forest arthropods associated with soil and litter of locations in Dickinson County. Our purpose is to establish baseline data about the composition and ecology of those populations before, during, and after erection and operation of the antenna.

Selection of suitable forest sites for study depended upon similarities of vegetation, soils, and climatic factors. During 1982 two sites were selected for initial investigations to validate methods, gather preliminary samples for analysis, and train our staff. One site, "Silver Lake" (T44N-R29W-S19), was used to evaluate the effects of spacing between pit-traps on catch (Snider and Snider 1986). The site is dominated by *Populus grandidentata* Michx., with *Acer saccharum* Marsh subdominant. Another site, "Turner Road" (T43N-R29W-S8), was looked at in 1982. *Acer saccharum* dominated, with *Tilia americana* L. subdominant.

Definitive sites for the ecological monitoring program were finally selected in 1983; these are designated "test" (T44N-R29W-S25) and "control" (T43N-R30W-S11). Both locations are dominated by *A. saccharum* with *T. americana* subdominant. Both soils are well drained spodosols. The A horizon in both sites is a mull, including small amounts of poorly developed moder. Climate conditions are given in Snider and Snider (1986).

The Collembola taken between summer of 1982 and 1985 were obtained by several collecting methods: pit-traps with and without barriers, day and night pickups; litter samples extracted by the Tullgren funnel method; soil cores and squares, Tullgren method; and hand collecting under logs, bark, and sweeping with white enamel pans. All specimens were preserved in 95% ethanol and, when necessary, examined as slide mounts with phase-contrast microscopy.

Previous records of Collembola taken in Michigan are available in Bernard (1973, 1976, 1977), Snider (1967a, 1967b, 1969a, 1969b, 1978), Snider and Fisher (1964),

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[1]Support for this research was provided by the Naval Electronic Systems Command through a subcontract to IIT Research Institute under contract N00039-81-C-0357

[2]Department of Zoology, Michigan State University, East Lansing, MI 48824.

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Snider and Husband (1966), and Snider and Snider (1986). In the following account,published records are designated LP (Lower Peninsula), UP (Upper Peninsula), DC (Dickinson County), followed by tier, range, and section. The system of classification follows Christiansen and Bellinger (1981). United States and Canadian distribution records are also taken from Christiansen and Bellinger (1981). Additions to the U.S. list are from Bellinger (1982) and Fjellberg (1984, 1985).

We have collected 80 species from the ELF Project area of which two are species new to science, one is recorded in the United States for the first time, 29 are new Michigan records, and 15 are new records from the Upper Peninsula.

Order COLLEMBOLA
Suborder ARTHROPLEONA
Family HYPOGASTRURIDAE
Subfamily HYPOGASTRURINAE

Hypogastrura (Hypogastrura) nivicola (Fitch), 1846. LP, UP, T44N-R29W-S25, 16–17 July, night pit-trap. While this species, known as "the snow flea," has been observed by many people, mostly hikers and hunters, it has not actively been collected and recorded with frequency. The specimens were adult with fully developed black pigmentation. A species common in the northern half of the United States.

Xenylla acauda Gisin, 1947. UP, DC, T43N-R30W-S11, 7 May–15 Oct. from litter and soil cores; T44N-R29W-S25, 15 May–28 July, from litter and soil cores. U.S. records: California and Idaho.

Xenylla pallescens (Scott), 1960. T43N-R30W-S11, 22 May–17 July, litter and pit trap; T44N-R29W-S25, 22 May–3 July, pit-trap. Our studies show this species to be day-active. U.S. records: Colorado and New Mexico.

Willemia denisi Mills, 1932. T43N-R29W-S8, 10 Aug.–22 Oct., litter. U.S. records: Alaska (Fjellberg 1985), California, Colorado (Fjellberg 1984), Washington. Canadian records: Alberta and Northwest Territories.

Willemia intermedia Mills, 1934. LP. T43N-R29W-S8, 10 Aug.–16 Oct., litter and soil cores. Frequently taken with *W. denisi* and *W. similis*. U.S. records: California, Colorado (Fjellberg 1984), Connecticut, Iowa, Massachusetts, Tennessee, Utah. Canadian records: Quebec.

Willemia similis Mills, 1934. T43N-R29W-S8, 25–30 Aug., litter and soil cores. U.S. records: Arctic Alaska, California, Colorado (Fjellberg 1984), Indiana, Iowa, Kansas, Tennessee, Utah. Canadian records: Northern Canada.

Subfamily Neanurinae

Odontella substriata Wray, 1952. UP, DC, T43N-R29W-S8, 25–30 Aug., litter and soil cores. U.S. records: Connecticut, Illinois, North Carolina.

Friesia sublimis Macnamara, 1921. T43N-R29W-S8, 10 Aug.–22 Sept., litter. U.S. records, Connecticut, Illinois, Indiana, Massachusetts, New Hampshire, New York, Pennsylvania, Vermont (Bellinger 1982). Canadian records: Arnprior.

Pseudachorutes aureofasciatus (Harvey), 1898. LP. T43N-R30W-S11, 8 May–16 Oct., pit-trap. Our largest numbers were taken from diurnal pit traps. U.S. records: California, Connecticut, Illinois, Indiana, Iowa, Maine, Maryland, Montana, New York, North Carolina, South Carolina, Tennessee, Vermont (Bellinger 1982), West Virginia. Canadian records: Alberta, British Columbia, Quebec.

Pseudachorutes indiana Christiansen and Bellinger, 1980. T43N-R30W-S11, 7 May–7 Aug.; T44N-R29W-S25, 30 Aug.–29 Sept., litter. U.S. records: Alaska (Fjellberg 1985), Colorado (Fjellberg 1984), Indiana, West Virginia.

Pseudachorutes saxatilis Macnamara, 1920. LP, T43N-R30W-S11, 15 May–20 Oct.;

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T44n-R29W-S25, 15 May–20 Oct., litter, soil cores, pit-traps. Diel studies using pit-traps show this species to be predominantly day-active. Immature specimens were taken from soil cores: adults were litter inhabiting. U.S. records: Indiana, Iowa, Maryland, North Carolina, Pennsylvania, South Carolina, Tennessee, West Virginia. Canadian records: Ontario.

Anurida (Anurida) granaria (Nicolet), 1847. T43N-R30W-S11, 21 May–20 Oct.; T44N-R29W-S25, 7 May–29 Sept., litter soil cores. This species appears to prefer the soil-litter interface. U.S. records: Alaska, California, Connecticut, Illinois, Indiana, Iowa, Kentucky, Massachusetts, New York, North Carolina, Vermont (Bellinger 1982), West Virginia. Canadian records: Ontario, Northwest Territories, Quebec, Ellesmore Is.

Anurida (Micranurida) furcifera (Mills), 1934. T43N-R29W-S8, 16 Aug.–16 Oct., litter and soil cores. U.S. records: Connecticut, Iowa.

Anurida (Micranurida) pygmaea (Borner), 1901. LP, T43N-R29W-S8, 25 Aug., litter. U.S. records: Alaska (Fjellberg 1985), Colorado (Fjellberg 1984), Connecticut, Iowa, Kentucky, Maryland, Massachusetts, Vermont (Bellinger 1982) West Virginia. Canadian records: Alberta, Manitoba, Northwest Territories, Ontario, Quebec.

Neanura (Neanura) muscorum (Templeton), 1835. LP, UP, DC, T43N-R29W-S25, 7 May–16 Oct., litter, under bark, soil cores and pit-traps. This species appears to be active at night. It is frequently encountered in our samples. U.S. records: Arizona, California, Colorado, Connecticut, Idaho, Illinois, Indiana, Iowa, Louisiana, Maine, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, North Carolina, Ohio, South Carolina, Tennessee, Utah, Vermont (Bellinger 1982), Washington, Virginia. Canadian records: Hudson Strait, Manitoba, Ontario, Ungava Bay.

Family ONYCHIURIDAE

Onychiurus (Archaphorura) affinis Agren, 1903. T43N-R29W-S8, 10 Aug.–22 Oct., litter. U.S. records: Colorado (Fjellberg 1984). Canadian records: Alberta, Manitoba, Quebec, Northwest Territories.

Onychiurus (Archaphorura) allanae Christiansen and Bellinger, 1980. T43N-R30W-S11, 28 July–20 Oct.; T44N-R29W-S25, 15 Aug.–20 Oct., litter and soil cores. U.S. records: Massachusetts, Oregon.

Onychiurus (Protaphorura) encarpatus Denis, 1931. T43N-R30W-S11, 21 May–15 Oct., litter and soil cores. U.S. records: California, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maryland, Massachusetts, Missouri, New York, North Carolina, Ohio, Pennsylvania, Utah.

Onychiurus (Protaphorura) parvicornis Mills, 1934. T43N-R29W-S8, 10 Aug.–4 Oct., litter. U.S. records: Connecticut, Illinois, Indiana, Iowa, Massachusetts, Missouri, Vermont (Bellinger 1982), West Virginia.

Onychiurus (Protaphorura) similis Folsom, 1917. T43N-R29W-S8, 16 Aug.–16 Oct., T43N-R30W-S11, 7 May–20 Oct.; T44N-R29W-S25, 28 July–29 Sept., litter and soil cores. U.S. records: California, Connecticut, Illinois, Indiana, Iowa, Kentucky, Maine, Massachusetts, New Mexico, Texas, West Virginia, Wisconsin. Canadian records: Quebec.

Onychiurus (Protaphorura) talus Christiansen and Bellinger, 1980. T43N-R30W-S11, 16 Oct., pit- trap. U.S. records: New Hampshire, Oregon, Wisconsin.

Tullbergia clavata Mills, 1934. T43N-R30W-S11, 7 May–15 Oct.; T44N-R29W-S25, 28 July–20 Oct., soil cores. U.S. records: Idaho, Illinois, Indiana, Iowa, New York, North Carolina, Ohio, South Carolina, Tennessee, Utah, West Virginia. Canadian records: Quebec.

Tullbergia granulata Mills, 1934. LP, T43N-R29W-S8, 10 Aug.–16 Oct., T43N-R30W-S11. 7 May–20 Oct.; T44N-R29W-S25, 28 July–20 Oct., litter and soil cores. U.S. records: Colorado, Connecticut, Georgia, Illinois, Indiana, Iowa, Maryland, Massa-

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chusetts, Missouri, New Hampshire, North Carolina, South Carolina, Utah, West Virginia, Wisconsin. Canadian records: Manitoba, Quebec.

Tullbergia mala Christiansen and Bellinger, 1980. T43N-R29W-S8, 16 Aug.–16 Oct.; T43N-R30W-S11, 7 May–20 Oct.; T44N-R29W-S25, 28 July–14 Sept., litter and soil cores. This is a very common species in litter and soil cores. U.S. records: Colorado, Connecticut, Illinois, Iowa. Canadian records: Alberta.

Tullbergia yosiii Rusek, 1967. T43N-R30W-S11, 7 May–20 Oct.; T44N-R29W-S25, 15 Aug.–20 Oct., litter and soil cores. U.S. records: Connecticut, Indiana, Iowa, Kentucky, Louisiana, Maine, New York. Canadian records: British Columbia.

Family ISOTOMIDAE

Anurophorus (Anurophorus) altus Christiansen and Bellinger, 1980. T43N-R29W-S8, 22 Sept., litter. U.S. records: New York, Pennsylvania.

Anurophorus (Anurophorus) septentrionalis Palissa, 1966. T43N-R30W-S11, 7 May–15 Oct., litter and soil cores. U.S. records: Alaska, Colorado, Connecticut, Illinois, Kentucky, Maine, Massachusetts, New Mexico, North Dakota, Oregon, Washington. Canadian records: Nova Scotia.

Anurophorus (Pseudanurophorus) binoculatus (Kneseman), 1934, T43N-R29W-S8, 22 Sept.–11 Oct.; T43N-R30W- S11, 7 May–20 Oct.; T44N-R29W-S25, 7 May–20 Oct., litter, pit-trap, soil cores. Most of the collection was taken in litter, only a few in soil cores. U.S. records: Colorado (Fjellberg 1984), Connecticut, Massachusetts, Tennessee.

Proisotoma (Proisotoma) minima (Absolon), 1901. LP, T43N-R29W-S8, 12 Aug.–22 Sept.; T43N-R30W- S11, 7 May–10 Sept.; T44N-R29W-S25, 7 May–15 Oct. litter and soil cores. U.S. records: Connecticut, Iowa, Louisiana, Massachusetts, New York, North Carolina, Tennessee, Utah. Canadian records: Quebec.

Cryptopygus decemoculatus (Folsom), 1937. T43N-R30W-S11, 8 May–20 Oct.; T44N-R29W-S25, 7 May–20 Oct., litter and pit-trap. U.S. records: Idaho, Illinois, Utah, Washington.

Folsomia bisetosa Gisin, 1953. T43N-R30W-S11, 16 Sept., soil core. Canadian records: Ellesmere Is.

Folsomia nivalis (Packard), 1873. LP, T43N-R29W-S8, 10 Aug.–22 Oct.; T43N-R30W-S11, 7 May–20 Oct.; T44N-R29W-S25, 16 July–20 Oct., litter and soil cores. U.S. records: California, Colorado, Connecticut, Idaho, Illinois, Indiana, Iowa, Kentucky, Maine, Maryland, Massachusetts, Montana, New Jersey, New York, North Carolina, Pennsylvania, South Dakota, Tennessee, Texas, Utah, Virginia, West Virginia, Washington, Wisconsin, Wyoming. Canadian records: British Columbia, Manitoba, Northwest Territories, Nova Scotia, Quebec.

Isotomiella minor (Schaeffer), 1896. LP, T43N-R29W-S8, 11 Oct.; T43N-R30W-S11, 7 May–15 Oct.; T44N-R29W-S25, 7 May–15 Oct., soil cores. U.S. records: Colorado, Connecticut, Idaho, Illinois, Indiana, Iowa, Maryland, Massachusetts, Missouri, New Jersey, New York, North Carolina, South Carolina, Tennessee, Utah, Vermont (Bellinger 1982).

Isotoma (Desoria) creli Fjellberg, 1978. T43N-R30W-S11, 8 May–16 Oct., pit-trap. U.S. records: Alaska.

Isotoma (Desoria) nigrifrons Folsom, 1937. LP, UP, DC, T43N-R29W-S8, 10 Aug.–22 Oct.; T44N-R29W-S19, 3 Aug.–8 Oct.; T43N-R30W-S11, 7 May–16 Oct.; T44N-R29W-S25, 7 May–16 Oct., litter, soil cores, pit-trap. This species and *I. notabilis* are very numerous in our samples. U.S. records: Colorado, Illinois, Iowa, Montana, Tennessee, Utah, Vermont (Bellinger 1982), West Virginia, Wyoming.

Isotoma (Desoria) notabilis Schaeffer, 1896. LP, T43N-R30W-S11, 7 May–16 Oct.; T44N-R29W- S25, 7 May–15 Oct., litter, soil cores, pit-trap. U.S. records: ubiquitous.

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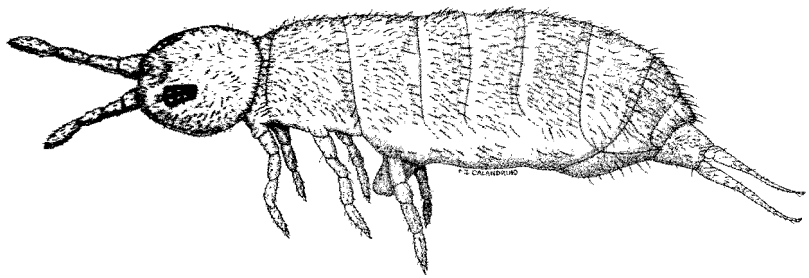

Fig. 1. *Isotoma (Desoria) nympha* n.sp. Habitus, drawn from specimen on microscope slide.

Isotoma (Desoria) nympha **n.sp.**
(Figs. 1–11)

COLOR AND PATTERN (Holotype, on slide): (Fig. 1). Body uniformly blue, with whitish intersegmental bands, pale or pigmentless areas on tergites and head. Head with dark blue pigment extending from frons posteriorly between the eyepatches and narrowing to form a dark spot medio-dorsally posterior to eyepatches, white patches medially anterior to eyepatches, V- shape mark extending from dark spot towards posterior edge of eyepatches. Antennae darker towards tip. Legs, manubrium and furcula lightly pigmented.

HEAD: eyes 8+8 with dark pigment, ocelli G and H subequal (Fig. 2). Postantennal organ elliptical, one and one-half as long as diameter of nearest eye. Apex of fourth antennal segment with "pin" seta and well developed secondary seta, subapical organ spherical (Fig. 3). First antennal segment without modified sensory setae on ventral surface. Labrum without visible ciliations (Fig. 4).

BODY: Abd. V–VI separate with smooth macrochaeta ranging from 2.5 to 4 times as long as inner hind unguis. Manubrium with free apical teeth and approx. 56 ventral setae (Fig. 5). Dens with many dorsal crenulations. Mucro quadridentate with apical tooth the longest and basal teeth subequal and on same level (Figs. 6–7). Retinaculum with 3 setae (Fig. 8). Collophore with 1 frontal seta, 5 lateral and 4 caudal setae (Fig. 9). unguis with minute inner tooth unguiculus with no corner tooth (Fig. 10–11). Length, 1.1mm.

DIAGNOSIS: *Isotoma (Desoria) nympha* n.sp. keys out nearest to *Isotoma (Desoria) japonica* Yosii in Christiansen and Bellinger (1981). However, besides morphological characteristics, color pattern will separate the two species. The following will distinguish the species

I.(D.) nympha	*I.(D.) japonica*
subapical antennal organ spherical	peg-like
unguis without lateral tooth	lateral tooth
56 ventral manubrial setae	16 setae
basal teeth of mucro subequal	unequal

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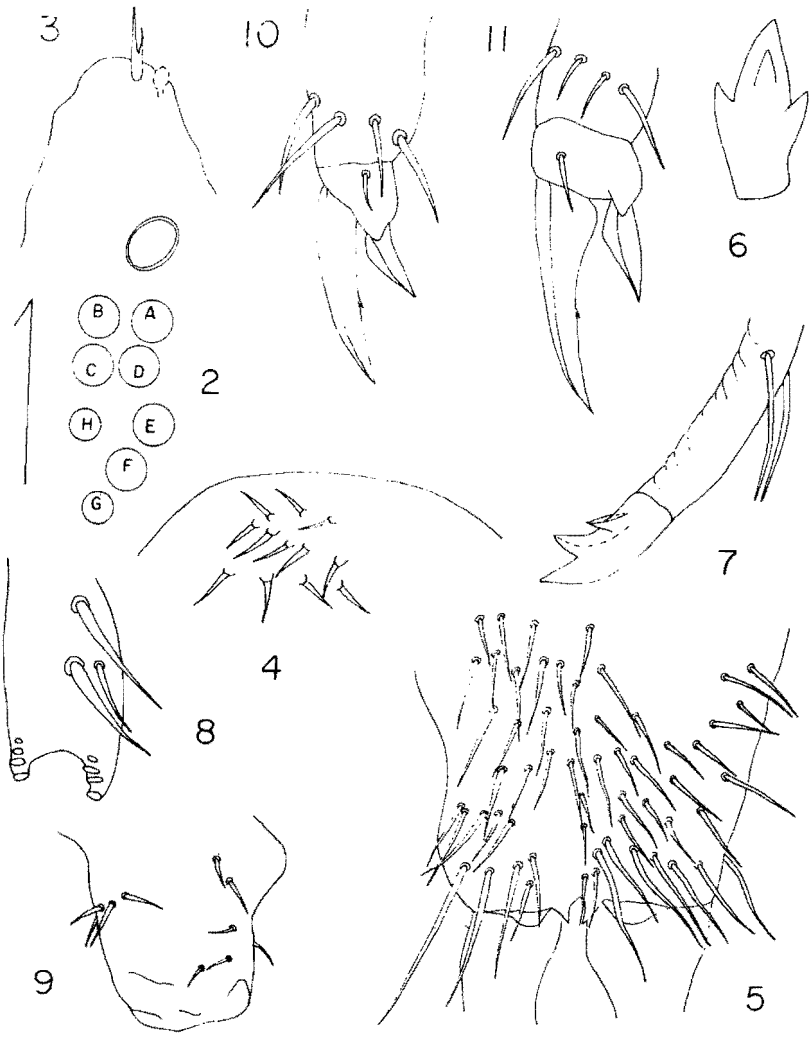

Figs. 2–11. *Isotoma (Desoria) nympha* n.sp. (2) right ocellar patch, (3) apex of 4th antennal segment, (4) labrum, (5) manubrium, ventral view, (6) mucro, dorsal view, (7) mucro, lateral view, (8) retinaculum, (9) collophore, lateral view, (10) foreleg, claw, (11) metaleg, claw.

TYPES: Holotype and one paratype on slides. All types deposited in the Entomology Museum, Michigan State University.

Collection data: Michigan, Dickinson County T43N-R30W-S11, barrier pitfall trap 28-VI-84 and 16-VIII-84.

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Isotoma (Isotoma) viridis Bourlet, 1839. LP, UP, DC, T43N-R29W-S8, 4 Oct.; T44N-R29W-S19, 3 Aug.–8 Oct.; T43N-R30W-S11, 7 May–27 Oct.; T44N-R29W-S25, 7 May–16 Oct., litter, soil cores, pit-trap. U.S. records: ubiquitous.

Family Entomobryidae
Subfamily Entomobryinae

Orchesella ainsliei Folsom, 1924. LP, UP, DC, T44N-R29W-S25, 4 Aug., pit-trap. U.S. records: Illinois, Indiana, Iowa, Kentucky, Louisiana, Maryland, Minnesota, Missouri, New York, North Carolina, South Carolina, Tennessee, Virginia, West Virginia, Wisconsin, Texas. Canadian records: Ontario.

Orchesella hexfasciata Harvey, 1895. LP, UP, DC, T43N-R29W-S8, 25 Aug.–22 Oct.; T43N-R30W-S11, 7 May–27 Oct.; T44N-R29W-S25, 8 May–0 Oct., T44N-R29W-S19, 3 Aug.–5 Oct., litter, soil cores, pit-trap. U.S. records: Connecticut, Illinois, Indiana, Iowa, Kansas, Louisiana, Maryland, Massachusetts, Missouri, New York, North Carolina, Ohio, Tennessee, Vermont, West Virginia. Canadian records: Nova Scotia, Ontario.

Entomobrya (Entomobrya) assuta Folsom, 1924. LP, UP, DC, T44N-R29W-S19, 5 Aug.–14 Sept.; T43N-R29W-S8, 19 Aug.–22 Oct.; T44N-R29W-S25, 28 July–6 Oct., litter, pit-trap. U.S. records: Arizona, Connecticut, Florida, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maryland, Massachusetts, Missouri, New York, North Carolina, South Carolina, Texas, Utah, Vermont, Wisconsin. Canadian records: Ontario, Quebec.

Entomobrya (Entomobrya) clitellaria Guthrie, 1903. LP, UP, DC, T44N-R29W-S19, 7 Aug.–7 Oct.; T43N-R29W-S8, 19 Aug., pit-trap. U.S. records: California, Illinois, Indiana, Iowa, Louisiana, Massachusetts, Minnesota, New York, Oregon, Pennsylvania. Canadian records: Ontario, Quebec.

Entomobrya (Entomobrya) comparata Folsom, 1919. T44N-R29W-S19, 6–30 Aug.; T43N-R29W-S8, 3 Aug.–23 Oct.; T43N-R30W-S11, 7 May–15 Oct.; T44N-R29W-S25, 4 June–20 Oct., soil cores, pit-trap. Our specimens are yellow to flesh color with light purple intersegmental lines. Christiansen and Bellinger (1981) reported that this species has so far only been taken from mountainous regions. In the forests of the ELF Project area, this is a dominant species. In color pattern, it comes closest to the mountain tundra form illustrated by Christiansen and Bellinger (1981) (Figs. 12–13). U.S. records: Alaska, California, Colorado, Idaho, Maine, Montana, Nevada, New Hampshire, New Mexico, Washington, Wyoming. Canadian records: Alberta, Northwest Territories.

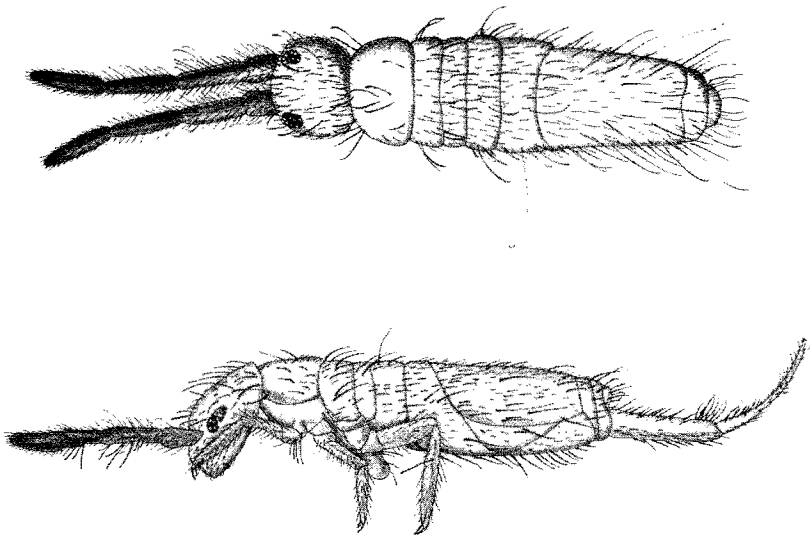
Entomobrya (Entomobrya) nivalis (L.), 1758. LP, UP, DC, T44N-R29W-S19, 16 Sept–4 Oct.; T43N-R30W-S11, 22 May–27 Oct.; T44N-R29W-S25, 10 May–20 Oct. litter, soil cores, pit-trap. U.S. records: Massachusetts, North Carolina, Wisconsin. Canadian records: Ontario.

Entomobrya (Entomobryoides) purpurascens (Packard), 1873. LP, UP, DC, T44N-R29W-S19, 4–5 Aug.; T43N-R30W-S11, 4 June–15 Oct.; T44N-R29W-S25, 5 June–14 Sept., litter, soil core, pit-trap, U.S. and Canadian records: ubiquitous.

Willowsia buski (Lubbock), 1870, LP, UP, DC, T43N-R30W-S11, 30 Aug.; T44N-R29W-S25, 15 Aug.–6 Oct., litter, soil cores, pit-trap. U.S. records: California, Colorado, Connecticut, Illinois, Iowa, Louisiana, Maine, Massachusetts, Minnesota, New York, North Carolina, Utah, Washington, Wisconsin. Canadian records: British Columbia, Manitoba, Ontario, Quebec, Saskatchewan.

Lepidocyrtus helenae Snider, 1967. LP, UP, DC, T44N-R29W-S19, 4–6 Aug.; T43N-R29W-S8, 4 Aug.–27 Oct.; T43N-R30W-S11, 21 May–20 Oct.; T44N-R29W-S25, 29 May–29 Sept., litter, soil cores, pit-trap. U.S. records: Arkansas, Connecticut, Illinois, Indiana, Kentucky, Louisiana, Mississippi, Vermont (Bellinger 1982).

Exhibit 12



Figs. 12–13. *Entomobrya comparata* Folsom. (12) Habitus, lateral view, (13) Habitus, dorsal view.

Lepidocyrtus hirtus Christiansen and Bellinger, 1981. T44N-R29W-S19, 4 Aug., pit-trap. U.S. records: Iowa

Lepidocyrtus lignorum (Fabricius), 1775. LP, UP, DC, T44N-R29W-S19, 5 Aug.; T44N-R29W-S25, 21 May–2 Oct., pit-trap. U.S. records: Arkansas, Connecticut, Illinois, Indiana, Kansas, Louisiana, Tennessee, West Virginia.

Lepidocyrtus paradoxus Uzel, 1891. LP, UP, DC, T44N-R29W-S19, 5 Aug.–5 Oct.; T4 3N-R29W-S8, 10 Aug.–22 Oct.; T4 3N-R30W-S11, 8 May–15 Oct.; T44N-R29W-S25, 25 June–26 Sept., litter, pit-trap. This species was found in large numbers in the basement of our research facility and in a barn where soil samples were processed.

Lepidocyrtus violaceous (Fourcroy), 1785, LP, UP, DC, T44N-R29W-S19, 5–12 Aug., T43N-R30W-S11, 15 May–15 Oct., T44N-R29W-S25, 15 May–4 Sept., litter, soil cores, pit-trap. U.S. records: California, Colorado, Connecticut, Illinois, Indiana, Kentucky, Maine, Massachusetts, New York, Utah. Canadian records: Nova Scotia, Northwest Territories.

Pseudosinella rolfsi Mills, 1932. LP, T43N-R30W-S11, 20–21 Aug.; T44N-R29W-S25, 25 Aug.–14 Sept., litter, pit-trap. U.S. records: Arizona, California, Colorado, Connecticut, Florida, Illinois, Iowa, Louisiana, Massachusetts, New Mexico, New York, North Carolina, Ohio, Pennsylvania, Texas, Utah, Washington, Wisconsin.

Pseudosinella violenta (Folsom). 1924 LP, UP, T43N-R30W-S11, 18–21 Aug.; T44N-R29W-S25, 27 July–20 Oct., soil cores, pit-trap. U.S. records: Arkansas, California, Colorado, Connecticut, Florida, Illinois, Indiana, Iowa, Louisiana, Kentucky, Maryland, Massachusetts, Missouri, New Jersey, New Mexico, New York, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Washington. Canadian records: Nova Scotia, Ontario, Quebec.

Exhibit 12

Subfamily Tomocerinae

Tomocerus (Pogonognathellus) flavescens Tullberg, 1871. LP, UP, DC, T44N-R29W-S19, 4 Aug.–8 Oct.; T43N- R29W-S8, 4 Aug.–29 Oct.; T43N-R30W-S11, 7 May–16 Oct.; T44N- R29W-S25, 8 May–16 Oct., litter, soil cores, pit-trap. A dominant species in the woodlots. U.S. records: ubiquitous.

Tomocerus (Tomocerina) lamelliferus Mills, 1934. LP, UP, DC, T44N-R29W-S19, 4–30 May.; T43N-R30W-S11, 7 May–20 Oct.; T44N-R29W-S25, 28 July–20 Oct., litter, soil cores, pit-trap. U.S. records: east coast, California, Indiana, Washington. Canadian records: Ontario.

Suborder SYMPHYPLEONA
Family NEELIDAE

Neelus (Megalothorax) minimus (Willem), 1900. T43N-R29W-S8, 10 Aug.–22 Oct.; T43N-R30W-S11, 28 July–20 Oct.; T44N-R29W-S25, 28 July–15 Aug., litter, soil cores. U.S. records: Alabama, Alaska, Colorado, (Fjellberg 1984), Connecticut, Florida, Illinois, Indiana, Iowa, Kentucky, Maryland, Massachusetts, Missouri, New York, Tennessee, Utah, Vermont (Bellinger 1982), Virginia, Wisconsin. Canadian records: Alberta, Ellesmere Is., Northwest Territories, Nova Scotia, Quebec.

Neelus (Megalothorax) incertus (Börner), 1903. T43N-R29W-S8, 10 Aug.–4 Oct.; T43N-R30W-S11, 28 July–30 Aug.; T44N-R29W-S25, 28 July–30 Aug., litter, soil cores. We believe this species shows enough variation with *Neelus (Megalothorax) tristani* Denis, 1933 to be the same. U.S. records: California, Illinois, Indiana, Iowa, Kansas, Louisiana, North Carolina, South Carolina, Tennessee. Canadian records: Quebec.

Neelus (Neelides) minutus (Folsom), 1901. LP, T43N-R29W-S8, 10–12 Aug.; T43N-R30W-S11, 28 July–30 Aug., litter, soil cores. U.S. records: Alaska, California, Idaho, Illinois, Indiana, Iowa, Kansas, Maryland, Massachusetts, Mississippi, New York, North Carolina, Tennessee, Utah, Vermont (Bellinger 1982).

Neelus (Neelides) snideri (Bernard), 1975. LP, T43N-R29W-S8, 10 Aug–22 Oct.; T43N-R30W-S11, 3 July., litter, pit-trap. U.S. records: Michigan (type).

Family SMINTHURIDAE
Subfamily Sminthuridinae

Sminthurides (Sphaeridia) pumilis Krausbauer, 1898. LP, T44N-R29W-S25, 17 July, pit-trap. U.S. records: Alaska, California, Colorado, Idaho, Indiana, Iowa, Louisiana, Minnesota, Mississippi, Missouri, Nebraska, New Mexico, New York, Oklahoma, South Carolina, Tennessee, Utah. Canadian records: Manitoba, Northwest Territories.

Sminthurides (Sminthurides) lepus Mills, 1934. LP, UP, DC, T44N-R29W-S19, 3 Aug.–8 Oct.; T43N-R29W-S8, 10 Aug.–4 Oct.; T43N-R30W-S11, 7 May–20 Oct.; T44N-R29W-S25, 21 May–16 Oct.; litter, soil cores, pit-trap. This is one of the most numerous species to be found in the ELF Project area. U.S. records: Connecticut, Illinois, Indiana, Iowa, Louisiana, Maryland, New York, North Carolina, South Carolina, Vermont (Bellinger 1982). Canadian records: Ontario.

Sminthurides (Sminthurides) occultus Mills, 1934. LP, UP, DC, T44N-R29W-S25, 16 July, pit-trap. U.S. records: California, Illinois, Indiana, Iowa, New York, North Carolina, South Carolina, Tennessee. Canadian records: Manitoba, Northwest Territories, Ontario.

Exhibit 12

Subfamily Katianninae

Arrhopalites amarus Christiansen, 1966. UP, DC, T44N-R29W-S19, 4 Aug.–8 Oct.; T43N-R29W-S8, 3 Aug.–4 Oct.; T43N-R30W-S11, 15–30 Aug.; T44N-R29W-S25, 28 July–20 Oct., litter, pit-trap. U.S. records: California, Colorado (Fjellberg 1984), Connecticut, Illinois. Canadian records: Labrador, Ontario.

Arrhopalites benitus (Folsom) 1896. LP, UP, DC, T44N-R29W-S19, 4 Aug.–8 Oct.; T43N-R29W-S8, 7–9 Sept.; T43N-R30W-S11, 7 May–16 Oct.; T44N-R29W- S25, 11 June–20 Oct., litter, soil cores, pit-trap. U.S. records: Illinois, Massachusetts, North Carolina, Oregon, South Dakota, Virginia, West Virginia, Wisconsin.

Arrhopalites caecus (Tullberg), 1871. LP, UP, DC, T43N-R30W-S11, 28 July–4 Sept., soil cores, pit-trap. U.S. records: California, Colorado, Illinois, Indiana, Iowa, Massachusetts, Minnesota, New York, North Carolina, South Dakota, Tennessee, Utah, Wisconsin. Canadian records: Alberta.

Sminthurinus (Katiannina) macgillivrayi (Banks), 1897. LP, UP, T43N-R29W-S8, 29 Sept.; T43N-R30W-S11, 7 May–12 June.; T44N-R29W-S25, 15 May–26 June., pit-trap. U.S. records: Illinois, Indiana, Kentucky, Maryland, Missouri, New York, North Carolina, Pennsylvania, Tennessee, Vermont (Bellinger 1982) Canadian records: Ontario.

Sminthurinus (Polykatianna) intermedius Snider, 1978. UP, DC, T44N-R29W-S19, 7 Aug.–6 Oct., pit-trap. U.S. records: Connecticut, Illinois, Indiana, Iowa, Maryland.

Sminthurinus (Sminthurinus) conchyliatus Snider, 1978. UP, DC, T44N-R29W-S19, 7 Aug.–6 Oct., pit-trap. U.S. records: Illinois.

Sminthurinus (Sminthurinus) henshawi (Folsom), 1906. LP, UP, DC, T44N-R29W-S19, 3 Aug.–8 Oct.; T43N-R29W-S8, 4 Aug.–29 Oct.; T43N-R30W-S11, 15 May–27 Oct.; T44N-R29W-S25, 21 May–27 Oct., litter, pit-trap. This is a very common species in our woodlots. U.S. records: ubiquitous.

Sminthurinus (Sminthurinus) quadrimaculatus (Ryder), 1879. LP, UP, DC, T44N-R29W-S19, 4 Aug.–7 Oct.; T43N-R29W-S8, 2 Sept.; T43N-R30W-S11, 5 July–4 Sept.; T44N-R29W-S25, 14 May–2 Oct., pit-trap. The two-spotted form occurs in the woodlots. U.S. records: California, Colorado (Fjellberg 1984), Connecticut, District of Columbia, Florida, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Minnesota, New York, North Carolina, Pennsylvania, Tennessee, Wyoming. Canadian records: New Brunswick, Quebec, Ungava Bay.

Subfamily Sminthurinae

Bourletiella (Bourletiella) hortensis (Fitch), 1868. LP, UP, DC, T44N-R29W-S19, 30 Aug.; T43N-R29W-S8, 10 Aug.–4 Oct.; T43N-R30W-S11, 11–12 June, litter, pit-trap. U.S. records: ubiquitous.

Bourletiella (Deuterosminthurus) russata Maynard, 1951, LP, UP, T43N-R30W-S11, 5 June–3 July.; T44N-R29W-S25, 17 July, pit-trap. U.S. records: Illinois, Indiana, Iowa, New York, Utah.

Bourletiella (Heterosminthurus) koontzi, **n.sp.** (Figs. 14–46)

During the summer of 1984, sminthurids were collected in Dickinson County, Michigan (T43N-R30W-S8). The specimens were taken in a field by using a white enamel pan for sweeping grass and shrubs. It was a sunny, windy day with a temperature of approximately 24°C.

COLOR AND PATTERN (female): (Figs. 14–15). Background faint yellow. Antennae uniformly purple. Head with olive green mosaics forming two lines originating from behind the head and extending to approximately the posterior edge of the

Exhibit 12

eyepatches. Frons with light patches of green. Thorax with light green paramedial broken lines. Lateral olive green mosaics originating on the third thoracic segment converging with the paramedial lines on the greater abdomen; fifth abdominal segment with dark green bands on the posterior margins; abdominal segment VI with two black maculae. Bothriotricha A.B.C surrounded by black pigment. Venter, legs, furcula colorless.

HEAD: eyes 8 + 8 with dark pigment; ocelli A and H subequal (Fig. 16). Antennal segment ratio 1:2:3:7; ANT IV with 9 subsegments, apical bulb (Fig. 17), subsegments with or without fine setulae in the following distribution: II, III, VII, VIII, IX with none, I-1, IV-2, V-2, VI-1 (Fig. 18) with sense organ with two blunt setae withdrawn into a pit with accessory seta (Fig. 19). Dorsum of head with 4 spine-like setae (Fig. 20).

FORELEG: coxa with 1 seta and no oval organs (Fig. 21); trochanter with 1 anterior and 2 posterior setae and no oval organs (Fig. 22); femur with 7 anterior and 8 posterior setae and one oval organ (Fig. 23); anterior and posterior surface with 3 oval organs (Figs. 24–25); tibiotarsus with 3 strongly clavate tenent hairs; pretarsus with posterior curving setulae; unguis curving—lanceolate with no inner or outer teeth, without tunica; unguiculus lanceolate, without lamella, with long strong apical filament (Fig. 26).

MESOLEG: coxa with 2 setae and 1 oval organ (Fig. 27); trochanter with 5 anterior setae and 1 posterior seta, with 1 oval organ (Fig. 28); femur with 1 oval organ, 12 anterior and 4 posterior setae (Fig. 29); anterior and posterior surface of tibiotarsus with 3 oval organs (Figs. 30–31); tibiotarsus with 3 strongly clavate tenent hairs; unguis similar to forefoot; unguiculus with large basal lamella, apical filament stout, pointed.

METALEG: coxa with 4 setae and 1 oval organ (Fig. 32); trochanter with 1 oval organ, 5 anterior and 1 posterior setae (Fig. 33); femur with 1 oval organ, 10 anterior and 5 posterior setae (Fig. 34); anterior and posterior surface of tibotarsus with 3 oval organs (Figs. 37–38); tibiotarsus with 2 strongly clavate tenent hairs; pretarsus with anterior curving setulae; unguis curving, lanceolate; unguiculus with large basal lamella, apical filament stout and pointed (Fig. 35). NOTE: oval organs are reported, but we suspect others will be found.

BODY: Collophore with 1 + 1 subapical setae (Fig. 39). Tenaculum with 3 setulae, ramus with 2 teeth (Fig. 36). Manubrium with 8 + 8 dorsal setae (Fig. 40). Dens ventrally with 5 V_e setae and 3 V_{e2} dens dorsally with 9 E setae, 7 ID setae, 7 L setae (Figs. 44–45). Mucro with external margin weakly crenulate, internal margin smooth (Figs. 41–42). Female subanal appendage acuminate (Fig. 43). Bothriotrichia A, B, C, D. Body setae smooth. Length, 0.75 mm.

DIAGNOSIS: *Bourletiella (Heterosminthurus) koontzi* n.sp. keys out nearest to *Bourletiella (Heterosminthurus) dreisbachi* (Snider) in Christiansen and Bellinger (1981). However, besides morphological characteristics, color pattern will separate the two species. The following will distinguish the species:

B. (H.) koontzi	*B. (H.) dreisbachi*
Dorsum of head with 4 spine-like setae	no spine-like setae
ocelli A and H subequal, others reduced in diameter	ocelli C and H subequal others subequal
metaunguiculus with lamella tapering	lamella rounded

TYPES: Holotype (female), allotype (male) and 50 paratypes in ethanol; three females and three males on slides. All types deposited in the Entomology Museum, Michigan State University.

Collection data: Michigan, Dickinson county T43N-R30W-S8, sweeping shrubs in field, 18-VI-84 and 24-VI-84, F.J. Calandrino, collector.

We take pleasure in naming this species for Captain Ronald L. Koontz, Program Manager, ELF Communication System, Department of the Navy Space and Naval Warfare Systems Command.

Neosminthurus bakeri Snider, 1978. T44N-R29W-S25, 18 June, pit-trap. This is the northern-most range so far recorded for this species. U.S. records: Kentucky, North Carolina. Tennessee.

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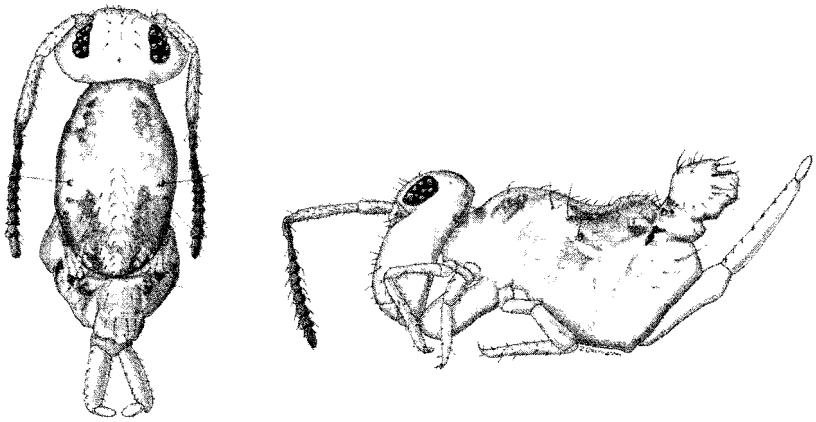

Figs. 14–15. *Bourletiella (Heterosminthurus) koontzi*, n.sp. (14) Habitus, dorsal view, (15) Habitus, lateral view.

Sminthurus (Sminthurus) butcheri Snider, 1969. LP, UP, DC, T44N-R29W-S19, 3 Aug.; T43N-R29W-S8, 4 Aug.–9 Sept.; T43N-R30W-S11, 17 July, litter, pit-trap. U.S. records: Connecticut, Louisiana, Utah.

Sminthurus (Sminthurus) nigromaculatus Tullberg, 1871. T43N-R30W-S8, 27 July–16 Sept., grass sweeping. This species has been in doubt until recently. Its color pattern (Figs. 47–48) is similar to *Sminthurus viridis* (L.) and the two are frequently confused. Hammer (1953) reported *S. viridis* from Canada. Examination of her slides revealed that the specimens were *S. nigromaculatus*. The two species appear to occupy the same range in Europe, however only *S. nigromaculatus* ranges into North America. *S. viridis* feeds on plant fluids while *S. nigromaculatus* gut contents contain hyphae and spores. Morphological separation is possible by examination of the collophore; *S. viridis* lacks a pair of lateral setulae. For a discussion of population variation and habitat descriptions, see Wallace (1973). Canadian records: Northwest Territories.

Sminthurus (Allacma) purpurescens (MacGillivray), 1894. T43N-R30W-S11, 16–17 July, pit-traps. The specimens reported here are patterned with white not frequently seen in published illustrations (Figs. 49–50). U.S. records: Massachusetts, Minnesota, New York, North Carolina, Tennessee. Canadian records: Newfoundland.

Subfamily Dicyrtominae

Dicyrtoma (Dicyrtoma) aurata (Mills), 1934. T43N-R30W-S11, 7 May–16 Oct.; T44N-R29W-S11, 7 May–16 Oct.; T44N-R29W-S25, 3–29 Sept., pit-trap. U.S. records: Iowa, North Carolina.

Dicyrtoma (Ptenothrix) atra (L.), 1758. LP, UP, DC, T43N-R30W-S11, 25 Aug., pit-trap. U.S. records: Arkansas, Connecticut, Illinois, Indiana, Iowa, Idaho, Kentucky, Louisiana, Maine, Massachusetts, Minnesota, New Hampshire, New York, North Carolina, Ohio, South Carolina, Vermont, Wisconsin. Canadian records: Nova Scotia, Ontario, Quebec.

Dicyrtoma (Ptenothrix) marmorata (Packard), 1873. LP, UP, DC, T44N-R29W-S19, 3 Aug.–14 Sept.; T43N-R29W-S8, 10 Aug.–29 Sept.; T43N-R30W-S11, 8 May–16 Oct.; T44N-R29W-S25, 3 July–4 Sept., litter, pit-trap. U.S. records: ubiquitous.

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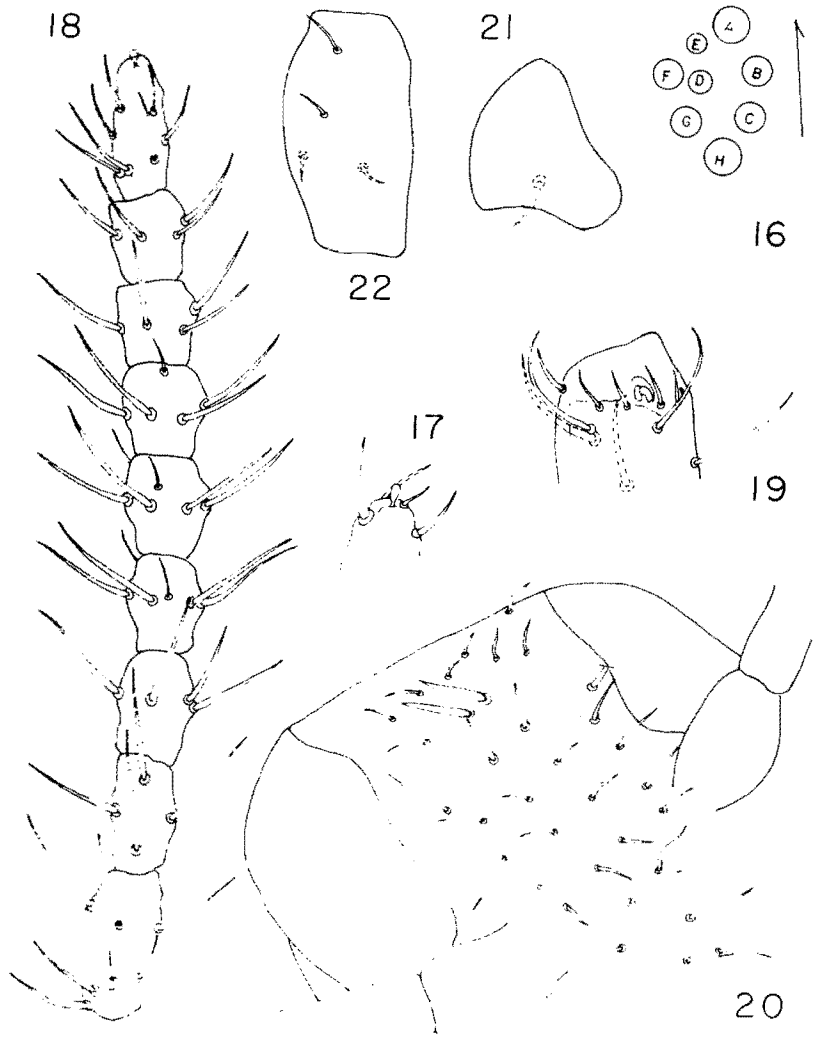

Figs. 16–22. *Bourletiella (Heterosminthurus) koontzi*, n.sp. (16) left ocellar patch, (17) apex of 4th antennal segment, (18) antennal segment 4, (19) antennal segment 3, (20) setal pattern of head, (21) foreleg, coxa, (22) foreleg, trochanter.

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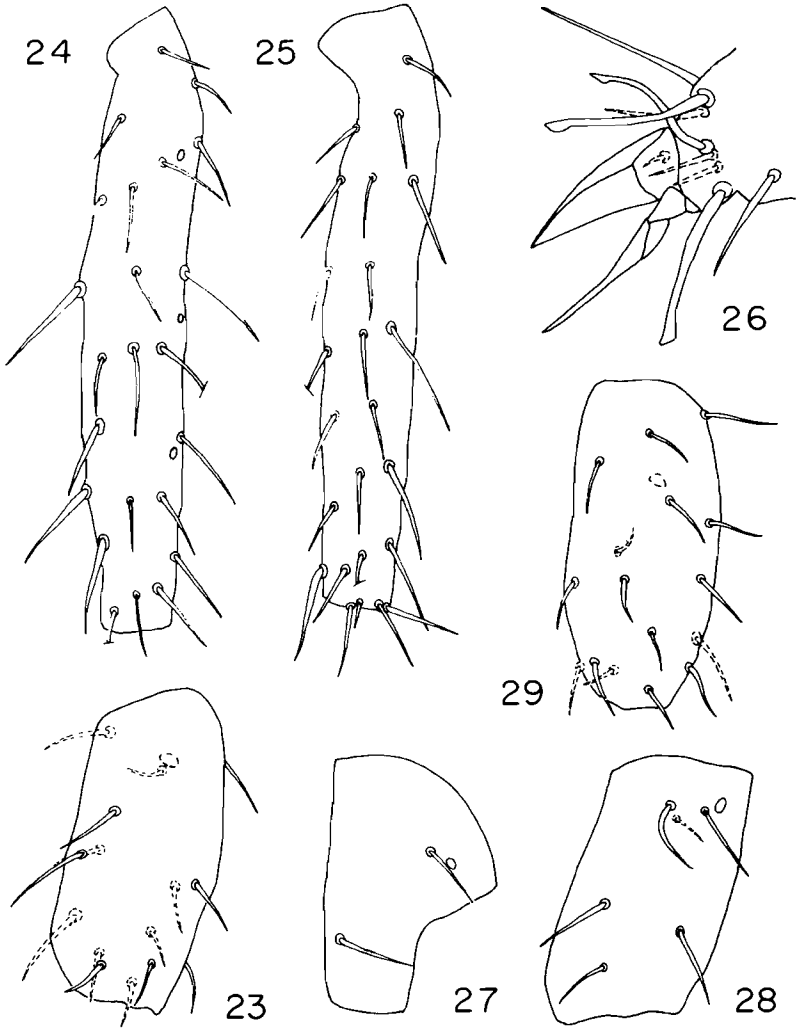

Figs. 23–29. *Bourletiella (Heterosminthurus) koontzi*, n.sp. (23) foreleg, femur, (24) foreleg, posterior surface of tibia, (25) foreleg, anterior surface of tibia, (26) foreleg, claw, (27) mesoleg, coxa, (28) mesoleg, trochanter, (29) mesoleg; femur.

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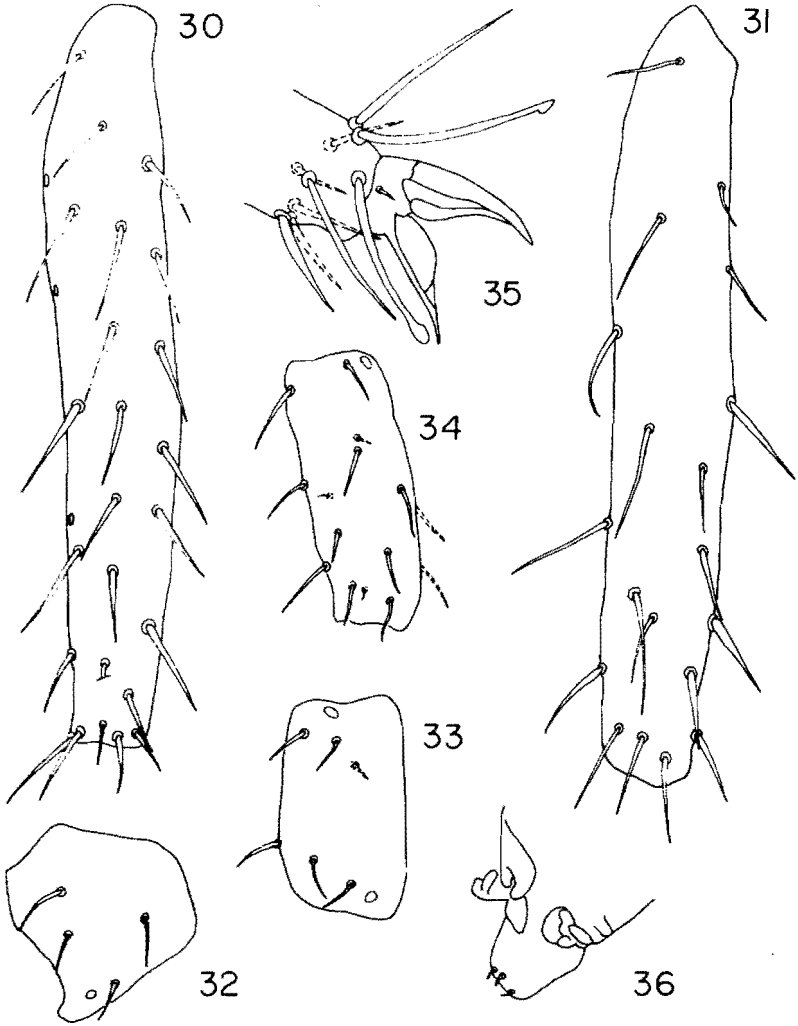

Figs. 30–36. *Bourletiella (Heterosminthurus) koontzi*, n.sp. (30) mesoleg, anterior surface of tibia, (31) mesoleg, posterior surface of tibia, (32) metaleg, coxa, (33) metaleg, trochanter, (34) metaleg, femur, (35) metaleg, claw, (36) retinaculum.

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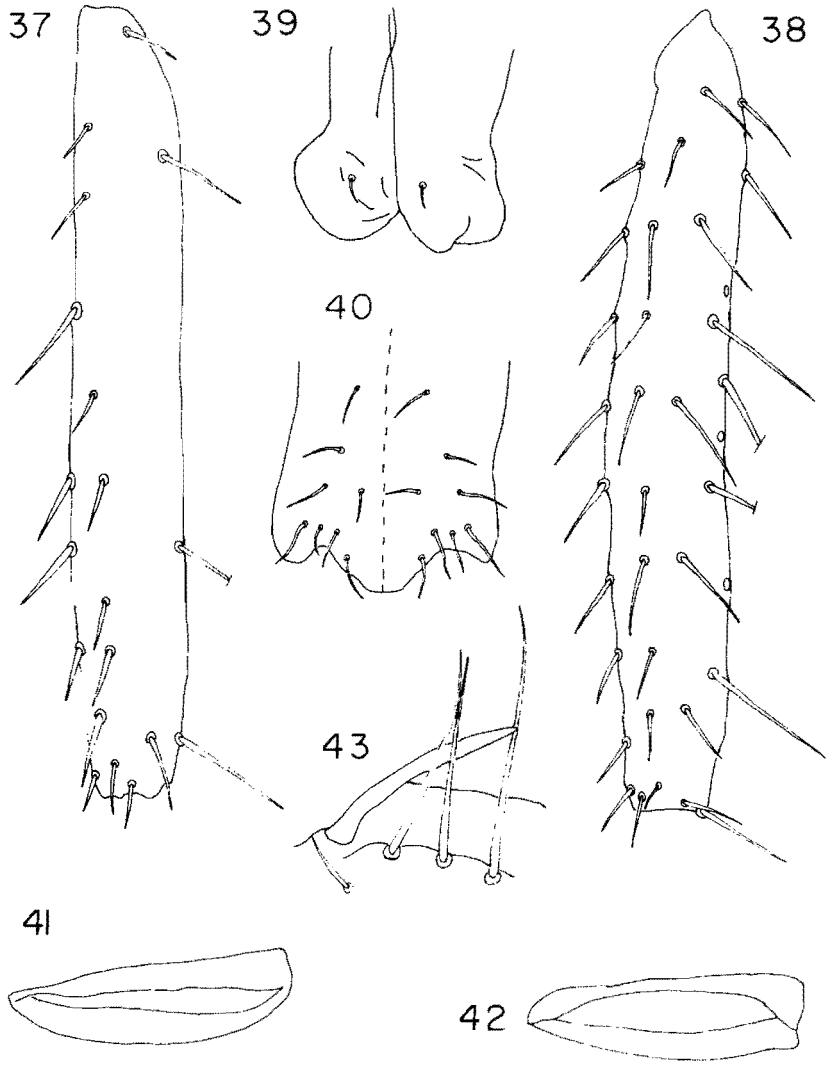

Figs. 37–43. *Bourletiella (Heterosminthurus) koontzi*, n.sp. (37) metaleg, posterior surface of tibia, (38) metaleg, anterior surface of tibia, (39) collophore, posterior view, (40) manubrial setae, (41) mucro, lateral view, (42) mucro, dorsal view, (43) female subanal appendage.

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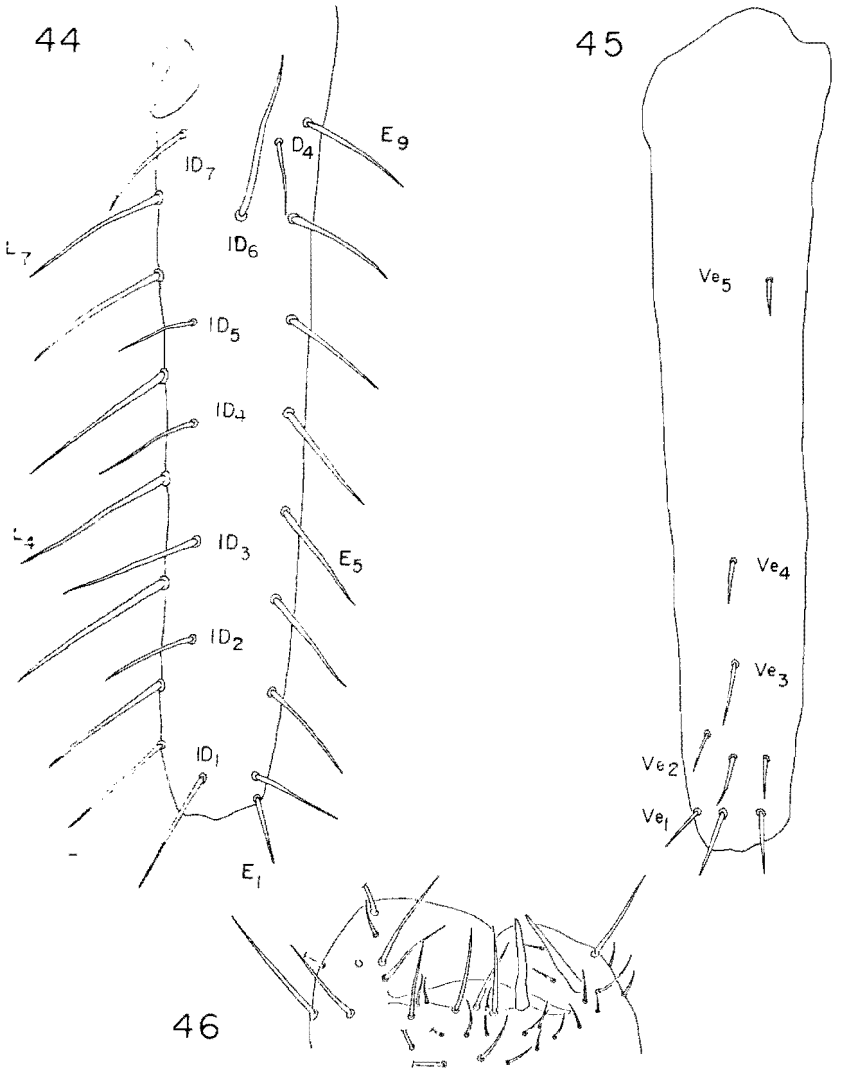

Figs. 44–46. *Bourletiella (Heterosminthurus) koontzi*, n.sp. (44) dens, dorsal view, (45) dens, ventral view, (46) female anal papilla.

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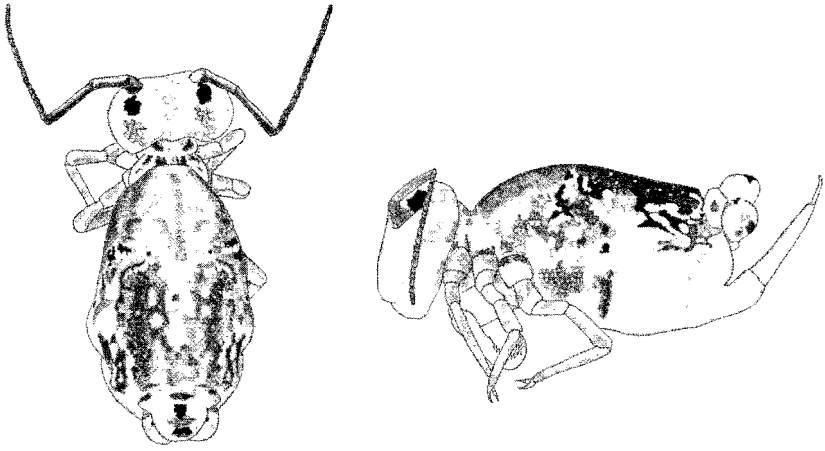
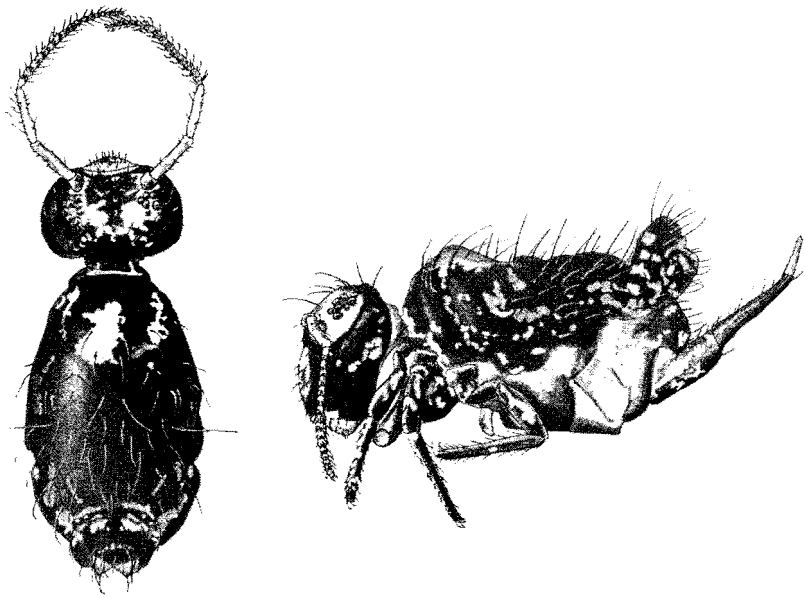


Figs. 47–48. *Sminthurus (Sminthurus) nigromaculatus* Tullberg. (47) Habitus, dorsal view, (48) Habitus, lateral view.



Figs. 49–50. *Sminthurus (Allacma) purpurescens* (MacGillivray). (49) Habitus, dorsal view, (50) Habitus, lateral view.

Exhibit 12

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Exhibit 12

PUDDLING BY FEMALE FLORIDA TIGER SWALLOWTAIL BUTTERFLIES, *PAPILIO GLAUCUS AUSTRALIS* (LEPIDOPTERA: PAPILIONIDAE)

J. Mark Scriber [1]

Many species from all families of Rhopalocera have been reported to drink water (Norris 1936). Bates (1863) noted that, in the Amazon, 80 species from 22 genera flocked about the damp edges of water and, with very few exceptions, all of these individuals were males. Adler (1982) reported that of 3417 known individuals of night-puddling moths (representing 93 genera from 10 families), 1.3% were represented by female individuals from only 16 species. A distinction between "puddle-butterflies" (which assemble together at puddles) and "roadside-butterflies" (which are often seen drinking, but not in groups) was made by Clark (1932). This individual puddling has been described by Berger and Lederhouse (1985).

Assemblages of butterflies have also been reported on dung, urine, perspiration, saliva, salt, blood, campfire ashes, aphid honeydew, tree sap, and animal carrion (Scudder 1889, Norris 1936, Sevastopulo 1974, Downes 1973, Adler 1982). Aggregation of butterflies is often catalyzed by the use of dead specimens or yellow "decoy" substrates (Denton 1889, Clark 1932), and these have been successfully used in puddling experiments with the eastern tiger swallowtail butterfly, *Papilio glaucus* L. (Arms et al. 1974). While the choice of the puddling spot by the initial male butterfly may be made largely by chemical attraction (Couper 1873, Norris 1936), it has been shown that duration of puddling behavior is extended on moist sand containing sodium ions regardless of the anion present (Arms et al. 1974). Furthermore, while male tiger swallowtail butterflies ingest amino acids during puddling, Arms et al. (1974) concluded that ingestion of amino acids is less likely to be the major function of puddling than is ingestion of sodium. Adler and Pearson (1982) postulated that the reduction of sodium in male butterflies may be a consequence of mating (spermatophore transfers). Why sodium would be significantly more important for male butterflies than females has not been entirely resolved because females are known to lose up to 75% of their sodium via oviposition (Adler and Pearson 1982). Moreover, it has not been resolved to what degree female tiger swallowtail butterflies actually engage in such "puddling" behavior.

To my knowledge, no published records existed until recently (Berger and Lederhouse 1985) of puddling by females of any populations of *Papilio glaucus*. No females were observed puddling at any time during the Arms et al. (1974) study, nor have I observed any female of *P. glaucus glaucus* L. or *P. glaucus canadensis* Rothschild & Jordan amongst the hundreds (probably several thousand) of puddling males I have seen in the subsequent nine years (Scriber and Lintereur 1983, Lederhouse 1982, Wagner 1978). My recent observations of single puddling females of *P. glaucus australis* Maynard in Highlands County, Florida, during 1–4 August 1983, are here reported.

I observed four different *Papilio glaucus australis* females individually engaged in brief, but definite, puddling behavior. These observations ranged from 10 to 25 sec in duration. Three of these females were of the yellow morph phenotype and one was a dark morph (Scriber et al., in press). On 2 August 1983, each of the three yellow females was first observed in slow gliding flight along the sand and muck drainage ditches adjacent to

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Hall Road and route 29 S, near the McClellan Bulb Farm south of Lake Placid, Florida (Highlands County). At 1136, 1146, and 1626 h, each of these single females alighted on the ground and began to probe the moist soil with its extended proboscis. The dark morph female was observed slowly flying over the muck field and at 1345 h alighted on the muck soil and probed about with its proboscis on a moist clod of muck. All four females were eventually captured and are currently preserved in our *Papilio* research collection at Michigan State University. No additional puddling observations of any type were made during the following two days of continuous collecting, perhaps because the ground had dried considerably and insignificant rainfall had occurred compared to that which occurred on 1 August. The total numbers of captures for females and males of *P. glaucus* at this site were not significantly different during 2 August (23 males, 4 dark morph females, 13 yellow morph females) and 3 August (20 males, 1 dark and 10 yellow females). No male *P. glaucus* butterflies were observed puddling at any time. One perfect (apparently newly eclosed) *Papilio troilus* L. male was observed to settle on the sandy road to probe on the morning of 4 August 1983.

The question of why puddling behavior in female butterflies is rare as has been assumed, has not been adequately resolved. Perhaps it is not really as rare as generally believed. Among the various explanations of the scarcity of female puddling observations could be the apparently brief duration of the behavior (less than 30 sec) relative to that for males. Hundreds of male *P. glaucus* may sit in dense aggregations for extended periods of time (Couper 1873, Scudder 1889). It is also possible that the females never aggregate as do males, and therefore the individual behavior is much less obvious in the case of females. Thirdly, the time and (or) location of puddling behavior may be generally different than males. For example, it is generally the newly eclosed (i.e. very fresh looking) males which predominate (almost to exclusion) in any puddling aggregation (Lederhouse 1982), whereas two of the females I observed in Florida were obviously worn and likely to be many days old. Similarly, a single female *Papilio polyxenes* Fabricius observed puddling in 1973, in New York State, was extremely worn. Finally, the specific reasons for puddling behavior remain uncertain, and it is possible that these are very different in magnitude and (or) type for female than for male Lepidoptera (e.g. mate location). Berger and Lederhouse (1985) have suggested that individual puddling behavior by females may be to avoid harassment by males.

The degree to which females of the different subspecies of the *Papilio glaucus* complex engage in puddling behavior may be of ecological interest, but must await further study. This report of female puddling represents the first for *P. g. australis*; that of Berger and Lederhouse (1985) represented the first for New York *P. glaucus* (*P. g. glaucus* or *P. glaucus canadensis*). New York is a likely hybrid zone for these two subspecies (Scriber 1982, Ritland and Scriber 1985). The suggestion that introgressive hybridization might account for the origin of puddling behavior in some Lepidoptera has been made (Clark and Clark 1951), but still needs additional study (Shapiro 1979).

ACKNOWLEDGEMENTS

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APPEARANCE OF DAMAGE SYMPTOMS AND REINFESTATION RATES FOR CHRISTMAS TREES ATTACKED BY THE ZIMMERMAN PINE MOTH, *DIORYCTRIA ZIMMERMANI* (LEPIDOPTERA: PYRALIDAE)[1]

James W. Yonker and Donald L. Schuder[2]

ABSTRACT

Two blocks of Scotch pine Christmas trees were inspected to determine an appropriate time to evaluate Zimmerman pine moth damage, and to determine reinfestation rates for trees previously attacked by this insect. Results showed that damage evaluation should be delayed until mid-August and possibly later, in early fall. Evaluation done before this time could result in underestimation of total damage. In the reinfestation study, previously attacked trees were shown to sustain both a higher rate of reattack and more attacks per tree the following year than control trees. However, at most, only 61% of the new attacks the following year were on trees with a previous attack. Also, 47% or more of the infested trees observed the second year were newly infested. These results indicate little practical benefit of using attacked trees solely as a trap crop for ovipositing moths. Attacked trees with severe damage should therefore be removed.

The Zimmerman pine moth (ZPM), *Dioryctria zimmermani* (Grote), is a primary pest of Christmas trees grown in the Midwest (Rennels 1960, Schuder 1960, Butcher and Carlson 1962). Its preferred host is Scotch pine, *Pinus sylvestris* (L.), but it does attack all *Pinus* spp. grown in the Great Lakes region (Schuder 1960; Yonker 1982). The damage it causes can be aesthetic and monetary, as broken terminals, dead laterals, and altered tree-form can all result from attack.

Carlson (1965) developed regression relationships for infested whorls and terminals to predict the extent of an infestation on a plantation-wide basis. However, an attempt to correlate the number of damaged lateral branches with the total number of infested trees in a field was not successful. Also, timing of tree inspections with respect to appearance of damage was not established. In the current study, individual trees were inspected to determine when initial damage appears, and when maximum damage is sustained. Results of this study should help growers evaluate the full extent of damage in their fields, and aid them in making control decisions.

Several authors have outlined chemical control programs (Butcher and Carlson 1962, Appleby and Randell 1980, Schuder 1983), including recommendations for removing heavily infested, damaged trees (Rennels 1960, Schuder 1960). These latter authors stated that once a tree is attacked, it is often reattacked in following years and serves as a source of infestation for other trees. This relationship was further studied, with emphasis on the feasibility of using attacked trees as a natural trap crop for ovipositing females.

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Table 1. Infestation characteristics of blocks A and B.

Block (Year)	No. Trees	No. (%) Attacked	No. (%) Damaged	% Attacked Showing Damage
A (1978)	839	18 (2.1)	—	—
A (1979)	839	63 (7.5)	31 (3.7)	49.2
A (1980)	839	138 (16.4)	63 (7.5)	45.7
A (1981)	839	179 (21.3)	—	—
B (1978)	870	109 (12.5)	—	—
B (1979)	870	152 (17.5)	84 (9.7)	55.3
B (1980)	371	53 (14.3)	17 (4.6)	32.1[a]

[a]Due to harvest, damage estimate was based upon an August, not November evaluation.

MATERIALS AND METHODS

Two blocks of Scotch pine Christmas trees located in Rochester, Indiana, were chosen for study. The presence of ZPM in 1978 and the minimal use of insecticides prior to this study were two criteria for block selection. In 1979, trees in block A were 4 years old, with heights ranging from 0.9 to 1.2 m. Trees in block B were 6 years old, with heights from 1.8 to 2.4 m. Both blocks were surrounded by other blocks of trees in this 8.1-ha field.

Each tree was initially examined for ZPM attacks in late June. Both the number and location of all attacks was carefully noted, as well as the appearance of all visible damage. Damage included broken or dead terminal and lateral leaders, and dead lateral branches. Trees with attacks were reinspected in mid-July, August, and November to document later occurring damage. The November inspection was chosen to ascertain final (recognizable) damage before the occurrence of fall needle yellowing and drop that could disguise damage. From the inspections, initial and maximum damage were determined, as well as infestation rates for previously attacked and unattacked trees.

RESULTS

Table 1 describes the infestation rates and damage characteristics of blocks A and B. During the study, an average of 11.8 and 14.8% of the trees sustained at least one ZPM attack in blocks A and B, respectively. Approximately 48% of the attacked trees from both blocks showed some degree of damage. One or more dead lateral branches extending from an infested whorl area was the most common damage observed. Dead terminal or secondary leaders resulting from attack(s) in the top whorl were less common. ZPM tunneled leaders were rarely observed.

Figure 1 shows the chronological appearance of all ZPM damage observed. For both blocks, the percentage of trees ultimately damaged that showed damage in June was less than 15%. Through July and early August, damage increased substantially, but began to level-off by mid-August. Damage occurred earlier in block A and may be related to the smaller tree's inability to tolerate ZPM attacks. Only 6–14% of the total damage observed occurred after mid August.

Data collected from trees with old and current attacks were used to determine reinfestation rates for trees in both blocks. Reinfestation rates were compared to rates of attack for trees not attacked the first year, but attacked the second year (control trees). Table 2 shows that for each study year, trees with an attack were much more prone to attack the following year than the control trees ($P < 0.05$, χ^2 analysis in 2×2 contingency table). Also, these trees sustained significantly ($P < 0.05$) more attacks per

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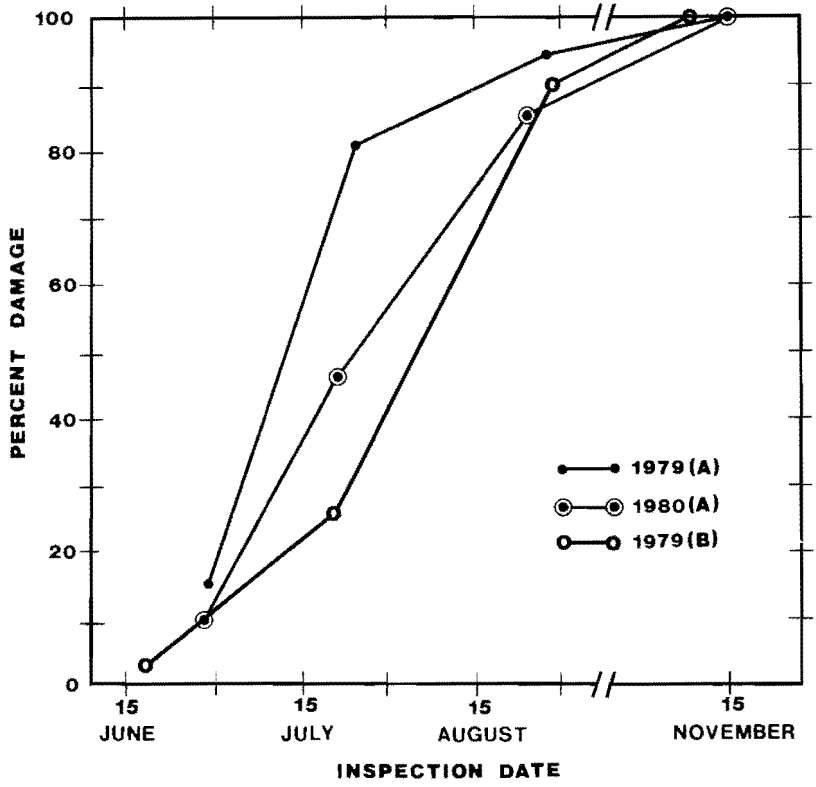

Fig 1. Chronological appearance of damage caused by Zimmerman pine moth in blocks A and B.

Table 2. A comparison of the following years' rates of ZPM attack and the mean number of attacks per tree for previously attacked and control trees.

Block (Year)	% Trees Attacked Following Year		$\bar{x}$ Attacks/Tree Following Year	
	Attacked Trees	Control Trees	Attacked Trees	Control Trees
A (1978)	63	6	1.4	1.2
A (1979)	52	14	1.9[a]	1.3
A (1980)	59	13	2.3[a]	1.4
B (1978)	72	10	2.1[a]	1.5

[a]Mean significantly different from control mean ($P < 0.05$; χ^2 test).

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Table 3. Efficiency of ZPM-infested trees as a trap crop for ovipositing ZPM moths.

Block (Year)	No. Trap Crop Trees	% New Attacks on Trap Crop[a]	No. Newly Infested Trees	% Infested Trees Newly Infested
A (1978)	16	18 (0)	53	84
A (1979)	63	31 (8)	105	76
A (1980)	138	56 (27)	93	53
B (1978)	109	61 (34)	71	47

[a]Number in parentheses is the percentage of attacks on trap crop trees with two or more current attacks.

tree the following year than the control trees. These results imply either a moth attraction for previously attacked trees, some degree of restriction of ovipositing moths to trees from which they emerged, or a higher larval survival rate on the attacked trees.

Table 3 shows the potential of using ZPM infested trees as a natural trap crop for ovipositing females. In the best years, infested trees "caught" only 61 and 56% of the following years' attacks. Even then, 47–53% of all trees attacked the second year were newly infested. Table 3 also shows the protection afforded by those trap crop trees with at least two active attacks. These trees caught, at most, 34 and 27% of the attacks observed the following year.

DISCUSSION

The damage evaluation study showed that a time lag of at least three months exists between ZPM attack (mid-April) and the appearance of substantial damage (late July). These results suggest that the most accurate time to assess damage is after mid-August. Growers who evaluate damage earlier, for instance at shearing (June), may severely underestimate total damage. Evaluation done at moth emergence (early to mid-August) provides a better estimate, and also allows for the application of an insecticide at a time when ZPM is susceptible.

Although most damage, even that appearing in June, was still evident in November, its cause (ZPM, other insect, or mechanical) was sometimes not discernible in November. This suggests that growers should still make evaluations in late summer or early fall to help distinguish all ZPM damage. Damage evaluation at this time is also practical for growers who prefer a spring (April) insecticide application (Appleby and Randell 1980).

The reinfestation results showed that although the infested trees sustained a higher rate of reattack than the control trees, many newly infested trees were observed the following year. Attacked trees, particularly those most heavily infested, did not provide adequate protection for the previously uninfested trees. Since a trap crop does not seem feasible, the recommendation to remove the heavily infested, unsellable trees seems justified (Rennels 1960, Schuder 1960). Also, chemical protection should still be considered for all trees to prevent the current infestation from spreading away from the attacked trees left in the plantation.

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AN IMPROVED BIOTIC INDEX OF ORGANIC STREAM POLLUTION[1]

William L. Hilsenhoff[2]

ABSTRACT

Major improvements were made in using a biotic index of the arthropod fauna to evaluate organic stream pollution. All tolerance values were reevaluated, many were changed, and the scale for tolerance values was expanded to 0–10 to provide greater precision. Keys to larvae of *Ceratopsyche* have been developed and tolerance values for species in this important genus are provided. Sorting of samples in the laboratory instead of in the field is recommended, and directions for processing and evaluating samples are included.

A "saprobic index" (Pantel and Buck 1955) and a "biotic index" (Chutter 1972) were proposed for evaluating the water quality of streams through a study of their fauna. I introduced a similar biotic index (Hilsenhoff 1977) that used only arthropods for evaluation, thus simplifying collecting, sorting, and identification. It was based on a sample of 100 or more arthropods collected from a riffle area. This index is a measure of organic and nutrient pollution, which causes lower dissolved oxygen levels, especially at night during the summer and after heavy rain. Lowered levels of dissolved oxygen in turn affect the ability of each species of arthropod to survive in a particular stream. For the purpose of calculating the biotic index, every species or genus was assigned a tolerance value of 0–5, with 0 assigned to species most intolerant of organic pollution and 5 assigned to the most tolerant species. Intermediate values were assigned to species intermediate in their tolerance of organic pollution. The biotic index is an average of tolerance values for all individuals collected from a site.

Initially the index was used mostly in Wisconsin. In 1979 and 1980 the Wisconsin Department of Natural Resources (DNR), in cooperation with the University of Wisconsin, used the index to evaluate more than 1000 stream sites in spring and autumn. Personnel in my laboratory identified all the arthropods and calculated biotic index values for all sites. Experience from this cooperative study and several other studies enabled me to publish new recommendations for using the biotic index, revised tolerance values, and regional keys to species in important genera (Hilsenhoff 1982).

Recently, additional improvements have been made in the biotic index. Most important are an expansion of the scale of tolerance values to 0–10 to provide greater precision, a reevaluation of all tolerance values, and inclusion of tolerance values for many additional species. Procedures for sampling and sorting were updated, and a discovery that *Simulium vittatum* is really two genetically distinct species (Rothfels and Featherston 1981) with differing ecological requirements (Adler and Kim 1984) altered my recommendation for dealing with these sibling species. Adequate correction factors for current, temperature,

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and seasonal differences are needed, and studies to correct these deficiencies will be completed soon.

REASSIGNMENT OF TOLERANCE VALUES

Initial tolerance values for each species were based mostly on a study of 53 Wisconsin streams in which physical and chemical parameters were evaluated to determine the degree of organic and nutrient pollution in each stream (Hilsenhoff 1977). Tolerance values for species not found or occurring rarely in these streams were based on their occurrence in other streams and their association with species to which tolerance values had been asigned.

Data from more than 2000 samples collected in the 1979–80 cooperative study with the DNR were used to reevaluate tolerance values by comparing the tolerance value of each species with the average biotic index value of streams in which that species most commonly occurred. A description of the procedure that was used can be obtained from the author. It became apparent that intermediate values would increase precision, so the 0–5 scale of tolerance values was expanded to 0–10 to accommodate intermediate values while retaining whole numbers for ease in making calculations. New tolerance values assigned to 359 species or genera found in the DNR samples are listed in Appendix 1.

Forty-nine additional species that were not collected from the 1979–80 study streams, mostly because their life cycles precluded their being present in spring or fall samples, were assigned tolerance values based on our knowledge of streams in which they occurred. Previous experience was also used to adjust tolerance values of nine species that were found in less than five samples from the study streams, and subsequent experience resulted in adjusting values of *Asellus, Crangonyx* and *Hyallela.*

IDENTIFICATION

Accurate identification of arthropods to species is often necessary, especially when a species is numerous in a stream and thus greatly influences calculation of the biotic index. Tolerance values marked with an asterisk (Appendix 1) are least reliable, but the species involved are uncommon in stream riffles and rarely exert much influence on the biotic index. Generic identifications are used only when species identifications are not possible or very difficult, or when in a region all known species in a genus have the same tolerance value. Merritt and Cummins (1984) included keys to North American genera and also referenced regional generic keys, which are easier to use. Hilsenhoff (1981) provided a regional key to genera and references to species keys, which are widely scattered in the literature. Brigham, Brigham and Gnilka (1982) contained regional species as well as generic keys, and Merritt and Cummins (1984) listed species keys, regional keys, and other taxonomic references published through 1982. Recent species keys and identification problems as they relate to the biotic index are discussed below for each order.

PLECOPTERA. Mature nymphs of *Acroneuria, Allocapnia, Pteronarcys,* and *Taeniopteryx* can be identified, but there is a degree of uncertainty in many identifications, especially when nymphs are immature. Because in these genera all species in the western Great Lakes region appear to have similar tolerance values, only a generic tolerance value is used. *Perlesta placida* may be a species complex, with one or more of the species being much less tolerant of organic pollution.

EPHEMEROPTERA. Identification of mayfly nymphs in many genera is not possible, and in other genera species identification must be regarded as somewhat tentative. McCafferty (1975) keyed species of Ephemeridae Polymitarcyidae, and Potamanthidae, but separation of nymphs in these families is not always possible. Since they are relatively uncommon in riffle samples, and because species within each genus appear to have similar tolerance values, only generic tolerance values have been assigned. A recent key by Kondratieff and Voshell (1984) identified nymphs of *Isonychia,* but separation of

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species requires mature nymphs and is difficult. Only a generic tolerance value was provided for this genus, and it may be too low for one or more of the species. *Ephemerella* species A (Hilsenhoff 1982), which occurs in western Wisconsin, is probably *E. inermis* or a sibling species of that species. Reared adults most closely fit the description of *E. inermis*, as do dark-colored nymphs. *Pseudocloeon* species A (Hilsenhoff 1982) may be a new species, or a species for which nymphs have not been described. Arwin Provonsha at Purdue University has revised the genus *Caenis* and developed keys to the nymphs, which he will publish soon. Identification of *Caenis* nymphs is difficult, and because the three riffle species all have similar tolerance values, only a generic value is included.

ODONATA: Several Odonata that were assigned tolerance values are essentially lentic and occur only occasionally in streams and rarely in riffles. Only nine species or genera were found in 10 or more of the 1979–80 study streams. They rarely made up more than 10% of a sample, so this order is usually not important to biotic index values. Generic tolerance values are used for uncommon genera when species identification is difficult. Only mature nymphs of *Ophiogomphus* can be identified to species (Walker 1958, Needham and Westfall 1955), so a generic tolerance value is also used for this important genus.

TRICHOPTERA: Species identification of larvae in this important order is often difficult or impossible. Recent studies of larvae of Brachycentridae (Chapin 1978, Flint 1984) and Hydropsychidae (Schuster and Etnier 1978, Schefter and Wiggins 1986) and regional keys to most species in these families (Hilsenhoff 1985, Schmude and Hilsenhoff 1986) permitted assignment of tolerance values for many species of these important families. Unfortunately larvae of *Cheumatopsyche* cannot be identified, and apparently relatively intolerant as well as tolerant species exist.

COLEOPTERA: Elmidae adults were observed crawling out of an artificial stream when dissolved oxygen levels become too low, so their value as indicator organisms may be questioned, but larvae probably do not react in the same manner. The genus *Stenelmis* is being revised, and several undescribed species exist. However, almost all adults, and probably larvae also, that were collected from riffles in Wisconsin streams were *S. crenata*. The tolerance value for this species is 5, and that value has been assigned to the entire genus because there is no indication that other species have significantly different tolerance values. Larvae of *Optioservus* and *Dubiraphia* cannot be identified to species so generic tolerance values are used.

DIPTERA: Identification of larvae to species is usually not possible, and sometimes even genera cannot be separated. Larvae of Simuliidae are often common, and well illustrated keys to Canadian species have been published (Wood et al. 1963, Peterson 1970), but their identification is difficult. Pigmentation of the head is variable within the same population, and pupal respiratory filaments must be dissected from mature larvae to identify some species. Furthermore, several species are complexes of genetically distinct species that cannot be separated by morphological characters as was discovered for *Simulium vittatum* (Rothfels and Featherston 1981). Fortunately many species occur on macrophytes or in deeper water and are unlikely to be collected from riffles. Efforts were also made to distinguish species groups within several genera of Chironomidae, but much more work is needed on this important family and tolerance values for Chironomidae have been assigned only to genera. Recent keys separate *Tribelos* from *Endochironomus* and *Phaenopsectra* (Simpson and Bode 1980), *Tvetenia* from *Eukiefferiella* (Bode 1983), and *Xylotopus par* from *Brillia* (Oliver 1982).

COLLECTION AND EVALUATION OF SAMPLES

Organic stream pollution is evaluated by calculating biotic index values for arthropod communities that inhabit rock or gravel riffles. Samples from pools or under the banks of streams should not be used. Arthropods that inhabit riffles are found on rocks and pebbles or in sand and gravel associated with the riffle, and especially in organic debris that

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accumulates between rocks and pebbles. In deeper streams that have no riffles, samples from rock or gravel runs may be substituted, and in sand-bottomed streams samples of debris that collects on sticks or other objects wedged into the sand in swift current may be used. Slow flowing, silt-bottomed streams presently cannot be evaluated with the biotic index. The season of the year affects the biotic index, with much higher biotic index values often being recorded during the summer months. Results from the first year of a study to develop seasonal correction factors suggest that evaluation may not be possible in the summer months, and that streams should be evaluated from samples collected in the spring before 1 June or after 1 September and before 15 October in the autumn. Samples collected from organically enriched or polluted streams tend to have distinctly higher biotic index values after mid-October and very much higher values in the summer.

In 1982 I recommended a procedure for collecting and sorting samples that involved picking 100+ live arthropods from a sample in the field and included an alternative procedure for picking samples in the laboratory. Experience since that time suggests that many more streams can be sampled in a given period of time if valuable field time is not used to pick the samples. The greatest difficulty in collecting samples for processing in the laboratory was in knowing when an adequate sample had been collected. Our experience with several hundred samples from six diverse streams suggests that when there is enough debris in the sample to fill an 8-ounce (237-ml) jar there will be enough arthropods, and such a sample takes less than 5 minutes to collect. Revised procedures for collecting, sorting, and evaluating samples with the biotic index follow.

1. Use an aquatic net to sample a site where the current is greater than 0.30 m/sec (1.0 ft/sec) and the substrate is composed of gravel, pebbles, and (or) small rocks. This should preferably be a riffle area where the substrate causes a disturbance of the water's surface. All riffle areas with a depth of at least 10 cm will have a current of at least 0.30 m/sec. In sand-bottomed streams, sample debris collected on snags in fast current. Collection of arthropods is best accomplished by placing the net against the stream bottom and disturbing the substrate immediately upstream from the net with your feet. In very fast currents avoid having the net so close to your feet that gravel and pebbles are washed into it. Avoid collecting from rooted macrophytes and filamentous algae.
2. Collect until there is enough debris in the net to fill an 8- ounce (237 ml) jar, or until it is obvious that more than 100 arthropods have been captured. Remove sticks and large undecomposed leaves from the rest of the debris, washing arthropods from them by rinsing in the net in a pool area.
3. Place the arthropods along with all debris in a labeled jar and add enough 95% ethanol to produce a concentration of about 70% when mixed with the water in the debris. Include all arthropods clinging to the net that are 3 mm long and all adult Elmidae.
4. After returning to the labortory, or if in the field for more than a day, sample jars completely filled with debris should be drained of ethanol by pouring through a screen or net with a 1.0 mm or smaller mesh. The ethanol should then be replaced with 70% ethanol. An alternative is to refrigerate the samples to allow ample time for diffusion of the ethanol throughout the debris and into the arthropods.
5. About 15 minutes before picking and sorting a sample in the laboratory, strain the ethanol from the sample and replace it with water. No arthropods should remain floating on the surface of the water.
6. Place the contents of the jar in a large, flat pan marked with a grid, add two or three additional jars full of water, and spread the contents evenly over the bottom of the pan. If the jar is completely filled with fine debris, especially filamentous algae, only half of the sample should be initially placed in the pan for sorting, with care being taken to assure that each half of the sample contains the same amount and kinds of debris. A 30 by 45-cm pan with a 5-cm grid is satisfactory. Larger pans allow the debris to be spread more thinly, making it easier to see the arthropods, but pans that are too large are unwieldy. Number the squares in the grid and select a starting square for each sample by picking a number from a box of corresponding numbers or from a table of random numbers. Remove all arthropods from the starting square and then remove arthropods from each successively

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higher numbered square. An arthropod on a line is considered to be in the square that contains its head, or in the square closest to its head. After the highest numbered square has been sampled, return to square 1. Remove and preserve at least 100 arthropods. Remove all arthropods from the last square to be picked. Do not collect Hemiptera, or Coleoptera other than Dryopoidea. Except for adult Elmidae and fifth instar Hydroptilidae larvae, which have expanded abdomens and are usually in cases, do not collect arthropods less than 3 mm long because most cannot be identified. An illuminated 5X magnifier on a long, movable arm (Luxo®) will facilitate finding and removing arthropods from the pan.

7. Preserve all arthropods in 70% ethanol for identification to genus or species in the laboratory. Isopropyl alcohol may also be used.

8. Sort and identify all arthropods to genus, except Chironomidae, which should be placed in a separate vial. When all samples have been identified to genus, species identification should be made whenever necessary and possible. This is best accomplished by working on one genus at a time and identifying species in that genus from all samples before identifying species in another genus.

9. Chironomidae are sorted to genus by placing those that look alike together. Head color, head size and shape, markings on the head, antennal length and structure, number and location of eye spots, general shape and pigmentation of the mentum, length and color of preanal papillae and setae, length of prolegs and color of their claws, and general coloration are among the characters that can be used to separate genera. Mount the two most dissimilar larvae from each group in Hoyer's medium under separate cover slips on the same slide. If both are found to be the same genus, the remainder may be assumed to be also the same and need not be mounted. If they are different, further sorting and slide mounting is needed or all must be mounted on slides. An alternative is to clear all larvae in 10% KOH and make temporary mounts in glycerine for identification.

10. Record the number of each species on a data sheet and multiply the number by the tolerance value for that species. Sum the products and divide by the total number of arthropods in the sample to obtain the biotic index for the stream. Table 1 is a general guide to the water quality of streams. Replicate samples, or both spring and fall samples, will add to the confidence of the evaluation.

Table 1. Evaluation of water quality using biotic index values of samples collected in March, April, May, September, and early October.

Biotic Index	Water Quality	Degree of Organic Pollution
0.00–3.50	Excellent	No apparent organic pollution
3.51–4.50	Very Good	Possible slight organic pollution
4.51–5.50	Good	Some organic pollution
5.51–6.50	Fair	Fairly significant organic pollution
6.51–7.50	Fairly Poor	Significant organic pollution
7.51–8.50	Poor	Very significant organic pollution
8.51–10.00	Very Poor	Severe organic pollution

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Appendix 1. Tolerance values for stream arthropods.[a]

PLECOPTERA

Acroneuria spp. 0, *Agnetina capitata* 2, *Allocapnia* spp. 3, *Alloperla* spp. 0*, *Amphinemura delosa* 3, *A. linda* 0*, *Attaneuria ruralis* 1*, *Clioperla clio* 1, *Haploperla brevis* 1, *Hastaperla* = *Haploperla, Isogenoides frontalis* 0*, *I. olivaceus* 0*, *Isoperla bilineata* 4*, *I. clio* = *Clioperla clio, I. cotta* 1, *I. dicala* 2, *I. frisoni* 0, *I. lata* 0, *I. marlynia* 4, *I. nana* 5, *I. richardsoni* 2, *I. signata* 2, *I. slossonae* 2, *I. transmarina* 0, *Leuctra ferruginea* 0*, *L. sibleyi* 0*, *L. tenella* 0*, *L. tenuis* 0*, *Nemoura trispinosa* 1, *Neoperla stewarti* 1, *Oemopteryx glacialis* 1, *Paracapnia angulata* 1*, *Paragnetina media* 1, *Perlesta placida* 5, *Perlinella drymo* 1*, *P. ephyre* 1*, *Phasganophora* = *Agnetina, Prostoia completa* 1*, *P. similis* 2*, *Pteronarcys* spp. 0, *Shipsa rotunda* 2*, *Soyedina vallicularia* 0*, *Strophopteryx fasciata* 3*, *Taeniopteryx* spp. 2.

EPHEMEROPTERA

Ameletus spp. 0*, *Arthroplea bipunctata* 5*, *Attenella attenuata* 3*, *Baetis brunneicolor* 4, *B. flavistriga* 4, *B. frondalis* 5*, *B. hageni* 5*, *B. intercalaris* 6, *B. longipalpus* 5*, *B. macdunnoughi* 5, *B. propinquus* 6*, *B. pygmaeus* 4, *B. vagans* 2, *Baetisca lacustris* 5*, *B. laurentina* 3*, *B. obesa* 5*, *Brachycercus* spp. 3*, *Caenis spp.* 7, *Callibaetis* spp. 9, *Centroptilum* spp. 2*, *Choroterpes basalis* 2*, *Cloeon alamance* 2*, *Cloeon* spp. 4*, *Dannella lita* 4*, *D. simplex* 2*, *Drunella cornutella* 0, *Epeorus vitreus* 0, *Ephemera simulans* 1, *Ephemerella aurivillii* 0*, *E. catawba* 1*, *E. dorothea* 1*, *E. excrucians* 2, *E. inermis* 1, *E. invaria* 1, *E. needhami* 2, *E. subvaria* 1, *Ephoron* spp. 2*, *Eurylophella aestiva* 5*, *E. bicolor* 1, *E. funeralis* 0*, *E. lutulenta* 6*, *E. temporalis* 5, *Habrophlebiodes americana* 6*, *Heptagenia diabasia* 3, *H. flavescens* 4*, *H. hebe* = *Leucrocuta, H. lucidipennis* = *Nixe, H. pulla* 0*, *Heterocloeon curiosum* 2*, *Hexagenia* spp. 6, *Isonychia* spp. 2, *Leptophlebia* spp. 4, *Leucrocuta hebe* 1, *Litobrancha recurvata* 6*, *Nixe lucidipennis* 2*, *Paraleptophlebia* spp. 1, *Pentagenia vittigera* 6*, *Potamanthus* spp. 4, *Pseudiron centralis* 5*, *Pseudocloeon carolina* 2, *P. dubium* 4, *P. myrsum* 3*, *P. parvulum* 4, *P. punctiventris* 5, *P.* species A 4*, *Rhithrogena* spp. 0, *Serratella deficiens* 2, *S. sordida* 2, *Siphlonurus* spp. 7, *Siphloplecton* spp. 2*, *Spinadis* sp. 5*, *Stenacron interpunctatum* 7, *Stenonema exiguum* 5, *S. femoratum* 5, *S. integrum* = *S. mexicanum, S. mediopunctatum* 3, *S. mexicanum* 4*, *S. modestum* 1, *S. pulchellum* 3, *S. terminatum* 4, *S. vicarium* 2, *Tricorythodes* spp. 4.

ODONATA

Aeshna spp. 5, *Amphiagrion saucium* 9, *Anax junius* 8*, *Argia apicalis* 8*, *A. moesta* 6, *A. tibialis* 6*, *Basiaeschna janata* 6, *Boyeria vinosa* 2, *Calopteryx aequabilis* 5, *C. maculata* 5, *Chromagrion conditum* 4*, *Coenagrion resolutum* 8*, *Cordulegaster maculatus* 3, *Didymops transversa* 4*, *Enallagma antennatum* 8, *E. civile* 9*, *E. ebrium* 9, *E. hageni* 9*, *Epitheca* spp. 7, *Gomphurus* spp. 6*, *Gomphus* spp. 5*, *Hagenius brevistylus* 1*, *Hetaerina americana* 6, *Hylogomphus brevis* 3, *Ischnura verticalis* 9, *Lestes* spp. 9, *Leucorrhinia intacta* 9*, *Libellula pulchella* 9*, *Macromia illinoiensis* 2, *Neurocordulia molesta* 5*, *N. obsoleta* 0*, *N. yamaskanensis* 0*, *Ophiogomphus* spp. 1, *Plathemis lydia* 8*, *Somatochlora* spp. 1*, *Stylogomphus albistylus* 0*, *Stylurus* spp. 4*, *Sympetrum* spp. 10*.

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TRICHOPTERA

Agapetus spp. 0, *Agarodes distinctum* 3, *Agraylea* spp. 8*, *Agrypnia* spp. 7*, *Anabolia* spp. 5, *Asynarchus montanus* 6, *Brachycentrus americanus* 1, *B. incanus* 0*, *B. lateralis* 1*, *B. numerosus* 1, *B. occidentalis* 1, *Ceraclea* spp. 3, *Ceratopsyche alhedra* 3, *C. alternans* 3, *C. bronta* 5, *C. morosa* bifida[b] 6, *C. morosa* morosa[b] 2, *C. recurvata* = *alternans, C. riola* = *alhedra, C. slossonae* 4, *C. sparna* 1, *C. walkeri* 1, *C. vexa* 3, *Cheumatopsyche* spp. 5, *Chimarra aterrima* 4, *C. feria* 1, *C. obscura* 4, *C. socia* 0, *Cyrnellus fraternus* 8*, *Diplectrona modesta* 0*, *Dolophilodes distinctus* 0, *Frenesia missa* 0*, *Glossosoma* spp. 0, *Glyphopsyche irrorata* 1*, *Goera stylata* 0*, *Helicopsyche borealis* 3, *Hesperophylax designatus* 3, *Hydatophylax argus* 2, *Hydropsyche arinale* 5, *H. betteni* 6, *H. bidens* 3, *H. cuanis* 6, *H. dicantha* 2, *H. leonardi* 0, *H. orris* 5*, *H. phalerata* 1*, *H. placoda* 3, *H. scalaris* 2, *H. simulans* 7, *Hydroptila* spp. 6, *Ironoquia* spp. 3, *Lepidostoma*, spp. 1, *Leucotrichia pictipes* 2, *Limnephilus* spp. 3, *Lype diversa* 2, *Macronema* = *Macrostemum, Macrostemum zebratum* 3, *Micrasema kluane* 1, *M. rusticum* 2, *M. wataga* 2, *Molanna* spp. 6*, *Mystacides sepulchralis* 4, *Nectopsyche* spp. 3, *Nemotaulius hostilis* 3, *Neophylax* spp. 3, *Neotrichia* spp. 2*, *Neureclipsis* spp. 7, *Nyctiophylax* spp. 5, *Ochrotrichia* spp. 4*, *Oecetis* spp. 8, *Oligostomis ocelligera* 2, *Onocosmoecus quadrinotatus* 2*, *Oxyethira* spp. 3*, *Parapsyche apicalis* 0*, *Phryganea* spp. 8*, *Phylocentropus placidus* 5*, *Platycentropus* spp. 4, *Polycentropus* spp. 6, *Potamyia flava* 5*, *Protoptila* spp. 1, *Pseudostenophylax uniformis* 0*, *Psilotreta indecisa* 0*, *Psychoglypha subborealis* 0*, *Psychomyia flavida* 2, *Ptilostomis* spp. 5, *Pycnopsyche* spp. 4, *Rhyacophila brunnea* 0*, *R. fuscula* 0*, *R. lobifera* 4*, *R. vibox* 2*, *Setodes* spp. 2, *Stactobiella* spp. 2*, *Symphitopsyche* = *Ceratopsyche, Triaenodes* spp. 6, *Wormaldia moestus* 0*.

MEGALOPTERA

Chauliodes pectinicornis 4*, *C. rastricornis* 4*, *Corydalus cornutus* 6, *Nigronia serricornis* 0, *Sialis* spp. 4.

LEPIDOPTERA

Nymphula spp. 7*, *Petrophila* (= *Paragyractis)* spp. 5, *Parapoynx* spp. 5.

COLEOPTERA

Ancyronyx variegata 6, *Dubiraphia bivittata* 8*, *D. minima* 5, *D. quadrinotata* 5, *D. vittata* 6, *Dubiraphia* larvae 6, *Ectopria* spp. 5, *Helichus lithophilus* 5*, *H. striatus* 5, *Macronychus glabratus* 4, *Microcylloepus pusillus* 3*, *Optioservus fastiditus* 4, *O. trivittatus* 2, *Optioservus* larvae 4, *Psephenus herricki* 4, *Stenelmis* spp. 5.

DIPTERA—except Chironomidae

Antocha spp. 3, *Atherix variegata* 2, *Bezzia* spp. 6, *Blepharicera tenuipes* 0*, *Chaoborus* spp. 8*, *Chrysogaster* spp. 10*, *Chrysops* spp. 6, *Cnephia dacotensis* 0*, *Culicoides* spp. 10, *Dicranota* spp. 3, Dolichopodidae 4, *Ectemnia* spp. 1*, Empididae 6, Ephydridae 6*, *Erioptera* spp. 7, *Eristalis* spp. 10*, *Eusimulium* = *Simulium, Helius* spp. 4*, *Hesperoconopa* spp. 1, *Hexatoma* spp. 2, *Limnophila* spp. 3, *Limonia* spp. 6*, *Monohelea* spp. 6*, Muscidae 6, *Nilobezzia* spp. 6*, *Palpomyia* spp. 6, *Pedicia* spp. 6*, *Pericoma* spp. 4*, *Pilaria* spp. 7, *Probezzia* spp. 6, *Prosimulium fuscum* 6*, *P. gibsoni* 6*, *P. magnum* 1*, *P. mixtum* 3, *P. mysticum* 2*, *Pseudolimnophila* spp. 2, *Psychoda*

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spp. 10, *Simulium aurium* 7*, *S. corbis* 2*, *S. croxtoni* 1*, *E. euryadminiculum* 2*, *S. fibrinflatum* 6*, *S. jenningsi* 4, *S. johannseni* 0*, *S. latipes* 2*, *S. luggeri* 5*, *S. pictipes* 4*, *S. rugglesi* 5*, *S. tuberosum* 4, *S. venustum* 5, *S. verecundum* 6, *S. vittatum*[c], *Sphaeromais longipennis* 6*, *Stegopterna mutata* 5, *Tabanus* spp. 5*, *Tipula* spp. 4.

DIPTERA— Chironomidae

Ablabesmyia spp. 8, *Acricotopus* spp. 10, *Brillia* spp. 5, *Cardiocladius* spp. 5, *Chaetocladius* spp. 6, *Chironomus* spp. 10, *Cladopelma* spp. 9*, *Cladotanytarsus* spp. 7, *Clinotanypus* spp. 8, *Conchapelopia* spp. 6, *Cordites* spp. 4*, *Corynoneura* spp. 7, *Cricotopus* spp. 7, *Cryptochironomus* spp. 8, *Cryptotendipes* spp. 6, *Demicryptochironomus* spp. 8*, *Diamesa* spp. 5, *Dicrotendipes* spp. 8, *Diplocladius* spp. 8*, *Djalmabatista* spp. 3*, *Einfeldia* spp. 9*, *Endochironomus* spp. 10, *Epoicocladius* spp. 4, *Eukiefferiella* spp. 8, *Glyptotendipes* spp. 10, *Guttipelopia* spp. 5*, *Harnischia* spp. 8, *Heterotrissocladius* spp. 0*, *Hydrobaenus* spp. 8, *Kiefferulus* spp. 10*, *Labrundinia* spp 7*, *Larsia* spp. 6, *Limnophyes* spp. 8, *Microcricotopus* spp. 5*, *Micropsectra* spp. 7, *Microtendipes* spp. 6, *Monodiamesa* spp. 7*, *Nanocladius* spp. 3, *Natarsia* spp. 8, *Nilotanypus* spp. 6, *Nilothauma* spp. 2, *Odontomesa* spp. 4, *Orthocladius* spp. 6, *Pagastia* spp. 1, *Parachironomus*, spp. 10, *Paracladopelma* spp. 7*, *Paralauterborniella* spp. 8, *Parametriochemus* spp. 5, *Paraphaenocladius* spp. 4*, *Paratanytarsus* spp. 6, *Paratendipes* spp. 8, *Pentaneura* spp. 6, *Phaenopsectra* spp. 7, *Polypedilum* spp. 6, *Potthastia* spp. 2, *Procladius* spp. 9, *Prodiamesa* spp. 3, *Psectrocladius* spp. 8*, *Psectrotanypus* spp. 10, *Pseudochironomus* spp. 5, *Pseudorthocladius* spp. 0*, *Pseudosmittia* spp. 6*, *Rheocricotopus* spp. 6, *Rheotanytarsus* spp. 6, *Saetheria* spp. 4, *Smittia* spp. 6*, *Stempellina* spp. 2, *Stempellinella* spp. 4, *Stenochironomus* spp. 5, *Stictochironomus* spp. 9, *Sympotthastia* spp. 2, *Synorthocladius* spp. 2*, *Tanypus* spp. 10, *Tanytarsus* spp. 6, *Thienemanniella* spp. 6, *Tribelos* spp. 5, *Tvetenia* spp. 5, *Xenochironomus* spp. 0*, *Xylotopus par* 2*, *Zalutschia* spp. 7*, *Zavrelimyia* spp. 8.

AMPHIPODA AND ISOPODA

Asellus intermedius 8, *A. racovitzai* 8, *Crangonyx gracilis* 8, *C. pseudogracilis* 8*, *Gammarus pseudolimnaeus* 4, *Hyallela azteca* 8.

[a]An asterisk denotes decreased reliability because collections were made in less than five of the 1979–80 study streams or because fewer than 10 individuals were collected.

[b]Although Schefter and Unzicker (1984) synonymized *Ceratopsyche bifida* with *C. morosa*, we found that larvae of both forms can be readily identified (Schmude and Hilsenhoff 1986). Since *C. morosa* morosa form occurs only in northern Wisconsin in clean streams while *C. morosa* bifida form occurs statewide and often in organically enriched streams, I recommend that both forms be identified.

[c]*Simulium vittatum* has a tolerance value of 7 *unless* three or more species with tolerance values of 2 or less make up at least 10% of the sample. Then the tolerance value is 4.

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CHANGE IN NUTRITIONAL QUALITY OF DETACHED ASPEN AND WILLOW FOLIAGE USED AS INSECT FOOD IN THE LABORATORY

William E. Miller[1]

ABSTRACT

Leaves of *Populus tremuloides* and *Salix babylonica* held in the laboratory as for feeding insects were analyzed for total nitrogen, total phenolics, and total sugars at 0, 3, and 6 days. More often than not, the three components varied due to leaf age, time since excision, or temperature. Temporal changes altered nutritional balance and probable impact on insect performance. Results suggest that other woody plant species would not remain nutritionally stable for long in the laboratory.

Although artificial diets are available for feeding many kinds of insects in the laboratory, natural foods may be used for convenience or for more purposeful reasons. Natural foods are often used as controls in the evaluation of artificial diets (Singh 1977). For herbivores, foliage-bearing branchlets with cut ends usually in water are provided for stated periods or until consumed. While the nutritional quality of fresh foliage for insects is becoming better known, the stability of detached foliage is uncertain.

Reported here are chemical analyses of foliage from detached aspen and willow branchlets held in the laboratory as for insect feeding. The components analyzed are important indicators of nutritional quality: total nitrogen, total phenolics, and total sugars. The dietary significance of these components for insects might be succinctly characterized as positive for nitrogen (Mattson 1980) and sugars (House 1974), and negative for phenolics (Levin 1971).

MATERIALS AND METHODS

Mid-crown branch tips 20–30 cm long were cut at mid-day from 4-m-tall quaking aspen (*Populus tremuloides* Michx.) at one site. Similar sized pendant branch tips reachable from the ground were cut from a mature weeping willow (*Salix babylonica* L.). Cut ends were placed immediately in distilled water, and the branchlets promptly transferred to the laboratory for assignment to treatments. Cut ends were kept in distilled water throughout treatments.

Treatments consisted of 12-h fluorescent light photophase and four temperature regimes in controlled environment chambers: (1) constant 16°C, (2) constant 20°C, (3) day-night cycling 22-10°C, and (4) day-night cycling 28-16°C. Aspen branchlets were held at the first two temperatures, and willow branchlets at the last two. At intervals of 0, 3, and 6 days, 8–12 leaves with petioles were harvested from branchlets sampled along their length. Sampled branchlets were not returned to the experiment.

Harvested leaves of each treatment were pooled in a Petri dish, and immediately stored at -15°C. The contents of each Petri dish were later freeze-dried for 45 h and ground in

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a Wiley mill to pass a 40-mesh screen. Total nitrogen was measured by a micro- Kjeldahl method, total phenolics by photocolorimetry using Folin-Denis reagent (Rosenblatt and Peluso 1941), and total sugars by high-pressure liquid chromatography.

Analyses of both species were carried out with branchlets of different ages: partly expanded leaves collected 16 May, and fully expanded leaves collected 10 June. On neither date was there noticeable natural insect or other injury to the foliage of either species. Foliage from the same sources in other years was used to feed insects in studies published (Miller 1977, Muggli and Miller 1980) and unpublished.

RESULTS

Nitrogen was the most stable component (Fig. 1). In aspen expanding (May) foliage, it ranged from 5.0 to 6.0%, apparently increasing at both temperatures at first, then leveling off. It persisted near 2.0% at both temperatures in expanded (June) foliage. In willow expanding (May) foliage, it ranged from 4.3 to 4.9%, and in expanded (June) foliage, from 3.6 to 3.8%, varying little with temperature regime.

Phenolic content was nearly stable over the treatment period (Fig. 1). In aspen expanding (May) foliage, phenolic content ranged from 6.1 to 7.2%, and in expanded (June) foliage, from 13.8 to 15.6%, where it appeared to increase at both temperatures. In willow expanding (May) foliage, it varied from 3.9 to 5.0%, and in expanded (June) foliage, from 4.7 to 7.5%. It appeared to increase in willow leaves at both temperature regimes.

Sugar content declined steadily from 15 to less than 11% in aspen expanding (May) foliage at both temperatures, and from 16 to less than 14% in expanded (June) foliage (Fig. 1). In willow foliage of both ages, sugar content increased from 16% at the lower temperature regime, then declined, and at the higher temperature regime, it changed in the opposite way.

DISCUSSION

Because this study was replicated but once, sampling variation in components is largely unknown. Results are therefore preliminary.

The large differences in total nitrogen and total phenolics between aspen expanding (May) and expanded (June) foliage (Fig. 1) conform with well known seasonal changes in these components (Mattson 1980). The lesser corresponding differences between willow expanding (May) and expanded (June) foliage are partly due to willow flushing a week or more earlier than aspen, and there being less difference in willow leaf expansion between collection dates.

No pronounced trends related to temperature emerged for nitrogen in either species. For total phenolics, there may have been more accumulation in expanding (May) leaves of both species at lower than at higher temperatures, and the opposite in expanded (June) foliage. Temperature effects for total sugars were mostly nondescript, except for the divergence-convergence sequence in willow leaves (Fig. 1).

Insects benefit in direct proportion to foliar nitrogen content (Mattson 1980). Other things being equal, an increase in total nitrogen from 5.0 to 5.5 or 6.0%, as occurred in aspen expanding (May) foliage (Fig. 1), should benefit insects measurably. However, concurrent increase in phenolics can reduce nitrogen availability to insects (Mattson 1980).

The temporal increases in phenolics (Fig. 1) are similar to those following mechanical damage to intact foliage (Rhoades 1983). Results here supplement evidence of a localized phenolic response. Few dosage-response studies of phenolics and insects are available. Those reported show that for one-compound tests, amounts from 0.2 to 0.4% in artificial diets prolonged development, reduced pupal weights, and increased mortality compared with amounts from 0.1 to 0.2% (Shaver and Lukefahr 1969). Because phenolics appear

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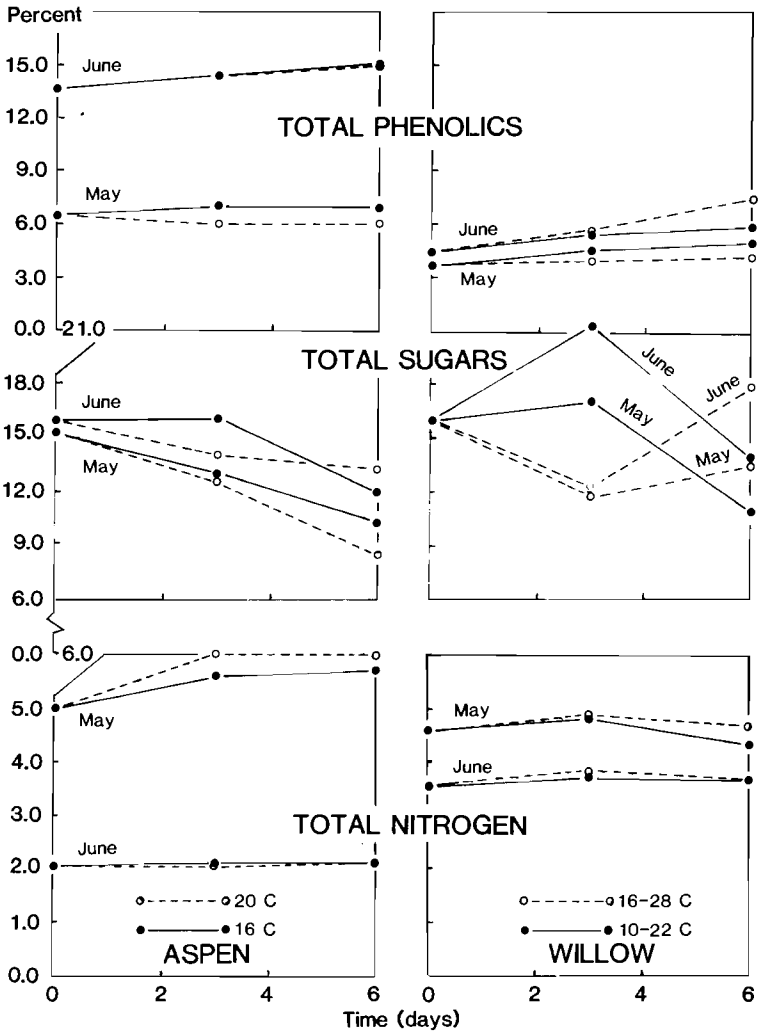

Fig. 1. Dry weight percentages of three chemical components of expanding (May) and expanded (June) aspen and willow foliage on days 0, 3, and 6 at different temperatures in the laboratory.

to act in a dosage-dependent manner, buildups as in aspen and willow expanded (June) foliage may adversely affect insect performance. However, undetermined facors like specific composition of the phenolics, and capacity of some insects to overcome their adverse effects, may be important.

Although sugars are important feeding stimulants, their temporal fluctuation in detached aspen and willow foliage (Fig. 1) lies in a nutritionally significant range.

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Different insects have different qualitative and quantitative sugar requirements and tolerances (House 1974); despite such complexities, insects investigated by Beck (1957) and Matsuoka (1965) benefited in direct proportion to sugar concentrations between threshold and inhibitory levels. For another species investigated by Harvey (1974), change in sucrose concentration from 1 to 4% in artificial diets produced female pupae 65% heavier in less time. If insects of similar constitutions consumed aspen and willow foliage at some combinations of leaf age and temperature in this study, they would encounter marked temporal changes in extractable energy.

CONCLUSION

Detached aspen and willow foliage not immediately consumed does not retain its original balance of nutritionally important components, although some components may persist at original levels under some conditions. Conditions of change in investigated components include age or degree of leaf expansion, time, and temperature. The changes in detached leaves may not differ greatly from those on intact leaves of the source plants. Overall nutritional quality cannot be estimated for detached aspen and willow foliage because not enough is known about interactive or compensatory effects of changing components for specific insects. However, to avoid unknown and unwanted variation in insect performance, investigators should discard detached foliage not consumed within a few hours.

The similarity in changes observed here between aspen and willow foliage suggests that detached foliage of other woody plant species likewise does not remain nutritionally stable for long under insect rearing conditions in the laboratory.

ACKNOWLEDGMENT

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A STUDY OF THE BIOLOGY OF *RHOPALOSIPHUM PADI* (HOMOPTERA: APHIDIDAE) IN WINTER WHEAT IN NORTHWESTERN INDIANA[1]

J. E. Araya[2], J, E. Foster[3], and S. E. Cambron [3]

ABSTRACT

Periodic collections of the bird cherry-oat aphid, *Rhopalosiphum padi*, during two years revealed small populations on winter wheat in Lafayette, Indiana. The greatest numbers were found on volunteer wheat plants before planting. In the autumn, aphids were detected on one-shoot plants by mid-October and also early March. The populations remained small until mid-June. We conclude that the aphid feeding did not significantly affect the plants, but helped spread barley yellow dwarf virus.

The bird cherry-oat aphid, *Rhopalosiphum padi* (L)., is an important insect pest of cereals, damaging the hosts both by feeding and by transmitting barley yellow dwarf virus (BYDV) (Stern 1967, Kolbe 1973). In the United States, severe epidemics of BYDV in small grains apparently occurred prior to 1951 (Anon. 1959, Bruehl 1961, Rochow 1961). The aphid has a wide range of hosts that include various species of cereals and grasses as summer hosts, and *Prunus* spp. as fall and spring hosts (Richards 1960, Robinson and Hsu 1963).

Several reports documented losses in small grains due to feeding damage, BYDV, and their combined action. For example, in Indiana yield losses were estimated at about 27.5% in oats due to infection by BYDV in 1959 (Caldwell et al. 1959), while in Mississippi, reported losses in oat yields were as high as 30–40% (Rothman et al. 1959). In Canada, seed weight losses of 60–86% occurred for spring wheats naturally infected with BYDV in 1978 (Gill 1980). Fall infections of BYDV on hard red winter wheat in Kansas caused yield reductions of 25–60%, while spring infection yield reductions were 5–35% (Palmer and Sill 1966). Similar results were obtained by Carrigan et al. (1981).

In Italy, spring barley, immediately after sprouting became infested by aphids that had previously developed on maize (Suss and Colombo 1982). In the autumn, aphids (especially *R. padi* and *Sitobion avenae* (Fabricius)) infested the basal leaf-sheaths of maize, from which they migrated to the tender shoots of well-fertilized wheat and barley when the maize plants dried up. A relationship was established between spring cereals and *R. padi* and *Metopolophium dirhodum* (Walker), which were able to transmit BYDV from maize (on which it produced no symptoms) or wild grasses and pass it on to wheat and barley.

The interaction of *R. padi* with cereals warrants the study of its biology and makes the study of its relationships with BYDV a necessity. The objectives of this research were to

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study the life cycle of *R. padi* on winter wheat in the field, in order to evaluate the feasibility of controlling alate migrant aphids (BYDV vectors) in early fall, and late spring crops.

MATERIALS AND METHODS

The number of *R. padi* on wheat was determined from weekly samples of 50 stems. These were taken randomly from four blocks with three wheat plots each, corresponding to three different wheat rotations with corn and soybeans from the USDA-ARS Integrated Pest Management Project at the Purdue University Agronomy Farm located near Lafayette, Indiana. Samples were taken throughout the year when the crop was present for two years, starting in September 1982 with volunteer wheat plants. Winter wheat seedlings were sampled during the fall of 1982, and in the same fields during spring 1983. The second season commenced October 1983 and continued through June 1984 except in midwinter.

Since many *R. padi* develop within the seedling leaf whorls, the sample plants were cut at ground level and placed in vials in 70% alcohol. The aphids per seedling or per stem in taller plants, were counted later in the laboratory. This method has proven to be effective in determining the proportions of different morphs of *S. avenae* in field studies in England by Dewar et al. (1982).

RESULTS AND DISCUSSION

The numbers of *R. padi* collected periodically on winter wheat plots during two crop cycles (1982–83 and 1983–84) appear in Figure 1. The data are expressed as the average number of nymphs, apterae, and alatae collected on 50 stems.

The wheat plots where the aphids were collected were part of a study with three different rotations including wheat, corn, and soybeans, the most common crops in Indiana. The aphids collected are representing the average number occurring in winter wheat rotated with other crops.

Aphid numbers were low during both crop years. The highest populations occurred in 1982 on volunteer wheat plants just prior to fall planting (Fig. 1). These and other graminaceous plants were important sources of aphid infestation and BYDV inoculum for wheat seedlings in October. The small seedlings are often invaded by alate aphids that are efficient vectors of the virus (Gill 1970, 1972). Even though present in small numbers, they spread the virus in the crop when it is most susceptible (Endo and Brown 1963, Smith 1967). It has been reported that a fall infection of winter wheat by BYDV is more severe than a spring infection (Palmer and Sill 1966). During a mild winter, some aphids may survive, and although normally inactive during the cold months (Forbes 1962, Harper and Blakeley 1968), they become active and start reproducing parthenogenetically earlier in spring (Dixon 1971), causing larger infestations than average.

In 1983, the first aphid nymphs were collected on 5 March, when the plants were in the one-leaf stage (stage 1 of the Feekes scale [Large 1954]) and probably were progeny of winged immigrants that had arrived earlier. The first winged individuals were collected on 20 May. The populations were relatively small until mid-June, when aphids were easily detected by sight; however, by this time the crop had flowered (stage 10.5.4 of Feekes) and most of the aphids were below the heads. It is thought that plants can withstand such infestations without any adverse effect on the yield. As the crop matured and the temperatures of summer increased, the populations declined to nearly negligible levels. The heat and drought of the summer of 1983 are believed to have been the cause of the small population available to attack wheat the following fall. The aphids were detected on 14 October 1983, on plants at the one-leaf stage, and winged immigrants were collected on 26 October. The population remained small until 8 June and reached a peak on 15 June. This increase occurred after all the heads had formed and were out of the sheath

Exhibit 12

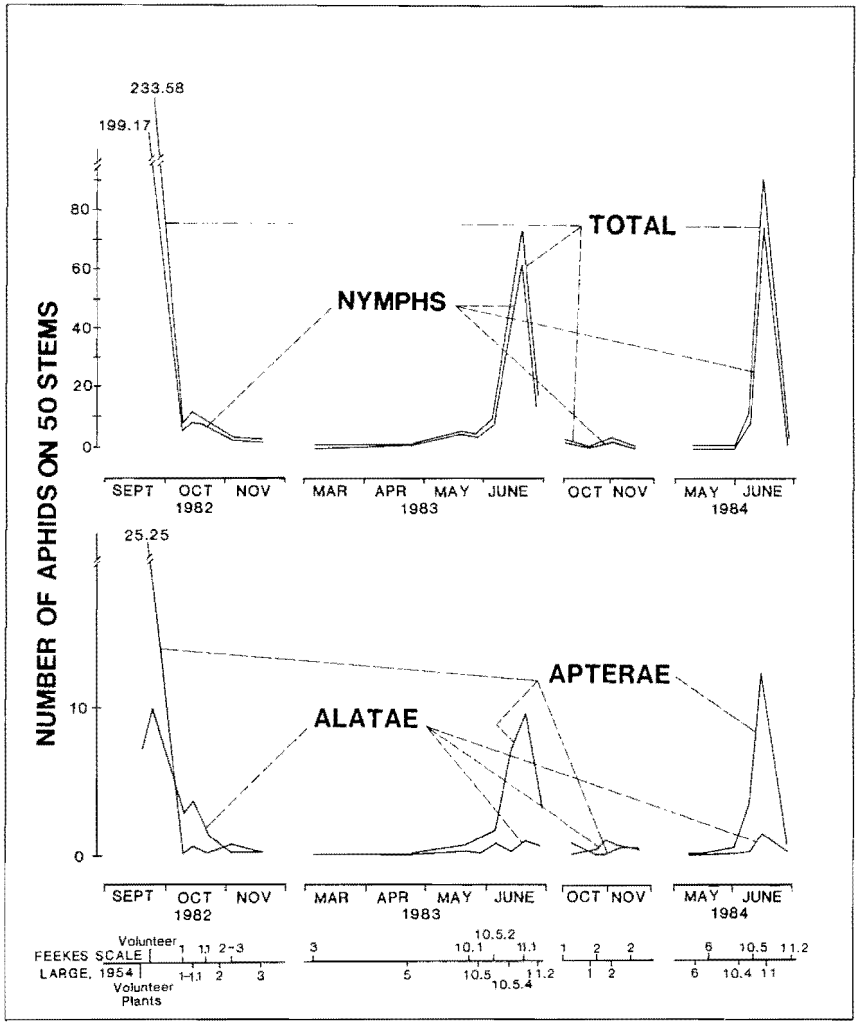

Figure 1. Numbers of ***Rhopalosiphum padi*** collected on wheat plots in the Integrated Pest management Area at the Purdue Agronomy Farm

(stage 10.5 of Feekes); the maximum number occurred during the ripening (stage 11), and was of a relatively low level. We conclude that in 1984 the crop was unaffected by direct aphid feeding.

From this study, aphids invaded winter wheat crops in the area of Lafayette, Indiana, early in the season, enabling winged immigrants to spread BYDV when the crop was most susceptible to the virus. Relatively large numbers of winged aphids such as found on volunteer wheat in September of 1982, pose a danger to wheat crops in Indiana that may

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become infected very early with BYDV. This danger may increase as minimum tillage practices gain widespread acceptance, leading to more volunteer wheat.

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Exhibit 12

ECONOMIC THRESHOLDS FOR CENTRAL EUROPEAN AND NORTH AMERICAN WHEAT INSECTS[1]

Stanley G. Wellso[2] and Theo Wetzel[3]

ABSTRACT

The economic thresholds for implementing control of 24 wheat insect pests from Central Europe and North America are discussed. Additional studies on wheat pests are necessary to better define the existing thresholds.

Wheat (*Triticum aestivum* L.) has played a major role in human economic and social development, and provided more nourishment than any other food crop (Inglett 1974). Much information has been published about the relationship of insects to losses in wheat and their control. A primary task of many entomologists is to evaluate insect damage to a crop relative to its yield and biomass loss; from these data economic thresholds can be established to reduce future losses. For wheat, however, the situation is more complex than just described because insects usually are not the sole or primary consideration causing yield reduction, and often it is difficult to correlate the economic losses directly to insect numbers and their damage. Many other factors influence wheat yield, e.g., the genetic potential of the cultivar, or cumulative environmental and biological effects during the growth and development of the plant including diseases, weeds, and mineral and water deficiencies or excesses.

Boyer (1982) suggested that U.S. wheat productivity falls far short of the potential of the crop and noted the following wheat data from the USDA (1965): record yield, 14,500 kg/ha; avg. yield, 1880 kg/ha (or 13.0% of the record yield); loss from diseases, 336 kg/ha (2.3%); insects, 134 kg/ha (0.9%); weeds, 256 kg/ha (1.8%); other unfavorable environmental conditions, 11,900 kg/ha (82.0%). The major losses in wheat are attributed to climate and soil conditions and include drought, excess water, hail, and wind. Pesticide usage in 1955 equalled 1% of the total crop value, and this had risen to 4.6% by 1968 (Neumeyer et al. 1969). About 3.8% of all insecticides used in the U.S. in 1985 were used on wheat pests (USDA 1985). This percentage is low relative to the value of the crop and is due, in part, to compensation of wheat to insect attack by tillering.

In this paper, we compare the recommended thresholds for control of wheat insects in the United States and Central Europe (primarily the German Democratic Republic). Since the climate and some pests from the two regions are similar, evaluating the differences in small grain insect control in the two regions should bring about a better understanding of economic thresholds.

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CEREAL YIELDS AND QUALITY

The world's wheat acreage is concentrated in the Northern Hemisphere with over 90% of the acreage in Eurasia and North America (Reitz 1967). Cereal losses are typically determined by the components of yield, i.e., the density of heads per unit area, the number of seeds per head ("ear" or "spike"), and the seed weight often expressed as the weight/1000 seeds. The corresponding loss percentages relative to total yield are 48% with respect to the density of the stand, 29% with respect to the seeds per spike, and 23% with respect to the weight/1000 seeds (Damisch 1970). In addition, the straw of wheat is also an important article of commerce. Cereal feeding insects may affect the quality as well as quantity of the grain. Wratten (1975, 1978) and Freier and Wetzel (1976) found a reduction of grain protein of wheat and assumed that it was probably due to nitrogen depletion by aphids feeding on the heads.

INSECT PESTS OF WHEAT

Many factors must be considered before reaching the decision that insecticides should be used to control an insect pest. The following are perhaps the most important criteria that should be considered when evaluating pest damage of a crop: (1) the stage of growth at the time of the infestation (spring or fall plants, tillering or heading); (2) the size and expected duration of the infestation; (3) the transmission of diseases or the injection of toxins that injure the crop more than nutrient removal; (4) other pests attacking the crop; (5) the vigor of the plants and their ability to tolerate or withstand attack; (6) the nature of any host plant resistance; (7) the presence of predators and parasitoids to suppress the pest; (8) the yield potential or value of the crop under present light, soil, and moisture conditions; and (9) the cost of control (the insecticide and application) relative to other expenditures already incurred during the development of the crop and relative to the future anticipated monetary return.

Many insect pests of North America were introduced unknowingly by immigrants. Since most immigrants came from Europe, it is appropriate to compare and contrast the thresholds for insect control of wheat insects of North America with European thresholds. We selected only those insects that are more important pests, although other insects are occasionally classified as pests. In addition, both areas are quite large; thus we used the most typical thresholds for both continents.

Table 1 provides information on the number of insects per unit area or plant that serve as thresholds before initiating chemical control. No specific insecticides are recommended because these vary from region to region and tend to change as new products become available. Of the 24 pest groups or species listed in Table 1, eight are from both continents, and eight are each from Europe or North America. The recommended thresholds are quite similar for the species that occur on both continents.

CEREAL LEAF BEETLES

Control measures for *Oulema* spp. are recommended when three or more eggs or larvae, or both, are present per plant, or one larva or more per flag leaf. These leaf-feeding insects often prefer to attack wheat in one or two fields in an area, and their populations then may warrant insecticidal control. In the 1960's and early 1970's, the cereal leaf beetle, *Oulema melanopus* (L.), was frequently controlled in North America with insecticides. In the 1970's, four species of Europen parasitoids were established in North America, and the need for insecticidal control was greatly reduced from 1975 to 1985. These leaf feeding insects, *Oulema* spp., are considered sporadic pests in Europe.

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Table 1. Current thresholds for control of common wheat pests in Central Europe and North America

Insect Pest	Central Europe (CE)	North America (NA)
	ROOTS	
COLEOPTERA		
Phyllophaga spp.	N/A[a]	32–43 larvae/M^2[b,c]
Agriotes spp.	2–3 larvae/0.05 × 0.15 M core causes 10% loss[d]	N/A
Melanotus spp.	N/A	Occasional pests
Eleodes spp.	N/A	do.
HOMOPTERA		
Rhopalosiphum insertum (Walker)	Occasional pests	N/A
	STEMS AND BLADES	
ORTHOPTERA		
Grasshoppers	N/A	8/M^2 on small plants[e]
LEPIDOPTERA		
Pseudaletia unipunctata (Haworth)	N/A	4/0.3M of row[e]
COLEOPTERA		
Zabrus tenebroides Goeze	1–2 larvae/M^2 in autumn[f]	N/A
Oulema melanopus (L.)	1 or more eggs or larvae/flag leaf[f]	3 eggs or larvae/plant or 1 or more larvae/flag leaf[e]
Oulema lichinis (Voet)	1 or more eggs or larvae/flag leaf[f]	N/A
HEMIPTERA		
Blissus leucopterus Say	N/A	Occasional pest
HOMOPTERA		
Schizaphis graminum Rondani	15–25 aphids/plant between flowering and milk stage[g]	10–15 cm, 50 aphids/plant[h] 15–25 cm, 200 do. 46–51 cm, 300 do. > 76 cm, 800 do.
Sitobion avenae (Fabricius)	do.	Occasional Pest
Rhopalosiphum maidis Fitch	do.	do.
Rhopalosiphum padi (L.)	do.	do.
Sitobion fragariae (Walker)	do.	do.
Metropolophium dirhodum (Walker)	do.	N/A
DIPTERA		
Delia coarctata (Fallen)	125 larvae/M^2 in soil Jan.–Mar.[i] 60–90 eggs/M^2 in soil Sept.[f]	N/A
Mayetiola destructor (Say)	1–6 larvae/plant[f]	20% stems infested[j]
HYMENOPTERA		
Cephus pygamaeus (L.)	30 larvae/M^2 in stubble (indicator for popln. next year)[f]	Occasional pest
Cephus cinctus Norton	N/A	70% tunneling – 10% loss in grain[g]
	HEADS	
HOMOPTERA		
Sitobion avenae (Fabricus)	3–5 larvae/head at flowering and 60–80% infestation[f]	Occasional pest
DIPTERA		
Sitodiplosis mosellana (Gehin)	1 ♀/3 heads just before flowering (ca. 13 larvae/head)[k]	1 ♀/head at flowering[k]
Contarina tritici (Kirby)	1 ♀/head at start of flowering[f]	N/A
Haplodiplosis equestris (Wagner)	5 larvae on culm on internode below the head (13% loss)	N/A
Meromyza americana Fitch	N/A	Control when infestation > 15%[m]

[a]N/A = not applicable
[b]Painter et al. (1954)(NA)
[c]Coppock et al. (1984)(NA)
[d]Griffiths et al. (1967)(CE)
[e]Ruppel and Bird (1981)(NA)
[f]Wetzel and Freier (1981)(NA)
[g]Bonnemaison (1980)(CE)
[h]Daniels (1962)(NA)
[i]Maskell and Gair (1961)(CE)
[j]Hill et al. (1943)(NA)
[k]Basedow and Schutte (1973)(CE,NA)
[l]Nijveldt and Hulshoff (1968)(CE)
[m]Kieckhefer and Morrill (1970)(NA)

Exhibit 12

CEREAL APHIDS

Rabbinge and Coster (1984) noted that cereal aphids cause direct yield loss through assimilate consumption and changes in the nitrogen balance, and indirect yield loss through honeydew excretion affecting photosynthesis, senescence, and pythotropic fungi. In addition, their ability to transmit various cereal diseases must always be considered when evaluating the need for control.

Aphid control recommendations are more variable, with insecticidal control being implemented when aphid numbers per plant in Europe are 15–25 near flowering or in the milk stage. The guidelines for aphid control in North America typically use crop height while Europeans use host maturity, and both use number of aphids per plant or linear foot of row. Although the current recommendations are not species specific, greenbugs, *Schizaphis graminum* (Rondani), whose saliva is much more phytotoxic than the saliva of the other aphids listed in Table 1, usually cause more cereal damage (Wadley 1929). Cramer (1967), summarizing statistics for 1965 from the USDA (1965), listed the greenbug as causing more wheat yield loss (23.3%) than any other insect. Coppock et al. (1984) noted that parasitoids occasionally attack enough greenbugs in the field to reduce infestations below economic levels, and that mummified greenbugs can be used to evaluate the presence of the parasitoid. In Europe the English grain aphid, *Sitobion avenae* (Fabricius), requires control on wheat heads; in North America other aphids attack small grains, but generally only greenbugs require control. In general, economic thresholds are less precise for aphids than many other insects because of the low correlation between aphid numbers and yield loss (Rabbinge and Mantel 1981). Although the transmission of diseases by insect vectors has not been mentioned specifically, some aphids may become more mobile after receiving sublethal or slow killing insecticides (Broadbent 1969). The aphids may move more frequently from plant to plant feeding on many more plants, thus innoculating them with viruses that are transmitted mechanically on their stylets in less than 1 min. of feeding time, in contrast to the less mobile untreated insects. Fortunately, the most important insect-transmitted disease of wheat, barley yellow dwarf, is not transmitted as rapidly, and insecticidal control may be helpful, but a definitive study on barley yellow dwarf transmission is still pending. The situation becomes more complex when one notes that the barley yellow dwarf viruses (or strains) exhibit varying degrees of specificity among grass feeding aphids (Sylvester 1980).

HESSIAN FLY

The Hessian fly, *Mayetiola destructor* (Say), of European origin, is not a major pest there, but is a very serious wheat pest in North America. Insecticidal control is typically not used, but control is warranted where the percentage of stems infested is about 20% (Hill et al, 1943). The use of resistant varieties in combination with the fly-free date are the principal control methods. The causative biotype is identified based on its survival on wheats having different genes for resistance, and the proper resistance is incorporated into commercial varieties by plant breeders to suppress the infesting biotype(s). In 1974, 16 million acres in North America were planted with Hessian fly resistant varieties (Gallun 1977).

WHEAT BLOSSOM MIDGES

The orange wheat blossom midge, *Sitodiplosis mosellana* (Gehin), was not considered a major pest on either continent until 1983, when a $30 million loss to spring wheat occurred in northeast Saskatchewan, Canada (Olfert et al. 1985). They found that one, two, three, or four larvae per kernel resulted in an infestation level of 38, 58, 78, and 96%, respectively. In addition, infestations of 30, 60, and 90% reduced spring wheat yields by 40, 65, and 79%, respectively. Usually fewer than 10 larvae are present per

Exhibit 12

wheat head (ear), and seed weight may be significantly different between infested and noninfested heads. Although the midge is not dependent upon the presence of glume blotch, *Septoria nodorum* (Berk.) Berk., to attack, Wellso and Freed (1982) found that a positive association exists between the insect and glume blotch with more larvae present in those heads infected with glume blotch. In Europe, the lemon wheat blossom midge, *Contarinia tritici* (Kirby), appears to be more abundant than the orange wheat blossom midge, and its larvae feed on the wheat flower, killing the stigma and preventing pollination and grain development. Control in Europe is recommended when one or more adults are present per ear (head) when sampled throughout the field.

WHEAT STEM SAWFLIES

The European wheat stem sawfly, *Cephus pygmaeus* (L.), attacks spring wheats more than winter wheats and is a more important pest in Europe than North America. In North America, it is found only in northeastern United States and adjacent Canada, while its European distribution is greater. Another species, the wheat stem sawfly, *Cephus cinctus* Norton, is economically more important in North America as it attacks wheat west of the Mississippi River, primarily in North Dakota, Montana, and western Canada. Solid stemmed cereals are resistant to *C. cinctus* and deter oviposition and larval development. Insectidical control has not been very successful, and burning the straw and deep plowing have helped reduce sawfly populations (Bonnemaison 1980).

OTHER WHEAT PESTS

The other pests listed are from either Europe or North America, and, even within these areas, may be economically detrimental in only part of the wheat growing area. In some years, grasshoppers in North America may be very important pests, especially west of the Mississippi River. They are more important in years that are drier than average, as egg hatch is often reduced in moist years by soil-inhabiting fungi. Grasshoppers require control when 6–12 nymphs/m^2 are present. Various cutworm species and the armyworm, *Pseudoaletia unipuncta* (Haworth), may be important pests occasionally. The cyclic nature of these pests in the past seems to be related to favorable environmental conditions. With greater emphasis on minimum tillage practice, these insects may become more important economic pests. Chinch bugs, *Blissus leucopterus* Say, are only an occasional pest on small grains in Kansas and adjacent states. This insect may develop in wheat or grasses, stunting some plants or causing them them to die in small areas. This insect may become a serious pest to corn and sorghum after the wheat is harvested. The wheat stem maggot, *Meromyza americana* Fitch, damages spring wheat more than other cereals with losses ranging from a maximum of 9% with averages of 1–3% in South Dakota (Kieckhefer and Morrill 1970). The larvae feed within the culm and may cause the heads to die. Wireworms, including *Melanotus* sp., *Eleodes* sp., and *Agriotes* sp. may live in the soil from 2 to 6 years with the remaining larvae moving very far from the oviposition site. They feed on the wheat roots and may cause spotty damage in the field. Like armyworms and cutworms, these insects may become more abundant under minimum tillage practices. June beetles, *Phyllophaga* spp., like wireworms, may occasionally damage the roots of cereals.

Wheat bulb fly, *Delia coarctata* (Fallen), larvae move through the soil in Eurasian cereal fields and penetrate the underground stem (crown). The larvae move upward through the culms and feed upon the terminal buds, and may cause as much as 10% crop loss (ABMAC 1965).

We have described and compared the major damage to wheat by Central European and North American insect pests. Most entomologists agree that the current recommended thresholds need to be improved and that this will occur only after we better understand the insect-plant interactions. Since environmental stresses cause the major losses, the

Exhibit 12

relationship of insects, weeds, and diseases to each other and during these various stresses must be more clearly defined relative to crop loss. We are improving our biological and environmental monitoring and sampling, and this, together with a better understanding of the tolerance of plants to withstand insect attack, will bring about a better understanding of yield losses.

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INFORMATION FOR AUTHORS

Papers dealing with any aspect of entomology will be considered for publication in *The Great Lakes Entomologist*. Appropriate subjects are those of interest to amateur and professional entomologists in North Central States and Canada, as well as general papers and revisions directed to a larger audience while retaining an interest to readers in our geographical area.

Manuscripts must be typed, double-spaced, with wide margins on white 8-1/2 × 11″ or equivalent size paper, and submitted in *duplicate*. Footnotes, legends, and captions of illustrations should be typed on separate sheets of paper. Titles should be concise, identifying the order and family discussed. The author of each species mentioned must be given fully at least once in the text. A common name for each species or group should be given at least once when such a name exists. The format of references should follow that used in recent issues. Photographs should be glossy. Drawings, charts, graphs, and maps must be scaled to permit proper reduction without loss of detail. Contributors should follow recommendations of the *Council of Biology Editors Style Manual*, 5th ed.

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Authors will receive page proofs, together with an order blank for separates.

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Exhibit 12

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MEMO

To:
Western Energy Company

Copies:

From:
Penny Hunter, ARCADIS
Jason Vogel, ARCADIS

Date:
December, 2014

ARCADIS Project No.:
CO001837.00001

Subject:
Western Energy - Rosebud
Aquatic Survey Assessment

---

1. INTRODUCTION

The following letter report describes the results of the aquatic habitat assessment and benthic community survey work performed by ARCADIS on October 9, 2014 within the East Fork Armells Creek (EFAC).

2. SAMPLE LOCATIONS

Aquatic surveys within EFAC were conducted to support existing permitting efforts for surface water discharges, per recent comments received by Montana Department of Environmental Quality (MDEQ). These recent comments included a June 3rd, 2014 MDEQ letter to Western Energy Company (WEC) stating that their application for Permit ID C1984003B Amendment AM4 was deficient and that WEC needed to "confirm, based on current and future anticipated concentrations in the stream, that uses have not or will not be impaired (MDEQ 2014)." In addition, MDEQ requested that WEC "conduct a current aquatic survey along stretches of East Fork Armells Creek (EFAC) adjacent to the Rosebud Mine permit areas (Areas A, B, and C) to identify assemblages of aquatic life using the stream habitat." MDEQ states the data collected from the aquatic survey will be used for future permit revisions in Area A and Area C.

Prior to conducting the aquatic survey, two ARCADIS scientists performed a reconnaissance along the stretch of EFAC adjacent to the Rosebud Mine permit areas (Areas A, B, and C) on October 9, 2014. The reconnaissance was performed to confirm existing drainage conditions (i.e., wetted extents and potential

Exhibit 11

habitat types) that would be representative of the current EFAC aquatic community. Based on the largely homogeneous aquatic habitat observed, consisting of primarily low-gradient drainage with minimal flow, heavy siltation, and riparian and emergent wetlands, two representative locations were selected to survey the current benthic community. The attached Figure 1 indicates the locations of EFAC1 and EFAC2. Location EFAC1 is positioned lower in the EFAC drainage. Compared to more upstream stretches, EFAC1was less impounded, had more visible flow sections and a higher degree of meander and sinuosity patterns in the drainage. This location had an established riparian zone with herbaceous, shrub, and tree vegetation layers, and some in-channel woody debris. Location EFAC2 is found in the middle portion of the EFAC drainage and near the upper extent of the wetted conditions observed during the reconnaissance. EFAC2 represents a low-gradient drainage. Compared to EFAC1, this location had a minimally developed flowing channel, relatively wider and more impounded wetted channel, and less meander and sinuosity. The riparian zone contained emergent vegetation.

3. SURVEY METHODS

Benthic macroinvertebrates were surveyed on October 9, 2014. Survey protocols and taxonomic identification of the benthic community organisms followed both MDEQ's sampling and analysis protocols *Sample Collection, Sorting, Taxonomic Identification, and Analysis of Benthic Macroinvertebrate Communities Standard Operating Procedure* (MDEQ SOP) (MDEQ 2012) and USEPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (RBP) (Barbour et al. 1999). The MDEQ SOP details a semi-quantitative reach wide sampling technique to collect samples from a known area, which allows the estimation of population density, in addition to diversity and abundance. This sampling technique includes the use of a d-frame net at a total of 11 transects within a sampling reach to be collected as kick samples working downstream to upstream. Barbour et al. (1999) recommends either 40 times the wetted stream width or a representative 100 meter reach (as a minimum for smaller-sized streams) for sampling. Based on drainage conditions, an approximate 100 meter reach was established at each benthic community survey location. Following RBP methodologies, general aquatic habitat conditions were detailed to include measurements of water quality parameters and physical characterization of riparian vegetation, instream features, presence of aquatic vegetation and large woody debris, and sediment and substrate components.

Based on existing habitat observed, the number of transects to provide a representative benthic community sample was reduced down from 11 to 8. Based on professional judgment, the MDEQ SOP methodology and its applicability to these low gradient survey reaches was compromised by the lack of riffles, exposed inorganic substrate, and the largely homogeneous habitat observed within each of the survey reaches. The individual area (1 ft^2 – 0.093 m^2) sampled within each survey reach was increased slightly (1.3 ft^2 – 0.12 m^2) to account for the difference and to obtain a representative 1 m^2 area sampled for the reach. Benthic organism abundance was noted throughout the collection process and available habitats were sampled to provide the representation of the existing community. For EFAC1, this included kick net samples, sweeps of emergent vegetation, and hand-picking and rinsing of functional large woody

debris. For EFAC2, the primary habitat was emergent vegetation and exposed root mats of emergent vegetation within a limited free-flowing narrow channel, which was sampled primarily by sweeping emergent vegetation and kicking substrate and root mat and detritus into kick net.

A representative area (approximately a 1.3 ft^2 quadrat) was selected along each transect to collect each of the kick samples. In an area of flow, the kick sample was collected within the representative area, by using hands with a hand trowel or by feet to disturb the area and wash and large rocks, sticks, or debris into the net for a period of 30 seconds. For slackwater habitats with emergent vegetation, the kick net was swept through the vegetation for 30 seconds within the representative area. All individual kick net samples were composited into a 5 gallon bucket and then elutriated to remove large debris. Contents were sieved using a standard #35 (500 micron) mesh size and then transferred to a wide-mouthed plastic sample jar. Samples were preserved with 90% isopropyl alcohol, and sent to Normandeau Environmental Consultants (Normandeau) in Stowe, Pennsylvania, for taxonomic identification. Normandeau taxonomic identification and community sample processing followed by MDEQ protocols to subsample an approximate 500 ± 10% organisms.

Water quality parameters were collected using a YSI 556 multimeter and a Hach 2100P turbidity meter at representative locations within EFAC1 and EFAC2.

4. RESULTS

The aquatic conditions of EFAC are indicative of low-gradient streams, with influences from a mixture of water origins (seasonal runoff, groundwater), and supportive of a tolerant benthic community. Existing habitat is characterized by heavy siltation, low flow, and high amount of organic substrates, with prevalent emergent vegetation along riparian zones.

Table 1 provides a summary of the temperature, specific conductance, dissolved oxygen, pH and turbidity measured at each location. Table 2 summarizes the main physical characteristics and substrate observations for both EFAC1 and EFAC2. Attachment 1 includes observations included during the RBP assessment of aquatic habitat and a set of photographs detailing the habitats surveyed at EFAC1 and EFAC2.

Table 3 provides the results of the taxonomic identification for the EFAC1 and EFAC2 benthic community samples. Community diversity and abundance was similar between the two locations, with a total of 25 and 26 taxa identified at EFAC1 and EFAC2, respectively. Communities were represented by eight orders of aquatic organisms, including aquatic worms, snails, amphipods, mayflies, damselflies, caddisflies, beetles, midges, and fly larvae. Within EFAC1, the side swimmer amphipod within the genus of *Hyalella* was the most dominant benthic organism observed. Within EFAC2, the non-biting midge within the genus of *Paramerina* was the most dominant benthic organism observed. For both locations, mainly tolerant Dipteran taxa comprised over 50% of the community, with *Hyalella* following closely at nearly 25% and

above within the community. Based on the MDEQ protocols, a community indicator metric (Hilsenhoff Biotic Index [HBI]) was calculated using Montana-specific tolerance values for identified taxa. The HBI metric represents the relative sensitivity of the sample to nutrient perturbation. The HBI, based on 2005 operable Taxonomic Units (taxonomic endpoints) found in Appendix A of the MDEQ SOP, was calculated for both locations (6.98, 7.90), and indicates “fairly poor” to “poor” conditions (Hilsenhoff 1987).

In summary, the aquatic habitat assessment and benthic community survey was conducted in general accordance with RBPs and MDEQ SOP protocols to satisfy the current deficiency letter and to support the potential for future permitting within existing areas A, B, C within the EFAC.

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Attachments

Figure 1 – Aquatic Habitat Assessment and Benthic Community Survey Locations

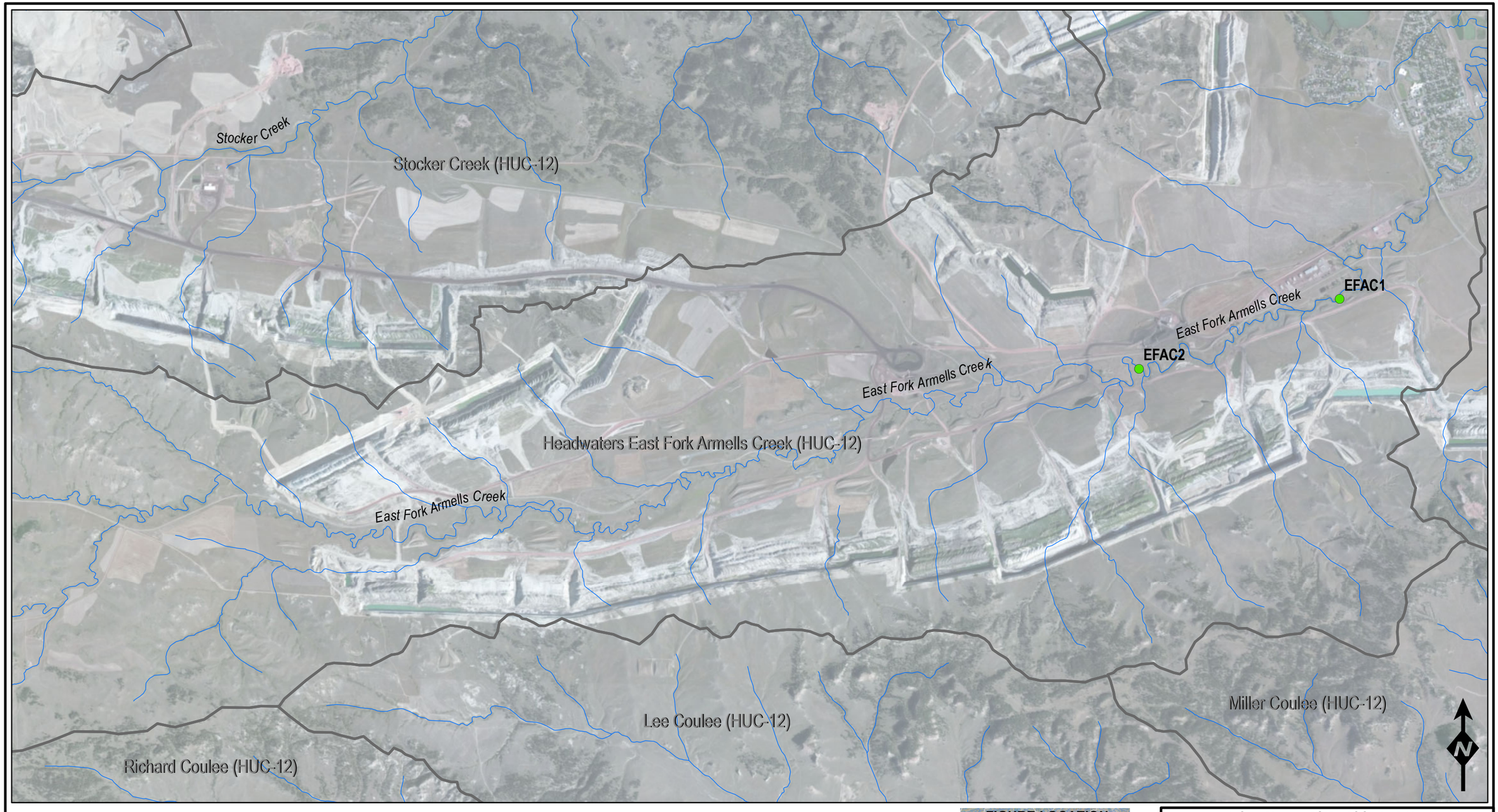
Table 1 – Water Quality Parameters for East Fork Armells Creek

Table 2 – Physical Characterization and Substrate Summary for East Fork Armells Creek

Table 3 – Benthic Community Samples for East Fork Armells Creek

Attachment 1 – Photolog

FIGURE AND TABLES



Aquatic Habitat Assessment and Benthic Community Survey Location

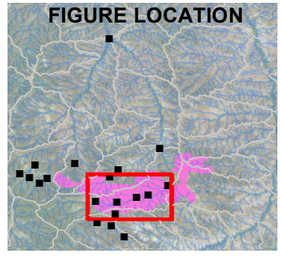
- Benthic Community Survey
- USGS NHD Streams
- Watershed Boundaries (HUC12)

0 2,000 4,000 Feet

GRAPHIC SCALE

Notes:
Projection: UTM Zone 13 NAD83
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

FIGURE LOCATION



WESTERN ENERGY - ROSEBUD MINE
COLSTRIP, MONTANA

AQUATIC HABITAT ASSESSMENT AND BENTHIC COMMUNITY SURVEY

EAST FORK ARMELLS CREEK AREA

ARCADIS

FIGURE 1

Document Path: Z:\GISPROJECTS_ENV\Western_Energy_Rosebud\MXD\2014\WE_Rosebud Benthic Community Assessment 0001.mxd

Exhibit 11

Table 1. Water Quality Parameters for East Fork Armells Creek (Rosebud, MT)

Parameter	EFAC1	EFAC2
Temperature (°C)	16.9	12.9
Specific Conductance (mS/cm)	2.5	2.4
Dissolved Oxygen (mg/L)	9.90	3.52
pH (std units)	8.8	8.4
Turbidity (NTU)	2.49	25.4

Notes:
°C = degress Celsius
mS/cm = milliSiemens per centimeter
mg/L = milligrams per liter
NTU = Nephelometric Turbidity Units

Exhibit 11

Table 2. Physical Characterization and Substrate Summary for East Fork Armells Creek (Rosebud, MT)

Parameter	EFAC1	EFAC2
Reach Length (m)	100	100
Average Wetted Width (m)	1.9	5.3
Average Stream Depth (in)	5.4	4.5
Average Stream Velocity (ft/sec)	0.22	0.078
Large Woody Debris (m^2)	40	0
Aquatic Vegetation (%)	60	90
Detritus (%)	75	60
Muck-Mud (%)	25	40
Inorganic Substrate Type (Dominant, %)	100% Silt	100% Silt

Notes:
m = meter
in = inch
ft/sec = feet per secon
m^2 = square meter

Table 3. Benthic Community Samples for East Fork Armells Creek (Rosebud, MT)

Sample Date: October 9, 2014
Gear: Kick Net (Montana DEQ: 500-specimen sub-sample)

Taxon	Tol.*	Common name	EFAC1 Number	EFAC1 Percent	EFAC2 Number	EFAC2 Percent
Nematoda	5	round worm			2	0.4%
Haplotaxida						
Enchytraeidae	4	earth worm	2	0.4%		
Tubificinae						
Ilyodrilus	10	tube worm			3	0.5%
Limnodrilus	10	tube worm	1	0.2%	1	0.2%
Basommatophora						
Lymnaeidae						
Fossaria	6	pond snail	15	3.1%		
Physidae						
Physa/Physella	8	pouch snail	6	1.2%	22	4.0%
Amphipoda						
Hyalellidae						
Hyalella	8	side swimmer	187	38.6%	134	24.4%
Ephemeroptera						
Baetide						
Callibaetis	9	mayfly	1	0.2%	4	0.7%
Odonata						
Coenagrionidae	7	damselfly	11	2.3%	16	2.9%
Argia	7	damselfly			25	4.5%
Trichoptera						
Limnephilidae	3	caddisfly			2	0.4%
Coleoptera						
Dytiscidae						
Agabus	5	diving beetle	7	1.4%		
Hydroporini	5	diving beetle			1	0.2%
Diptera						
Chironomidae						
Alotanypus	-	midge			4	0.7%
Apsectrotanypus	8	midge	42	8.7%	18	3.3%
Chironomus	10	midge			1	0.2%
Diplocladius	5	midge	11	2.3%		
Heterotrissocladius	0	midge			7	1.3%
Micropsectra	4	midge	63	13.0%	6	1.1%
Natarsia	-	midge			4	0.7%
Orthocladiinae	10	midge	5	1.0%		
Paramerina	-	midge	25	5.2%	211	38.4%
Parametriocnemus	5	midge			3	0.5%
Paratendipes	10	midge	2	0.4%	4	0.7%
Tanypodinae	-	midge	4	0.8%	42	7.6%
Tanytarsus	6	midge	59	12.2%	1	0.2%
Thienemannimyia gr.	-	midge	16	3.3%		
Other Diptera						
Ceratopogonidae						
Atrichopogon	6	sand fly			1	0.2%
Culicoides	10	sand fly	8	1.7%	28	5.1%
Dasyhelea	6	sand fly	1	0.2%	1	0.2%
Palpomyia gr.	6	sand fly	5	1.0%	8	1.5%
Probezzia	6	sand fly	7	1.4%		

Table 3. Benthic Community Samples for East Fork Armells Creek (Rosebud, MT)

Sample Date: October 9, 2014
Gear: Kick Net (Montana DEQ: 500-specimen sub-sample)

Taxon	Tol.*	Common name	EFAC1 Number	EFAC1 Percent	EFAC2 Number	EFAC2 Percent
Other Diptera (continued)						
Empididae						
Chelifera	5	dance fly	1	0.2%		
Ephydridae	6	shore fly			1	0.2%
Simuliidae						
Simulium	5	black fly	3	0.6%		
Tipulidae						
Limnophila	3	crane fly	1	0.2%		
Ormosia	6	crane fly	1	0.2%		
Total Individuals			484	100.0%	550	100.0%
Total Taxa			**25**		**26**	
Hilsenhoff Biotic Index			**6.98**		**7.90**	
(water quality rating: from Hilsenhoff, 1987)			(fairly poor)		(poor)	

Reference:*

Tol = Tolerance values as found in Appendix A of:

Montana Department of Environmental Quality (MT DEQ). 2012. Sample Collection, Sorting, Taxonomic Identification, and Analysis of Benthic Macroinvertebrate Communities Standard Operating Procedure. MT DEQ, WQPBWQM - 009

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ATTACHMENT 1

Exhibit 11

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PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No.	Date:
1344	10/9/14

Direction Photo Taken:

Facing northwest

Description:

Wetland area on EFAC approximately 0.4 stream miles downstream of EFAC1 survey location. Standing water present.

Lat: 45.869200
Long: -106.63763

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No.	Date:
1345	10/9/14

Direction Photo Taken:

Facing southeast

Description:

Wetland area on EFAC approximately 0.4 stream miles downstream of EFAC1 survey location. Standing water extends under Castle Rock Road through culvert.

Lat: 45.868820
Long: -106.637500

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1348

Date: 10/9/14

Direction Photo Taken:

Facing northwest

Description:

Wetland area on EFAC approximately 0.8 stream miles downstream of EFAC2 survey location. Proximate to intersection of EFAC, Castle Rock Road, and haul road.

Lat: 45.861580
Long: -106.652240

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1349

Date: 10/9/14

Direction Photo Taken:

Facing northwest

Description:

Wetland area on EFAC approximately 0.5 stream miles downstream of EFAC2 survey location. Castle Rock Road in distance

Lat: 45.860400
Long: -106.656270

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No.	Date:
1351	10/9/14

Direction Photo Taken:

Facing west

Description:

Upstream extent of EFAC wetland area. Standing water present. Approximately 0.2 stream miles upstream of EFAC2 survey location. Dry conditions observed continuing upstream.

Lat: 45.859860
Long: -106.664020

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No.	Date:
1352	10/9/14

Direction Photo Taken:

Facing southwest

Description:

Dry channel approximately 0.75 stream miles upstream of EFAC2 survey location. Castle Rock Road observed on right edge of photo.

Lat: 45.859930
Long: -106.670680

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1353

Date: 10/9/14

Direction Photo Taken:

Facing northwest

Description:

Dry channel approximately 1.1 stream miles upstream of EFAC2 survey location. Castle Rock Road observed n upper right of photo.

Lat: 45.857170
Long: -106.675190

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1354

Date: 10/9/14

Direction Photo Taken:

Facing northeast

Description:

Dry channel approximately 2.3 stream miles upstream of EFAC2 survey location.

Lat: 45.854550
Long: -106.686500

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1355

Date: 10/9/14

Direction Photo Taken:

Facing downward into water

Description:

Downstream extent of EFAC1 at EFAC1-1 transect. Kicksweep area. Substreate consists of detritus and much/mud. Principally silt.

Lat: 45.86633
Long: -106.63821

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 2356

Date: 10/9/14

Direction Photo Taken:

Facing southwest - upstream

Description:

Near to downstream extent of EFAC1 at EFAC1-2 transect. Kicksweep area. Substreate consists of detritus and muck/mud. Principally silt. Woody debris present.

Lat: 45.86628
Long: -106.63821

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1360

Date: 10/9/14

Direction Photo Taken:

Facing northeast - downstream

Description:

Near to midstream extent of EFAC1 at EFAC-1-6. Sample collected from sweeping of watercress. Silt streambed material. Emergent vegetation, woody debris, and coarse plant material.

Lat: 45.86595
Long: -106.63861

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1362

Date: 10/9/14

Direction Photo Taken:

Facing west - downstream

Description:

Upstream extent of EFAC1 at EFAC-1-8. Kick area. Silt streambed material. Emergent vegetation, woody debris, and coarse plant material.

Lat: 45.86581
Long: -106.63855

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1363

Date: 10/9/14

Direction Photo Taken:

Facing northwest - upstream

Description:

Downstream extent of EFAC2 at EFAC2-1 transect. Shows extent of survey area. Decaying root matt. Silty/fine/muck and mud bed. Sedges present in area.

Lat: 45.85940
Long: -106.66233

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 3364

Date: 10/9/14

Direction Photo Taken:

Facing southeast - downstream

Description:

Downstream extent of EFAC2 at EFAC2-1 transect. Shows downstream of survey area. Sedges in foreground and cattails in background downstream.

Lat: 45.85940
Long: -106.66233

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1370

Date: 10/9/14

Direction Photo Taken:

Facing northwest - upstream

Description:

Near to upstream extent of EFAC2 at EFAC-2-7 transect. Open water and decaying sedges. Cattails in area. Silt bottom and iron oxide sheen present.

Lat: 45.85970
Long: -106.66307

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1372

Date: 10/9/14

Direction Photo Taken:

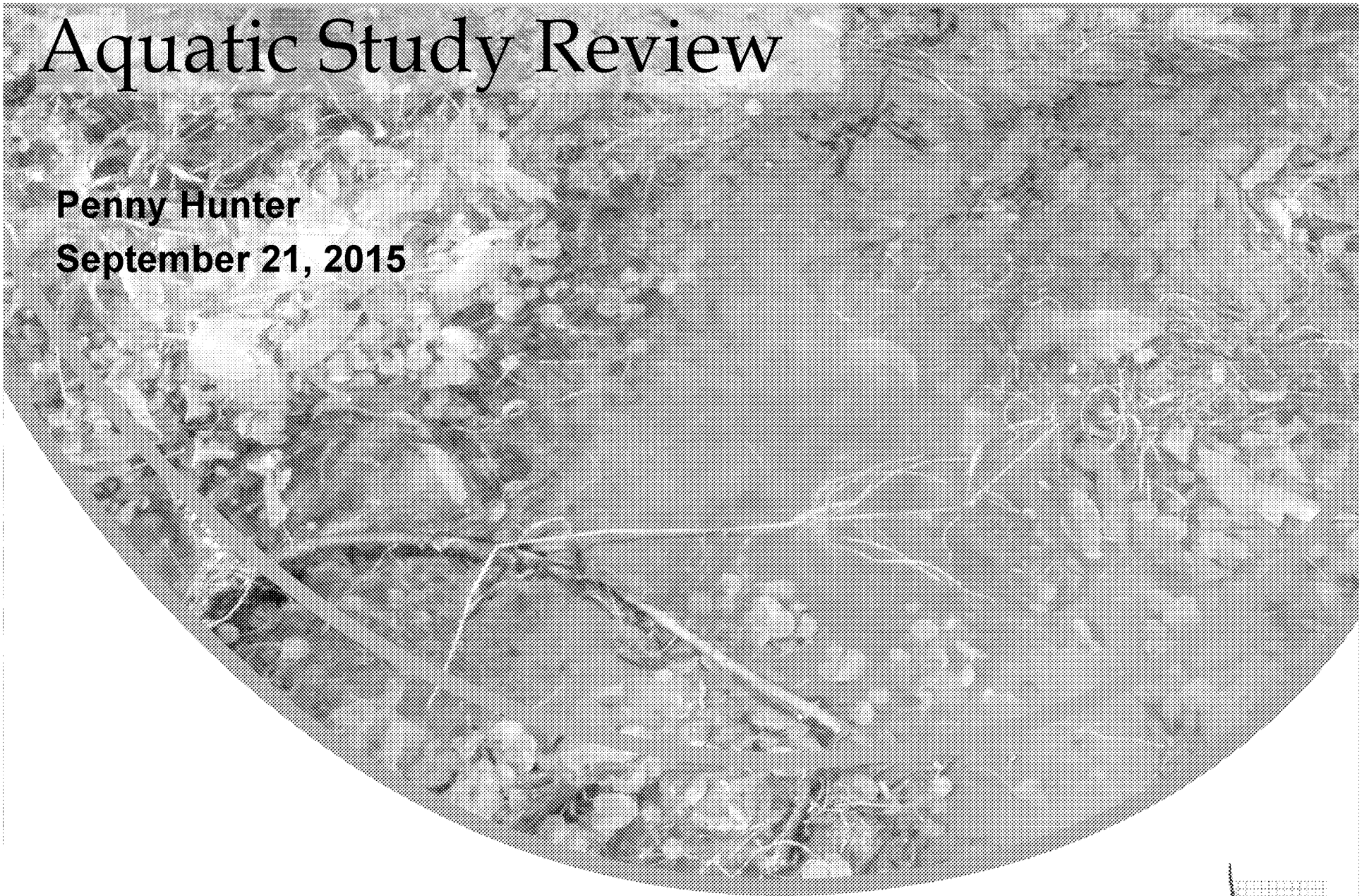
Facing southeast - downstream

Description:

Upstream extent of EFAC2 at EFAC-2-8 transect. Upstream of cattail os photo 1370. Silty bed. Decaying sedges and root matt.

Lat: 45.85976
Long: -106.66317

Aquatic Study Review



Penny Hunter

September 21, 2015

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Agenda

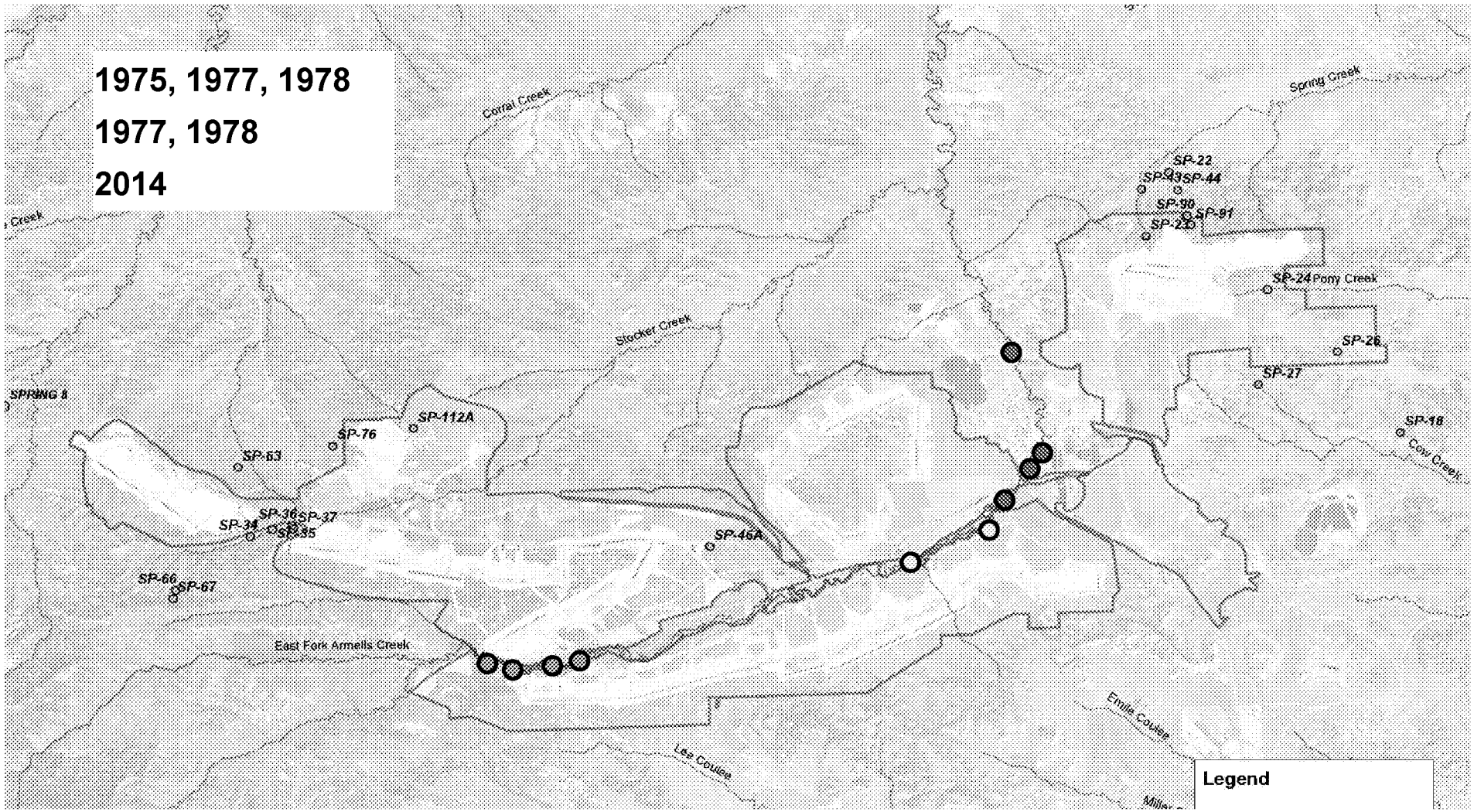
1. Review the aquatic surveys to date for EFAC
   - Benthic community composition
   - Water quality at the time of surveys
2. Recommendations made based on data collected to date

EFAC Aquatic Surveys to date

Year of Sampling	Report Reference
1. 1975	1. Ecological Consulting Service Division, Inc. 1976. Invertebrate and Water Quality Studies of Four Armells Creek Stations, Two Rosebud Creek Stations, and One Reclamation Pond.
2. 1977 (5x) and 1978 (4x)	2. Schwer, D.J. 1981. The Ecology of East Fork Armells Creek and Some Ponds Near Colstrip, Montana. Final Report. December
3. 2014	3. ARCADIS. 2014. Western Energy – Rosebud Aquatic Survey Assessment. Technical Memorandum, December.

Exhibit 10
WCCPROD00000938

Sampling Locations



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EFAC Conditions Summary

- EFAC consists of low-gradient streams with several water sources: groundwater, seasonal runoff, precipitation, NPDES permitted outfalls.
- Low flow, high organic matter content and ephemeral flows are conditions conducive of a tolerant benthic community.
- The surveys date show expected community composition:
  - Diptera dominate the community (flies) - Chironomid, Amphipod
  - Low number of taxa and total abundance
  - HBI indicates “fairly poor” to “poor” conditions (2014)

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A Temporal Trends Analysis: 1977 - 1978

- Organisms were sampled quantitatively in 1978 to determine the relative abundance of various species.
- Multiple sites abandoned due to insufficient flow
- Some sites sampled once due to insufficient flow

Exhibit 10
WCCPROD00000941

A Temporal Trends Analysis: 1977 - 1978

Table 5. Organisms Collected with an Ekman Dredge from East Fork Armells Creek in 1978

Station	1A				1				2A			9
Date	3/22	6/13	9/07	11/29	3/22	6/13	9/07	11/29	3/22	6/13	9/07	11/29
Odonata												
Aeshna							2					
Libellula							1					
Plathemis								4				
Amphiagrion					1			3				4
Ischnura	2	1	26			2	7	12				14
Ephemeroptera												
Callibaetis			3				7					
Caenis							1	4		1		1
Trichoptera												
Hydropsyche											1	
Cheumatopsyche					1							
Limnephilus	6			3	1							2
Diptera												
Chironomidae (unknown)		6				17						
Tanypus										1		
Macropelopia								11		26		
Procladius	16		11					15	5			
Psectrotanypus									23	12		
Thienemannimyia group												7
Odontomesa										7		
Chironomus	35								235	30		
Cryptochironomus								1		1		1
Glypotendipes						1						
Micropsectra	64					13		1	1	1		43
Paratanytarsus									3			
Acricotopus	3								6	6		

-- *Reproduced from Schwer 1981*

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A Temporal Trends Analysis: 1977 - 1978

Table 6. Number of Organisms, Number of Taxa, and Shannon's Diversity (d) for Invertebrate Samples Collected from East Fork Armells Creek in 1978.

Station	1A				1				2A			9
Date	3/22	6/13	9/7	11/29	3/22	6/13	9/7	11/29	3/22	6/13	9/7	11/29
Number of Organisms	164	164	135	30	7	261	135	238	291	80	1	300
Number of Taxa	14	11	9	4	5	16	8	15	10	14	1	15
Shannon's d	2.73	1.25	1.69	1.77	2.13	2.36	.94	1.73	1.20	2.82	0	2.56
March and June Combined:												
Number of Organisms	328				268				371			
Number of Taxa	20				20				18			
Shannon's d	2.67				2.49				1.78			

-- Reproduced from Schwer 1981

A Temporal Trends Analysis: 1977 - 1978

- Schwer (1981) found no consistency or trends noted in diversity on a sample by sample basis, due to:
  - occurrence of a patchy distribution,
  - seasonal optimums,
  - inadequate sample size and/or
  - the inability to sample all microhabitats equally." (p. 25).
- *"Unfortunately, the lack of an equal number of samples from each site prevented a meaningful description of population changes along the creek."*

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Water Chemistry

Table 2. Chemical Analyses of Water Sampled from East Fork of Armells Creek, 10.8k m North of Colstrip (at Station No. 1A as used in this report). Source: USGS; 1976, 1977 and 1978.

	Number of Samples	Mean	Range
Specific Cond. (Micromhos/cm)	27	4116	290 - 6990
pH	27	8.1	7.5 - 8.6
Dissolved Oxygen (On Site)	25	9.6	6.0 - 12.0
Total Dissolved Solids	27	3348	178 - 4580
Turbidity (J.T.U.)	27	9.2	0.0 - 40
Sodium Adsorption Ratio	27	3.5	0.5 - 4.5
Boron	27	0.82	0.12 - 1.30
Total Alkalinity as $CaCO_3$	6	314	58 - 502
Bicarbonate as HCO_3	27	461	71 - 656
Carbonate as CO_3	27	0	0
Chloride	27	49	2 - 86
Nitrate + Nitrite as N	27	0.15	0.00 - 0.88
Sulfate as SO_4	27	2147	75 - 3000
Fluoride	27	0.4	0.00 - 0.7
Total Hardness as $CaCO_3$	27	1879	110 - 2600
Calcium	27	229	22 - 310
Magnesium	27	317	13 - 460
Sodium	27	352	13 - 490
Potassium	27	17	7.4 - 23
Ammonia Nitrogen as N	27	0.21	0.0 - 1.1
Organic Nitrogen as N	27	0.96	0.0 - 2.6
Total Kjeldahl Nitrogen as N	27	1.16	0.42 - 3.10

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Water Quality and Aquatic Life Criteria

- Water quality in EFAC is very variable and often exceeds EPA aquatic life criteria – as seen in 1975, 1977, 1978
- In ephemeral systems, water flow and water quality conditions may change weekly or even daily (EPA 2006).
- Criteria are available for metals – this is based on effects to sensitive invertebrates and fish
- TDS – consists of major ions (Ca, Mg, K, Na, Cl, SO_4); Precise thresholds of effect are dependent on the combination of ions in solution and the benthic organism

Exhibit 10
WCCPROD00000946

Conclusions and Recommendations

- The large amount of variability inherent within ephemeral systems, and the low quality of habitat and benthic communities, would not provide a strong indicator of water quality impacts due to mining activity.
  - Flow and natural levels of organic matter are more likely to drive aquatic community dynamic than other factors

- Although EFAC supports aquatic life, aquatic life criteria are not met.
  - Baseline conditions are a better indicator of existing use
  - Criteria are based on different organisms not present in EFAC
- Aquatic life monitoring will likely demonstrate natural variability; unlikely to demonstrate impacts from mining

Thank You – Additional Questions?

Water quality at 9 / 9A

Table 13. Chemical Analyses of Water Sampled in 1978 from East Fork Armells Creek Station Nos. 9A and 9.

	Station 9A		Station 9	
Date	3/22	6/13	9/7	11/29
Specific Cond. (Micromhos/cm)	4100	4240	3910	3780
pH (Laboratory)	7.4	8.0	7.9	8.1
Dissolved Oxygen (On Site)	5.5	11.0	5.8	9.7
Total Suspended Solids	20	11	6	12
Total Dissolved Solids	3834	3970	3870	3390
Oil and Grease	-5	-5	-5	-5
Turbidity (J.T.U.)	12	4.3	6.0	4.2
Fecal Coliform (Col/100 ml.)	-1	880	164	2
Total Coliform (Col/100 ml.)	10	1700	320	18
Sodium Adsorption Ratio	2.52	2.57	2.49	2.56
Boron	0.2	0.7	0.5	0.3
Total Alkalinity as $CaCO_3$	400	418	355	401
Bicarbonate as HCO_3	488	509	434	489
Carbonate as CO_3	0	0	0	0
Acidity	0	0	0	0
Chloride	23	17	22	19
Nitrate as N	0.11	0.01	0.08	0.38
Nitrite as N	0.11	-0.01	-0.01	-0.01
Ortho-phosphate as P	-0.01	0.01	0.01	-0.01
Sulfate as SO_4	2365	2410	2300	2140
Fluoride	-0.01	0.30	0.30	0.28
Total Anions (meq/l)	57.94	58.99	55.70	53.23
Total Hardness as $CaCO_3$	2249	2370	2140	2060
Calcium	220	252	222	242
Magnesium	414	423	386	355
Sodium	275	287	265	267
Potassium	7	12	15	14
Ammonia Nitrogen as N	0.1	0.4	0.3	-0.1
Organic Nitrogen as N	0.1	1.2	14.0	2.0
Total Kjeldahl Nitrogen as N	0.2	1.6	14.3	2.0
Silica	16	10	13	17
Total Cations (meq/l)	57.10	60.13	54.70	53.28
Aluminum, total	0.6	0.2	-0.1	0.2
Dissolved	-0.1	-0.1	-0.1	-0.1
Antimony, Total	-0.02	-0.02	-0.02	-0.02
Dissolved	-0.02	-0.02	-0.02	-0.02
Arsenic, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Cadmium, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Chromium, Total	-0.02	-0.02	-0.02	0.03
Dissolved	-0.02	-0.02	-0.02	-0.02
Hexavalent	-0.01	-0.01	-0.01	-0.01
Copper, Total	-0.01	0.02	-0.02	0.02
Dissolved	-0.01	0.02	-0.01	0.02
Iron, Total	1.23	0.61	0.55	0.21
Dissolved	0.16	0.05	0.33	0.14

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Exhibit 10

WCCPROD00000949

Meeting Notes
Conference Call

To: Daniel Munoz

From: Dicki Peterson

cc: Kent Salitros, Wade Steere, Mike Kegley, John Martin, Penny Hunter, Ben Latham, Dwayne Siler, Michael Nicklin, Stephanie Vandaele

Date: June 13, 2014

Re: Application 00184 (AM 4) – 7th Round deficiency

Discussion on which direction WECo should response to the 7th round of deficiencies, received on June 3, 2014, pertaining to the Area B-East Amendment. Chris Yde with MDEQ has requested a face to face meeting to discuss the deficiencies one on one. (planned for July 7, 2014)

Aquatic Studies –

The big question "is there aquatic life in Armell's Creek?"

Items were discussed which are written into the "IMPACT ON THE PHYSICAL ENVIRONMENT" and the "FACT SHEET FOR MAJOR MODIFICATION" sections, of the Environmental Assessment of the Rosebud Mine's Draft MPDES Permit MT0023965. These items may have basis in which WECo has grounds not to conduct aquatic studies.

"IMPACT ON THE PHYSICAL ENVIRONMENT" section

Resource	[Y/N] Potential Impacts and Mitigation Measures
2. WATER QUALITY, QUANTITY AND DISTRIBUTION: Are important surface or groundwater resources present? Is there potential for violation of ambient water quality standards, drinking water maximum contaminant levels, or degradation of water quality?	[N] All direct receiving waters are ephemeral streams that flow as a result of precipitation. Discharges to receiving waters are infrequent, short in duration, and typically occur as a result of runoff that exceeds the 10-yr, 24-hr precipitation event. All effluent imitations and monitoring requirements in the modified 2012 permit are either equal to or more stringent than those in the previous (I999) permit. Self-monitoring requirements of discharges have been increased substantially to assure compliance with permit conditions and to track levels of pollutants of concern.
5. TERRESTRIAL, AVIAN AND AQUATIC LIFE AND HABITATS: Is there substantial use of the area by imp0l1ant wildlife, birds or fish?	[N] No impacts anticipated from modification of MPDES permit.

"FACT SHEET FOR MAJOR MODIFICATION" section

C. Water Quality-based Effluent Limitations

Determining the Need for WQBELs

EPA regulations at 40 CFR I 22.44(d), which are incorporated into ARM 17.30.1344 by reference, require that all discharges be assessed by DEQ to determine the need for water quality-based effluent limits (WQBELs) in the permit. Specifically, 40 CFR 122.44(d)(l)(i) states, "Limitations must be established in permits to control all pollutants or pollutant parameters that are or may be discharged at a level that will cause, have the reasonable potential to cause, or contribute to an excursion above any state water quality standard (emphasis added by DEQ)." Often, this regulation is referred to as the "reasonable potential" regulation and the process that DEQ uses to determine whether a WQBEL is required is called a "reasonable potential analysis." Thus, a reasonable potential analysis may be used to determine whether a discharge, alone or in combination with other sources of pollutants to a water body and under some set of conditions arrived at by making a series of reasonable assumptions, could lead to an excursion above an applicable water quality standard or applicable level of nondegradation policy protection.

Nondegradation

The Montana Water Quality Act includes a nondegradation policy in 75-5-303 MCA. This policy is applied during the permit application process through a nondegradation review of any new or increased source. As described in Section 1. A. above, Outfalls 030, 127, 128, 128D, 129, 136, 137, and 139 were found to be previously permitted under different names. Therefore, these outfalls are no longer defined as new or increased sources per ARM 17.30.702(18) and are not subject to nondegradation review in the modified permit. However, Outfalls 10C, 128A, 128B, and 128C are new sources; discharge at these four outfalls is considered in DEQ's nondegradation review.

The three aspects of the State nondegradation policy parallel the three "tiers" of a federal antidegradation policy as required by USEP A in 40 CFR 131.12. These three tiers are as follows:

1. Tier 1: Existing uses of State waters and the level of water quality necessary to protect those uses must be maintained and protected (75-5-303(1));
2. Tier 2: Unless authorized by DEQ through a nondegradation analysis or exempted from review under 75-5-317 MCA, the quality of high-quality waters must be maintained (75- 5-303(2)-(7)); and
3. Tier 3: The Board may not authorize degradation of State waters classified as "outstanding resource waters" (75-5-303(8)).

Regulations at ARM 17.30.701-718 address implementation of this policy. These regulations apply when someone proposes an activity of man resulting in a new or increased Source that may cause degradation.

Tier 1: Protection of Existing Uses ARM 17.30.705(2)(a) requires that, for all State waters, existing and anticipated uses and the water quality necessary to protect those uses must be maintained. As such, when tier 1 protection is applicable, effluent limitations must be developed and numeric and narrative standards apply to protect the existing and designated beneficial uses of the receiving water.

Outfalls 10C, 128A, 128B, and 128C were not previously permitted, and are considered new or increased source outfalls for the purpose of nondegradation review. Therefore, effluent limitations in this permit are derived from and comply with applicable WQS, thus ensuring the level of water quality necessary to attain and maintain existing and anticipated uses.

Tier 2: Protection of High Quality Waters The receiving water for discharges from Outfalls 10C, 128A, 128B, and 128C is an ephemeral drainage, which is not high quality water as defined at MCA 75-5-103. Therefore, the nonsignificance determination criteria of ARM 17.30.715 do not apply.

Tier 3: Protection of Outstanding Resource Waters ARM 17.30.705(2)(c) requires that, for outstanding resource waters, no degradation and no permanent change in the quality of outstanding resources

waters resulting from a new or increased point source discharge are allowed. Receiving waters for the discharges from the facility have not been designated as outstanding resources waters. Therefore this regulation is not applicable.

Proposed Water Quality-based Effluent Limits
The receiving waters are within the Yellowstone River drainage between the Billings water supply intake and the North Dakota state line, and are classified as C-3. ARM 17.30.629 establishes the designated beneficial uses for C-3 waters and prescribes the standards to protect those designated uses. However, all permitted outfalls discharge to receiving waters that hydrologically meet the definition of ephemeral [ARM 17.30.602(12)]. ARM 17 .30.637(4) is specific to ephemeral streams of all classes and prescribes the standards applicable to protect the uses of hydrologically ephemeral streams. Pursuant to ARM 17.30.637(4), the applicable water quality standards for hydrologically ephemeral streams include the prohibitions and treatment requirements in ARM 17.30.637. Therefore, the prohibitions and treatment requirements applicable to ephemeral streams in ARM 17.30.637 will apply to the permitted discharges in addition to the applicable technology based effluent limits.

The specific water quality standards for C-3 waters found in ARM 17.30.629 do not apply to ephemeral streams pursuant to ARM 17.30.637(4). Therefore, evaluation of reasonable potential to exceed the numeric standards in DEQ-7, as adopted by ARM 17.30.629, is unnecessary.

The resulting effluent limitations are summarized in Tables 3 through 9.

Also discussed: Aquatic life studies compare themselves to themselves
Aquatic life studies should be on a regular basis
Aquatic life studies are climatic in nature

John Martin summarized his meeting with John North (MDEQ) and Dana David (MDEQ) in May 2014.

- He feels that MDEQ are trying to do the right thing
- Accessing the cumulative impacts – concerned there is material damage off the mine site and what mitigation would be used if necessary.
- Chlorine issue

Other Discussions -

- Chlorine issue - secondary standard which is aquatic life standards basis. No other livestock or wildlife basis.
- SW-75 and SW-55 are in-conclusive in nature – water quality is subjective at best
- Comparison of well vs SW site?
- Possibly drill another well?
- Water Budget – Michael Nicklin stated the preliminary work for the water budget shouldn't be adverse to the mine and the "Van Voast" evaluation was reasonable.
- Lignin Sulfate – not much information out there on how the substance breaks down – organic – tree sap – MSDS....
- TDS – specifically addressed in detail in the PHC.

Conclusions –

Draft responses should have technical and scientific data clearly demonstrating our view points

- Penny Hunter will write something up for the aquatic study response. Dicki will forward the aquatic studies to Penny.
- Wade will follow up with Michael Nicklin on the water budget.
- Dicki will follow up and find information on the lignin sulfonate.

- Dicki will write the response to the TDS section. (With help from Wade if necessary)
- Short summary of todays call and what possible issues to Mike Kegley

Area B AM4 Permit C1984003B

Comprehensive Evaluation of Probable Hydrologic Consequences Areas A, B and C Western Energy Rosebud Mine

Prepared for

WESTERN ENERGY COMPANY – *Rosebud Mine*
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Rosebud Lane Colstrip, MT 59323 (406) 748 5100

Prepared by:

Nicklin Earth & Water
670 S Ferguson Ave, Suite 1
Bozeman, MT 59718
406.582.0413

January, 2014

Exhibit 8

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Comprehensive Evaluation of
Probable Hydrologic Consequences
Areas A, B and C
Western Energy Rosebud Mine

1.0 INTRODUCTION

Western Energy is proposing to expand mining in Area B of the Rosebud Mine as described in AM4 (Amendment 00184). Western Energy has operated the Rosebud Mine located near Colstrip Montana in Rosebud County since 1975 (See Figure 1). The mine is operating under five separate surface mine permits (SMP) approved and regulated by Montana Department of Environmental (DEQ); C1986003A (Area A), C1984003B (Area B), C1985003C (Area C), C1986003D (Area D), and C1981003E (Area E). Figure 2 shows a site map of the Rosebud Mine.

This PHC provides the comprehensive evaluation of probable hydrologic consequences to support the Area B AM4 (Amendment 00184) application in accordance with ARM 17.24.314(3). The mining progression for this Area B-East Revision is shown on Figure 3A.

This PHC utilizes hydrologic monitoring data from Areas A, B and C in the development and evaluation of hydrologic consequences. Data from other mine areas were not included except where deemed relevant. There is no indication that Area E is hydrogeologically separated from Area B East. However, the groundwater quality and quantity in Area E may be affected by several factors not within the scope of this PHC, such as: location adjacent to the town of Colstrip and several large impoundments and the occurrence of pre-1976 historical mining (Van Voast et al., 1977).

1.1 Background

There have been many previous investigations and evaluations conducted in the vicinity of and at the Rosebud Mine. Background reports considered in this PHC include:

- *Hydrology of Area 49, Northern Great Plains and Rocky Mountain Coal*

Provinces, Montana and Wyoming, Slagle et al, United States Geological Survey, January 1983.

- *Hydrogeologic Conditions and Projections Related to Mining Near Colstrip, Southeastern Montana*, Van Voast, Hedges, and McDermot, Montana Bureau of Mines and Geology, 1977.
- *Hydrogeologic Responses: Twenty Years of Surface Coal Mining in Southeastern Montana*, Van Voast and Reiten, Montana Bureau of Mines and Geology, 1988.
- *Final Environmental Impact Statement, Western Energy Company's Rosebud Mine, Area C, Block 1*, Montana Department of State Lands, US Office of Surface Mining, 1982.

Relevant Rosebud Mine reports include baseline monitoring and investigation reports, mining permit applications, and annual monitoring reports.

1.2 Report Objectives

The objectives of this report are to:

- Present a historical summary of analyses conducted for the Rosebud Mine.
- Provide updated information using data collected through mining operations to current.
- Present an interpretative summary of the analyses of mining impacts to date associated with the Rosebud Mine.
- Present conclusions of a Probable Hydrologic Consequence analysis addressing relevant portions of Administrative Rules of Montana (ARM 17.24.304) and Surface Mine and Reclamation Act (SMCRA - 30 CFR 780.21).
- Provide baseline information per Environmental Resources and ARM 17.24.314 Plan for Protection of the Hydrologic Balance necessary to evaluate probable hydrologic consequences in association with the proposed expansion.

Data used for this analysis are from a period extending from the early 1970s to present. Data collection activities in conjunction with the existing permit are also relevant to the proposed expansion.

1.3 Approach

Numerous previous investigations and hydrologic monitoring activities have been performed at the Rosebud Mine resulting in a very large amount of hydrologic data. Compilation, presentation, and evaluation of the available data allow for the identification and evaluation of probable hydrologic consequences beyond those developed based on baseline data.

Hydrologic consequences have been identified in previous permit applications. These are evaluated in comparison with the available hydrologic data.

The hydrologic data are condensed to statistical tables to allow identification of hydrologic impacts, including water quantities and quality as well as comparison to water quality standards. This PHC includes hydrologic data collected up to water year (WY) 2011. Data collected during WY 2012 (October 1st 2011 to September 31st, 2012) are presented in the 2012 Annual Hydrologic Report. The focus of this PHC is on hydrologic data collected within and near mine Area A, B and C permit boundaries. In addition, hydrologic data from Areas D and E were used to evaluate spoils water quality and groundwater level recovery rates.

The key hydrologic components that make up the hydrologic balance include:

- Climate
- Topography and Geology
- Erosion and Sediment Yield
- Surface Water (Stream Water)
- Springs
- Ponds
- Wetlands
- Groundwater

The key time-frames of interest include:

- Baseline (pre-mining)
- Short-term (during mining and reclamation)
- Long-term (post-mining and bond release).

1.3.1 Existing Hydrologic Consequences

Hydrologic impacts associated with surface mining in eastern Montana are generally understood. Previous permit applications for the Rosebud Mine have identified and discussed hydrologic consequences. In addition to evaluating the monitoring database for previously unforeseen impacts, this PHC compares and evaluates the existing hydrologic consequences to the monitoring data.

The identified hydrologic consequences from existing permits are summarized in the following subsections.

1.3.1.1 Surface Water

Due to mining operations, the surface water system will be impacted. More specifically, there will be impacts to the topography, surface water quantity, surface water quality, and erosional stability. Short-term impacts are expected during mining.

Surface Water Quantity

Potential Short-Term Impacts

As mining proceeds through the drainages, stream flow patterns will be disrupted by the mine pit and the construction of sediment control structures. During mining much of the surface and channelized flow will be captured in sediment control structures.

Potential Long-Term Impacts

As reclamation proceeds, the drainage system will be restored. All major drainages and stream channels will be constructed to approximate original drainage configurations. A tributary system will be designed and built to restore the pre-mining system of incised drainages that collected runoff and sediment from the uplands and conveyed them to the stream channels in the primary valleys. The post-mining channels and floodplains are designed to mimic the pre-mining channels' response to rainfall events. These measures are designed to eliminate long-term changes to the surface drainage system. As the mine area is reclaimed, long term effects on the drainage system are expected to be minimal.

Surface Water Quality

The surface water quality at the Mine is continually monitored to ensure that the surface water is protected. By continuing to monitor the surface water and enforcing the mine's hydrologic control plan, current and future impacts to the surface water will be minimized.

Potential Short-Term Impacts

The Mine will continue to enforce the hydrologic control plan as the mine pits advance. If needed, additional ponds, traps and MPDES points will be added to the plan to account for the additional area of disturbance.

Potential Long-Term Impacts

Reclamation actions, including topography, vegetation and soil qualities that resemble pre-mine conditions, will minimize long-term affects to the surface water quality at the mine.

Sediment Yields

By enforcing the Mine's hydrologic control plan, current and future impacts to the sediment yield will be minimized.

Potential Short-Term Impacts

The Mine will continue to enforce the hydrologic control plan as the mine pits advance which will prevent any additional sediment from leaving the site. If needed, additional ponds, traps and MPDES points will be added to the plan to account for the additional area of disturbance.

Potential Long-Term Impacts

By establishing vegetation and soil qualities that resemble pre-mine conditions and by developing the approved post mining topography (PMT), it is anticipated that long-term effects on the sediment yield will be minimal.

1.3.1.2 Groundwater

Mining will cause impacts to both the quantity and the quality of the groundwater in the mine area. Studies in the mine area have been performed to determine the intensity and

the duration of the impacts (See Section 4.0 and Attachment D and E). That section discusses impacts to groundwater quantity, groundwater quality, and groundwater wells in the immediate or adjacent areas.

Groundwater Quantity

Mining will remove the Rosebud coal aquifer and cause diminished water levels in this aquifer in the mine vicinity for the duration of mining (See Attachment E). Drawdown commonly extends laterally into unmined coal adjacent to mine pits. The degree of drawdown in unmined coal diminishes with distance from the mine pits, with the most extensive depression of the groundwater surface occurring down-gradient of the coal removal area.

A numerical groundwater model, designated as “The Rosebud Mine Groundwater Model” was developed to simulate and predict impacts to groundwater levels and flow from mining. The Rosebud Mine Groundwater Model (See Attachment D) represents groundwater conditions from baseline (premine) to current time (2012). This model is also used to predict the groundwater response from permitted mining into the future.

For this PHC, the model incorporates the additional mining proposed in the Area B AM4 Amendment to predict the groundwater response into the future from that activity. This model application (See Attachment E) is designated as the “Area B AM4 (Amendment Application 00184) Model” (a.k.a, “AM4 Groundwater Model”). Comparison of the future predictions from the baseline Rosebud Mine Model which represents currently permitted mining to predictions simulated by the AM4 Model allows for the evaluation of the incremental groundwater response from the AM4 expansion in Area B.

Following completion of reclamation, backfill water levels are expected to approximate pre-mining coal-seam water levels. The time required for the full recovery of groundwater in the backfill aquifer will vary mine wide and will exceed 50 years in most portions that are mined (See Attachment E). Although it could take considerable time, there is no reason to expect that the regional groundwater flow gradient will not eventually recover because recharge and discharge areas for the principal aquifer will not be affected by mining. The hydraulic characteristics of the spoils will facilitate storage and transmission of groundwater between the undisturbed up-gradient and down-gradient coal aquifers restoring the essential function of conveying groundwater from recharge to discharge areas. The rate and direction of flow should eventually

equilibrate to near pre-mine water table conditions.

During mining, some tributary surface flow is retained to manage water quality. Runoff from disturbed lands is retained in mine pits, sediment ponds and traps. The retention of this runoff impacts the infiltration of water from channels, such as the East Fork Armells Creek (EFAC), to the underlying alluvial aquifer. Some of the retained water infiltrates from sediment ponds located near the alluvium and recharges the alluvial aquifer. Runoff flows from areas up-gradient of mining and from undisturbed lands continue to recharge the alluvial aquifer.

Following mining and reclamation, the function of ephemeral runoff is restored to mimic the premine conditions and the postmine contribution of runoff to alluvial aquifers should be similar to premine conditions

Groundwater Quality

Groundwater quality, within the mine area, will be impacted. This has been the subject of considerable study throughout the Powder River Basin and elsewhere (Van Voast and others 1975, 1977, 1978, and 1988). TDS concentrations in backfill aquifers generally are greater than in the coal aquifers they replaced. Resaturation of backfill, primarily by lateral groundwater flow from the undisturbed coal aquifers, can be expected to result in temporary increases in TDS concentrations as a result of elevated levels of soluble salts, (primarily calcium, magnesium, sodium and sulfate) leached from the overburden. According to Van Voast and Reiten (1988), average TDS concentrations of groundwater in mine spoils in Decker area mines are 50 to 200 percent higher than the concentrations in the undisturbed coal aquifers. Locally, TDS values may be even higher. Similar geochemical conditions have also been simulated in the laboratory with bench scale column-leach and paste-extract leaching tests using overburden materials representative of those to be disturbed by mining at specific mines. Generally, the dissolved-solids concentrations in the backfill water reach a maximum during initial saturation and then decrease to an equilibrium level after one or more pore volumes of water pass through the backfill. A study suggests that dissolved-solids concentrations may decrease as water moves from the backfill into the un-mined, down-gradient coal (Clark 1995).

As re-saturation of the backfill continues, salt concentrations are expected to be extremely variable and peak at a concentration potentially two to three times that of the

baseline coal groundwater and then decline to some equilibrium value after being flushed by one or more pore volumes of groundwater. The impacts of mining will likely result in deterioration of groundwater quality within some areas of the mine backfill to a degree that will require at least temporary reclassification of the groundwater to a lower usage class.

1.4 Mining Progression

1.4.1 Present Mining Situation

Mining has occurred at the Rosebud Mine since 1975. Active mining at Rosebud Mine is presently occurring in Areas A, B and C. Figure 3B depicts the current permitted mining at Areas A, B and C.

Mining at Rosebud consists of a combination of topsoil removal, overburden removal, and coal removal. Topsoil is salvaged with appropriate mining equipment prior to overburden removal and stockpiled as necessary or hauled directly to regraded areas. Overburden is moved by the dragline and the coal is removed by means of a truck and loader operation.

1.4.2 Area B AM4 (Amendment Application 00184) Mining

The additional proposed mining under this application is shown on Figure 3A. This application provides for the proposed mining to occur from 2013 to 2026

1.4.3 Potential Future Mining

Additional potential future mining (See Figure 3A) includes:

- Application Area B-East AM4 Application 00184

2.0 PRECIPITATION AND CLIMATE

This section describes climatological data for the Rosebud Mine and vicinity. Data presented in earlier permitting efforts are updated and presented to provide a basis for evaluating hydrologic aspects of the project.

2.1 Climate

The climate of eastern Montana is classified as semiarid continental and is characterized by hot moderately dry summers, cool dry falls, cold dry winters and cool moist springs. Winter cold spells are often interrupted by periods of warmer weather. The passage of mid-latitude storm systems is typical of the climate of this area; day-to-day weather changes can be quite extreme because of the migrating systems.

At the mine, precipitation occurs predominantly as snow from about November to April. About one-third of the total annual precipitation is in the form of snow. Due to the prevailing westerly wind, the snow typically accumulates on the leeward slopes of drainage.

2.2 Climate Monitoring

Climate data are collected at the mine and also at the nearby climate station at Colstrip, Montana (241905). Figure 4 shows the location of the current climate monitoring sites. Climate data for the Colstrip station are available from the Western Regional Climate Center (WRCC). Given that the Rosebud Mine is adjacent to Colstrip, the climatic conditions at the mine are similar to that of the town. The period of record for the Colstrip station extends from March 1927 to December 2011.

2.3 Temperature

Table 1 provides the statistical summary of the climate at Colstrip. The average maximum and average minimum daily temperatures as measured at Colstrip are 88.1^{o} F in July and 9.6^{o} F in January respectively. The maximum and minimum temperatures ever recorded at Colstrip are 111° F (8/6/1961) and -50° F (2/15/1936).

2.4 Precipitation

The average annual precipitation at Colstrip is 15.17 inches. The annual precipitation

and monthly average precipitation are shown on Figure 5. The 30 year monthly precipitation data from the Colstrip weather station are provided in Attachment A (Table A-1).

Western Energy currently collects precipitation data from four rain loggers. The locations of the on-site precipitation stations are shown on Figure 4. Table 2 compares water year 2011 precipitation data from the Colstrip weather station to the data collected at four locations at the mine. Precipitation data collected at the mine are reasonably comparable to that from the Colstrip station. The Colstrip data are used in this PHC as they have a longer and more complete record.

Western Energy also collects precipitation data from 9 wedge rain gauges located at surface water monitoring sites (Figure 4). These data are reported in the Annual Hydrology Report for each water year.

2.5 Long-Term Climate

Figure 6 shows the departure from average (DFA) plot of the annual precipitation data. The DFA calculations are shown in Table A-2 in Attachment A. The DFA plot provides a qualitative representation of precipitation trends. Periods with negative values are indicative of lower than average precipitation (drought) and periods with positive values represent wetter than normal precipitation.

The uppermost plot on Figure 6 shows the precipitation trends for the period of record at Colstrip extending from 1927 to 2011. The lower plot shows the DFA for the time period from 1981 to 2011. As the plot shows, precipitation tended to be below average from about 1981 to 1990, and was about average from 1990 to 1999. This was followed by a drier period from 1999 to 2004 and it has been relatively wet since then until current (2011).

2.6 Evaporation

Annual pan evaporation data have been collected in the vicinity of the Rosebud Mine at the Huntley climate station for a period of record extending from 1911-2005 and at the Yellowtail Dam climate station from 1948 to 2005 (www.wrcc.dri.edu/htmlfiles/westevap.final.html). It is typical to apply a pan coefficient from about 0.7 to 0.8 to obtain an estimate closer to the actual evaporation from a surface water body. The average annual pan evaporation for Huntley and Yellowtail

Dam is 41.27 and 47.56 inches, respectively. Assuming a pan coefficient of 0.75 the approximate annual evaporation at the Rosebud Mine ranges from 30.95 to 35.67 inches. Most of the evaporation in the vicinity of Huntley occurs from April to September, whereas at Yellowtail Dam most of the evaporation occurs from May through October.

Potential evaporation at Colstrip exceeds precipitation. This condition is common and typical of semiarid areas with warm summers.

The amount of evaporation at the mine at any time is primarily dependent on the extent of the ponded surface area of the mine ponds. This varies from year to year, and seasonally and is dependent upon the amount of surface water runoff, and mine pit pumping that is necessary.

Another factor contributing to loss of moisture in an area is sublimation. Sublimation is a direct conversion of ice or snow to water vapor without passing through a water phase. Chow (1964) estimates sublimation losses in the middle latitudes during the winter season to be about 0.5 inches of water per month of snow cover. Snow normally occurs in the Colstrip area from November through March and accounts for approximately one-third of the total annual precipitation for the Colstrip area. Thus, during this period, sublimation could transfer about half of the precipitation (2.5 inches) occurring from November through March back into the atmosphere.

3.0 SURFACE WATER

3.1 Regional Setting

The Rosebud Mine is located within the Armells Creek and Rosebud Creek drainages which are tributary to the Yellowstone River drainage (Figure 7). Both Armells and Rosebud Creeks flow to the north and join the Yellowstone River roughly 27 miles from the mine.

3.2 Local Surface Water Regime

The drainage areas containing the Rosebud Mine are part of the Yellowstone River Basin. The total drainage area of the Yellowstone River Drainage is 69,083 square miles (44,226,000 acres) which includes flow from the Clark Fork of the Yellowstone, Bighorn, Tongue and Powder River basins. The nearest long-term downstream gaging station on the Yellowstone River is at Miles City, Montana (USGS 06309000). Discharge, reflecting a drainage area of 48,253 square miles at this station has been measured since 1922. This station is just downstream of and includes discharge from the Tongue River. Boysen Reservoir and the Yellowtail Dam on the Bighorn River and the Tongue River Reservoir provide for artificial regulation of flows above this station.

The USGS gaging station Yellowstone River at Forsyth (USGS 6295000) is located between the mouths of Armells and Rosebud Creeks. Discharges have been measured at this site since 1977.

Figures 8A and 8B show the period of record annual discharge and average monthly discharge for these Yellowstone River gaging stations. The highest seasonal discharges on the Yellowstone typically occur from mid-June through early July reflecting upstream higher elevation mountain snowmelt.

Surface water runoff from the Rosebud Mine discharges to the Rosebud Creek and Armells Creek Drainages (Figure 7). Both flow to the north and are tributary to the Yellowstone River. Rosebud Creek drains 1,302 square miles and discharge was measured at USGS Station 6296003 (Rosebud Creek at mouth near Rosebud, MT) from 1974 to 2006. The Armells Creek drainage is 370 square miles. Discharge at USGS 6294995 (Armells Creek near Forsyth, MT) was measured from 1974 to 1995. Figure 8B shows average monthly discharge for these measuring stations.

Table 3A shows the annual discharges for the time period 1975 to 2006 to allow comparison of Rosebud and Armells flows to those of the Yellowstone River. Table 3B shows the mean monthly discharges for the same stations.

As shown in Tables 3A and 3B, the Rosebud Mine drainages contribute relatively small discharges to the Yellowstone River (Armells Creek 0.06% and Rosebud Creek 0.25%). Therefore, activities at the mine are unlikely to have any measurable impact to the Yellowstone River.

The 10-year, 24-hour (1Q10) peak flows (McCarthy [USGS], 2004) (See Attachment B) for the key surface water stations are:

Station	Discharge (cfs)
Yellowstone River at Forsyth	69,100
Rosebud Creek near Rosebud	1,020
Armells Creek near Forsyth	981

These peak flows are indicative of the nature of the Armells and Rosebud Creeks response to intense precipitation events but again show limited potential for impacts associated with mining at Rosebud to the Yellowstone River.

3.2.1 Local Setting

The land surface at Rosebud Mine can be characterized by gentle slopes and subdued drainage divides. There are steeper slopes and narrow ridges present in the western portions of the area.

The numerous ephemeral tributaries at the mine, as shown on Figure 9, flow only during periods of snowmelt and/or after periods of significant rainfall. When rainfall or snowmelt exceeds the infiltration rate of soils, water flows overland and then to drainage channels. During runoff, alluvium underlying the ephemeral drainages may become saturated and then slowly drain.

Stream channels form via erosion processes in response to flow events. In upper

tributaries, stream channels are often not well defined as having distinct channel beds and banks. These undefined stream channels reflect sediment erosion and deposition processes.

East Fork of Armells Creek is the most significant tributary at the mine. The creek is ephemeral at the mine but becomes a perennial stream sourced by groundwater down-gradient of the project area in the vicinity of the Town of Colstrip. Recharge from the Castle Rock Lake reservoir, the Colstrip wastewater treatment plant, and the PPL treatment pond leakage significantly contributes to the flow in the creek downstream from the mine.

A recent field inspection of the East Fork Armells Creek showed three short segments of flowing water between Areas A and B (Figure 10). Six ponded sections were present. Most of the creek bed upstream from Area A was dry. The limited flow sections and ponded sections are generally expressions of the groundwater table. Progressing from west to east along the East Fork Armells Creek, the following is observed:

- The alluvium is bounded by overburden (upgradient of Area B).
- The alluvium then comes into contact with the Rosebud coal as the overburden pinches out (between Areas B and C to the west) (Figure 11).
- The alluvium then dissects into the Rosebud coal and into the upper portions of the interburden (from eastern portions of channel between Areas B and C, and in the western portion between Areas A and B)
- The alluvium eventually dissects into the McKay coal (eastern portion of channel between Areas A and B) (Figure 11).

In other words, the contribution of groundwater from the Rosebud coal to the alluvial groundwater increases progressing from west to east along the East Fork Armells Creek. At the very eastern edge of the Mine, the McKay coal groundwater also contributes to the alluvial groundwater. Note, however that most flow in the alluvium is dominated by upgradient alluvial sources of groundwater. In comparison, Rosebud coal and McKay coal contributions are small.

3.2.2 Local Drainages

Local drainages at the Rosebud Mine Areas A, B, and C include (Figure 9):

Drainage	Sub-Drainage	Mine Permit Area
Armells Creek Drainage	Upper West Fork Armells Creek	C
	East Fork Armells Creek	A, B, C
	Stocker Creek	A, C
	Donley Creek Black Hank Creek	C
Rosebud Creek Drainage	Lee Coulee	B
	Cow Creek	B

3.2.3 Stream Water

3.2.3.1 Flows

Surface water at Rosebud Mine flows in response to significant snowmelt or rainfall events as typical of local drainage basins in Eastern Montana. Flow patterns vary as they are dependent on precipitation patterns (e.g., wet vs. dry climate periods), the nature and intensity of precipitation and snow accumulation and snow melt, soil conditions (dry, wet, frozen, etc.), vegetative cover, slopes, natural storage and storage resulting from mining water management.

In practice, it has been difficult to measure these infrequent ephemeral flows. Continuous flow monitoring equipment is susceptible to equipment related operational issues. In particular, the Stevens Recorders, which plot water stage on circular paper charts, have not been reliable over extended times. Sites with Stevens Recorders were upgraded to utilize electronic pressure transducers and data loggers in Water Year 2012. Initial operation shows increased reliability, including during wintertime, and better data when compared to the Stevens Recorders. Additionally, measurable flows tend to occur during spring snowmelt and precipitation. At times, the resulting wet soil conditions from precipitation and snowmelt limit physical access to the monitoring sites.

Surface water flow monitoring sites are summarized in Table 4 and shown on Figure 12. The available surface water flow data reflect ephemeral flows based on precipitation driven runoff. Figures 13 and 14 graphically depict the available discharge data from surface water monitoring sites SW-55 (East Fork Armells Creek) and SW-65 (Stocker Creek), respectively. The data showed only three flow events exceeding five cfs at SW-55 and five events at SW-65 over a time period of about 28 years. Please note that there are missing flow data due to frozen conditions and equipment malfunction. It is likely that flow events occurred but are not reflected in the data.

The data shown on Figures 13 and 14 do not identify significant flows from about the late 1990s to 2009. The lack of observed flows in the data is likely a result of a combination of:

- Missing data
- Capture of tributary flows during mining
- Climatic factors (i.e., drought)

3.2.3.2 Water Quality

Water quality data for the East Fork Armells Creek, Cow Creek, Stocker Creek and West Fork Armells Creek drainages are summarized in Tables 5A through 5D. The tables show water quality statistics for baseline samples and other data. Baseline samples were isolated from the surface water quality dataset based on analysis of sampling location, sampling date and maps showing mining progression over time. Only samples collected before mining activities started upstream were considered baseline. All other samples, which include those taken after mining started up-gradient and samples for which only the drainage is known, were grouped together in 'other data'.

The data illustrate the extremely high variability of the surface water quality in these drainages, with the standard deviation of a given water quality parameter often higher than or similar to the average. This variability is to be expected given the ephemeral nature of flow in the drainages. Comparison of East Fork Armells Creek and Stocker Creek water quality parameter averages shows that in many cases baseline averages are lower. However, given the high variability of the data, as indicated by the standard deviations for water quality parameters, it is difficult to ascertain whether this increase is related to mining activities or other factors (e.g. the amount of precipitation and runoff).

Regional water quality statistics for trace elements from the Area 49 study (Slagle et al., 1983) are shown in Table 6. The extent of the Area 49 study area is shown on Figure 15. Comparison of baseline trace element concentrations in the Rosebud Mine vicinity and Area 49 samples, shows that in some cases the ranges observed in Rosebud Mine samples are larger. Again, this is likely due to the ephemeral nature of stream flow in the vicinity of the Rosebud Mine. Most Area 49 surface water quality samples were collected at locations with perennial stream flow, where the variability in stream water quality is expected to be lower.

Chromium, cadmium, lead and mercury concentrations in excess of DEQ-7 standards have been observed in baseline surface water samples. Nitrate plus nitrite nitrogen concentrations in excess of 10 mg/L were found in samples taken at SW-01, SW-65 and SW-66. SW-01 is located in the East Fork Armells Creek drainage downstream from the town of Colstrip. SW-65 and SW-66 are located in the Stocker Creek and Cow Creek drainages, respectively. One sample from SW-65 and SW-66 had nitrate plus nitrite nitrogen concentrations in excess of DEQ-7 standards.

Table 7 and Figure 16 identify MPDES discharge points at the Rosebud Mine. Water quality samples are collected in accordance with permit requirements and reported to DEQ in monthly discharge monitoring reports. In general, MPDES outfall samples for planned discharges meet the standards set forth in the MPDES permit. From water year 1999 through 2011, there were fewer than ten permit limitation exceedances during planned discharges. It is standard practice at Rosebud Mine to collect a water quality sample before a planned discharge to ensure the water will meet MPDES permit requirements. The majority of discharges occurring at Rosebud Mine are planned, with most unplanned discharges occurring from April through July during very wet years, e.g. 2011.

3.2.4 Surface Water Uses

Historically, the only known use of surface water in the vicinity of the mine has been for livestock watering. Livestock impoundments were constructed on drainages to retain ephemeral discharges for seasonal livestock use.

Currently, livestock water use continues and surface water is also used for dust suppression.

3.2.5 Impoundments

Surface water flows at the mine are controlled using impoundments to retain runoff for sediment control. Impoundments at the Rosebud Mine include sediment control structures and livestock watering ponds. Information about the impoundments in or around Areas A, B and C is summarized in Table 8. The locations of these impoundments are shown on Figure 17.

Impoundments are typically filled by surface runoff from snowmelt and precipitation. Some livestock water ponds are sourced by spring flows. There are a few impoundments on East Fork of Armells Creek where the bottom of the channel intercepts the underlying alluvial aquifer.

Most of the sediment control impoundments will be removed following mining, but a few may remain as permanent features (see Table 8).

Water quality statistics from samples collected at stock ponds are summarized in Table 9. The comparison of stock pond water quality to livestock water quality criteria is provided in Table 10. The water quality criteria for livestock are presented in Attachment C. Figure 18 shows the changes (e.g., time series) in TDS in impoundments over time.

3.2.5.1 Sediment Control Structures

During mining, surface water runoff and erosion control measures are implemented to capture runoff water for sediment control. Detailed information about specific runoff and erosion control measures is provided in Exhibit D (Approximate Hydrologic Control Plan) of the permit amendment (AM4) application.

Pits

Pits will be used to control runoff at active mining areas. Excess water will be managed in the pits, or pumped to sumps.

Ponds (Impoundments)

Sediment traps and ditches are designed to manage runoff (10-year 24-hour storm event) from spoils and disturbed areas away from active pits. Smaller traps and ditches will be used per provisions in the MPDES permit to control runoff from disturbed areas

during reclamation.

3.2.5.2 Livestock Ponds

Livestock ponds retain runoff in stream channels and discharge from springs. There are currently four dams in the EFAC stream channel within the Rosebud Mine, which retain runoff for livestock watering purposes (Figure 10).

3.2.6 Springs

Ninety springs have been identified in the Rosebud Mine area. Of these, 28 springs are located within or adjacent to Areas A, B and C. Table 11 lists and summarizes information about these springs and their locations are identified on Figure 19. Most of these springs are associated with the Rosebud and McKay coal or clinker; however, there are a few that originate from the overburden and spoils.

3.2.6.1 Spring Flow

The monitored springs in the vicinity of Area C typically seep over a broad area. Therefore flow is typically not measurable. With the exception of spring SP-76, all springs have been dry at times during the period of monitoring. One spring monitoring site, SP-66, has consistently been dry. Although no flow data are available, all monitored springs have at times discharged to ponds and available water depth data are presented in Figure 20. Most springs show seasonal variations with most ponding occurring in the spring time. No clear trends in the depth of ponded springs can be observed.

Two springs have developed in reclamation; SP-46A in Area C East and SP-112A in Area C North. Both springs seep out over an area that is only a few feet wide. At times these springs are ponded with water levels up to 0.3 feet.

3.2.6.2 Spring Water Quality

Spring water quality fluctuates and is variable. This variability in water quality and degree of mineralization was also reported in the hydrogeologic study conducted in the Colstrip area by Van Voast et al. (1977).

The water quality of monitored springs located in or near Area C is summarized in Table 12. There are no monitored springs in or near Areas A and B. TDS concentrations

below 1,000 mg/L have been observed at Rosebud coal springs SP-35 and SP-37 near the permit boundary of Area C West. Both of these springs discharge from coal seams. The highest TDS concentration of 3,950 mg/L is associated with spoils spring SP-112A in Area C.

Comparison of spring water quality data in Table 12 to that of their associated aquifers (Table15C) yields the following observations:

- The water quality of Rosebud coal springs is generally comparable to that of the baseline Rosebud coal groundwater. However, the average bicarbonate concentrations in spring water are higher compared to groundwater and the sodium and sulfate concentrations tend to be lower.

- The TDS concentrations in McKay coal spring SP-63 fall within the range of TDS concentrations reported for baseline McKay coal groundwater for Area C. The average bicarbonate concentration in the spring water is higher than in McKay coal groundwater, whereas the average sodium and sulfate concentrations are lower.

- The TDS concentrations in overburden springs fall within the range reported for baseline overburden groundwater in Area C.

- The average TDS concentration in the two spoils springs, SP-46A and SP-112A, is lower than the average TDS concentration in Area C spoils groundwater.

Figure 19 shows TDS time series plots for all monitored springs in the vicinity of Areas A, B and C for which more than two water quality samples are available. TDS concentrations are generally variable, with occasional spikes. One spring, SP-46A, shows a slight gradual increase in TDS levels during the 2000s. This spring is located next to the haul road in Area C East and is associated with spoils. The increase in TDS concentration is mainly due to an increase in sulfate concentrations. The water quality of this spring is similar to the spoils groundwater quality at this location. Comparison of water quality data from SP-46A and SP-112A with Area C spoils groundwater quality (Table 15C) shows that the spoils spring water has higher bicarbonate concentrations and lower sulfate and sodium concentrations. Similar differences were observed when comparing the water quality of springs issuing from coal seams to the groundwater

quality in the coal seams.

Water Quality Standards Exceedances

One spring sample taken from SP-35 on June 24th 2008 showed exceedances of Montana numeric water quality standards. Total mercury and dissolved mercury concentrations in this sample were 0.13 mg/L and 0.006 mg/L, respectively. More recent samples from this well showed mercury concentrations below detection limit.

Conclusion

Analysis of the existing spring water quantity and quality data showed no obvious direct impacts from mining activities on the flow and water quality of existing springs. The lack of historical spring water quality data combined with the generally high variability in water quality between springs and over time for a given spring makes it difficult to draw any definite conclusions at this point. Further sampling efforts are required to analyze possible hydrological impacts of future mining activities on the water quality of existing springs.

The data indicate that new springs may occur in spoils deposits. The water quality in these springs is projected to be similar to the quality of the groundwater in these deposits. In general, springs tend to have higher bicarbonate and lower sodium and sulfate concentrations compared to the groundwater in the stratum from which they are sourced.

3.3 Probable Hydrologic Consequences

3.3.1 Surface Water Quantity

3.3.1.1 Short Term Impacts – During Mining

Generally, surface water flow at the mine is ephemeral and it is dominated by short-term/episodic precipitation and snowmelt runoff events. In a few instances in EFAC, limited intermittent flow has been observed. However, such intermittent flows are typically associated with the presence of immediately up-gradient ponds or ponded conditions. Figure 10 shows that there are currently four dams on the EFAC. In effect, it is apparent that the intermittent flow conditions are artificially induced by the presence of the ponds that act to temporally store surface water runoff which in turn seeps or infiltrates into the underlying alluvium. This leads to a localized increase in the water table which in turn manifests itself in some instances as the limited intermittent flow that is sometimes observed in EFAC.

During mining, the alluvial groundwater levels may become depressed when mine dewatering occurs in the vicinity of alluvium. If those groundwater levels intercept the thalweg and lead to intermittent flow, then those intermittent flows could be affected or reduced accordingly. An example of water level changes in association with mine dewatering can be ascertained from Figure 21 which shows water level changes in selected East Fork Armells Creek alluvial wells. The figure shows that alluvial groundwater levels tend to decline when mining activities are closest to the alluvial wells. For example, mining closest to well WA-114, which is located between Area A and B, was conducted in 1984 and the graph shows a decline in water level between 1980 and 1985. Water levels in the two alluvial wells (WA-209 and WA-104) between Areas B and C show a more gradual decrease. Note also that some of the water level changes (e.g., prior to 1992) are most likely due to changes in climate.

When the Area B Permit was written in 1986, the East Fork Armells Creek was described to possess two short segments respectively within Sections 8 and 15 (T1N, R40E) which had continuous base flow during much of the year ranging from no flow to about 30 gpm. A recent field survey (Section 3.2.1) of EFAC showed no flow in Section 15. The previous PHC (WECo, 1986) described the source of the flow as alluvium with possible contribution of the Rosebud coal in Section 15. Given the decreased water levels in alluvial wells between Areas B and C, it is possible that the change in flow is a

result of mine related dewatering. With regard to Section 8, alluvium in that vicinity is bounded by overburden and this alluvium is most likely hydraulically isolated from the Rosebud coal being mined. Hence, it is deemed as unlikely that any declination of flow in EFAC at this location is a result of mining. Rather, it is associated with presence or absence of stored surface water in the rather sizeable pond observed in Section 8 which captures water from the ephemeral runoff events.

Ephemeral flow from lateral tributaries into the EFAC will be affected by mining as flow from such tributaries is detained by sediment control ponds. Hence, some temporal flow will not reach to the EFAC alluvium. As a result, recharge in the alluvium will be reduced. However, there would be some recharge in the vicinity of the sediment control ponds. The degree that "natural" recharge would be offset by recharge from the sediment ponds cannot be quantified.

Another mining-induced factor affecting alluvial groundwater levels, which in turn may affect surface water flows, is associated with the Mine's MPDES discharges. Mine staff report that even relatively large discharges are observed to infiltrate from the channel to the alluvium over relatively short distances and time periods. Hence, this infiltration acts to recharge the underlying alluvial groundwater which in turn causes increased water levels.

Given that there are non-mining factors affecting the alluvial water level observations (e.g., climate and pre-existing ponds), it is sometimes difficult to differentiate mining induced observations from those associated with non-mine factors. Climatic factors such as periods of drought and high precipitation influence alluvial groundwater levels, which in turn may impact surface water flows. In general, groundwater levels decline in response to drought and then increase upon wetter climate. The groundwater levels changes in WA-118 upstream from Area B and C (Figure 21) are most likely in response to climatic factors.

3.3.1.2 Long Term Impacts – After Mining

No long term impacts on surface water flow are expected to result from mining activities. Following mining, the disturbed lands are reclaimed and tributary surface runoff is no longer detained. As the main-stem channels (e.g., EFAC) are not significantly physically disturbed (e.g., not mined out), runoff reaching the channel will infiltrate to the alluvium similar to premine conditions.

Tributary drainages will be restored during reclamation and flow patterns reestablished, including incised drainages that collect runoff and sediment from uplands and transport these to the primary drainages. Reclamation revegetation will mimic premine conditions and provide for similar surface runoff rates and volumes.

The tables presented in Attachment G compare the pre and postmine geomorphology, drainage basin characteristics, and runoff. These evaluations demonstrate that the postmine surface water flows will be essentially the same when compared to premine, as the reclamation will result in similar geomorphic and hydraulic characteristics.

Ephemeral flows, which are infrequent and occur in response to precipitation events and snowmelt, are mainly influenced by climate. More specifically, the ephemeral flows reflect the nature of the snow accumulation and melt and higher intensity precipitation events. These factors are independent of mining activities and these surface water flows should be essentially the same as premine upon completion of reclamation.

Following mining, it is projected that alluvial groundwater will return to pre-mine levels. This is demonstrated by referring to Figure 21 which illustrates that alluvial groundwater levels between Areas A and B are recovering as mining moves further away. In the case of well P-04, which has the longest period of record, and wells WA-101, WA-128 and WA-124, water levels have increased slightly above initial measurement levels. This may be a result of the previously described factors (e.g., MPDES discharges) that led to increasing alluvial groundwater during mining.

Given that the alluvial groundwater levels will recover, the pre-mine conditions that led to the intermittent flow reaches before mining commenced will be re-established.

3.3.2 Surface Water Quality

As noted previously, tributary flows are intercepted during mining. Implementation of the hydrologic control plan as mining progresses will minimize current and future impacts to surface water.

During mining, sediment control measures, including pits, sediment ponds, etc. will protect water quality at the primary drainages such as East Fork Armells Creek. Planned and unplanned discharges will occur in compliance with mine MPDES discharge permit requirements.

Long-term surface water quality will return essentially to pre-mine conditions. Reclamation revegetation will control erosion and protect water quality.

The comparison of premine to postmine geomorphology, drainage basins, and runoff provided in Attachment G shows that the postmine hydrology is essentially the same as premine. When combined with reclamation revegetation, the postmine water quality will be similar to premine.

Generally, the quality of the surface water at the Mine is highly variable, due to the nature of the flows. As such, statistically significant correlations of changes in surface water quality to mining were not observed. It should be noted that continued monitoring, data collection and evaluation will allow identification of trends should they occur.

As discussed in the Section 4.0 (Groundwater), the alluvial groundwater quality shows potential impacts from mining. Changes in alluvial groundwater quality have potential to negatively impact surface water quality.

3.3.3 Springs

Evaluation of spring monitoring data does not result in the identification of changes in water quality or water quantity associated with mining. Continued monitoring will allow ongoing evaluation of changes to spring water quality and quantity.

Observations show new springs may develop in reclaimed areas. The water quality of these springs is similar to the spoils water quality at that location.

3.3.4 Erosion and Sediment Yield

Water quality is protected by the implementation of hydrologic control plans to intercept and treat storm water discharges. The comparison of premine to postmine geomorphology, drainage basins, and runoff that is provided in Attachment G shows that postmine hydrologic function will be very similar to premine. When combined with the revegetation of disturbed lands, the mine reclamation will result in similar erosion and sediment yield to premine conditions.

4.0 GROUNDWATER

4.1 Regional Setting

The Rosebud Mine is located in the northern portion of the Powder River Basin. Regional hydrology is reported in the USGS Area 49 Hydrologic Investigation (USGS, Slagle et al., 1983).

4.1.1 Regional Hydrogeology

Principal geologic units include the Fort Union Formation, Hell Creek Formation, Fox Hills Sandstone and Bearpaw Shale., Coal beds are generally found in the Tongue River Member of the Fort Union Formation. On a regional basis, the majority of water use is from alluvium and Tongue River consolidated deposits. The alluvial groundwater tends to flow in relation to surface topography towards streams and drainages. In deeper aquifers, groundwater tends to flow to the north and towards the Yellowstone River.

4.1.2 Regional Water Quality

Slagle (1983) reports that groundwater at depths greater than 200 feet is generally dominated by sodium and bicarbonate with TDS concentrations ranging from 400 to 5,700 mg/L (average of 1,400 mg/L).

Shallower water from recharge areas is characterized by higher TDS concentrations with averages ranging from about 1,500 to 2,000 mg/L.

Generally, these concentrations result in the classification of the groundwater as Class II or Class III, which may limit use for human consumption and some irrigation.

4.2 Mine Area Hydrogeology

4.2.1 Geology

The Tongue River Member of the Fort Union consists of fine-grained sandstone with thinner interbeds of yellowish brown, orange, or tan siltstone; light-colored mudstone, and clay; and coal beds. The sandstone tends to be massive or cross-bedded. The main coal beds and adjacent consolidated strata of interest for the given project are part of this member.

The specific hydrogeologic units include components of the Tongue River Member and these units are designated as:

- overburden
- clinker (generally contiguous with coal strata)
- Rosebud coal
- interburden
- McKay coal
- sub-McKay

Another key geologic feature found within the footprint and the vicinity of the Rosebud Mine includes unconsolidated alluvium.

Figure 11 illustrates the key hydrogeologic units and the mining process.

4.2.2 Local Hydrogeology

Groundwater at the Rosebud mine occurs in shallow alluvial and colluvial deposits found in drainage bottoms and in Fort Union Formation consolidated deposits as discussed below:

4.2.2.1 Alluvium

The unconsolidated geologic deposits of main hydrologic interest in the immediate vicinity of the Rosebud Mine are of Quaternary age and consist of alluvium and colluvium. The main water-bearing unit is the alluvium which can vary widely in thickness being generally less than 15 feet but it can be up to 35 feet in some areas (Vuke, et al 2001). Water-bearing alluvial deposits are present in the main drainages transecting the Rosebud Mine area which includes East Fork Armells Creek and its tributaries (refer to Figure 9). The most transmissive alluvial aquifer sequence adjacent to the Rosebud Mine is likely contained in the main stem of East Fork Armells Creek where it is bounded by Area C to the north and Areas B and B-extension to the south.

Water bearing zones of interest in the permit area are the Rosebud overburden and Rosebud coal. The alluvial aquifer associated with East Fork Armells Creek will be disturbed by mining along a short distance of the upper terrace parallel to East Fork

Armells Creek in Sections 10 and 15 (T1N, R40E). Major changes in ground water storage in the East Fork Armells Creek alluvium, however, are not expected and will not be considered here. Mining will disturb the West Fork Armells and Stocker channels in the upper reaches of the watershed. During mining, infiltration and discharge from sedimentation ponds and mine pits should mitigate the disruption of the headwater drainages. Impacts of disrupting the thin and discontinuous alluvium in Upper West Fork Armells and Stocker Creeks will have little effect on alluvial water levels downstream of the mining areas.

4.2.2.2 Clinker

Clinker deposits are red, pink, orange, black, and yellow, very resistant metamorphosed sandstone, siltstone, and shale of the Fort Union Formation. Bedrock was baked by natural burning of underlying coal, and collapsed into voids created by the burning. Clinker thickness ranges from as little as 10 feet up to 300 feet (Vuke, et al, 2001). From a hydrogeologic perspective these deposits are very permeable. Generally, the saturated thickness of clinker deposits at the Rosebud Mine is very limited. Groundwater that is present in these deposits at the Rosebud Mine tends to be perched water which is generally hydraulically isolated from the underlying strata.

Clinker is also relevant as portions of it are present in alluvial deposits. Owing to the relatively coarse nature of this clinker, the transmissivity of the alluvial deposits tends to be much higher when compared to the consolidated stratum that bounds the alluvium.

4.2.2.3 Rosebud Coal/Interburden/McKay Coal

The overburden, Rosebud Coal, interburden, and the McKay Coal (and sub-McKay) are all strata from the Tongue River Member of the Fort Union Formation. The Tongue River Member can be as thick as 540 feet. These units yield low quantities of water but at sufficient rates to provide domestic and stock well water supplies. Low yield springs also occur at outcrops from these deposits and they are frequently used for stock water supply purposes.

In the immediate vicinity of the mine, the alluvium, overburden and the Rosebud Coal are the strata most directly affected by the mining process.

4.2.3 Hydraulic Properties

Groundwater levels have been monitored at Rosebud since 1974. Table 13 lists and Figure 22 shows the locations of groundwater monitoring sites in Areas A, B and C. Monitoring wells are classified according to hydrostratigraphic units including:

- Alluvium
- Overburden
- Spoils
- Rosebud Coal
- Interburden
- McKay Coal
- Sub McKay

Figure 23A depicts simulated groundwater levels prior to mining in Areas A, B, and C. Figure 23B shows an interpretive potentiometric map based on current monitoring well data.

Hydrographs for Rosebud Mine monitoring wells are shown in Figures 5 through 14 of the Rosebud Mine Ground-Water Model Report found in Attachment D. The report contains a detailed review of well water level data collected by Western Energy up to 2011. The following is a summary of the analysis of well hydrographs in the Rosebud Mine area:

- Alluvial well water levels seem to be influenced mainly by climatic factors. Some wells in the East Fork Armells Creek alluvium appear to have responded to dewatering/mining activities in nearby areas.
- The majority of overburden wells have not been responsive to nearby mining activities. Wells that have responded are located very near active high walls.
- The response of Rosebud Coal wells to nearby mining has been variable. Wells that are most responsive are located relatively near mine pit high walls.
- The majority of interburden and McKay Coal wells have not responded to nearby mining activities. Exceptions are wells located very near active high walls.
- In general, water levels in most non-dry spoil wells have been increasing, with

the most dramatic increases in wells in the vicinity of the East Fork Armells Creek.

- The radius of influence of mining activities on water levels seems to be relatively greater in areas south of Area B and Area B extension. This observation can be explained by the degree of confinement of the Rosebud Coal and underlying strata. Southern portions of the mine tend to be more confined than the northern portions.

Figure 24 shows example hydrographs from the Montana's Groundwater Information Center (GWIC). The hydrographs illustrate drawdown in the Rosebud and McKay Coal wells, recovery in the spoils wells and seasonal influences in alluvial wells. A more in depth discussion of the predicted magnitude of the drawdown response to mining is presented in section 4.3.1.

4.2.4 Groundwater Quality

4.2.4.1 General Water Quality Evaluation

The 1983 Slagle Area 49 study provides some regional baseline groundwater quality data. Slagle data are summarized in Table 14 and provide a reference to pre-mine conditions.

Table 13 summarizes and Figure 22 shows the locations of groundwater monitoring points at Rosebud Mine. Tables 15A, 15B, and 15C provide statistical summaries of groundwater quality by hydrogeologic unit for mine Areas A, B and C, respectively. A sample is considered to represent baseline conditions if it was collected before mining approached within 0.5 miles. There were only three overburden samples (in Area A) and no interburden and sub-McKay samples meeting this criterion, as mining started in 1975. Table 16 shows the statistical water quality summary of the alluvium.

Review of the data shows that the groundwater quality varies significantly depending on mine area and geologic stratum. An example of this is the groundwater in the overburden and Rosebud coal in Area C as compared to Areas A and B. The average TDS and sulfate concentrations are lower in the Areas A and B overburden and Rosebud coal.

In Area A, with the exception of sodium, the average major ion concentrations and the TDS concentration in the spoils is higher than in the overburden after mining. The

standard deviations and range between minimum and maximum values in Area A is high, with exception of those of the sub-McKay samples.

In Area B, the average major ion concentrations and the TDS concentration in the spoils is higher than in the overburden baseline. Initial comparison of baseline average data with average after mining data indicates that interburden, McKay and sub-McKay groundwater quality is not affected by mining. Rosebud groundwater quality may be affected. Additional analysis is performed below to better characterize the nature of potential impacts.

In Area C, the average major ion concentrations and the TDS concentration in the spoils is higher than in the overburden baseline. Comparison of baseline average data with average after mining data indicates that McKay and sub-McKay groundwater quality is not affected by mining. Rosebud coal and interburden groundwater quality may be affected. Additional analysis is performed below to better characterize the nature of potential impacts.

4.2.4.2 Detailed Groundwater Quality Evaluation

Total Dissolved Solids

To evaluate changes in water quality over time, time series graphs of total dissolved solids concentration (TDS) were created for all wells in Areas A, B and C for which more than two data points are available and for all Area D and E spoils wells. The concentration of TDS was used as an indicator compound for water quality.

TDS is the main water quality indicator parameter used in several hydrogeological studies in the area (Van Voast et al. 1988, Van Voast et al. 1977). The TDS concentration is an indicator of the degree of mineralization of the water. The major chemical constituents in the groundwater in the Fort Union Formation and other shallow aquifers in southeastern Montana are: calcium, magnesium, sodium, sulfate and bicarbonate. They comprise typically more than 97% of all dissolved constituents in the groundwater. Carbonate, potassium and chloride are also common, but usually in very low concentrations (Van Voast et al., 1988).

The quality of groundwater in the Colstrip area is a product of salt dissolution and, to a lesser degree, cation exchange. Salts are produced in recharge areas by weathering and oxidation and are then dissolved by percolating groundwater. Groundwater in

recharge areas is characterized by relatively higher calcium, magnesium and bicarbonate concentrations (see also Area 49 report). Salt dissolution in the Colstrip area typically results in increased sulfate concentrations as groundwater percolates, whereas cation exchange in the Colstrip area can increase sodium concentrations with depth (Van Voast et al., 1988).

TDS is generally linearly correlated to the specific conductivity (SC) of the water. Figure 25 shows a plot of TDS versus SC and illustrates this linear correlation. Specific conductivity is also used for classification of the groundwater in beneficial use classes (Table 17).

The analyte TDS is the main indicator of water quality. Time series for the other major ions concentrations listed in Tables 15A through 15C and Table 16 were created when upward trends in TDS were observed. TDS time series graphs for different hydrogeologic units are presented in the following figures:

- Figure 26: selected overburden, McKay coal and sub-McKay wells
- Figures 27A through 27E: Area A, B and C Rosebud coal wells
- Figures 28A through 28E: Area A, B and C interburden wells
- Figures 29A and 29B : Area A, B, C, D and E spoils wells
- Figures 30A through 30C : East Fork Armells Creek alluvial wells
- Figure 31: Stocker Creek alluvial wells
- Figures 32A and 32B : West Fork Armells Creek alluvial wells

The following sections provide a detailed discussion of changes in water quality for each hydrogeologic unit, using TDS as the indicator parameter.

Overburden

TDS time series graphs for all Area A, B and C overburden wells were generated using the Rosebud Mine Water Monitoring Database. Well locations in relation to mining progression over time were analyzed when the time series graph showed increasing TDS concentrations. This evaluation showed that, in general, the water quality in overburden wells has not been impacted by mining. Two exceptions are (see Figure 26):

- WO-162, located south of mining activities in Area B, shows increased TDS

concentrations in recent years. The increase in TDS concentration is mainly due to increased sulfate concentrations. The hydrograph for this well shows decreasing water levels starting in 1998. At this time mining was occurring about 0.25 miles from this well. The recent change in TDS concentrations in this well may be influenced by water level changes as a result of nearby mining activities.

- WO-165, located in Area C, showed an increase in TDS concentrations before it was mined out in 1999. The increase in TDS concentration was mainly due to increases in sulfate, magnesium and bicarbonate concentrations. The hydrograph for this well shows decreasing water levels starting in 1993. The changes in TDS concentrations in this well may be attributable to changing water levels as a result of nearby mining activities.

The evaluation of water quality time series of overburden wells generally shows that overburden water quality has not been impacted by mining.

Rosebud Coal

Figures 27A through 27E show time series graphs for TDS in Rosebud coal wells in Areas A, B and C.

Area A

Time series for wells WR-110, WR-111, WR-105 and WR-130 show no trends in TDS concentrations. Well WR-104 shows slightly elevated TDS concentrations for the most recent sampling years. This could be explained by the proximity of WR-104 to a mining pit and the relatively high precipitation during these latter sampling years.

TDS concentrations in well WR-127 are relatively higher than for the other Rosebud coal wells and show a gradual increase over the sampling period. The increase in TDS concentrations is due to an increase in all major ions concentrations. The well is located about 250 feet south of Area A spoils in close proximity to spoils well WS-113. TDS concentrations in spoils well WS-113 have increased from 3,500 to about 4,500 mg/L (Figure 29A). TDS concentrations in WR-127 increased from about 2,500 to about 4,000 mg/L. It is possible that the increase in TDS concentrations in the Rosebud Coal well is a result of spoils groundwater flowing into the coal at this location.

Area B

The TDS concentrations in about half of the wells in Area B have remained constant. The following wells show variable TDS concentrations:

- Well WR-124 shows a spike in 1985 and higher TDS concentrations in the two most recent samples. Since mining closest to this well occurred in the late 1990s, the spike is most likely not related to mining. Since the well is up-gradient from mining activities, the more recent increase is likely due to natural causes not related to mining.
- Well WR-116 shows a spike in TDS concentration in 1983. Since mining in the vicinity of this well did not start until the mid-1990s, the spike is most likely not related to mining.
- Well WR-164 shows an increase of TDS concentrations from 1987 to 1997. Since mining up-gradient from this well did not start until 1999 this increase is most likely not related to mining.
- Well WR-160 shows an increase in TDS concentrations from about 1980 to 1990. This increase occurred for all major ion concentrations with the exception of chloride. Mining north of the well occurred in the early 1980s and more recently since 2004. The hydrograph of this well shows a decrease in water level for both periods of mining, with a recovery period in between. It is likely that the groundwater quality in this well is influenced by changes in water level as a result of mining.
- Wells WR-205 and WR-207 are located adjacent to Area B spoils dating from the early 1980s. Well WR-205 shows variable TDS concentrations ranging from about 2,000 to about 3,000 mg/L. The limited data available for well WR-207 show slightly higher TDS concentrations. Hydrographs for both wells show seasonal variations of water levels for both wells. Spoils groundwater sampled from well WS-184, located about 400 feet from well WR-207 shows TDS concentrations ranging from about 1,500 mg/L to 2,500 mg/L (Figure 29A). Alluvial wells in the vicinity (WA-101 and WA-139) show highly variable TDS concentrations between about 350 and 2,500 mg/L (Figure 30B). Variable TDS concentrations in these Rosebud Coal wells could be influenced by TDS concentrations in both alluvial and spoils groundwater, however the variability of TDS concentrations suggests that alluvial groundwater may be more responsible.

Area C

With a few exceptions the TDS concentrations in Rosebud coal wells in Area C are relatively constant. The following wells have variable TDS concentrations:

- Well WR-103 is located up-gradient from mining activities near the East Fork Armells Creek. TDS concentrations in this well have generally decreased from about 6,500 and 3,500 mg/L. Because of its location, this change in TDS concentration is not likely related to mining activities.
- Well WR-121 shows a gradual increase in TDS concentrations from about 1980 to 1990, followed by a gradual decrease from 1997 to 2006. Mining northwest of this well started in 2000 and has progressed closer since then. A hydrograph of the well shows the water level has decreased in this well since 2000, likely as a result of the dewatering associated with mining activities. It is possible that the recent change in TDS concentrations is influenced by the change in groundwater levels associated with mining.
- Well WR-126 shows a considerable increase in TDS concentrations from about 2,000 to over 8,000 mg/L. The increase in TDS is caused by an increase in all major ion concentrations. Mining immediately up-gradient from this well occurred from about 1984 onward. No spoils groundwater quality data are available in the vicinity of this well, however since a potentiometric map (Figure 23B) shows that the well is located downstream from the spoils, the increased TDS concentration might be due to spoils groundwater flowing into the Rosebud coal aquifer.
- Well WR-169 shows a sharp drop in TDS concentrations in 1990, followed by a gradual increase in TDS until the well was mined out in 2000. Mining in the vicinity of the well started in 1990. A hydrograph of the well shows a drop in water level due to dewatering associated with mining starting around 1990, followed by a partial recovery as mining activities progressed further away. As was the case for WR-121, the decrease in water level was associated with a drop in TDS concentrations. Similarly, the partial recovery occurred at the same time as the gradual increase in TDS concentration.

Interburden

Figures 28A through 28E show time series graphs for TDS in interburden wells in Areas A, B and C.

Area A

Two wells in Area A show increases of TDS concentration in the interburden groundwater:

- The TDS concentration in well WI-111 decreased in the early 1980s and then increased again to the same level in the late 1990s. Mining south of the well occurred in the late seventies and mining west of the well occurred from the late 1980s to 2000. The hydrograph shows increasing water levels from about 1985 to 2000. It is likely that the changes in TDS concentrations in this well are a result of changes in water level. However, it is not clear if changes in water level are due to climate or a result of mining activities.
- Well WI-102 shows a gradual increase in TDS concentrations from about 2,000 to about 3,000 mg/L, with spikes around 3,500 mg/L. This increase in TDS is a result of increases of all major ion concentrations. The well is located at the edge of Area A spoils adjacent to spoils well WS-106. The TDS concentrations in spoils groundwater from WS-106 have remained relatively constant at about 3,000 mg/L (Figure 29A). It is likely that the increase in TDS concentrations in well WI-102 groundwater is influenced by TDS concentrations in spoils groundwater. However given the relatively constant TDS concentration measured at WS-106, it is not expected that the TDS concentrations at WI-102 will continue to increase.

Area B

The following wells in Area B show increases in TDS concentrations in the interburden groundwater:

- Well WI-157 is located in Area B spoils and adjacent to spoils well WS-157. TDS concentrations in the interburden groundwater from this well show a slight increase from 1,300 to about 2,000 mg/L. This increase in TDS concentration is due to increases in calcium, magnesium and bicarbonate concentrations. As discussed earlier, higher concentrations of these ions are typically associated with recharge areas. TDS concentrations in the spoils groundwater at this location have remained relatively constant at 2,500 mg/L and the average TDS concentration in the closest alluvial well (WA-125) is 2,245 mg/L. The hydrograph for well WI-157 shows a gradual water level increase of over 30 feet at this well during the sampling period. Comparison of water levels in this well to those in the closest alluvial well shows that the interburden is likely being recharged by the alluvial groundwater in this area.

The increase in TDS concentrations in the interburden groundwater at this location is likely largely due to inflow of alluvial groundwater and possibly to a lesser extent the overlying spoils groundwater.

- WI-159 is located in Area B spoils adjacent to spoils well WS-159. TDS concentrations in the interburden groundwater from this well have increased from about 2,500 to 4,500 mg/L. The increase in TDS concentration in this well is mainly due to increases in sulfate and magnesium concentrations. The TDS concentration in the spoils groundwater at this location has increased from about 3,800 to 4,300 mg/L. It is possible that the increase in TDS concentrations in the interburden groundwater at this location is influenced by TDS concentrations in the overlying spoils.
- Well WI-160 is located south of Area B spoils and adjacent to Rosebud coal well WR-160. TDS concentrations in interburden groundwater at this location increased slightly from the early 1980s to the early 1990s and have remained relatively constant since then. A similar increase was seen for the adjacent Rosebud coal well WR-160. The hydrograph of WI-160 shows decreases in water level for two periods of mining, with a recovery period in between. It is likely that the groundwater quality in this well is influenced by changes in water level as a result of mining.
- Well WI-184 is located in Area B spoils adjacent to spoils well WS-184. TDS concentrations in both the interburden and spoils groundwater at this location have increased from about 1,500 to about 2,350 mg/L. The increased TDS concentration is due to an increase in all major ion concentrations with the exception of bicarbonate. It is likely that TDS concentrations in the interburden groundwater at this location are influenced by TDS concentrations in the overlying spoils.
- Well WI-164 is located adjacent to Rosebud coal well WR-164 and south of current mining activities. Comparison of time series graphs for both wells show that TDS concentrations in WI-164 are very similar to TDS concentrations in WR-164. As was discussed earlier these changes are not likely related to mining activities.

Area C

The following wells in Area C show increases in TDS concentration in the interburden groundwater:

- Well WI-153 is located adjacent to Rosebud coal well WR-126 and north of

Area C spoils. No water quality data are available for WS-122; the closest spoils well located about 600 feet south of WI-153. TDS concentrations in interburden groundwater at this location increased from about 1,500 mg/L to about 2,500 mg/L in the 1980's when mining activities were occurring in the vicinity of the well. This increase was observed for all major ion concentrations with the exception of bicarbonate. Since this increase, TDS concentrations have remained relatively constant. It is possible that the increase in TDS in the 1980's is related to mining activities occurring up-gradient from this well.

- Well WI-181 is located adjacent to Rosebud coal well WR-181. The two most recent interburden groundwater samples at this location showed an increased TDS concentration. Since this well is located up-gradient from mining activities, this increase is not likely related to mining activities.
- Well WI-186 is located in Area C spoils adjacent to spoils well WS-186. No spoils water quality data are available in the vicinity of this well. From 1995 to 2007 the TDS concentration in the interburden groundwater at this location increased considerably from about 500 to 4,670 mg/L (2007). This change is due to increased concentrations of chloride, sulfate, magnesium and calcium. Mining in the immediate vicinity of this well started in 1984. It is possible that the increase in TDS concentrations in this well is due to infiltration from spoils groundwater.
- Well WI-180 is located in the western corner of the permit boundary in Area C and shows considerable variations in TDS concentration. Since mining activities in this area did not start until 2008, these variations are likely caused by natural processes not related to mining.

McKay coal

TDS time series graphs for all Area A, B and C McKay coal wells were generated using the Rosebud Mine Water Monitoring Database. Well locations in relation to mining progression over time and well logs were analyzed when the time series graph showed increasing TDS concentrations. This evaluation showed that, in general, the water quality in McKay coal is not impacted by mining. However, there are a few instances in which McKay coal wells showed upward trends in TDS that could be related to nearby mining activities (see Figure 26):

- Groundwater from WM-106, located in Area B, showed an increase in TDS concentrations before the well was mined out. The increase in TDS in the

McKay groundwater at this location may be influenced by upgradient mining activities. The log for well WO-106 indicates that the interburden at this location is relatively thin at approximately 17 feet.

- WM-157 is located in Area B spoils just south of the EFAC and is paired with WI-157 discussed earlier. TDS concentrations in this well increased slightly before it was abandoned. The log for this well shows an interburden thickness of 16 feet. It appears that the increase in TDS concentration in McKay groundwater at this location is due to flow through the interburden.

- Groundwater from WM-161, located in Area B, showed an increase in TDS concentrations before the well was mined out in 2002. The increase in TDS in the McKay groundwater at this location may be influenced by upgradient mining activities. The log for well WM-161 indicates that the interburden at this location is relatively thin, at approximately 20 feet.

- WM-184 is screened in the McKay coal beneath Area B spoils just south of the EFAC alluvium and is paired with interburden well WI-184 discussed previously. In recent years the TDS concentration in the McKay groundwater at this location has increased to about 1,500 mg/L. The log for this well indicates an interburden thickness of 40 feet at this location. However, the interburden just north of this well may be truncated by alluvium, resulting in a smaller effective thickness of the interburden in proximity of WI-184. It appears that the recent increase in TDS concentrations in WM-184 is due to infiltration from the interburden groundwater at this location.

- WM-186 is screened in the McKay coal beneath Area C spoils and is paired with spoils well WS-186 and interburden well WI-186. The TDS concentration in the McKay groundwater at this location has increased to from about 500 mg/L to a maximum value of about 2,500 mg/L. The log for this well indicates an interburden thickness of about 24 feet at this location. It appears that the increase in TDS concentrations at this location is due to infiltration from interburden groundwater at this location.

The detailed evaluation of water quality time series of McKay coal wells shows that, in general, McKay coal groundwater quality has not been impacted by mining activities.

Exceptions seem to occur in areas where the thickness of interburden separating the Rosebud coal or spoils and McKay coal is thin. In these areas the McKay coal groundwater seems to be more vulnerable to impacts from mining.

Sub-McKay

TDS time series graphs for all Area A, B and C sub-McKay coal wells were generated using the Rosebud Mine Water Monitoring Database. Well locations in relation to mining progression over time and well logs were analyzed when the time series graph showed increasing TDS concentrations. In general, there are no changes in sub-McKay groundwater quality as a result of mining activities. The analysis isolated one well showing an increasing TDS trend that could be due to by nearby mining (see Figure 26). Well WD-186 is paired with McKay coal well WM-186 discussed above. Both wells show similar increases in TDS concentrations. It is likely that the same geologic factors increasing the vulnerability of McKay groundwater to impacts from mining also contribute to the vulnerability of sub-McKay groundwater.

Spoils

Time series graphs for TDS concentrations in spoils wells are shown on Figures 29A and 29B. With a few exceptions, spoils groundwater contains substantially higher TDS concentrations than does groundwater in undisturbed aquifers. Tables 15A through 15C show that the constituents that comprise most of the changes are sodium, calcium, magnesium and sulfate. Figures 29A and 29B show that the water quality in the new mine spoils is highly diverse with TDS concentrations between 1,000 and 9,000 mg/L.

Time series graphs show that TDS concentrations in most spoils wells vary over time. This attests to the newness of the spoils and their poor chemical equilibrium with recharge water (Van Voast, 1988). Figures 29A and 29B show the following types of time series graphs:

- Decreasing trend (e.g. WS-112), which occurs when salts are leached by groundwater more rapidly than they are replenished by recharge.
- Increasing trend (e.g. WS-100), which occurs when soluble weathering products are introduced more rapidly than they can be flushed from the system.
- Variable (e.g., WS-114), which can occur when TDS varies as a result of water level changes. This is more likely to happen when the groundwater flow rate

is slower and if recharge rates are less.

- Stable (e.g. WS-106), which may attest to the establishment of some degree of equilibrium.

Alluvium

East Fork Armells Creek Alluvium

Within the Rosebud mine the East Fork Armells Creek bed is located between mine Areas A and B, and B and C. The alluvium in this area consists of sand and gravel beds overlain by beds of silt and clay. The thickness of the alluvium can be as high as 40 feet. Groundwater flow in the alluvium of the East Fork Armells Creek is almost parallel to the watercourse. Recharge of the alluvium occurs vertically by streamflow and precipitation and laterally from other aquifers (Van Voast et al., 1977).

Between Areas A and B, near alluvial wells P-03, P-04 and P-05, the alluvial gravel cuts into the McKay coal, and as a result, the gravel in this area is recharged directly by the McKay coal (see also Section 3.2.1). Before mining started in this area, the alluvial groundwater at this location was chemically very similar to the McKay coal groundwater. Alluvium is also recharged indirectly by water from the Rosebud coal subcrop and the stream channel (Van Voast et al., 1977). Nearby mining activities which are usually associated with dewatering can temporarily cause the recharge from the Rosebud coal to cease. After mining activities have ceased and groundwater levels reach equilibrium, indirect recharge from the spoils might impact alluvial groundwater quality at this location.

Between Areas B and C, in the vicinity of alluvial well WA-122, the alluvial gravel lies on top of the Rosebud coal. Upstream from this location, the alluvium is isolated from the Rosebud coal by the overburden. Recharge from the overburden, which is characterized by much lower hydraulic conductivities compared to the Rosebud coal, is expected to be relatively small in these areas. As a result, it is expected that mining activities will not impact the water quality of the alluvial groundwater at this location.

Between the two cross sections described above, the potential impact of mining activities on the alluvial water quality is expected to increase gradually moving downstream along the East Fork Armells Creek alluvium.

Figures 30A, 30B and 30C show TDS concentrations for alluvial wells along the East

Fork Armells Creek. Table 16 gives an overview of the water quality statistics for the drainages of concern. Water quality statistics for East Fork Armells Creek are separated by location: upstream, between Areas B and C, between Areas A and B, and downstream from the mine. TDS concentrations in wells up-gradient from mining activities are relatively constant with an average value of 1,864 mg/L. Within the mine area, TDS concentrations area are more variable, with average TDS concentrations of 2,544 and 2,784 mg/L, between Areas A and B, and B and C, respectively. The highest TDS concentrations are observed in alluvial groundwater near the town of Colstrip. The average TDS concentration downstream from the mine is 4,084 mg/L. Evaluation of water quality in wells around Colstrip is outside the scope of this PHC.

General analysis of the available TDS time series and well hydrographs shows that alluvial water quality is likely impacted by mining activities. Examples of processes that might cause TDS concentrations in alluvial groundwater to change are explained below.

- After conclusion of mining activities, overburden material is backfilled and spoils water levels typically show a gradual increase until they reach equilibrium. If alluvial water levels in the vicinity of the spoils are lower than the spoils groundwater levels, spoils groundwater could be flowing into the alluvial groundwater. Since spoils groundwater typically has higher TDS concentrations, this could cause an increase in TDS concentration in the alluvial groundwater. Comparison of groundwater levels at alluvial well WA-131 and WS-113 indicates that this might be happening at well WA-131.

- Mining activities are usually associated with some form of dewatering. If mining occurs near the alluvium, these dewatering activities can cause alluvial groundwater to flow towards the active mining and influence the quality of Rosebud Coal or interburden groundwater. This type of alluvial recharge would likely continue until active mining moves further away and water levels in the spoils increase enough to cause the direction of groundwater flow to reverse again. Comparison of groundwater levels at alluvial well WA-125 and interburden and spoils wells WI-157 and WS-157 shows that the alluvium is likely recharging the interburden and spoils at this location.

- The decrease in water levels in the alluvium as a result of dewatering activities in one nearby mine area might cause groundwater from other mining areas to flow towards the alluvium. If that groundwater originates in the spoils, this

might cause TDS concentrations in the alluvium to increase even if groundwater flows from the alluvium towards the closest mining activities. Comparison of groundwater levels in alluvial well WA-128, with those of spoils wells WS-114, WS-106 and WS-118 shows that this might be happening at this location.

Stocker Creek Alluvium

The Stocker Creek alluvium is located in Area C and north of mine Areas A and C. Time series graphs for TDS concentrations are shown on Figure 31. Table 16 gives water quality statistics for the Stocker Creek drainage. The average TDS concentration in the Stocker Creek alluvial groundwater is 2,719 mg/L. TDS concentrations for the alluvial wells in Area C are between 1,500 and 3,500 mg/L (WA-110, WA-111 and WA-217). Groundwater in wells WA-164 through WA-170 has generally higher TDS concentrations between 2,200 and 6,040 mg/L. The earliest mining up-gradient from these wells occurred in 1984, therefore any TDS concentrations measured before that time can be considered baseline values. The TDS concentrations in wells WA-169 and WA-170 seem to be impacted by changes in precipitation, as is illustrated by higher TDS concentrations measured during relatively wetter years.

The time series graphs do not show any long term upward trends in TDS concentrations. Possible exceptions are wells WA-108, WA-109 and WA-167. Given the distance of these wells from the Rosebud coal outcrop to the south, it is highly unlikely that the increase is related to mining activities.

West Fork Armells Creek

The West Fork Armells Creek alluvium is located north of the western portion of Area C. Mining at this location did not start until 2008, so any groundwater samples taken before this date can be considered baseline. Figures 32A and 32B show time series graphs for TDS concentrations in the West Fork Armells Creek drainage and Table 16 summarizes water quality statistics for the drainage. The average TDS concentration in the alluvial groundwater is 3,372 mg/L, which is higher than measured in the Stocker Creek alluvium and the East Fork Armells Creek alluvium within the mine. TDS time series do not show any long term increasing trends for the groundwater in the West Fork Armells Creek alluvium.

Other Major Ions

Comparison of averages of baseline and after mining major ion concentrations shows that the chloride concentration in the Rosebud coal in Area A increased disproportionally compared to TDS. Similarly, comparison of average upstream major ion concentrations for East Fork Armells Creek alluvial groundwater with average major ion concentrations in the alluvium between Areas B and C and between Areas A and B shows that the chloride concentration between Areas A and B increased disproportionally compared to TDS. Chloride time series for all active alluvial monitoring wells between Areas A and B and Rosebud wells in Area A are presented in Figure 33. Note that Area A Rosebud coal well WR-130 is not shown on the figure as it is located in the central part of Area A. Chloride concentrations in this well have remained relatively constant.

The wells showing increases in chloride are located in the vicinity of the facilities area in Area A. The highest chloride concentrations are observed in alluvial wells P-03 through P-05. The chloride concentrations in these wells exceed those in the nearest upgradient spoils well WS-115, in which a maximum chloride concentration of 50 mg/L has been observed. The highest chloride concentration in Area A spoils groundwater is 79.9 mg/L (Table 15A) at WS-114. This indicates that the increase in chloride in this area cannot be explained solely by infiltration from spoils groundwater. A potential source of chloride is magnesium chloride which was used until recently for dust control purposes at Rosebud Mine. A portion of the chloride may have entered the shallow groundwater via runoff from the road bed and possibly from infiltration through the road bed. All wells with elevated chloride concentrations in Figure 33 are located in close proximity to a road. The aerial photograph of this area also shows the presence of several small sediment impoundments or traps next to the main haul roads. Although no recent water quality data are available for these ponds, collection of runoff water from the road followed by evaporation could increase the chloride concentrations in these ponds. The use of magnesium chloride as a dust suppressant has been discontinued at Rosebud Mine. Assuming magnesium chloride is responsible for the disproportionate increases in chloride concentrations, it is expected that elevated chloride concentrations will slowly attenuate with time.

4.2.4.3 Water Quality Standard Exceedances

Table 18 shows exceedances of Circular DEQ-7 (Montana Numeric Water Quality

Standards [October 2012 edition]) Human Health Standards for groundwater. The WECo water quality database contains data for a total of 3,853 groundwater samples, with sampling dates ranging from 1975 to 2011.

The following DEQ-7 (October 2012 edition) water quality standards were evaluated:

Element / Chemical Compound	DEQ-7 Human Health Standard (mg/L)
Arsenic (As)	0.01
Cadmium (Cd)	0.005
Chromium (Cr)	0.1
Copper (Cu)	1.3
Fluoride (F)	4
Lead (Pb)	0.015
Mercury (Hg)	0.002
Nitrate Nitrogen (NO_3-N)	10
Nitrate plus Nitrite Nitrogen (NO_3-N + NO_2-N)	10
Selenium (Se)	0.052
Zinc (Zn)	2

DEQ-7 standards for arsenic, cadmium, fluoride, lead, nitrate plus nitrite and nitrate nitrogen, selenium, and zinc concentrations in groundwater in the Rosebud Mine area have been exceeded. The number of exceedances and the maximum concentration is given in the table below:

Standard	Max Value (mg/L)	Number of Exceedances
Arsenic (As)	0.1	12
Cadmium (Cd)	0.24	63
Fluoride (F)	801	3

Lead (Pb)	0.67	74
Nitrate Nitrogen (NO_3-N)	12	1
Nitrate plus Nitrite Nitrogen	351	24
Selenium (Se)	0.18	3
Zinc (Zn)	8.61	33

There are two wells with more than one sample containing arsenic concentrations higher than the DEQ-7 (October 2012 edition) standard: sub-McKay Coal well WD-195 and interburden well WI-153. The arsenic concentrations in WD-195 range from 0.013 to 0.019 mg/L. Since these samples were taken before mining activities started within 0.5 mile of the well, the concentrations are considered baseline. The arsenic concentrations in well WI-153 range from 0.0089 to 0.018 mg/L and show no persistent trend.

Sixty-eight percent of cadmium exceedances occurred in alluvial groundwater, however cadmium concentrations in excess of DEQ-7 (October 2012 edition) standards were found in groundwater obtained from all geologic strata. Van Voast et al. (1977) reported cadmium concentrations in the groundwater from Colstrip area of 0.01 mg/L or lower. Table 18 shows that 13 samples have cadmium concentrations higher than 0.01 mg/L. No long term trends are observed for any of the wells with more than one sample containing cadmium concentrations in excess of DEQ-7 (October 2012 edition) standards.

The exceptionally high fluoride concentration of 801 mg/L was detected in well WA-118 in 2004. Since the 13 other samples taken from this well contain fluoride concentrations below DEQ-7 (October 2012) standards, it is likely that this high value is due to a laboratory quantification error. The second highest fluoride concentration was 13 mg/L, which was found in groundwater sampled from interburden well WI-102.

The lead exceedances occur in all geologic strata. The Van Voast report from 1977 mentions that higher lead concentrations do occur naturally in the area, but states that the waters associated with the mine spoils might contain higher concentrations and that the lead concentrations could be more diverse in the mined area water. Thebaseline lead concentrations reported by Van Voast et al. range from less than 0.05 to 0.11 mg/L. Lead concentrations in mined areas ranged between less than 0.05 to 0.21 mg/L.

The highest baseline lead concentration in samples collected by WECo is 0.18 mg/L (WI-166). Groundwater samples from McKay coal well WM-158, interburden well WI-162 and alluvial WA-204 contained a lead concentration higher than this baseline value. None of these wells show a persistent trend in lead concentrations.

Nitrate plus nitrite nitrogen exceedances were found mostly in alluvium along the EFAC and spoils wells. The maximum value of 351 mg/L was detected in a sample from alluvial well WA-113. The most recent samples from this well contain nitrate plus nitrite nitrogen concentrations below the DEQ-7 (October 2012 edition) standard. The highest nitrate plus nitrite nitrogen concentration measured in spoils wells is 50 mg/L. High nitrate plus nitrite nitrogen in spoils could possibly be due to dissolved residuals from ammonium-nitrate explosives used in blasting coal and overburden.

Two exceedances of the DEQ-7 (October 2012 edition) standard for selenium were found in alluvial wells and one sub-McKay well. The highest selenium concentration of 0.18 mg/L was measured in a sample taken from alluvial well WA-119. Since the closest mining was occurring at least two miles down-gradient from this well when this sample was taken, it is highly unlikely that this selenium concentration is related to mining activities.

Zinc exceedances were found mostly in coal strata and interburden wells. The highest baseline zinc concentration found in samples collected by WECo is 5.45 mg/L (WD-179). No samples contained zinc concentrations in excess of this baseline value.

4.2.5 Groundwater Use

A comprehensive list of all groundwater users within an area three miles downgradient and one mile upgradient from Areas A, B and C is included in Attachment F. The list was composed using the Montana Groundwater Information Center (GWIC) dataset and the National Resource Information System (NRIS) water rights dataset. Wells owned by WECo and wells mined out before 2013 are not included in the list.

Most of the groundwater users in this list are monitoring wells or wells owned by industrial users (Montana Power Co., Northern Pacific Railway Co., Peabody and Big Sky Coal Co., PPL Montana, B.N.S.F.). The main uses for the remaining groundwater wells are livestock watering and domestic use. Some wells may be removed during mining and will be replaced during reclamation.

4.3 Probable Hydrologic Consequences

Mining impacts of hydrological importance that can occur are destruction of horizontal continuity in the overburden strata and mixture of the overburden strata in the backfilled pits creating a more isotropic media. During this process, some geological materials that are saturated are intermixed with materials that are unsaturated. In addition, a variety of lithologies are mixed including siltstones, sandstones and shales. The mining process substantially increases the surface area of excavated materials exposed to air and water. During the mining process, soil structure is altered, vegetation is removed, and the replaced subsoil and topsoil probably has a slightly increased bulk density.

The dragline removes overburden material by pulling the bucket upward from near the base of the cut toward the top. This material is then "cast" into spoil ridges in the preceding cut. As the stripped overburden material is cast, it is spread over a relatively large area, as much as perhaps 150 meters by 50 meters horizontally and 20 to 30 meters vertically. During this process, the materials are thoroughly mixed, and blocks of geologic materials tumble down steep spoil pile slopes and form a "rubble layer" at the base of the replaced spoil (Van Voast et al., 1988). Moran et al. (1979) conclude that the rubble zone is probably thin but has a substantially higher permeability than the original materials. Backfilled spoils have a higher porosity than the original strata and these spoils probably have a higher vertical percolation rate since the materials when backfilled are more isotropic. Most sedimentary materials exhibit a strong preferential horizontal permeability.

4.3.1 Groundwater Flow

The Rosebud Mine Groundwater Model Report (Attachment D) gives a detailed description of the development of a regional steady-state groundwater model for the Rosebud Mine area. This steady state model was used as the basis for a series of transient groundwater models simulating the mining process from 1975 to current (2012). For a detailed description of the model development, application and results, refer to Attachment D.

The Rosebud Model is used as the starting point to evaluate the groundwater response to the AM4 Amendment mining. This application of the model is designated as the “Area B AM4 Model”. Please refer to the report of this application provided in Attachment E for the discussion of the model development, application and results.

Model simulations predict groundwater drawdowns in the Rosebud and McKay coals at the end of mining and fifty years following the end of mining for both the current permitted mining and the proposed AM4 Amendment. This allows evaluation of the incremental response to the AM4 Amendment. In summary, the AM4 Amendment is predicted to result in an additional 40 feet increase in drawdown at the end of mining when compared to the current permitted mining. At fifty years past, the model simulates a net increase of 15 feet of drawdown in the Rosebud, again when compared to the current permit.

Comparison of the simulated pre-mine and current permitted mine conditions (2012) shows that dewatering of the Rosebud coal will lead to a decline in groundwater levels within Areas A, B and C of the mine and in the immediate vicinity of the mine. Outside of the permit boundary, the projected drawdown is more significant south of Areas B and B extension as compared to other directions. This can be explained by the higher degree of confinement of the Rosebud coal and underlying strata in the southern portions of the mine as compared to the northern mine portion. Another significant factor is that the structural base of the Rosebud coal decreases southward in this portion of the mine. Simulated drawdown for life-of-mine was highest in the Rosebud Coal and neighboring strata.

Mine dewatering discharge rates increase as a result of the proposed AM4 Amendment. Annual and cumulative average mine discharge rates are presented in Table E-1 of Attachment E.

4.3.2 Re-Establishment of Groundwater Levels

A postmine model simulation was run to predict groundwater levels in the Rosebud Mine and its vicinity at 50 years after the cessation of mining (Attachment E). The simulation results show that following mining, water levels should show a gradual recovery. However, substantial residual drawdown is projected to remain fifty years following mining.

Table 19 summarizes water level recovery observed in spoils wells in mine areas A, B, C, D and E to date. A rate of recovery was calculated for each recovering spoils well with a period of record of ten years or more. The average rate of recovery for all Rosebud Mine areas is seven inches/year. The average rate of recovery in Area A is lower at about four inches/year. All of the Area A spoils wells in Table 19 are located in

the southeastern portion of Area A which was mined from 1975 through 1979. The lower recovery rate could be a result of limited lateral inflow from bounding strata. The average rate of recovery in Area B East spoils wells is eleven inches/year. Possible factors influencing this higher rate are lateral inflow from bounding strata and inflow from standing water in mine pits in Area B East. Most Area C spoils wells have been dry to date and only one well had sufficient data to calculate a recovery rate of four inches/year. It is likely that ongoing mining activities in Areas A, B and C are impacting the rate of recovery of spoils groundwater. It is expected that the rate will stabilize after mining activities in the vicinity have been completed. The average recovery rate in Area E, where mining was completed in 1986, is eight inches per year.

As expected, the extension of mining by six years as proposed in the AM4 Amendment delays the groundwater level recovery accordingly. At 50 years past mining, the incremental maximum drawdrown is projected to be about 15 feet greater when compared to current permitted mining.

Outside of the mine permit boundary, at the end of mining (2026), the maximum residual drawdown of 80 feet is predicted to occur in the Rosebud Coal. After 50 years the projected maximum residual drawdown is about 40 feet. Figures showing the drawdowns for these time periods are provided in Attachment E.

4.3.3 Groundwater Quality

The TDS concentration of groundwater in spoils will be higher than the TDS concentration in pre-mine overburden groundwater. At the Rosebud Mine TDS concentrations in spoils groundwater in Areas A, B and C have ranged from 860 to 8,750 mg/L. Average TDS concentrations in Area A, B and C spoils groundwater are 3,103, 3,378 and 5,582 mg/L, respectively. The range of specific conductivity values observed in spoils groundwater categorizes it as Class II or Class III groundwater, which is similar to premine conditions.

In areas where spoils groundwater flows into adjoining strata, it can lead to increased TDS concentrations in those strata. Time series of TDS concentrations in Area A, B and C wells show that this has likely occurred in some areas of the Rosebud Mine. More specifically, inflow of spoils groundwater could be a factor in the increased TDS concentrations that were observed for:

- Selected East Fork Armells Creek alluvial wells between Areas A and B
- Selected Rosebud Coal wells in Areas A and C
- Selected interburden wells in Areas A, B and C

Section 4.2.4.2. - East Fork Armells Creek Alluvium describes some instances where mining activities may have temporarily reversed the direction of alluvial groundwater flow. As a result there are instances where the Rosebud coal, spoils and interburden groundwater between Areas A and B may be influenced by recharge from alluvial groundwater. This type of alluvial recharge is expected to be a temporary result of nearby mining and dewatering activities. As mining moves further away from the alluvium and water levels in the nearby spoils increase, the direction of groundwater is expected to reverse again.

In addition to changes in water quality in the adjoining strata, TDS time series analysis showed that specific geologic conditions, namely thin interburden thickness, may contribute to the vulnerability of the McKay coal and sub-McKay groundwater to changes in water quality. More specifically, possible mining related water quality changes were observed in McKay coal wells in the eastern half of Area B and near the northern permit boundary of Area C and in one sub-McKay well in Area C.

Furthermore, analysis of TDS time series of groundwater in Areas A, B and C shows that the changes in water level associated with nearby dewatering activities likely result in variable TDS concentrations in those wells.

4.3.4 Groundwater Use

The potential hydrological impact from mining in Areas A, B and C on the private wells and water supply wells within a one to three mile radius of the permit boundary is determined by the location of the well with respect to mining and the stratum in which it is completed.

To evaluate potential impacts to private wells, the comprehensive list of groundwater users presented in Attachment F was narrowed down as follows:

- All monitoring wells were removed from the list: MBMG, USGS, Hydrometrics and MBMG wells and wells drilled by Haz Tech Drilling and Maxim Technologies.

- Industrial users were removed from the list: Montana Power Co., Northern Pacific Railway Co., Peabody and Big Sky Coal Co., PPL Montana, B.N.S.F.

- Simulated 5-foot drawdown contours were created for Rosebud coal, McKay coal and sub-McKay at the end of mining in Area B (2026).

Table 20 and Figure 34 present the remaining wells within the maximum extent of the simulated five-foot drawdown contours. The likelihood of these groundwater users being impacted was evaluated based on available static water levels and well log data. This analysis identified four wells that could potentially be impacted by mining:

- GWIC 307: located in Area A, likely mined out
- GWIC 11982: located west of Area B, this overburden well may be impacted by mining, depending on the elevation of the pump in the well.
- GWIC 12002: located in Area B, this well might have been abandoned or mined out

In addition, two wells in Area C will be mined out: WR 42KJ183300 00 and 42KJ 106451 00.

Potential impacts were not evaluated for wells for which no well logs and static water level data are available. In general, the likelihood of impact is dependent on the location of the well with respect to mining and the stratum in which it is completed.

Drawdown maps generated by the Rosebud Groundwater Model show that that wells in the immediate vicinity and to the south of the Area B have the highest potential to be impacted. Alluvial wells to the north and west of Areas A and C and to the west of Area B are not expected to be impacted.

Wells are not likely to be adversely impacted unless the water level in the well is drawn down to the point that the required pumping column for the well cannot be maintained. The required minimum water column is well-specific. Wells that become impacted can be replaced with deeper wells as needed.

5.0 SUMMARY

The general hydrologic consequences as discussed in Section 1.3.1 can be summarized as:

1) Interception of tributary surface flows during mining.
2) Diminished alluvial aquifer recharge from the reduced surface flows during mining.
3) Groundwater level drawdowns resulting from mine dewatering.
4) Changes in groundwater quality as the mined coal is backfilled with spoils.
5) Changes in groundwater quality in the alluvial aquifer associated with spoils.
6) Changes in surface water quality as a result of changes in alluvial groundwater quality.

This comprehensive PHC evaluation compared these hydrologic consequences to the hydrologic monitoring data collected at the Rosebud Mine since 1975. The evaluation generally validates those hydrologic consequences as applicable and identified data limitations and potential future monitoring issues.

Following mining and reclamation, surface water flows and quality should return to pre-mine conditions. Groundwater levels will recover over many years. There is potential for impacts to private wells located near the mine until groundwater levels recover. These impacts can be mitigated. Wells located at distance from the mine should not be impacted. It is anticipated that groundwater quality will reestablish geochemical equilibrium over time. Changes in groundwater quality are not expected to negatively affect existing uses. Future monitoring should focus on spoils water quality and impacts to the alluvial aquifer.

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Tables

Area B – AM4 (Application Amendment 00184)
Comprehensive Evaluation of Probable Hydrologic Consequences
Areas A, B and C
Western Energy Rosebud Mine

Exhibit 8

Table 1
Climate Summary
Colstrip Weather Station (241905)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	34.4	38.8	47	58.6	68.6	77.7	88.1	86.7	75.1	62.3	46.6	37.2	60.1
Average Min. Temperature (F)	9.6	14.4	21.9	31.5	40.8	49.3	55.5	53.4	43.5	33.3	22.2	13.1	32.4
Average Total Precipitation (in.)	0.6	0.54	0.92	1.64	2.61	2.69	1.31	1.13	1.25	1.26	0.65	0.57	15.17
Average Total SnowFall (in.)	7	6.2	7.5	5.1	0.6	0.2	0	0	0.6	2.5	5	7	41.6
Average Snow Depth (in.)	3	2	1	0	0	0	0	0	0	0	1	2	1

Period of Record: 3/1/1927 to 2/27/2012
Western Regional Climate Center, wrcc@dri.edu

Table 2
Comparison of 2011 Climate Data
Rosebud Mine versus Colstrip Weather Station

	Colstrip Weather Station (241905)				Rosebud Mine, Precipitation			
	Average Min Temp (F)	Average Max Temp (F)	Average Temp (F)	Precipitation (inches)	RL-1	RL-2	RL-3	RL-4
					(inches)			
Oct-2010	37.87	67.39	52.63	0.55	0.70	[a]	0.46	0.59
Nov-2010	20.13	42.07	31.10	1.35	0.42	[a]	0.51	0.29
Dec-2010	14.90	33.32	24.11	0.45	0.2	[a]	0.24	0.15
Jan-2011	13.26	32.61	22.94	1.31	0.7	[a]	0.66	0.55
Feb-2011	6.89	29.00	17.95	0.85	0.45	0.46	0.54	[a]
Mar-2011	21.52	43.23	32.37	0.70	1.6	1.37	1.51	[a]
Apr-2011	31.73	51.20	41.47	2.36	1.86	1.6	1.6	[a]
May-2011	41.13	57.06	49.10	10.00	11.03	9.08	8.67	[a]
Jun-2011	49.40	71.80	60.60	3.12	2.96	2.85	2.79	2.77
Jul-2011	58.61	84.90	71.76	2.32	2.83	2.78	2.13	2.34
Aug-2011	56.06	86.35	71.21	0.51	0.42	0.37	0.45	0.7
Sep-2011	45.73	77.10	61.42	0.17	0.16	0.15	0.22	0.22
Total				23.69				

Notes
Table adapted from 2011 Rosebud Mine Annual Hydrological Report
(a) Data not available due to equipment malfunction

Table 3A
Average Annual Discharge (cfs)
Adjacent Surface Water

Year	Yellowstone River near Forsyth	Yellowstone River near Miles City	Rosebud Creek near Rosebud	Rosebud Creek near Colstrip	Armells Creek near Forsyth
1975		16,640	105.4	95.9	16.7
1976		14,590	45.5	49.7	3.37
1977		7,971	33.1	36.1	1.17
1978	14,200	15,610	112.5	75.3	15.6
1979	11,370	11,950	81.2	69	13.1
1980	9,877	10,360	22.7	27.8	0.394
1981	10,600	10,970	13.2	14.1	0.383
1982	12,740	13,020	29	22.4	5.89
1983	12,420	12,680	15.1	14.5	2.54
1984	12,130	12,760	8.53	12.4	2.89
1985	8,232	8,756	7.91	12.7	
1986	11,440	12,430	27.4	20.6	0.617
1987	8,318	8,695	13.4	12.3	3.38
1988	7,398	7,710	7.95	11.6	1.11
1989	8,355	8,860	14.8	10.2	2.94
1990	9,148	9,812	6.71	7.58	1.27
1991	11,350	11,840	10.9	6.06	9.11
1992	9,539	9,855	2.57	4.78	17.4
1993	11,420	11,760	29.3	11.2	5.63
1994	8,561	8,827	50	27.5	
1995	11,970	12,610	24.8	19.4	
1996	14,250	15,080	30.9	28.2	
1997	17,590	17,470	37.5	23	
1998	11,350	11,610	12.6	15.7	
1999	12,410	12,730	32.6	19	
2000	8,456	8,383	6.54	9.66	
2001	6,026	6,176	4.63	6.88	
2002	6,980	7,096	1	2.96	
2003	7,556	7,660	11.4	11.9	
2004	6,115	6,251	4.12	3.58	
2005	8,209	8,477	9.77	5.52	
2006	8,211	8,416	7.86	6.55	
Average	10,215	10,845	26	22	6

Source: USGS National Water Information System

Note: Discharge data time period limited for comparative evaluation.
Data up to current are available for the Yellowstone River gaging stations.

Table 3B
Mean Monthly Discharge (cfs)
Adjacent Surface Water

Month	Yellowstone River near Forsyth	Yellowstone River near Miles City	Rosebud Creek near Rosebud	Rosebud Creek near Colstrip	Armells Creek near Forsyth
Jan	5,484	5,280	17	14	4.3
Feb	5,765	6,065	35	25	7
Mar	6,611	8,031	66	44	27
Apr	7,378	8,126	40	37	6.1
May	17,370	17,440	56	47	9.6
Jun	30,200	34,650	38	33	6
Jul	18,490	20,250	16	17	3.1
Aug	7,882	8,098	7.2	8.1	1
Sep	6,685	7,102	7.5	5.9	2.5
Oct	7,143	7,597	7.8	8.4	0.81
Nov	6,710	7,023	8.3	11	0.65
Dec	5,846	5,711	9	11	0.53

Source: USGS National Water Information System

Table 4
Surface Water Monitoring Sites (d)

Site ID (a)	MP Type	Drainage (b)	Status (c)	Monitoring Schedule	Northing (NAD83)	Easting (NAD83)
CG-01		EFAC	inactive		599913	2733995
CG-02		CC	inactive		601492	2710236
CG-04		EFAC	inactive		608354	2695721
CG-05		EFAC	inactive		606259	2699186
CG-06		CC	inactive		597801	2723755
CG-07		SC	inactive		614175	2679201
CG-08		SC	inactive		605217	2664902
CG-11		HC	inactive		592814	2714773
CG-12		HC	inactive		593218	2717791
CG-13		CC	inactive		602876	2703091
CG-19		EFAC	inactive		617079	2679949
CG-21		EFAC	inactive		624016	2648124
CG-23	crest gauge	EFAC	active	Monthly	615396	2649401
CG-30		EFAC	inactive		599297	2686934
CG-35		EFAC	inactive		595697	2674225
CG-40		SC	inactive		612149	2685601
CG-45		SC	inactive		607232	2668643
CG-50		SC	inactive		604169	2660032
CG-55		EFAC	inactive		605674	2699704
CG-60		EFAC	inactive		596034	2678788
CG-65		SC	inactive		607268	2666541
CG-75		EFAC	inactive		593910	2658243
CG-90		CC	inactive		607920	2720946
GSW1		CC	inactive		605897	2729242
GSW2		CC	inactive		605323	2730900
GSW3		CC	inactive		605158	2734616
GSW5		CC	inactive		604680	2740156
GSW6		CC	inactive		602891	2747766
SW-01		EFAC	inactive		615255	2698913
SW-09		EFAC	inactive		594474	2670231
SW-10		EFAC	inactive		617817	2697635
SW-11		EFAC	inactive		599940	2688774
SW-12		EFAC	inactive		596034	2678788
SW-13		EFAC	inactive		626834	2694760
SW-14		EFAC	inactive		593952	2653039
SW-15		EFAC	inactive		599047	2695604
SW-17		EFAC	inactive		605974	2699695
SW-19		EFAC	inactive		608134	2701631
SW-20		EFAC	inactive		599291	2690494
SW-21		EFAC	inactive		609709	2700782
SW-22		EFAC	inactive		614070	2699449
SW-23		EFAC	inactive		630605	2693745
SW-24		EFAC	inactive		615942	2698492
SW-25		EFAC	inactive		600085	2693571
SW-26		EFAC	inactive		600246	2692266
SW-27		EFAC	inactive		600361	2692763
SW-30		EFAC	inactive		599291	2686939

Table 4
Surface Water Monitoring Sites (d)

Site ID (a)	MP Type	Drainage (b)	Status (c)	Monitoring Schedule	Northing (NAD83)	Easting (NAD83)
SW-30	continuous recorder, crest gauge	EFAC	active	Monthly	599576	2686684
SW-35	precipitation gauge	trib EFAC	active	Monthly	595689	2674223
SW-40		SC	inactive		612149	2685601
SW-45	continuous recorder, crest gauge	SC	active		608124	2668813
SW-50		SC	inactive		604169	2660032
SW-55	continuous recorder, crest gauge	EFAC	active	Monthly	605432	2699425
SW-60	precipitation gauge	EFAC	active	Monthly	596204	2678577
SW-61		CC	inactive		604154	2702352
SW-62		EFAC	inactive		605774	2699701
SW-64		CC	inactive		608211	2717336
SW-65	continuous recorder, crest gauge	SC	active	Monthly	607994	2667479
SW-66		CC	inactive		607272	2719365
SW-68		CC	inactive		608244	2721737
SW-73		EFAC	inactive		612045	2700112
SW-75	continuous recorder, crest gauge	EFAC	active	Monthly	593889	2658236
SW-81		CC	inactive		608544	2715124
SW-82		CC	inactive		607333	2724666
SW-83		CC	inactive		607148	2725171
SW-84		CC	inactive		602446	2702104
SW-85		EFAC	inactive		602818	2697890
SW-87		EFAC	inactive		625307	2693906
SW-88		EFAC	inactive		589371	2638583
SW-91		EFAC	inactive		605200	2698919
SW-92		SC	inactive		625534	2691498
SW-93		SC	inactive		625092	2690110
SW-94		SC	inactive		623329	2688063
SW-95		SC	inactive		621602	2687215
SW-96		SC	inactive		620872	2686237
SW-97		SC	inactive		620021	2684562
SW-98		SC	inactive		617604	2680733
SW-99		SC	inactive		613960	2679343
SW-100		EFAC	inactive		614357	2649618
SW-101		EFAC	inactive		614257	2649621
SW-102		EFAC	inactive		613762	2649786
SW-103		EFAC	inactive		613274	2650201
SW-104		SC	inactive		601840	2650898
SW-105		SC	inactive		603238	2672216

Table 4
Surface Water Monitoring Sites (d)

Site ID (a)	MP Type	Drainage (b)	Status (c)	Monitoring Schedule	Northing (NAD83)	Easting (NAD83)
SW-106		EFAC	inactive		599919	2697978
SW-107		CC	inactive		599510	2700992
SW-108		CC	inactive		599720	2704588
SW-109		EFAC	inactive		599392	2693793
SW-110		EFAC	inactive		598448	2692371
SW-111		EFAC	inactive		599128	2691700
SW-112		EFAC	inactive		608200	2693925
SW-113		EFAC	inactive		608987	2693501
SW-114		EFAC	inactive		606070	2692989
SW-115		EFAC	inactive		606037	2691890
SW-116		CC	inactive		598902	2704012
SW-117		CC	inactive		599244	2705402
SW-118		CC	inactive		601667	2702828
SW-119		EFAC	inactive		597680	2690143
SW-120		EFAC	inactive		611171	2701153
SW-121		EFAC	inactive		602554	2692496
SW-123		EFAC	inactive		601206	2694238
SW-124		EFAC	inactive		597916	2691336
SW-125		EFAC	inactive		615306	2698962
SW-126		EFAC	inactive		606994	2690460
SW-127		CC	inactive		608216	2707631
SW-128		SC	inactive		603260	2663061
SW-130		EFAC	inactive		606785	2693468
SW-131		CC	inactive		602912	2707592
SW-132		CC	inactive		603726	2706367
SW-133		EFAC	inactive		605731	2694842
SW-134		EFAC	inactive		604119	2697901
SW-135		EFAC	inactive		615295	2649189
SW-136		EFAC	inactive		600439	2688758
SW-144		EFAC	inactive		603211	2694377
SW-145		EFAC	inactive		599582	2690185
SW-146		EFAC	inactive		598431	2685218
SW-147		EFAC	inactive		605677	2699804
SW-148		SC	inactive		604665	2659917
SW-149		SC	inactive		613959	2672740
SW-150		EFAC	inactive		599502	2689187
SW-151		EFAC	inactive		598425	2685018
SW-152		EFAC	inactive		610585	2698355
SW-153		CC	inactive		611582	2716333
SW-154		CC	inactive		607005	2720474
SW-156		CC	inactive		608014	2720743
SW-157		CC	inactive		607602	2717054
SW-159		SC	inactive		605018	2671511
SW-160		EFAC	inactive		608054	2692429
SW-161		EFAC	inactive		599207	2690997
SW-162		CC	inactive		612390	2710005
SW-163		SC	inactive		605590	2663991

Table 4
Surface Water Monitoring Sites (d)

Site ID (a)	MP Type	Drainage (b)	Status (c)	Monitoring Schedule	Northing (NAD83)	Easting (NAD83)
SW-165		CC	inactive		612218	2720815
SW-166		CC	inactive		612021	2720922
SW-167			inactive		601577	2694927
SW-168		CC	inactive		611863	2712422
SW-169		CC	inactive		611927	2711220
SW-170		SC	inactive		604952	2682518
SW-171		SC	inactive		609810	2684372
SW-173		CC	inactive		612561	2722206
SW-178		CC	inactive		611606	2710529
SW-179		EFAC	inactive		605474	2699711
SW-180		EFAC	inactive		595208	2684515
SW-181		EFAC	inactive		605727	2699803
SW-182		CC	inactive		614486	2713143
SW-183		CC	inactive		607218	2724169
SW-191		EFAC	inactive		599510	2691088
SW-300		LC	inactive		583292	2684177
SW-301		LC	inactive		584042	2682503
SW-305		LC	inactive		580437	2689633
SW-02A		EFAC	inactive		606598	2700477
SW-09A		EFAC	inactive		593214	2668268
SW-10A		EFAC	inactive		617932	2698132
SW-2A		EFAC	inactive		606598	2700477
SW-60B		EFAC	inactive		596034	2678788
SW-9A		EFAC	inactive		593214	2668268

Notes

(a) CG = Crest Gauge, SW = Surface Water

(b) Drainages
EFAC = East Fork Armells Creek
WFAC = West Fork Armells Creek
RC = Rosebud Creek
SC = Stocker Creek (EFAC tributary)
CC = Cow Creek (RC tributary)
PC = Pony Creek (RC tributary)
HC = Hay Coulee (RC tributary)
LC = Lee Coulee (RC tributary)

(c) Status as documented in 2011 Annual Hydrological Report

(d) Only surface water sites in drainages to which Areas A, B and C contribute are shown.

Table 5A
Surface Water Quality Statistics - East Fork Armells Creek (a)

	Units	baseline data (b)							other data						
		average	median	min.	max.	st.dev.	# samples	# of ND	average	median	min.	max.	st.dev.	# samples	# of ND
Physical Parameters															
Conductivity	umhos/cm	1655	742	13	4750	1663	88	0	2362	2240	33	13800	2108	200	0
Oil and Grease	mg/L			<1	5		61	57			<1	6		154	133
pH	s.u.	7.4	7.7	0.5	8.6	1.0	95	0	7.7	7.7	5.9	9.9	0.5	210	0
Total Dissolved Solids	mg/L	1421	242	2	5180	1674	90	0	2205	1875	12	17000	2333	204	0
Total Settleable Solids	mg/L	0.8	0.5	<0.2	2.5	0.7	12	2	0.8	0.5	<0.2	2	0.7	13	5
Total Suspended Solids	mg/L	1745	57	2	50350	6939	87	0	438	44	<1	24400	1999	197	2
Turbidity	NTU	917	55	2	20000	3319	67	0	183	24	0.85	4750	534	157	0
Common Ions															
Acidity	mg/L	10	1.5	<1	102	23	20	5			<1	15.5		37	23
Alkalinity, Total	mg/L	218	127	5	1050	200	91	0	253	235	14	1641	227	202	0
Alkalinity, Bicarbonate	mg/L	256	125	6	1280	241	96	0	292	276	17	877	234	206	0
Alkalinity, Carbonate	mg/L	9.6	3	1	29.0	12.1	5	0	14.7	10	1	56	15.1	11	0
Alkalinity, Hydroxide	mg/L			1	1		2	0			1	1		1	0
Total Hardness	mg/L	899	219	3	3013	998	90	0	1332	1179	15	9550	1354	202	0
Calcium	mg/L	100	44.5	<1	335	100	96	1	163	158.5	4	603	132	206	0
Chloride	mg/L	11	3	<1	120	16	96	7	46	26	<1	695	87	203	4
Fluoride	mg/L	0.18	0.17	<0.01	0.7	0.11	86	14	0.23	0.22	<0.01	0.77	0.14	193	26
Magnesium	mg/L	148	15	<1	562	182	96	2	218	180	1	1960	259	205	0
Potassium	mg/L	4.2	4	1	15	3.0	92	0	5.2	5	1	23	3.4	185	0
Sodium	mg/L	102	10	<1	471	131	97	11	165	143	<1	1030	195	206	10
SAR		1.14	0.46	<0.01	4.5	1.18	90	5	1.66	1.8	<0.01	7.2	1.40	203	4
Sulfate	mg/L	849	95	<1	3340	1061	96	1	1308	1060	1	10900	1497	211	0
Trace Metals															
Aluminum, Diss	mg/L	0.5	0.1	<0.1	12	1.6	69	29			<0.001	0.8		165	101
Aluminum, Total	mg/L	12.1	0.7	<0.1	309	45.7	78	7	2.3	0.5	<0.1	58.6	6.3	172	27
Boron	mg/L	0.2	0.1	<0.1	2.3	0.3	75	35	0.6	0.4	<0.01	7	0.9	190	52
Boron, Diss	mg/L	0.1	0.1	<0.1	0.1	0.0	17	5			<0.1	0.7		33	19
Cadmium, Diss	mg/L			<0.0001	0.005		63	51			<0.001	0.015		171	139
Cadmium, Total	mg/L			<0.0001	0.063		71	55			<0.001	0.019		163	119

Table 5A
Surface Water Quality Statistics - East Fork Armells Creek (a)

	Units	baseline data (b)							other data						
		average	median	min.	max.	st.dev.	# samples	# of ND	average	median	min.	max.	st.dev.	# samples	# of ND
Chromium, Diss	mg/L			<0.01	0.04		67	52			<0.01	0.1		157	130
Chromium, Total	mg/L			<0.01	0.41		75	44			<0.01	0.2		165	119
Copper, Diss	mg/L			<0.01	0.19		69	48			<0.01	0.57		180	127
Copper, Total	mg/L	0.04	0.01	<0.01	0.86	0.11	77	36	0.03	0.02	<0.01	0.58	0.06	172	84
Iron, Diss	mg/L	0.80	0.1	<0.03	14.2	2.81	70	17	0.13	0.05	<0.01	3.19	0.33	180	71
Iron, Total	mg/L	12.32	0.95	<0.05	344	46.62	91	4	3.76	0.79	<0.03	69.1	8.94	189	9
Lead, Diss	mg/L			<0.003	0.02		69	53			<0.0005	0.05		177	161
Lead, Total	mg/L			<0.003	0.25		77	48			<0.0005	2.83		170	132
Manganese, Diss	mg/L	0.12	0.02	<0.005	1.92	0.29	67	33	0.54	0.04	<0.0002	16.2	1.59	174	60
Manganese, Total	mg/L	0.83	1.03	0.028	1.98	0.73	7	0	0.05	0.048	<0.0002	0.11	0.04	5	0
Mercury, Diss	mg/L			<0.0006	0.02		63	57			<0.0005	0.007		154	151
Mercury, Total	mg/L			<0.0006	0.02		71	64			<0.0006	0.048		157	155
Nickel, Diss	mg/L										<0.03	<0.03		1	1
Selenium, Diss	mg/L			<0.001	0.01		70	53			<0.001	0.1		162	132
Selenium, Total	mg/L			<0.001	0.016		76	56			<0.001	0.035		169	134
Vanadium, Diss	mg/L			<0.05	1		69	57			<0.01	1		163	153
Vanadium, Total	mg/L			<0.05	1		78	66			<0.01	1		170	159
Zinc, Diss	mg/L	0.03	0.02	<0.01	0.34	0.05	69	23	0.05	0.02	<0.01	1.68	0.17	176	69
Zinc, Total	mg/L	0.09	0.03	<0.01	0.99	0.17	77	8	0.10	0.04	<0.01	1.81	0.24	170	34
Nutrients															
Nitrite + Nitrate as N	mg/L	0.5	0.29	<0.01	7.48	1.0	80	8	1.7	0.34	<0.01	18.5	3.4	194	21
Nitrate N	mg/L	0.7	0.27	0.04	4.29	1.2	13	0	2.6	0.415	0.01	10.09	3.9	10	0
Ortho Phosphate as P	mg/L	0.2	0.08	<0.01	2.02	0.3	78	12	0.6	0.1	<0.01	7	1.3	176	15

Notes

(a) Values below detection limit were substituted with the detection limit to calculate statistics. No statistics were calculated if 50 % or more than half of the values were below detection limit or if less than 5 samples were available.

(b) Only samples collected upstream from mining and samples collected before mining started upstream from sampling location were considered baseline.

Table 5B
Surface Water Quality Statistics - Cow Creek (a)

		baseline (b)				other data						
	Units	min.	max.	# samples	# of ND	average	median	min.	max.	st.dev.	# samples	# of ND
Physical Parameters												
Conductivity	umhos/cm	1130	4430	4	0	704	463	56	3150	747	73	0
Oil and Grease	mg/L	<1	1	4	2			<1	6		54	51
pH	s.u.	7.4	8.1	4	0	7.3	7.2	5.4	9	0.6	73	0
Total Dissolved Solids	mg/L	925	4810	4	0	551	301.5	26	2810	682	70	0
Total Settleable Solids	mg/L											
Total Suspended Solids	mg/L	4	98	4	0	5669	276	<1	129000	18631	73	1
Turbidity	NTU	1	26	4	0	3330	197	1	69000	10022	66	0
Common Ions												
Acidity	mg/L					7	2	<1	31	11	8	3
Alkalinity, Total	mg/L	102	245	2	0	73	56	<1	486	70	60	1
Alkalinity, Bicarbonate	mg/L	125	473	4	0	94	71	<6	593	84	73	1
Alkalinity, Carbonate	mg/L							<1	12		2	1
Alkalinity, Hydroxide	mg/L											
Total Hardness	mg/L	614	2430	2	0	358	222	12	1800	411	60	0
Calcium	mg/L	122	528	4	0	76	53	3	434	87	73	0
Chloride	mg/L	4	58	4	0	11	3	<1	171	23	73	7
Fluoride	mg/L	<0.1	0.85	4	1	0.22	0.16	<0.01	0.95	0.18	56	11
Magnesium	mg/L	61	584	4	0	37	18	1	346	59	73	0
Potassium	mg/L	4	9	4	0	4	3	1	9	3	71	0
Sodium	mg/L	28	119	4	0	23	8	<1	203	40	73	11
SAR		0.41	0.89	4	0	0.39	0.23	<0.01	2.51	0.48	65	1
Sulfate	mg/L	543	3100	4	0	296	136	2	1820	432	73	0
Trace Metals												
Aluminum, Diss	mg/L	<0.01	<0.1	4	4			<0.1	0.8		57	36
Aluminum, Total	mg/L	<0.1	0.5	4	2	7.2	2.78	<0.1	86	13.7	57	3
Boron	mg/L	0.6	2.6	4	0			<0.1	1.6		58	34
Boron, Diss	mg/L							<0.1	0.1		2	2

Table 5B
Surface Water Quality Statistics - Cow Creek (a)

		baseline (b)				other data						
	Units	min.	max.	# samples	# of ND	average	median	min.	max.	st.dev.	# samples	# of ND
Cadmium, Diss	mg/L	<0.001	0.005	4	1			<0.001	0.011		57	40
Cadmium, Total	mg/L	0.001	0.005	4	0			<0.001	0.014		57	36
Chromium, Diss	mg/L	<0.02	<0.02	4	4			<0.02	0.2		53	51
Chromium, Total	mg/L	<0.02	<0.02	4	4			<0.02	0.1		53	39
Copper, Diss	mg/L	<0.01	<0.01	4	4			<0.01	0.03		57	54
Copper, Total	mg/L	<0.01	<0.01	4	4			<0.01	0.14		57	35
Iron, Diss	mg/L	0.04	0.06	4	0	0.12	0.05	<0.02	0.66	0.15	57	24
Iron, Total	mg/L	0.14	3.02	4	0	7.9	3.04	0.1	128	17.0	69	0
Lead, Diss	mg/L	<0.01	<0.01	4	4			<0.01	0.07		57	50
Lead, Total	mg/L	<0.01	0.06	4	2			<0.01	1.32		57	33
Manganese, Diss	mg/L	<0.02	0.35	4	2			<0.02	0.86		57	30
Manganese, Total	mg/L											
Mercury, Diss	mg/L	<0.001	<0.001	4	4			<0.0005	<0.001		56	56
Mercury, Total	mg/L	<0.001	<0.001	4	4			<0.001	0.002		53	51
Nickel, Diss	mg/L											
Selenium, Diss	mg/L	<0.005	0.005	4	3			<0.005	0.015		56	46
Selenium, Total	mg/L	0.006	0.01	4	0	0.006	0.005	<0.005	0.015	0.002	57	45
Vanadium, Diss	mg/L	<0.1	<0.1	4	4			<0.1	<1		57	57
Vanadium, Total	mg/L	<0.1	<0.1	4	4			<0.1	0.26		57	55
Zinc, Diss	mg/L	<0.01	<0.01	4	3	0.02	0.02	<0.01	0.14	0.02	57	27
Zinc, Total	mg/L	<0.01	0.05	4	1	0.09	0.04	<0.01	0.56	0.12	57	4
Nutrients												
Nitrite + Nitrate as N	mg/L	<0.05	0.54	4	3	0.92	0.39	<0.05	12.1	1.81	67	6
Nitrate N	mg/L											
Ortho Phosphate as P	mg/L	<0.01	0.08	4	2	0.08	0.06	<0.01	0.41	0.08	57	7

Notes

(a) Values below detection limit were substituted with the detection limit to calculate statistics. No statistics were calculated if 50 % or more than half of the values were below detection limit or if less than 5 samples were available.

(b) Only samples collected upstream from mining and samples collected before mining started upstream from sampling location were considered baseline.

Table 5C
Surface Water Quality Statistics - Stocker Creek (a)

	Units	baseline (b)							other data						
		average	median	min.	max.	st.dev.	# samples	# of ND	average	median	min.	max.	st.dev.	# samples	# of ND
Physical Parameters															
Conductivity	umhos/cm	1098	248	21	9510	2008	32	0	1501	998	11	6360	1552	91	0
Oil and Grease	mg/L			<5	5		21	18			<1	5		21	14
pH	s.u.	7.4	7.4	6.2	8.2	0.5	32	0	7.4	7.5	6.1	8.3	0.6	104	0
Total Dissolved Solids	mg/L	1105	199	17	9400	2058	29	0	1177	658	<10	6420	1443	91	1
Total Settleable Solids	mg/L								4	0.5	<0.1	66.7	14	24	6
Total Suspended Solids	mg/L	2679	187.5	<1	32800	7057	32	1	3055	66	<1	76300	11636	103	3
Turbidity	NTU	2609	225	1	31000	6777	26	0	289	28.5	<0.1	3600	666	64	1
Common Ions															
Acidity	mg/L			<1	14		2	1			<1	6		42	22
Alkalinity, Total	mg/L	181	93.5	9	740	193	24	0	144	79.5	5	1290	186	90	0
Alkalinity, Bicarbonate	mg/L	185	105	11	903	216	32	0	187	109	0.64	1570	230	104	0
Alkalinity, Carbonate	mg/L										1	21		2	0
Alkalinity, Hydroxide	mg/L										1	1		1	0
Total Hardness	mg/L	770	163	11	4580	1205	24	0	651	348	4	3600	804	91	0
Calcium	mg/L	65	32	2	354	86	32	0	94	71	1	392	99	104	0
Chloride	mg/L	10	2	<1	126	23	32	4	11	3	<1	94	15	104	11
Fluoride	mg/L	0.12	0.1	<0.1	0.27	0.06	22	6	0.17	0.1	<0.01	0.73	0.15	60	20
Magnesium	mg/L	106	9	<1	897	212	32	3	119	49.5	<1	704	165	104	2
Potassium	mg/L										0.03	0.03		1	0
Sodium	mg/L	79	2.5	<1	1150	214	32	8	91	19	<1	558	130	104	13
SAR		0.82	0.18	<0.01	7.4	1.52	28	3	1.07	0.43	<0.01	4.74	1.15	93	4
Sulfate	mg/L	598	17.5	<1	6190	1314	32	2	750	396	<1	4460	981	104	1
Trace Metals															
Aluminum, Diss	mg/L	0.32	0.1	<0.1	2.4	0.50	22	7			<0.03	10.5		62	33
Aluminum, Total	mg/L	5.49	1.95	<0.1	23	7.16	22	1	8.05	0.95	<0.05	130	24.61	62	5
Boron	mg/L			<0.1	1.3		22	12	0.2	0.1	<0.1	0.6	0.1	81	24
Boron, Diss	mg/L			<0.1	<0.1		2	2	0.2	0.1	<0.1	0.5	0.13427	49	16
Cadmium, Diss	mg/L			<0.001	0.005		22	19			<0.00008	0.015		50	27
Cadmium, Total	mg/L			<0.001	0.009		22	14	0.003	0.001	<0.0001	0.015	0.003	50	23
Chromium, Diss	mg/L			<0.02	0.02		22	22			<0.001	0.03		61	36
Chromium, Total	mg/L			<0.02	0.08		22	17			<0.001	0.17		62	33

Table 5C
Surface Water Quality Statistics - Stocker Creek (a)

	Units	baseline (b)							other data						
		average	median	min.	max.	st.dev.	# samples	# of ND	average	median	min.	max.	st.dev.	# samples	# of ND
Copper, Diss	mg/L			<0.01	0.02		22	21	0.04	0.02	<0.01	0.57	0.10	62	21
Copper, Total	mg/L	0.02	0.02	<0.01	0.05	0.01	22	10	0.09	0.02	<0.01	1.75	0.24	62	19
Iron, Diss	mg/L	0.26	0.11	<0.01	2.74	0.57	22	6	0.70	0.07	<0.01	16.4	2.66	64	11
Iron, Total	mg/L	8.0	3.28	0.08	38.1	10.9	29	0	33.8	1.085	<0.03	870	128.3	94	3
Lead, Diss	mg/L			<0.01	0.06		22	21			<0.00005	0.05		62	37
Lead, Total	mg/L			<0.01	1.31		22	16	0.05055	0.01	<0.0005	1.11	0.15677	62	30
Manganese, Diss	mg/L			<0.02	1.48		22	15	0.08	0.02	<0.005	0.5	0.12	62	21
Manganese, Total	mg/L								1.06	0.16	0.026	5.57	1.71	16	0
Mercury, Diss	mg/L			<0.001	0.001		22	22			<0.00001	0.001		46	39
Mercury, Total	mg/L			<0.001	0.001		22	22			<0.0006	0.006		46	37
Nickel, Diss	mg/L														
Selenium, Diss	mg/L	3	2	1	8	2	28	0	5	5	<1	18	4	100	1
Selenium, Total	mg/L			<0.005	0.011		22	19	0.006	0.005	<0.001	0.011	0.003	62	28
Vanadium, Diss	mg/L			<0.1	<1		22	22			<0.01	1		62	43
Vanadium, Total	mg/L			<0.1	<1		22	22			<0.01	1		62	42
Zinc, Diss	mg/L			<0.01	0.03		22	13	0.03	0.01	<0.01	0.42	0.06	62	29
Zinc, Total	mg/L	0.11	0.05	<0.01	0.57	0.16	22	2	0.08	0.03	<0.01	0.94	0.16	62	12
Nutrients															
Nitrite + Nitrate as N	mg/L	0.71	0.11	<0.01	6.42	1.44	27	5	0.67	0.265	<0.05	18.7	2.33	66	12
Nitrate N	mg/L														
Ortho Phosphate as P	mg/L	0.12	0.07	<0.01	0.52	0.15	22	2	0.15	0.14	<0.01	0.91	0.15	60	5

Notes

(a) Values below detection limit were substituted with the detection limit to calculate statistics. No statistics were calculated if 50 % or more than half of the values were below detection limit or if less than 5 samples were available.

(b) Only samples collected upstream from mining and samples collected before mining started upstream from sampling location were considered baseline.

Table 5D
Surface Water Quality Statistics - West Fork Armells Creek (a)

		baseline data (b)						
	Units	average	median	min.	max.	st.dev.	# samples	# of ND
Physical Parameters								
Conductivity	umhos/cm	527	242	42	1260	468	11	0
Oil and Grease	mg/L			<5	1		7	6
pH	s.u.	7.1	7.2	6	7.7	0.5	11	0
Total Dissolved Solids	mg/L	387	163	10	928	376	11	0
Total Settleable Solids	mg/L							
Total Suspended Solids	mg/L	897	72	<1	3050	1230	11	1
Turbidity	NTU	134	41	3	760	256	8	0
Common Ions								
Acidity	mg/L			11	11		1	0
Alkalinity, Total	mg/L	102	113.5	20	158	41	10	0
Alkalinity, Bicarbonate	mg/L	117	131	25	193	54	11	0
Alkalinity, Carbonate	mg/L	3	2	<1	8	2.5	11	2
Alkalinity, Hydroxide	mg/L							
Total Hardness	mg/L	281	146	22	586	232	10	0
Calcium	mg/L	43	30	6	98	31	11	0
Chloride	mg/L			<0.02	<0.02	0	7	7
Fluoride	mg/L			<0.1	0.22		7	6
Magnesium	mg/L	37	12	2	92	39	11	0
Potassium	mg/L	4.7	6	1	8	2.9	10	0
Sodium	mg/L	22	8	<1	66	24	11	2
SAR		0.58	0.38	0.25	1.2	0.37	9	0
Sulfate	mg/L	215	50	3	588	243	11	0
Trace Metals								
Aluminum, Diss	mg/L			<0.1	0.1		7	6
Aluminum, Total	mg/L	0.8	0.2	<0.1	4	1.4	7	2
Boron	mg/L	0.17	0.1	<0.1	0.3	0.1	10	4
Boron, Diss	mg/L							
Cadmium, Diss	mg/L			<0.001	0.004		7	5
Cadmium, Total	mg/L	0.004	0.005	<0.001	0.006	0.002	7	3
Chromium, Diss	mg/L			<0.02	<0.02	0	7	7
Chromium, Total	mg/L			<0.01	<0.02		7	7
Copper, Diss	mg/L							
Copper, Total	mg/L			<0.01	0.02		7	6
Iron, Diss	mg/L	0.04	0.02	<0.02	0.11	0.03	7	2
Iron, Total	mg/L	9.7	0.4	0.07	40.2	14.9	11	0
Lead, Diss	mg/L			<0.01	<0.02		7	7
Lead, Total	mg/L			<0.01	0.11		7	4
Manganese, Diss	mg/L			<0.02	<0.02		7	7
Manganese, Total	mg/L							
Mercury, Diss	mg/L			<0.001	<0.001	0	7	7

Table 5D
Surface Water Quality Statistics - West Fork Armells Creek (a)

		baseline data (b)						
	Units	average	median	min.	max.	st.dev.	# samples	# of ND
Mercury, Total	mg/L			<0.001	<0.001	0	7	7
Nickel, Diss	mg/L							
Selenium, Diss	mg/L			<0.005	0.01		7	6
Selenium, Total	mg/L			<0.005	0.01		7	5
Vanadium, Diss	mg/L			<0.1	<0.2		7	7
Vanadium, Total	mg/L			<0.1	<0.2		7	7
Zinc, Diss	mg/L			<0.02	0.02		7	4
Zinc, Total	mg/L	0.03	0.02	<0.02	0.05	0.01	7	3
Nutrients								
Nitrite + Nitrate as N	mg/L	0.22	0.11	<0.05	0.96	0.31	8	2
Nitrate N	mg/L							
Ortho Phosphate as P	mg/L	0.05	0.05	0.02	0.14	0.04	7	0

Notes

(a) Values below detection limit were substituted with the detection limit to calculate statistics. No statistics were calculated if 50 % or more than half of the values were below detection limit or less than 5 samples were available.

(b) Only samples collected upstream from mining and samples collected before mining started upstream from sampling location were considered baseline. All West Fork Armells Creek samples were baseline.

Table 6
Area 49 Surface Water Quality Statistics
Trace Element Data

Analyte	Units		Armells Creek near Forsyth	Rosebud Creek at mouth near Rosebud	All Area 49 samples
Arsenic	mg/L	Average	0.002	0.002	0.002
		Minimum	0.001	0.001	ND
		Maximum	0.006	0.004	0.009
		Number of Samples	16	17	203
Boron	mg/L	Average	0.45	0.21	0.26
		Minimum	0.12	0.08	0.004
		Maximum	0.73	0.5	0.84
		Number of Samples	70	75	621
Cadmium	mg/L	Average	0.001	0.001	0.001
		Minimum	ND	ND	ND
		Maximum	0.002	0.003	0.008
		Number of Samples	15	16	169
Chromium	mg/L	Average	0.008	0.01	0.006
		Minimum	ND	ND	ND
		Maximum	0.02	0.03	0.02
		Number of Samples	16	16	202
Iron	mg/L	Average	0.064	0.045	0.059
		Minimum	0.01	0.01	0.01
		Maximum	0.51	0.42	1.8
		Number of Samples	70	75	711
Lead	mg/L	Average	0.003	0.004	0.005
		Minimum	ND	ND	ND
		Maximum	0.013	0.017	0.041
		Number of Samples	15	16	207
Mercury	mg/L	Average	0.0003	0.0002	0.0003
		Minimum	ND	ND	ND
		Maximum	0.0005	0.0009	0.0009
		Number of Samples	16	16	209
Selenium	mg/L	Average	0.001	0.001	0.001
		Minimum	ND	ND	ND
		Maximum	0.001	0.002	0.007
		Number of Samples	14	14	201
Zinc	mg/L	Average	0.019	0.016	0.02
		Minimum	ND	ND	ND
		Maximum	0.07	0.04	0.72
		Number of Samples	16	16	210

Notes
ND = Below detection limit
Source = Slagle et al. (1983) Table 8.4.-1
All trace element concentrations are dissolved concentrations.

Table 7
MPDES Discharge Points

Outfall ID	Alternate ID	Type	Drainage (a)	Status	Northing NAD83	Easting NAD83
9		MPDES Outfall	EFAC	Active	606092	2699419
11		MPDES Outfall	EFAC	Active	603805	2699415
12		MPDES Outfall	EFAC	Active	602947	2698152
13		MPDES Outfall	EFAC	Active	604199	2697558
14		MPDES Outfall	EFAC	Active	602345	2695159
15		MPDES Outfall	EFAC	Active	601799	2695894
16		MPDES Outfall	EFAC	Active	601840	2694237
18		MPDES Outfall	EFAC	Active	600070	2693394
19		MPDES Outfall	EFAC	Active	600813	2693694
20		MPDES Outfall	EFAC	Active	599456	2691088
21		MPDES Outfall	EFAC	Active	599409	2690299
22		MPDES Outfall	EFAC	Active	599602	2690157
23		MPDES Outfall	EFAC	Active	600090	2688351
24		MPDES Outfall	EFAC	Active	599562	2686598
25		MPDES Outfall	EFAC	Active	597863	2685016
26		MPDES Outfall	EFAC	Active	596913	2683198
30		MPDES Outfall	SC	Active	605506	2663940
32		MPDES Outfall	SC	Active	604824	2665016
33		MPDES Outfall	SC	Active	604916	2667488
34		MPDES Outfall	SC	Active	604925	2667952
35		MPDES Outfall	SC	Active	605092	2671553
36		MPDES Western Alkaline	SC	Active	605092	2675159
37		MPDES Western Alkaline	SC	Active	605278	2676348
38		MPDES Western Alkaline	SC	Active	605246	2677599
39		MPDES Western Alkaline	EFAC	Active	605112	2679803
40		MPDES Western Alkaline	EFAC	Active	604695	2680420
41		MPDES Western Alkaline	EFAC	Active	604263	2680784
42		MPDES Western Alkaline	EFAC	Active	601633	2683474
43		MPDES Outfall	EFAC	Active	598681	2683990
44		MPDES Outfall	EFAC	Active	597809	2682984
46		MPDES Outfall	EFAC	Active	598617	2680787
48		MPDES Outfall	EFAC	Active	596116	2680125
49		MPDES Outfall	EFAC	Active	597104	2677634
51		MPDES Outfall	EFAC	Active	596630	2676059
52		MPDES Outfall	EFAC	Active	595422	2674794
54		MPDES Outfall	EFAC	Active	594950	2673965
56		MPDES Outfall	EFAC	Active	593853	2672978
58		MPDES Outfall	EFAC	Active	594827	2671427
59		MPDES Outfall	EFAC	Active	594553	2669782
60		MPDES Outfall	EFAC	Active	593842	2665049
61		MPDES Outfall	EFAC	Active	593210	2668320
63		MPDES Outfall	EFAC	Active	594198	2664012

Table 7
MPDES Discharge Points

Outfall ID	Alternate ID	Type	Drainage (a)	Status	Northing NAD83	Easting NAD83
64		MPDES Outfall	EFAC	Active	595316	2662272
69		MPDES Outfall	SC	Active	607910	2680300
70		MPDES Outfall	SC	Active	609008	2681103
71		MPDES Outfall	SC	Active	610918	2684012
72		MPDES Outfall	SC	Active	613489	2689144
73		MPDES Western Alkaline	SC	Active	612930	2690334
74		MPDES Western Alkaline	SC	Active	612777	2691735
75		MPDES Outfall	EFAC	Active	612440	2693704
95		MPDES Outfall	WFAC	Active	608444	2641328
96		WFAC	WFAC trib	Active	608805	2636399
98		MPDES Outfall	WFAC trib	Active	609628	2638847
100		MPDES Outfall	WFAC	Active	607956	2642401
101		MPDES Outfall	WFAC	Active	606918	2643131
103		MPDES Outfall	WFAC	Active	606321	2644544
104		EFAC	WFAC	Active	606069	2645547
105		MPDES Outfall	WFAC	Active	604537	2647721
106		MPDES Outfall	WFAC	Active	604488	2648498
107		MPDES Outfall	WFAC	Active	604523	2649006
108		MPDES Outfall	WFAC	Active	604554	2649516
109		MPDES Outfall	WFAC	Active	604437	2651010
112		MPDES Outfall	WFAC	Active	609715	2654519
113		MPDES Outfall	WFAC	Active	609952	2657830
116		MPDES Western Alkaline	SC	Active	611204	2661657
119		MPDES Western Alkaline	SC	Active	608507	2665126
130		MPDES Outfall	LC	Active	589173	2668634
131		MPDES Outfall	LC	Active	589326	2673191
132	135	MPDES Outfall	LC	Active	589400	2674582
133	55	MPDES Outfall	EFAC	Active	593594	2673989
134		MPDES Outfall	LC	Active	589490	2677166
073A		MPDES Western Alkaline	SC	Active	612795	2690579
08D		MPDES Outfall	EFAC	Active	608585	2697352
09A		MPDES Outfall	EFAC	Active	604866	2698652
104A		EFAC	WFAC	Active	605619	2646342
112A		MPDES Outfall	WFAC	Active	609960	2658093
112B	115	MPDES Outfall	WFAC	Active	610457	2658652
116A		MPDES Western Alkaline	SC	Active	610987	2662736
121A		MPDES Western Alkaline	SC	Active	606964	2664081
130A		MPDES Outfall	LC	Active	589258	2671091
130B		MPDES Outfall	LC	Active	589263	2671488
131A		MPDES Outfall	LC	Active	589354	2673737
13A		MPDES Outfall	EFAC	Active	603539	2696990
16A		MPDES Outfall	EFAC	Active	600701	2692306

Table 7
MPDES Discharge Points

Outfall ID	Alternate ID	Type	Drainage (a)	Status	Northing NAD83	Easting NAD83
71C		MPDES Outfall	SC	Active	611689	2685357
95A		MPDES Outfall	WFAC	Active	608828	2640781

Notes
Outfalls in use during water year 2011. Coordinates are approximate.

(a) ***Drainages***

EFAC = East Fork Armells Creek
WFAC = West Fork Armells Creek
CC = Cow Creek
SC = Stocker Creek
SpC = Spring Creek
LC = Lee Coulee
PC = Pony Creek
trib = tributary

Table 8
Impoundment Sites (b)

Site ID	MP Type	Drainage (a)	Sampling Schedule	Status	Northing (NAD83)	Easting (NAD83)	Permanent
PI-10	Pit	EFAC		Inactive	602318	2697906	
PI-11	Pit	EFAC		Inactive	601542	2695428	
PI-12	Pit	EFAC		Inactive	602118	2697912	
PI-13	Pit	EFAC		Inactive	600652	2702358	
PI-14	Pit	EFAC		Inactive	602956	2689282	
PI-15	Pit	EFAC		Inactive	603126	2691578	
PI-16	Pit	EFAC		Inactive	601053	2694142	
PI-17	Pit	EFAC		Inactive	599856	2699181	
PI-18	Pit	EFAC		Inactive	600319	2694665	
PI-21	Pit	CC		Inactive	599092	2700405	
PO-008	Sediment Imp.	EFAC		Inactive	608917	2695144	
PO-009	Sediment Imp.	EFAC		Inactive	605765	2699402	
PO-010	Sediment Imp.	EFAC		Inactive	612770	2692886	
PO-011	Sediment Imp.	EFAC		Inactive	603372	2699674	yes
PO-012	Sediment Imp.	EFAC		Active	602724	2698093	
PO-013	Sediment Imp.	EFAC		Active	604620	2697936	yes
PO-014	Sediment Imp.	EFAC		Inactive	602436	2695201	
PO-016	Sediment Imp.	EFAC		Inactive	600652	2692454	
PO-017	Sediment Imp.	EFAC		Inactive	601191	2693738	
PO-018	Sediment Imp.	EFAC		Inactive	600688	2693653	
PO-019	Sediment Imp.	EFAC		Active	600700	2694053	yes
PO-021	Sediment Imp.	EFAC		Inactive	598483	2690218	
PO-022	Sediment Imp.	EFAC		Inactive	599846	2688977	
PO-023	Sediment Imp.	EFAC		Inactive	600077	2688369	
PO-024	Sediment Imp.	EFAC		Active	599928	2686403	
PO-026	Sediment Imp.	EFAC		Active	596535	2683295	yes
PO-029	Sediment Imp.	SC		Active	601737	2657856	
PO-030	Sediment Imp.	SC		Active	604635	2662219	
PO-031	Sediment Imp.	SC		Inactive	604528	2662652	
PO-032	Sediment Imp.	SC		Active	603630	2665351	yes
PO-033	Sediment Imp.	SC		Inactive	604896	2667513	
PO-034	Sediment Imp.	SC		Inactive	604914	2668113	
PO-035	Sediment Imp.	SC		Inactive	605021	2671611	
PO-036	Sediment Imp.	SC		Inactive	604447	2675120	
PO-037	Sediment Imp.	SC		Inactive	604976	2676715	
PO-038	Sediment Imp.	SC		Inactive	604906	2677718	
PO-041	Sediment Imp.	SC		Inactive	604298	2680738	
PO-042	Sediment Imp.	EFAC		Inactive	601378	2683427	
PO-043	Sediment Imp.	EFAC		Active	598679	2683509	
PO-044	Sediment Imp.	EFAC		Inactive	600102	2680965	
PO-045	Sediment Imp.	EFAC		Inactive	600139	2682164	
PO-046	Sediment Imp.	EFAC		Active	598791	2680605	
PO-059	Sediment Imp.	EFAC		Active	594576	2669037	
PO-070	Sediment Imp.	SC		Active	608859	2682700	yes
PO-072	Sediment Imp.	EFAC		Active	613358	2689166	yes

Table 8
Impoundment Sites (b)

Site ID	MP Type	Drainage (a)	Sampling Schedule	Status	Northing (NAD83)	Easting (NAD83)	Permanent
PO-073	Sediment Imp.	EFAC		Inactive	612800	2690584	
PO-075	Sediment Imp.	EFAC		Active	612089	2693507	
PO-08A	Sediment Imp.	EFAC		Inactive	611244	2695333	
PO-08B	Sediment Imp.	EFAC		Inactive	607736	2695140	
PO-08D	Sediment Imp.	EFAC		Active	608457	2696800	Yes
PO-08E	Sediment Imp.	EFAC		Inactive	608491	2696918	
PO-08W	Sediment Imp.	EFAC		Inactive	608485	2696718	
PO-093	Sediment Imp.	SC		Active	601858	2665131	
PO-095	Sediment Imp.	WFAC		Active	607844	2640117	
PO-100	Sediment Imp.	WFAC		Active	607121	2641516	
PO-101	Sediment Imp.	WFAC		Active	606191	2643156	
PO-105	Sediment Imp.	WFAC		Active	603940	2647351	
PO-10C	Sediment Imp.	EFAC		Active	601470	2702934	
PO-111	Sediment Imp.	EFAC		Inactive	603372	2699674	
PO-112	Sediment Imp.	WFAC		Active	608267	2658409	
PO-112A	Sediment Imp.	WFAC		Active	609343	2658662	
PO-112B	Sediment Imp.	WFAC		Active	609341	2657808	
PO-119	Sediment Imp.	SC		Active	608525	2663204	
PO-11A	Sediment Imp.	EFAC		Active	602669	2699596	
PO-129D	Sediment Imp.	EFAC		Inactive	590655	2662748	
PO-137	Sediment Imp.	EFAC		Active	594980	2677904	
PO-13A	Sediment Imp.	EFAC		Inactive	605790	2691997	yes
PO-14A	Sediment Imp.	EFAC		Active	603111	2694370	
PO-14B	Sediment Imp.	EFAC		Active	603608	2690963	yes
PO-19A	Sediment Imp.	EFAC		Inactive	599030	2693128	
PO-21AC	Sediment Imp.	EFAC		Active	598574	2690050	yes
PO-21D	Sediment Imp.	EFAC		Inactive	596049	2685180	
PO-28B	Sediment Imp.	SC		Active	603358	2652974	
PO-30A	Sediment Imp.	SC		Active	601665	2661246	
PO-34A	Sediment Imp.	SC		Inactive	604427	2668528	
PO-35A	Sediment Imp.	SC		Inactive	604730	2671920	
PO-35B	Sediment Imp.	SC		Active	603911	2672341	
PO-36A	Sediment Imp.	SC		Inactive	604455	2675380	
PO-36B	Imp.	SC		Inactive	604041	2675393	
PO-41A	Sediment Imp.	SC		Inactive	603904	2680950	
PO-46A	Sediment Imp.	EFAC		Active	599654	2679378	
PO-46B	Sediment Imp.	EFAC		Active	598946	2677121	
PO-46C	Sediment Imp.	EFAC		Active	601212	2677763	
PO-52A	Sediment Imp.	EFAC		Active	596639	2673327	
PO-58A	Sediment Imp.	EFAC		Active	595483	2670965	
PO-70A	Sediment Imp.	SC		Active	607696	2684411	
PO-71A	Sediment Imp.	SC		Active	610162	2684411	
PO-71B	Sediment Imp.	SC		Active	610516	2684550	
PO-71C	Sediment Imp.	SC		Active	611370	2686325	yes
PO-71D	Sediment Imp.	SC		Active	608990	2684268	

Table 8
Impoundment Sites (b)

Site ID	MP Type	Drainage (a)	Sampling Schedule	Status	Northing (NAD83)	Easting (NAD83)	Permanent
PO-71E	Sediment Imp.	SC		Active	609952	2685227	
PO-73A	Sediment Imp.	EFAC		Inactive	612800	2690584	
PO-74A	Sediment Imp.	SC		Inactive	622809	2690700	
PO-901	Sediment Imp.	EFAC		Inactive	612770	2692886	
PO-909	Sediment Imp.	EFAC		Inactive	605486	2696809	
PO-910	Stock Imp.	SC		Inactive	608859	2682700	
PO-911	Sediment Imp.	EFAC		Inactive	600213	2697769	
PO-915	Sediment Imp.			Inactive	611212	2689352	
PO-916	Stock Imp.	SC		Inactive	612547	2685539	
PO-920	Sediment Imp.	EFAC		Inactive	605737	2691899	
PO-922	Stock Imp.	WFAC		Inactive	605446	2649388	
PO-923	Stock Imp.	WFAC	semi-annual	Active	605374	2649324	
PO-924	Stock Imp.	SC		Inactive	605909	2677787	
PO-925	Stock Imp.	SC		Inactive	606644	2675629	
PO-926	Stock Imp.	SC		Inactive	616563	2672509	
PO-927	Stock Imp.	SC		Inactive	617223	2671198	
PO-928	Stock Imp.	SC		Inactive	615010	2669966	
PO-929	Stock Imp.	EFAC		Inactive	593762	2669852	
PO-930	Stock Imp.	SC		Inactive	607419	2667721	
PO-931	Imp.	SC		Inactive	601066	2666137	
PO-932	Stock Imp.	SC		Inactive	612822	2666024	
PO-934	Stock Imp.	CoC		Inactive	622949	2663541	
PO-935	Imp.	SC		Inactive	605258	2663873	
PO-936	Stock Imp.	SC		Inactive	611603	2663185	
PO-937	Stock Imp.	EFAC		Inactive	594800	2662612	
PO-938	Stock Imp.	SC		Inactive	605235	2662201	
PO-939	Stock Imp.	WFAC		Inactive	621432	2659295	
PO-940	Stock Imp.	WFAC		Inactive	610232	2657976	
PO-941	Stock Imp.	WFAC		Inactive	622350	2657599	
PO-942	Stock Imp.	WFAC		Inactive	619649	2658018	
PO-943	Stock Imp.	WFAC		Inactive	621946	2656961	
PO-944	Stock Imp.	WFAC		Inactive	622628	2655837	
PO-945	Stock Imp.	WFAC		Inactive	612800	2655113	
PO-946	Stock Imp.	WFAC		Inactive	619387	2653330	
PO-947	Stock Imp.	WFAC		Inactive	614282	2649396	
PO-948	Stock Imp.	WFAC		Inactive	619196	2649283	
PO-949	Stock Imp.	EFAC		Inactive	597582	2649836	
PO-950	Sediment Imp.	EFAC trib		Inactive	605731	2691699	
PO-955	Sediment Imp.	EFAC		Inactive	594921	2691527	
PO-970	Stock Imp.	WFAC	semi-annual	Active	607148	2647618	
PO-971	Stock Imp.	WFAC		Inactive	610648	2646665	
PO-972	Stock Imp.	WFAC		Inactive	610980	2646515	
PO-973	Stock Imp.	WFAC		Inactive	598835	2643475	
PO-974	Stock Imp.	WFAC		Inactive	598259	2643256	
PO-975	Stock Imp.	WFAC trib		Inactive	619568	2642301	

Table 8
Impoundment Sites (b)

Site ID	MP Type	Drainage (a)	Sampling Schedule	Status	Northing (NAD83)	Easting (NAD83)	Permanent
PO-976	Stock Imp.	WFAC		Inactive	607804	2647636	
PO-977	Stock Imp.	WFAC trib		Inactive	620158	2641082	
PO-978	Stock Imp.	WFAC trib	semi-annual	Active	611930	2638708	
PO-979	Stock Imp.	WFAC trib		Inactive	612578	2633483	
PO-980	Stock Imp.	WFAC trib		Inactive	598143	2634259	
PO-982	Stock Imp.	RC trib		Inactive	588269	2683325	
PO-983	Stock Imp.	RC trib		Inactive	586351	2686309	
PO-984	Stock Imp.	RC trib		Inactive	579773	2690187	
PO-986	Stock Imp.	RC trib		Inactive	587828	2668832	
PO-989	Imp.	EFAC		Inactive	590628	2667525	
PO-990	Imp.	EFAC		Inactive	594605	2681879	

Notes
Imp. = Impoundment

(a) ***Drainages***
EFAC = East Fork Armells Creek
WFAC = West Fork Armells Creek
RC = Rosebud Creek
SC = Stocker Creek (EFAC tributary)
CC = Cow Creek (RC tributary)
CoC = Corral Creek (EFAC tributary)

Table 9
Stock Pond Water Quality Statistics
Major Constituents

Parameter	Units	Average	Median	Minimum	Maximum	St Dev	# Samples	# Samples below DL
pH	s.u.	8.2	8.1	6.9	9.6	0.5	51	0
TDS	mg/L	1614	1520	70	5000	1103	47	0
Specific Conductivity	umhos/cm	1911	1870	125	4840	1085	51	0
Total Hardness	mg/L	970	944	60	2859	586	51	0
Total Alkalinity	mg/L	374	400	54	698	168	51	0
Sodium Adsorption Ratio	-	21.8	1.8	0.01	1020	142.6	51	0
TSS	mg/L	50	12.5	1	1270	179	50	6
Turbidity	FTU	22	5	0.89	390	60	51	0
Calcium	mg/L	100	89	18	245	54	51	0
Magnesium	mg/L	177	172	4	605	118	51	0
Sodium	mg/L	143	131	0.5	525	110	51	2
Potassium	mg/L	10	8	1	31	7	51	0
Bicarbonate	mg/L	409	473.5	0.605	852	210	46	0
Carbonate	mg/L			ND	118		45	29
Chloride	mg/L	10	9	0.5	35	7	51	4
Sulfate	mg/L	877	696	5	3220	725	51	0
Nitrate and Nitrite N	mg/L	0.19	0.025	0.005	4.03	0.63	46	24
Fluoride	mg/L	0.34	0.25	0.03	1.4	0.30	51	3
Orthophosphate	mg/L	0.02	0.006	ND	0.188	0.03	51	9

Notes
ND = Value below detection limit.
To calculate statistics, values below detection limit were substituted with half the detection limit.
Carbonate concentrations were below detection limit in the majority of samples, so only minimum and maximum values are given.

Table 10
Comparison of Stock Pond Water Quality to Livestock Water Quality Criteria
Frequency of Exceedances

Pond ID	Period of Data	pH	*Count*	Sulfate	*Count*	Al Total	*Count*	Al Diss	*Count*	B Total	*Count*	B Diss	*Count*	Hg Total	*Count*	Hg Diss
Standard (a)		**6.5-8.5**		**2500**		**5**		**5**		**5**		**5**		**0.00005**		**0.00005**
PO-910	1981-1982	1	3	none	3	none	3	none	3	none	3			none	3	none
PO-916	1982	none	1	none	1	none	1	none	1	none	1			none	1	none
PO-922	1983	none	1	none	1			none	1	none	1					none
PO-923	1983-2011	none	0	none	20	none	19	none	19	none	20	none	19	1	19	1
PO-929	1986	none	1	none	1	none	1	none	1	none	1			none	1	none
PO-938	1989	none	1	1	1	none	1	none	1	none	1			none	1	none
PO-970	2003-2011	none	5	none	5	1	5	none	5	none	5	none	5	none	5	none
PO-976	2003-2007	1	7	none	7	none	7	none	7	none	7	none	7	1	7	1
PO-978	2003-2011	6	8	none	8	none	8	none	8	none	8	none	8	none	8	none
PO-978-M	2008	1	1	none	1	none	1	none	1	none	1	none	1	none	1	none
PO-982	1986	none	1	none	1	none	1	none	1	none	1	none	1	none	1	none
PO-984	1986	1	1	none	1	none	1	none	1	none	1	none	1	none	1	none
PO-985	1986	none	1	none	1	none	1	none	1	none	1	none	1	none	1	none
PO-986	1986	none	1	none	1	none	1	none	1	none	1	none	1	none	1	none

Notes

(a) Livestock standards - see Attachment C (lowest of two standards was used).
There were no exceedances of the lifestock standards for akalinity, chloride, cadmium, chromium, copper, fluoride, lead, nitrate+nitrite-N, oil and grease, selenium, vanadium and zinc.
Dissolved constituents concentrations and standards are in mg/L.

Table 11
Spring Sites

Site ID	Drainage (a)	Status	Sampling Schedule	Northing (NAD83)	Easting (NAD83)	TDS Trend (b)
SP-01	SC	Inactive		603831	2675249	
SP-02	SC	Inactive		604209	2674537	
SP-03	SC	Inactive		605076	2663556	
SP-04	SC	Inactive		601923	2665152	
SP-05	SC	Inactive		605038	2662307	
SP-06	EFAC	Inactive		604680	2696633	
SP-08	WFAC	Inactive		622460	2656175	
SP-11	RC trib	Inactive		583529	2655757	
SP-19	SC	Inactive		604739	2672220	
SP-20	SC	Inactive		604742	2672320	
SP-21	SC	Inactive		608628	2682872	
SP-28	EFAC	Inactive		600086	2693308	
SP-30	SC	Inactive		604424	2675031	
SP-31	SC	Inactive		601328	2666153	
SP-32	EFAC	Inactive		587764	2637331	
SP-33	WFAC (PO-923)	Active		604925	2648704	
SP-34	WFAC	Active	semi-annual	602043	2648194	no trend
SP-35	WFAC	Active	semi-annual	602526	2649665	no trend
SP-36	WFAC	Active	semi-annual	602765	2650980	*no trend*
SP-37	WFAC	Active	semi-annual	602553	2651065	*increasing*
SP-45	SC	Inactive		605800	2677490	
SP-46	SC	inactive		606342	2675573	
SP-47	SC	Inactive		616543	2672162	
SP-48	SC	Inactive		617409	2671035	
SP-49	SC	Inactive		615170	2669802	
SP-50	SC	Inactive		607404	2667737	
SP-51	SC	Inactive		612744	2665674	
SP-52	CoC	Inactive		623191	2663756	
SP-53	SC	Inactive		611450	2662612	
SP-54	WFAC	Inactive		622030	2658489	
SP-55	WFAC	Inactive		609917	2658256	
SP-56	WFAC	Inactive		619892	2657253	
SP-57	WFAC	Inactive		622190	2657183	
SP-58	WFAC	Inactive		621679	2656799	
SP-59	WFAC	Inactive		612934	2655464	
SP-60	WFAC	Inactive		614160	2649724	
SP-61	WFAC	Inactive		619343	2649066	
SP-62	EFAC	Inactive		597447	2649531	
SP-63	WFAC	Active	semi-annual	606665	2647379	decreasing
SP-64	WFAC	Inactive		610571	2646831	
SP-65	WFAC	Inactive		610800	2646239	
SP-65	WFAC	Inactive		611064	2646616	
SP-66	WFAC	Active	semi-annual	598432	2643186	
SP-67	WFAC	Active	semi-annual	597893	2643008	no trend

Table 11
Spring Sites

Site ID	Drainage (a)	Status	Sampling Schedule	Northing (NAD83)	Easting (NAD83)	TDS Trend (b)
SP-68	WFAC	Active		607651	2642144	
SP-69	WFAC trib	Inactive		619606	2647857	
SP-70	WFAC trib	Inactive		620215	2648139	
SP-71	WFAC trib	Inactive		612385	2650578	
SP-72	WFAC trib	Inactive		598837	2652490	
SP-73	WFAC trib	Inactive		613546	2655845	
SP-74	WFAC trib	Inactive		598453	2656304	
SP-76	WFAC	Active	semi-annual	608091	2653724	*increasing*
SP-77	RC trib	Inactive		585238	2662608	
SP-78	RC trib	Inactive		588916	2668399	
SP-79	EFAC	Inactive		589800	2667872	
SP-112A	WFAC	Active	semi-annual	609266	2659108	*decreasing*
SP-46A	EFAC	Active	semi-annual	601382	2678951	increasing

Notes

(a) ***Drainages***
EFAC = East Fork Armells Creek
WFAC = West Fork Armells Creek
RC = Rosebud Creek
SC = Stocker Creek (EFAC tributary)
CC = Cow Creek (RC tributary)
CoC = Corral Creek (EFAC tributary)

(b) ***TDS Trend***
Trend designation is based on examination of TDS graphs. All springs for which

Table 12
Spring Water Quality Statistics
Major Constituents

Site ID	Sampling Period (1)	Associated Strata (2)		pH s.u.	TDS mg/L	SC umhos/cm	TSS mg/L	Turbidity FTU	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	HCO3 mg/L	CO3 mg/L	Cl mg/L	SO4 mg/L	NO3+NO2 mg/L	F mg/L	orthoP mg/L
SP-34	1983-2011	Overburden (3)	Average	7.7	1705	2687	65.1	29.7	166	312	120	8	776	NC	8.3	1198	0.03	0.23	0.017
			Median	7.9	1460	2020	53.0	35.0	157	231	79	8	770	NC	8.0	915	0.03	0.25	0.02
			Min	7.3	53	1760	6.8	6.4	116	181	52	3	552	ND	3.0	507	0.01	0.17	0.01
			Max	8.2	3740	4740	177.0	56.0	274	617	274	11	1023	ND	13.0	2530	0.05	0.26	0.022
			St Dev	0.4	1128	1172	56.6	22.3	59	171	83	3	155	NC	3.9	782	0.01	0.04	0.005
			Count	7	7	7	7	7	7	7	7	7	6	6	7	7	6	7	7
SP-35	1983-2011	Rosebud Coal	Average	7.8	1617	1976	37.7	21.4	150	194	63	8	611	NC	8.3	799	0.03	0.23	0.0104
			Median	7.8	1635	1960	25.0	14.0	165	199	65	9	658	NC	9.0	845	0.03	0.22	0.011
			Min	7.5	952	1230	7.0	1.3	71	106	40	0	394	ND	4.0	436	<0.01	0.14	0.003
			Max	8.1	2050	2360	92.0	74.0	187	237	79	11	735	ND	10.0	1020	0.06	0.32	0.02
			St Dev	0.2	395	373	34.4	24.6	44	43	13	4	134	NC	2.3	200	0.02	0.07	0.006504
			Count	7	6	7	7	7	7	7	7	7	6	6	7	7	6	7	7
SP-36	1983-2011	Rosebud Coal	Average	7.6	1900	2423	83.5	37.5	150	241	79	5	970	NC	23.0	906		0.33	0.040
			Median	7.7	1730	2110	11.0	11.0	156	222	70	8	970	NC	23.0	799		0.33	0.011
			Min	7.4	1550	1930	2.4	1.6	128	183	60	0	721	ND	13.0	799	<0.05	0.32	0.01
			Max	7.7	2420	3230	237.0	100.0	167	318	108	8	1218	ND	33.0	1120	1.11	0.33	0.1
			St Dev	0.2	459	704	133.0	54.3	20	69	25	5	351	NC	14.1	185		0.01	0.052
			Count	3	3	3	3	3	3	3	3	3	2	2	3	3	2	3	3
SP-37	2010-2011	Rosebud Coal	Average	8.5	965	1260	2.7	1.6	69	124	53	4			4.2	523		0.22	0.0077
			Min	8.4	809	1140	1.9	1.4	54	110	47	3			4.2	399		0.22	0.0034
			Max	8.5	1120	1380	3.4	1.7	84	138	60	5			4.2	646		0.22	0.012
			Count	2	2	2	2	2	2	2	2	2			2	2		2	2
SP-46A	2001-2010	Spoils	Average	7.3	2061	2095	61.6	76.3	262	238	38	9	846	NC	17.1	913	0.06	0.21	0.011
			Median	7.2	1970	2290	32.8	25.0	275	232	37	9	912	NC	18.0	836	0.03	0.18	0.009
			Min	6.9	1490	5	5.0	1.7	137	110	28	7	235	ND	3.0	503	<0.01	0.14	0.001
			Max	8.4	2690	2930	271.0	500.0	312	300	46	11	1060	6	22.0	1300	0.39	0.36	0.021
			St Dev	0.4	350	831	79.9	128.8	44	46	5	1	219	NC	4.8	238	0.09	0.07	0.007
			Count	17	15	16	16	17	17	17	17	17	17	16	17	17	17	17	17
SP-63	1983-2011	McKay Coal	Average	8.0	1961	2436	252.4	56.0	107	283	137	7	646	NC	17.5	1080	0.08	0.25	0.012
			Median	7.8	1830	2280	26.0	12.9	103	266	131	5	627	NC	16.5	992	0.03	0.24	0.006
			Min	7.6	1200	1660	1.0	0.5	27	159	79	2	408	ND	3.0	563	0.02	0.17	0.002
			Max	9.0	3770	3860	3360.0	700.0	183	579	234	16	930	56	43.0	2220	0.27	0.35	0.072
			St Dev	0.4	629	588	860.4	166.8	37	105	46	4	163	NC	10.9	453	0.09	0.05	0.017
			Count	18	17	18	16	17	18	18	18	18	16	15	18	18	16	18	18
SP-67	1983-2010	Overburden	Average	7.9	2460	2822	50.8	20.7	243	230	184	10	722	NC	6.2	1309		0.16	0.009
			Median	7.9	2410	2770	51.6	1.5	239	228	185	11	724	NC	6.0	1320		0.17	0.003
			Min	7.6	2260	2590	0.9	0.1	193	181	145	5	565	ND	2.0	1130	0.21	0.10	0.001
			Max	8.0	3010	3260	98.0	65.0	298	293	219	14	879	ND	9.0	1700	0.42	0.23	0.040
			St Dev	0.1	218	211	31.3	25.2	31	29	20	2	91	NC	1.9	150		0.04	0.014
			Count	11	10	11	9	10	11	11	11	11	10	9	11	11	10	11	11

Table 12
Spring Water Quality Statistics
Major Constituents

Site ID	Sampling Period (1)	Associated Strata (2)		pH s.u.	TDS mg/L	SC umhos/cm	TSS mg/L	Turbidity FTU	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	HCO3 mg/L	CO3 mg/L	Cl mg/L	SO4 mg/L	NO3+NO2 mg/L	F mg/L	orthoP mg/L
SP-76	2010-2011	Rosebud clinker	Average	7.9	1825	2125	52.2	3.5	166	215	80	6			10.2	896		0.10	0.0093
			Min	7.7	1540	1800	20.3	3.0	149	178	66	6			8.3	652		0.10	0.0046
			Max	8.0	2110	2450	84.0	4.0	182	252	94	7			12.0	1140		0.10	0.014
			Count	2	2	2	3	2	2	5	2	6			2	2		2	2
SP-112A	2008-2011	Spoils (4)	Average	7.6	3280	3345	4.9	3.4	438	324	53	12	1140	NC	13.8	1900		0.19	0.008
			Min	7.3	2610	2760	2.0	3.3	310	258	49	11	1140	ND	9.6	1380	0.01	0.19	0.001
			Max	7.8	3950	3930	7.7	3.5	565	390	57	14	1140	ND	18.0	2420	0.01	0.19	0.015
			Count	2	2	2	2	2	2	2	2	2	1	1	2	2	1	2	2

Notes
(1) Data collected up to, and including, water year 2011.
(2) Aquifer designation was made based on analysis of outcrop maps, topographical data and information provided by WECo.
(3) This spring could possibly be associated with Rosebud coal
(4) The 2005 aerial photograph shows this spring is located in disturbance area, WECo mapping shows that it is located outside the mined out area. It is designated as a spoils spring, but might be issuing from remaining Rosebud Coal at this location.

ND = Value below detection limit
TDS = Total Dissolved Solids
SC = Specific Conductivity
NC = No statistics were calculated for carbonate concentrations due to high percentage of ND values
Nitrate and nitrate nitrogen statistics were calculated by setting ND values equal to half the detection limit.

Table 13
Groundwater Monitoring Wells

Site ID	Associated Strata (a)	Drainage or Mine Area (b)	Status	Monitoring Schedule	Northing (NAD83)	Easting (NAD83)	TDS Trend (c)
P-03	Alluvium	EFAC	Active	Quarterly	604897	2699096	Increasing
P-04	Alluvium	EFAC	Active	Quarterly	605093	2698940	No trend
P-05	Alluvium	EFAC	Active	Periodic	605276	2698791	No trend
WA-100	Alluvium	EFAC			599473	2688598	*Decreasing*
WA-101	Alluvium	EFAC	Active	Quarterly	600876	2692530	No trend
WA-102	Alluvium	EFAC			595471	2678626	*Decreasing*
WA-103	Alluvium	EFAC			595699	2678594	Increasing
WA-104	Alluvium	EFAC	Active	Quarterly	595937	2678556	No trend
WA-105	Alluvium	EFAC			596123	2678528	Increasing
WA-106	Alluvium	EFAC			596328	2678530	No trend
WA-107	Alluvium	SC			616643	2680610	
WA-108	Alluvium	SC			616937	2680303	Increasing
WA-109	Alluvium	SC	Active	Quarterly	617085	2680170	Increasing
WA-109-B	Alluvium	SC			617085	2680170	
WA-110	Alluvium	SC			604618	2660298	Decreasing
WA-111	Alluvium	SC			604565	2660347	No trend
WA-113	Alluvium	EFAC	Active	Quarterly	608809	2697677	No trend
WA-114	Alluvium	EFAC	Active	Quarterly	599091	2688429	Increasing
WA-115	Alluvium	EFAC			602901	2698169	
WA-116	Alluvium	EFAC			601398	2695344	
WA-117	Alluvium	EFAC			601211	2695566	
WA-118	Alluvium	EFAC	Active	Quarterly	593761	2652614	No trend
WA-119	Alluvium	EFAC			593904	2652639	*No trend*
WA-120	Alluvium	EFAC			594032	2652583	
WA-121	Alluvium	EFAC			594423	2652451	
WA-122	Alluvium	EFAC			593569	2669221	No trend
WA-123	Alluvium	EFAC			593955	2669055	*No trend*
WA-124	Alluvium	EFAC	Active	Quarterly	603215	2697763	Increasing
WA-125	Alluvium	EFAC			602273	2696672	*Increasing*
WA-126	Alluvium	EFAC	Active	Quarterly	602558	2696549	Increasing
WA-127	Alluvium	EFAC			602817	2696415	Increasing
WA-128	Alluvium	EFAC	Active	Quarterly	602036	2695101	Increasing
WA-129	Alluvium	EFAC			602886	2697972	Increasing
WA-130	Alluvium	EFAC			600900	2693460	No trend
WA-131	Alluvium	EFAC	Active	Quarterly	603806	2696673	Increasing
WA-139	Alluvium	EFAC			601101	2693130	No trend
WA-140	Alluvium	EFAC			601634	2693130	
WA-141	Alluvium	EFAC			602013	2693126	
WA-149	Alluvium	EFAC			612897	2699890	Increasing
WA-150	Alluvium	EFAC			612792	2699735	Decreasing
WA-151	Alluvium	EFAC			612816	2699631	No trend
WA-152	Alluvium	EFAC			612742	2699495	No trend
WA-153	Alluvium	EFAC			620758	2695659	Increasing
WA-154	Alluvium	EFAC			620790	2695881	Increasing
WA-155	Alluvium	SC	Active	Quarterly	625806	2691437	No trend
WA-156	Alluvium	SC			625663	2691450	Decreasing
WA-157	Alluvium	SC			625525	2691478	Decreasing
WA-158	Alluvium	SC			625339	2691522	Decreasing
WA-159	Alluvium	SC			620983	2686306	No trend
WA-160	Alluvium	SC	Active	Quarterly	620927	2686325	No trend

Table 13
Groundwater Monitoring Wells

Site ID	Associated Strata (a)	Drainage or Mine Area (b)	Status	Monitoring Schedule	Northing (NAD83)	Easting (NAD83)	TDS Trend (c)
WA-161	Alluvium	SC			620769	2686376	Decreasing
WA-162	Alluvium	SC			614052	2679307	
WA-163	Alluvium	SC			614006	2679428	
WA-164	Alluvium	SC	Active	Quarterly	614074	2672909	No trend
WA-165	Alluvium	SC			614174	2672867	No trend
WA-166	Alluvium	SC			614437	2672798	No trend
WA-167	Alluvium	SC			611606	2671699	Increasing
WA-168	Alluvium	SC	Active	Quarterly	611546	2671549	No trend
WA-169	Alluvium	SC	Active	Quarterly	606060	2666246	No trend
WA-169-B	Alluvium	SC			606060	2666246	
WA-170	Alluvium	SC			606025	2666195	Decreasing
WA-171	Alluvium	EFAC	Active	Quarterly	593470	2662801	No trend
WA-182	Alluvium	WFAC			614944	2649041	*Decreasing*
WA-183	Alluvium	WFAC			615063	2649034	Decreasing
WA-184	Alluvium	EFAC			615156	2649036	Decreasing
WA-185	Alluvium	WFAC			615268	2649032	No trend
WA-186	Alluvium	WFAC	Active	Quarterly	614895	2649274	Decreasing
WA-187	Alluvium	WFAC			614891	2649246	Decreasing
WA-188	Alluvium	WFAC			615182	2649224	No trend
WA-189	Alluvium	WFAC			609778	2649026	No trend
WA-190	Alluvium	WFAC	Active	Quarterly	605799	2649070	No trend
WA-191	Alluvium	WFAC			605784	2649014	No trend
WA-192	Alluvium	WFAC			605868	2649041	No trend
WA-193	Alluvium	WFAC			609199	2643010	*Increasing*
WA-194	Alluvium	WFAC			609176	2642966	Increasing
WA-195	Alluvium	WFAC			609102	2642994	Increasing
WA-196	Alluvium	WFAC			609089	2643036	Increasing
WA-197	Alluvium	WFAC			623877	2647707	No trend
WA-198	Alluvium	WFAC			623902	2647787	No trend
WA-199	Alluvium	WFAC	Active	Quarterly	623936	2647883	No trend
WA-200	Alluvium	WFAC			623969	2647981	Increasing
WA-201	Alluvium	WFAC			624004	2648082	No trend
WA-202	Alluvium	WFAC			609674	2654467	
WA-203	Alluvium	WFAC			613908	2656829	
WA-204	Alluvium	WFAC	Active	Quarterly	611005	2656907	Decreasing
WA-205	Alluvium	WFAC			610970	2656908	No trend
WA-208	Alluvium	SC			603557	2654940	
WA-209	Alluvium	EFAC	Active	Quarterly	594559	2670892	Increasing
WA-210	Alluvium	EFAC			594148	2670868	No trend
WA-211	Alluvium	EFAC			594860	2668143	Decreasing
WA-212	Alluvium	EFAC			593445	2668109	Decreasing
WA-213	Alluvium	EFAC			593062	2668203	Increasing
WA-214	Alluvium	EFAC	Active	Quarterly	592739	2662877	No trend
WA-215	Alluvium	EFAC	Active	Quarterly	593752	2660834	No trend
WA-216	Alluvium	EFAC			593230	2660859	*Decreasing*
WA-217	Alluvium	SC	Active	Quarterly	604529	2660186	Increasing
WA-218	Alluvium	WFAC	Active	Quarterly	609104	2642995	*Increasing*
WD-100	SMK	B			598291	2694766	*Increasing*
WD-101	IB	C			599760	2683803	*Increasing*
WD-102	SMK	C			600296	2665240	No trend

Table 13
Groundwater Monitoring Wells

Site ID	Associated Strata (a)	Drainage or Mine Area (b)	Status	Monitoring Schedule	Northing (NAD83)	Easting (NAD83)	TDS Trend (c)
WD-107	SMK	A	Active	Semi-Annual	608613	2682813	No trend
WD-109	SMK	C north of	Active	Semi-Annual	611169	2671867	No trend
WD-110	SMK	A			606110	2696885	
WD-111	SMK	C, south of			598546	2682413	
WD-112	SMK	C, south of			598443	2682316	
WD-153	SMK	C	Active	Semi-Annual	604337	2672305	No trend
WD-155	SMK	C			598615	2676071	*Increasing*
WD-159	SMK	B	Active	Semi-Annual	600921	2700394	No trend
WD-160	SMK	B	Active	Semi-Annual	597183	2701030	Decreasing
WD-162	SMK	B			592283	2680404	*Increasing*
WD-170	SMK	C			601201	2656008	No trend
WD-171	SMK	B, west of			593449	2657805	No trend
WD-173	SMK	B			589687	2665510	No trend
WD-176	SMK	C			607512	2657504	No trend
WD-177	SMK	C			603593	2650571	Decreasing
WD-178	SMK	C	Active	Semi-Annual	600714	2650088	Decreasing
WD-179	SMK	C			604335	2645867	No trend
WD-180	SMK	C			607787	2638726	No trend
WD-181	SMK	C	Active	Annual	603033	2640145	*Decreasing*
WD-184	SMK	B	Active	Semi-Annual	599733	2693111	Decreasing
WD-185	SMK	B	Active	Semi-Annual	597542	2687145	No trend
WD-186	SMK	C	Active	Semi-Annual	603981	2677013	Increasing
WD-195	SMK	B, west of	Active	Quarterly	593462	2657776	No trend
WD-196	SMK	B	Active	Quarterly	592530	2669550	Increasing
WI-100	SMK	C			599738	2683805	*Decreasing*
WI-101	IB	A			609266	2685459	Decreasing
WI-102	IB	A	Active	Semi-Annual	603094	2693382	Increasing
WI-103	IB	B			598258	2694794	*No trend*
WI-104	IB	C			600286	2665224	Decreasing
WI-111	IB	A	Active	Semi-Annual	607499	2692149	No trend
WI-112	IB	A			604323	2683137	
WI-153	IB	C	Active	Semi-Annual	604549	2672323	Increasing
WI-154	IB	C			602019	2671101	*Increasing*
WI-155	IB	C			598620	2676053	*Decreasing*
WI-156	IB	C			602245	2679106	*Increasing*
WI-157	IB	B	Active	Semi-Annual	601845	2697079	Increasing
WI-159	IB	B	Active	Semi-Annual	600903	2700381	Increasing
WI-160	IB	B	Active	Semi-Annual	597171	2701011	Increasing
WI-161	IB	B			595645	2690402	No trend
WI-162	IB	B	Active	Semi-Annual	592268	2680417	Decreasing
WI-163	IB	B			594409	2677508	No trend
WI-164	IB	B	Active	Semi-Annual	590111	2674466	Decreasing
WI-165	IB	C			596862	2669574	Increasing
WI-166	IB	B			592414	2669700	No trend
WI-167	IB	C			602799	2667097	*Decreasing*
WI-168	IB	C	Active	Semi-Annual	596872	2666244	No trend
WI-169	IB	C			601679	2660102	Decreasing
WI-170	IB	C			601205	2656018	Increasing
WI-171	IB	B, west of	Active	Semi-Annual	593442	2657787	No trend
WI-172	IB	C, west of	Active	Semi-Annual	596452	2659694	Decreasing

Table 13
Groundwater Monitoring Wells

Site ID	Associated Strata (a)	Drainage or Mine Area (b)	Status	Monitoring Schedule	Northing (NAD83)	Easting (NAD83)	TDS Trend (c)
WI-173	IB	B	Active	Semi-Annual	589689	2665491	No trend
WI-176	IB	C			607518	2657523	
WI-177	IB	C			603587	2650566	
WI-178	IB	C	Active	Semi-Annual	600728	2650098	Increasing
WI-179	IB	C			604334	2645885	Decreasing
WI-180	IB	C			607790	2638719	No trend
WI-181	IB	C	Active	Annual	603024	2640156	Increasing
WI-184	IB	B	Active	Semi-Annual	599734	2693129	Increasing
WI-185	IB	B	Active	Semi-Annual	597533	2687161	Decreasing
WI-186	IB	C	Active	Semi-Annual	603979	2677028	Increasing
WM-100	McKay	B			594677	2683067	Decreasing
WM-101	McKay	A			610587	2689805	Decreasing
WM-102	McKay	B			599437	2688598	No trend
WM-103	McKay	A	Active	Quarterly	600855	2692536	Decreasing
WM-104	McKay	A	Active	Quarterly	603657	2687180	No trend
WM-105	McKay	A, north of	Active	Quarterly	611315	2682672	No trend
WM-106	McKay	B			598268	2694771	Increasing
WM-107	McKay	C, west of	Active	Quarterly	596457	2659706	No trend
WM-108	McKay	C			600266	2665244	No trend
WM-109	McKay	C			601198	2655991	Decreasing
WM-111	McKay	C			603618	2650603	No trend
WM-112	McKay	C			607782	2638721	No trend
WM-113	McKay	B			592404	2669695	Decreasing
WM-114	McKay	C			602761	2675865	*Decreasing*
WM-117	McKay	A			608320	2697429	
WM-118	McKay	A, east of			608330	2698172	
WM-129	McKay	A	Active	Quarterly	607504	2692158	No trend
WM-129-M	McKay	A			607504	2692158	
WM-130	McKay	A	Active	Semi-Annual	603072	2693354	No trend
WM-131	McKay	A			608623	2682812	
WM-137	McKay	A			604319	2683147	
WM-139	McKay	B	Active	Quarterly	593464	2662810	*No trend*
WM-153	McKay	C	Active	Semi-Annually	604546	2672332	No trend
WM-154	McKay	C			602027	2671093	*Decreasing*
WM-155	McKay	C			598618	2676061	*Decreasing*
WM-156	McKay	C			602240	2679098	Decreasing
WM-157	McKay	B			601851	2697094	*Increasing*
WM-158	McKay	B	Active	Quarterly	602541	2698387	No trend
WM-159	McKay	B	Active	Semi-Annual	600913	2700387	No trend
WM-160	McKay	B			597186	2701011	No trend
WM-161	McKay	B			595640	2690392	Increasing
WM-162	McKay	B	Active	Quarterly	592275	2680410	Decreasing
WM-163	McKay	B			594406	2677514	No trend
WM-164	McKay	B	Active	Quarterly	590100	2674468	No trend
WM-165	McKay	C			596859	2669582	No trend
WM-167	McKay	C			602809	2667087	*Decreasing*
WM-168	McKay	C	Active	Quarterly	596864	2666254	No trend
WM-169	McKay	C			601672	2660110	No trend
WM-171	McKay	B, west of			593446	2657796	No trend
WM-173	McKay	B	Active	Quarterly	589689	2665499	No trend

Table 13
Groundwater Monitoring Wells

Site ID	Associated Strata (a)	Drainage or Mine Area (b)	Status	Monitoring Schedule	Northing (NAD83)	Easting (NAD83)	TDS Trend (c)
WM-176	McKay	C			607518	2657523	No trend
WM-178	McKay	C	Active	Quarterly	600721	2650092	No trend
WM-179	McKay	C			604335	2645876	No trend
WM-181	McKay	C	Active	Annually	603028	2640149	No trend
WM-184	McKay	B	Active	Quarterly	599734	2693119	Increasing
WM-185	McKay	B	Active	Quarterly	597537	2687154	No trend
WM-186	McKay	C	Active	Semi-Annual	603980	2677021	Increasing
WM-191	McKay	B, west of	Active	Quarterly	593459	2657802	*Increasing*
WO-100	OB	A			609248	2685494	No trend
WO-101	OB	B			594619	2683068	No trend
WO-102	OB	A			602766	2675866	*No trend*
WO-103	OB	C			600273	2665207	No trend
WO-105	OB	A	Active	Semi-Annual	607548	2692244	No trend
WO-107	OB	C			595559	2670761	No trend
WO-108	OB	B			592932	2670934	*No trend*
WO-109	OB	B			591875	2668237	No trend
WO-110	OB	C			594144	2665400	Decreasing
WO-154	OB	C			602006	2671117	*No trend*
WO-155	OB	C			598621	2676044	*No trend*
WO-156	OB	C			602258	2679122	*No trend*
WO-160	OB	B	Active	Semi-Annual	597155	2700997	No trend
WO-162	OB	B	Active	Semi-Annual	592255	2680434	Increasing
WO-164	OB				590094	2674477	
WO-165	OB	C			596865	2669564	Increasing
WO-166	OB	B			592409	2669691	No trend
WO-168	OB	C	Active	Semi-Annual	596884	2666227	No trend
WO-169	OB	C			601686	2660089	Decreasing
WO-170	OB	C			601210	2656026	No trend
WO-171	OB	B, west of	Active	Semi-Annual	593440	2657776	No trend
WO-172	OB	C, south of	Active	Semi-Annual	596452	2659694	Decreasing
WO-173	OB	B	Active	Semi-Annual	589680	2665474	Decreasing
WO-176	OB	C			607520	2657533	
WO-178	OB	C	Active	Semi-Annual	600734	2650102	Increasing
WO-179	OB	C			604333	2645894	Increasing
WO-180	OB	C			607793	2638713	
WO-181	OB	C	Active	Annual	603011	2640172	No trend
WR-100	OB	B			594646	2683061	No trend
WR-101	RCL	B			598318	2694753	No trend
WR-102	RCL	B			599457	2688598	*Decreasing*
WR-103	RCL	C, south of	Active	Quarterly	596483	2659685	Decreasing
WR-104	RCL	A	Active	Quarterly	603678	2687176	Increasing
WR-105	RCL	C			607489	2692126	Decreasing
WR-106	RCL	C			601181	2655962	Decreasing
WR-109	RCL	A			604311	2683127	
WR-110	RCL	A			609256	2685479	No trend
WR-111	RCL	A			610589	2689788	*No trend*
WR-112	RCL	C			607512	2657528	Decreasing
WR-113	RCL	C			607797	2638723	No trend
WR-114	RCL	C			604335	2645852	No trend
WR-115	RCL	C			596854	2669594	Increasing

Table 13
Groundwater Monitoring Wells

Site ID	Associated Strata (a)	Drainage or Mine Area (b)	Status	Monitoring Schedule	Northing (NAD83)	Easting (NAD83)	TDS Trend (c)
WR-116	RCL	B			594403	2677525	Decreasing
WR-117	RCL	C			602770	2675853	No trend
WR-121	RCL	C	Active	Quarterly	600742	2650109	Decreasing
WR-122	RCL	C			598608	2676059	No trend
WR-124	RCL	B	Active	Quarterly	593451	2662818	Increasing
WR-125	RCL	B, west of	Active	Quarterly	593439	2657798	Decreasing
WR-126	RCL	C	Active	Semi-Annual	604535	2672322	Increasing
WR-127	RCL	A	Active	Semi-Annual	603801	2696661	Increasing
WR-130	RCL	A	Active	Quarterly	607493	2692138	No trend
WR-136	RCL	C	Active	Quarterly	593744	2665439	No trend
WR-154	RCL	C			602013	2671109	*Increasing*
WR-156	RCL	C			602250	2679112	No trend
WR-160	RCL	B	Active	Semi-Annual	597162	2701003	Increasing
WR-161	RCL	B			595651	2690411	No trend
WR-162	RCL	B	Active	Quarterly	592261	2680425	No trend
WR-164	RCL	B	Active	Quarterly	590118	2674464	No trend
WR-167	RCL	C			602791	2667104	*Decreasing*
WR-168	RCL	C	Active	Quarterly	596880	2666234	No trend
WR-169	RCL	C			601683	2660095	Decreasing
WR-173	RCL	B	Active	Quarterly	589684	2665481	No trend
WR-177	RCL	C			603580	2650560	
WR-181	RCL	C	Active	Annual	603015	2640166	No trend
WR-205	RCL	B	Active	Quarterly	600467	2693516	Increasing
WR-206	RCL	B			600279	2693411	*Increasing*
WR-207	RCL	B			600073	2693269	*Increasing*
WR-208	RCL	B			600083	2693064	*No trend*
WR-215	RCL	B			599336	2693372	
WR-217	RCL	B			599053	2693983	
WR-221	RCL	B			598995	2694443	
WR-227		B			599368	2689350	
WR-228	RC	C			609114	2656072	
WR-229	RC	C			608219	2655206	
WR-230	RC	C			608007	2657709	
WS-100	Spoils	A	Active	Semi-Annual	606553	2698261	Increasing
WS-101	Spoils	A	Active	Semi-Annual	607655	2697942	*Decreasing*
WS-102	Spoils	A	Active	Semi-Annual	607560	2695653	
WS-103	Spoils	A	Active	Semi-Annual	606878	2696660	
WS-104	Spoils	A			608318	2697419	
WS-105	Spoils	A			608323	2698180	
WS-106	Spoils	A	Active	Semi-Annual	603082	2693368	No trend
WS-107	Spoils	A	Active	Semi-Annual	601798	2690251	Decreasing
WS-108	Spoils	D			611188	2709445	*Decreasing*
WS-109	Spoils	E	Active	Semi-Annual	604848	2709814	
WS-110	Spoils	E, southeast of	Active	Semi-Annual	595435	2714801	Increasing
WS-111	Spoils	E, southeast of	Active	Semi-Annual	594254	2717572	Decreasing
WS-112	Spoils	E, southeast of	Active	Semi-Annual	593569	2723575	Decreasing
WS-113	Spoils	A	Active	Semi-Annual	603933	2696079	Increasing
WS-114	Spoils	A	Active	Semi-Annual	603473	2694890	No trend
WS-114-B		A			603473	2694890	
WS-115	Spoils	A	Active	Semi-Annual	604823	2697343	Increasing

Table 13
Groundwater Monitoring Wells

Site ID	Associated Strata (a)	Drainage or Mine Area (b)	Status	Monitoring Schedule	Northing (NAD83)	Easting (NAD83)	TDS Trend (c)
WS-116	Spoils	E	Active	Semi-Annual	607136	2705995	Increasing
WS-117	Spoils	E	Active	Semi-Annual	598091	2712531	No trend
WS-118	Spoils	B	Active	Semi-Annual	601369	2696047	Increasing
WS-119	Spoils	E, southeast of			596585	2718364	
WS-120	Spoils	C	Active	Semi-Annual	604148	2679243	
WS-121	Spoils	C	Active	Quarterly	599147	2676518	Increasing
WS-122	Spoils	C	Active	Semi-Annual	604016	2672592	
WS-123	Spoils	A	Active	Quarterly	610765	2685532	
WS-124	Spoils	E	Active	Semi-Annual	600843	2713699	No trend
WS-125	Spoils	D	Active	Semi-Annual	611992	2706471	No trend
WS-126	Spoils	D	Active	Semi-Annual	609223	2707905	Increasing
WS-127	Spoils	D	Active	Semi-Annual	609717	2706349	No trend
WS-128	Spoils	D	Active	Semi-Annual	614517	2703628	*Increasing*
WS-129	Spoils	D	Active	Quarterly	612745	2709110	
WS-130	Spoils	E	Active	Semi-Annual	604413	2706865	
WS-157	Spoils	B	Active	Semi-Annual	601836	2697064	No trend
WS-158	Spoils	B	Active	Semi-Annual	602537	2698379	No trend
WS-159	Spoils	B	Active	Quarterly	600895	2700375	Increasing
WS-184	Spoils	B	Active	Quarterly	599734	2693139	Increasing
WS-185	Spoils	B	Active	Quarterly	597531	2687168	
WS-186	Spoils	C	Active	Semi-Annual	603978	2677036	
WS-187	Spoils	D	Active	Quarterly	616589	2711120	Increasing
WS-188	Spoils	D	Active	Quarterly	618216	2705317	No trend
WS-189	Spoils	B	Active	Quarterly	595863	2683702	
WS-190	Spoils	B	Active	Quarterly	594073	2678602	
WS-191	Spoils	B	Active	Quarterly	592522	2669532	
WS-192	Spoils	D	Active	Quarterly	616255	2717914	
WS-193	Spoils	D	Active	Quarterly	615630	2721883	

Notes

Table contains all Area A, B and C monitoring wells and Area D and E spoils wells.

(a) ***Strata***
OB = Overburden
RCL = Rosebud Clinker
RC = Rosebud Coal
IB = Interburden
SMK = SubMcKay

(b) ***Drainage***
EFAC = East Fork Armells Creek
WFAC = West Fork Armells Creek
SC = Stocker Creek
SpC = Spring Creek
CC = Cow Creek
PC = Pony Creek

(c) **TDS Trend**
Trend designation is based on examination of TDS graphs. All wells for which 2 or more TDS concentrations are available were designated a TDS trend.
Italics - only 2 or 3 data points available

Table 14
Baseline Water Quality Statistics - Major Ions
Area 49

Analyte	Units		Area 49
TDS	mg/L	Average	1909
		Minimum	110
		Maximum	6300
		# Samples	516
Sulfate	mg/L	Average	906
		Minimum	390
		Maximum	4400
		# Samples	516
Chloride	mg/L	Average	19
		Minimum	0.4
		Maximum	770
		# Samples	516
Carbonate	mg/L	Average	5
		Minimum	ND
		Maximum	440
		# Samples	516
Bicarbonate	mg/L	Average	705
		Minimum	20
		Maximum	2000
		# Samples	516
Potassium	mg/L	Average	7
		Minimum	1
		Maximum	48
		# Samples	516
Sodium	mg/L	Average	421
		Minimum	3.2
		Maximum	1900
		# Samples	516
Magnesium	mg/L	Average	95
		Minimum	0.1
		Maximum	680
		# Samples	516
Calcium	mg/L	Average	96
		Minimum	1
		Maximum	460
		# Samples	516

Notes
ND - Non-Detect
Source - Area 49 concentrations from Slagle et al. (1983). Groundwater quality data are both from wells > 200 ft deep and < 200 ft deep. No specific aquifer distinction is made in the report.

Table 15A
Area A Water Quality Statistics per Strata
Major Ions

			Overburden		Spoils	Rosebud Coal		Interburden	McKay Coal		Sub McKay
			Baseline	After Mining (a)		Baseline	After Mining	After Mining	Baseline	After Mining	After Mining
TDS	mg/L	Average	393	1567	3103	1020	2000	2009	2805	2115	3294
		Median	328	2080	3100	516	1475	1850	2770	2025	3310
		Minimum	316	308	860	466	472	877	1770	984	3130
		Maximum	536	2800	6710	2150	4080	3480	3650	3670	3370
		Standard Dev.	124	895	1079	700	1069	863	474	543	86
		No of samples	3	13	70	9	36	22	10	44	9
Specific Conductivity	umhos/cm	Average	573	2202	3329	1284	2344	2342	3324	2542	4400
		Median	574	2710	3370	745	1920	2330	3245	2450	4240
		Minimum	560	569	1170	660	744	1270	1950	1410	4140
		Maximum	584	3490	6090	2330	4000	3460	4530	4110	4860
		Standard Dev.	12	1075	962	704	997	728	660	610	278
		No of samples	3	14	70	9	35	22	10	44	9
pH	mg/L	Average	7.9	7.4	6.9	7.6	7.3	7.2	7.7	7.4	7.7
		Median	7.9	7.5	6.9	7.6	7.3	7.1	7.8	7.3	7.8
		Minimum	7.9	6.85	5.6	7.2	6.8	6.8	7.1	6.9	7.2
		Maximum	8.0	8.1	7.9	8	7.9	7.7	8	8.1	8.1
		Standard Dev.	0.1	0.4	0.5	0.3	0.3	0.3	0.3	0.3	0.3
		No of samples	3	15	70	9	36	22	10	44	10
Sulfate	mg/L	Average	49	819	1720	408	1012	1023	1644	1175	3294
		Median	49	1015	1710	140	546	980.5	1615	1150	3310
		Minimum	45	49	368	135	147	306	1150	422	3130
		Maximum	54	1800	4020	1050	2430	2040	2260	2240	3370
		Standard Dev.	5	543	728	382	734	571	270	382	86
		No of samples	3	14	71	9	35	22	10	44	9
Bicarbonate	mg/L	Average	302	571	759	497	651	648	471	545	343
		Median	297	623	702	341	620	643	507	559	363
		Minimum	259	322	291	303	326	412	94	376	273
		Maximum	350	763	1450	739	1000	998	618	942	397
		Standard Dev.	46	181	279	201	152	123	155	103	50
		No of samples	3	14	69	9	33	20	10	42	

Table 15A
Area A Water Quality Statistics per Strata
Major Ions

			Overburden		Spoils	Rosebud Coal		Interburden	McKay Coal		Sub McKay
			Baseline	After Mining (a)		Baseline	After Mining	After Mining	Baseline	After Mining	After Mining
Chloride	mg/L	Average	7	24	31	5	21	16	11	9	10
		Median	9	20.3	28	4	9	10.5	11	8	10
		Minimum	2	2	4	2	3	6	2	4	7
		Maximum	10	104	79.9	11	67	39	21	26	14
		Standard Dev.	4	26	15	3	21	10	6	4	2
		No of samples	3	13	71	9	35	22	10	44	9
Calcium	mg/L	Average	41	114	390	128	250	215	203	187	65
		Median	39	131	345	70	193	172	221	176	65
		Minimum	39	45	94	64	76	46	102	90	47
		Maximum	46	185	3821	261	1287	409	287	432	77
		Standard Dev.	4	47	454	82	209	115	63	73	11
		No of samples	3	14	71	9	36	22	10	46	9
Magnesium	mg/L	Average	37	66	295	94	179	162	133	138	24
		Median	37	72.5	294	57	153	150.5	146	149.5	26
		Minimum	36	39	69	47	56	24	39	29	14
		Maximum	38	90.1	808	168	377	325	246	256	29
		Standard Dev.	1	17	117	52	92	83	70	62	5
		No of samples	3	14	71	9	36	22	10	46	9
Sodium	mg/L	Average	19	356	166	59	153	142	458	279	971
		Median	20	451	145	15	121	140	401	144	961
		Minimum	13	11	42	10	11	14	25	68	914
		Maximum	25	616	367	144	318	239	873	888	1030
		Standard Dev.	6	231	84	58	73	58	251	248	37
		No of samples	3	14	71	9	36	22	10	46	9
Potassium	mg/L	Average	3	5	8	3	7	7	4	6	6

Table 15A
Area A Water Quality Statistics per Strata
Major Ions

	Overburden		Spoils	Rosebud Coal		Interburden	McKay Coal		Sub McKay
	Baseline	After Mining (a)		Baseline	After Mining	After Mining	Baseline	After Mining	After Mining
Median	3	2.5	8	2	7	8	5	7	8
Minimum	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum	5	13	16	9	21	18	8	15	11
Standard Dev.	3	4	5	3	4	4	3	3	4
No of samples	3	14	71	9	36	22	10	46	9

Notes
ND = value below detection limit.
Baseline samples are samples obtained before mining started within 0.5 miles radius of the well.
(a) Overburden wells 'after mining' are wells located on the periphery of mining activities.
Only two chloride samples were below detection limit. The ND values were not included in the statistics calculation.
Potassium concentrations below detection limit were set to zero to calculate statistics.
All Carbonate concentrations were <= 1 mg/L in all samples.

Table 15B
Area B Water Quality Statistics per Strata
Major Ions

			Overburden (a)		Spoils	Rosebud Coal		Interburden		McKay Coal		Sub McKay	
			Baseline	After Mining		Baseline	After Mining	Baseline	After Mining	Baseline	After Mining	Baseline	After Mining
TDS	mg/L	Average	1416	972	3378	1221	1685	1740	1570	1802	1453	1632	1364
		Median	1450	795	2380	1200	1645	1530	1320	1785	1270	1450	1495
		Minimum	330	294	1340	334	360	610	400	426	52	946	112
		Maximum	3350	1900	8750	3680	3220	2930	4390	2880	3150	2770	1870
		Standard Dev.	750	635	2151	751	874	739	948	570	639	576	551
		No of samples	23	24	49	40	60	23	76	38	88	11	36
Specific Conductivity	umhos/cm	Average	1823	1376	3485	1504	2019	2055	1906	2255	1881	2047	1903
		Median	1850	1400	2630	1455	2250	1790	1760	2285	1720	1920	2070
		Minimum	603	550	1410	540	590	974	718	840	88	1330	338
		Maximum	4230	2500	8420	3300	3310	3290	4180	3160	3140	3320	2820
		Standard Dev.	902	748	1856	661	837	690	863	527	661	602	659
		No of samples	23	25	50	40	63	23	80	38	89	11	37
pH	mg/L	Average	7.6	7.4	7.1	7.5	7.3	7.5	7.3	7.7	7.5	7.6	7.4
		Median	7.6	7.5	7.1	7.6	7.3	7.6	7.3	7.7	7.5	7.6	7.4
		Minimum	7	6.6	5.6	6.4	6.9	6.74	6.2	6.89	6.74	7.1	6.6
		Maximum	8.4	8.3	8	8.4	7.9	8.2	8.1	8.3	8.2	8.2	8.4
		Standard Dev.	0.4	0.4	0.4	0.4	0.2	0.4	0.4	0.4	0.3	0.4	0.5
		No of samples	23	28	51	41	63	24	85	39	93	11	40
Sulfate	mg/L	Average	701	446	1883	555	870	868	758	933	757	872	719
		Median	676	487	1360	534.5	941	752	664	885	623	756	791
		Minimum	55	42	724	57	6.13	143	68	79	5	355	25
		Maximum	2080	1290	5440	2290	1800	1670	2370	1580	2730	1540	1080
		Standard Dev.	510	416	1364	470	572	486	543	357	454	368	314
		No of samples	23	25	49	40	62	23	80	38	89	11	37
Bicarbonate	mg/L	Average	506	485	767	493	555	574	631	549	495	494	463
		Median	489	452	634	495	561	563	555	540	485.5	481	486.5
		Minimum	44	286	400	302	312	439	368	237	44	426	135
		Maximum	907	947	1648	679	899	764	3280	768	994	580	602
		Standard Dev.	198	174	308	109	103	104	360	91	129	48	121
		No of samples	23	24	47	40	61	23	78	38	86	11	36
Chloride	mg/L	Average	8	6	43	6	13	7	9	8	6	14	6
		Median	6	6.5	24	5	6	7	6	7	6	6	6
		Minimum	2	1	7	2	0.25	0.3	1	2	1	2	4
		Maximum	24	17	200	14	44	13	30	18	19	74	10
		Standard Dev.	5	4	50	3	12	4	7	4	3	21	2
		No of samples	23	22	49	40	60	23	77	38	86	11	35

Table 15B
Area B Water Quality Statistics per Strata
Major Ions

			Overburden (a)		Spoils	Rosebud Coal		Interburden		McKay Coal		Sub McKay	
			Baseline	After Mining		Baseline	After Mining	Baseline	After Mining	Baseline	After Mining	Baseline	After Mining
Calcium	mg/L	Average	101	84	304	122	168	173	173	142	133	121	89
		Median	110	82	209	104	166	147	149	158	112	114	85
		Minimum	13	9	128	41	48	80	34	14	9	47	5
		Maximum	174	202	857	473	324	301	528	275	405	200	210
		Standard Dev.	37	55	178	82	84	74	113	86	79	42	61
		No of samples	23	25	50	40	63	23	80	38	90	11	37
Magnesium	mg/L	Average	129	114	353	127	168	161	153	124	103	116	75
		Median	131	83	275.5	126	175	138	146	158	89.5	117	40
		Minimum	27	5	148	31	37	72	46	5	3	23	2
		Maximum	240	258	1070	354	308	267	389	230	352	192	187
		Standard Dev.	59	70	228	70	77	62	80	76	60	39	72
		No of samples	23	25	50	40	63	23	80	38	90	11	37
Sodium	mg/L	Average	176	87	240	71	111	130	104	246	184	235	259
		Median	108	61	130	59	110	139	94	189	173	155	233
		Minimum	10	11	58	11	12	23	17	22	1	114	22
		Maximum	901	606	858	178	273	201	310	554	468	557	657
		Standard Dev.	236	125	237	47	68	58	76	150	117	159	188
		No of samples	23	25	50	40	62	23	80	38	90	11	37
Potassium	mg/L	Average	5	6	9	4	7	4	7	4	6	5	7
		Median	4	6	8	4	7	5	7	5	6	4	8
		Minimum	ND	1	ND	ND	ND	ND	ND	ND	ND	1	ND
		Maximum	9	16	21	9	12	8	23	9	15	9	13
		Standard Dev.	3	4	6	3	3	3	4	3	3	3	3
		No of samples	23	25	50	40	62	23	80	38	89	11	37

Notes
ND = value below detection limit
Baseline samples are samples obtained before mining started within 0.5 miles radius of the well.
(a) Overburden wells 'after mining' are wells located on the periphery of mining activities.

Eleven samples out of 475 had chloride concentrations below detection limit. The ND values were not included in the statistics calculation
Potassium concentrations below detection limit were set to zero to calculate statistics.
All Carbonate concentrations were <= 11 mg/L in all samples.

Table 15C
Area C Water Quality Statistics per Strata
Major Ions

			Overburden (a)		Spoils	Rosebud Coal		Interburden		McKay Coal		Sub McKay	
			Baseline	After Mining		Baseline	After Mining	Baseline	After Mining	Baseline	After Mining	Baseline	After Mining
TDS	mg/L	Average	1911	2056	5582	1855	2209	1751	2279	2047	1843	1833	1930
		Median	1355	1770	7130	1370	2075	1460	2295	2090	1980	1785	1765
		Minimum	136	184	2150	214	216	112	340	386	310	221	694
		Maximum	4740	4750	7360	4270	8240	4240	4670	3890	3300	4460	3170
		Standard Dev.	1479	1449	2392	1292	1551	995	1091	651	1005	621	804
		No of samples	58	20	5	74	36	81	44	76	45	58	26
Specific Conductivity	umhos/cm	Average	2163	2325	5364	2215	2437	2144	2476	2579	2202	2372	2449
		Median	1745	2090	6510	1785	2390	1890	2600	2630	2260	2355	2340
		Minimum	424	352	2700	421	436	461	552	707	583	1060	1010
		Maximum	5030	5120	7090	4640	6680	4550	4310	4180	3650	3490	3620
		Standard Dev.	1346	1391	1913	1291	1262	996	942	690	982	415	830
		No of samples	58	20	5	76	36	84	43	78	48	58	26
pH	mg/L	Average	7.5	7.4	7.1	7.5	7.2	7.4	7.1	7.6	7.5	7.6	7.4
		Median	7.5	7.4	7.0	7.5	7.2	7.4	7.2	7.6	7.5	7.6	7.3
		Minimum	6.5	6.8	7	6.7	6.4	6.7	6.5	6.8	6.9	6.8	6.8
		Maximum	8.5	7.9	7.2	8.3	7.8	8.3	7.8	8.4	8.1	8.4	8.2
		Standard Dev.	0.4	0.3	0.1	0.4	0.3	0.3	0.3	0.4	0.3	0.4	0.3
		No of samples	57	22	5	78	36	84	46	78	50	59	27
Sulfate	mg/L	Average	1043	1227	3448	1050	1259	935	1325	1100	1057	944	1084
		Median	661	1240	4370	612	1135	755	1405	1110	1070	906	960
		Minimum	18	15	1220	30	31	15	51	68	49	312	262
		Maximum	2960	3320	4820	5100	4850	2730	2610	2230	3040	1960	1720
		Standard Dev.	936	1024	1621	948	984	659	735	412	737	308	508
		No of samples	58	21	5	76	36	84	44	78	48	59	26
Bicarbonate	mg/L	Average	530	510	620	521	455	550	458	558	412	530	490
		Median	510	509	590	505	477	572	468	558	392	505	459
		Minimum	157	224	520	249	203	251	266	318	229	328	383
		Maximum	903	731	705	895	619	753	669	854	638	1089	648
		Standard Dev.	183	138	82	140	111	123	112	112	107	127	93
		No of samples	58	20	5	76	36	84	43	78	46	59	26
Chloride	mg/L	Average	15	9	37	8	18	6	11	8	8	8	10
		Median	6	10	44	6	10	5	9	7	7	7	10
		Minimum	1	2	11	1	1	2	3	2	1	2	3
		Maximum	481	17	58	32	163	19	32	31	22	57	24
		Standard Dev.	62	4	19	7	30	4	6	4	5	9	5
		No of samples	58	21	5	76	36	84	44	78	48	59	26

Table 15C
Area C Water Quality Statistics per Strata
Major Ions

			Overburden (a)		Spoils	Rosebud Coal		Interburden		McKay Coal		Sub McKay	
			Baseline	After Mining		Baseline	After Mining	Baseline	After Mining	Baseline	After Mining	Baseline	After Mining
Calcium	mg/L	Average	170	169	346	184	212	166	253	143	168	101	149
		Median	117	153	394	134	167	156	225	138	135	64	157
		Minimum	20	31	192	30	32	38	41	9	33	10	13
		Maximum	418	338	439	550	855	348	466	394	419	323	242
		Standard Dev.	121	97	100	134	164	66	130	87	127	82	85
		No of samples	58	21	5	76	36	84	44	78	48	59	26
Magnesium	mg/L	Average	208	224	524	164	217	155	208	112	124	96	103
		Median	152	212	637	152	191	149	185	110	113	72	134
		Minimum	14	30	128	30	30	27	36	3	12	3	4
		Maximum	509	513	809	429	830	435	442	278	311	344	170
		Standard Dev.	157	149	315	107	158	89	109	78	98	95	64
		No of samples	58	21	5	76	36	84	44	78	48	59	26
Sodium	mg/L	Average	118	131	466	161	135	164	112	360	211	353	316
		Median	76	97	484	109	124	103	57	330	78	353	410
		Minimum	6	3	305	11	8	7	18	34	33	82	74
		Maximum	560	392	604	890	625	624	427	965	746	656	562
		Standard Dev.	115	112	128	183	126	158	113	224	217	170	179
		No of samples	58	21	5	76	36	84	44	78	48	59	26
Potassium	mg/L	Average	5	6	13	5	8	5	9	5	7	5	6
		Median	5	6	12	5	8	5	8	5	6	5	6
		Minimum	ND	ND	9	ND	ND	ND	ND	ND	ND	ND	ND
		Maximum	11	9	18	16	16	15	20	11	21	9	14
		Standard Dev.	3	3	3	3	4	4	6	3	5	3	4
		No of samples	58	21	5	76	36	84	44	77	48	58	25

Notes
ND = value below detection limit
Baseline samples are samples obtained before mining started within 0.5 mile radius of the well.
(a) Overburden wells 'after mining' are wells located on the periphery of mining activities.

Potassium concentrations below detection limit were set to zero to calculate statistics.
All Carbonate concentrations were <= 13 mg/L in all samples.

Table 16
Alluvium Water Quality Statistics
Major Ions

			East Fork Armells Creek				Stocker Creek	West Fork Armells Creek
			Upstream	Between B&C	Between A&B	Downstream		
TDS	mg/L	Average	1864	2784	2544	4084	2719	3372
		Median	1860	2765	2430	4240	2600	3475
		Minimum	514	876	348	186	425	216
		Maximum	4680	4960	5110	11400	6040	5890
		Standard Dev.	506	1014	883	1770	813	1154
		No of Samples	48	90	179	74	148	136
Specific Conductivity	umhos/cm	Average	2338	2973	2816	4051	2956	3635
		Median	2280	2960	2730	4225	2870	3840
		Minimum	967	1210	624	322	629	1450
		Maximum	4530	5100	4810	8070	5380	5790
		Standard Dev.	489	896	764	1380	675	982
		No of Samples	48	89	190	76	149	143
pH	s.u.	Average	7.5	7.6	7.4	7.3	7.5	7.4
		Median	7.5	7.7	7.4	7.3	7.5	7.5
		Minimum	7.1	6.86	6.5	6.8	6.7	6.48
		Maximum	8.2	8.2	8.1	8	8.1	8.3
		Standard Dev.	0.2	0.3	0.3	0.3	0.3	0.3
		No of Samples	49	97	189	76	153	148
Sulfate	mg/L	Average	970	1608	1403	2442	1745	1945
		Median	991	1620	1325	2500	1500	2045
		Minimum	9	362	69	47	97	590
		Maximum	3010	3280	3010	5910	21270	3730
		Standard Dev.	371	706	552	1088	1691	771
		No of Samples	48	90	190	76	151	140
Bicarbonate	mg/L	Average	620	533	609	644	490	626
		Median	586	537	588	631	480	637
		Minimum	405	135	292	178	239	281
		Maximum	2080	789	2240	947	1420	1110
		Standard Dev.	237	67	178	135	123	163
		No of Samples	47	90	186	75	147	141
Chloride	mg/L	Average	11	16	41	39	23	19
		Median	11	15	23	36	21	18
		Minimum	4	2	4	ND	10	6
		Maximum	35	161	250	259	58	42
		Standard Dev.	5	17	45	32	9	6
		No of Samples	48	89	190	75	151	142
Calcium	mg/L	Average	145	207	235	320	223	207
		Median	136	182	209	338	210	195
		Minimum	52	90	31	13	71	97
		Maximum	728	387	546	807	676	608
		Standard Dev.	88	68	96	122	92	64
		No of Samples	48	90	190	76	151	143

Table 16
Alluvium Water Quality Statistics
Major Ions

			East Fork Armells Creek				Stocker Creek	West Fork Armells Creek
			Upstream	Between B&C	Between A&B	Downstream		
Magnesium	mg/L	Average	208	291	262	417	281	312
		Median	209	297	260	410	271	265
		Minimum	71	107	44	ND	25	114
		Maximum	264	542	512	1310	704	588
		Standard Dev.	37	102	82	205	96	114
		No of Samples	48	90	190	76	151	143
Sodium	mg/L	Average	135	190	154	269	182	355
		Median	132	197	145	257	180	339
		Minimum	39	44	14	14	18	103
		Maximum	370	376	304	525	321	887
		Standard Dev.	42	84	52	134	48	183
		No of Samples	47	90	190	76	151	142
Potassium	mg/L	Average	8	5	8	8	5	7
		Median	8	5	8	7	6	8
		Minimum	ND	ND	ND	ND	ND	ND
		Maximum	34	14	23	26	14	17
		Standard Dev.	5	3	4	5	3	4
		No of Samples	48	90	190	76	151	142

Notes
All carbonate concentrations were <5 mg/L
One sample (EFAC - Downstream) had a chloride concentration below detection limit. This sample was not included in statistics calculation.
Fifty samples had potassium concentrations below detection limit. Statistics were calculated by substituting these concentrations with zero.

Table 17
Montana Groundwater Classification Summary

Classification	Use	Specific Conductance microSiemens/cm @ 25C
Class I	public and private water supplies, culinary and food processing purposes, irrigation drinking water for livestock and wildlife, commercial and industrial purposes	<= 1,000
Class II	public and private water supplies, culinary and food processing purposes, irrigation of some agricultural crops, drinking water for livestock and wildlife, and most commercial and industrial purposes	1,000 to 2,500
Class III	irrigation of some salt tolerant crops, some commercial and industrial purposes, drinking water for some livestock and wildlife, and drinking, culinary, and food processing purposes where the specific conductance is less than 7,000 microSiemens/cm at 25ºC	2,500 to 15,000
Class IV	some industrial and commercial uses	> 15,000

Notes
Source: Montana ARM 17.30.1006, Classifications, Beneficial Uses and Specific Standards for Groundwater

Table 18
Groundwater Water Quality DEQ-7 (October 2012 Edition) Human Health Standard Exceedances (a)

Well ID	Strata	Drainage or Mine Area (b)	Baseline (c)	Date	NO2+NO3-N mg/L	NO3-N mg/L	F mg/L	As Diss mg/L	Cd Diss mg/L	Pb Diss mg/L	Se Diss mg/L	Zn Diss mg/L
DEQ-7 Groundwater Standard (mg/L)					**10**	**10**	**4**	**0.01**	**0.005**	**0.015**	**0.05**	**2**
P-04	Alluvium	EFAC		8/19/1999	0.61		0.16	0.005	0.001	***0.1***		0.03
P-05	Alluvium	EFAC		11/20/1979	***23.35***		0.27		<0.005	<0.02	<0.005	0.04
P-05	Alluvium	EFAC		5/20/1980	***20.83***		0.25		<0.005	<0.02	<0.005	0.06
P-05	Alluvium	EFAC		5/15/1985	4.13		0.1	0.0003	0.002	***0.15***	0.0001	<0.003
WA-104	Alluvium	EFAC		11/14/1984	0.95		0.18		***0.034***	<0.02	<0.005	0.07
WA-104	Alluvium	EFAC		1/28/1987	0.29		0.22		***0.01***	<0.02	<0.005	0.05
WA-106	Alluvium	EFAC		8/28/1981	0.85		0.16		<0.002	***0.03***	<0.005	0.07
WA-107	Alluvium	SC		5/20/1986	0.24		0.14		***0.009***	<0.01	0.009	0.03
WA-108	Alluvium	SC		6/15/1988	0.84		0.22		***0.006***	<0.02	0.021	0.03
WA-110	Alluvium	SC		12/8/1983	2.57		0.13		<0.005	***0.02***	<0.005	0.4
WA-111	Alluvium	SC		7/11/1989	0.17		0.17		***0.01***	<0.02	0.017	<0.02
WA-113	Alluvium	EFAC		12/18/1985	***351***		0.19		***0.013***	<0.01	0.03	0.35
WA-113	Alluvium	EFAC		7/25/1989	0.19		0.37		<0.005	***0.02***	<0.005	0.03
WA-113	Alluvium	EFAC		11/19/1991	***88.1***		0.6		0.003	<0.01	<0.01	<0.01
WA-113	Alluvium	EFAC		8/4/1993	***10.5***		0.22		<0.001	<0.01	0.007	0.03
WA-118	Alluvium	EFAC		8/11/2004	0.18		***801***	<0.003	<0.0001	<0.003		<0.01
WA-119	Alluvium	EFAC		7/21/1995	0.74		0.39		<0.001	<0.01	***0.18***	<0.01
WA-121	Alluvium	EFAC		8/28/1981	***19.73***		0.15		<0.002	<0.02	<0.005	0.1
WA-123	Alluvium	EFAC		7/3/1989	0.59		0.48		***0.007***	<0.02	0.016	0.02
WA-124	Alluvium	EFAC		12/9/1980	0.04		0.19		<0.005	<0.02	<0.005	0.09
WA-124	Alluvium	EFAC		12/7/1983	***15.4***		0.22		<0.005	<0.02	<0.005	0.09
WA-124	Alluvium	EFAC		12/12/1985	5.1		0.22		***0.009***	<0.01	<0.005	<0.01
WA-124	Alluvium	EFAC		8/2/1993	<0.05		0.24		<0.001	***0.02***	<0.005	<0.01
WA-124	Alluvium	EFAC		8/12/2004	0.11		0.34	***0.011***	<0.0001	<0.003		<0.01
WA-127	Alluvium	EFAC		7/26/1989	<0.05		0.18		***0.012***	<0.02	0.01	<0.02
WA-128	Alluvium	EFAC		8/1/1989	<0.05		0.18		***0.007***	<0.02	<0.005	<0.02
WA-131	Alluvium	EFAC		7/9/1984	<0.05		0.19		0.004	***0.02***	0.007	0.35
WA-149	Alluvium	EFAC		7/10/1989	4.11		0.48		***0.008***	<0.02	0.011	0.04
WA-150	Alluvium	EFAC		7/18/1985	0.83		0.23		***0.006***	<0.01	<0.005	<0.01
WA-151	Alluvium	EFAC		6/5/1985	1.76		0.2		***0.007***	<0.01	<0.005	0.32
WA-151	Alluvium	EFAC		7/11/1989	2.42		0.22		***0.012***	<0.02	<0.005	0.02
WA-151	Alluvium	EFAC		8/10/1993	0.38		0.18		<0.001	***0.02***	<0.005	<0.01
WA-152	Alluvium	EFAC		6/14/1985	0.77		0.19		***0.009***	<0.01	<0.005	<0.01
WA-153	Alluvium	EFAC		9/10/1993	3.34		0.32		0.003	***0.02***	<0.005	<0.01
WA-154	Alluvium	EFAC		7/18/1985	1.21		0.25		***0.007***	<0.01	<0.005	<0.01
WA-154	Alluvium	EFAC		7/26/1995	***10.7***		0.32		<0.001	<0.01	0.024	<0.01

Table 18
Groundwater Water Quality DEQ-7 (October 2012 Edition) Human Health Standard Exceedances (a)

Well ID	Strata	Drainage or Mine Area (b)	Baseline (c)	Date	NO2+NO3-N mg/L	NO3-N mg/L	F mg/L	As Diss mg/L	Cd Diss mg/L	Pb Diss mg/L	Se Diss mg/L	Zn Diss mg/L
DEQ-7 Groundwater Standard (mg/L)					**10**	**10**	**4**	**0.01**	**0.005**	**0.015**	**0.05**	**2**
WA-156	Alluvium	SC		7/6/1989	1.27		0.19		***0.007***	<0.02	0.012	0.03
WA-157	Alluvium	SC		7/6/1989	2.67		0.24		***0.013***	<0.02	0.011	<0.02
WA-158	Alluvium	SC		9/17/1984	0.22		0.27		0.003	***0.02***	<0.005	0.03
WA-159	Alluvium	SC		9/6/1994	0.07		0.29		<0.001	***0.02***	<0.005	<0.01
WA-160	Alluvium	SC		2/10/1987	0.26		0.25		***0.008***	<0.01	0.005	0.05
WA-161	Alluvium	SC		8/29/1990	0.28		0.32		<0.001	***0.02***	<0.005	0.04
WA-165	Alluvium	SC		7/6/1989	0.44		0.26		***0.007***	<0.02	0.013	0.05
WA-166	Alluvium	SC		7/6/1989	0.15		0.23		***0.015***	<0.02	0.008	0.1
WA-167	Alluvium	SC		7/6/1989	0.31		0.23		***0.008***	<0.02	<0.005	<0.02
WA-167	Alluvium	SC		9/7/1993	0.06		0.17		<0.001	***0.02***	<0.005	0.02
WA-168	Alluvium	SC		7/2/1985	0.48		0.16		***0.008***	<0.01	0.005	0.01
WA-168	Alluvium	SC		7/6/1989	0.17		0.2		***0.006***	<0.02	0.005	0.04
WA-170	Alluvium	SC		6/4/1985	0.15		0.27		***0.009***	<0.01	<0.005	0.31
WA-170	Alluvium	SC		7/6/1989	0.26		0.34		***0.013***	<0.02	0.01	0.03
WA-171	Alluvium	EFAC		8/1/1989	2.52		0.29		***0.01***	<0.02	<0.005	<0.02
WA-183	Alluvium	WFAC		5/29/1986	0.14		0.22		***0.008***	<0.01	0.01	<0.01
WA-183	Alluvium	WFAC		7/9/1990	0.21		0.31		0.002	***0.02***	<0.005	0.04
WA-184	Alluvium	EFAC		5/29/1986	0.11		0.2		***0.008***	<0.01	0.009	<0.01
WA-184	Alluvium	EFAC		5/19/1994	0.3		0.25		<0.001	***0.02***	<0.005	0.02
WA-185	Alluvium	WFAC		7/3/1989	0.06		0.33		***0.007***	<0.02	0.007	<0.02
WA-186	Alluvium	WFAC		9/28/2000	0.05		0.22	0.005	0.001	0.01		***2.09***
WA-187	Alluvium	WFAC		5/29/1986	0.57		0.14		***0.008***	<0.01	0.006	<0.01
WA-187	Alluvium	WFAC		7/9/1990	0.37		0.2		<0.001	***0.02***	<0.005	<0.01
WA-188	Alluvium	WFAC		5/29/1986	1.8		0.15		***0.007***	<0.01	0.006	<0.01
WA-189	Alluvium	WFAC		8/30/1993	0.1		0.26		<0.001	***0.02***	<0.005	0.11
WA-190	Alluvium	WFAC		9/14/1984	0.24		0.42		0.002	***0.02***	<0.005	0.07
WA-191	Alluvium	WFAC		8/30/1993	0.27		0.41		<0.001	***0.02***	<0.005	<0.01
WA-192	Alluvium	WFAC		8/30/1993	0.57		0.34		0.003	***0.02***	<0.005	0.02
WA-193	Alluvium	WFAC		6/3/1985	0.12		0.37		***0.006***	<0.01	<0.005	0.21
WA-196	Alluvium	WFAC		6/3/1985	0.08		0.28		***0.006***	<0.01	<0.005	0.17
WA-204	Alluvium	WFAC		6/24/1985	<0.05		0.39		***0.006***	<0.01	<0.005	<0.01
WA-204	Alluvium	WFAC		7/26/1989	0.15		0.51		***0.007***	<0.02	0.009	0.05
WA-204	Alluvium	WFAC		7/18/2001	0.21		0.34	0.003	0.0001	***0.67***		0.04
WA-205	Alluvium	WFAC		7/25/1989	<0.05		0.4		***0.006***	<0.02	0.012	0.02
WA-209	Alluvium	EFAC		7/5/1989	1.71		0.26		***0.006***	<0.02	0.01	<0.02

Table 18
Groundwater Water Quality DEQ-7 (October 2012 Edition) Human Health Standard Exceedances (a)

Well ID	Strata	Drainage or Mine Area (b)	Baseline (c)	Date	NO2+NO3-N mg/L	NO3-N mg/L	F mg/L	As Diss mg/L	Cd Diss mg/L	Pb Diss mg/L	Se Diss mg/L	Zn Diss mg/L
DEQ-7 Groundwater Standard (mg/L)					**10**	**10**	**4**	**0.01**	**0.005**	**0.015**	**0.05**	**2**
WA-210	Alluvium	EFAC		7/5/1989	<0.05		0.29		***0.015***	<0.02	<0.005	<0.02
WA-210	Alluvium	EFAC		8/4/1993	0.45		0.24		0.003	***0.03***	<0.005	<0.01
WA-211	Alluvium	EFAC		8/19/1985	0.29		0.3		***0.006***	<0.02	<0.005	0.03
WA-211	Alluvium	EFAC		7/5/1989	0.33		0.28		***0.01***	<0.02	0.01	<0.02
WA-212	Alluvium	EFAC		8/5/1993	1.06		0.28		<0.001	<0.01	***0.096***	0.03
WA-213	Alluvium	EFAC		7/5/1989	0.75		0.36		***0.009***	<0.02	0.007	<0.02
WA-214	Alluvium	EFAC		7/13/1989	2.78		0.28		<0.005	***0.03***	0.01	<0.02
WA-214	Alluvium	EFAC		7/16/2001	0.05		0.18	***0.014***	0.0001	0.003		0.02
WA-214	Alluvium	EFAC		9/5/2007	0.11		***7.29***	0.01	<0.00008	<0.0005		<0.01
WA-215	Alluvium	EFAC		8/19/1985	<0.05		0.3		***0.006***	<0.02	<0.005	0.02
WA-218	Alluvium	WFAC		8/27/2003	1.02		0.5	***0.013***	<0.0001	<0.003		0.03
WD-107	SubMcKay	A	N	7/19/1990	<0.05		0.84		<0.001	***0.02***	<0.005	0.02
WD-159	SubMcKay	B	N	9/7/1989	<0.05		0.19		<0.005	***0.02***	<0.005	1.97
WD-159	SubMcKay	B	N	7/8/1994	<0.05		0.19		<0.001	***0.03***	<0.005	0.04
WD-177	SubMcKay	C	Y	12/11/1987	0.55		0.79		<0.001	***0.02***	<0.005	0.42
WD-178	SubMcKay	C	Y	8/20/1992	0.05		1.2		<0.001	<0.01	***0.091***	0.08
WD-179	SubMcKay	C	Y	12/11/1984	0.07		0.33		<0.005	<0.02	<0.005	***5.45***
WD-179	SubMcKay	C	Y	7/20/1988	<0.05		0.2		***0.006***	<0.02	<0.005	***3.62***
WD-180	SubMcKay	C	Y	7/24/1989	***27.6***		0.24		***0.009***	***0.03***	<0.005	0.11
WD-184	SubMcKay	B	Y	8/30/1985	<0.05		0.39		<0.005	<0.02	<0.005	***2.37***
WD-195	SubMcKay	B, west of	Y	9/16/2009	<0.005		0.27	***0.017***	<0.00004	0.00012		0.0033
WD-195	SubMcKay	B, west of	Y	9/16/2010	<0.01		0.28	***0.019***	<0.00008	<0.0001		0.0069
WD-195	SubMcKay	B, west of	Y	9/20/2011		0.02	<1.0	***0.013***	<0.000080	0.00049		0.022
WI-102	Interburden	A	N	11/16/1993	<0.05		0.22		0.001	***0.02***	0.006	<0.01
WI-102	Interburden	A	N	9/18/2008	<0.01		***13***	<0.003	<0.00008	<0.0005		0.01
WI-111	Interburden	A	N	7/18/1988	<0.05		0.3		***0.006***	<0.02	<0.005	***2.94***
WI-111	Interburden	A	N	8/28/1996	0.23		0.2		<0.001	***0.02***	<0.005	0.02
WI-111	Interburden	A	N	8/27/2002	***21.2***		0.16	<0.003	0.0002	<0.003		<0.01
WI-153	Interburden	C	N	7/2/2000	0.05		0.46	***0.017***	0.001	0.01		0.04
WI-153	Interburden	C	N	8/25/2003	<0.05		0.47	***0.012***	<0.0001	<0.003		0.02
WI-153	Interburden	C	N	9/15/2009	0.01		0.52	***0.016***	<0.00004	<0.00025		0.012
WI-153	Interburden	C	N	9/16/2010	<0.01		0.53	***0.018***	<0.00008	<0.0001		0.0088
WI-157	Interburden	B	N	11/3/1993	0.11		0.15		0.002	***0.02***	<0.005	<0.01
WI-159	Interburden	B	N	12/11/1985	0.05		0.16		<0.005	<0.02	<0.005	***2.16***

Table 18
Groundwater Water Quality DEQ-7 (October 2012 Edition) Human Health Standard Exceedances (a)

Well ID	Strata	Drainage or Mine Area (b)	Baseline (c)	Date	NO2+NO3-N mg/L	NO3-N mg/L	F mg/L	As Diss mg/L	Cd Diss mg/L	Pb Diss mg/L	Se Diss mg/L	Zn Diss mg/L
DEQ-7 Groundwater Standard (mg/L)					**10**	**10**	**4**	**0.01**	**0.005**	**0.015**	**0.05**	**2**
WI-159	Interburden	B	N	9/20/1993	<0.05		0.11		0.003	***0.03***	<0.005	0.04
WI-162	Interburden	B	Y	1/21/1983	<0.05		0.14		<0.005	<0.02	<0.005	***3.05***
WI-162	Interburden	B	N	8/23/2006	0.01		0.21	<0.003	<0.00008	***0.37***		<0.01
WI-165	Interburden	C	Y	9/1/1982	0.09		0.26		<0.005	<0.02	<0.005	***3.23***
WI-166	Interburden	B	Y	9/23/1985	1.18		0.18		<0.005	***0.18***	<0.005	1.51
WI-168	Interburden	C	Y	7/24/1986	0.88		0.2		<0.005	***0.04***	<0.005	0.88
WI-170	Interburden	C	Y	11/2/1989	0.89		0.1		<0.005	***0.02***	<0.005	<0.02
WI-172	Interburden	C, west of	Y	11/2/1982	<0.05		0.17		<0.005	0	<0.005	***2.66***
WI-172	Interburden	C, west of	Y	9/9/1988	<0.05		0.22		<0.005	***0.02***	<0.005	***2.04***
WI-177	Interburden	C	Y	12/10/1987	0.13		0.19		<0.001	***0.02***	<0.005	0.53
WI-178	Interburden	C	Y	6/23/1988	<0.05		0.22		<0.005	<0.02	0.012	***3.46***
WI-179	Interburden	C	Y	8/27/1990	<0.05		0.16		<0.001	***0.02***	<0.005	0.03
WI-180	Interburden	C	Y	7/17/1989	0.05		0.18		***0.007***	<0.02	<0.005	0.88
WI-186	Interburden	C	N	7/11/2001	***13.9***		0.16	0.003	0.0012	0.003		0.06
WM-100	McKay	B	N	12/16/1985	0.17		0.16		0.003	<0.01	0.005	***3.22***
WM-101	McKay	A	N	1/25/1988	0.88				<0.005	<0.02	0.014	***2.75***
WM-104	McKay	A	N	9/11/1989	<0.05		0.14		<0.005	<0.02	<0.005	***2.21***
WM-104	McKay	A	N	9/8/2005	0.1		0.19	<0.003	<0.0001	***0.02***		0.03
WM-105	McKay	A, north of	N	7/13/1994	0.4		0.53		<0.001	***0.12***	<0.005	0.09
WM-109	McKay	C	Y	11/20/1987	0.06		1		<0.001	***0.02***	<0.005	0.05
WM-111	McKay	C	Y	12/10/1993	<0.05		0.22		<0.001	***0.02***	<0.005	<0.01
WM-112	McKay	C	Y	7/20/1989	0.07		0.29		<0.005	<0.02	<0.005	***2.24***
WM-158	McKay	B	N	8/7/1982	0.21		0.33		<0.005	***0.02***	<0.005	0.08
WM-158	McKay	B	N	11/11/1993	<0.05		0.25		<0.001	***0.03***	<0.005	0.02
WM-158	McKay	B	N	8/31/2001	0.05		0.22	0.003	0.0001	***0.29***		0.02
WM-164	McKay	B	Y	6/14/1994	0.07		0.12		<0.001	***0.11***	<0.005	0.04
WM-165	McKay	C	Y	7/18/1986	2		0.2		<0.005	***0.04***	<0.005	0.03
WM-165	McKay	C	Y	9/15/1988	0.05		0.16		<0.005	***0.04***	0.022	0.85
WM-168	McKay	C	Y	7/25/1986	0.42		0.17		<0.005	***0.02***	<0.005	0.76
WM-168	McKay	C	Y	12/1/1987	<0.05		0.16		0.001	<0.01	<0.005	***3.79***

Table 18
Groundwater Water Quality DEQ-7 (October 2012 Edition) Human Health Standard Exceedances (a)

Well ID	Strata	Drainage or Mine Area (b)	Baseline (c)	Date	NO2+NO3-N mg/L	NO3-N mg/L	F mg/L	As Diss mg/L	Cd Diss mg/L	Pb Diss mg/L	Se Diss mg/L	Zn Diss mg/L
DEQ-7 Groundwater Standard (mg/L)					**10**	**10**	**4**	**0.01**	**0.005**	**0.015**	**0.05**	**2**
WM-168	McKay	C	Y	10/25/1989	0.13		0.2		<0.005	<0.02	<0.005	***4.6***
WM-176	McKay	C	Y	11/2/1989	<0.05		0.4		<0.005	***0.02***	<0.005	<0.02
WM-179	McKay	C	Y	6/28/1988	0.12		0.22		0.005	<0.02	0.022	***2.31***
WM-179	McKay	C	Y	12/21/1992	<0.05		0.17		<0.001	***0.02***	<0.005	0.01
WM-181	McKay	C	Y	7/28/1988	0.45		0.2		<0.005	<0.02	<0.005	***4.67***
WM-181	McKay	C	Y	7/31/1990	1.02		0.25		<0.001	<0.01	<0.005	***2.71***
WM-185	McKay	B	N	2/9/1987	<0.05		0.16		0.004	<0.01	<0.005	***3.58***
WO-101	Overburden	B	N	8/30/1989	0.07		0.29		***0.006***	<0.02	0.006	0.68
WO-103	Overburden	C	Y	9/23/1980	0.05		0.23		<0.005	***0.03***	<0.005	0.02
WO-103	Overburden	C	Y	9/10/1982	***103***		0.22		<0.005	<0.02	<0.005	0.04
WO-107	Overburden	C	Y	8/22/1985	<0.05		0.16		<0.005	***0.03***	<0.005	<0.02
WO-107	Overburden	C	Y	2/12/1987	<0.05		0.25		***0.01***	<0.01	<0.005	<0.01
WO-108	Overburden	B	Y	6/28/1990	0.15		0.19		0.001	***0.02***	<0.005	<0.01
WO-166	Overburden	B	Y	9/23/1985	0.87		0.24		<0.005	***0.05***	<0.005	0.09
WO-166	Overburden	B	N	10/21/1993	0.24		0.16		<0.001	***0.03***	<0.005	0.09
WO-172	Overburden	C, south of	Y	9/13/1988	<0.05		0.26		<0.005	***0.06***	0.008	1.98
WO-178	Overburden	C	Y	1/29/1984	<0.05		0.21		***0.02***	***0.08***	<0.005	0.97
WO-179	Overburden	C	Y	6/28/1988	0.87		0.27		***0.006***	<0.02	0.024	0.11
WR-103	Rosebud	C, south of	Y	7/29/1986	1.27		0.21		<0.005	***0.06***	0.005	0.27
WR-103	Rosebud	C, south of	Y	9/1/1988	<0.05		0.18		<0.005	<0.02	0.005	***4.36***
WR-104	Rosebud	A	N	9/12/1989	<0.05		0.1		<0.005	<0.02	<0.005	***3.81***
WR-105	Rosebud	C	N	8/30/1990	<0.05		0.11		<0.001	***0.04***	<0.005	0.02
WR-111	Rosebud	A	N	9/13/1989	0.13		0.08		***0.014***	<0.02	0.005	0.21
WR-112	Rosebud	C	Y	6/17/1988	0.1		0.13		***0.01***	<0.02	0.012	1.09
WR-115	Rosebud	C	Y	7/18/1986	0.92		0.2		<0.005	***0.02***	<0.005	<0.02
WR-125	Rosebud	B, west of	Y	12/31/1981	<0.01		0.25		<0.002	<0.02	<0.005	***3.21***
WR-125	Rosebud	B, west of	Y	12/31/1982	0.03		0.23		<0.002	<0.02	<0.005	***3.21***
WR-125	Rosebud	B, west of	Y	7/23/1986	0.38		0.25		<0.005	***0.02***	<0.005	***3.64***
WR-125	Rosebud	B, west of	Y	10/12/1987	<0.05		0.16		0.002	<0.01	<0.005	***2.24***
WR-125	Rosebud	B, west of	Y	6/1/2000	***34.6***		0.23	0.005		0.01		0.05
WR-126	Rosebud	C	N	9/5/2007	***16.7***		0.46	0.005	<0.00008	<0.0005		0.01
WR-127	Rosebud	A	N	11/7/1989	0.16		0.2		<0.005	***0.02***	0.005	<0.02
WR-154	Rosebud	C	N	2/13/1987	<0.05		0.17		***0.008***	<0.01	0.008	0.38

Table 18
Groundwater Water Quality DEQ-7 (October 2012 Edition) Human Health Standard Exceedances (a)

Well ID	Strata	Drainage or Mine Area (b)	Baseline (c)	Date	NO2+NO3-N mg/L	NO3-N mg/L	F mg/L	As Diss mg/L	Cd Diss mg/L	Pb Diss mg/L	Se Diss mg/L	Zn Diss mg/L
DEQ-7 Groundwater Standard (mg/L)					**10**	**10**	**4**	**0.01**	**0.005**	**0.015**	**0.05**	**2**
WR-160	Rosebud	B	N	8/24/1982	0.26		0.3		<0.005	***0.02***	<0.005	1.11
WR-160	Rosebud	B	N	8/19/1988	0.22		0.14		<0.005	***0.07***	0.005	1.91
WR-162	Rosebud	B	Y	9/30/1988	0.1		0.21		<0.005	***0.03***	0.012	1.34
WR-168	Rosebud	C	Y	11/23/1987	0.16		0.15		0.004	<0.01	<0.005	***2.52***
WR-168	Rosebud	C	N	9/15/2010	0.01		<0.2	<0.0005	***0.24***	<0.0001		<0.005
WR-181	Rosebud	C	Y	2/17/1984	<0.05		<0.1		***<0.005***	<0.02	<0.005	***2.15***
WR-181	Rosebud	C	Y	7/20/1988	<0.05		0.1		<0.005	<0.02	<0.005	***4.77***
WR-181	Rosebud	C	Y	8/1/1990	<0.05		<0.1		<0.001	***0.02***	<0.005	0.01
WR-206	Rosebud	B	N	7/27/2000		0.05	0.17		***0.007***	0.01		0.02
WR-207	Rosebud	B	N	7/27/2000	0.05		0.17	0.005	***0.007***	0.01		0.02
WR-208	Rosebud	B	N	4/13/2000	0.05		0.13	***0.1***	0.001	0.01		1.12
WS-100	Spoils	A	N	9/16/2009	***10.5***		<0.21	0.00088	<0.00004	0.00014		0.0067
WS-105	Spoils		N	10/30/1989	2.55		0.2		<0.005	<0.02	<0.005	***2.23***
WS-106	Spoils	A	N	9/30/1981	1.35		0.33		<0.002	<0.02	<0.005	***2.61***
WS-106	Spoils	A	N	9/22/1983	1.7		0.21		***0.015***	<0.02	<0.005	1.2
WS-107	Spoils	A	N	12/18/1985	***23.6***		0.25		0.002	<0.01	<0.005	0.31
WS-107	Spoils	A	N	9/8/2005	***19***		0.2	<0.003	<0.0001	<0.003		0.01
WS-108	Spoils	D	N	2/11/1987	0.11		0.18		***0.009***	<0.01	0.006	0.12
WS-110	Spoils	E, southeast of	N	7/6/1990	0.23		0.19		<0.001	***0.04***	<0.005	0.03
WS-111	Spoils	E, southeast of	N	9/8/2005	***16***		0.17	<0.003	0.0002	<0.003		0.1
WS-111	Spoils	E, southeast of	N	9/18/2008	***12.2***		0.16	<0.003	0.00012	0.0009		0.05
WS-111	Spoils	E, southeast of	N	9/22/2011		***12***	0.35	0.004	0.00032	0.0074		0.085
WS-113	Spoils	A	N	6/16/1988	0.08		0.21		***0.009***	<0.02	0.026	<0.02
WS-114	Spoils	A	N	7/19/1999	0.05		0.21	0.005	***0.006***	0.01		0.09
WS-115	Spoils	A	N	8/7/1997	0.05		0.15		***0.02***	***0.08***	<0.005	0.18
WS-116	Spoils	E	N	9/27/1993	<0.05		0.13		<0.001	***0.05***	<0.005	<0.01
WS-116	Spoils	E	N	8/6/1995	<0.05		0.1		<0.001	***0.02***	<0.005	<0.01
WS-117	Spoils	E	N	11/17/1993	<0.05		0.11		<0.001	***0.02***	<0.005	0.01
WS-126	Spoils	D	N	9/29/1999	0.05		0.17	0.005	0.001	0.01		***3***
WS-127	Spoils	D	N	9/29/1999	***39.7***		0.18	0.005	0.001	0.01		0.13
WS-127	Spoils	D	N	8/23/2002	***11.6***		0.91	0.005	<0.0001	<0.003		0.01
WS-127	Spoils	D	N	9/8/2005	***50***		0.27	<0.003	0.0001	<0.003		0.07
WS-127	Spoils	D	N	9/18/2008	***11.8***		0.23	0.007	<0.00008	<0.0005		0.01
WS-157	Spoils	B	N	8/17/1982	***16.48***		0.18		<0.005	<0.02	<0.005	1.07
WS-158	Spoils	B	N	12/4/1987	1.84				<0.005	***0.02***	0.005	0.69

Table 18
Groundwater Water Quality DEQ-7 (October 2012 Edition) Human Health Standard Exceedances (a)

Well ID	Strata	Drainage or Mine Area (b)	Baseline (c)	Date	NO2+NO3-N mg/L	NO3-N mg/L	F mg/L	As Diss mg/L	Cd Diss mg/L	Pb Diss mg/L	Se Diss mg/L	Zn Diss mg/L
DEQ-7 Groundwater Standard (mg/L)					**10**	**10**	**4**	**0.01**	**0.005**	**0.015**	**0.05**	**2**
WS-187	Spoils		N	8/23/2002	0.67		0.58	***0.013***	0.0001	<0.003		<0.01
WS-188	Spoils	D	N	8/22/2002	0.26		0.2	<0.003	***0.0061***	<0.003		0.05

Notes

(a) Samples from wells in Area A, B and C and spoils wells in Area D and E.
Circular DEQ-7, Montana Numeric Water Quality Standards, October 2012 edition.

(b) ***Drainages***
EFAC = East Fork Armells Creek
WFAC = West Fork Armells Creek
RC = Rosebud Creek
SC = Stocker Creek (EFAC tributary)
SpC = Spring Creek (RC tributary)
CC = Cow Creek (RC tributary)
PC = Pony Creek (RC tributary)
CoC = Corral Creek (EFAC tributary)

(c) Baseline samples are samples obtained before mining started within 0.5 mile radius of the well.

Table 19
Groundwater Level Recovery in Spoils

Station ID	Mine Area	Initial Water Level		Most Recent Water Level		Recovery (inches)	Period (years)	Rate of Recovery	Average Rate per Area
		Date	Elevation (ft above msl)	Date	Elevation (ft above msl)				
EX-202	A	8/1/80	3257.83	11/12/96	3260.39	31	16.3	2	
EX-203	A	8/1/80	3257.12	11/12/96	3261.97	58	16.3	4	
EX-204	A	9/12/80	3259.81	11/12/96	3264.57	57	16.2	4	
S-33	A	8/30/82	3282.21	8/3/95	3286.32	49	12.9	4	
WS-100	A	10/25/79	3246.60	6/15/11	3256.95	124	31.6	4	
WS-101	A	10/25/79	3253.30	6/16/11	3257.84	54	31.6	2	
WS-106	A	10/25/79	3279.80	6/18/11	3294.02	171	31.6	5	
WS-107	A	5/22/80	3292.10	6/16/11	3306.50	173	31.1	6	
WS-113	A	8/1/80	3265.70	6/15/11	3272.29	79	30.9	3	
WS-114	A	8/1/80	3275.26	6/15/11	3288.25	156	30.9	5	
WS-115	A	8/1/80	3255.98	6/22/11	3264.59	103	30.9	3	**4**
1+00	B	10/10/78	3227.7	3/16/94	3241.98	171	15.4	11	
CR-2	B	10/10/78	3238	12/17/96	3243.96	72	18.2	4	
D-2	B	2/15/78	3234.2	12/13/96	3243.57	112	18.8	6	
S-35	B	9/27/82	3238.22	8/26/96	3245.76	90	13.9	7	
S-36	B	8/27/82	3230.11	7/24/96	3244.18	169	13.9	12	
S-37	B	8/27/82	3229.94	7/24/96	3244.83	179	13.9	13	
SB-2	B	9/26/84	3233.41	7/24/96	3245.55	146	11.8	12	
SB-3	B	6/29/84	3232.98	5/22/96	3252.80	238	11.9	20	
T-3A-P	B	11/11/77	3237.2	6/15/94	3244.24	84	16.6	5	
T-5B-P	B	11/15/77	3229.80	12/17/96	3244.79	180	19.1	9	
WS-118	B	8/30/82	3233.22	6/16/11	3266.88	404	28.8	14	
WS-157	B	8/27/82	3224.10	6/16/11	3263.88	477	28.8	17	
WS-158	B	9/28/82	3228.24	6/16/11	3259.63	377	28.7	13	
WS-159	B	8/27/82	3233.87	9/2/11	3252.09	219	29.0	8	
WS-184	B	8/29/85	3264.16	9/21/11	3284.83	248	26.1	10	**11**

Table 19
Groundwater Level Recovery in Spoils

Station ID	Mine Area	Initial Water Level		Most Recent Water Level		Recovery (inches)	Period (years)	Rate of Recovery	Average Rate per Area
		Date	Elevation (ft above msl)	Date	Elevation (ft above msl)				
WS-121	C	12/30/97	3419.11	8/24/11	3423.48	52	13.6	4	**4**
WS-125	D	12/1/98	3252.79	6/28/11	3259.60	82	12.6	6	
WS-126	D	10/15/98	3242.70	6/23/11	3250.77	97	12.7	8	
WS-127	D	12/1/98	3243.21	6/23/11	3251.42	99	12.6	8	
WS-128	D	12/1/98	3265.54	6/29/11	3268.97	41	12.6	3	**6**
EPA-05	E	12/11/74	3184.12	11/1/96	3205.97	262	21.9	12	
EPA-06	E	1/10/75	3183.14	11/1/96	3205.94	274	21.8	13	
EPA-08	E	12/11/74	3185.08	11/1/96	3206.92	262	21.9	12	
EPA-10	E	12/11/74	3184.46	11/1/96	3208.79	292	21.9	13	
EPA-12	E	12/11/74	3185.16	11/1/96	3206.5	256	21.9	12	
S-01	E	10/23/73	3199.2	1/29/90	3201.14	23	16.3	1	
S-02	E	10/23/73	3189.48	7/6/90	3199.72	123	16.7	7	
S-07	E	10/3/75	3244.49	3/24/86	3246.17	20	10.5	2	
SE-3	E	6/28/84	3218.98	12/17/96	3226.45	90	12.5	7	
WS-110	E	11/23/82	3251.31	6/30/11	3257.71	77	28.6	3	
WS-111	E	1/21/83	3202.24	6/30/11	3210.53	99	28.4	3	
WS-112	E	12/9/80	3196.81	6/30/11	3206.29	114	30.6	4	
WS-116	E	7/10/81	3219.32	6/21/11	3254.53	423	29.9	14	
WS-117	E	7/13/81	3237.50	6/30/11	3241.68	50	30.0	2	**8**

Notes

Other factors may contribute to the rate of recovery in these wells as there are ongoing mining activities in Areas A, B and C.
Wells exhibiting recovery and for which more than 10 years of water level data are available are shown.

Table 20
Private Wells within 5-foot Simulated Drawdown Contour (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	Static Water Level	Driller	Completion or Priority Date	Comments	Potentially Impacted (d)
P/O	GWIC	204		2679305.1	597133.7	Farley B	40	9		18991230	no well log	U
P/O	GWIC	212		2673950.4	594317.4	Farley Ranch				18991230		U
P/O	GWIC	213		2673797.7	594312.0	Farley Inc		20		18991230		U
P/O	GWIC	216		2668375.0	593391.5	Farley Inc				18991230		U
P/O	GWIC	307		2685214.1	601503.4	Kimball L.S.	50	6		18991230	likely mined out, no well log	Y
P/O	GWIC	331		2711356.6	597499.7	Mcrae	51			18991230		U
P/O	GWIC	1068		2677584.0	605388.6	Fadhl George	252	75		19590101	Appears to be subMcKay well, possibly same as 14226, 42KJ 106458 00	N
P/O	GWIC	11979		2680284.9	598244.7	Farley's Inc.	150	20		19140101	no well log	U
P/O	GWIC	11980		2679206.5	597039.0	Farley's Inc.	100	20		19500101	well log illegible, unlikely to be alluvium	N
P/O	GWIC	11981		2673698.0	594246.5	Farley's Inc.		20		19140101	well log illegible	U
P/O	GWIC	11982		2658364.3	593184.9	Farleys, Inc.	145	70	Askin Drilling	19840209	Appears to be an overburden well, head in well > predicted drawdown	Y
P/O	GWIC	11983		2655579.8	593358.7	Farleys Inc.	20			19300101	shallow well	U
P/O	GWIC	11984		2655602.9	592688.4	Farleys Inc.	20			19630101	shallow well	U
P/O	GWIC	11985		2654917.9	593335.9	Farleys Inc.	225			19300101		U
P/O	GWIC	11988		2656698.1	589020.5	Farleys Inc.	225			19630101		U
P/O	GWIC	12002		2689271.5	599231.4	Farleys Inc.	381	144		19470101	possibly mined out, well log illegible	Y
P/O	GWIC	12003		2689921.3	599586.8	Farleys Inc.	50			19470101	well log illegible	U
P/O	GWIC	14226		2677402.8	605469.7	N.P.R.R. & Fadhl G.	252	146	B & H Drilling	19590412	Appears to be subMcKay well, possibly same as 1068, 42KJ 106458 00	N
P/O	GWIC	14252		2688488.8	612425.3	MacDonald, Duncan				19590101		U
P/O	GWIC	128355		2655145.9	591155.4	Eernisse, Gary	120	64	Sunrise Drilling Inc	19920514	head in well >> predicted drawdown	N
P/O	GWIC	139748		2692792.1	589306.4	Mcrea Doug	320		Askin Drilling	19910801	320 ft dry hole	N
P/O	GWIC	145092		2678886.5	606014.9	State Lands	100	14	Sunrise Drilling Inc	19921119	well head >> predicted drawdown, appears to be subMcKay well	N
P/O	GWIC	192519		2684087.4	610169.4	Anderson, Joe and Marlene	150	74.3	Corveau Drilling	20010605	well head >> predicted drawdown, appears to be subMcKay well	N
P/O	GWIC	192751		2661847.6	604433.7	Great Northern Properties	400	220	Sharp Drilling Inc	20010428	head in well >> predicted drawdown, subMcKay well	N
P/O	GWIC	212086		2673087.8	588429.2	Ashenhurst Ranch Inc	480	340	Ronald L Askin Drilling	20040518	head in well >> predicted drawdown	N
P/O	GWIC	246645		2642769.5	601324.6	Booth Land & Livestock	375	265	Gordon Drilling Inc	20080612	head in well >> predicted drawdown	N
P/O	GWIC	250613		2648241.4	602250.8	N49E1	200		Teton	19831104		U
P/O	GWIC	250616		2640606.8	601991.9	N49.5W 6000	320		Teton	19831103		U
S	GWIC, NRIS	11947	42KJ 162827 00	2635180.0	603578.8	Pinkerton, Bill	83	60		19570501	appears to be overburden well, impact from mining in ABC not likely	N
I/C	GWIC, NRIS	11972	42KJ 94831 00	2661571.9	604465.7	Ervin, Jack F.	105	28	Davis Drilling	19850619	appears to be McKay coal well, head in well >> predicted drawdown	N
D	GWIC, NRIS	11987	42KJ 68082 00	2655809.4	589172.1	Rhodes, Ronald & Michele	300	220	Ronald L Askin Drilling	19880407	head in well >> predicted drawdown	N
S	GWIC, NRIS	12019	42A 27337 00	2685332.2	583445.9	Greenleaf Land & Liv	90	30		19460901	head in well >> predicted drawdown	N

Table 20
Private Wells within 5-foot Simulated Drawdown Contour (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	Static Water Level	Driller	Completion or Priority Date	Comments	Potentially Impacted (d)
I/C	GWIC, NRIS	14254	42KJ 5632 00	2698510.9	610741.1	Frontier Village	175	40	Ronald L Askin Drilling	19731125	head in well >> predicted drawdown	N
I/C	GWIC, NRIS	14255	42KJ 25025 00	2698510.9	610741.1	Montana Frontier	460	200	Ronald L Askin Drilling	19791018	head in well >> predicted drawdown	N
I/C	GWIC, NRIS	136771	42KJ 85507 00	2681648.1	597006.3	County of Rosebud	141	70	Higgins Drilling Company	19930514		N
S	NRIS		42A 27339 00	2680091.6	584379.4					19451231		U
I/C	NRIS		42A 30010169	2683188.8	598053.2					20040325		U
S	NRIS		42A 42807 00	2711289.7	597570.5					19820319		U
S	NRIS		42A 52220 00	2673974.6	589469.9					19830321		U
I/C	NRIS		42A 56520 00	2701109.6	585971.3		67			19840716		U
S	NRIS		42A 58905 00	2686489.3	579851.9		120			19850322		U
I/C	NRIS		42A 58906 00	2689057.9	581251.0		97			19850322		U
I/C	NRIS		42A 5968 00	2706342.5	588148.1		297			19750715		U
S	NRIS		42KJ 106423 00	2678897.5	600217.1		80			19561231		U
S	NRIS		42KJ 106449 00	2652565.3	597322.5		143			19431231		U
S	NRIS		42KJ 106451 00	2657776.3	599475.2		115			19541231	will be mined out	Y
S	NRIS		42KJ 106456 00	2667278.4	607367.3		140			19571231		U
S	NRIS		42KJ 106458 00	2677180.4	605691.4		252			19591231	Appears to be subMcKay well, possibly same as 14226, 42KJ 106458 00	N
S	NRIS		42KJ 108298 00	2686800.2	598037.0		125			19631206		U
S	NRIS		42KJ 108382 00	2646607.4	597113.8		325			19601231		U
S	NRIS		42KJ 108499 00	2668557.1	593253.4					19811230		U
S	NRIS		42KJ 108508 00	2636571.7	601411.6					19811230		U
S	NRIS		42KJ 108525 00	2662232.1	604483.3					19811230		U
D	NRIS		42KJ 113990 00	2660939.6	603631.2		395			20010403		U
I/C	NRIS		42KJ 142734 00	2698300.7	608470.5		595			19360830		U
I/C	NRIS		42KJ 142735 00	2697635.6	608440.6		518			19430115		U
I/C	NRIS		42KJ 142736 00	2699630.5	608516.4		514			19460731		U
D	NRIS		42KJ 15835 00	2690036.5	599959.0		280			19771026		U
D	NRIS		42KJ 177153 00	2690053.3	599464.4					19471231		U
D	NRIS		42KJ 177605 00	2690053.3	599464.4					19471130		U
S	NRIS		42KJ 177609 00	2690053.3	599464.4					19471231		U
S	NRIS		42KJ 177610 00	2690053.3	599464.4					19471130		U
S	NRIS		42KJ 183220 00	2684693.0	601276.6					19321031		U
S	NRIS		42KJ 183243 00	2654018.4	593405.3					19300630		U
S	NRIS		42KJ 183263 00	2686800.2	598037.0					19600508		U
S	NRIS		42KJ 183290 00	2659960.8	593604.7		145			19460930		U
S	NRIS		42KJ 183300 00	2642118.8	603404.8		150			19460628	will be mined out	Y
S	NRIS		42KJ 183311 00	2652565.3	597322.5					19470410		U
S	NRIS		42KJ 183323 00	2683426.4	599715.7					19600831		U
S	NRIS		42KJ 183328 00	2673816.4	594089.7					19141231		U
S	NRIS		42KJ 183330 00	2647267.9	597136.2					19551231		U
S	NRIS		42KJ 183336 00	2678897.5	600217.1					19460404		U

Table 20
Private Wells within 5-foot Simulated Drawdown Contour (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	Static Water Level	Driller	Completion or Priority Date	Comments	Potentially Impacted (d)
S	NRIS		42KJ 183471 00	2667278.4	607367.3					19490430		U
S	NRIS		42KJ 183487 00	2657468.5	588896.5		220			19541220		U
S	NRIS		42KJ 183506 00	2679646.1	597596.7					19141231		U
S	NRIS		42KJ 183535 00	2654677.8	593426.4		110			19470702		U
D	NRIS		42KJ 183536 00	2673816.4	594089.7					19141231		U
S	NRIS		42KJ 30007772	2692821.4	612138.5		120			20030729		U
S	NRIS		42KJ 30007849	2676304.7	598806.4		247			20030915		U
S	NRIS		42KJ 30015552	2678733.1	605018.3		280			20050620		U
S	NRIS		42KJ 30052441	2642504.6	601597.2		298			20120103		U
S	NRIS		42KJ 30052533	2655463.4	605016.1		155			20120117		U
D	NRIS		42KJ 39568 00	2690053.3	599464.4					19471231		U
D	NRIS		42KJ 39570 00	2690053.3	599464.4					19471231		U
I/C	NRIS		42KJ 42049 00	2701912.7	608812.6					19820304		U
S	NRIS		42KJ 42797 00	2636571.7	601411.6					19820319		U
S	NRIS		42KJ 42801 00	2661571.9	604465.7		380			19820319		U
S	NRIS		42KJ 42802 00	2668557.1	593253.4					19820319		U
S	NRIS		42KJ 44176 00	2654677.8	593426.4					19820406		U
S	NRIS		42KJ 52501 00	2703166.8	602558.9		120			19830622		U
I/C	NRIS		42KJ 52502 00	2683470.9	598393.9		120			19830622		U
I/C	NRIS		42KJ 52503 00	2683448.4	599054.8		140			19830622		U
I/C	NRIS		42KJ 52504 00	2683470.9	598393.9		38			19830622		U
S	NRIS		42KJ 52505 00	2696440.1	605731.8		145			19830622		U
I/C	NRIS		42KJ 52531 00	2693963.2	600922.1					19830812		U
I/C	NRIS		42KJ 52532 00	2691985.7	600850.6					19830812		U
S	NRIS		42KJ 54877 00	2694529.8	603586.6		47			19831223		U
I/C	NRIS		42KJ 589 00	2692256.2	602514.1		84			19731003		U
I/C	NRIS		42KJ 63113 00	2673883.6	606244.6		355			19860716		U
D	NRIS		42KJ 80635 00	2656150.0	588853.3		120			19920615		U
S	NRIS		42KJ 8210 00	2667874.5	593891.0					19400415		U
I/C	NRIS		42KJ 870 00	2699906.3	609483.9		653			19731030		U
I/C	NRIS		42KJ 872 00	2698808.5	604074.3		84			19731030		U
M	NRIS		42KJ 94430 00	2700254.0	609157.2		450			19820422		U

Notes

(a) Non-industrial groundwater users within 2026 five foot drawdown contour (incl. Rosebud coal, McKay coal and subMcKay).

(b) Types
D = Domestic
I/C = Industrial or Commercial
M = Municipal
P/O = Private or Other
S = Stock

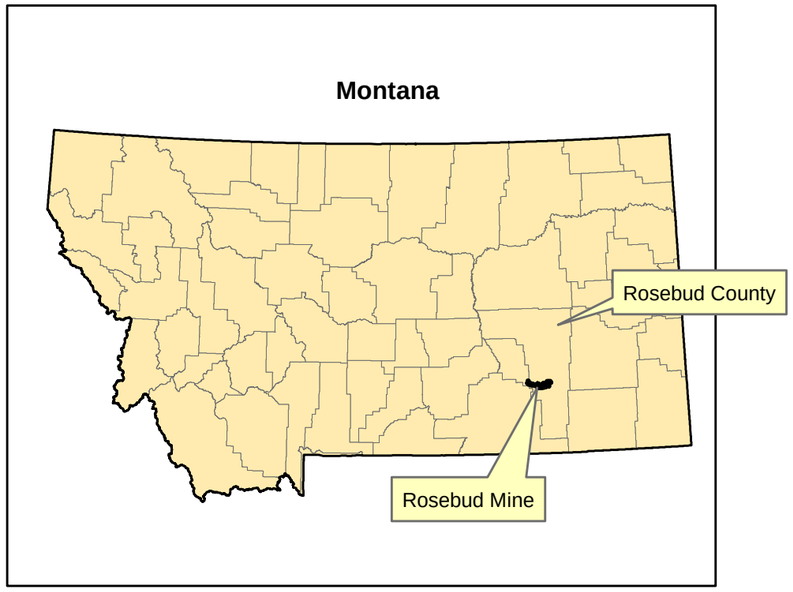
(c) Two public datasets from the National Resource Information System (NRIS) were consulted: GWIC wells and Water Rights Data
Mined out wells were removed from the selection. When enough data was available (well depth and completion/priority date) duplicate entries were merged.

(d) Potential impact: Y = yes, N = no, U = unknown, not enough information availabel to draw conclusion

Figures

Area B – AM4 (Application Amendment 00184)
Comprehensive Evaluation of Probable Hydrologic Consequences
Areas A, B and C
Western Energy Rosebud Mine

Exhibit 8



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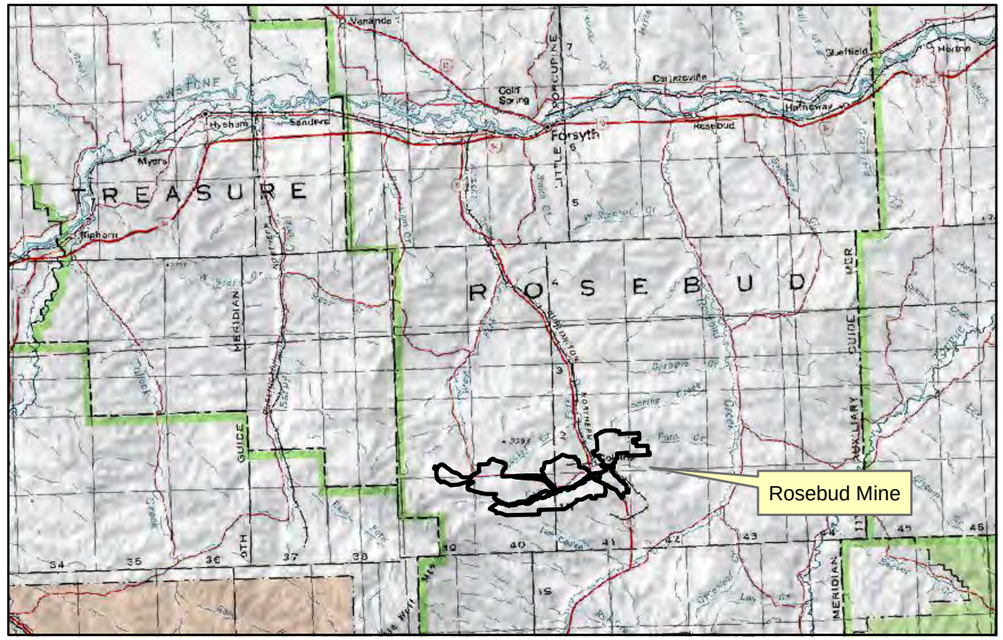
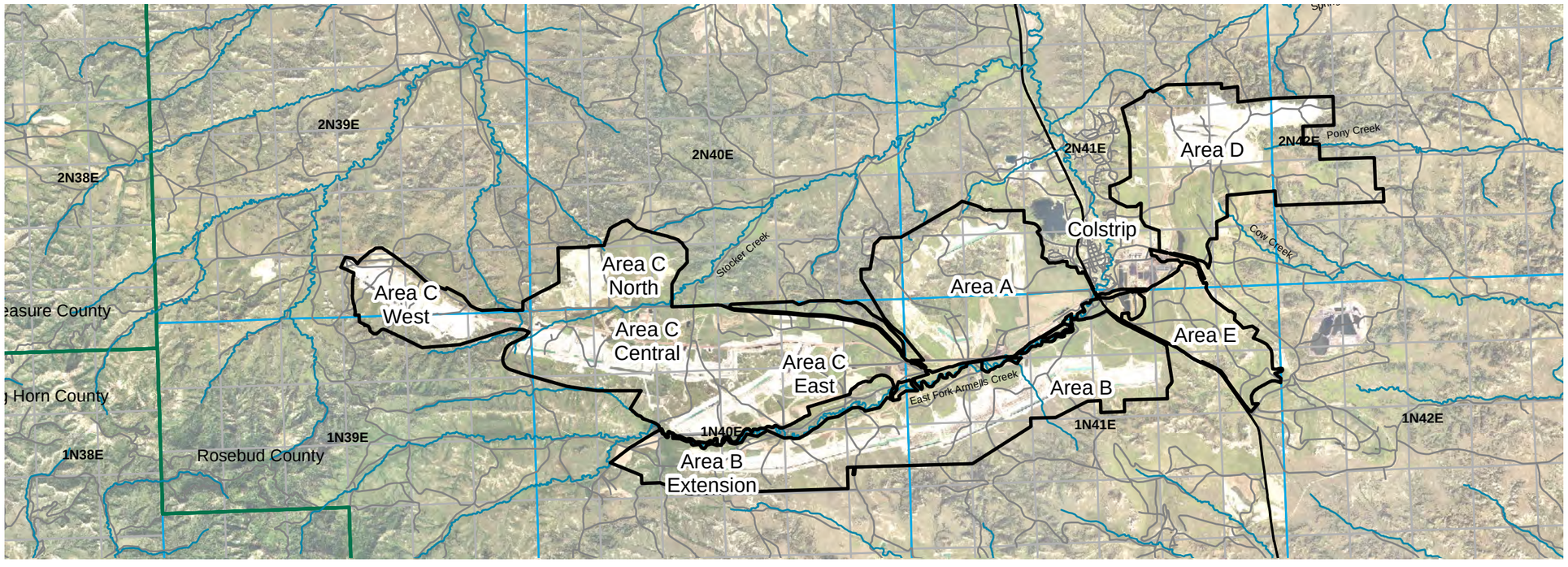




NICKLIN EARTH & WATER, INC.

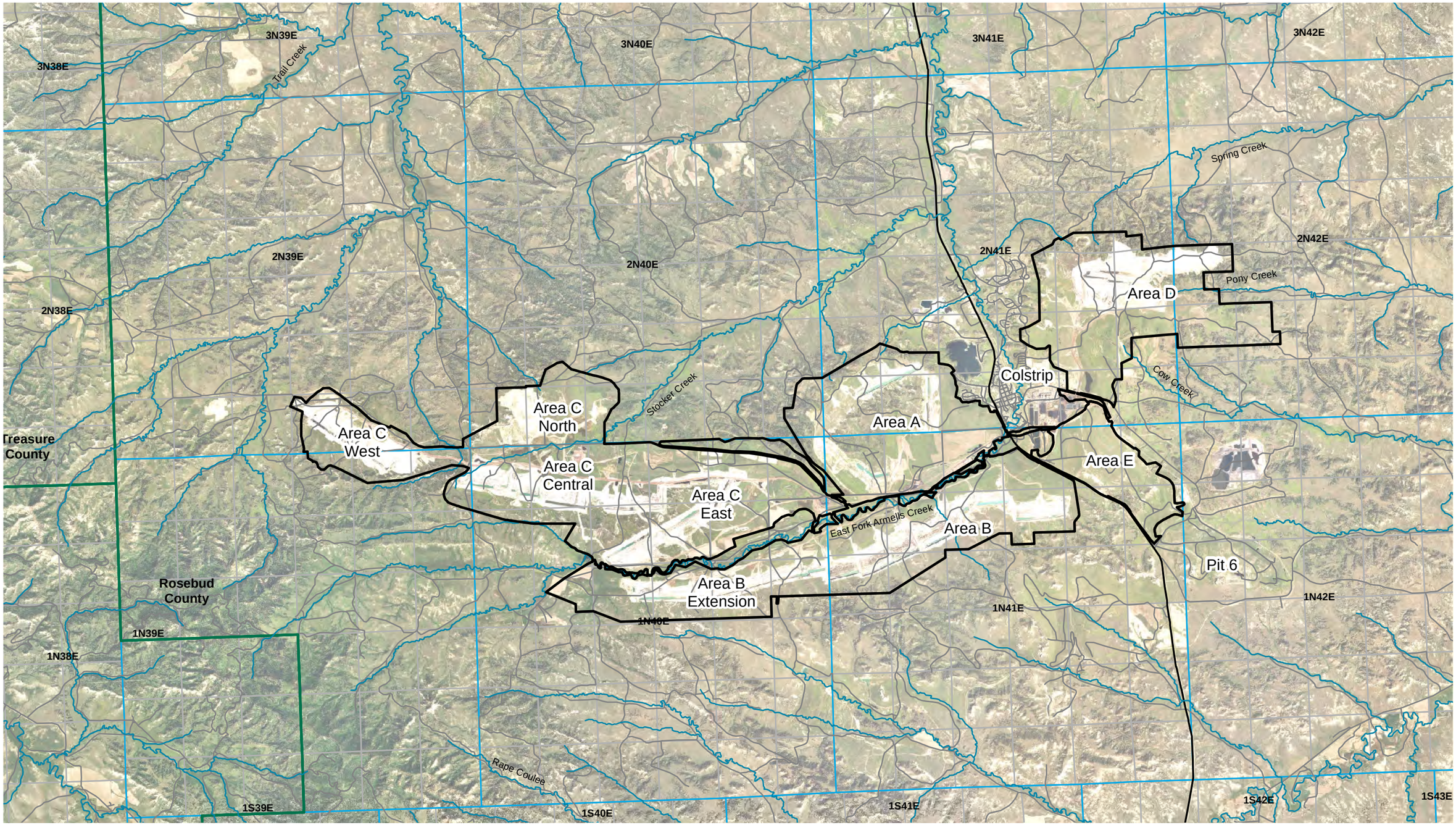
Notes:
1) Aerial Photographs: 2011 NAIP

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 1
Location Map
Areas ABC PHC

Date: 6/6/2013 File: F01 Project Location

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 5,000 10,000 Feet

N

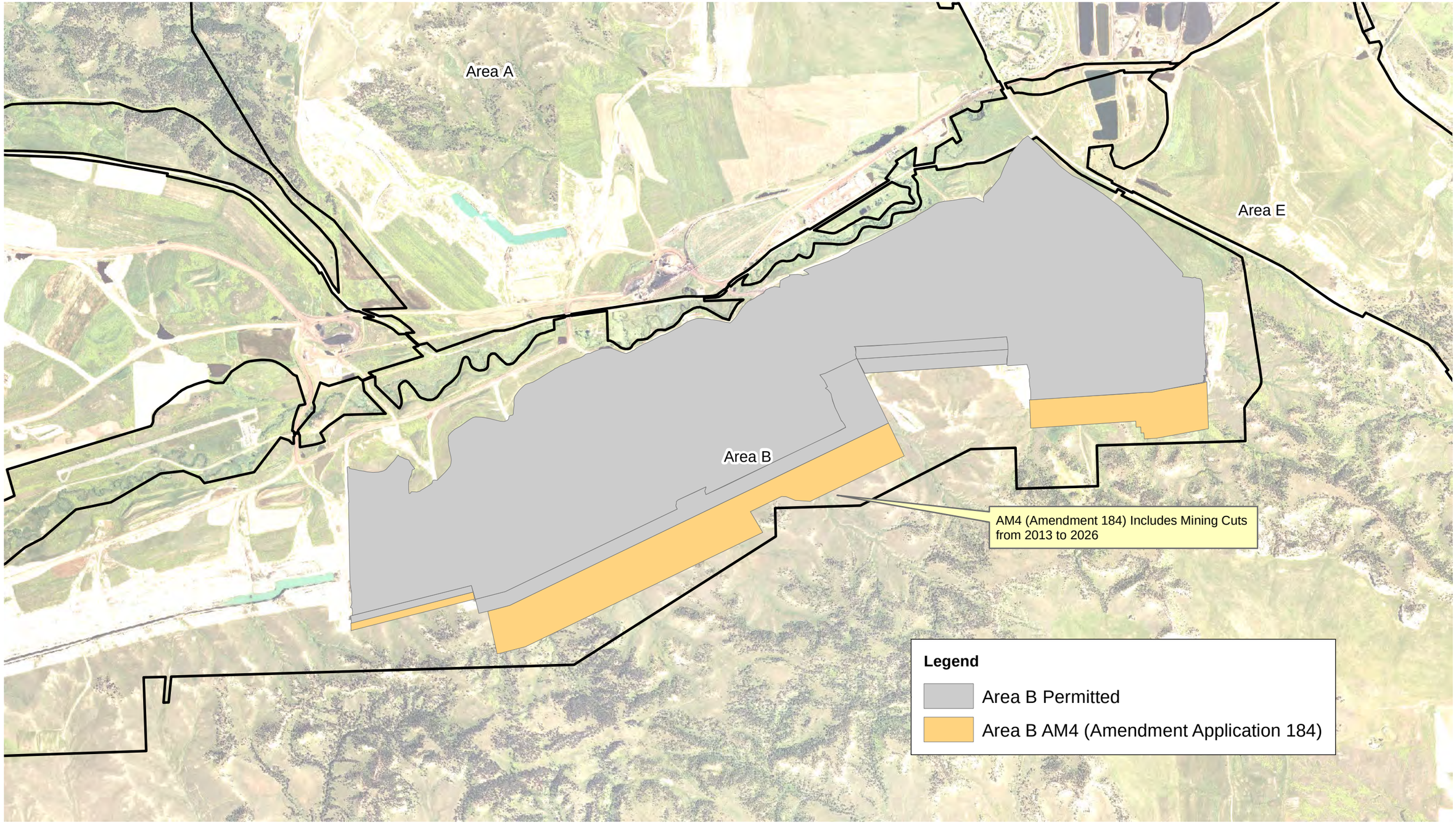
Notes:
Aerial Photo: 2011 NAIP

Date: 6/6/2013 File: F02 Site Map

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 2
Site Map
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

Feet
0 1,000 2,000

N

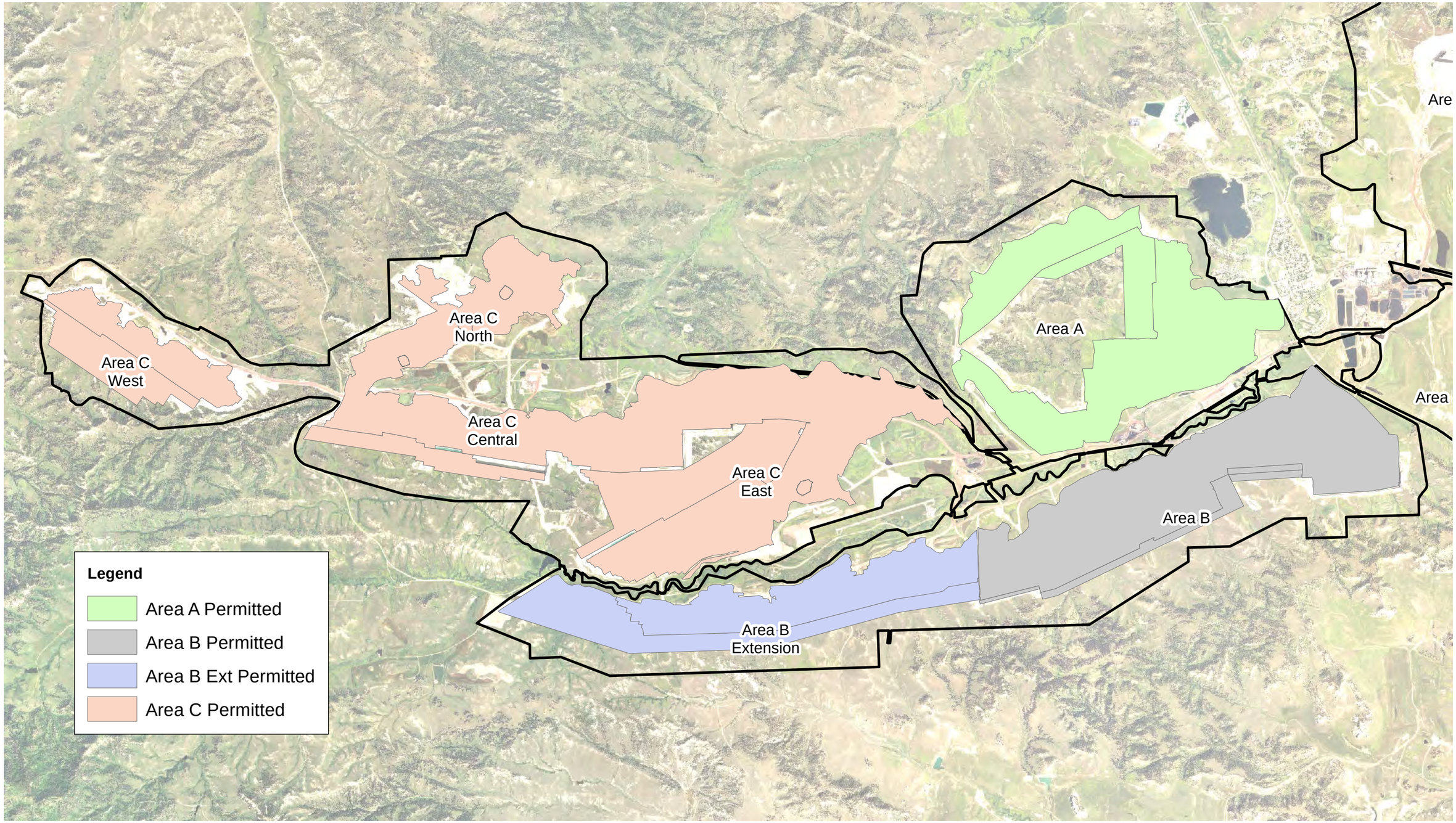
Notes: NAIP Aerial Photo (2011)

Date: 5/21/2013 File: F03A AM4

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 3A
Area B AM4 (Amendment Application 184)
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 2,500 5,000 Feet

N

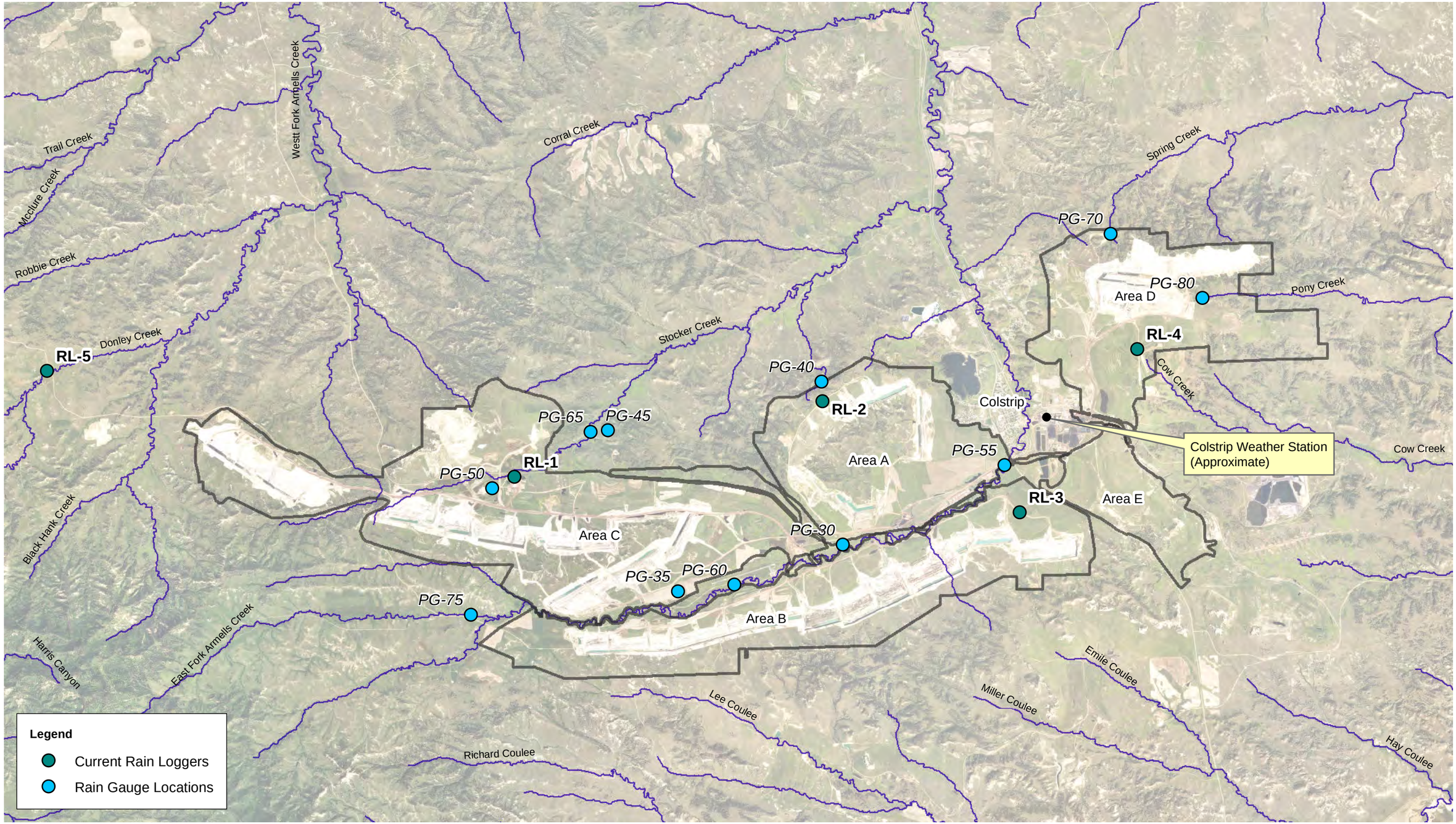
Notes: NAIP Aerial Photo (2011)

Date: 6/7/2013 File: F03B ABC Permitted

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 3B
Areas ABC Permitted
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 5,000 10,000 Feet

N

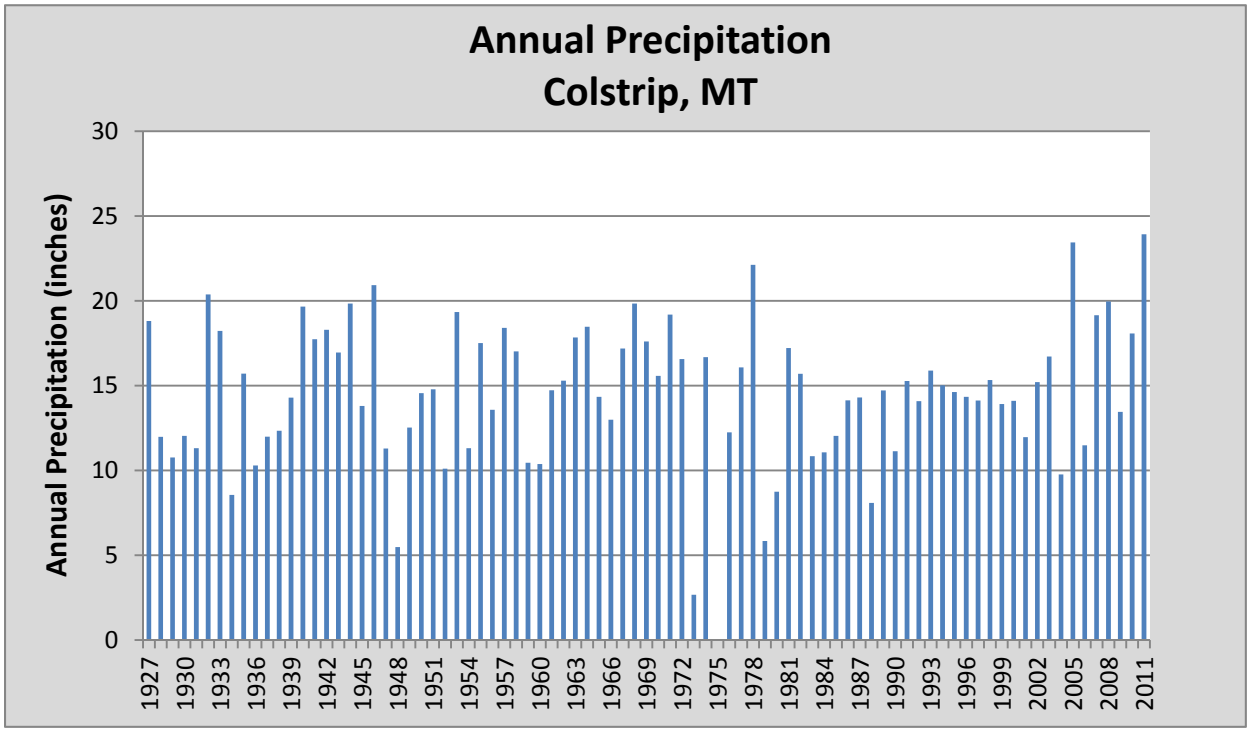
Notes:
1) Aerial Photographs: 2011 NAIP

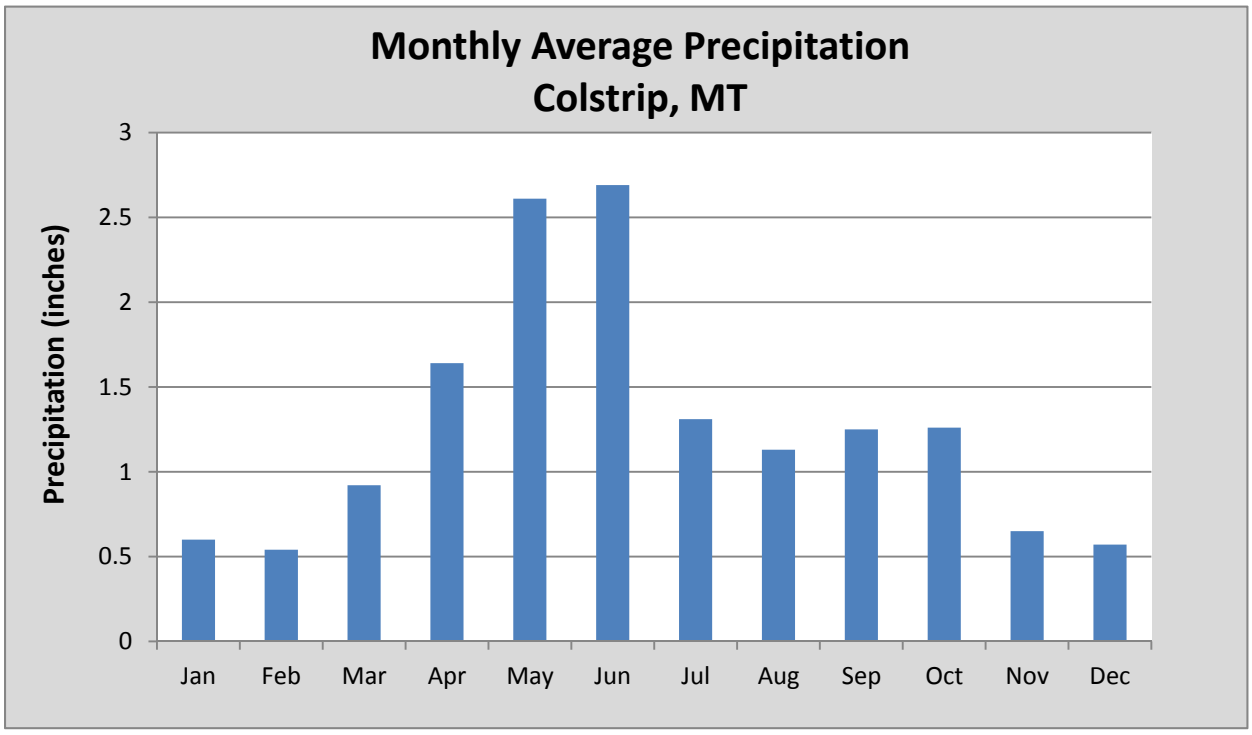
Date: 6/7/2013 Name: F04 - Climate_stations

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 4
Climate Monitoring Stations
Areas ABC PHC

Exhibit 8



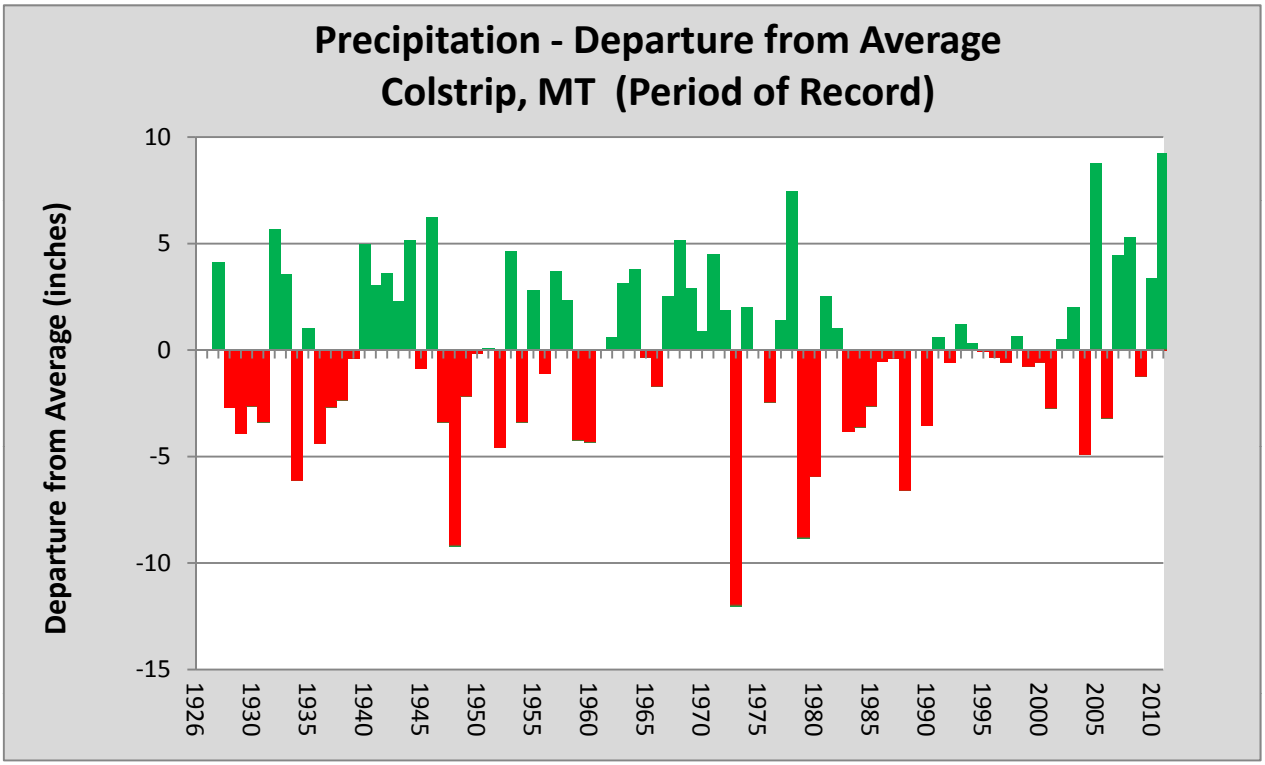


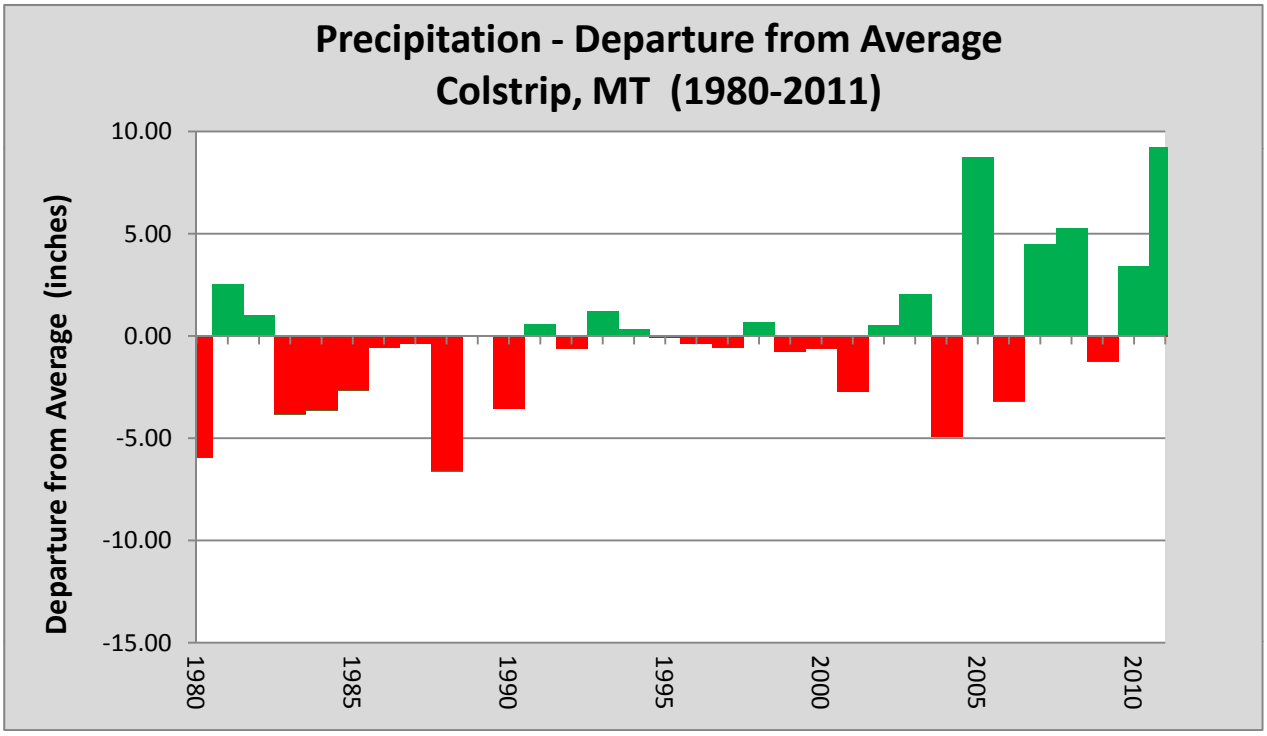
Note: Data as reported by Western Regional Climate Center for Colstrip (241905). Annual totals may not include missing data. All 1975 data are missing.

NICKLIN EARTH & WATER, INC.

Figure 5
Precipitation Data, Colstrip MT
Western Energy Rosebud Mine

Exhibit 8

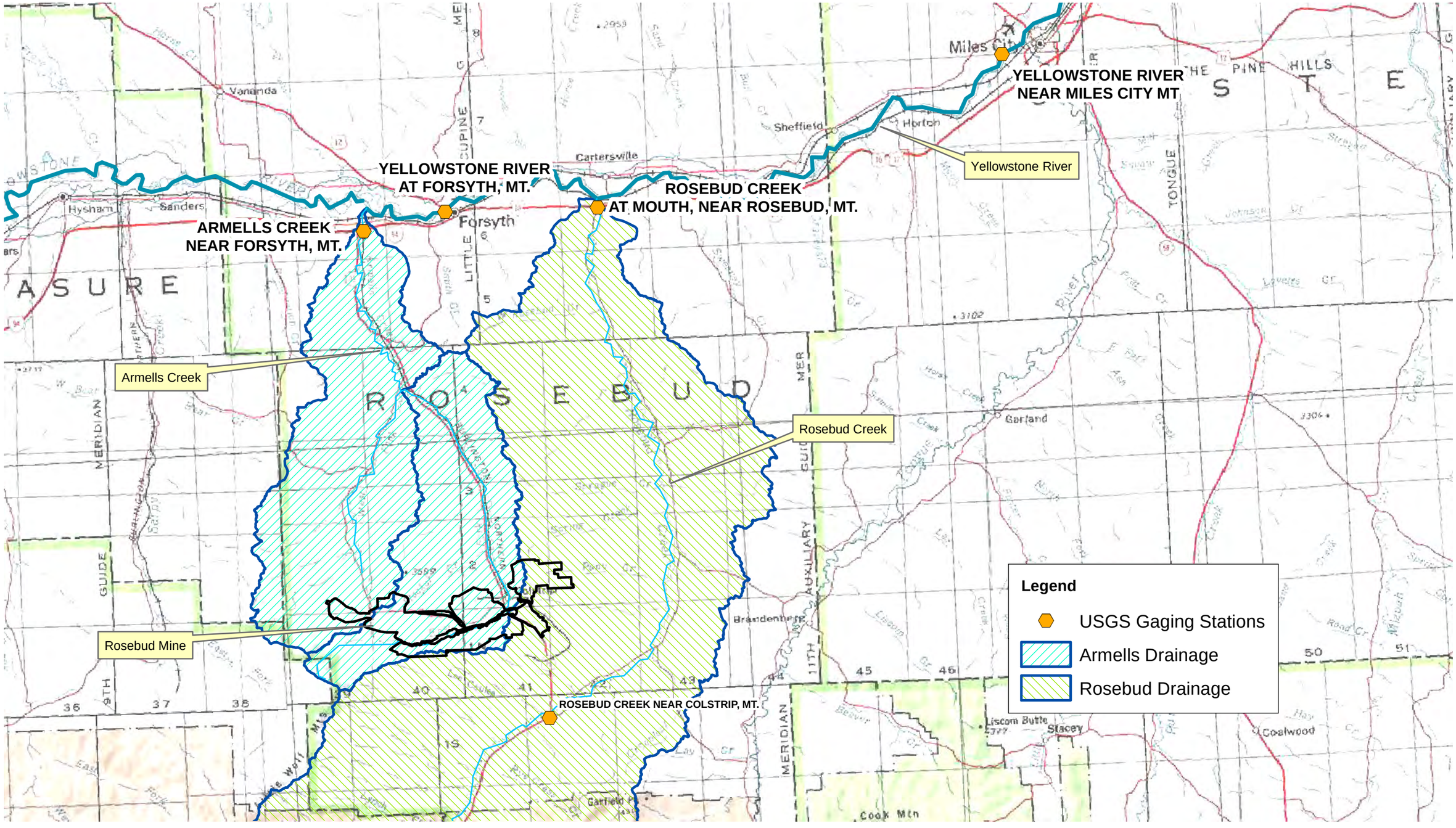




NICKLIN EARTH & WATER, INC.

Figure 6
Precipitation, Departure from Average
Western Energy Rosebud Mine

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 5 10 Miles

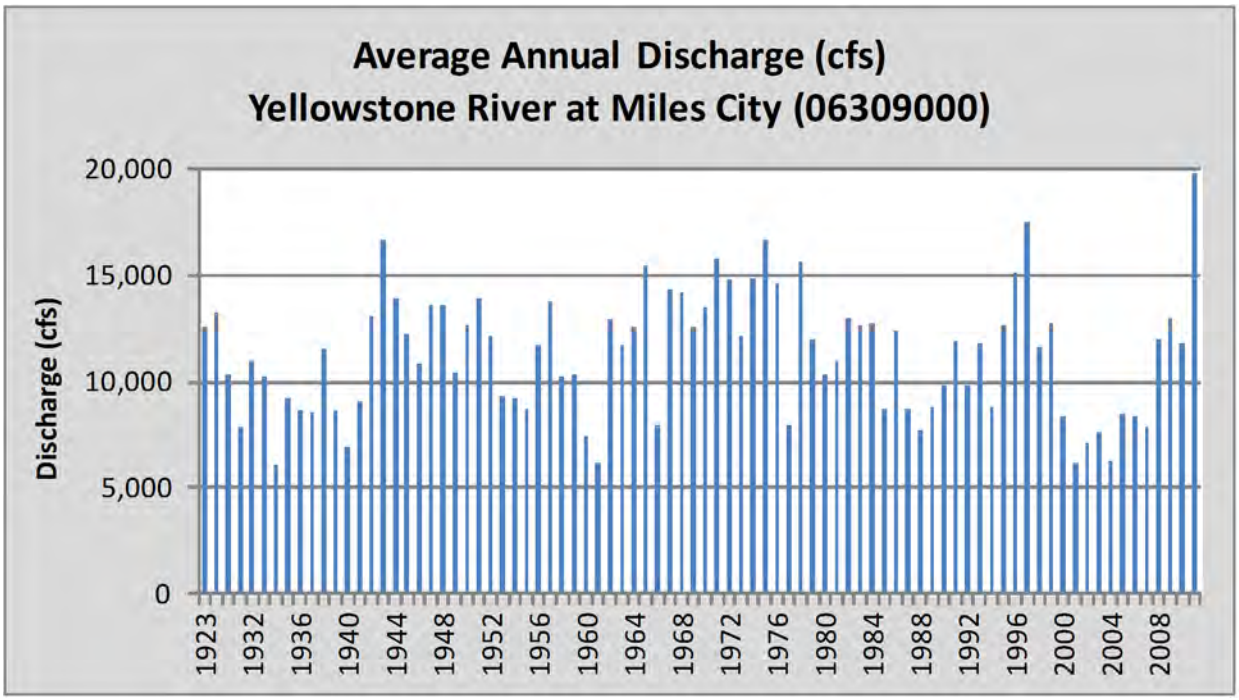
N

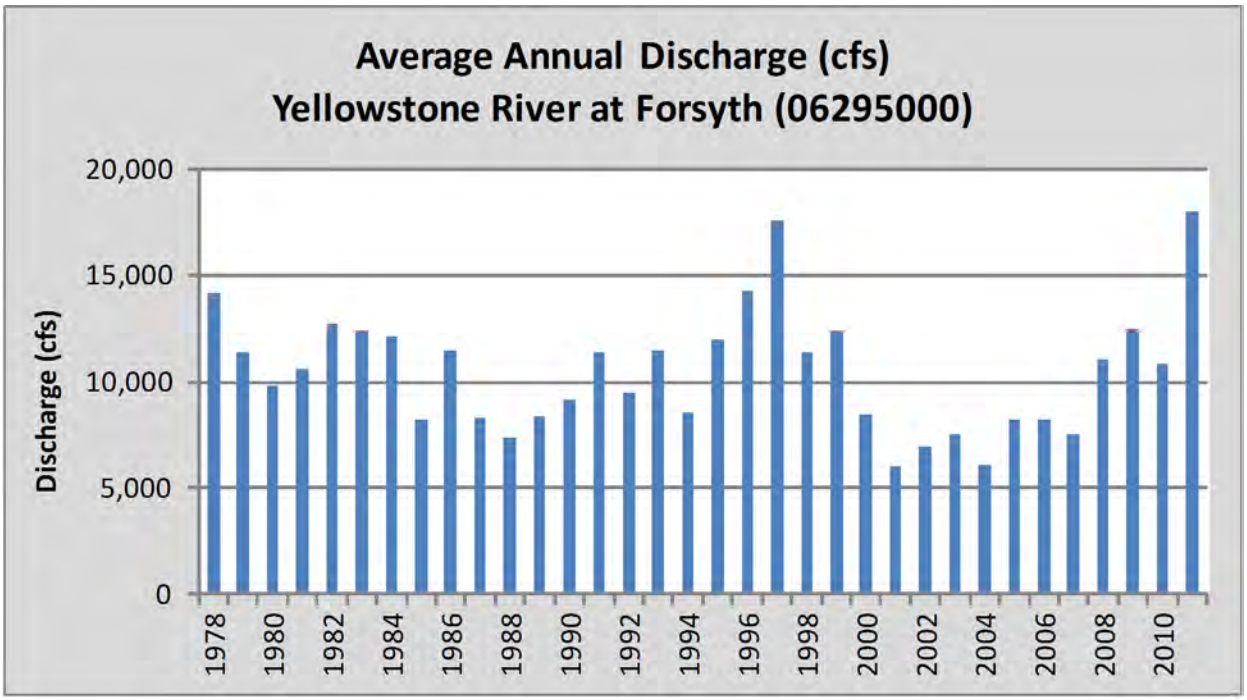
Date: 8/2/2013 File: F07 Regional Drainages

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 7
Regional Drainages
Areas ABC PHC

Exhibit 8

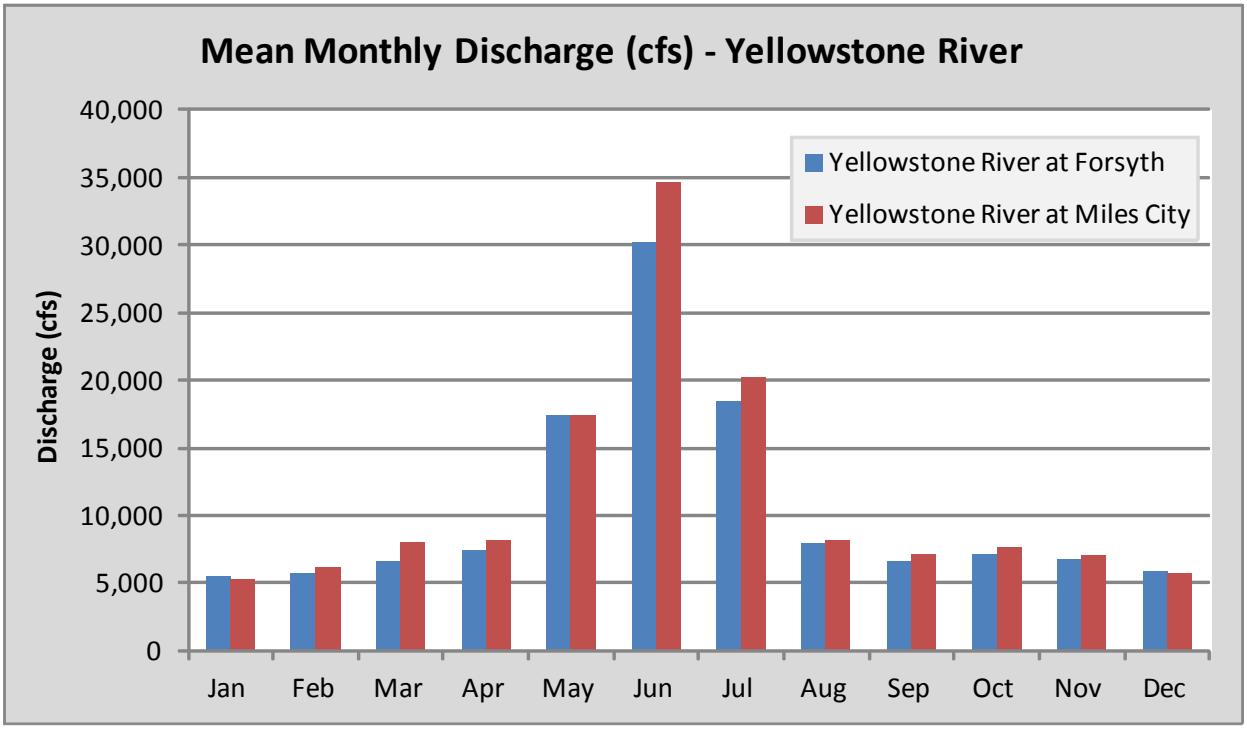


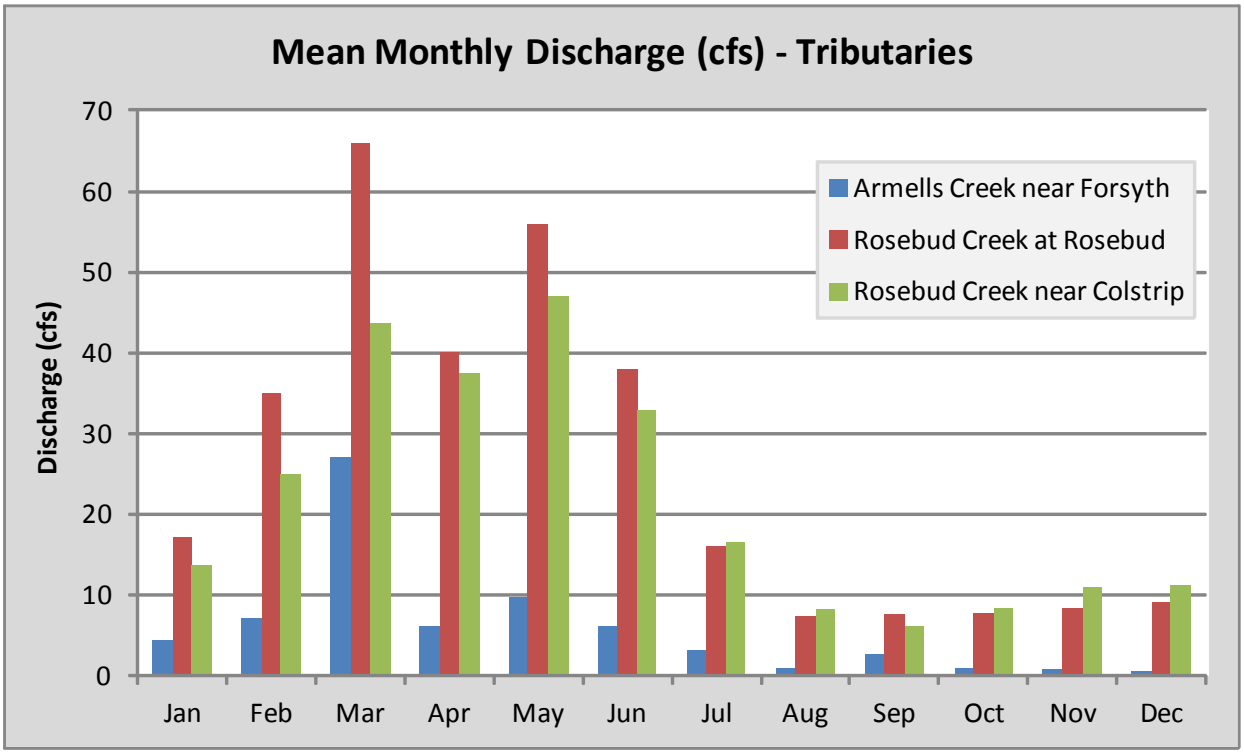


Source: USGS National Water Information System

Date: 06/12/12 Figure 8A.cvx	NICKLIN EARTH & WATER, INC.	**Annual Average Discharge Yellowstone River Stations**	**Figure 8A**

Exhibit 8

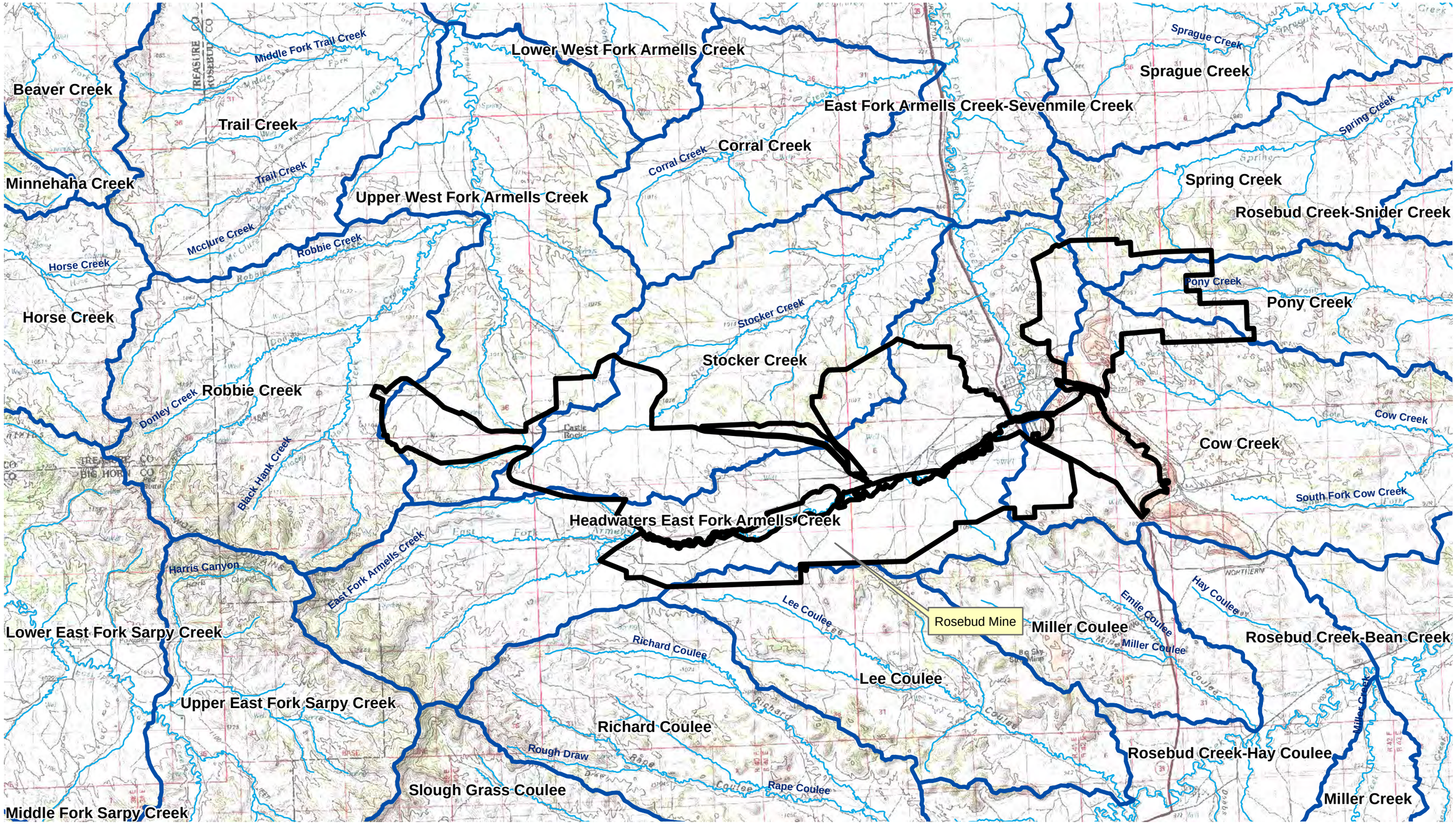




Source: USGS National Water Information System

Date: 06/12/12 Figure 8B.cvx	NICKLIN EARTH & WATER, INC.	**Mean Monthly Discharge Yellowstone River, Armells Creek and Rosebud Creek Stations**	**Figure 8B**

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 1 2 Miles

N

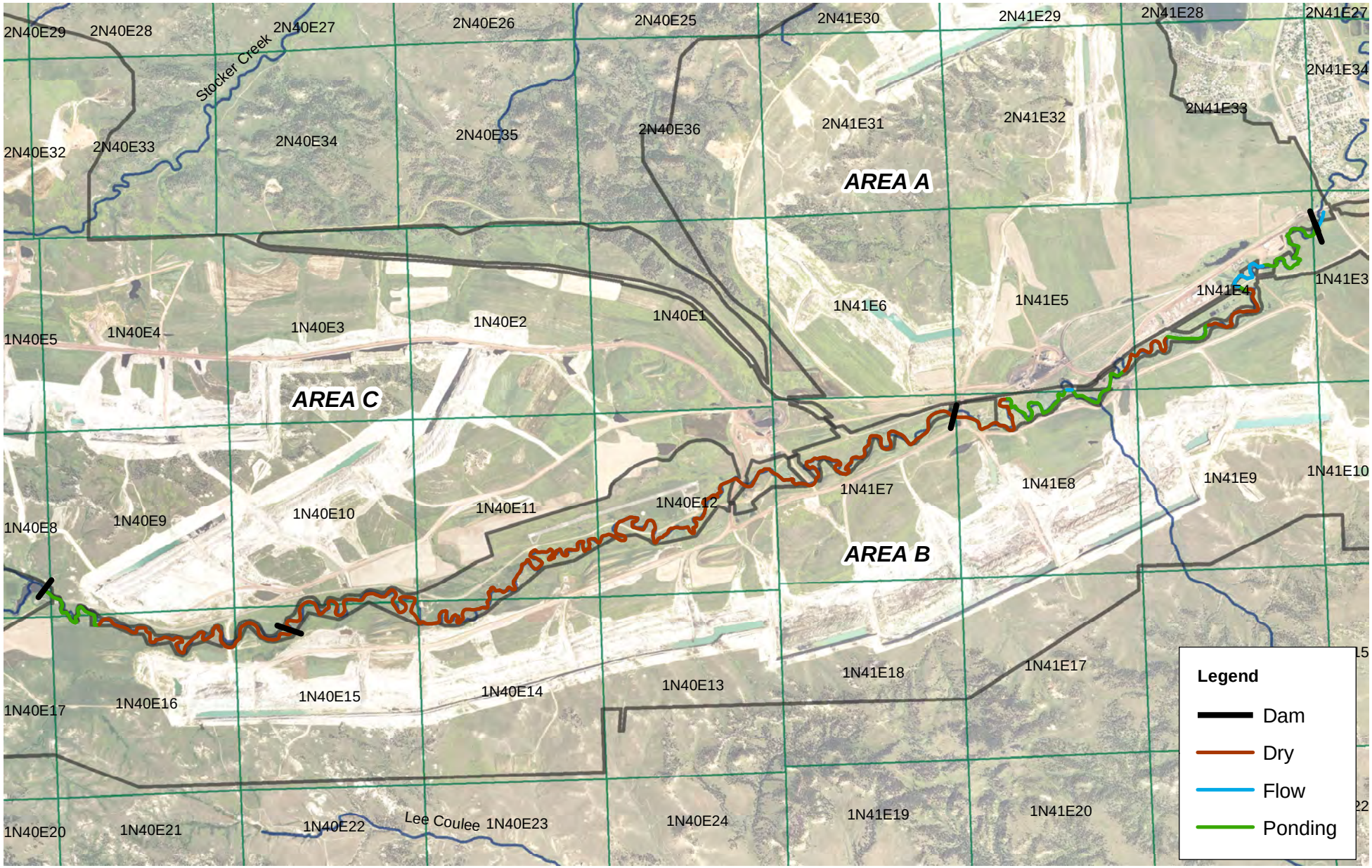
Notes:

Date: 6/6/2013 File: F09 Local Drainages

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 9
Local Drainages
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 2,000 4,000 Feet

N

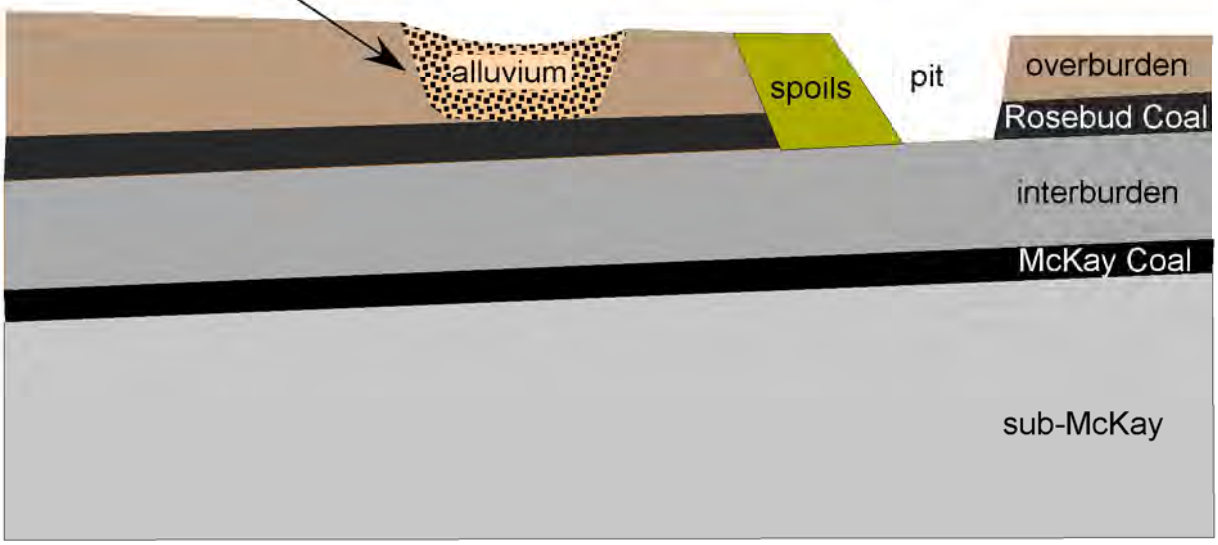
Notes:
1) Aerial Photographs: 2011 NAIP
2) Field Inspection performed by WECo in August 2013.
3) Dam locations are approximate.

Date: 9/19/2013 Name: F10 - EFAC Field Survey

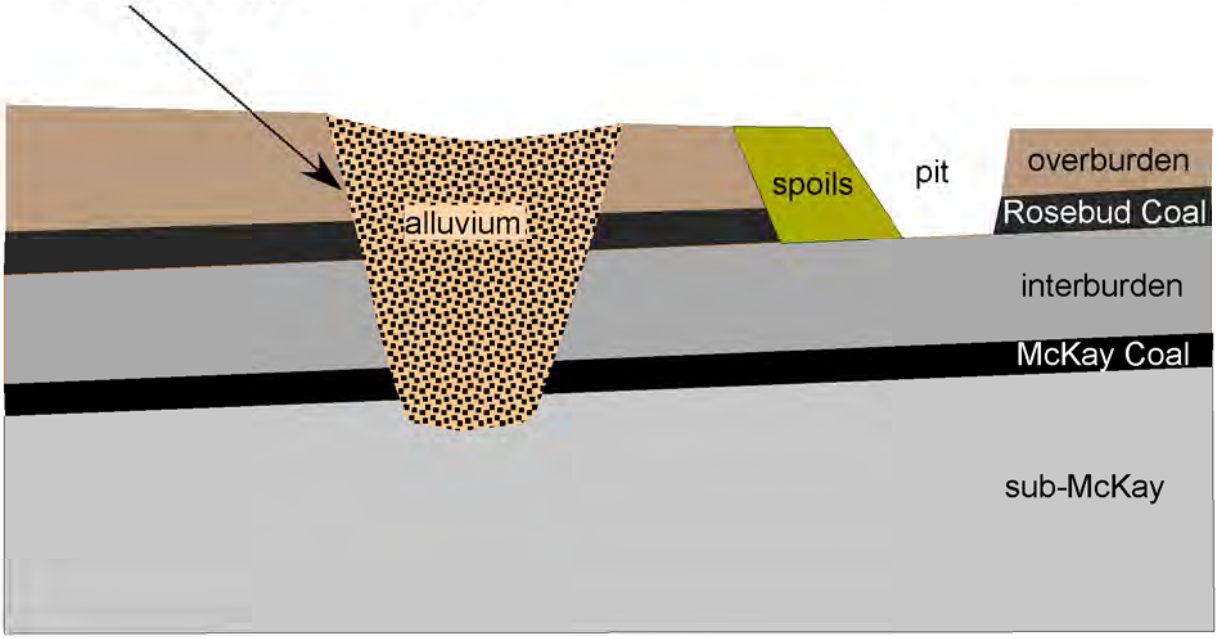
Figure 10
East Fork Armells Creek
Field Inspection Results
Areas ABC PHC

Exhibit 8

Approximate outline of East Fork Armells Creek alluvium between Areas B and C near wells WA-122 and WA-212.



Approximate outline of East Fork Armells Creek alluvium between Area A and B near wells P-03, P-04 and P-05.

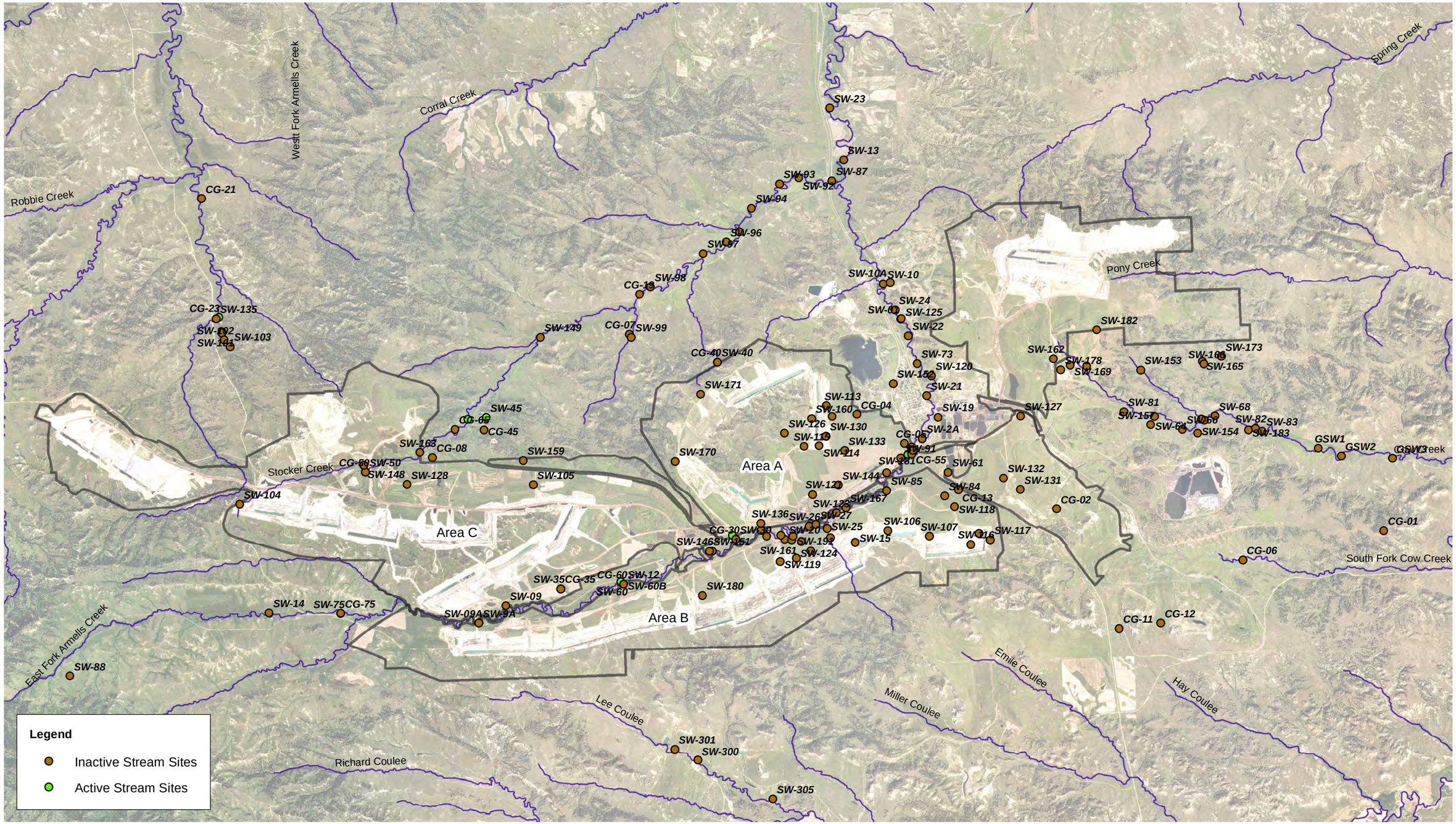


NICKLIN EARTH & WATER, INC.

Date: 09/05/13 F11.cvx

Figure 11
Conceptual Representation of Mining Process and Hydrogeologic Units Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 5,000 10,000 Feet

N

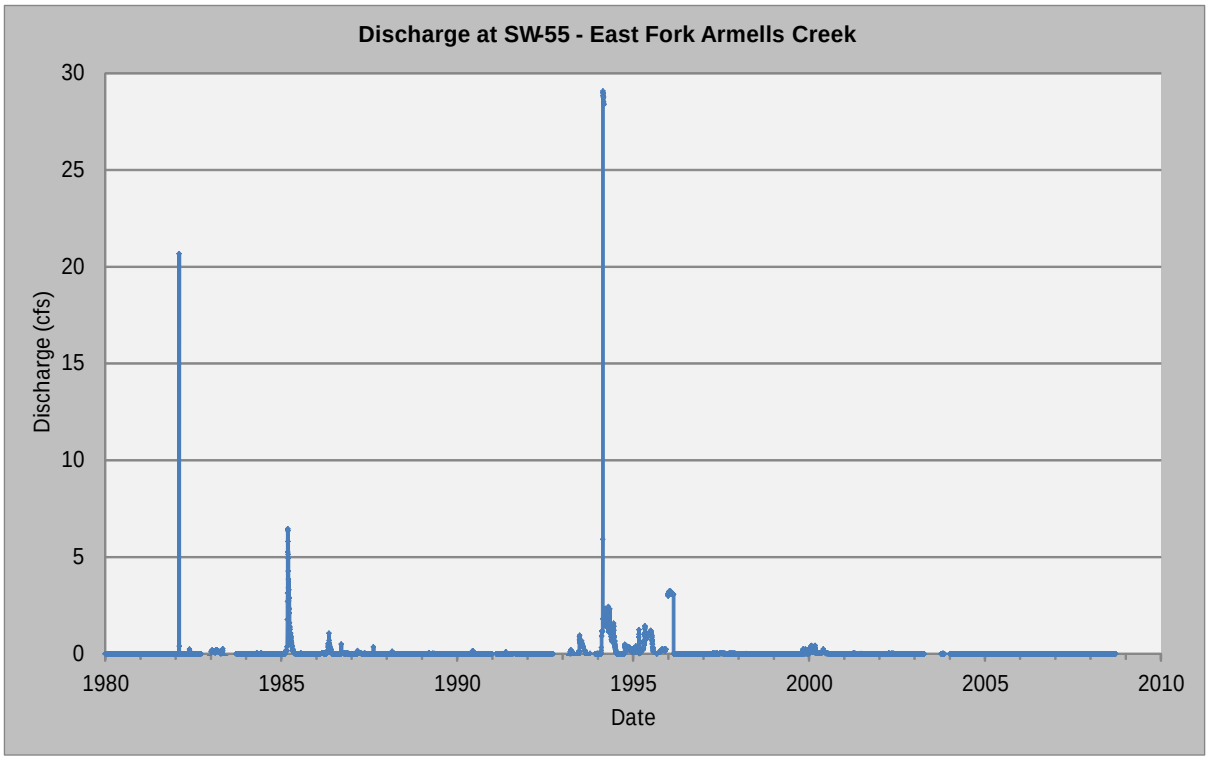
Date: 9/5/2013 Name: F12 - Stream_MP

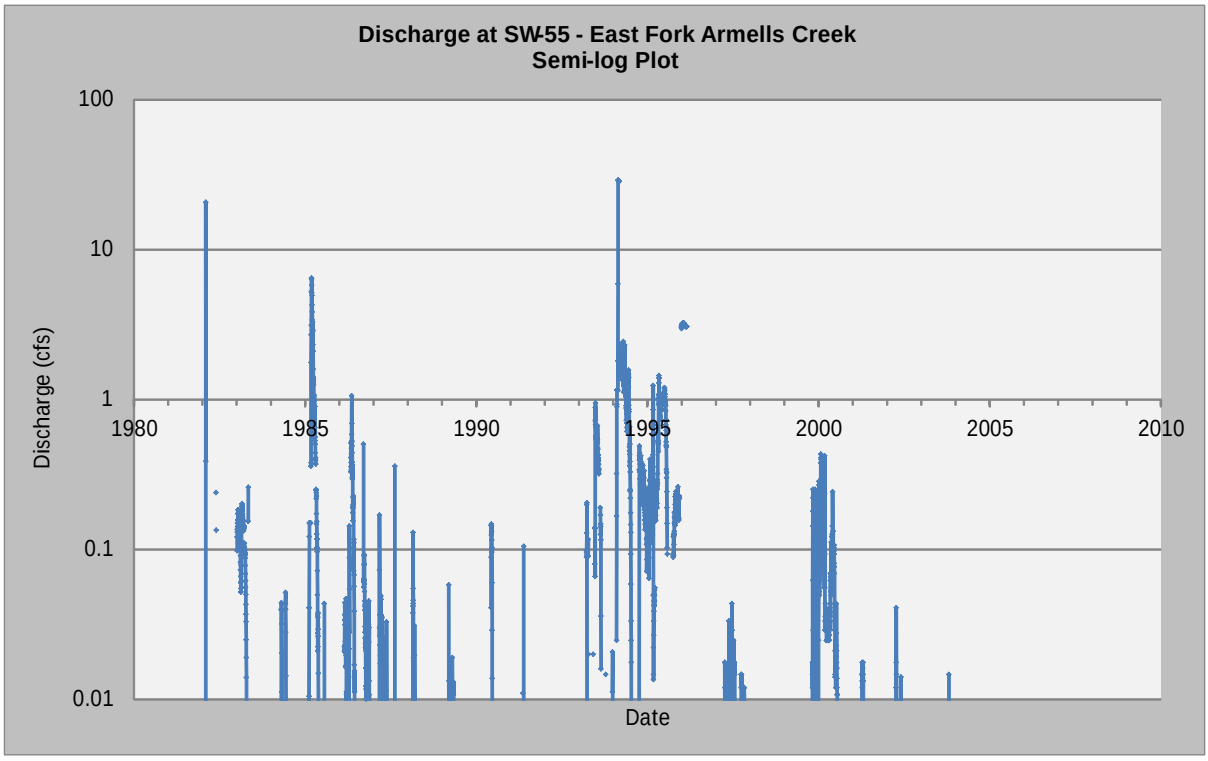
Notes:
1) Aerial Photographs: 2011 NAIP
2) Only WY 2011 stream sites in drainages to which Area A, B and C contribute are shown.

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 12
Stream Monitoring Points
Areas ABC PHC

Exhibit 8





Note: Plots refect available data.
There are significant periods of missing data due to equipment malfunction and frozen conditions.

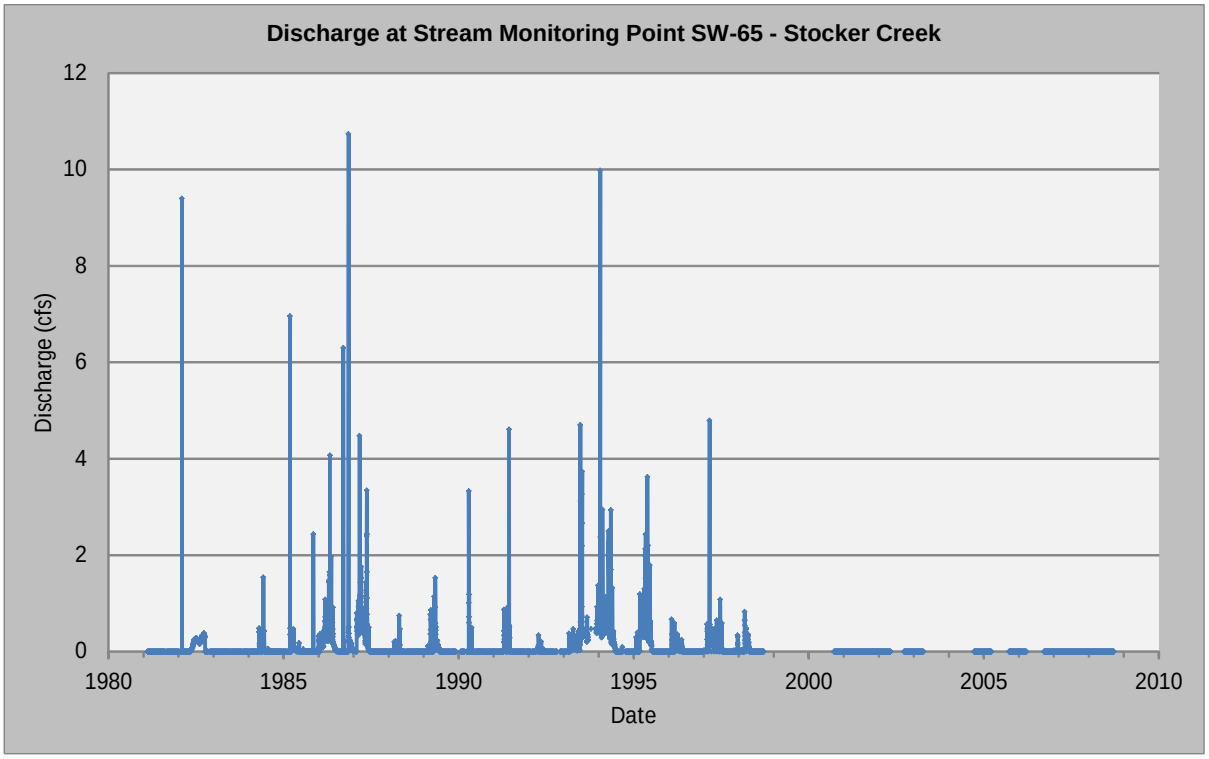
NICKLIN EARTH & WATER, INC.

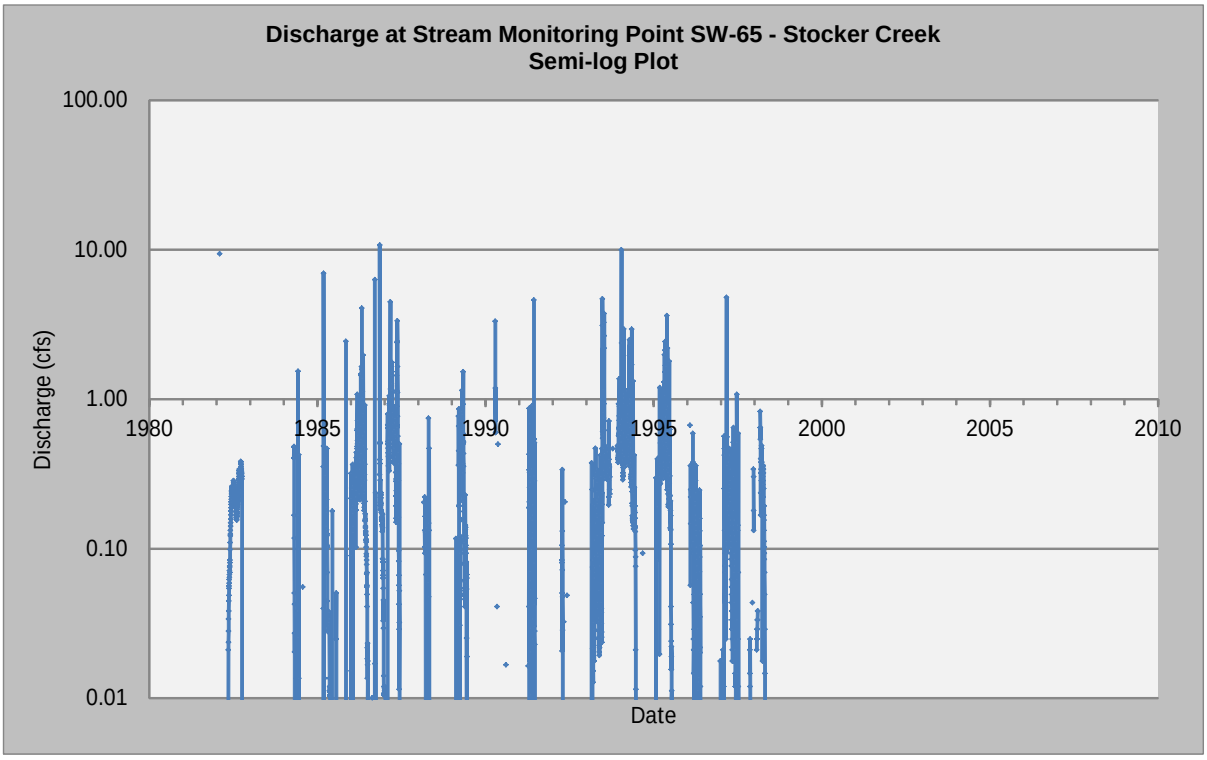
Date: 9/30/2013
File: F13 SW55 Discharge

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 13
Sample Plot of Discharge Data
SW-55 - Stocker Creek
Western Energy Rosebud Mine

Exhibit 8





Note: Plots refect available data.
There are significant periods of missing data due to equipment malfunction and frozen conditions.

NICKLIN EARTH & WATER, INC.

Date: 9/30/2013
File: F14 SW65 Discharge

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 14
Sample Plot of Discharge Data
SW-65 - Stocker Creek
Western Energy Rosebud Mine

Exhibit 8

Source: Map from Figure 1.2-1 (Slagle et al, 1983)

NICKLIN EARTH & WATER, INC.

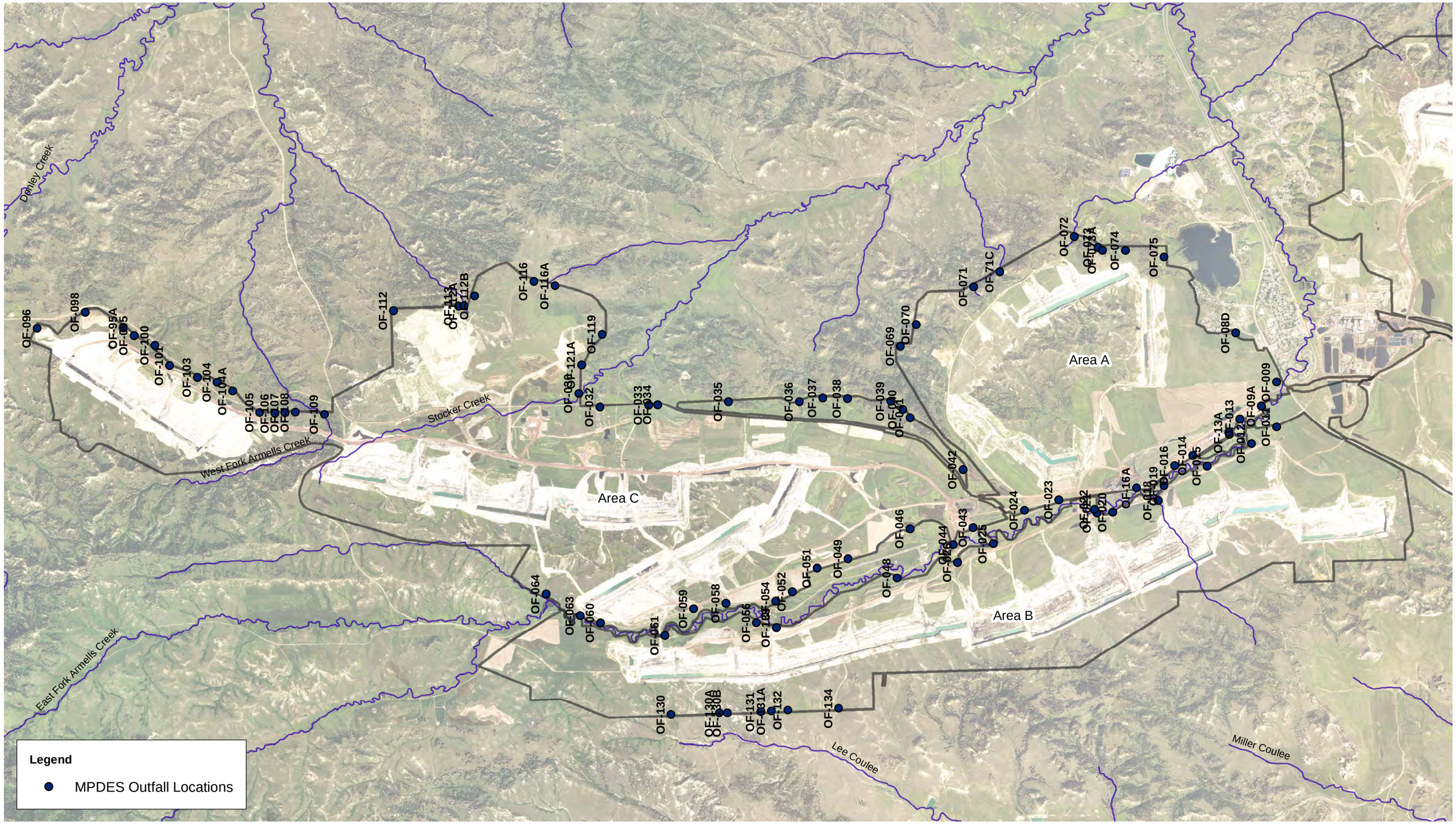
Miles
0 10 20

N

Date: 9/5/2013

Name: F15 - Area 49

Figure 15
Area 49 Study Area
Western Energy Rosebud Mine
Areas ABC PHC
Exhibit 8



NICKLIN EARTH & WATER, INC.

0 2,500 5,000 Feet

N

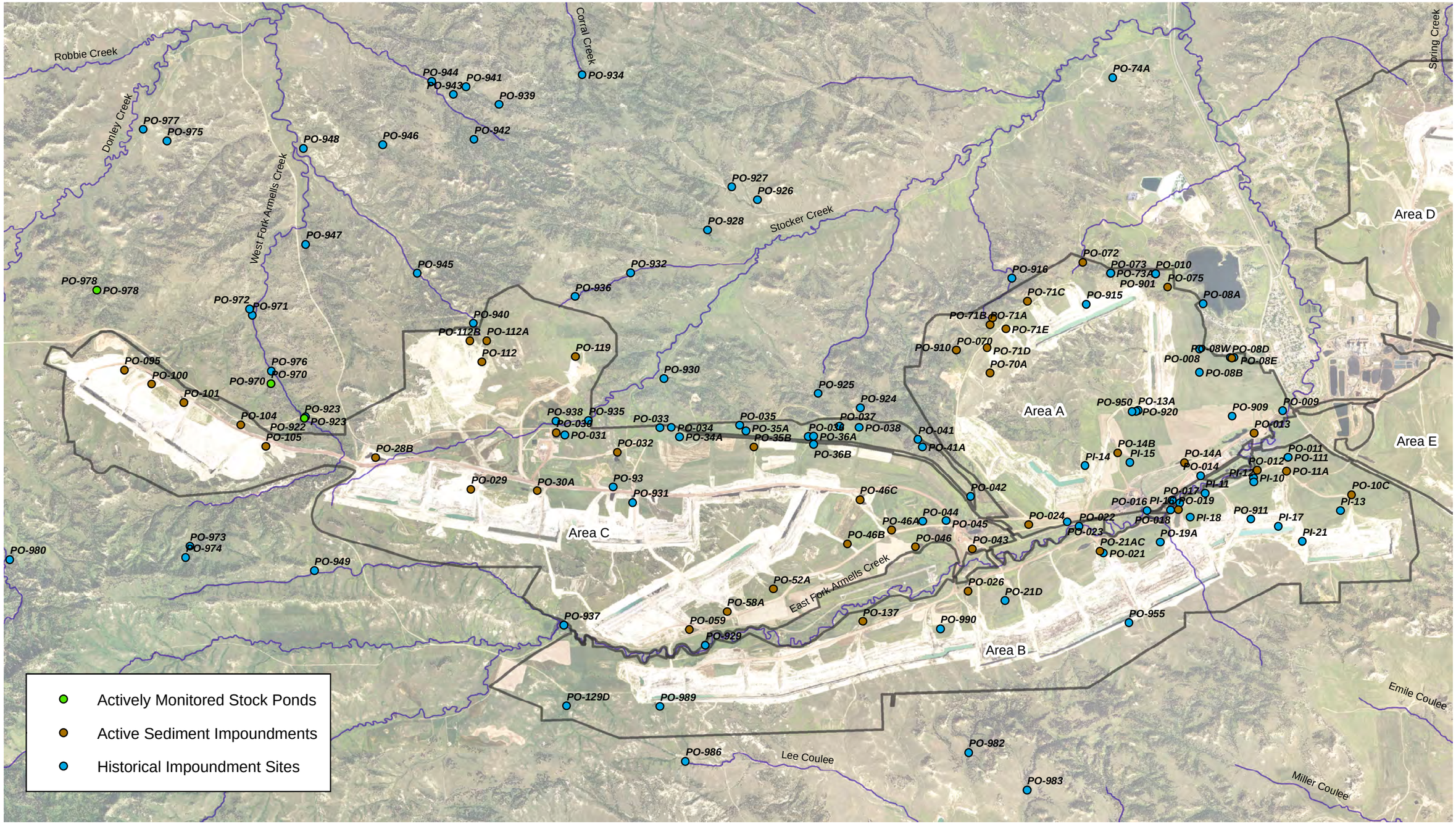
Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F16 - MPDES_Outfalls

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 16
MPDES Outfalls
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 3,500 7,000 Feet

N

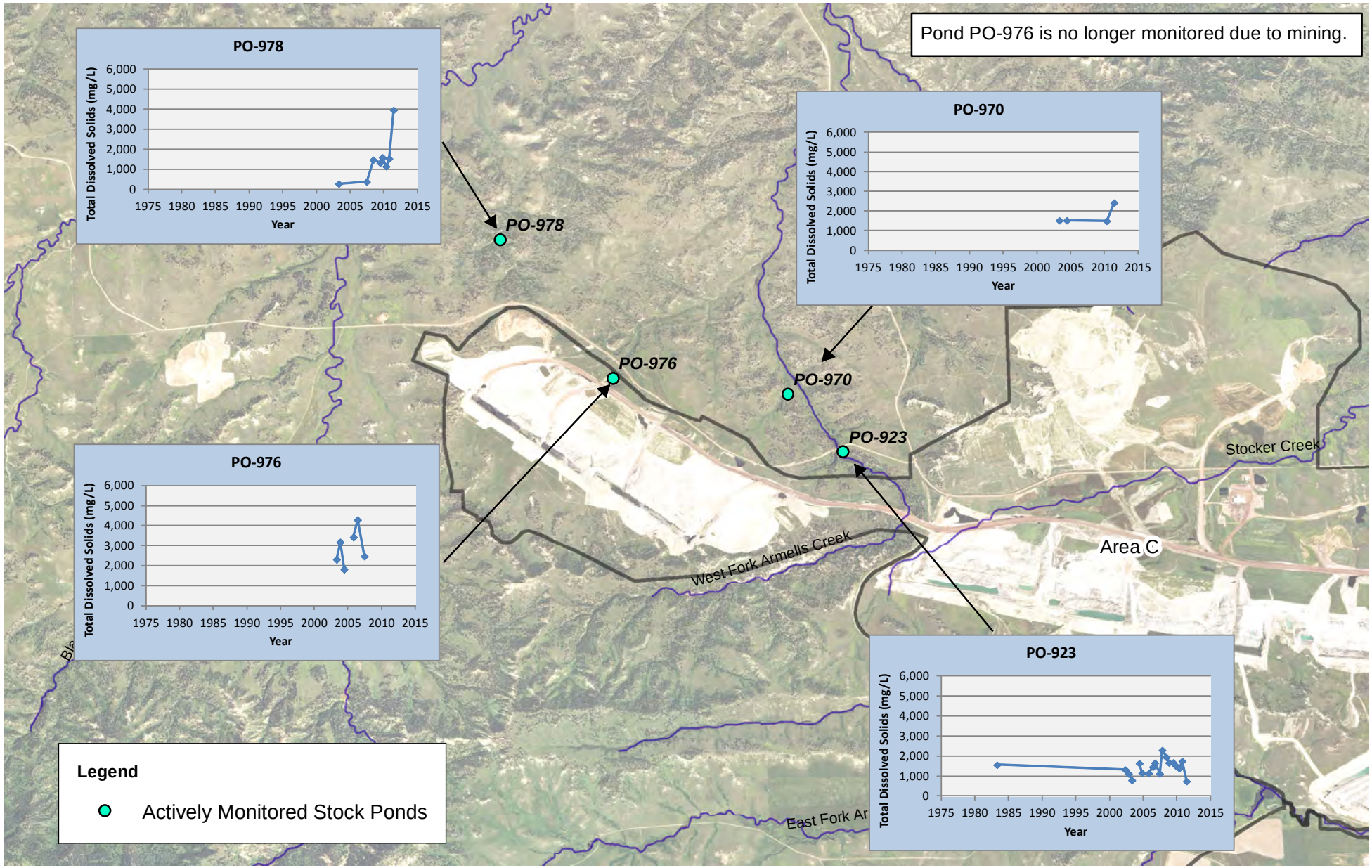
Date: 9/5/2013 Name: F17 - Impoundments

Notes:
1) Aerial Photographs: 2011 NAIP
2) Figure includes impoundments, pits and sediment traps

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 17
Impoundments
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 2,500 5,000 Feet

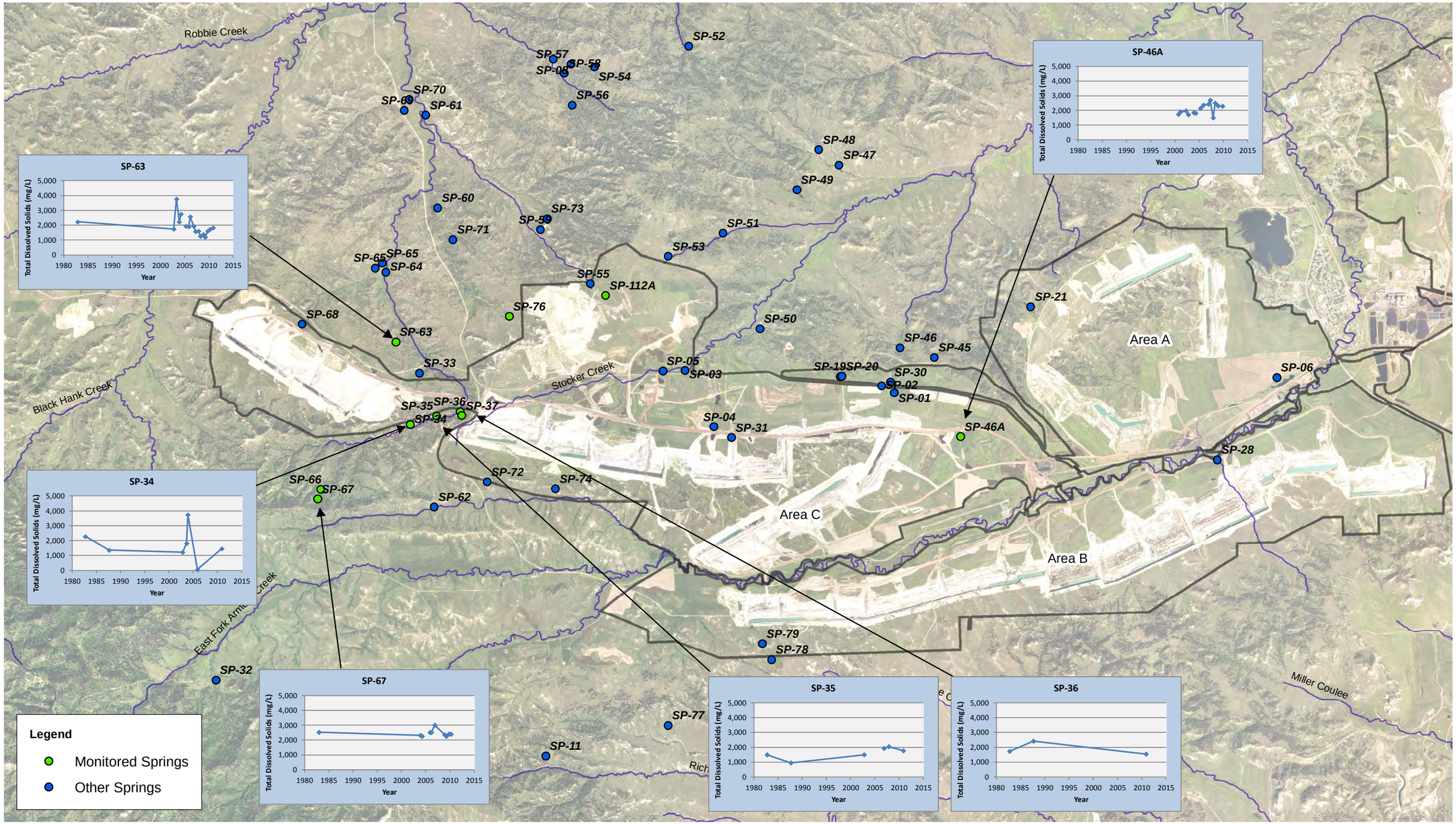
N

Notes:
1) Aerial Photographs: 2011 NAIP

Figure 18
TDS Concentration Time Series
Actively Monitored Stock Ponds
Areas ABC PHC

Date: 9/5/2013 Name: F18 - Impoundment_Timeseries

Exhibit 8



NICKLIN EARTH & WATER, INC.

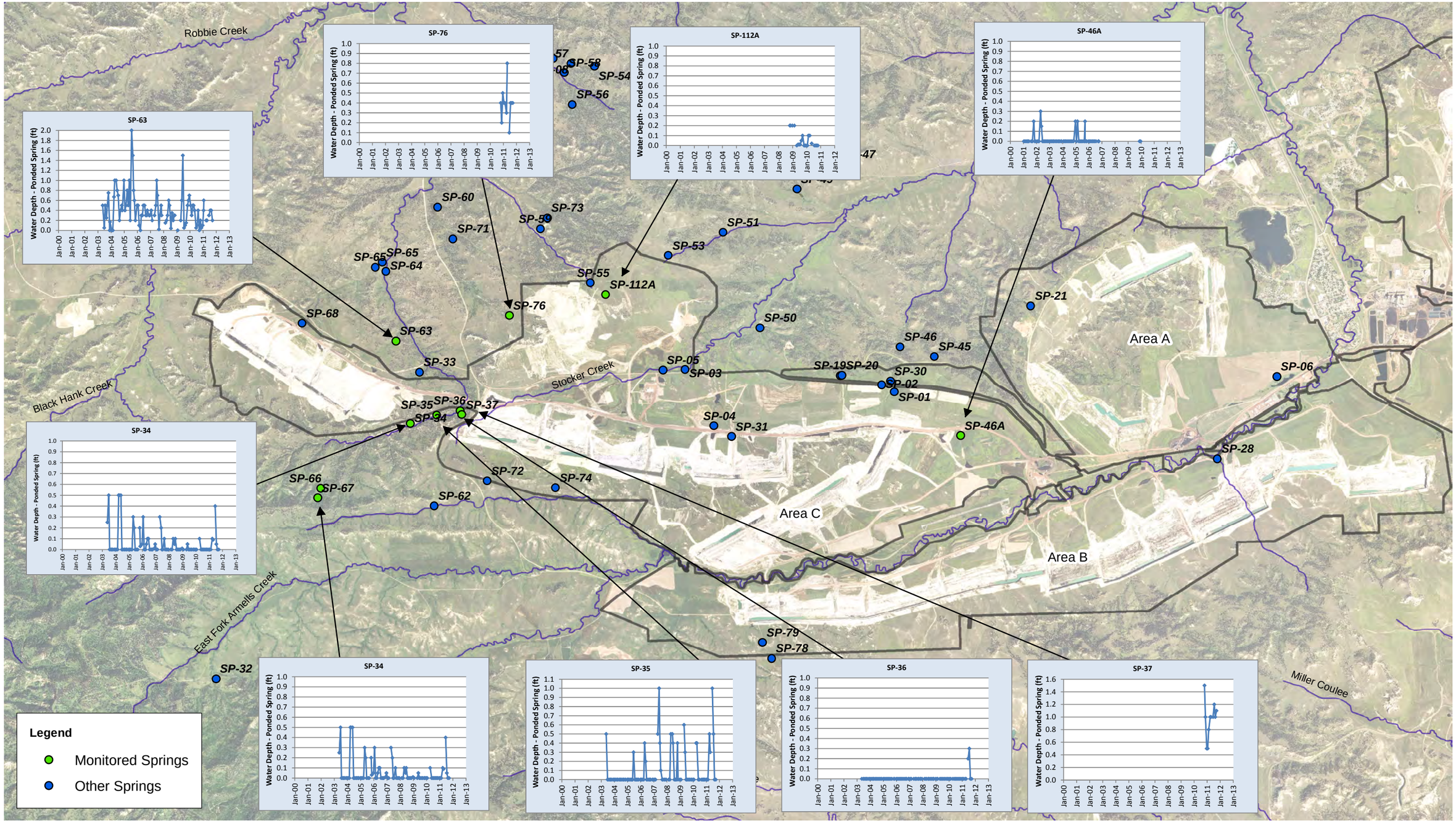
Notes:
1) Aerial Photographs: 2011 NAIP

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Date: 9/5/2013 Name: F19 - Springs_Timeseries_TDS

Figure 19
Springs
Total Dissolved Solids Concentration
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

Miles
0 0.5 1

N

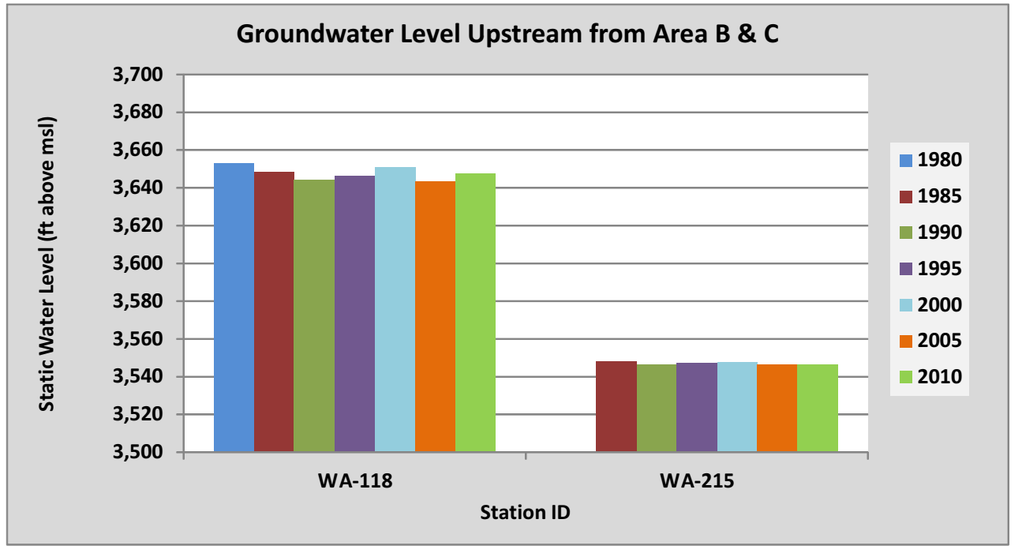
Notes:
1) Aerial Photographs: 2011 NAIP

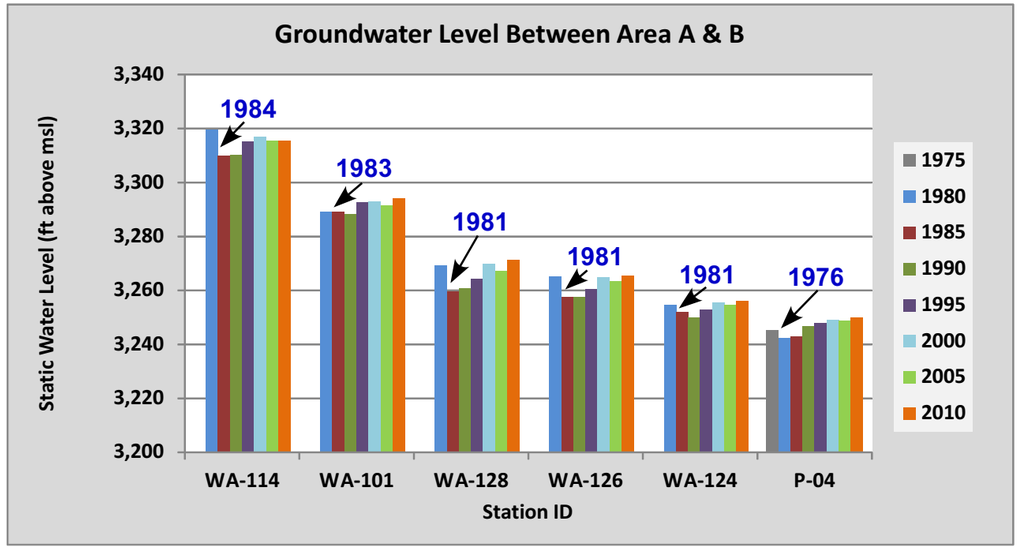
Date: 9/5/2013 Name: F20 - Springs_Depth

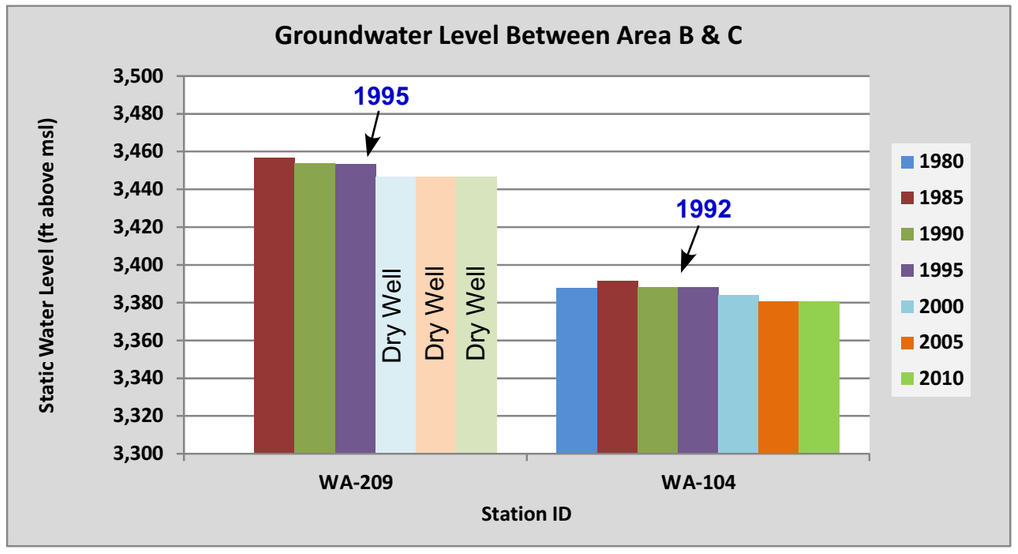
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

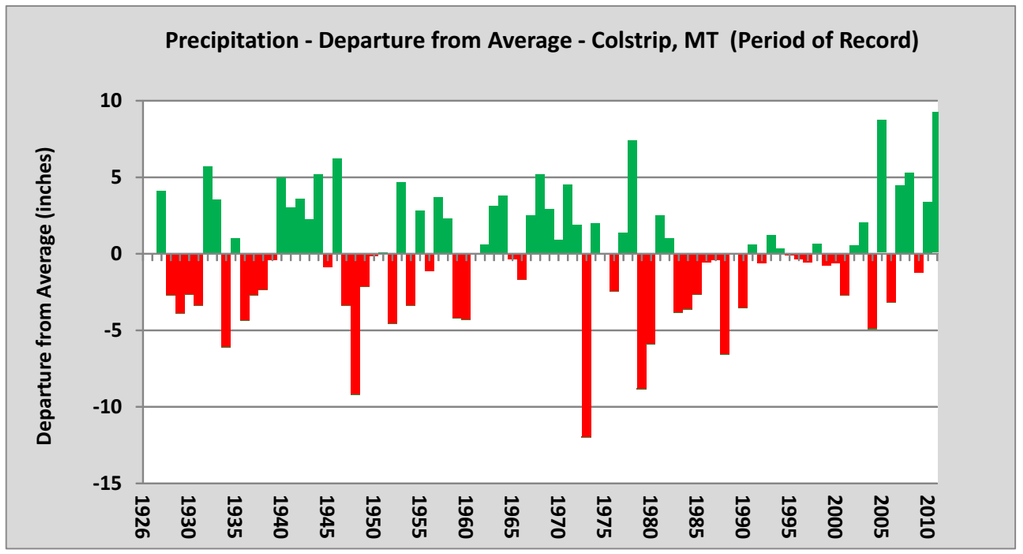
Figure 20
Springs
Water Depth - Ponded Springs
Areas ABC PHC

Exhibit 8









1984 - Year during which mining was closest to the well.

Water Levels in selected East Fork Armells Creek alluvial wells. September and October water level measurements were used. When no fall measurements were available, water levels from the nearest date were used (August-December). Source of Precipitation data: Western Regional Climate Center.

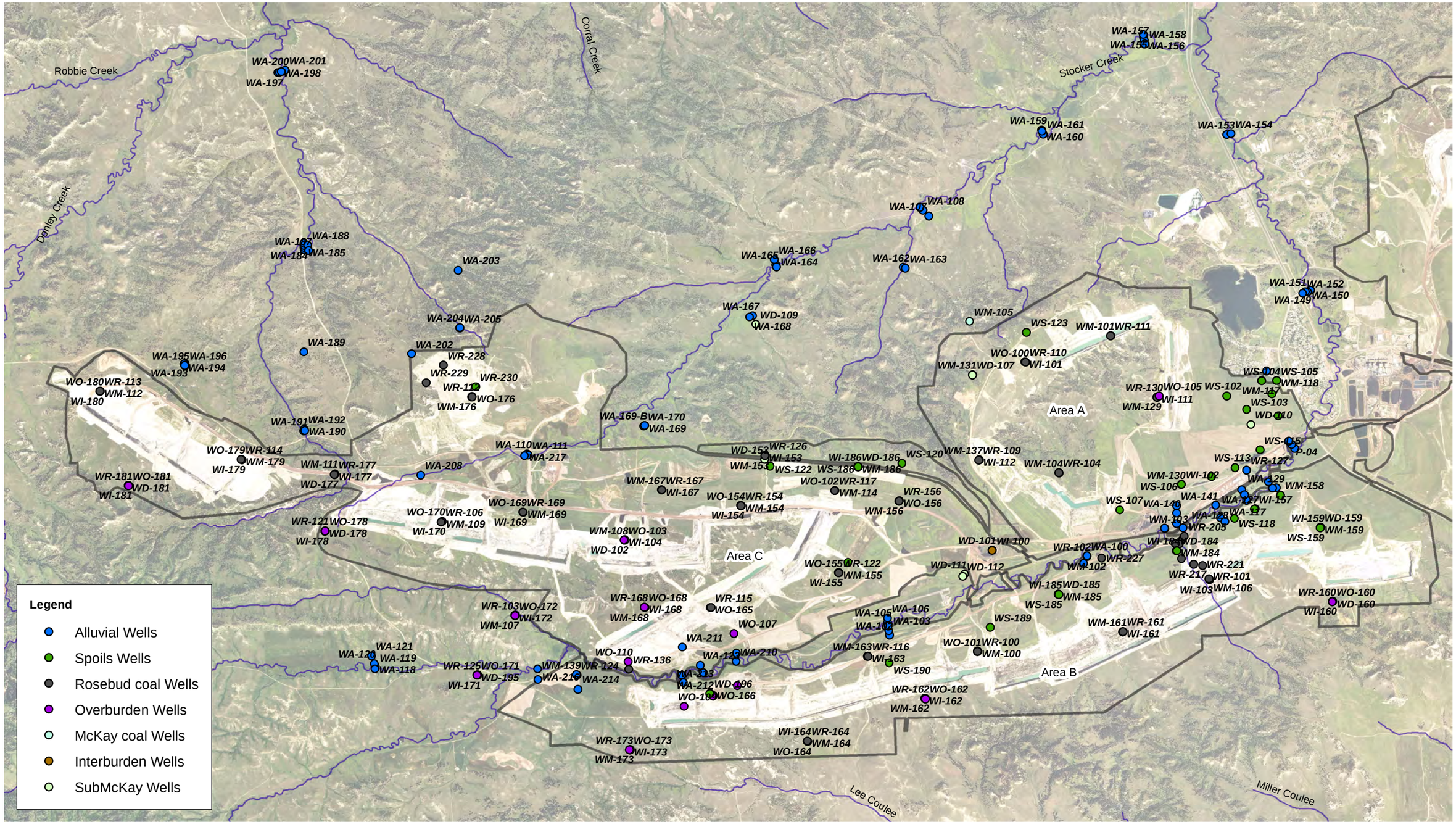
NICKLIN
EARTH & WATER, INC.

Date: 08/26/13 Name: F21_Water Levels Along EFAC.cvx

WESTERN ENERGY COMPANY - *Rosebud Mine*
A Subsidiary of WESTMORELAND COAL COMPANY

Figure 21
Groundwater Level in Alluvial Wells
East Fork Armells Creek
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F22 - Area ABC GroundwaterMP

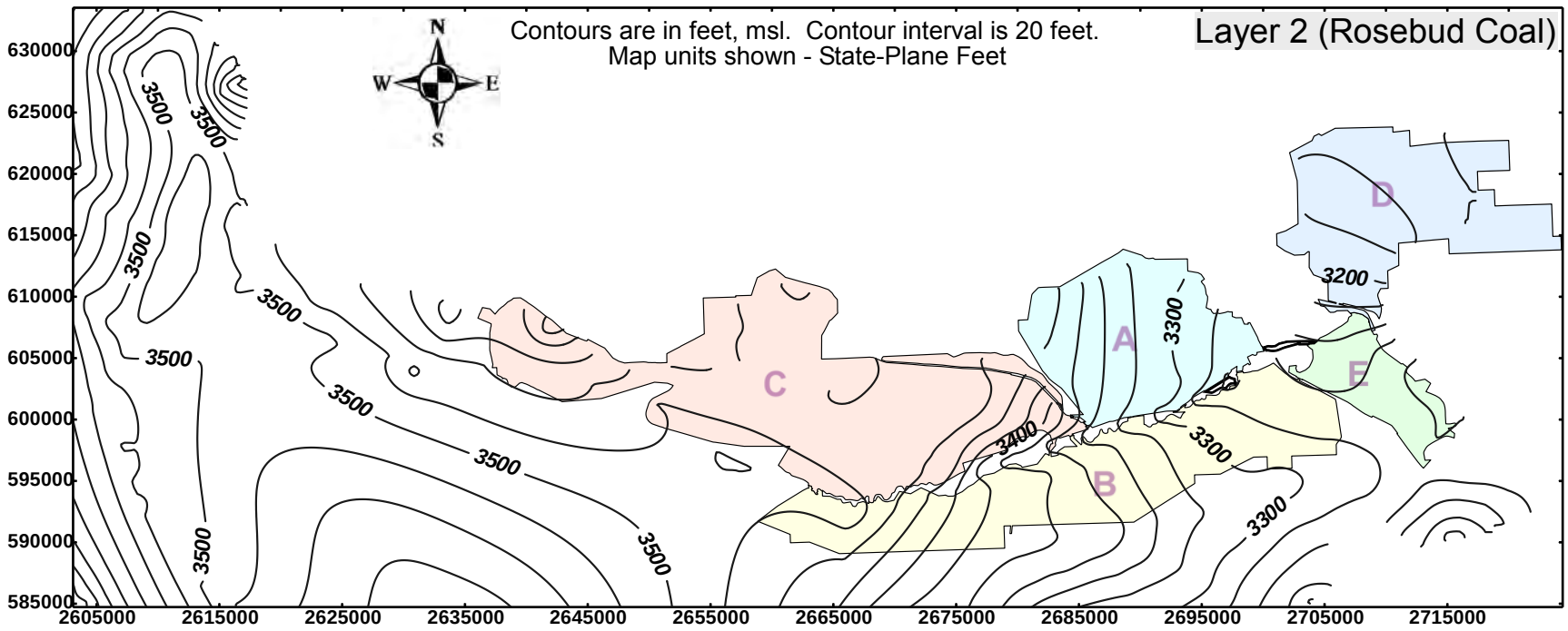
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 22
Groundwater Monitoring Wells
Areas A, B and C
Areas ABC PHC

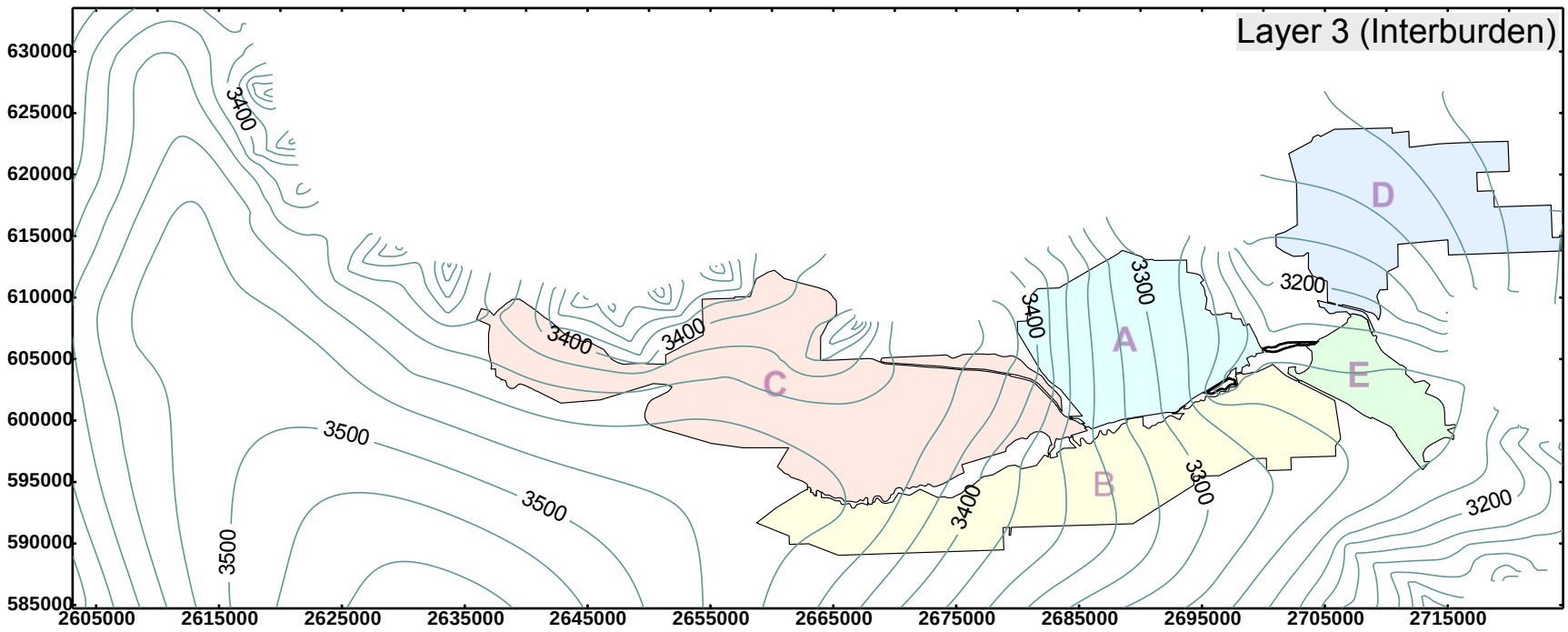
Exhibit 8

Contours are in feet, msl. Contour interval is 20 feet.
Map units shown - State-Plane Feet

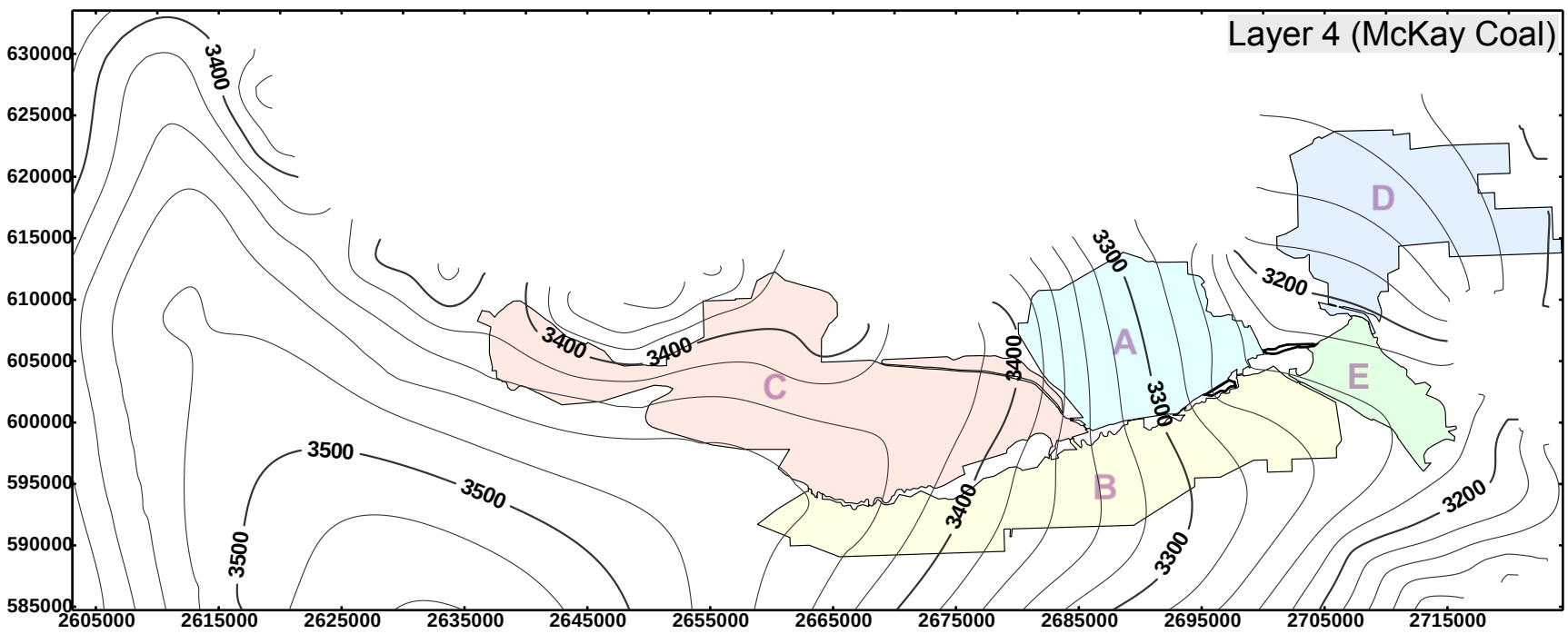
Layer 2 (Rosebud Coal)



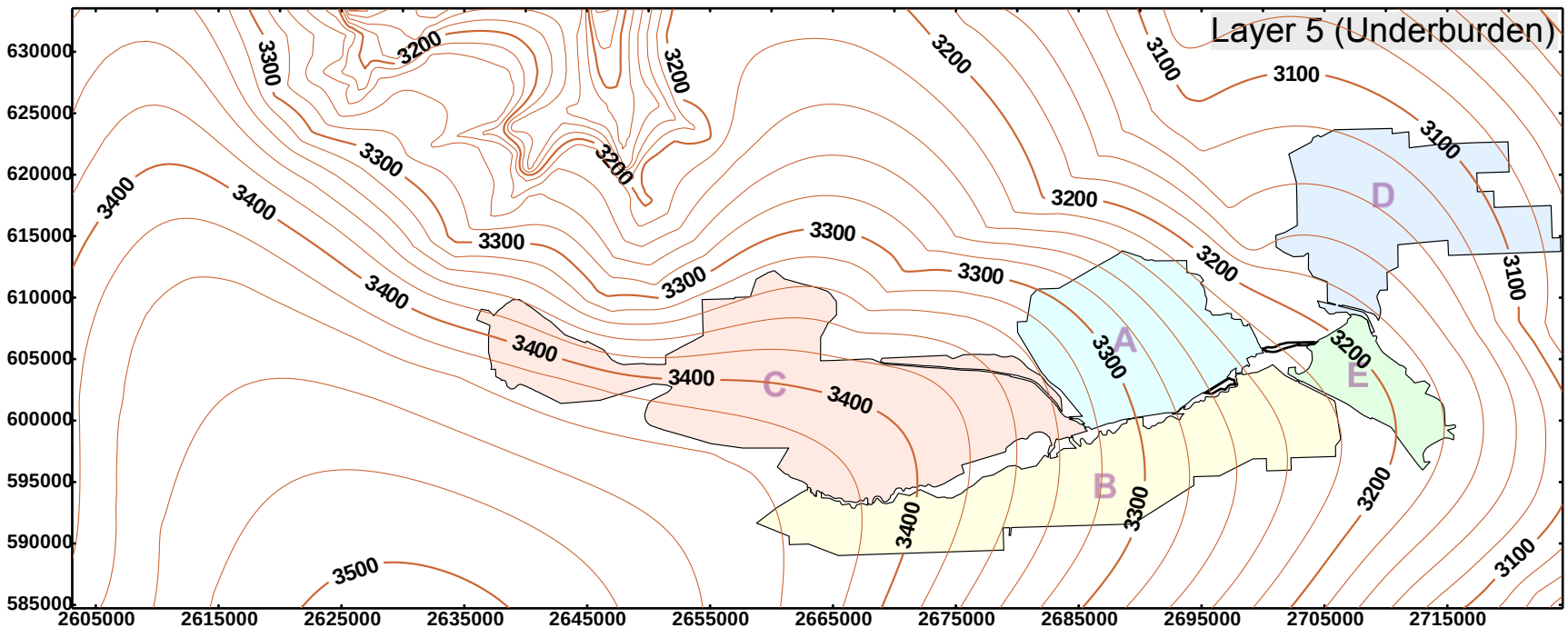
Layer 3 (Interburden)



Layer 4 (McKay Coal)



Layer 5 (Underburden)



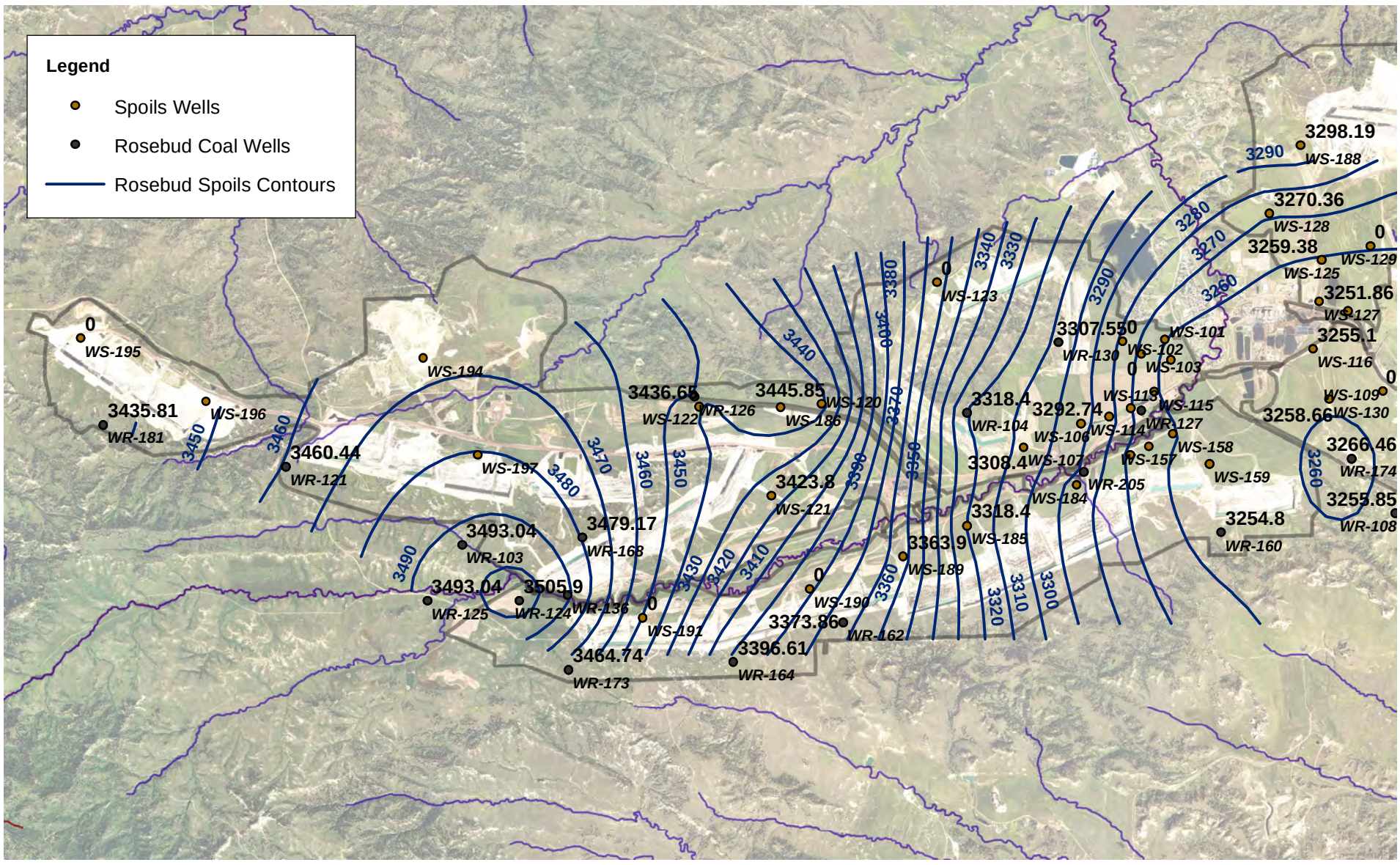
NICKLIN
EARTH & WATER, INC.

Date: 01/20/14 F23A.cvx

Figure 23A
Simulated Potentiometric Heads
Pre-Mine Conditions
Rosebud Mine Ground-water Model

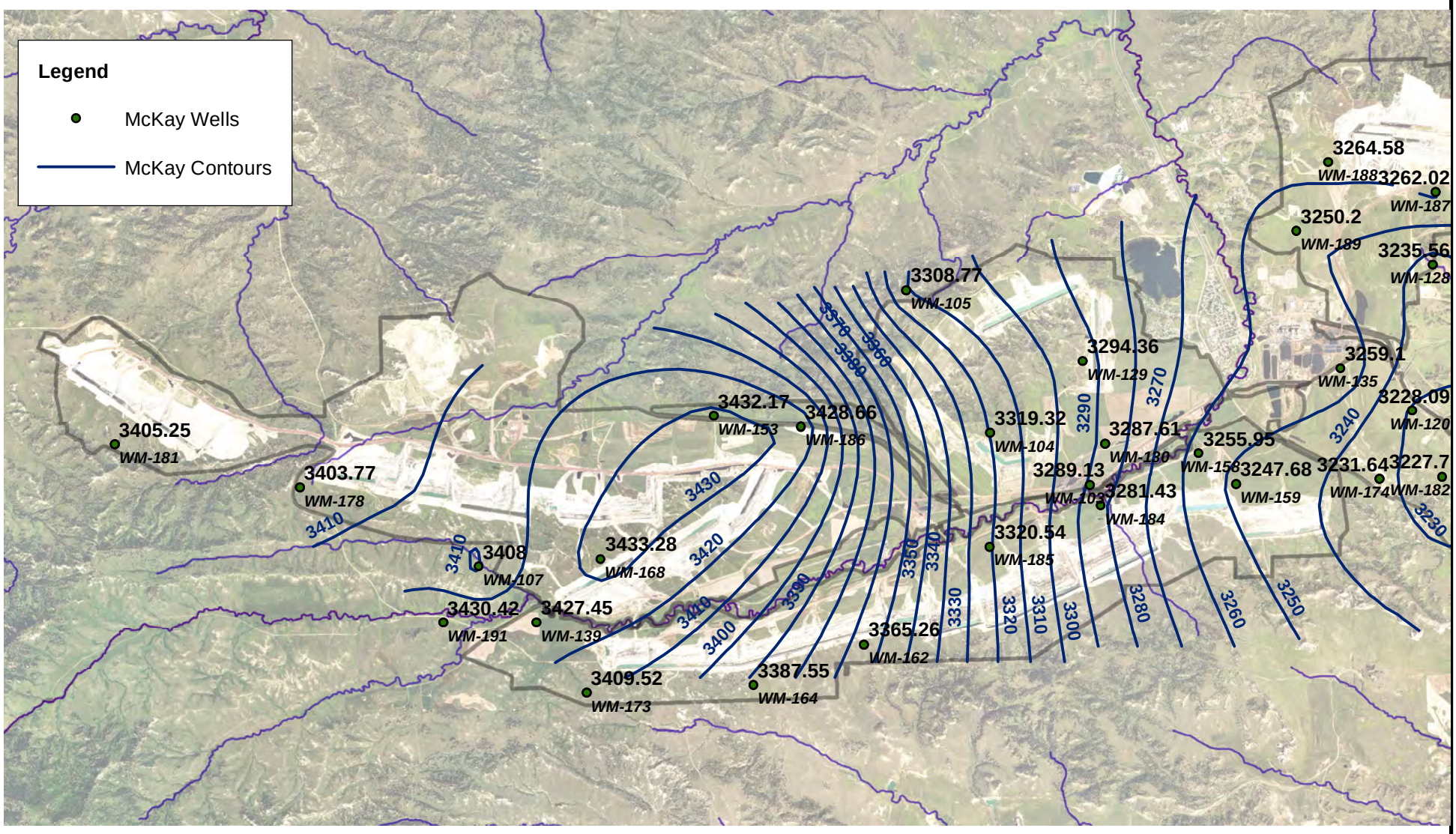
Exhibit 8

Rosebud Coal / Spoils Potentiometric Contours - December 2011



Contours were generated using December 2011 water levels in feet. Water level '0' indicates a dry well.

McKay Coal Potentiometric Contours - December 2011



Contours were generated using December 2011 water levels in feet. Water level '0' indicates a dry well.

NICKLIN EARTH & WATER, INC.

Miles
0 0.45 0.9

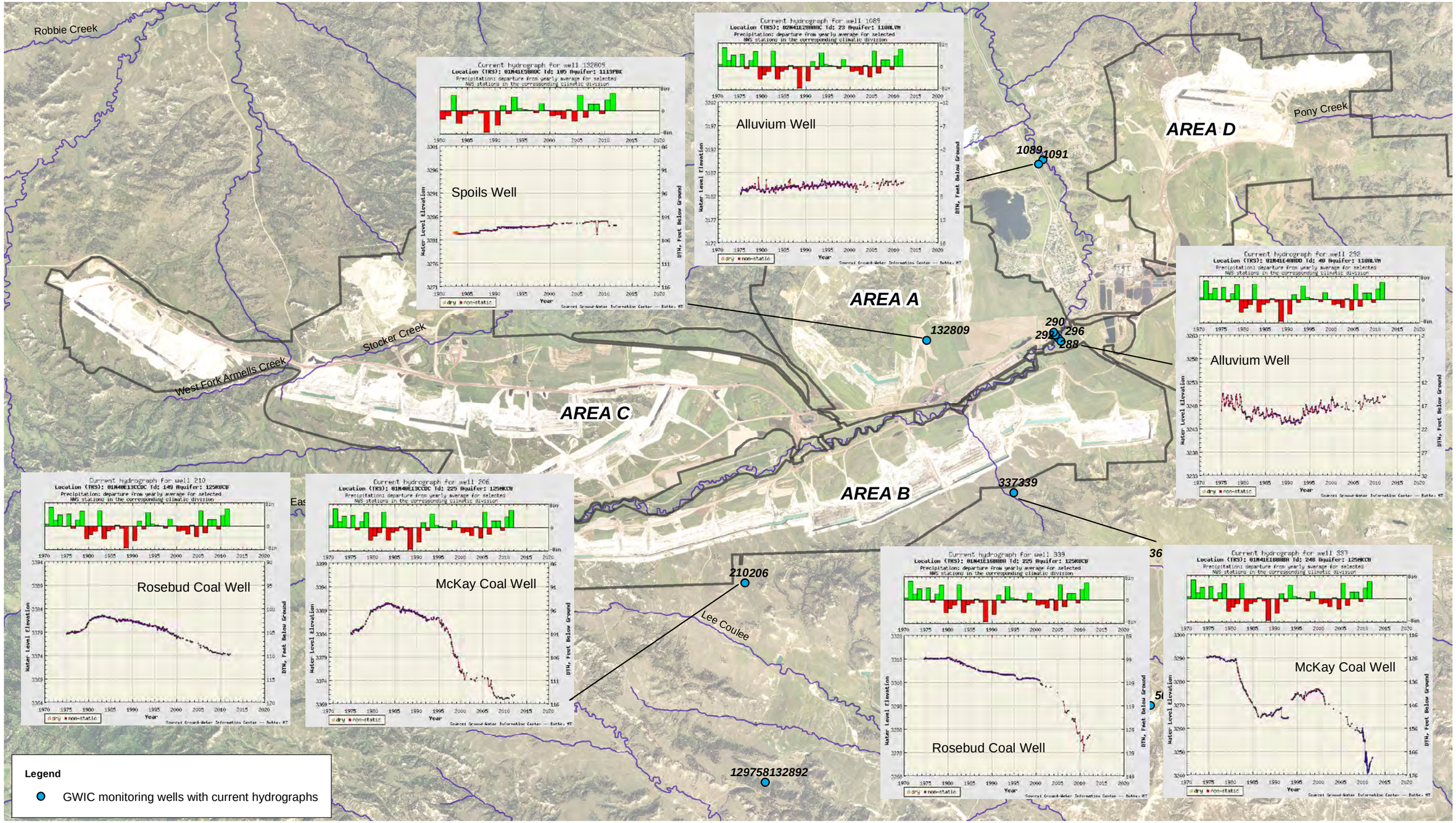
N

Notes:
1) Aerial Photographs: 2011 NAIP

Figure 23B
Potentiometric Map
Current Conditions
Areas ABC PHC

Date: 9/19/2013 Name: F23B - 2011 Potentiometric Map

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 3,000 6,000 Feet

N

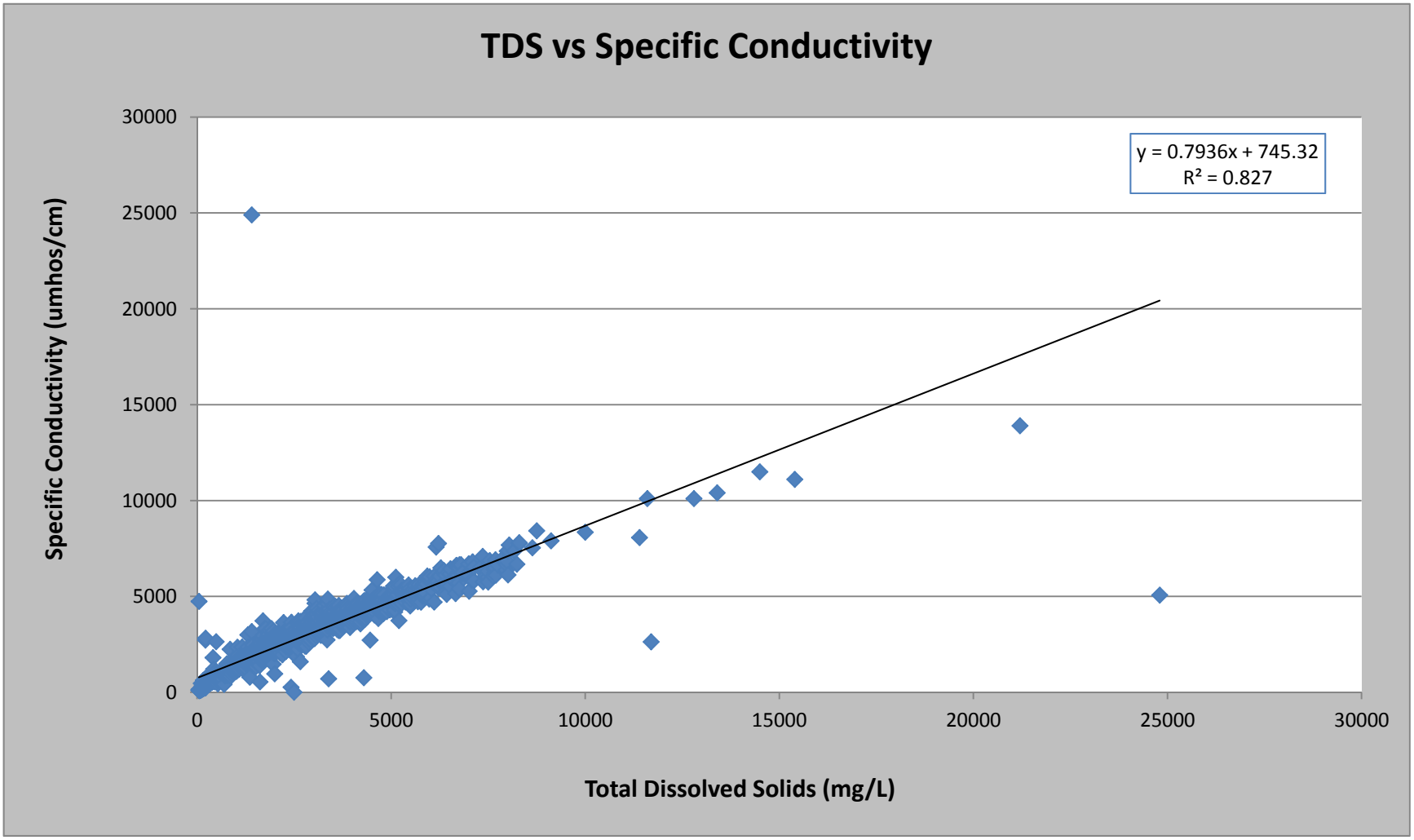
Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F24 - GWIC_hydrographs

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 24
Selected Hydrographs GWIC Wells
Areas ABC PHC

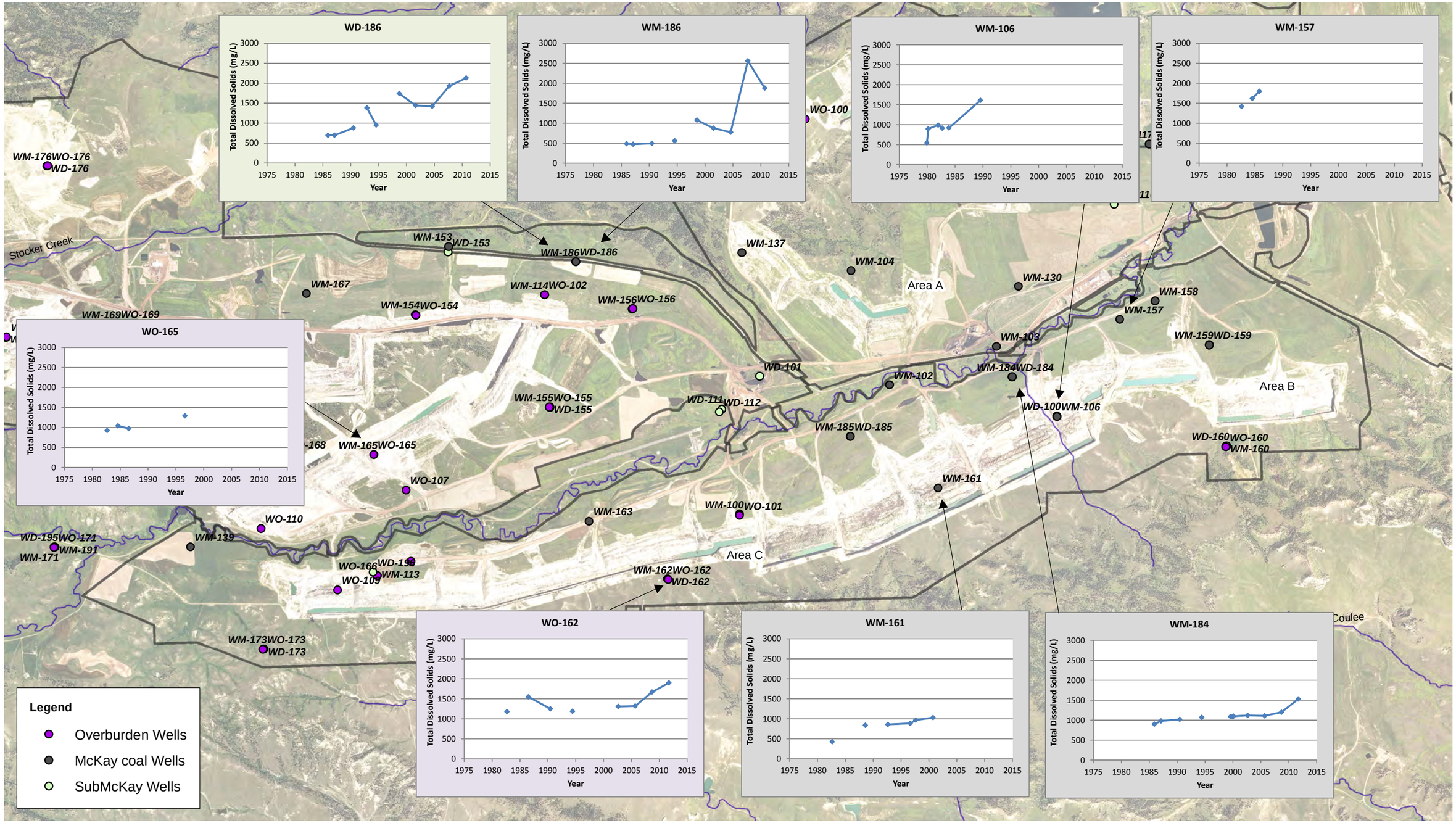
Exhibit 8



NICKLIN EARTH & WATER, INC.

Figure 25
Regression Curve: TDS vs Specific Conductivity in Groundwater
Western Energy Rosebud Mine

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

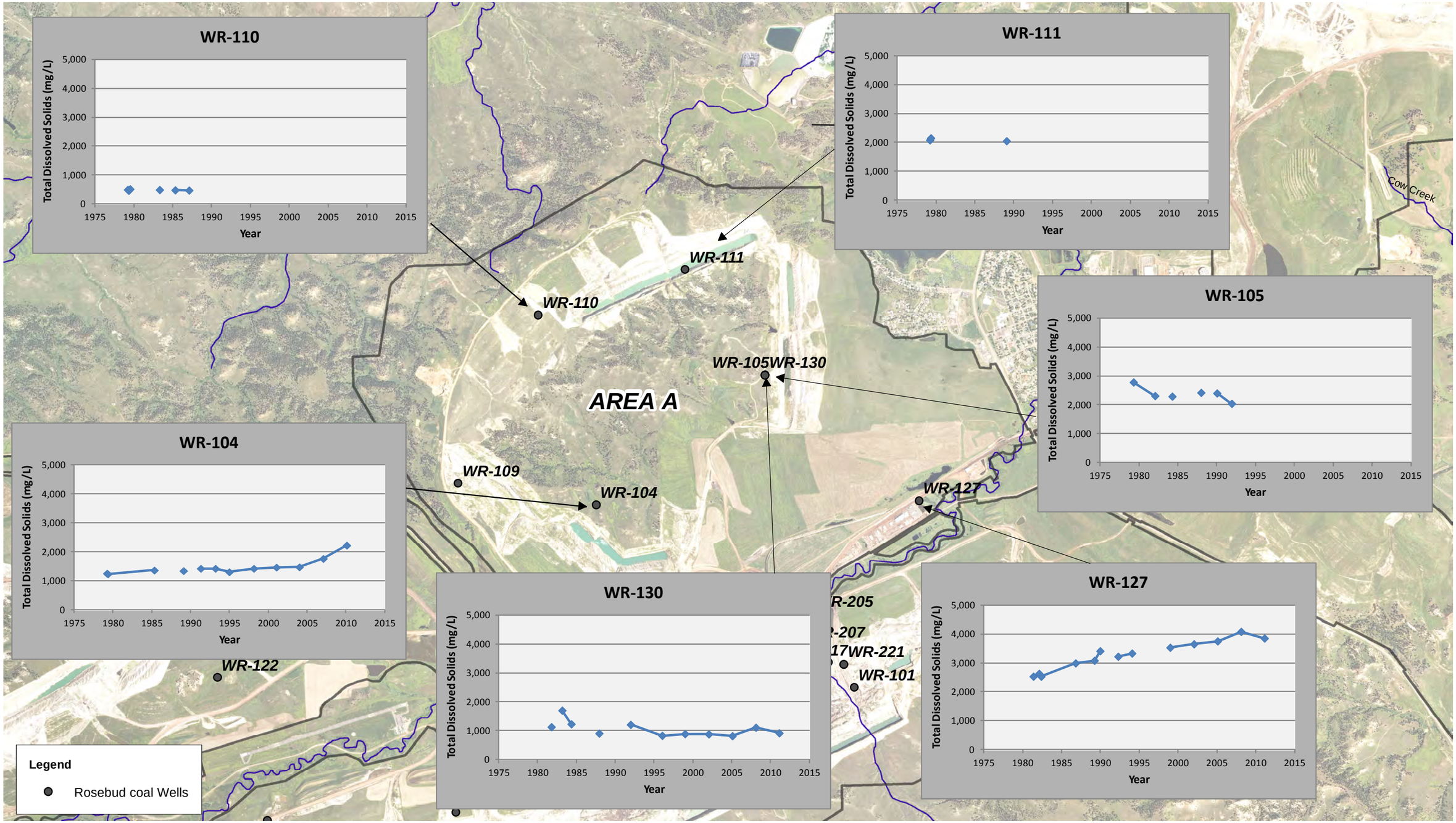
Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F26 - OB_McKay_subMcKay TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 26
TDS Time Series Graphs
Selected Overburden, McKay coal and SubMcKay Wells
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 1,500 3,000 Feet

N

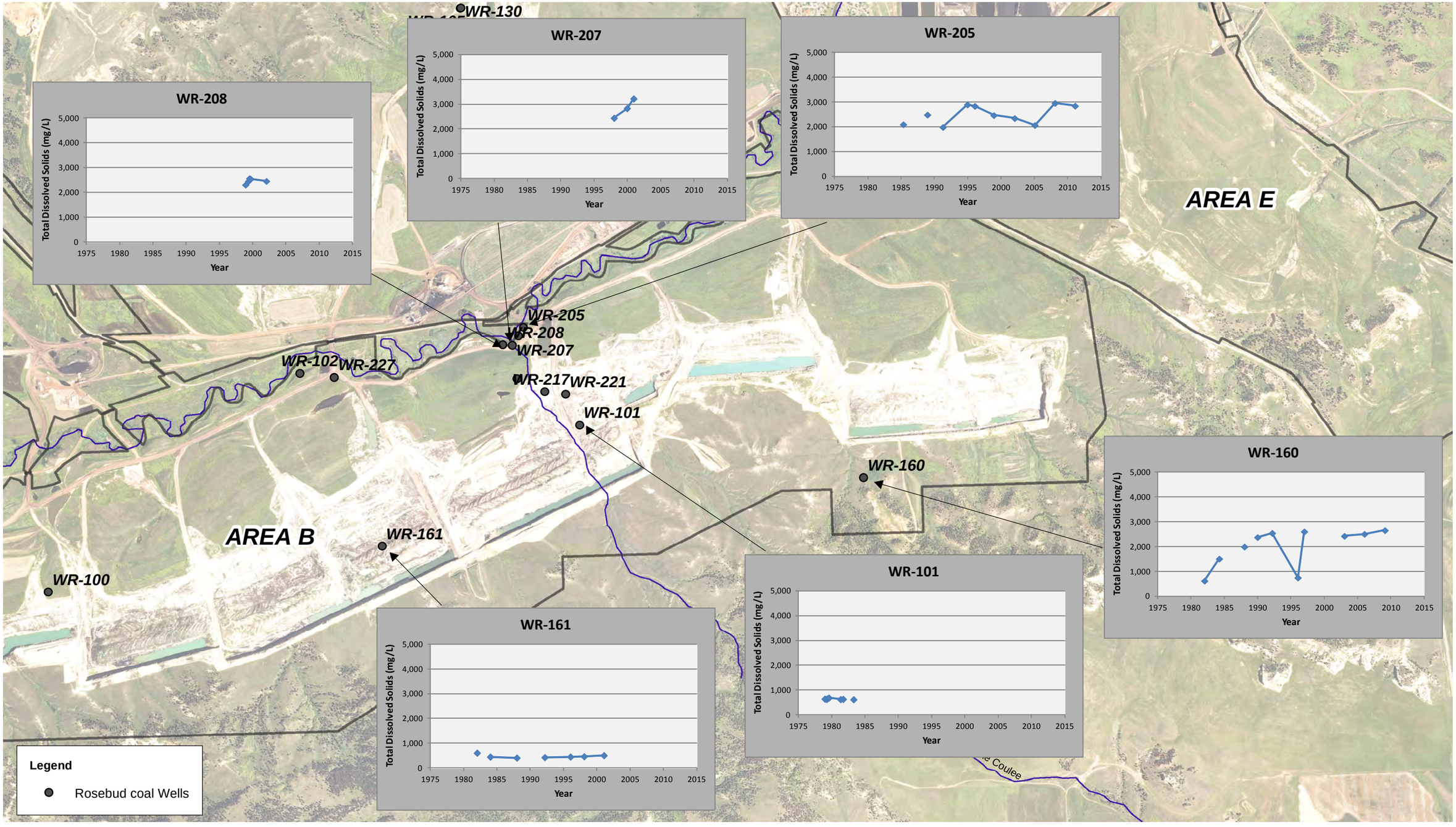
Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F27A - AreaA_RosebudCoal_TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 27A
TDS Time Series Graphs
Area A - Rosebud Coal
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 1,000 2,000 Feet

N

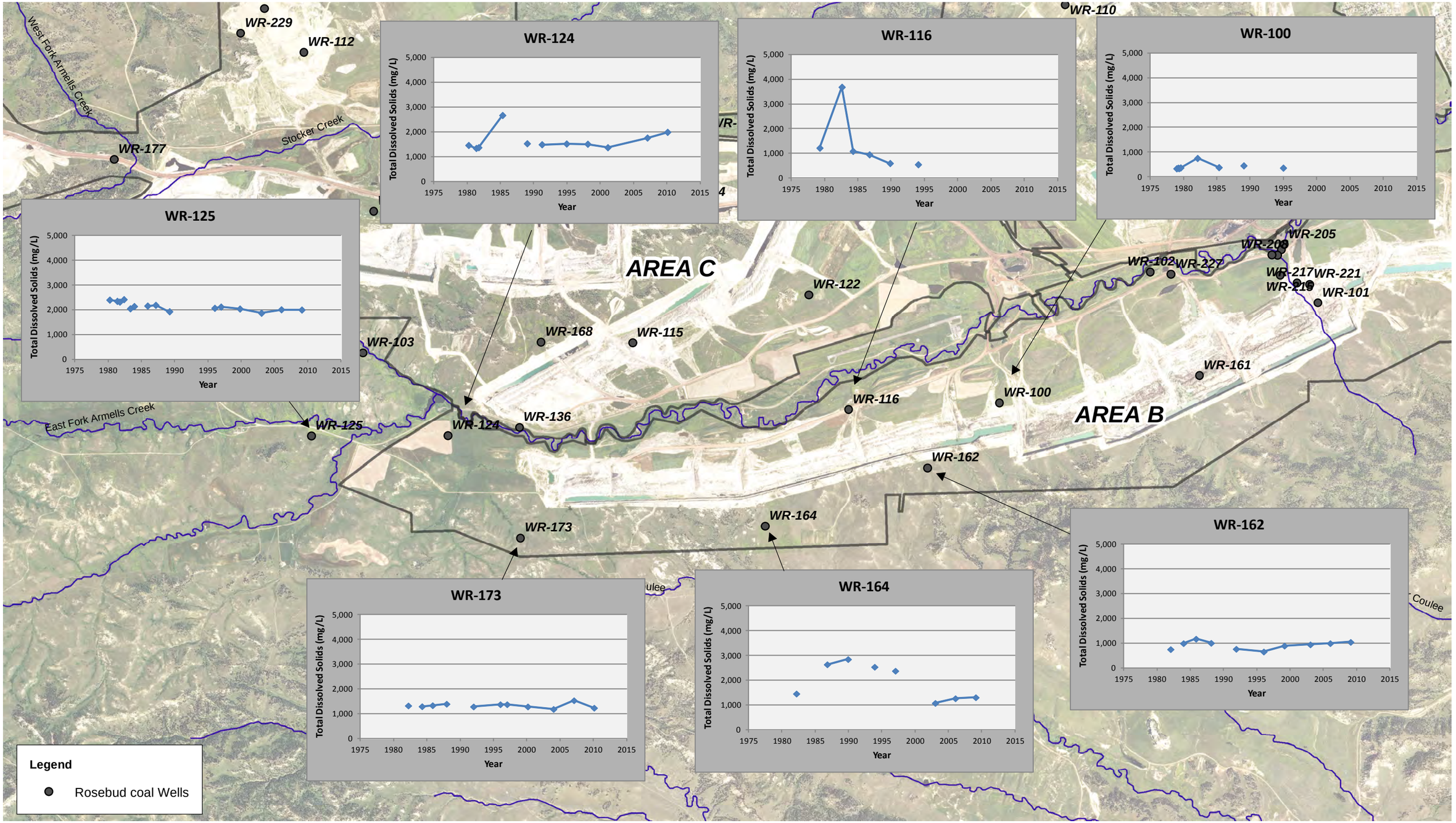
Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F27B - AreaB_East_RosebudCoal_TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 27B
TDS Time Series Graphs
Area B East - Rosebud Coal
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 2,500 5,000 Feet

N

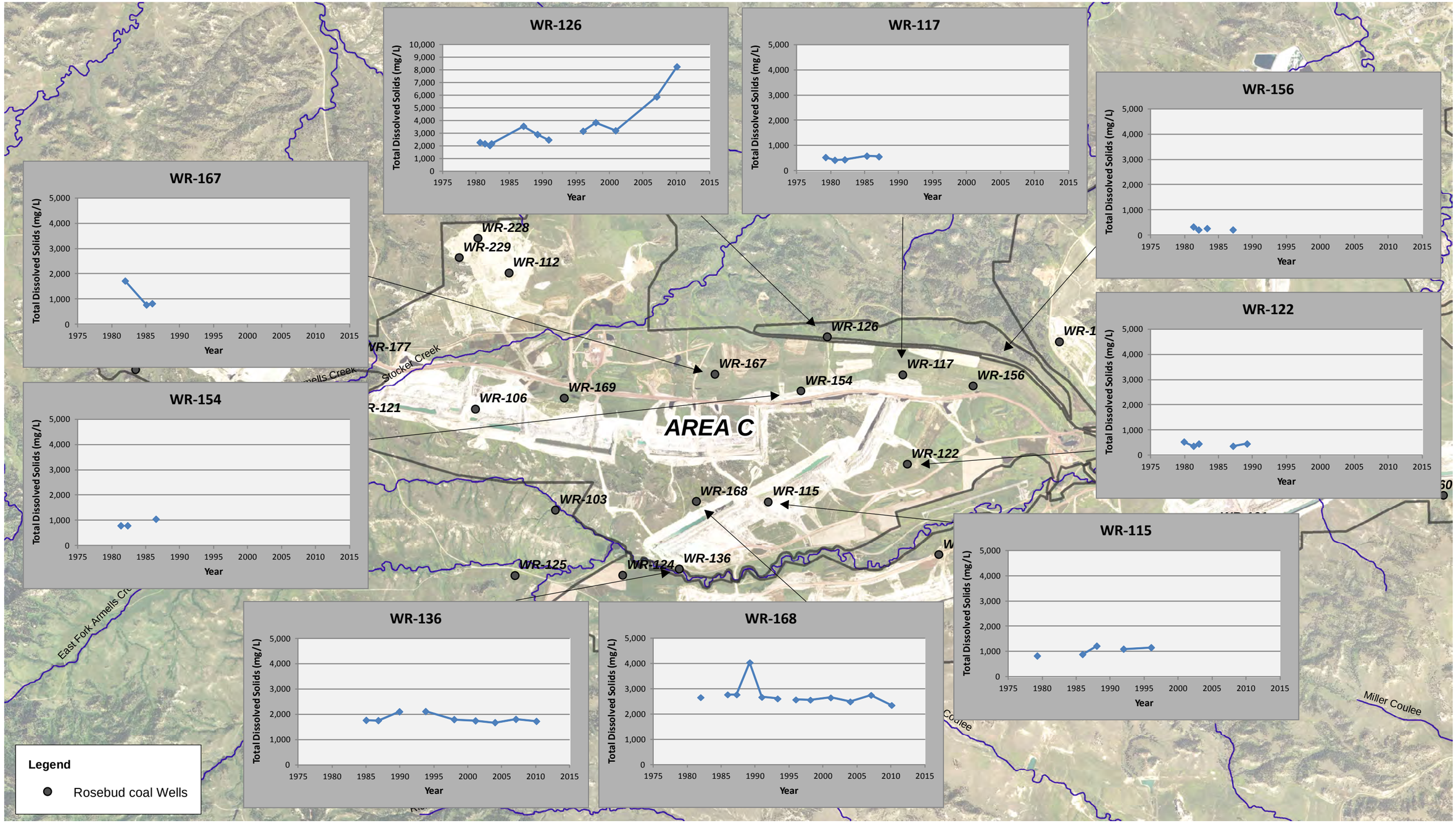
Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F27C - AreaB_West_RosebudCoal_TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 27C
TDS Time Series Graphs
Area B West - Rosebud Coal
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 3,000 6,000 Feet

N

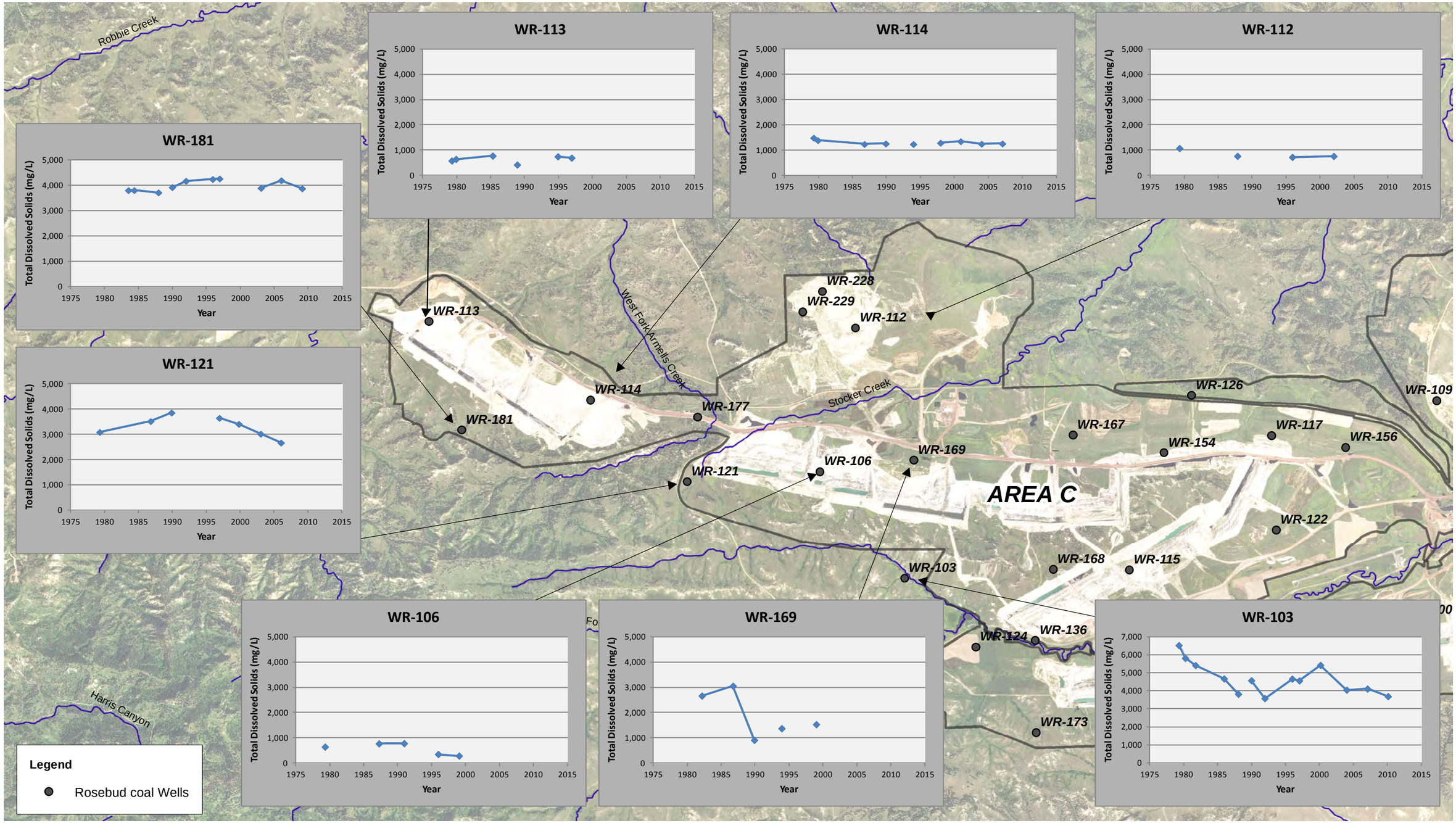
Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F27D - AreaC_East_RosebudCoal_TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 27D
TDS Time Series Graphs
Area C East - Rosebud Coal
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 3,000 6,000 Feet

N

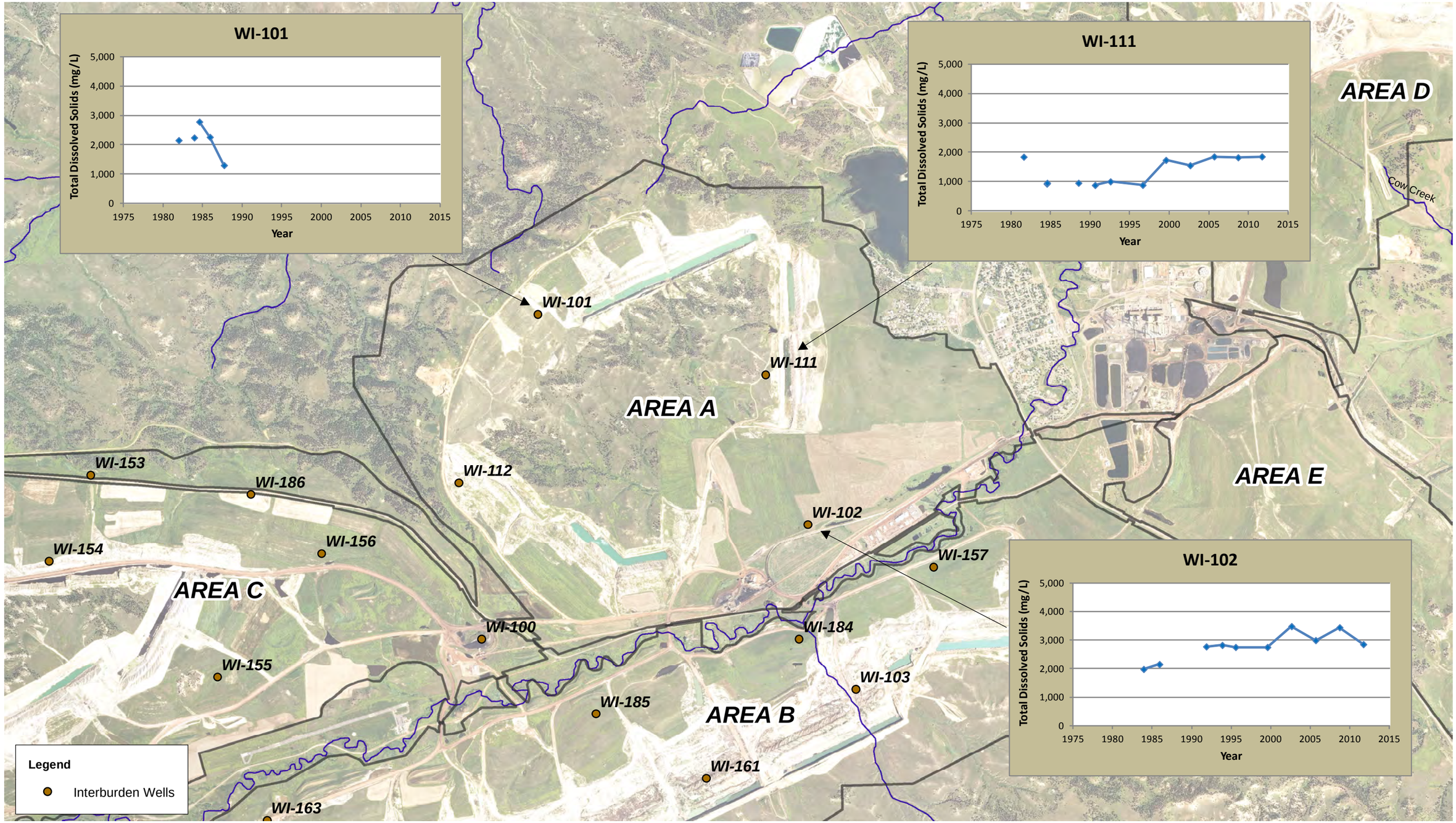
Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F27E - AreaC_West_RosebudCoal_TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 27E
TDS Time Series Graphs
Area C West - Rosebud Coal
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 2,000 4,000 Feet

N

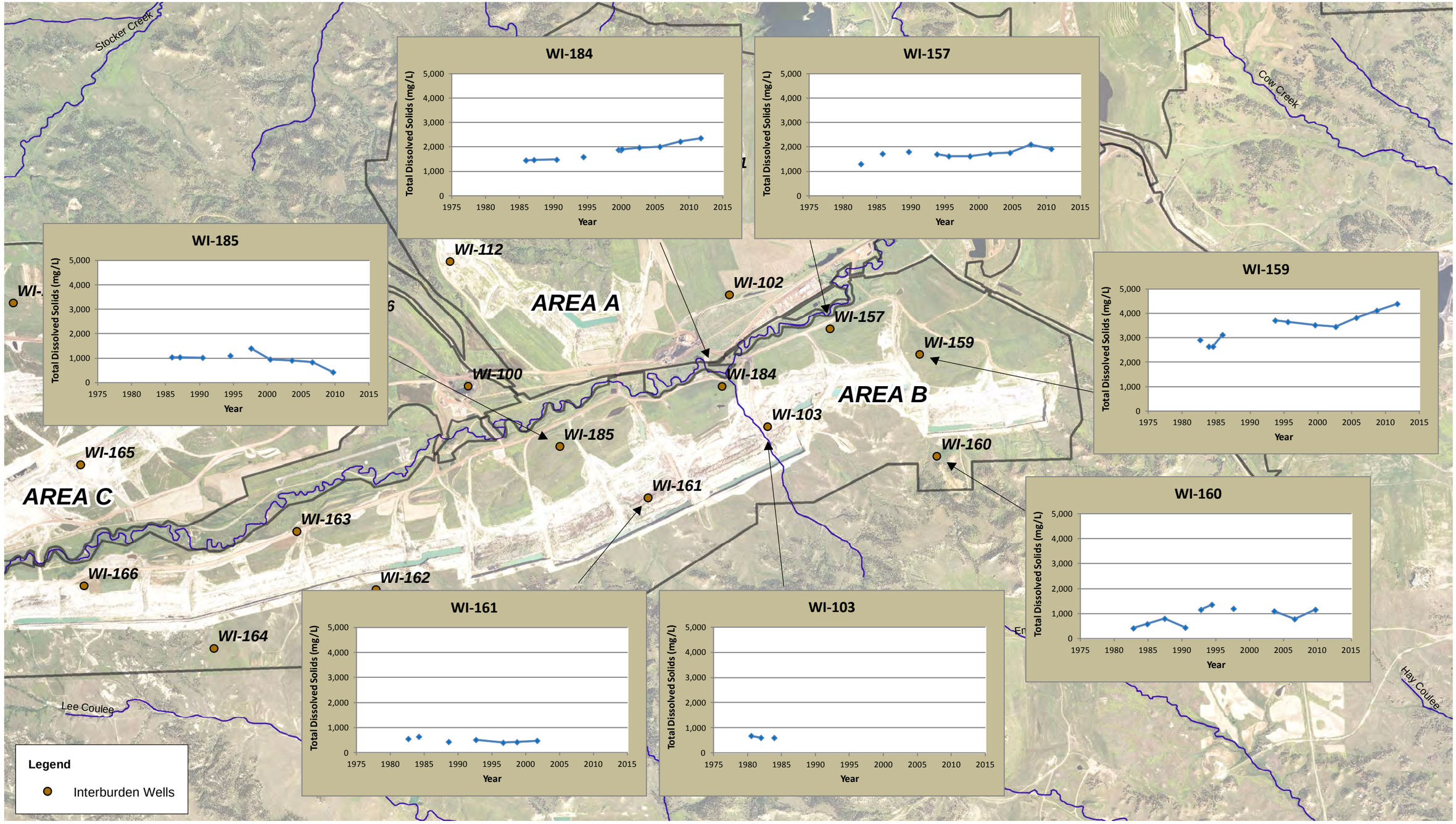
Notes:
1) Aerial Photographs: 2011 NAIP

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 28A
TDS Time Series Graphs
Area A - Interburden
Areas ABC PHC

Date: 9/5/2013 Name: F28A - AreaA_Interburden_TDS

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 2,500 5,000 Feet

N

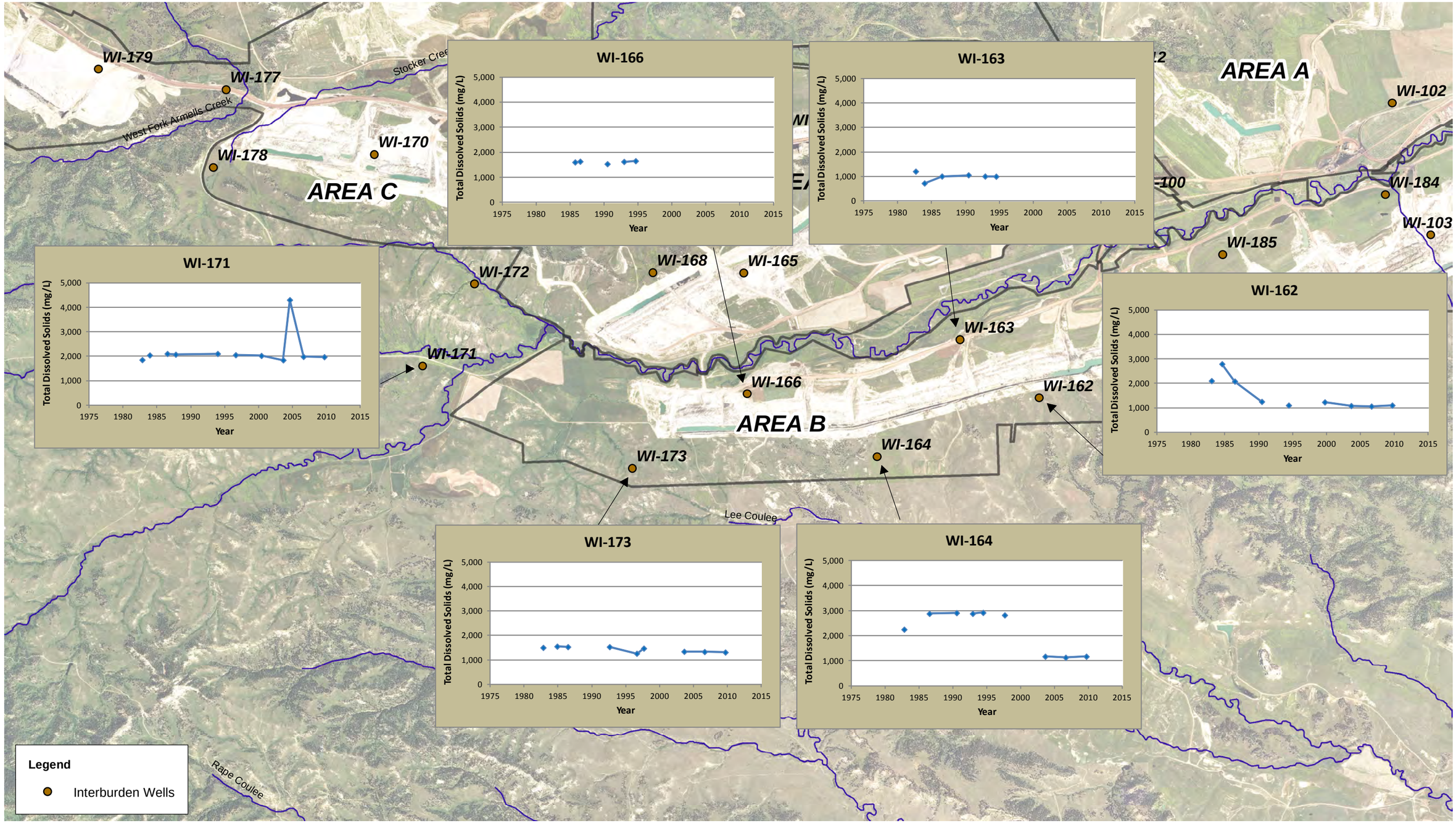
Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F28B - AreaB_East_Interburden_TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 28B
TDS Time Series Graphs
Area B East - Interburden
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 2,500 5,000 Feet

N

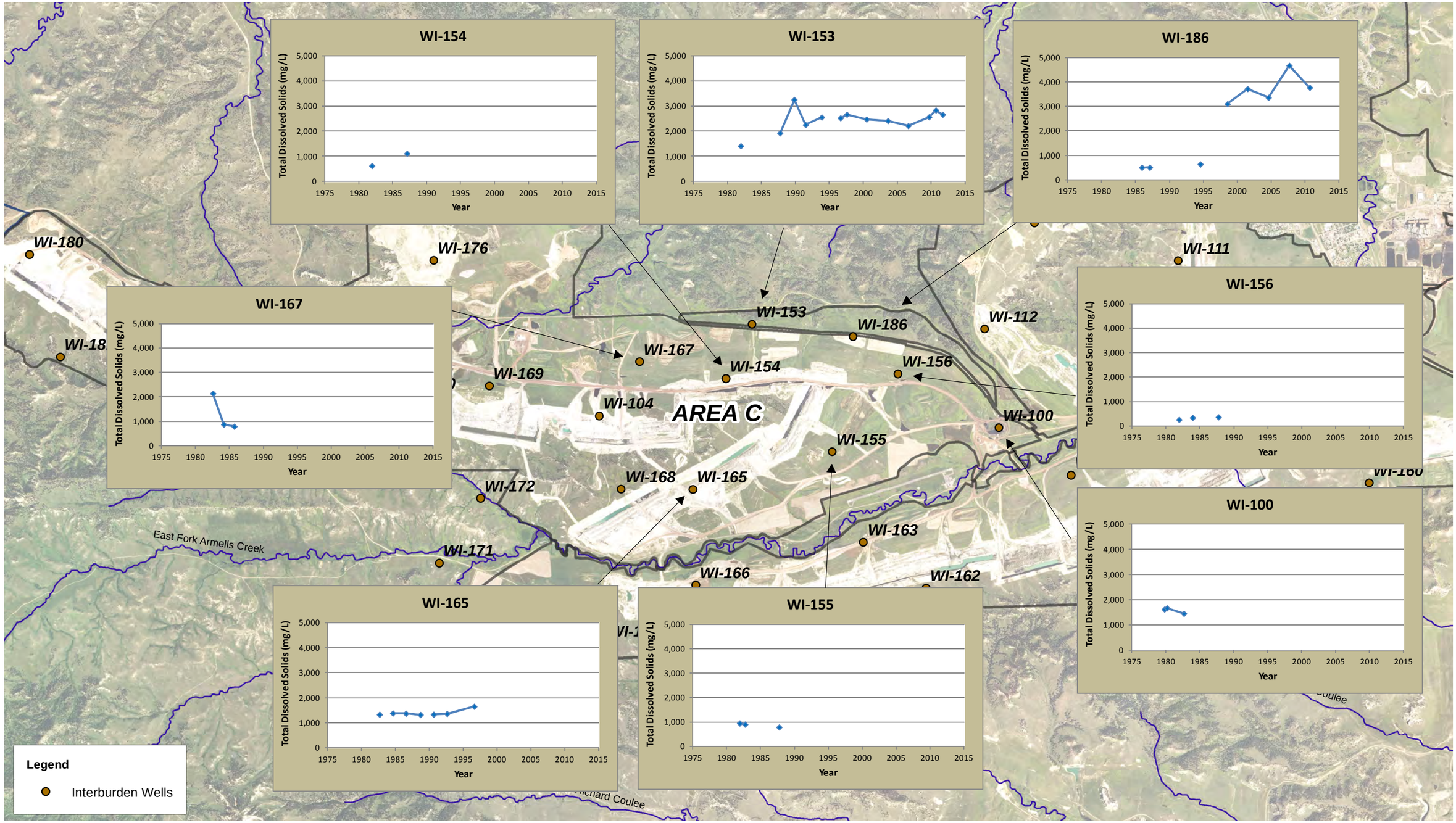
Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F28C - AreaB_West_Interburden_TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 28C
TDS Time Series Graphs
Area B West - Interburden
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 3,000 6,000 Feet

N

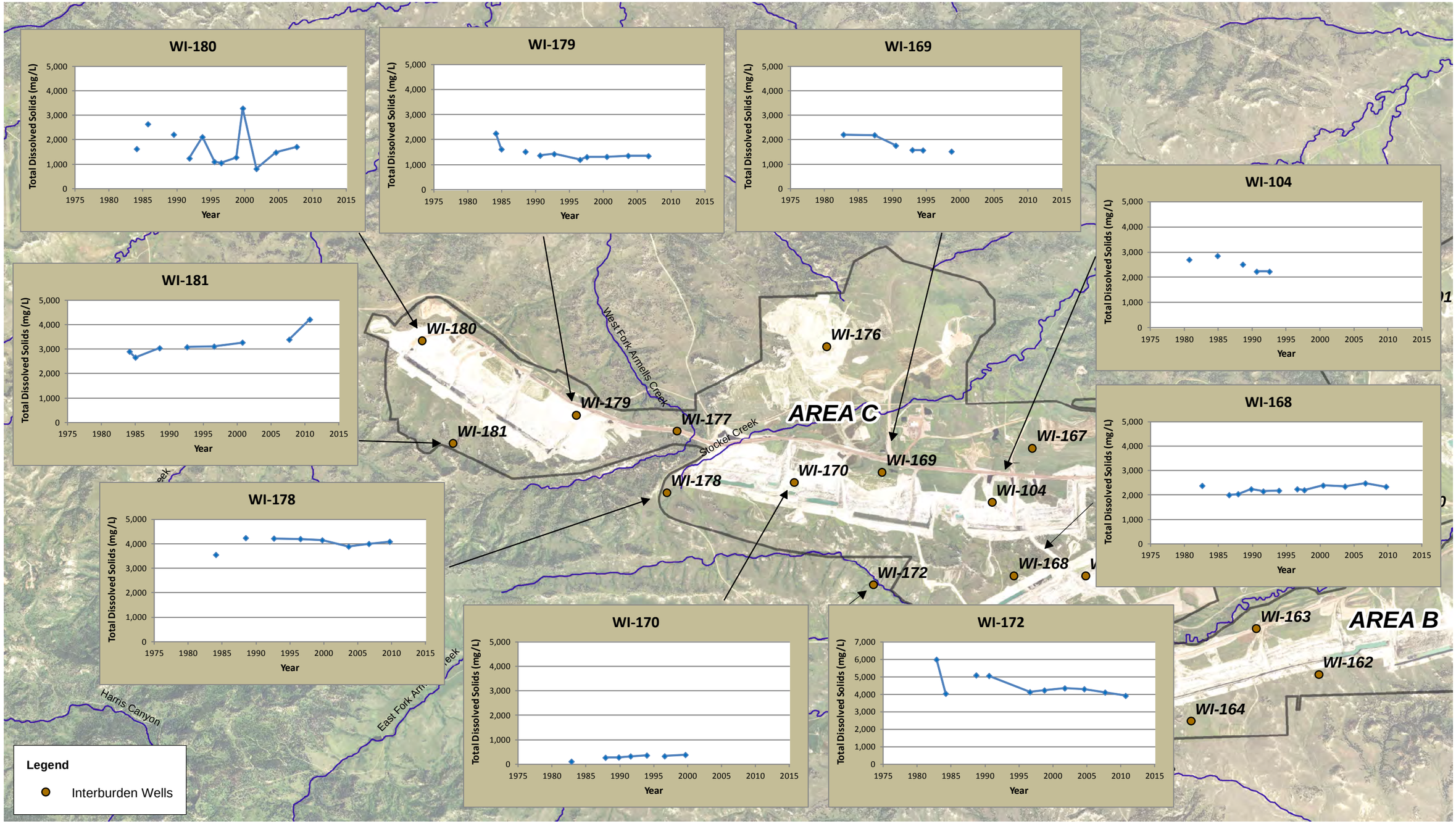
Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F28D - AreaC_East_Interburden_TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 28D
TDS Time Series Graphs
Area C East - Interburden
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 3,000 6,000 Feet

N

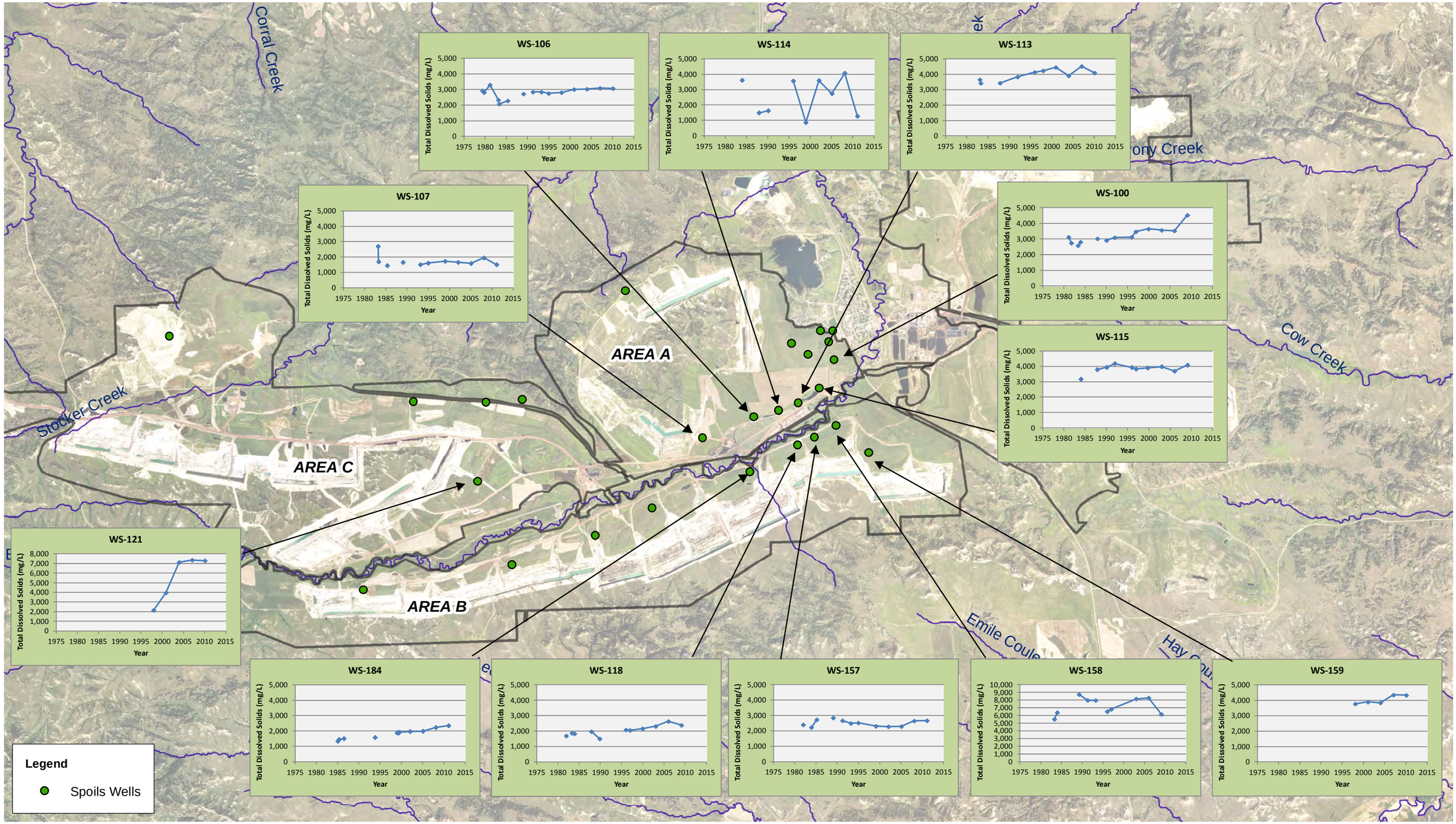
Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F28E - AreaC_West_Interburden_TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 28E
TDS Time Series Graphs
Area C West - Interburden
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 3,000 6,000 Feet

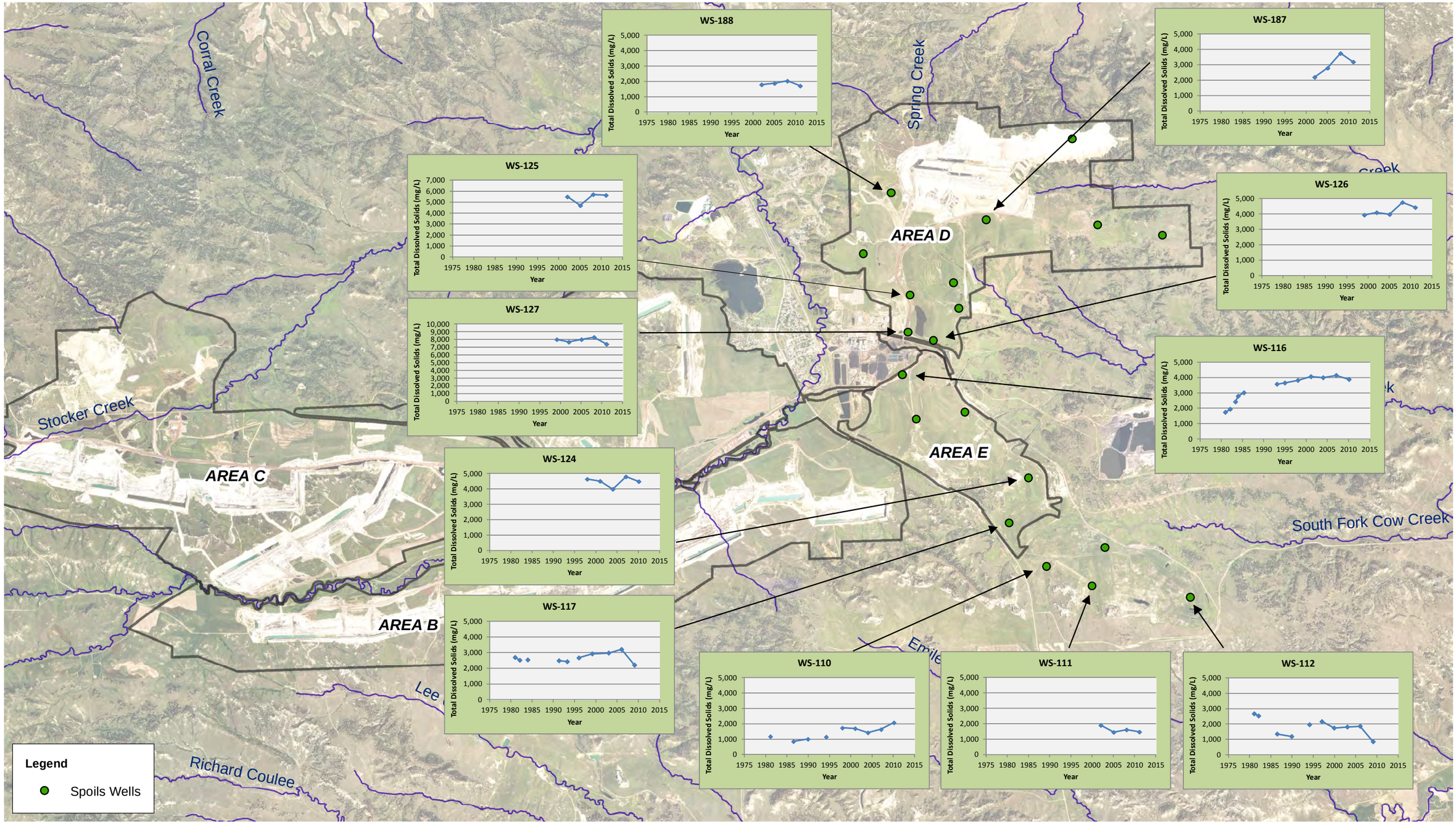
N

Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F29A - AreaABC_Spoils_TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 29A
TDS Time Series Graphs
Area A-B-C Spoils
Areas ABC PHC
Exhibit 8



NICKLIN EARTH & WATER, INC.

0 3,000 6,000 Feet

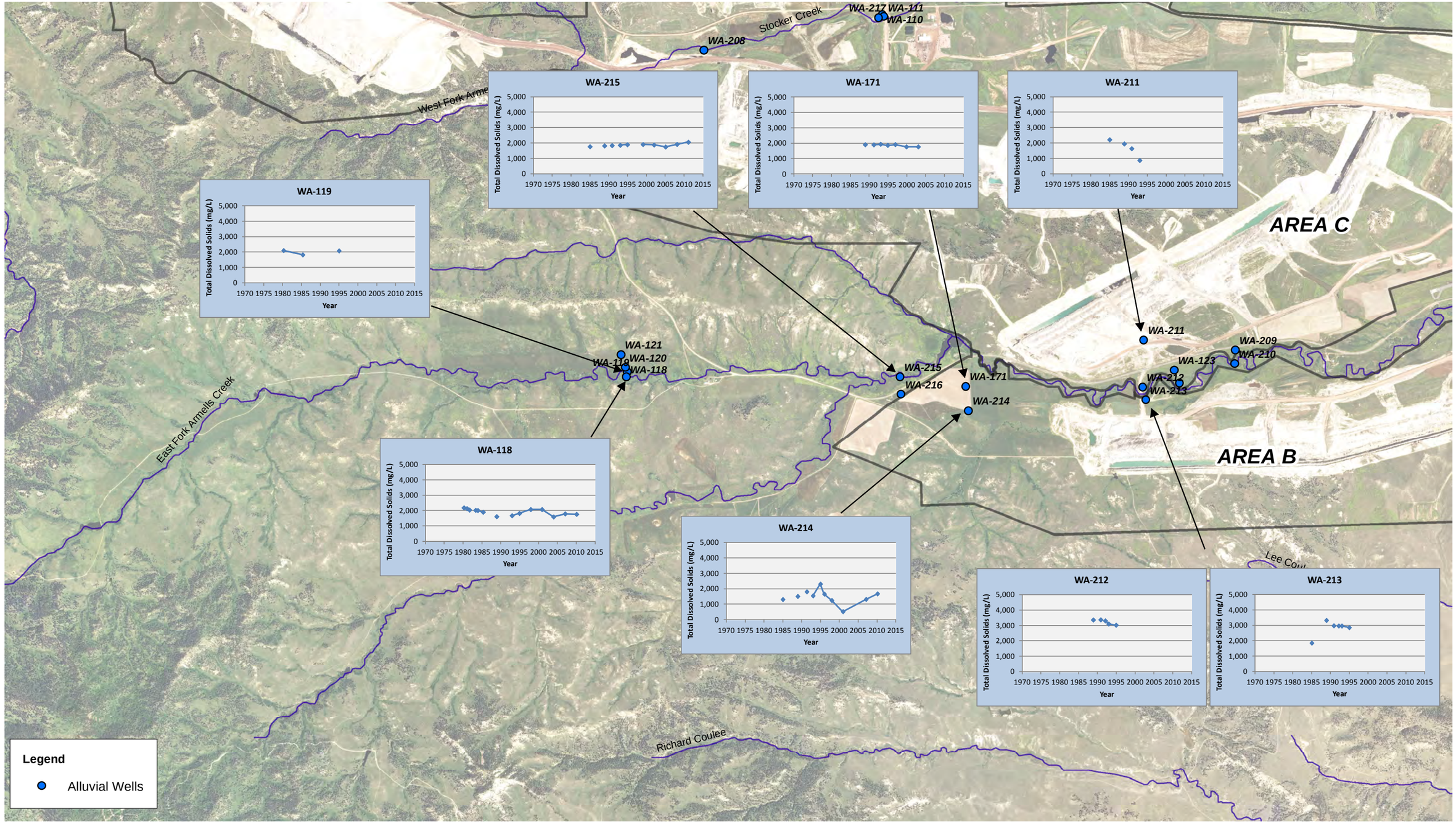
N

Notes:
1) Aerial Photographs: 2011 NAIP

Date: 9/5/2013 Name: F29B - AreaDE_Spoils_TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 29B
TDS Time Series Graphs
Area D-E Spoils
Areas ABC PHC
Exhibit 8



NICKLIN EARTH & WATER, INC.

0 1,500 3,000 Feet

N

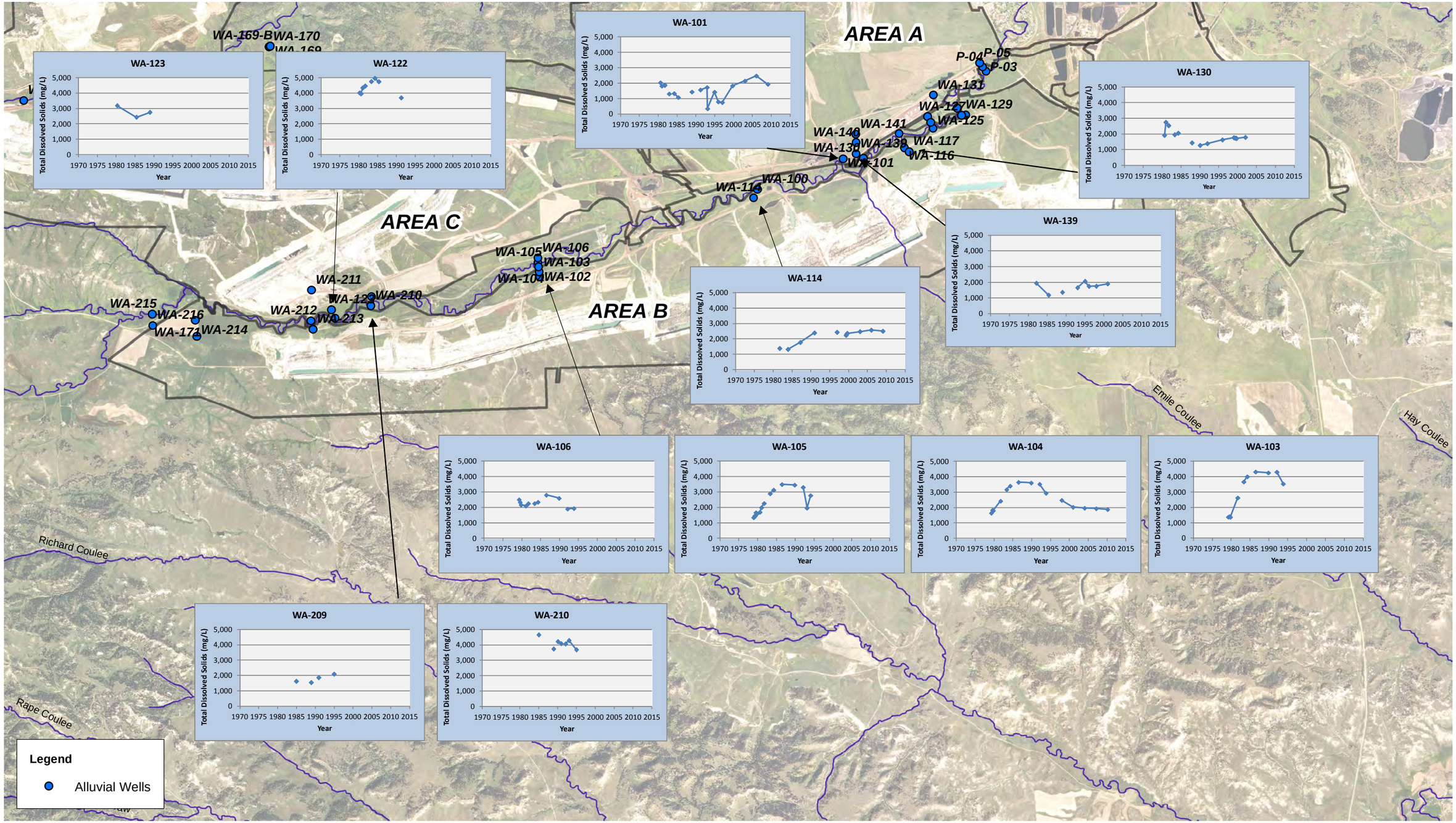
Notes:
1) Aerial Photographs: 2011 NAIP
2) Groups of graphs / wells are organized left to right, looking downstream

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Date: 9/5/2013 Name: F30A - EFAC_Upstream_Alluvium _TDS

Figure 30A
TDS Time Series Graphs
East Fork Armells Creek
Upstream - Alluvium
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 3,000 6,000 Feet

N

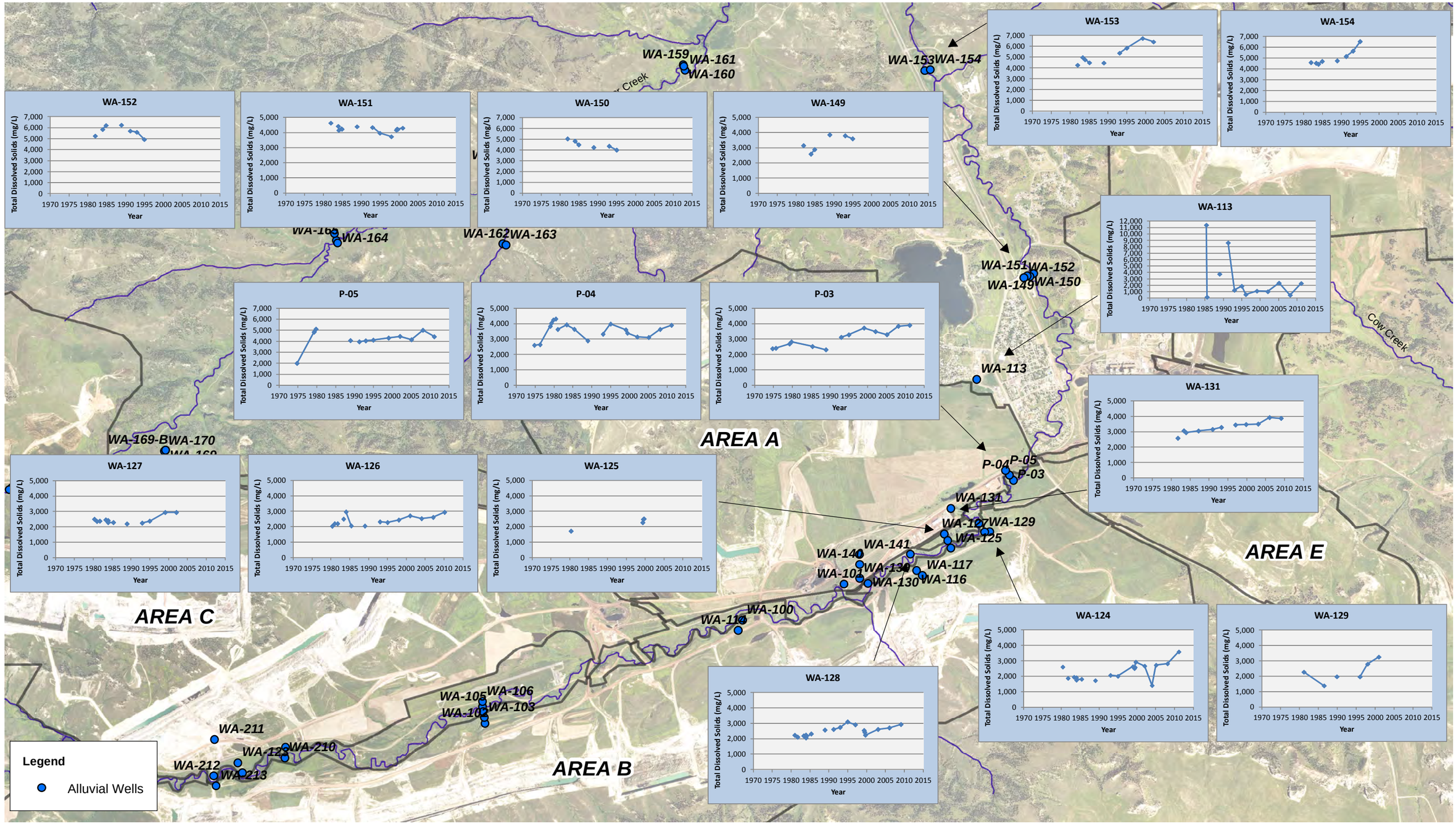
Notes:
1) Aerial Photographs: 2011 NAIP
2) Groups of graphs / wells are organized left to right, looking downstream

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Date: 9/5/2013 Name: F30B - EFAC_ Middle_Alluvium _TDS

Figure 30B
TDS Time Series Graphs
East Fork Armells Creek
Middle Section - Alluvium
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 2,500 5,000 Feet

N

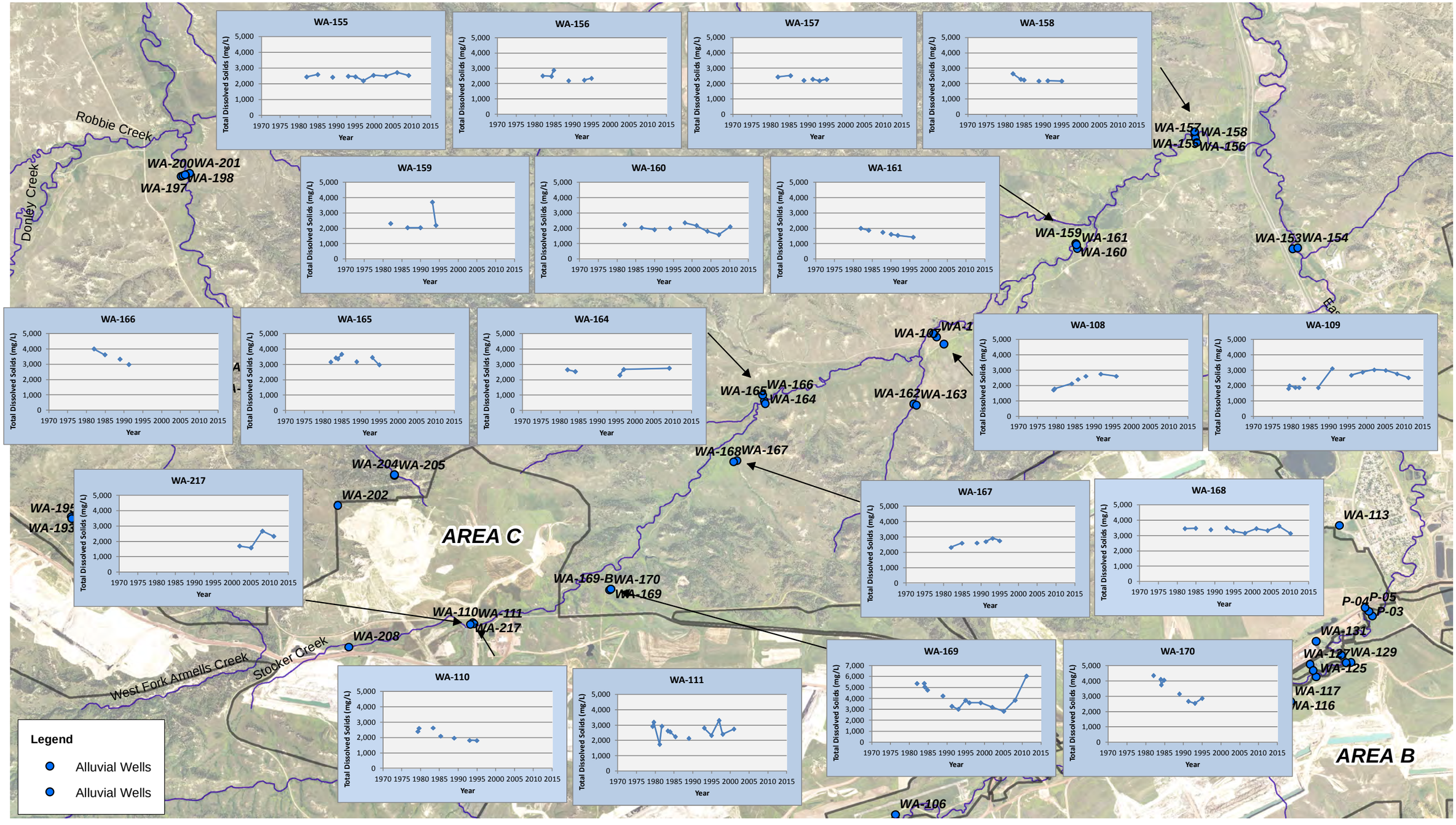
Notes:
1) Aerial Photographs: 2011 NAIP
2) Groups of graphs / wells are organized left to right, looking downstream

Date: 9/5/2013 Name: F30C - EFAC_DownstreamAlluvium _TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 30C
TDS Time Series Graphs
East Fork Armells Creek
Downstream - Alluvium
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

Feet
0 2,000 4,000

N

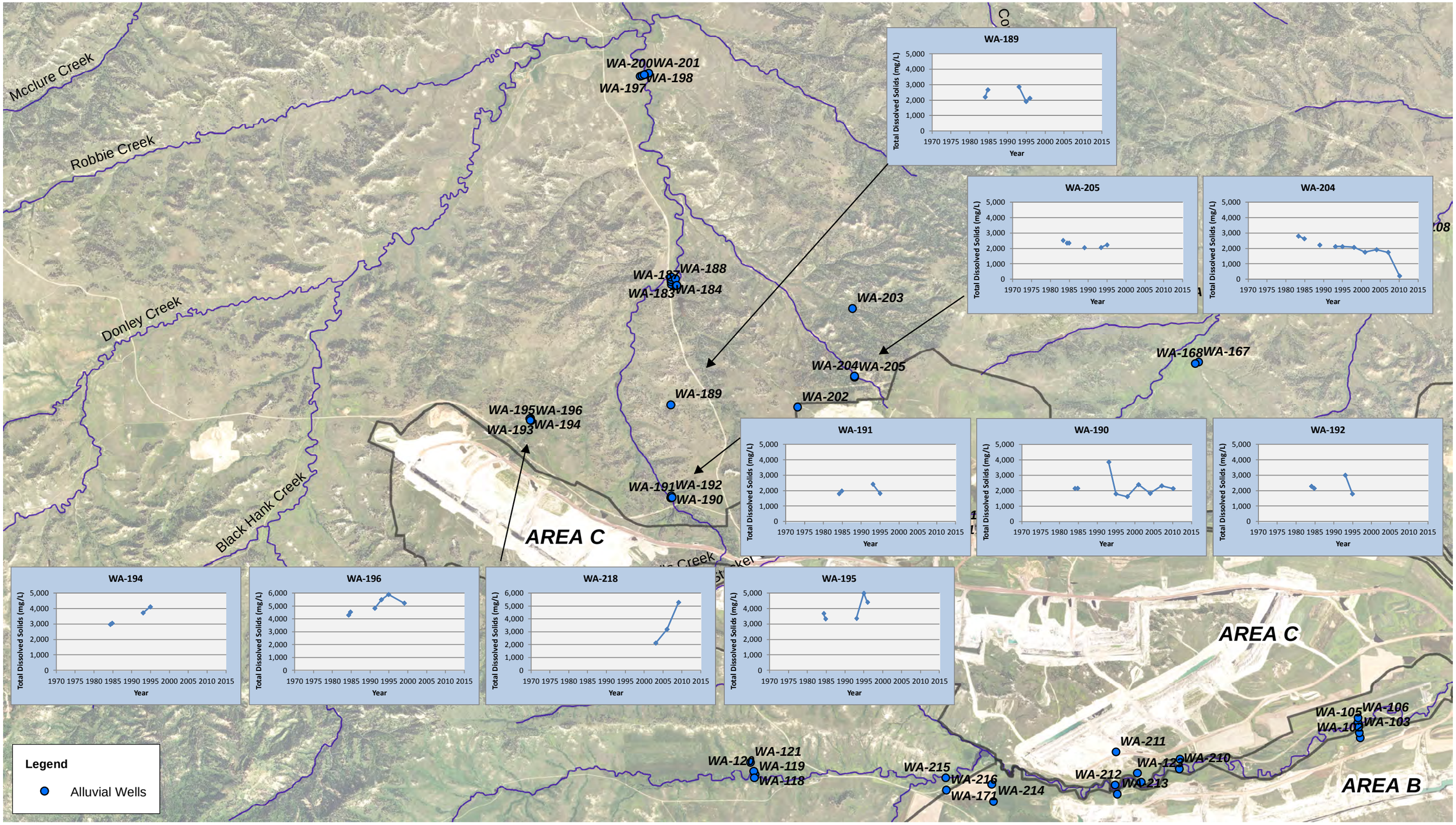
Notes:
1) Aerial Photographs: 2011 NAIP
2) Groups of graphs / wells are organized left to right, looking downstream

Date: 9/5/2013 Name: F31 - Stocker Creek_Alluvium_TDS

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 31
TDS Time Series Graphs
Stocker Creek - Alluvium
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 2,500 5,000 Feet

N

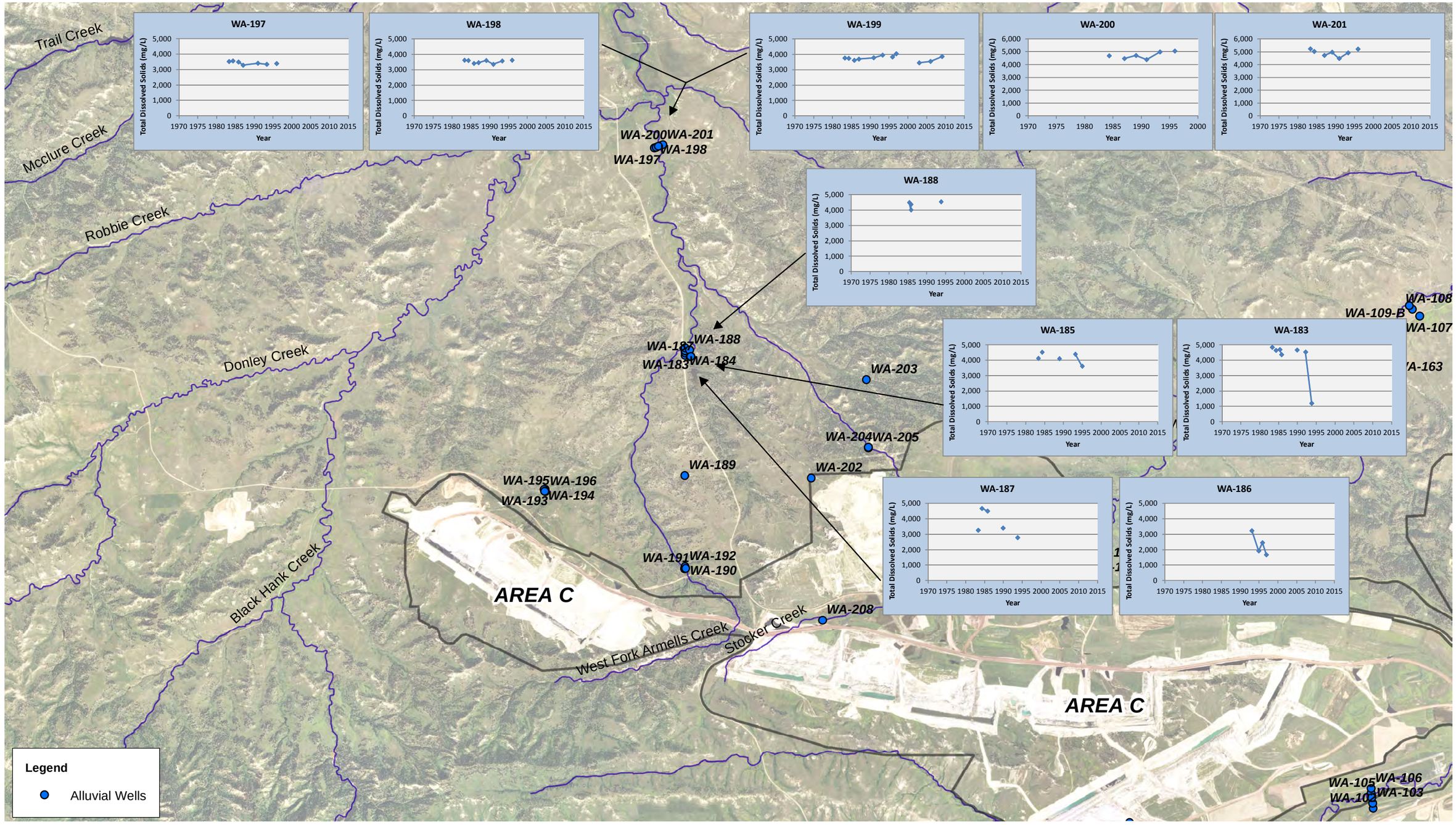
Notes:
1) Aerial Photographs: 2011 NAIP
2) Groups of graphs / wells are organized left to right, looking downstream

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Date: 9/5/2013 Name: F32A - WFAC_Upstream_Alluvium_TDS

Figure 32A
TDS Time Series Graphs
West Fork Armells Creek
Upstream - Alluvium
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

Feet
0 2,500 5,000

Date: 9/5/2013 Name: F32B - WFAC_Downstream_Alluvium_TDS

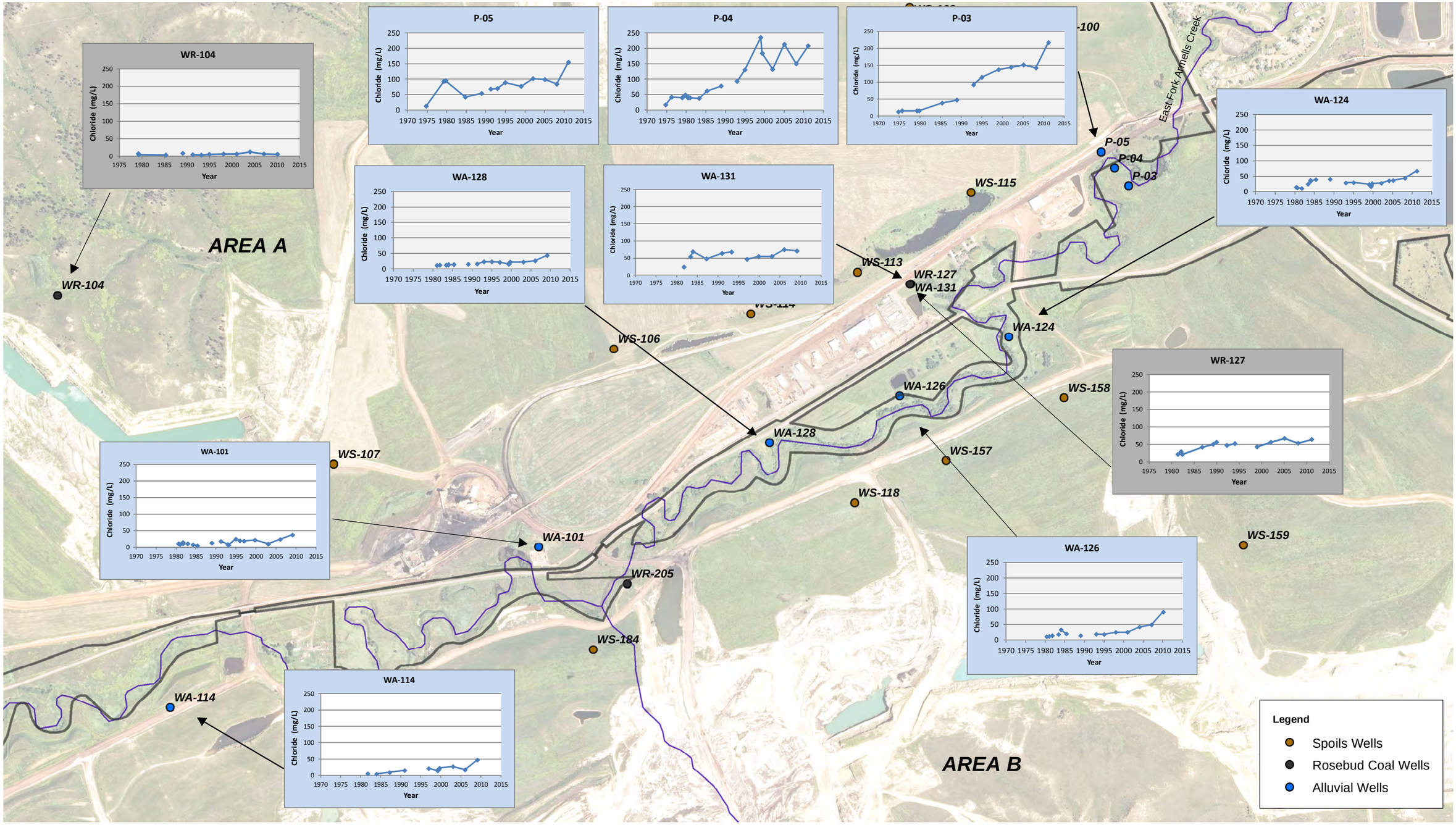
N

Notes:
1) Aerial Photographs: 2011 NAIP
2) Groups of graphs / wells are organized left to right, looking downstream

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 32B
TDS Time Series Graphs
West Fork Armells Creek
Downstream - Alluvium
Areas ABC PHC

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 500 1,000 Feet

N

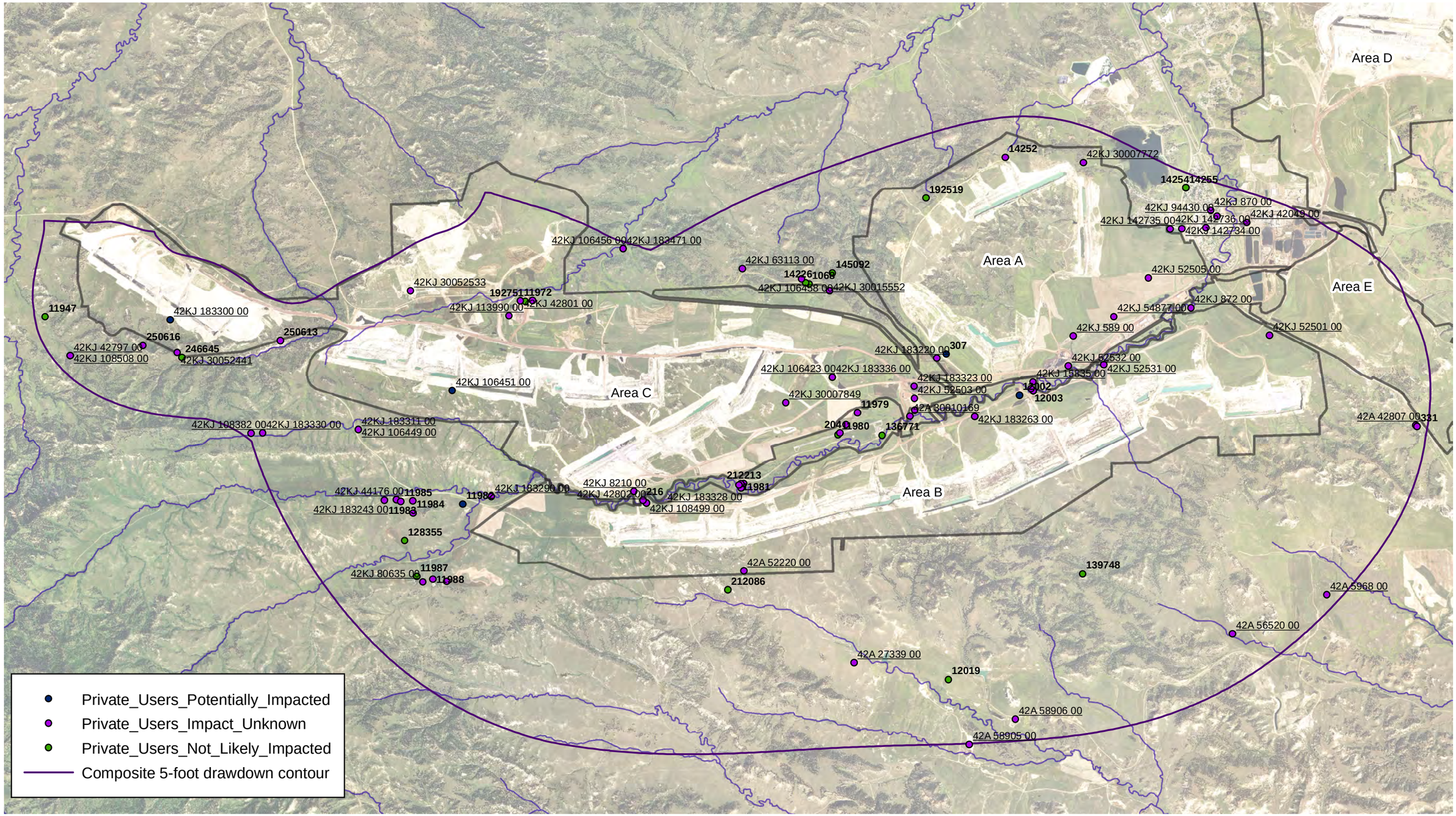
Notes:
1) Aerial Photographs: 2011 NAIP
2) Only time series for wells with more than 2 data points are shown.

Date: 9/5/2013 Name: F33_chloride time series

Western Energy Company
PO Box 99, Colstrip MT 59323
(406) 748-5100

Figure 33
Chloride Time Series Graphs
Alluvium Between Area A and B and Area A Rosebud Coal
Western Energy Rosebud Mine

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Date: 9/26/2013 Name: F34 - Private Users

Notes:
1) Aerial Photographs: 2011 NAIP
2) GWIC ID (bold) or WR number (underlined) shown.
3) Composite contour created from Rosebud and McKay coal and subMcKay maximum extent 5-foot drawdown contours at end of mining (2026).

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 34
Private Users
Areas ABC PHC

Exhibit 8

Attachments

Area B – AM4 (Application Amendment 00184)
Comprehensive Evaluation of Probable Hydrologic Consequences
Areas A, B and C
Western Energy Rosebud Mine

Exhibit 8

Attachment A
Climate Data

Area B – AM4 (Application Amendment 00184)
Comprehensive Evaluation of Probable Hydrologic Consequences
Areas A, B and C
Western Energy Rosebud Mine

Exhibit 8

Attachment A-1
Monthly Precipation (Last 30 Years)
Colstrip Weather Station

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1981	0.36	0.28	0.72		6.22	3.69	1.49	0.83	0.68	1.78	0.36	0.80	17.33
1982		0.20	1.83	1.37	1.64	2.67	0.93	1.25	1.95	1.29	0.41	0.58	15.69
1983	0.35	0.11	0.23	0.01	1.63	2.09	1.66	1.33	1.37	0.98	0.91	0.17	10.84
1984	0.16	0.14	0.62		1.71	3.67	0.25	0.74	0.98	0.39	0.59		11.06
1985	0.16	0.18	1.51	0.37	0.69	2.56	1.80	1.33	1.83	0.63	0.68	0.29	12.03
1986	0.28	0.54	0.74	1.67	3.47	0.91	0.48	1.31	3.52	0.55	0.59	0.07	14.13
1987	0.08	0.24	1.96	0.23	3.09	1.90	2.53	2.81	0.74	0.04	0.63	0.05	14.30
1988	0.04	0.60	0.35	0.77	1.17	1.30	0.12	0.41	1.78	0.86	0.35	0.33	8.08
1989	0.66	0.19	1.76	1.76	2.28	2.79	1.60	0.76	0.65	0.62	0.85	0.79	14.71
1990	0.38	0.06	0.43	1.10	2.79	2.58	1.11	0.90	0.22	0.86	0.30	0.40	11.13
1991	0.66	0.28	0.32	3.46	2.99	2.17	0.34	0.21	3.05	0.72	1.04	0.03	15.27
1992	0.03	0.04	0.86	1.87	1.77	2.87	2.03	1.28	0.89	0.75	1.05		14.08
1993		0.24	0.76	0.84	0.80	4.19	5.43	0.73	0.24	1.42	0.38	0.55	15.88
1994	1.09	0.72	0.87	1.11			0.63	0.24	1.77	3.19	1.05		15.02
1995	0.31	0.51	1.64	1.83		3.06	1.42	0.30	0.47	0.76	0.50	0.18	14.62
1996	1.24		1.43	0.66	4.10	1.23	0.89	0.05	1.15	1.28	0.90	1.21	14.34
1997	0.75	0.37	0.43	1.81	3.70			0.46	0.35	1.26	0.59	0.60	14.12
1998	0.42	0.42	1.52	0.66	0.41	2.84	1.19	2.10	1.72	2.25	1.40	0.40	15.33
1999		0.55	0.45	2.92	1.61	2.02	0.63	2.08	0.89	0.42	1.12		13.91
2000	0.23	0.83	0.73	1.80	2.40	2.98	1.23	0.27	1.77	0.57	1.01	0.28	14.10
2001	0.32	0.68	0.99	1.45	0.25	4.50	2.13	0.18	0.41	0.43	0.61	0.01	11.96
2002	0.45	0.59	0.74	1.93	1.61	1.91	3.03	1.75	2.10	0.81	0.06	0.22	15.20
2003	1.22	1.51	2.78	0.88		2.88	0.20	0.27	0.47	1.57	0.67	1.15	16.71
2004	0.27	0.74	0.22	0.43	0.91	1.75	1.11	0.54	2.05	1.59	0.03	0.12	9.76
2005	0.29	0.32	0.98	3.61	5.65	4.57	0.92	0.75	0.52	3.42	1.40	1.01	23.44
2006	0.11	0.64	1.23	2.68	1.15	0.28	0.87	0.25	2.58	1.25	0.26	0.18	11.48
2007			1.88	2.41	6.94	3.35	0.22	0.41	0.97	0.85	0.22	0.45	19.15
2008	0.89	0.45	0.55		6.84		1.05	1.19	1.62	2.71	0.94		19.96
2009	0.61	0.46	1.00	1.67	1.14	1.08	1.06	2.34	0.26	3.23	0.07		13.45
2010		0.33	0.08	2.35	4.67	2.39	2.73	1.61	1.11	0.55	1.35	0.45	18.07
2011	1.31	0.85	0.70	2.36	10.00	3.12	2.32	0.51	0.17	1.45	0.58	0.55	23.92
Average	0.52	0.44	1.04	1.46	2.6	2.54	1.41	0.96	1.28	1.24	0.68	0.46	14.63

Precipitation Data from Western Regional Climate Center, wrcc@dri.edu
Blanks indicate incomplete data
Annual and average data by WRCC

Attachment A-2
Departure from Average Calculations
Western Energy Rosebud Mine PHC

Colstrip MT Station total annual precipitation (inches)
Average annual precipitation (inches): 14.68

YEAR(S)	Precipitation (inches)	Departure from Average (inches)
1927	18.81	4.13
1928	11.98	-2.70
1929	10.76	-3.92
1930	12.03	-2.65
1931	11.31	-3.37
1932	20.37	5.69
1933	18.22	3.54
1934	8.55	-6.13
1935	15.7	1.02
1936	10.29	-4.39
1937	11.99	-2.69
1938	12.34	-2.34
1939	14.29	-0.39
1940	19.66	4.98
1941	17.73	3.05
1942	18.29	3.61
1943	16.95	2.27
1944	19.84	5.16
1945	13.8	-0.88
1946	20.92	6.24
1947	11.29	-3.39
1948	5.48	-9.20
1949	12.52	-2.16
1950	14.55	-0.13
1951	14.78	0.10
1952	10.1	-4.58
1953	19.34	4.66
1954	11.31	-3.37
1955	17.51	2.83
1956	13.57	-1.11
1957	18.4	3.72
1958	17.02	2.34
1959	10.45	-4.23
1960	10.37	-4.31
1961	14.72	0.04
1962	15.29	0.61
1963	17.84	3.16
1964	18.47	3.79
1965	14.34	-0.34
1966	12.99	-1.69
1967	17.19	2.51
1968	19.84	5.16
1969	17.6	2.92
1970	15.57	0.89
1971	19.19	4.51
1972	16.56	1.88
1973	2.67	-12.01

Attachment A-2
Departure from Average Calculations
Western Energy Rosebud Mine PHC

Colstrip MT Station total annual precipitation (inches)
Average annual precipitation (inches): 14.68

YEAR(S)	Precipitation (inches)	Departure from Average (inches)
1974	16.68	2.00
1975	no data	
1976	12.24	-2.44
1977	16.07	1.39
1978	22.12	7.44
1979	5.84	-8.84
1980	8.74	-5.94
1981	17.21	2.53
1982	15.69	1.01
1983	10.84	-3.84
1984	11.06	-3.62
1985	12.03	-2.65
1986	14.13	-0.55
1987	14.3	-0.38
1988	8.08	-6.60
1989	14.71	0.03
1990	11.13	-3.55
1991	15.27	0.59
1992	14.08	-0.60
1993	15.88	1.20
1994	15.02	0.34
1995	14.62	-0.06
1996	14.34	-0.34
1997	14.12	-0.56
1998	15.33	0.65
1999	13.91	-0.77
2000	14.1	-0.58
2001	11.96	-2.72
2002	15.2	0.52
2003	16.71	2.03
2004	9.76	-4.92
2005	23.44	8.76
2006	11.48	-3.20
2007	19.15	4.47
2008	19.96	5.28
2009	13.45	-1.23
2010	18.07	3.39
2011	23.92	9.24

Exhibit 8

Attachment B
10-Year, 24 Hour (1Q10) Peak Flows

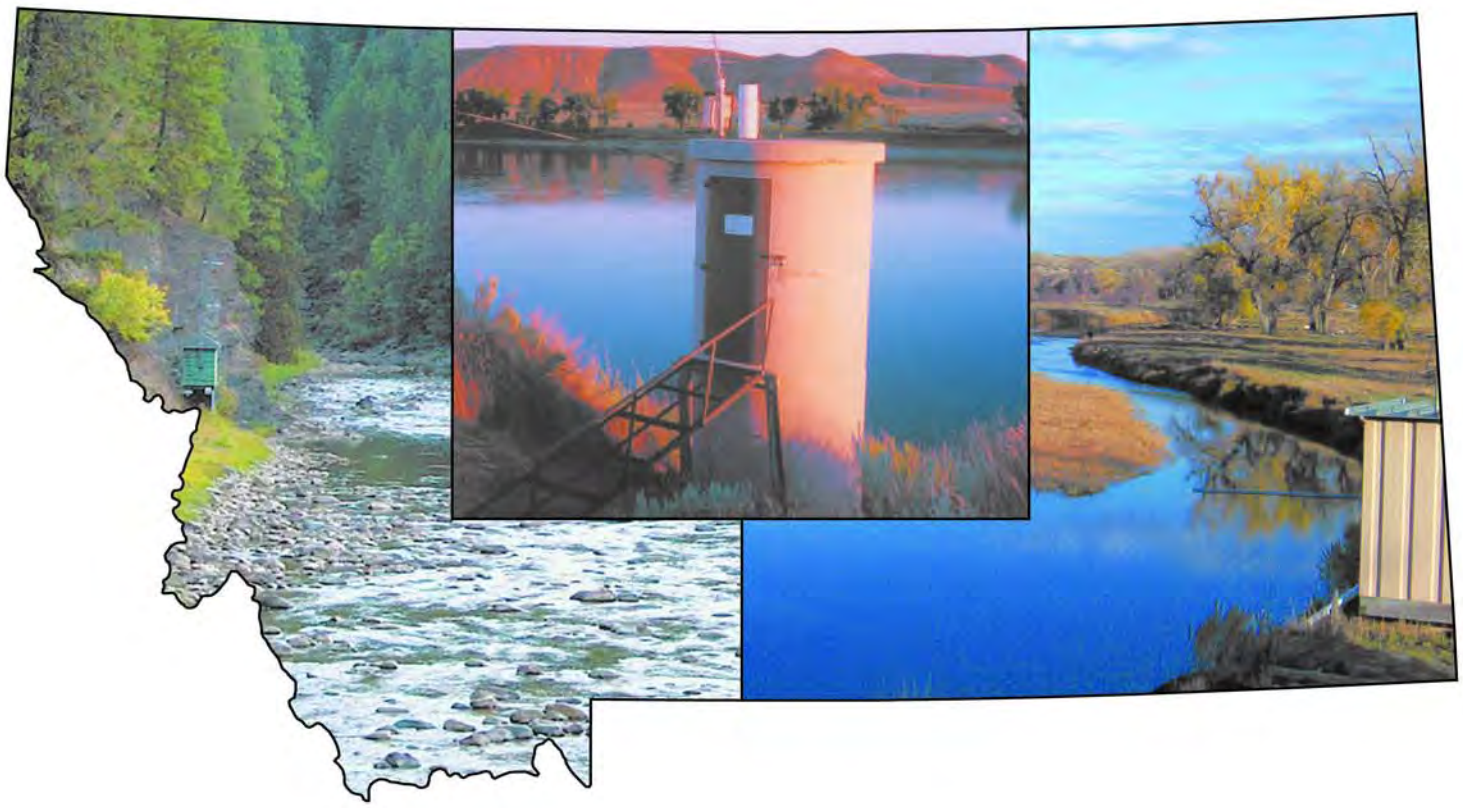
Area B – AM4 (Application Amendment 00184)
Comprehensive Evaluation of Probable Hydrologic Consequences
Areas A, B and C
Western Energy Rosebud Mine

Exhibit 8

USGS
science for a changing world

In cooperation with the
Montana Department of Environmental Quality,
Confederated Salish and Kootenai Tribes, and
Bureau of Land Management

Statistical Summaries of Streamflow in Montana and Adjacent Areas, Water Years 1900 through 2002



Scientific Investigations Report 2004-5266

U.S. Department of the Interior
U.S. Geological Survey

Exhibit 8

Statistical Summaries of Streamflow in Montana and Adjacent Areas, Water Years 1900 through 2002

By Peter M. McCarthy

In cooperation with the

Montana Department of Environmental Quality,
Confederated Salish and Kootenai Tribes, and
Bureau of Land Management

Scientific Investigations Report 2004-5266

U.S. Department of the Interior
U.S. Geological Survey

Exhibit 8

06295000 Yellowstone River at Forsyth, Mont.
Site Number 182

LOCATION.--Lat 46°15'58", long 106°41'24" (NAD 27), in NE¼NW¼NW¼ sec.23, T.6 N., R.40 E., Rosebud County, Hydrologic Unit 10100001, on right bank 0.3 mi downstream from U.S. Highway 12 bridge, at Forsyth, and at river mile 238.2.

DRAINAGE AREA.--40,146 mi^2.

PERIOD OF RECORD.--July 16, 1921, to September 30, 1923 (no winter records), October 1977 to current year (2002). Miscellaneous discharge measurements were made in 1974 to 1976 and are available in files of U.S. Geological Survey Montana District Office.

GAGE.--Water-stage recorder. Altitude of gage is 2,504.62 ft (NGVD 29), from nearby elevation determined by City of Forsyth. July 1921 to March 1922, nonrecording gage on discontinued highway bridge 10 ft downstream from gage at different datum. March 1922 to September 1923, nonrecording gage on discontinued highway bridge 10 ft downstream from gage at datum 2 ft higher.

REMARKS.--Diversions for irrigation of about 838,000 acres upstream from station. Flow regulated to some extent by Bighorn Lake, usable capacity, 1,312,000 acre-ft, on Bighorn River. Small diversion dam about 4,200 ft downstream from station. Bureau of Reclamation satellite telemeter at station.

Magnitude and probability of annual low flow
based on 24 years of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and non-exceedance probability, in percent					
	2	5	10	20	50	100
	50%	20%	10%	5%	2%	1%
1	3,230	2,320	1,920	1,640	--	--
3	3,460	2,520	2,100	1,800	--	--
7	3,880	2,970	2,560	2,260	--	--
14	4,630	3,620	3,090	2,670	--	--
30	5,150	4,100	3,520	3,050	--	--
60	5,460	4,400	3,820	3,340	--	--
90	5,890	4,780	4,170	3,670	--	--
120	6,200	5,040	4,420	3,910	--	--
183	6,610	5,240	4,530	3,980	--	--

Magnitude and probability of seasonal low flow from
March-June based on 25 seasons of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and non-exceedance probability, in percent					
	2	5	10	20	50	100
	50%	20%	10%	5%	2%	1%
1	5,200	3,600	2,830	2,250	1,690	--
3	5,320	3,760	3,000	2,440	1,880	--
7	5,460	4,060	3,400	2,900	2,390	--
14	5,900	4,610	4,030	3,590	3,150	--
30	6,260	4,850	4,240	3,790	3,340	--

Magnitude and probability of seasonal low flow from
November-February based on 25 seasons of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and non-exceedance probability, in percent					
	2	5	10	20	50	100
	50%	20%	10%	5%	2%	1%
1	3,350	2,360	1,930	1,650	1,320	--
3	3,630	2,600	2,140	1,820	1,450	--
7	4,080	3,200	2,790	2,480	2,160	--
14	4,650	3,760	3,330	2,990	2,630	--
30	5,250	4,410	3,970	3,610	3,230	--

Duration of daily mean flows based on 25 years of record

Discharge, in ft^3/s, which was equaled or exceeded for indicated percent of time							
99%	98%	95%	90%	80%	70%	60%	50%
2,560	3,110	3,660	4,420	5,190	5,970	6,780	7,610
40%	30%	20%	15%	10%	5%	2%	1%
8,440	10,300	13,500	16,700	23,200	32,000	43,200	48,800

Magnitude and probability of annual high flow
based on 25 years of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and exceedance probability, in percent					
	2	5	10	25	50	100
	50%	20%	10%	4%	2%	1%
1	41,500	57,300	69,100	85,500	99,000	--
3	39,600	54,000	64,000	77,200	87,400	--
7	36,100	49,500	58,900	71,400	81,300	--
15	33,300	45,500	53,900	65,000	73,600	--
30	30,000	40,500	47,500	56,400	63,100	--
60	25,300	33,800	39,300	46,100	51,100	--
90	21,100	28,000	32,300	37,600	41,500	--

Magnitude and probability of seasonal low flow from
July-October based on 24 seasons of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and non-exceedance probability, in percent					
	2	5	10	20	50	100
	50%	20%	10%	5%	2%	1%
1	5,520	4,030	3,300	2,740	--	--
3	5,630	4,080	3,330	2,760	--	--
7	5,790	4,180	3,410	2,830	--	--
14	5,970	4,280	3,480	2,880	--	--
30	6,230	4,450	3,650	3,060	--	--

Monthly and annual mean discharges

Month	Maximum (ft^3/s)	Minimum (ft^3/s)	Mean (ft^3/s)	Standard deviation (ft^3/s)	Years of record
October	10,700	3,520	7,490	2,120	25
November	10,500	4,190	6,990	1,700	25
December	8,930	3,620	6,110	1,190	25
January	7,800	3,240	5,720	1,120	25
February	10,200	3,510	6,140	1,590	25
March	15,100	3,220	7,060	2,530	25
April	13,300	4,220	7,720	2,340	25
May	27,800	10,000	17,300	4,270	25
June	63,700	10,000	29,800	12,000	25
July	34,400	6,140	18,300	8,680	25
August	17,600	2,740	8,150	3,590	25
September	11,300	2,720	6,960	2,370	25
Annual	17,600	6,030	10,600	2,630	25

Exhibit 8

06296003 Rosebud Creek at mouth, near Rosebud, Mont.
Site Number 185

LOCATION.--Lat 46°15'53", long 106°28'30" (NAD 27), in SW¼NW¼NE¼ sec.21, T.6 N., R.42 E., Rosebud County, Hydrologic Unit 10100003, on left bank 0.4 mi upstream from bridge on Interstate Highway 94, 0.8 mi upstream from mouth, and 1.6 mi southwest of Rosebud.
DRAINAGE AREA.--1,302 mi^2.
PERIOD OF RECORD.--October 1974 to current year (2002).
GAGE.--Water-stage recorder. Altitude of gage is 2,480 ft (NGVD 29).
REMARKS.--Diversions for irrigation of about 2,000 acres upstream from station.

Magnitude and probability of annual low flow based on 27 years of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and non-exceedance probability, in percent					
	2	5	10	20	50	100
	50%	20%	10%	5%	2%	1%
1	0.18	0.00	0.00	0.00	0.00	--
3	.20	.00	.00	.00	.00	--
7	.25	.01	.00	.00	.00	--
14	.29	.01	.00	.00	.00	--
30	.42	.01	.00	.00	.00	--
60	.69	.06	.01	.00	.00	--
90	1.5	.15	.04	.01	.00	--
120	2.3	.37	.12	.05	.01	--
183	4.0	.75	.26	.10	.03	--

Magnitude and probability of seasonal low flow from March-June based on 28 seasons of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and non-exceedance probability, in percent					
	2	5	10	20	50	100
	50%	20%	10%	5%	2%	1%
1	2.0	0.30	0.07	0.00	0.00	--
3	2.6	.38	.08	.00	.00	--
7	3.6	.54	.18	.07	.02	--
14	6.0	.93	.31	.11	.03	--
30	10	1.7	.60	.22	.07	--

Magnitude and probability of seasonal low flow from November-February based on 27 seasons of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and non-exceedance probability, in percent					
	2	5	10	20	50	100
	50%	20%	10%	5%	2%	1%
1	1.7	0.14	0.00	0.00	0.00	--
3	2.1	.15	.01	.00	.00	--
7	2.2	.22	.04	.00	.00	--
14	2.6	.27	.05	.00	.00	--
30	3.8	.50	.13	.04	.01	--

Duration of daily mean flows based on 28 years of record

Discharge, in ft^3/s, which was equaled or exceeded for indicated percent of time							
99%	98%	95%	90%	80%	70%	60%	50%
0.04	0.08	0.20	0.41	0.81	2.0	4.5	8.0
40%	30%	20%	15%	10%	5%	2%	1%
14	23	36	45	63	115	213	319

Magnitude and probability of annual high flow based on 28 years of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and exceedance probability, in percent					
	2	5	10	25	50	100
	50%	20%	10%	4%	2%	1%
1	216	580	1,020	1,930	2,980	--
3	161	455	818	1,580	2,480	--
7	115	322	579	1,120	1,760	--
15	88	237	409	746	1,110	--
30	70	178	286	472	649	--
60	54	131	200	307	400	--
90	46	109	165	251	324	--

Magnitude and probability of seasonal low flow from July-October based on 27 seasons of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and non-exceedance probability, in percent					
	2	5	10	20	50	100
	50%	20%	10%	5%	2%	1%
1	0.18	0.00	0.00	0.00	0.00	--
3	.22	.00	.00	.00	.00	--
7	.31	.01	.00	.00	.00	--
14	.35	.02	.00	.00	.00	--
30	.47	.03	.00	.00	.00	--

Monthly and annual mean discharges

Month	Maximum (ft^3/s)	Minimum (ft^3/s)	Mean (ft^3/s)	Standard deviation (ft^3/s)	Years of record
October	46	0.00	8.4	11	28
November	48	.01	9.4	12	28
December	48	.03	10	12	28
January	159	.03	19	31	28
February	187	.07	38	51	28
March	428	.04	72	93	28
April	180	5.0	44	42	28
May	478	.39	61	104	28
June	286	.48	41	62	28
July	133	.00	18	33	28
August	48	.00	8.2	12	28
September	77	.00	8.6	19	28
Annual	112	1.0	28	29	28

Exhibit 8

06294995 Armells Creek near Forsyth, Mont.
Site Number 181

LOCATION.--Lat 46°14'59", long 106°48'22" (NAD 27), in SE¼NW¼NE¼ sec.26, T.6 N., R.39 E., Rosebud County, Hydrologic Unit 10100001, on right bank 300 ft upstream from bridge on Interstate Highway 94, 2.2 mi upstream from mouth, and 6 mi southwest of Forsyth.
DRAINAGE AREA.--370 mi^2.
PERIOD OF RECORD.--July 1974 to September 1984, October 1987 to September 1995 (discontinued).
GAGE.-- Water-stage recorder. Altitude of gage is 2,557.11 ft (NGVD 29).
REMARKS.--Diversions for irrigation of about 200 acres upstream from station.

Magnitude and probability of annual low flow based on 17 years of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and non-exceedance probability, in percent					
	2	5	10	20	50	100
	50%	20%	10%	5%	2%	1%
1	0.00	0.00	0.00	0.00	--	--
3	.00	.00	.00	.00	--	--
7	.00	.00	.00	.00	--	--
14	.00	.00	.00	.00	--	--
30	.01	.00	.00	.00	--	--
60	.05	.01	.00	.00	--	--
90	.09	.02	.01	.01	--	--
120	.13	.03	.01	.01	--	--
183	.38	.08	.04	.02	--	--

Magnitude and probability of seasonal low flow from March-June based on 18 seasons of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and non-exceedance probability, in percent					
	2	5	10	20	50	100
	50%	20%	10%	5%	2%	1%
1	0.11	0.01	0.00	0.00	--	--
3	.17	.02	.00	.00	--	--
7	.40	.09	.04	.02	--	--
14	.77	.17	.06	.03	--	--
30	1.2	.33	.15	.07	--	--

Magnitude and probability of seasonal low flow from November-February based on 18 seasons of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and non-exceedance probability, in percent					
	2	5	10	20	50	100
	50%	20%	10%	5%	2%	1%
1	0.02	0.00	0.00	0.00	--	--
3	.03	.00	.00	.00	--	--
7	.04	.00	.00	.00	--	--
14	.06	.00	.00	.00	--	--
30	.08	.01	.00	.00	--	--

Duration of daily mean flows based on 18 years of record

Discharge, in ft^3/s, which was equaled or exceeded for indicated percent of time							
99%	98%	95%	90%	80%	70%	60%	50%
0.02	0.03	0.08	0.17	0.34	0.51	0.68	0.85
40%	30%	20%	15%	10%	5%	2%	1%
1.1	1.9	3.3	4.7	7.5	16	44	91

Magnitude and probability of annual high flow based on 18 years of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and exceedance probability, in percent					
	2	5	10	25	50	100
	50%	20%	10%	4%	2%	1%
1	87	439	981	2,250	--	--
3	62	291	627	1,380	--	--
7	41	175	363	772	--	--
15	26	101	197	394	--	--
30	17	58	105	196	--	--
60	12	36	63	111	--	--
90	9.0	27	48	84	--	--

Magnitude and probability of seasonal low flow from July-October based on 18 seasons of record

Period of consecutive days	Discharge, in ft^3/s, for indicated recurrence interval, in years, and non-exceedance probability, in percent					
	2	5	10	20	50	100
	50%	20%	10%	5%	2%	1%
1	0.00	0.00	0.00	0.00	--	--
3	.00	.00	.00	.00	--	--
7	.01	.00	.00	.00	--	--
14	.02	.00	.00	.00	--	--
30	.05	.01	.00	.00	--	--

Monthly and annual mean discharges

Month	Maximum (ft^3/s)	Minimum (ft^3/s)	Mean (ft^3/s)	Standard deviation (ft^3/s)	Years of record
October	4.4	0.02	0.81	1.3	18
November	2.4	.00	.65	.77	18
December	2.6	.01	.53	.77	18
January	48	.00	4.3	11	18
February	52	.00	7.0	15	18
March	175	.04	27	49	18
April	25	.29	6.1	6.9	18
May	58	.27	9.6	16	18
June	23	.12	6.0	6.7	18
July	37	.01	2.9	8.4	19
August	5.7	.02	.98	1.5	19
September	26	.01	2.3	5.9	19
Annual	17	.38	5.8	6.0	18

Exhibit 8

Attachment C
Water Quality Criteria For Livestock

Area B – AM4 (Application Amendment 00184)
Comprehensive Evaluation of Probable Hydrologic Consequences
Areas A, B and C
Western Energy Rosebud Mine

Exhibit 8

Attachment C
Water Quality Criteria for Livestock

Constituent or Parameter	Units	Standard 1	Standard 2
Alkalinity	mg/L	-	1000
Aluminum	mg/L	5	-
Arsenic	mg/L	0.2	0.2
Boron	mg/L	5	-
Cadmium	mg/L	0.05	0.05
Chloride	mg/L	2000	-
Chromium	mg/L	0.05	1
Cobalt	mg/L	1.0	1
Copper	mg/L	0.5	0.5
Fluoride	mg/L	-	2
Lead	mg/L	0.1	0.1
Mercury	mg/L	0.00005	0.01
Nickel	mg/L	-	1
Nitrite	mg/L	10	10
Nitrate+Nitrite	mg/L	100	100
Oil and Grease	mg/L	10	-
Selenium	mg/L	0.05	-
Sulfate	mg/L	3000	2500
Total Dissolved Solids	mg/L	5000	-
Uranium	mg/L	5	-
Vanadium	mg/L	0.1	0.1
Zinc	mg/L	25	25
pH	s.u.	6.5-8.5	-
228	pCi/L	5	-
Total Strontium	pCi/L	8	-
Gross alpha particle radioactivity including Radium 226 but excluding Radon and Uranium	pCi/L	15	-

Source

Standard 1

Criteria from Montana Supplements to the National Engineering Manual, MT543.00(e)(5)(iii)
A copy can be found on the NRCS website:
http://www.mt.nrcs.usda.gov/technical/eng/suppNEM.html#part543

Standard 2

Criteria from Suitability of Water for Livestock Fact Sheet (Sigler and Bauder, 2012)
http://waterquality.montana.edu/docs/WELL_EDUCATED/fact_sheets/Livestock_Suitability.pdf

Attachment D
Rosebud Mine Groundwater Model Report

Area B – AM4 (Application Amendment 00184)
Comprehensive Evaluation of Probable Hydrologic Consequences
Areas A, B and C
Western Energy Rosebud Mine

Exhibit 8

Attachment D
Rosebud Mine
Groundwater Model

Western Energy Company

Prepared for

WESTERN ENERGY COMPANY – *Rosebud Mine*
A Subsidiary of WESTMORELAND COAL COMPANY
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September 2013

Exhibit 8

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Rosebud Mine Groundwater Model
Western Energy Company

1.0 INTRODUCTION

1.1 Background

Western Energy Company - Rosebud Mine (WECo) has requested that Nicklin Earth & Water, Inc. (NE&W) conduct a hydrologic/hydrogeologic evaluation and then perform a groundwater modeling effort focusing on projected responses to mining associated with existing permits. Note that the Rosebud Mine Groundwater Model (GM) encompasses mining efforts specifically to permitted mining for Areas A, B, and C. Data from other areas are included in the baseline model, including data from Area E, additional monitoring sites outside the permit areas, and data collected at the Big Sky Mine.

1.2 Groundwater Modeling Objectives

The following are the modeling objectives:

- Objective 1: To summarize the conceptual understanding of the hydrogeologic regime at the Rosebud Mine for purposes of constructing a groundwater model focusing on existing permits.

- Objective 2: To develop a calibrated model with reliable predictive capability.

- Objective 3: To predict temporal and long-term hydraulic/hydrologic responses associated with existing and proposed permits.

Objective 1 is achieved through the baseline studies of the mine area hydrology, and the existing Probable Hydrologic Consequences (PHC) assessment. A combination of

these efforts provides substantial information for formation of a numeric simulation model which can be used to emulate the existing system responses to date, and then used to predict future system responses to mining activity. The last two objectives are achieved via the modeling effort described herein.

1.3 Modeling Approach

The groundwater modeling (modeling) effort includes the following:

- Element 1 - Development of the conceptual groundwater model.
- Element 2 - Definition of model structure and model calibration.
- Element 3 - Utilization of the calibrated model to evaluate hydraulic responses related to mining at the Rosebud Mine.

The following activities were performed:

- Developed model structure including model domain extent, steady-state model boundary conditions, and steady-state model stresses.
- Conducted steady-state model calibration.
- Completed steady-state sensitivity analysis.
- Ran transient simulations through the period of record to test the reliability of the steady-state calibration effort. A focus was placed on evaluating storativity.
- Conducted the following applications:
  - Simulated groundwater level changes over time.
  - Simulated water budget changes associated with mining.

1.4 Overview of Conceptual Model

1.4.1 Project Location

A map of the Rosebud Mine and the surrounding area is given in Figure GM-1**.**

1.4.2 Climate

The climate of eastern Montana is classified as semiarid continental and is characterized by hot moderately dry summers, cool dry falls, cold dry winters and cool moist springs typical of southeastern Montana. Winter cold spells are often interrupted by periods of warmer weather. The passage of mid-latitude storm systems is typical of the climate of this area; day-to-day weather changes can be extreme because of the migrating systems.

At the mine, precipitation occurs predominantly as snow from about November to April. About one-third of the total annual precipitation is in the form of snow. Due to the prevailing westerly wind, the snow typically accumulates on the leeward slopes of drainages. The average annual precipitation at Colstrip is 15.17 inches.

The average maximum and average minimum daily temperatures as measured at Colstrip are 88.1^{o} F in July and 9.6^{o} F in January respectively. The maximum and minimum temperatures ever recorded at Colstrip are 111° F (August 6, 1961) and -50° F (February 15, 1936).

1.4.3 Geology

General Stratigraphy

The Rosebud Mine lies entirely within the outcrop of the Fort Union Formation (Paleocene Age). Consolidated sedimentary rocks ranging in age from Cambrian to Cretaceous underlie the Fort Union Formation.

The Fort Union Formation is subdivided into three primary members that are designated as follows (see Figure GM-2):

- Tongue River Member;
- Lebo Member (or Lebo Shale); and

- Tullock Member.

The primary coal-bearing formation of the Fort Union is the Tongue River Member. Figure GM-3 provides a geologic outcrop map of the region surrounding the Rosebud Mine.

Tongue River Member

The Tongue River Member is the upper-most consolidated rock unit found in the immediate vicinity of the Rosebud Mine. The Tongue River Member can be as thick as 540 feet. This member outcrops throughout the Colstrip vicinity, except, where covered by alluvium or colluvium.

The Tongue River Member consists of fine-grained sandstone with thinner inter-beds of yellowish brown, orange, or tan siltstone; light-colored to dark-colored mudstone and clay; and coal beds. The sandstone tends to be massive or cross-bedded. Given that the Tongue River Member was deposited in a fluvial environment, it typically exhibits rapid vertical and lateral transitions in lithology. Although sandstone units occur, they are rarely laterally continuous, but more likely exist as isolated lenses. The coal beds tend to be much more laterally continuous than other lithologic units found in the Tongue River Member. In some instances, these coals burned near outcrops or in areas where the coal was present at relatively shallow depths. Any immediately overlying sandstones, mudstones, shale, and/or claystone were baked forming clinker. Note that local residents often apply the name “scoria” to this clinker. The clinker tends to be very resistant to erosion and it often leads to ridges forming where it is present.

Immediately underlying most of these coal beds is “under-clay” which is referred to in some portions of the country as “fire clay.” This under-clay tends to possess extremely low permeability. There are multiple coal beds in the Tongue River Member ranging from less than one foot to relatively greater thicknesses, such as the Rosebud coal. Given that these under-clays typically appear in concert with the coal seams, they are

also relatively more laterally extensive than other lithologic units present in the Tongue River Member. These under-clays and mudstones have significant implications as they substantially impede the vertical flow of groundwater. This impedance leads to the substantial vertical hydraulic gradients, and the significant potentiometric head separation, observed moving downward through the Tongue River stratigraphic sequence.

The specific consolidated hydrogeologic units within the Tongue River Member considered in the modeling effort are condensed to the following:

- Overburden (consists of multiple stratigraphic units and may contain clinker associated with shallower burned coal beds);
- Rosebud coal (often directly in contact with clinker);
- Interburden (Tongue River between Rosebud coal and McKay coal; and consists of multiple stratigraphic units);
- McKay coal
- Sub-McKay (Tongue River below McKay coal and consists of multiple stratigraphic units), which is in some instances referred to as sub-McKay sands.

In some portions of the coal beds, partings are present so that even individual coal beds could be considered multi-layered.

Lebo Member

The Lebo Member (Lebo shale) is the middle unit of the Fort Union sequence. This member is dominated by gray, smectitic shale and mudstone containing lenses of gray and yellow, very fine- to medium-grained sandstone, ironstone concretion zones from 1 to 12 inches thick, and a few thin coal beds (Vuke, et al, 2001). The thickness of the Lebo shale ranges from 95 to 200 feet in the region of the Rosebud mine. The Lebo shale is a confining unit in the area of the Rosebud Mine. It acts to retard groundwater flow much more significantly than does either the Tongue River or the Tullock members

of the Fort Union. The Lebo shale does not produce water except in relatively rare circumstances where localized sandstones exist. This Lebo shale outcrops/sub-crops north, east and west of the Rosebud Mine as seen in Figure GM-3.

Tullock Member

The Tullock Member of the Fort Union is the lowermost unit and is a light-yellow to light-brown, planar-bedded, fine-grained to medium-grained sandstone containing minor amounts of gray shale. Its thickness is about 240 to 260 feet. Sandstones of this member commonly provide water to wells at sufficient rates for domestic use and stock watering purposes.

Alluvium

The unconsolidated geologic deposits of main hydrologic interest in the immediate vicinity of the Rosebud Mine are of Quaternary age and consist of alluvium and colluvium. The main water-bearing unit when it is saturated is alluvium. Alluvium can vary widely in thickness, being generally less than 15 feet but it can be up to 35 feet in some areas (Vuke, et al, 2001).

1.4.4 Hydrogeologic/Hydraulic Properties

The water-bearing properties of the overburden, Rosebud coal, interburden, McKay coal, sub-McKay (underburden) and alluvium are discussed below.

Overburden

Again, the overburden above the Rosebud coal is comprised of interbedded sandstone, siltstone, mudstone, claystone, clinker, and coals. It appears in reviewing exploration logs, and then comparing those logs to observation well logs, that an alternative designation by some is to identify this mudstone as shale. Upper relatively shallower and elevated portions of the overburden above the Rosebud coal are more likely to be

unsaturated, except, in instances where perched groundwater is present. The perching is typically due to presence of mudstone (often coal under-clays) and claystone. In effect, the mudstone and claystone act to significantly retard the rate of flow through this overburden (and through the interburden and Sub-McKay as well) leading to perching of groundwater. Personal communications with Mr. Glenn Miller, geologist with Pronghorn Geologic Services (2013) indicate that the dark grey mudstones possess “extremely low permeability.” Similarly, Mr. Charlie Speake, mining engineer with WECo describes the prevalence of under-clays beneath the mine coal seams.

Again, the presence of mudstones intermixed with more permeable strata (e.g., sandstone or coal) leads to perching conditions, or otherwise, substantial impedance of vertical flow in the Tongue River strata. The significance of this issue is illustrated in Figure GM-4 and Figure GM-5. Figure GM-4 provides a conceptual cross-section of vertical flow. Figure GM-5 provides a sample calculation using principles of hydraulic conductivity as it is affected by anisotropy in multi-layered systems. Note that the effective vertical hydraulic conductivity is dominated by the magnitude of the conductivity of the low permeability units, in this instance, mudstone. Yet, the effective horizontal conductivity is dominated by the magnitude of the conductivity of the high permeability unit, in this case, the sandstones. The net effect of the multilayered systems of the Tongue River is to yield very large horizontal to vertical conductivity ratios or very low leakances. The hydraulic properties of the overburden vary widely as seen in Figure GM-6.

Clinker

Clinker deposits are red, pink, orange, black, and yellow, very resistant, thermally metamorphosed sandstone, siltstone, and shale of the Fort Union Formation. This clinker formed due to burning of the underlying coal followed by the collapse into the burned coal void space. Thicknesses of clinker range from as little as 10 feet up to 300 feet (Vuke, et al 2001). From a hydrogeologic perspective, these deposits are extremely permeable. They typically possess hydraulic conductivities several orders of

magnitude higher than other strata of the Tongue River member. Generally, the saturated thickness of clinker at the Rosebud Mine ranges from dry to a few feet in those instances when water is perched. Clinker is important from a recharge perspective. This clinker tends to be near the surface. Hence, given its very high permeability, greater recharge rates occur as well. Although this water tends to perch on low-permeability strata beneath the former coal, this perched water acts as a long-term source of seepage passing through any formation weakness, such as fractures and/or joints that are present.

An example of the relevance of clinker deposits as a recharge source occasionally occurs at the Stocker Creek flow measurement station SW-65. Stocker Creek is an ephemeral drainage, or a creek that is typically dry during normal years. Measurement station SW-65 is close to the headwaters of Stocker Creek. After a major precipitation or snowmelt event, flow may begin and then continue at this station for extended periods. For instance, a rare 10-inch precipitation event occurred in May 2011. After that event, flow was present at SW-65 until that flow ceased in early June 2012. It remained dry thereafter until late February of 2013. The best explanation for this sustained flow after the major recharge events is the presence of a substantial amount of clinker bounding Stocker Creek. Significant recharge occurred from the May 2011 event and was temporally stored in the clinker. Seepage from the clinker then sustained flow in Stocker Creek for an extended period. Hence, given that clinker is relatively abundant around the Rosebud mine, its presence is a significant source of recharge in the mine vicinity.

Some portions of eroded clinker also serve as gravel in the alluvial deposits, leading to a very permeable substrate. The alluvial clinker tends to concentrated in lower portions of the alluvium, which acts as the primary conduit for aquifer flow in the alluvial drainages.

Rosebud Coal/Interburden/McKay Coal

The Rosebud coal is the target of mining operations. This coal is typically about 26 feet thick at the Rosebud Mine. The water yielding capacity of this coal is limited, owing to the relatively low transmissivities in that coal. Transmissivity information for the Rosebud coal is provided in Figure GM-6. If this coal is sufficiently confined, it can supply water to provide limited sources of well water for both domestic and stock water users in the region. Nearer the coal outcrops, this coal is unconfined. In more southerly and up-gradient portions of the Rosebud Mine, and away from active coal mining, the Rosebud coal is semi-confined. In a few instances, where this coal outcrops, low flow springs or seeps occur (e.g., SP-35, SP-26, Spring 7). For spring locations refer to Figure GM-7.

The interburden is a convenient term used to define the stratigraphic sequence of the Tongue River Member between the Rosebud coal and the McKay coal. Its properties are similar to that of the overburden, i.e., it is a multilayered sequence. The thickness of the interburden varies substantially ranging from a few feet in some instances to well over one-hundred feet in other instances. The interburden typically possesses very low hydraulic conductivities and transmissivities (Figure GM-6).

The McKay coal underlies the interburden. In some portions of the region, this coal nearly merges with the Rosebud coal (as the interburden thins). The McKay coal is not a mining target for the Rosebud Mine. From a hydrogeologic perspective, it does not possess sufficient transmissivity to provide a reliable source of groundwater to wells. On the other hand, there is sufficient groundwater to yield low-flow springs and seeps in some instances at the outcrop/subcrop of this coal (e.g., SP-27, SP-63 and Spring 2). Figure GM-6 provides representative values of transmissivity for the McKay coal.

Alluvium

The most transmissive water-bearing alluvial deposits are present in the main drainages transecting the Rosebud Mine area, or in lower portions of the East Fork Armells Creek (E. Armells Creek) drainage (refer to Figure GM-1). The most transmissive alluvial aquifer sequence adjacent to the Rosebud Mine is likely the main stem of E. Armells Creek between Areas A and C to the North, and Areas B and B-extension to the south. The saturated thicknesses are up to as much as approximately 30 feet in this portion of E. Armells Creek (e.g., well P-05). Figure GM-6 provides a summary of the range of hydraulic properties for alluvium found at the Rosebud Mine.

Other Factors (Faults)

A potential factor affecting groundwater flow in the Rosebud Mine vicinity is the presence of faults. Several faults have been identified in the area by the MBMG and the USGS. In addition, an evaluation of exploratory logs indicates that another fault may be present at the western edge of the model domain (near Robbie Creek). Figure GM-8 identifies the existing faults and potential fault alignments.

The faults may act in different manners as they affect the local flow of groundwater. One way they may affect flow is if they truncate a given water-bearing stratum, effectively creating a local boundary to impede groundwater flow. These faults may also be associated with increased fracturing which could increase local transmissivity, flow, and/or local recharge to underlying strata. Based upon communications with mine staff, they have not observed a tendency for the Rosebud coal to be offset to the degree that the coal is truncated. Rather, the Rosebud coal beds tend to “bend” locally so that they remain connected, at least in areas that have been mined. However, given that the McKay is thinner, it is possible for this coal to be offset to the degree that it is truncated leading to a “no-flow” or “low-flow” boundary.

1.4.5 Observation Well Network and Well Hydrograph Summary

The monitoring well network for the vicinity of Rosebud Mine is subdivided into the primary formations of interest, for purposes of evaluation:

- Overburden
- Rosebud coal
- Interburden
- McKay coal
- Sub-Mckay (underburden)
- Alluvium
- Spoils

Well water level data that have been collected to date by WECo were compiled and evaluated by NE&W. Wells with sufficient data to develop hydrographs were plotted in Figures GM-9 through GM-17. All the well hydrographs are plotted at the same relative scale, except where noted, so that differences in variability can be compared. The relatively large scale for the ordinate shown on these figures makes it possible to account for the range of water level changes observed, and to provide the same relative perspective for comparing well responses to mining.

A summary of hydrograph observations is presented below.

Overburden Well Summary

Refer to Figure GM-9 (page 1), Figure GM-11 (page 1), Figure GM-12 (page 1), Figure GM-13, Figure GM-14 and Figure GM-17 (page 1) for overburden well hydrographs.

A majority of the overburden wells have been non-responsive to mining activities demonstrating that most of the overburden strata are hydraulically isolated from the underlying Rosebud coal. This observation is consistent with the conceptual model described previously. The presence of low permeability strata such as mudstones and claystones, and, under-clay associated with shallower coal seams, impedes flow downward to the Rosebud coal.

Examples of wells showing some response to nearby mining include:

- WO-101 and WO-173 (Area B-extension - Figure GM-11, page 1) – observed water level decline of about 6 to 9 feet [note that some caution is warranted here as an extended drought also could explain portions of any declines that are observed].
- WO-103 (Area C east - Figure GM-12, page 1) - observed decline of about 8 to 9 feet.
- WO-154 (Area C east - Figure GM-12, page 1) - observed decline of about 16 to 17 feet.
- WO-165 (Area C east - Figure GM-12, page 1) - observed decline of about 14 feet.

Again, some caution is warranted here in concluding that the changes in water level described above are entirely mining related. An extended drought may have been a factor for explaining portions of groundwater level declines in the overburden. With respect to declines in the overburden, it is probable that portions of the decline are directly caused by overburden removal during the mining process, and not by dewatering of the Rosebud coal. In other words, there is some question as to the degree of direct hydraulic communication between the overburden and the Rosebud coal. This is because some overburden wells may be measuring perched groundwater, rather than water connected directly/hydraulically to the Rosebud coal.

In summary, overburden wells have generally not been that responsive to mining activity with a few exceptions involving wells that are located very near active high walls. In essence, the observation data demonstrate that the radius of influence of mining activities on the overburden water levels is very limited.

Rosebud Coal Observation Well Summary

Refer to Figure GM-9 (page 1), Figure GM-10 (page 1), Figure GM-11 (page 2), Figure GM-12 (page 2), Figure GM-13, Figure GM-14 and Figure GM-17 (page 2) for a summary of Rosebud coal well hydrographs.

The response of Rosebud coal wells to mining has been variable. Some wells responded to nearby mining whereas other wells have not. Examples of wells showing response to mine dewatering include:

- WR-101 (Area B - Figure GM-10, page 1) - observed drawdown of about 58 feet.
- WR-161 (Area B - Figure GM-10, page 1) - observed drawdown of about 62 feet.
- WR-162 (Area B extension Figure GM-11, page 2) - observed drawdown of about 13 feet.
- WR-117 (Area C east - Figure GM-12, page 2) - observed drawdown of about 27 feet.

The radius of influence of mining on Rosebud coal water levels appears to be limited mainly to areas relatively near the mine pit high walls, especially during active mining.

Interburden Observation Well Summary

Interburden well hydrographs are provided on Figure GM-9 (page 2), Figure GM-10 (page 2), Figure GM-11 (page 3), Figure GM-12 (page 3), Figure GM-13 and Figure GM-14.

The response of interburden wells to mining has been variable. Some wells have responded to nearby mining whereas other wells have not. Examples of wells deemed responsive to mine dewatering include:

- WI-103 (Area B - Figure GM-10, page 2) - observed decline of about 73 feet.
- WI-157 (Area B - Figure GM-10, page 2) - observed increase in water level of about 39 feet. Well is near E. Armells Creek alluvium.
- WI-164 (Area B extension - Figure GM-11, page 3) - observed decline of about 21 feet.

In summary, a majority of interburden wells have not responded to mining activity with a few exceptions involving wells located very near the active high walls. In some instances, water levels in interburden wells have increased (e.g., WI-157). One potential factor responsible for these increases may be regional joints and faults that transect the area. Another likely factor affecting some wells is their relative proximity to E. Armells Creek alluvium.

The radius of influence of mining activity on interburden water levels is considered limited.

McKay Coal Observation Well Summary

McKay coal well hydrographs are provided Figure GM-9 (page 2), Figure GM-10 (page 3), Figure GM-11 (page 4), Figure GM-12 (page 4), Figure GM-13 and Figure GM-14 and Figure GM-17 (page 3).

The response of McKay coal wells to mining has been variable. Most wells have not responded to nearby mining. Examples of wells responding to mining include the following:

- WM-104 (Area A - Figure GM-9, page 2) - observed decline of about 20 feet.
- WM-157 (Area B - Figure GM-10, page 3) - water level increase of about 29 feet.
- WM-161 (Area B - Figure GM-10, page 3) - observed decline of about 57 feet.
- WM-164 (Area B extension - Figure GM-11, page 4) – observed decline of about 20 feet.

In summary, a majority of McKay coal wells have not responded to mining activity with the few exceptions being wells located very near the active high walls. In some instances, water levels in McKay coal wells have increased (e.g., WM-157). One potential factor responsible for these increases may be regional joints and faults that transect the area. Another factor may be the relative proximity of wells to the E. Armells Creek alluvium.

Underburden (Sub-McKay) Observation Well Summary

Sub-McKay well hydrographs are provided on Figure GM-10 (page 4), Figure GM-11 (page 5), Figure GM-12 (page 5) and Figure GM-17 (page 4).

The majority of sub-McKay wells have not responded to nearby mining activity. One possible exception is WD-100 in Area B (Figure GM-10, page 4), in which a decline in water levels of about 45 feet was observed.

Alluvial Observation Well Summary

Representative hydrographs from alluvial wells located between Areas A and B, and between Areas B and C are presented in Figure GM-15.

A review of the well hydrographs indicates that climatic factors dominate alluvial well water levels at/near the Rosebud Mine. However, some alluvial wells in the immediate vicinity of E. Fork Armells Creek appear to have shown effects of dewatering when mining/dewatering was performed in nearby areas (e.g., WA-211, WA-212, WA-213, WA-209) [refer to page 2 of Figure GM-15]. Other alluvial wells have not responded. Again, some observed responses are due to non-mining factors such as drought conditions. In some instances it is difficult to ascertain the primary factor (mining or climate-related) responsible for the changes that are observed (e.g., WA-127, WA-131).

In general, with the exception of the temporal dewatering observed when mining occurred adjacent to the E. Fork Armells Creek alluvium, most of the alluvial well responses in the Rosebud Mine area (both decreases and increases) correlate to climate as opposed to being mining induced.

2.0 MODEL DEVELOPMENT

2.1 Model Code Selection

The modeling effort was conducted using the program entitled MODFLOW: “A modular three-dimensional finite difference groundwater flow model developed by the United States Geological Survey” (McDonald and Harbaugh, 1988). MODFLOW 88/96 was used for model simulation efforts.

The three-dimensional movement of groundwater of constant density through porous earth material may be described using the following partial differential equation:

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)-W=S_s\frac{\partial h}{\partial t}$$

K_{xx}, K_{yy} and K_{zz} are values of hydraulic conductivity along the x, y, and z coordinate axes; h is the potentiometric head; W is volumetric flux; S_s is the specific storage; and t is time.

2.1.1 Rationale for Using MODFLOW

MODFLOW is a three-dimensional finite difference numerical simulation tool used to solve the above equation for a variety of complex conditions. MODFLOW, which is a public domain code, is the most widely used groundwater flow code. The code has been validated and most groundwater hydrologists/hydrogeologists are familiar with MODFLOW.

2.1.2 MODFLOW Packages

MODFLOW consists of a main program that applies a series of highly independent subroutines called “modules.” These modules are grouped into packages. The

packages may be combined to simulate a variety of groundwater flow conditions. In a sense, the manner that these packages may be pieced together is akin to “à la carte” dependent upon the situation. Some of these packages are required while others may be used for site-specific circumstances.

The following are packages which have been developed for MODFLOW. Parentheses () indicate if a package is required or discretionary. Brackets [ ] identify packages which were employed in the Rosebud Mine model.

- Basic Package (required) ***[BAS1 used]***.
- Block Centered Flow Package ***[BCF used]***
- Solver Package (one of these is required):
    - Strongly Implicit Procedure (SIP1)
    - Pre-Conditioned Conjugate Gradient (PCG1, PCG2, PCG3) ***[PCG2 used]***
    - Slice Successive Overrelaxation (SOR1)
- Recharge Package (discretionary) ***[RCH used]***
- Evapotranspiration (discretionary)
- Drain Package (discretionary) ***[DRN used]***
- River Package (discretionary)
- General Head Boundary Package (discretionary)
- Well Package (discretionary) ***[WEL used]***
- Horizontal Flow Barrier (discretionary)
- Stream Package (discretionary)
- Time Variant Specified Head (discretionary).

The packages that were employed in the Rosebud Mine model are briefly reviewed below.

Basic Package

The basic package serves as the administrator for MODFLOW. It has the following purposes:

- Identifies all the other packages which are to be incorporated into the model;
- Defines the active portions and grid characteristics of the model (that portion of the model domain which is included in the simulation process);
- Establishes initial conditions (e.g., starting heads);
- Defines stress periods and stress period lengths (e.g., the length of time, and the manner the time in each model run is subdivided);
- Computes the volumetric budget for entire model (e.g., summarizes all the inflows, outflows and changes in water storage in the model domain); and
- Defines the output control (portions of the modeling information that will be printed to output files).

Block Centered Flow Package

The Block Centered Flow Package is used to perform the following tasks:

- Defines whether the simulation is to be steady-state or transient;
- Develops the row and column sizes;
- Describes the layer type (confined or unconfined);
- Defines the storage properties;
- Defines model layer parameters;
- Transforms the input parameters to coefficients for the numerical matrices; and
- Determines the rate that flow moves into and out of storage at each model cell.

Solver Package

There are several numerical tools for solving the model's mathematical structure once it has been created to represent the groundwater flow system. As stated before, there are

three classes of solvers commonly employed with MODFLOW. The choice of the appropriate solver varies from application to application as one solver may work well for one problem, but not work so well on another. The PCG2 solver worked the best for this model simulation effort.

Recharge Package

The Recharge Package (RCH) is designed to simulate areal recharge over a model domain. For the Rosebud Mine area, this package was used to represent the net recharge less any direct abstractions such as evaporation and evapotranspiration. All water added over areal portions of the model domain is via the recharge package.

Drain Package

The purpose of the Drain Package is to simulate the effect that certain types of sinks, such as agricultural drains, have on groundwater systems. An inherent assumption in using the drain package is that drains can only remove water from a groundwater system. In essence, the groundwater potentiometric head must be above the base of the drain for it to remove water. When simulated heads are below the drain, no flow exits from a model cell used to emulate a drain.

The rate that flow passes from a drain is also directly proportional to the conductance of the drain. In essence, the Drain Package applies a numerical form of Darcy's Law in accounting for the rate that water leaves the subsurface via a drain.

The Drain Package was used to represent some of the larger channel, coulee, gully and/or ephemeral stream features in the mine vicinity.

The Drain Package was used as well to represent the hydraulic sinks associated with the mining process during the transient modeling phases.

Well Package

In one instance, the well package was used to represent a stock well. Refer to Section 2.1.4 for more details.

Graphical User Interfaces/Automatic Parameterization

Graphical User Interfaces (GUIs) were applied extensively in the Rosebud Mine modeling effort. The GUIs were used to:

- Compile all relevant hydrologic/hydrogeologic information into a relational database and into a visual format.
- Assist in creation of initial model structure and input files;
- Revise the model structure as necessary during the course of the modeling effort;
- Create and modify parametric zones;
- Modify parameters within zones during calibration;
- Provide calibration statistics during model calibration; and
- Develop presentation graphics for exhibiting simulation results.

ARCVIEW was used to develop model background images. In addition, drawing files from WECo were used to define mine progression over time.

Groundwater Vistas (GV), developed by Environmental Simulations, Inc. of Herndon, Virginia, served as the numerical interface for conducting groundwater simulations via MODFLOW. The GV interface served as both a pre-processor and post-processor for purposes developing the model input files, evaluating the simulation results, and for conducting sensitivity analysis.

For additional details about GV, the documentation associated with GV should be consulted.

In addition to using both ARCGIS and GV, Golden Software Surfer was used for developing illustrations from simulation results exported from GV. This included development of the potentiometric surfaces and drawdown for both steady-state and transient simulation efforts.

2.1.3 Model Construction/Calibration/Application Approach

The primary steps used to construct the groundwater model were the following:

- Step 1: The ARCVIEW database was constructed using a combination of the data available in Montana's Natural Resource Inventory System (NRIS) [coordinates were in NAD-83 State-Plane, feet].
- Step 2: Relevant graphical files were exported from ARCVIEW and then imported into Groundwater Vistas to assist in defining the following components of the model structure with the following general attributes:
    - Model domain was defined. The approximate model dimensions are about 27 miles (N-S) by 36 miles (E-W).
    - A variable spaced grid was used. However, a uniform grid density was applied to areas of permitted mining.
    - Five model layers were defined.
- Step 3: Initial model transmissivity and hydraulic conductivity values were assigned values similar in magnitude to those quantified in the Environmental Impact Statement (State of Montana, 1982) [refer to Figure GM-7].
- Step 4: Recharge values were initially distributed uniformly assigning a value of 0.25 inches per year.
- Step 5: The following model parameters were defined and modified area-wise as necessary to achieve as reasonable an approximation to potentiometric head as feasible:

  - Transmissivity
  - Recharge
  - Leakance (represents relative ease with which water may flow vertically).
- Step 6: A steady-state model calibration effort was first completed using the calibration targets presented in Table GM-1. The focus of target selection was to use water level data collected before the impacts of mine disturbance were significant. In some instances, mining had occurred prior to the collection of groundwater level data. Emphasis was placed on using data from wells deemed as representative of actual conditions. More information on the target selection process is given in Attachment GM-A. In areas of multiple well clusters of the same aquifer unit, one representative well was defined to reduce calibration bias. The steady-state calibration effort included modifying transmissivity, recharge, and leakance using a combination of the following:
  - Trial and error variation of parameters;
  - Use of the auto-sensitivity run feature of GV which allowed multiple simulations to be run automatically; and
  - PEST (Model-Independent Parameter Estimation, Doherty (2005)).
- Step 7: A series of sequential transient models representing each year of the mining process starting 1975 and ending in 2011 were constructed for conducting the simulations used to represent the extraction of groundwater during mining.
- Step 8: Sensitivity analysis was conducted focusing on storativity for the various hydrogeologic units to determine reasonable values of this parameter.
- Step 9: Transient model simulations were conducted for permitted mining extending to 2020 for Areas A, B, and C.

For Step 9, it is likely that actual mining timing set forth for future dates will vary from the projected dates depending upon coal demand, etc.

2.1.4 Summary of Model Construction

The areal domain of the groundwater model relative to the Rosebud Mine is shown in Figure GM-18. The domain varies by layer.

Vertical Discretization

The hydrogeology was represented in the model using a five-layer model. All layers were assumed to possess constant saturated thickness (confined). A limiting factor in selecting the most applicable criterion (confined versus unconfined) is the fact that some areas of the aquifer system in the vicinity of simulated area may be confined and others may be unconfined. Furthermore, even individual stratigraphic units can vary geographically from confined in one instance to unconfined in other cases (e.g., nearer outcrops).

The model layers were assigned as follows below (pre-mine conditions):

- Layer 1: Overburden and alluvium.
- Layer 2: Rosebud coal and alluvium
- Layer 3: Interburden and alluvium
- Layer 4: McKay coal
- Layer 5: Shallow Underburden or sub-McKay (confined)

The model layer thicknesses assigned to compute this transmissivity were as follows:

- Layer 1: 30 feet
- Layer 2: 26 feet
- Layer 3: 50 feet
- Layer 4: 8 feet
- Layer 5: 50 feet

Note that since the model is transmissivity based the thickness is not directly used in the simulation model of MODFLOW. The main purpose of assigning thicknesses was to calculate transmissivity. However, in the case of the Rosebud coal and McKay coal, the model layer thicknesses of 26 feet and 8 feet are deemed to be representative of the approximate thickness of these coals.
There are certain advantages and limitations in assuming that each of the modeled water bearing units is confined when compared to the potential for unconfined conditions when using MODFLOW. These include the following:

Advantages:

- The model construction process is greatly simplified. For instance, the elevation of specific stratigraphic features, or the elevation of specific model layer components, must be known throughout the model domain in order to define the structure of the unconfined model. This is generally an impractical requirement except in the immediate vicinity of the mine itself. Outside the immediate mine area the structure information is not known in detail, nor can it be practically defined.

- Numerical convergence problems often arise when numerous model cells may vary between unsaturated and saturated conditions during the simulation process using MODFLOW. Such problems are especially likely to occur when certain layers or portions of the model are “thinly” saturated. Convergence problems are usually not as significant with the utilization of constant thickness layers or transmissivity based models when using MODFLOW.

Limitations in assuming transmissivity based models for aquifer conditions when an unconfined assumption may be more appropriate include the following:

- There is a tendency to over-predict drawdown; and

- There is a tendency to over-predict the rate of flow from imposed boundary conditions such as drains or rivers.

In essence, the use of a confined aquifer assumption versus an unconfined assumption generally leads to more conservative results for purposes of estimating the amount of dewatering, and also projecting water level changes associated with coal mining.

Again, portions of the shallower strata, especially in the northern portions of the mine are unsaturated.

Horizontal Discretization

The model grid structure consists of 259 rows and 464 columns and it is variably spaced. The model cells are uniformly gridded over Rosebud Mine Areas A, B, C and E. This spacing is 250 feet. Those model cells on the periphery of the model domain possess larger spacing up to 2,500 feet. The maximum aspect for the rows (delta-y) is 10. The maximum aspect ratio for the columns (delta-x) is also 10. The aspect ratio represents the overall maximum dimension to minimum dimension for a given model cell. Generally, it is desirable to keep the aspect ratio less than 10 to ensure accuracy during the numerical simulation process. Outside the mine permit areas described above the cell dimensions are gradually increased. No aspect ratio of one cell adjacent to another exceeds a value of 1.5 which is in conformance with requirements of MODFLOW. This again, ensures accuracy will be maintained in the model simulation effort.

Boundary Conditions

The following were the primary boundary condition modules used:

- A majority of the model perimeter is along intermittent or ephemeral streams and/or Rosebud Creek. The goal here is to assign boundary condition water

levels deemed reasonably consistent with natural conditions. The remoteness of these boundaries eliminates any undue influence of artificial boundary conditions on the model calibration and model application efforts. For additional details, see Figure GM-18.

- All stream features are represented using the drain package. It should be emphasized that the “streams” in the vicinity of the Rosebud Mine are ephemeral and rarely flow. The lone exception is Rosebud Creek as it does possess perennial flow. Note that drain cells were assigned relatively low conductance which varies by model cell depending upon the length of the reach within a given cell. For smaller ephemeral drainages, for modeling purposes, the drain width was assigned as 4 feet, thickness as 2 feet, and the hydraulic conductivity as 5 ft/d. For larger drainages, the drain width was assigned as 8 feet, thickness as 2 feet and the hydraulic conductivity as 10 feet. Given that many of these drains represent dry alluvium and dry stream reaches, there was no attempt to calibrate drain conductances. A cross-reference to drain assignments is given at the end of Model Attachment GM-C.

As stated before, drains represent sinks associated with mining progress (e.g., mine passes) over time. For model simulation purposes, the drain width was assigned as 50 feet, the drain thickness as 2 feet and the hydraulic conductivity was set at 1 feet per day.

In one instance, site reconnaissance activity indicated that a livestock well is pumped continuously on a seasonal basis (from May through December) near alluvial observation well WR-231. Hence, in this instance, a well boundary condition is used to represent this pumping well.

2.1.5 Areal Sources/Sinks

Again, the source of flux into the model was application of water via the recharge package (RCH). The actual overall rate of recharge is very low as most precipitation is

low. Certain fractions of this precipitation are also lost to the evapotranspiration. Other fractions outflow at shallow springs from perched zones in the overburden. Hence, such water does not become deeper recharge to the lower portions of the overburden, or to underlying strata.

Therefore, the focus of this model is to define “net recharge” as that flow that ultimately reaches the hydrogeologic units of interest, namely the deeper overburden, Rosebud coal, interburden, McKay coal and sub-McKay. This rate and amount of “net recharge” ultimately reaching the underlying hydrogeologic stratum, on average, is very low.

The rate of recharge varies substantially in the area of the mine. It is likely that much greater recharge occurs at clinker zones (Heffern and Coates, 1999). Similarly, flows along drainages also act to provide greater recharge. Recharge may also be relatively higher in the immediate vicinity of major faults, or in areas of historic mining disturbance. Locally, higher recharge may also occur beneath stock ponds and mine sediment control ponds. In some instances, where relatively more permeable strata outcrop, recharge rates may be relatively higher as well.

There were no additional areal sources or sinks included in the model structure other than those defined previously.

3.0 MODEL CALIBRATION PROCESS

The model calibration process included using the statistical evaluation packages contained in GV. Two hundred and seventeen wells served as steady-state calibration targets (see Table GM-1).

3.1 Results

3.1.1 Statistical Summary

Table GM-2 provides a summary of the calibration results. Table GM-3 provides a layer-by-layer calibration summary. The following are the basic statistics presented in th Table GM-2:

- Residual mean is 0.19 feet. A residual is the difference between the observed potentiometric head (well water level) and the computed potentiometric head. The residual mean is the average of the residuals for all observation points. This mean represents the tendency of the model to either over-predict or under-predict water levels. Since the residual mean is very small (positive), there is very-slight tendency to under-predict observed well water levels when the steady-state model simulation results and data are evaluated as a whole.
- Residual standard deviation is 11.75 feet. This statistic is simply the standard deviation representing the dispersion of model residuals computed.
- The sum of squares is 29977.27. The sum of squares is the sum of each residual squared. In effect, the smaller this value the better the model fit. The size of this value is also dependent upon the number of observation points.
- Absolute residual mean is 9.03 feet. The absolute residual mean represents the magnitude of the difference between the measured water levels and the simulated water levels. The absolute residual mean was the primary statistic employed during the model calibration process and the goal was to minimize the value of this statistic.

- The minimum residual is -36.88 feet (negative implies over prediction) at WO-184. In effect, it states that actual water level (target) is 36.88 feet lower than the simulated value.
- The maximum residual was 30.11 feet at WM-121. This is the equivalent of stating that the actual water level (target) is 30.11 feet higher than the simulated value. Note that this well is not in the immediate vicinity of the area of interest.
- The scaled absolute residual mean is 0.017. This statistic assists in determining if the calibration is adequate. According to James Rumbaugh, developer of Groundwater Vistas, a typical modeling effort should obtain a value less than 0.1. Based upon this criterium, the model provides an excellent fit to the observation data.

Note that the relative ability to obtain a calibration fit is constrained significantly by the high degree of vertical head differences, including at the local scale, between the various hydrostratigraphic units.

Figure GM-19 provides the simulated potentiometric heads for each model layer. . Plates GM-B1 and GM-B2 given in Attachment GM-B provide comparisons between interpretative water level contours and simulated contours for the Rosebud and McKay coals respectively. Figures GM-20 and GM-21 provide graphical comparisons between observed and simulated water level observations. Figure GM-20 presents all the calibration data on one plot. Figure GM-21 presents the calibration results on a layer-by-layer basis. The upper plots compare the observed potentiometric head values with the simulated potentiometric heads. These plots demonstrate that the model reasonably represents the observed potentiometric heads.

The lower plots of Figures GM-20 and GM-21 compare the residuals to the observed potentiometric heads. If such a plot indicates a trend in the residuals, then it may indicate possible areas for model improvements. Since the residuals are randomly

distributed, there is little basis for substantively changing the model to improve the model calibration.

Figure GM-22 provides an area-wide depiction of residuals for each model layer.

Upon evaluating area-wide residuals, one of the more difficult areas for matching existing water levels extended was at the west edge of Area B, and at/near the southwestern and west portions of Area Cfor model layer 4 (representing the McKay coal). The tendency in this area was to over-predict groundwater levels in layer 4. The magnitude of this impact was reduced somewhat by decreasing the transmissivity of the McKay coal to the southwest of Areas B and C, yet, the tendency to over-predict for the McKay coal in this area could not be fully eliminated. The same trend for over-prediction in this portion of the mine was not observed in model layers 1 through 3. One possible explanation for this issue being primarily isolated to the McKay coal is the presence of faults in this area of the Rosebud Mine. Given that the McKay coal is thinner (~8 feet) than the Rosebud coal (~26 feet), it is possible that the McKay has been offset to the degree that the lateral hydraulic communication along this hydrogeologic unit is more likely affected for a given fault. As the Rosebud coal is thicker, hydraulic communication along the Rosebud may not be affected. However, the actual physical factor(s) that could explain the anomaly for water levels in this portion of the model for the McKay coal is (are) unknown.

The model also produces results which are reasonably representative of the vertical hydraulic gradients that are present in the strata at and near the Rosebud Mine. This is evident via the layer-by-layer statistics presented in Figure GM-21. Furthermore, Table GM-5 provides comparisons of vertical water levels at several well groups. In some instances, the model over-predicts the vertical differences and in other cases it under-predicts the vertical differences. A comparison of the average differences at the end of Table GM-5 indicates that the average difference from the upper simulated unit

compared to the lower simulated unit shows a slight underprediction of the vertical gradient with the simulation model. However, much of this difference is attributable to two clustered well series. One of these is the series WR-173, WI-173 and WM-173 while the other is the series WO-178, WR-121, WI-178, and WM-178. In general, it is deemed that the simulation model provides a reasonable depiction of the vertical gradients when the mine area is considered as a whole.

Based upon Tables GM-3 and GM-5 and Figures GM -20 through GM-22, the calibrated model provides a reasonable depiction of hydrogeologic conditions for Areas A, B and C. of the Rosebud Mine area.

3.1.2 Model Parameter Zonation

Figure GM-23 provides calibrated transmissivity and leakance estimates for the vicinity of the Rosebud Mine. Generally, the calibrated transmissivity values for the Rosebud mine model are reasonably consistent with the data collected during the 1982 EIS (see Figure GM-8).

Figure GM-24 presents recharge estimates applied in the modeling effort. Note that consistent with the conceptual model, and research of others, relatively higher recharge rates were applied in areas of mapped clinker deposits, and along the Little Wolf Mountain drainage divide, and in the base of drainages. Generally, relatively greater precipitation occurs in elevated areas along the Little Wolf Mountains. In addition, these ridges tend to be capped with clinker. Hence, it is rational to assume that greater recharge would occur in areas where greater precipitation occurs and where clinker is present. It is also rational to assume that runoff events would lead to recharge in the drainages. Another area where relatively higher recharges are applied includes Area E, which represents a historically mined area. The logic of this assumption is that the presence of low permeability layers does not exist, allowing more infiltration and vertical seepage to underlying strata. Given that the historic mining occurred in much of Area E

in the 1950s, it is assumed that groundwater levels have nearly fully recovered in those portions that were mined historically.

3.1.3 Volumetric Budget

Model Domain

Table GM-4 presents the mass balance results from the MODFLOW simulation. A low mass balance difference of 0.0024 percent was obtained. For the model simulation, the model fluxes for the aquifer system were quantified to be the following:

- Recharge (represents areal recharge) [10.42 cubic feet per second (cfs)]; and

- Drain Flux (from drain cells representing ephemeral drainages creeks, alluvial deposits in such drainages, etc.) [10.42 cfs]. Stock well (GWIC ID 1056) was at 0.01 cfs.

3.1.4 Steady-State Model Sensitivity Analysis

The steady-state model sensitivity analysis is provided in Attachment GM-C. The following summarizes the conclusions of that sensitivity analysis:

- The steady-state model is sensitive to transmissivity for the viable range of this parameter in the model domain.
- The model is sensitive to changes in recharge.
- The model is sensitive to changes to vertical leakance, and, in effect, the composited vertical hydraulic conductivity.
- The model shows low sensitivity to drain conductance.

It is noted as well, that in conducting the sensitivity analysis, some limited improvements in the calibration statistics could be obtained in some instances. However, it is deemed

that none of these would result in any substantive improvement in overall predictive capability.

4.0 MODEL APPLICATION PROCEDURE/TRANSIENT EVALUATION AND RESULTS

A conceptual representation of the transient representation of the mining process is given in Figure GM-25. The simplified mining progression in Area A, B and C for the 1975 through 2020 existing permits is presented in Figure GM-26.

Following the completion of the steady-state model calibration process, a series or cascade of MODFLOW models was created in order to represent the following mining phases:

- Past mining from 1975 through 2011. (Areas A, B, and C)
- Future mining - in Areas A, B and C from 2012 through 2020 as specified in the existing permits.

For simulations representing mining activity, the focus of the transient simulations was on the relative changes in water levels and the projected formation dewatering rates.

A transient evaluation was performed by varying storativity and comparing simulated drawdown results with observed drawdown results at selected wells at the mine. Subsequently, representative storativity values were applied to project future mining system response.

4.1.1 Procedure

The impacts of the mine dewatering process were represented using the Drain Package of MODFLOW. The drains were added sequentially to represent the effect of mining passes. Following a given mine pass, the drains were removed.

The parameters of the model cells used to represent spoils were adjusted to values representative of mine spoils. In essence, a series of BCF modules were created with

the only difference being the updated formation parameters in accordance with the mining activity progress (see Figure I-26). The updated parameters representing the spoils were as follows:

- Transmissivity was assigned to 13 ft^2/day.
- Vertical leakance was not changed between the layer representing the spoils and the underlying model layer under the assumption that the primary factor leading to impedance of vertical leakage from the coals and spoils was due to the underlying mudstone/under-clays which are typically of low to extremely low permeability.
- The initial storativity was assumed to be 0.01 for all layers of the model except for the spoils which was assigned a storativity of 0.1.
- Recharge in the spoils was assigned as 0.00005 ft/day or 0.22 inches per year. This is a conservative recharge rate for projecting future water level recovery rates.

In addition, model layer 1 was inactivated at the end of each mine pass since the overburden and Rosebud coal were removed (two layers) and replaced by mine spoils (one layer).

4.1.2 Storativity Analysis

One of the factors influencing the model's drawdown predictions is the storage coefficient or storativity (S) associated with each model layer. The storativity is defined as the volume of water that is released or taken into storage per unit surface area, per unit of head change (Todd, 1980). Storativity typically decreases as conditions become more confined.

The Rosebud Mine model focused on testing a limited range of storativities for historic observations (1975-2011) via the following scenarios:

- Scenario 1 – Storativities were set to:
    - S of layer 1 through 5 was set to 0.01
    - S of spoils in layer 2 was set to 0.1
- Scenario 2: Storativities were set to:
    - S of layer 1 was set to 0.01
    - S of layer 2 through 5 was set to 0.001
    - S of spoils in layer 2 set to 0.1

Figure GM-27 (page 1 and 2) presents observed and simulated drawdown for both scenarios in selected Rosebud coal and McKay coal wells throughout Rosebud Mine. As expected, the results show that decreasing S from 0.01 to 0.001 for layers 2 through 5 increased the predicted drawdown for the given layer. This resulted in a slightly better fit for most McKay coal wells, but generally led to a poorer fit for the Rosebud wells when compared to Scenario 1. Thus, it is demonstrated that assigning a storativity of 0.01 to model layer 2 yields more representative drawdown for the Rosebud Coal. Figure GM-27 (page 1) shows that Scenario 1 generally approximates observed drawdown values within 5 to 10 feet.

Another means of comparison is provided in Table GM-6. This table shows a comparison or the difference between observed and simulated drawdown at the selected Rosebud and McKay coal wells defined above. Note the following:

- Scenario 1 assumptions underpredicted the drawdown by an average of 3.95 feet.
- Scenario 2 assumptions overpredicted the drawdown by an average of 3.45 feet.
- Scenario 3 assumptions overpredicted the drawdown by an average of 1.42 feet.

It is deemed that Scenario 3 is the most representative of the three scenarios that were evaluated. It is also provides for conservative results as it slightly over-predicts

observed drawdown at the mine. Subsequently, the following storativities (Scenario 3) are used in the Rosebud Mine groundwater model:

- S = 0.1, assigned to alluvium (layer 2) and spoils (layer 2)
- S = 0.01, assigned to overburden (layer 1) and Rosebud coal (layer 2)
- S = 0.001, assigned to interburden (layer 3), McKay coal (layer 4) and sub-McKay (layer 5).

The model simulation results using the above parameters are provided in Figure GM-27 (pages 3 and 4). As this figure demonstrates, the model simulations reasonably represent observed drawdown for the Rosebud coal (see page 3).

One primary factor that may explain why a storativity of 0.01 produces representative drawdown results in the Rosebud coal is given by Van Voast and Reiten (1988, page 11) as quoted below:

> "The presence of thick sand beds in the Rosebud overburden supports the possibility of greater storage coefficients for a combined coal and sand-bed aquifer at that locale."

Note that the locale under reference is at the southern edge of Area B. In other words, the Rosebud coal in this portion of the mine tends to be unconfined due to the presence of the sandstone overlying this coal. Observation wells WR-162 and WR-164, more recently installed, also show the presence of siltstone/sandstone overlying the coal. Hence, Van Voast and Reiten were insightful in their assessment of the possibility of higher storativities for the Rosebud coal simply because substantial portions of the strata immediately overlying this coal are not true confining layers.

All storativity tests conducted using the prior model and the existing model lead to under prediction of drawdown for the McKay coal in some southern portions of Area B. For instance, refer to wells WM-161, WM-162 and WM-164 (Figure GM-27, page 4). It

should be noted that assigning lower storativities (e.g., 0.0001) to layers 3 through 5 was tested in an attempt to improve the fit for this area of the model. This assignment did not lead to any substantive improvement in simulating drawdown for the McKay coal in this area. It may be that some portion of drawdown can be attributed to Big Sky Mine operations (ceased in December, 2003) which are just south of Area B. On the other hand, the model tends to over-predict drawdown in some other portions of the mine for the McKay coal (e.g., WM-168 and WM-153).

A simulated rate of recovery was calculated for recovering spoils wells in Areas A, B and C. For a list of these wells refer to Table 19 of the PHC. The simulated average rate of recovery for spoils wells in Areas A and B was three and six inches/year, respectively. The model does not predict any recovery in Area C spoils well WS-121 for the period of record. The observed average rate of recovery for Areas A and B is 4 and 11 inches/year, respectively. Hence, the projected rate of recovery using the model is reasonably similar to that of the observations for Area A. Note that some standing water in the Area high-wall pits likely leads to the slightly higher observed recovery rate of 4 inches in the spoils compared to the simulated recovery of 3 inches per year.

The recovery rate in the vicinity of Area B is much higher than is predicted by the model. Much of the reason for this difference is believed to be a combination of historically leaky PPL ponds and standing water in high-wall pits. Note that each of these contributions cannot be practically accounted for without more information.

It is expected that as mining concludes, the simulated and observed recovery rates will become more similar with time.

In summary, based upon the information to date, the model simulations tend to produce conservative results in terms of groundwater level recovery.

4.1.3 Flow Evaluation

Area A, B, and C

In order for the model to be representative of the hydrogeologic media and the mining process, it should also provide reasonable predictions of discharge. Conversations with Rosebud Mine staff have yielded opinions that discharges from the geologic media in the main mine area tend to be about 100 gallons per minute in given active mine areas. Much higher flow rates were observed when WECo mined near the E. Fork Armells Creek alluvium. The amount of water that needs to be managed is a function of the total length of the active mine passes as well.

Table GM-7 provides a summary of the simulated groundwater extractions due to mining in Areas A, B and C. Review of Table GM-7 shows:

- Mining in Area A is projected to yield the smallest discharges with annual average mining discharge ranging from 4 to 103 gallons per minute (gpm). The simulated cumulative average is 39 gpm.
- Mining in Area B is projected to yield the largest discharges ranging with annual average mining discharge ranging from 25 to 422 gpm. The simulated cumulative average is 143 gpm.
- Mining in Area C is projected to yield annual average mining discharges ranging from 2 to 229 gpm. The simulated cumulative average is 107 gpm.

The following is noted with respect to these simulated flow rates:

- Actual instantaneous and longer-term flow rates will vary depending upon how the mine manages the water that enters the pits. In some instances, water may be pumped from one pit to another.
- Discharge rates during actual pumping may be much higher, and last for relatively shorter durations than a year.
- Some portion of the discharge likely enters the spoils during the mining process.
- There are likely to be anomalies, such as the presence of the alluvium or faults bounding, or in the proximity of mine passes.

- There are climatic factors as well, including evaporation, and impacts of major precipitation/runoff events which can add water to these pits.

In effect, it is possible that locally higher temporal discharges will be encountered in areas of the mine that bound the alluvium that are not apparent in the simulation results set forth in Table GM-7. These locally higher temporal discharges are likely to more apparent during initial mining activity in those areas bounding alluvium.

4.1.4 Projected Changes in Water Level

The following figures present simulated potentiometric heads in Rosebud coal (page 1) and McKay coal (page 2):

- Figure GM-28: simulated potentiometric head at the end of 2011.
- Figure GM-30: simulated potentiometric head as a result of existing permit mining activities in Areas A, B and C, at the end of 2020.

Simulated drawdown in the Rosebud coal (page 1) and McKay coal (page 2) is presented in the following figures:

- Figure GM-29: simulated drawdown at the end of 2011.
- Figure GM-31: simulated drawdown as a result of existing permit mining in Areas A, B and C, at the end of 2020.

5.0 SUMMARY AND CONCLUSIONS

The following summarize the results of this groundwater modeling effort:

- The model provides a conservative and consistent basis for comparing the hydrologic response of the relative impacts to the groundwater associated with mining in the proposed disturbance area.

- The steady-state calibrated model utilizes hydraulic parameters, namely transmissivity values, that are consistent with data defined in the EIS (1982).

- The model is sensitive to changes in transmissivity over the likely range of values for this parameter in the mine vicinity. The model is most sensitive to leakance (or vertical hydraulic conductivity) and recharge. Low values of leakance and low rates of recharge were generally required to match both discharge rates and water levels.

- The model consistently represents water level observations over time. In addition, transient simulations demonstrated that the model provided discharge rates reasonably consistent with observations.

- The Rosebud Mine model predicts that a majority of the impacts will arise in the within the permit boundary. Impacts to the water levels in areas outside the mine boundary are projected to be much smaller. The most significant drawdowns outside the mine are projected to occur near southern portions of Area B.

6.0 LIMITING ASSUMPTIONS OF THE MODELING EFFORT

There are limiting assumptions that should be noted when applying this flow model including the following:

- Models are predictive tools and they represent simplifications of complex systems.

- The model assumes each saturated zone for all layers is of constant thickness. The actual saturated zones are of variable thickness spatially and temporally.

- The mine stress periods assume a stress is instantaneously applied at each drain used to represent mine passes. In reality, the mine passes develop more gradually over time.

- There is uncertainty about the magnitude of various formation parameters including hydraulic conductivity (transmissivity), leakance, storativity, porosity and recharge rates.

- There is no unique modeling solution to a complex natural system. In essence, there are alternative conceptual and hydraulic models which could be applied to Rosebud Mine area.

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Tables

Table GM-1
Steady-State Calibration Targets
Rosebud Mine

Name	X	Y	Model Layer	Observed
AAL51	2703417	584715	1	3220.00
AOVM73	2701492	593319	1	3309.00
BOV1012	2697761	579885	1	3256.80
BOV112	2678045	587514	1	3373.20
BOV1712	2697296	580906	1	3257.00
BOV212	2677889	582113	1	3363.50
BOV512	2688402	587614	1	3318.50
BOV612	2690411	585269	1	3313.00
WA-103	2678594	595699	1	3389.20
WA-116	2695344	601398	1	3273.40
WA-117	2695566	601211	1	3276.00
WA-118	2652614	593761	1	3648.59
WA-122	2669221	593569	1	3472.80
WA-123	2669055	593955	1	3474.40
WA-131	2696673	603806	1	3262.41
WA-141	2693126	602013	1	3286.83
WA-171	2662801	593470	1	3530.21
WA-209	2670892	594559	1	3456.55
WA-210	2670868	594148	1	3455.26
WA-214	2662877	592739	1	3524.91
WA-216	2660859	593230	1	3543.83
WA-224	2618393	607659	1	3558.55
WA-226	2624540	607625	1	3511.97
WA-227	2631592	604535	1	3472.21
WO-101	2683068	594619	1	3386.60
WO-103	2665207	600273	1	3462.95
WO-107	2670761	595559	1	3463.79
WO-108	2670934	592932	1	3464.33
WO-155	2676044	598621	1	3450.85
WO-156	2679122	602258	1	3457.27
WO-162	2680434	592255	1	3385.90
WO-164	2674477	590094	1	3403.05
WO-165	2669564	596865	1	3469.84
WO-166	2669691	592409	1	3472.81
WO-168	2666227	596884	1	3483.15
WO-169	2660089	601686	1	3462.97
WO-172	2659694	596452	1	3495.25
WO-176	2657533	607520	1	3456.47
WO-178	2650102	600734	1	3510.84
WO-179	2645894	604333	1	3467.40
WO-181	2640172	603011	1	3483.20

Table GM-1
Steady-State Calibration Targets
Rosebud Mine

Name	X	Y	Model Layer	Observed
WO-184	2630654	603382	1	3482.23
WO-185	2619855	606696	1	3535.27
WO-186	2612943	615283	1	3539.67
WO-187	2615403	620103	1	3507.58
ARC30	2702394	581775	2	3226.50
ARC44	2697904	586799	2	3276.50
ARC52	2709606	593852	2	3296.50
ARC53	2710501	592917	2	3290.00
ARC66	2701562	586962	2	3248.00
ARCM63	2701278	591109	2	3295.50
ARCM67	2705383	594153	2	3317.50
BRC1013	2697761	579749	2	3256.80
BRC1313	2679977	589457	2	3380.00
BRC1413	2690761	584417	2	3313.00
BRC1513	2696265	582790	2	3267.00
BRC1713	2697295	580769	2	3257.20
BRC213	2677889	581976	2	3354.20
BRC513	2688401	587477	2	3319.30
BRC9163	2681077	576924	2	3299.00
WR-100	2683061	594646	2	3377.50
WR-101	2694753	598318	2	3304.40
WR-102	2688598	599457	2	3319.80
WR-103	2659685	596483	2	3490.30
WR-108	2710460	598204	2	3256.67
WR-112	2657528	607512	2	3434.98
WR-113	2638723	607797	2	3440.88
WR-115	2669594	596854	2	3465.80
WR-116	2677525	594403	2	3401.10
WR-117	2675853	602770	2	3457.00
WR-121	2650109	600742	2	3470.90
WR-122	2676059	598608	2	3444.79
WR-124	2662818	593451	2	3499.28
WR-125	2657798	593439	2	3494.15
WR-126	2672322	604535	2	3449.10
WR-154	2671109	602013	2	3465.06
WR-156	2679112	602250	2	3450.62
WR-161	2690411	595651	2	3333.54
WR-162	2680425	592261	2	3384.34
WR-164	2674464	590118	2	3404.05
WR-168	2666234	596880	2	3479.29
WR-169	2660095	601683	2	3459.82

Table GM-1
Steady-State Calibration Targets
Rosebud Mine

Name	X	Y	Model Layer	Observed
WR-173	2665481	589684	2	3480.83
WR-181	2640166	603015	2	3457.91
WR-205	2693516	600467	2	3286.33
WR-208	2693064	600083	2	3292.44
WR-215	2693372	599336	2	3296.33
WR-227	2689350	599368	2	3316.26
WR-229	2655206	608219	2	3453.01
WR-231	2630597	603367	2	3458.94
WR-233	2619863	606689	2	3505.42
WR-234	2615394	620091	2	3496.44
WR-236	2616822	615206	2	3517.06
WR-237	2623315	613499	2	3477.61
WR-239	2612940	615267	2	3525.66
BAL9031	2686009	581887	3	3284.50
BAL9041	2686677	580912	3	3262.00
BIN1017	2697762	579612	3	3226.50
BIN117	2678046	587241	3	3392.50
BIN1317	2679977	589760	3	3387.50
BIN217	2677890	581839	3	3361.00
BIN417	2680095	576715	3	3290.30
BIN517	2688403	587341	3	3318.00
BIN617	2690410	584996	3	3296.50
BIN717	2688639	573562	3	3241.50
WA-192	2649041	605868	3	3370.66
WA-194	2642966	609176	3	3353.16
WA-204	2656907	611005	3	3333.85
WA-220	2626540	612492	3	3404.58
WI-104	2665224	600286	3	3444.60
WI-106	2709829	604844	3	3226.86
WI-107	2715484	598677	3	3239.37
WI-117	2712532	598101	3	3236.87
WI-153	2672323	604549	3	3449.13
WI-154	2671101	602019	3	3461.68
WI-155	2676053	598620	3	3421.17
WI-156	2679106	602245	3	3444.55
WI-161	2690402	595645	3	3331.27
WI-162	2680417	592268	3	3386.64
WI-163	2677508	594409	3	3399.98
WI-164	2674466	590111	3	3409.22
WI-165	2669574	596862	3	3451.81
WI-166	2669700	592414	3	3437.18

Table GM-1
Steady-State Calibration Targets
Rosebud Mine

Name	X	Y	Model Layer	Observed
WI-167	2667097	602799	3	3435.36
WI-168	2666244	596872	3	3444.27
WI-169	2660102	601679	3	3436.38
WI-172	2659694	596452	3	3458.82
WI-173	2665491	589689	3	3464.41
WI-174	2708085	601172	3	3244.50
WI-176	2657523	607518	3	3419.40
WI-177	2650566	603587	3	3423.92
WI-178	2650098	600728	3	3435.88
WI-179	2645885	604334	3	3433.78
WI-180	2638719	607790	3	3426.58
WI-181	2640156	603024	3	3452.41
WI-182	2711486	601298	3	3232.76
AMC20	2702728	583670	4	3226.00
BMC1014	2697761	579475	4	3192.50
BMC114	2678045	587104	4	3392.50
BMC1314	2679977	589609	4	3388.00
BMC1414	2690751	584278	4	3285.00
BMC1514	2696268	582653	4	3252.00
BMC414	2680095	576579	4	3275.00
BMC614	2690410	584859	4	3284.00
BMC714	2688639	573426	4	3207.00
BMC9154	2681065	577078	4	3273.50
WM-100	2683067	594677	4	3364.80
WM-102	2688598	599437	4	3319.40
WM-106	2694771	598268	4	3281.20
WM-108	2665244	600266	4	3429.00
WM-109	2655991	601198	4	3417.22
WM-111	2650603	603618	4	3423.30
WM-113	2669695	592404	4	3433.40
WM-114	2675865	602761	4	3430.90
WM-120	2709841	604839	4	3225.34
WM-121	2714794	595424	4	3248.30
WM-122	2717573	594271	4	3208.50
WM-127	2716940	600022	4	3225.80
WM-136	2712535	598110	4	3227.86
WM-138	2716720	599414	4	3227.86
WM-153	2672332	604546	4	3432.91
WM-154	2671093	602027	4	3433.78
WM-155	2676061	598618	4	3418.82
WM-156	2679098	602240	4	3421.90

Table GM-1
Steady-State Calibration Targets
Rosebud Mine

Name	X	Y	Model Layer	Observed
WM-161	2690392	595640	4	3314.20
WM-162	2680410	592275	4	3386.70
WM-163	2677514	594406	4	3399.86
WM-164	2674468	590100	4	3408.15
WM-165	2669582	596859	4	3442.91
WM-167	2667087	602809	4	3419.89
WM-168	2666254	596864	4	3440.85
WM-169	2660110	601672	4	3424.11
WM-173	2665499	589689	4	3420.61
WM-176	2657523	607518	4	3399.09
WM-178	2650092	600721	4	3409.06
WM-179	2645876	604335	4	3411.36
WM-184	2693119	599734	4	3278.68
WM-192	2630613	603370	4	3434.81
WM-193	2619870	606681	4	3483.86
WM-195	2615381	620080	4	3439.19
WM-196	2618058	620592	4	3440.44
WM-197	2616801	615188	4	3476.37
WM-198	2623300	613497	4	3442.27
WM-199	2632022	609323	4	3390.34
AAL12	2712175	587289	5	3141.00
AAL14	2713157	587564	5	3147.00
AALM70	2712539	586264	5	3121.00
ASM2	2705556	584984	5	3188.00
ASMM27	2708341	588773	5	3172.00
ASMM32	2710489	590435	5	3169.40
ASMM69	2706496	590634	5	3186.20
BSM1015	2697761	579339	5	3185.00
WA-109	2680170	617085	5	3218.60
WA-135	2716670	606877	5	3149.30
WA-142	2715650	605913	5	3166.74
WA-145	2714380	605258	5	3166.74
WA-152	2699495	612742	5	3202.05
WA-153	2695659	620758	5	3145.08
WA-156	2691450	625663	5	3127.44
WA-161	2686376	620769	5	3171.63
WA-165	2672867	614174	5	3272.37
WA-168	2671549	611546	5	3295.64
WA-169	2666246	606060	5	3373.07
WA-183	2649034	615063	5	3229.78
WA-198	2647787	623902	5	3132.60

Table GM-1
Steady-State Calibration Targets
Rosebud Mine

Name	X	Y	Model Layer	Observed
WA-219	2633745	611181	5	3357.40
WA-221	2620877	618761	5	3377.21
WA-225	2630516	614013	5	3357.97
WD-100	2694766	598291	5	3262.00
WD-104	2715504	598665	5	3175.30
WD-174	2708106	601191	5	3202.35
WD-185	2687145	597542	5	3314.61
WD-186	2677013	603981	5	3344.97
WD-189	2612941	615229	5	3449.39
WD-192	2616816	615193	5	3439.87
WD-193	2623284	613489	5	3427.62
WD-194	2632026	609308	5	3385.77

Table GM-2
Steady-State Calibration Summary
Rosebud Mine

Name	Model Layer	Observed	Computed	Residual
AAL51	1	3220.00	3228.35	-8.35
AOVM73	1	3309.00	3302.59	6.41
BOV1012	1	3256.80	3249.58	7.22
BOV112	1	3373.20	3380.54	-7.34
BOV1712	1	3257.00	3256.93	0.07
BOV212	1	3363.50	3351.62	11.88
BOV512	1	3318.50	3342.66	-24.16
BOV612	1	3313.00	3311.77	1.23
WA-103	1	3389.20	3386.98	2.22
WA-116	1	3273.40	3277.77	-4.37
WA-117	1	3276.00	3281.19	-5.19
WA-118	1	3648.59	3634.68	13.91
WA-122	1	3472.80	3472.65	0.15
WA-123	1	3474.40	3475.85	-1.45
WA-131	1	3262.41	3271.65	-9.24
WA-141	1	3286.83	3301.11	-14.28
WA-171	1	3530.21	3535.56	-5.35
WA-209	1	3456.55	3466.90	-10.35
WA-210	1	3455.26	3461.98	-6.72
WA-214	1	3524.91	3530.67	-5.76
WA-216	1	3543.83	3546.08	-2.25
WA-224	1	3558.55	3549.97	8.58
WA-226	1	3511.97	3489.59	22.38
WA-227	1	3472.21	3473.60	-1.39
WO-101	1	3386.60	3379.63	6.97
WO-103	1	3462.95	3462.98	-0.03
WO-107	1	3463.79	3472.56	-8.77
WO-108	1	3464.33	3452.75	11.58
WO-155	1	3450.85	3446.96	3.89
WO-156	1	3457.27	3449.99	7.28
WO-162	1	3385.90	3389.00	-3.10
WO-164	1	3403.05	3411.28	-8.23
WO-165	1	3469.84	3471.08	-1.24
WO-166	1	3472.81	3463.82	8.99
WO-168	1	3483.15	3472.44	10.71
WO-169	1	3462.97	3465.54	-2.57
WO-172	1	3495.25	3495.68	-0.43
WO-176	1	3456.47	3441.01	15.46
WO-178	1	3510.84	3500.66	10.18
WO-179	1	3467.40	3449.48	17.92
WO-181	1	3483.20	3489.24	-6.04

Table GM-2
Steady-State Calibration Summary
Rosebud Mine

Name	Model Layer	Observed	Computed	Residual
WO-184	1	3482.23	3519.11	-36.88
WO-185	1	3535.27	3552.59	-17.32
WO-186	1	3539.67	3529.60	10.07
WO-187	1	3507.58	3506.84	0.74
ARC30	2	3226.50	3233.44	-6.94
ARC44	2	3276.50	3284.02	-7.52
ARC52	2	3296.50	3276.01	20.49
ARC53	2	3290.00	3266.06	23.94
ARC66	2	3248.00	3257.67	-9.67
ARCM63	2	3295.50	3287.62	7.88
ARCM67	2	3317.50	3291.14	26.36
BRC1013	2	3256.80	3248.84	7.96
BRC1313	2	3380.00	3384.59	-4.59
BRC1413	2	3313.00	3303.37	9.63
BRC1513	2	3267.00	3272.71	-5.71
BRC1713	2	3257.20	3256.00	1.20
BRC213	2	3354.20	3350.51	3.69
BRC513	2	3319.30	3340.69	-21.39
BRC9163	2	3299.00	3302.86	-3.86
WR-100	2	3377.50	3379.38	-1.88
WR-101	2	3304.40	3303.29	1.11
WR-102	2	3319.80	3318.02	1.78
WR-103	2	3490.30	3494.58	-4.28
WR-108	2	3256.67	3271.40	-14.73
WR-112	2	3434.98	3440.05	-5.07
WR-113	2	3440.88	3429.01	11.87
WR-115	2	3465.80	3470.89	-5.09
WR-116	2	3401.10	3402.54	-1.44
WR-117	2	3457.00	3471.65	-14.65
WR-121	2	3470.90	3476.74	-5.84
WR-122	2	3444.79	3446.49	-1.70
WR-124	2	3499.28	3488.22	11.06
WR-125	2	3494.15	3487.81	6.34
WR-126	2	3449.10	3469.70	-20.60
WR-154	2	3465.06	3471.26	-6.20
WR-156	2	3450.62	3448.81	1.81
WR-161	2	3333.54	3335.73	-2.19
WR-162	2	3384.34	3388.88	-4.54
WR-164	2	3404.05	3411.33	-7.28
WR-168	2	3479.29	3472.27	7.02
WR-169	2	3459.82	3465.35	-5.53

Table GM-2
Steady-State Calibration Summary
Rosebud Mine

Name	Model Layer	Observed	Computed	Residual
WR-173	2	3480.83	3467.36	13.47
WR-181	2	3457.91	3457.99	-0.08
WR-205	2	3286.33	3286.88	-0.55
WR-208	2	3292.44	3291.05	1.39
WR-215	2	3296.33	3302.33	-6.00
WR-227	2	3316.26	3314.13	2.13
WR-229	2	3453.01	3445.76	7.25
WR-231	2	3458.94	3469.18	-10.24
WR-233	2	3505.42	3506.92	-1.50
WR-234	2	3496.44	3506.67	-10.23
WR-236	2	3517.06	3494.62	22.44
WR-237	2	3477.61	3469.56	8.05
WR-239	2	3525.66	3527.86	-2.20
BAL9031	3	3284.50	3287.90	-3.40
BAL9041	3	3262.00	3276.25	-14.25
BIN1017	3	3226.50	3216.86	9.64
BIN117	3	3392.50	3370.65	21.85
BIN1317	3	3387.50	3372.67	14.83
BIN217	3	3361.00	3342.25	18.75
BIN417	3	3290.30	3294.82	-4.52
BIN517	3	3318.00	3321.97	-3.97
BIN617	3	3296.50	3295.93	0.57
BIN717	3	3241.50	3240.42	1.08
WA-192	3	3370.66	3371.53	-0.87
WA-194	3	3353.16	3352.57	0.59
WA-204	3	3333.85	3349.99	-16.14
WA-220	3	3404.58	3407.75	-3.17
WI-104	3	3444.60	3445.63	-1.03
WI-106	3	3226.86	3237.29	-10.43
WI-107	3	3239.37	3239.48	-0.11
WI-117	3	3236.87	3245.92	-9.05
WI-153	3	3449.13	3446.83	2.30
WI-154	3	3461.68	3445.28	16.40
WI-155	3	3421.17	3424.00	-2.83
WI-156	3	3444.55	3416.93	27.62
WI-161	3	3331.27	3323.92	7.35
WI-162	3	3386.64	3377.07	9.57
WI-163	3	3399.98	3395.77	4.21
WI-164	3	3409.22	3402.42	6.80
WI-165	3	3451.81	3449.31	2.50
WI-166	3	3437.18	3441.59	-4.41

Table GM-2
Steady-State Calibration Summary
Rosebud Mine

Name	Model Layer	Observed	Computed	Residual
WI-167	3	3435.36	3434.56	0.80
WI-168	3	3444.27	3455.38	-11.11
WI-169	3	3436.38	3443.77	-7.39
WI-172	3	3458.82	3470.01	-11.19
WI-173	3	3464.41	3451.11	13.30
WI-174	3	3244.50	3249.42	-4.92
WI-176	3	3419.40	3409.04	10.36
WI-177	3	3423.92	3428.68	-4.76
WI-178	3	3435.88	3453.97	-18.09
WI-179	3	3433.78	3417.55	16.23
WI-180	3	3426.58	3418.54	8.04
WI-181	3	3452.41	3444.21	8.20
WI-182	3	3232.76	3247.46	-14.70
AMC20	4	3226.00	3212.52	13.48
BMC1014	4	3192.50	3209.97	-17.47
BMC114	4	3392.50	3366.56	25.94
BMC1314	4	3388.00	3367.28	20.72
BMC1414	4	3285.00	3283.95	1.05
BMC1514	4	3252.00	3246.33	5.67
BMC414	4	3275.00	3291.73	-16.73
BMC614	4	3284.00	3289.84	-5.84
BMC714	4	3207.00	3232.02	-25.02
BMC9154	4	3273.50	3290.24	-16.74
WM-100	4	3364.80	3361.06	3.74
WM-102	4	3319.40	3322.07	-2.67
WM-106	4	3281.20	3289.86	-8.66
WM-108	4	3429.00	3438.44	-9.44
WM-109	4	3417.22	3444.67	-27.45
WM-111	4	3423.30	3419.56	3.74
WM-113	4	3433.40	3434.29	-0.89
WM-114	4	3430.90	3424.46	6.44
WM-120	4	3225.34	3227.50	-2.16
WM-121	4	3248.30	3218.19	30.11
WM-122	4	3208.50	3199.96	8.54
WM-127	4	3225.80	3221.73	4.07
WM-136	4	3227.86	3234.92	-7.06
WM-138	4	3227.86	3221.55	6.31
WM-153	4	3432.91	3433.16	-0.25
WM-154	4	3433.78	3434.38	-0.60
WM-155	4	3418.82	3414.99	3.83
WM-156	4	3421.90	3404.99	16.91

Table GM-2
Steady-State Calibration Summary
Rosebud Mine

Name	Model Layer	Observed	Computed	Residual
WM-161	4	3314.20	3319.30	-5.10
WM-162	4	3386.70	3372.38	14.32
WM-163	4	3399.86	3392.24	7.62
WM-164	4	3408.15	3398.44	9.71
WM-165	4	3442.91	3440.62	2.29
WM-167	4	3419.89	3426.42	-6.53
WM-168	4	3440.85	3447.99	-7.14
WM-169	4	3424.11	3436.68	-12.57
WM-173	4	3420.61	3444.93	-24.32
WM-176	4	3399.09	3398.57	0.52
WM-178	4	3409.06	3443.85	-34.79
WM-179	4	3411.36	3409.58	1.78
WM-184	4	3278.68	3293.72	-15.04
WM-192	4	3434.81	3459.49	-24.68
WM-193	4	3483.86	3478.97	4.89
WM-195	4	3439.19	3445.81	-6.62
WM-196	4	3440.44	3415.79	24.65
WM-197	4	3476.37	3458.40	17.97
WM-198	4	3442.27	3435.52	6.75
WM-199	4	3390.34	3410.20	-19.86
AAL12	5	3141.00	3145.68	-4.68
AAL14	5	3147.00	3141.32	5.68
AALM70	5	3121.00	3136.18	-15.18
ASM2	5	3188.00	3178.24	9.76
ASMM27	5	3172.00	3180.26	-8.26
ASMM32	5	3169.40	3176.26	-6.86
ASMM69	5	3186.20	3201.88	-15.68
BSM1015	5	3185.00	3195.33	-10.33
WA-109	5	3218.60	3217.82	0.78
WA-135	5	3149.30	3148.01	1.29
WA-142	5	3166.74	3160.16	6.58
WA-145	5	3166.74	3170.88	-4.14
WA-152	5	3202.05	3179.17	22.88
WA-153	5	3145.08	3128.10	16.98
WA-156	5	3127.44	3115.58	11.86
WA-161	5	3171.63	3167.05	4.58
WA-165	5	3272.37	3277.04	-4.67
WA-168	5	3295.64	3307.60	-11.96
WA-169	5	3373.07	3371.56	1.51
WA-183	5	3229.78	3229.30	0.48
WA-198	5	3132.60	3116.40	16.20

Table GM-2
Steady-State Calibration Summary
Rosebud Mine

Name	Model Layer	Observed	Computed	Residual
WA-219	5	3357.40	3358.89	-1.49
WA-221	5	3377.21	3374.48	2.73
WA-225	5	3357.97	3346.17	11.80
WD-100	5	3262.00	3274.98	-12.98
WD-104	5	3175.30	3176.19	-0.89
WD-174	5	3202.35	3210.92	-8.57
WD-185	5	3314.61	3318.62	-4.01
WD-186	5	3344.97	3363.51	-18.54
WD-189	5	3449.39	3424.44	24.95
WD-192	5	3439.87	3418.23	21.64
WD-193	5	3427.62	3402.89	24.73
WD-194	5	3385.77	3390.53	-4.76

Residual Mean	0.19
Absoluate Residual Mean	9.03
Residual Std. Deviation	11.75
Sum of Squares	29977.27
RMS Error	11.75
Min. Residual	-36.88
Max. Residual	30.11
Number of Observations	217.00
Range in Observations	527.59
Scaled Residual Std. Deviation	0.022
Scaled Absolute Residual Mean	0.017
Scaled RMS Error	0.022
Scaled Residual Mean	0.0004

Table GM-3
Steady-State Calibration Summary by Model Layer
Rosebud Mine

	Model Layer				
Statistic	**1**	**2**	**3**	**4**	**5**
Residual Mean	-0.29	0.11	1.33	-1.18	1.56
Absoluate Residual Mean	8.19	7.77	8.47	11.22	9.62
Residual Std. Deviation	10.90	10.18	10.64	14.35	11.95
Sum of Squares	5346	5183	4711	9948	4789
RMS Error	10.90	10.18	10.72	14.40	12.05
Min. Residual	-36.88	-21.39	-18.09	-34.79	-18.54
Max. Residual	22.38	26.36	27.62	30.11	24.95
Number of Observations	45	50	41	48	33
Range in Observations	428.59	299.16	237.91	291.36	328.39
Scaled Residual Std. Deviation	0.025	0.034	0.045	0.049	0.036
Scaled Absolute Residual Mean	0.019	0.026	0.036	0.039	0.029
Scaled RMS Error	0.025	0.034	0.045	0.049	0.037
Scaled Residual Mean	-0.0007	0.0004	0.0056	-0.0040	0.0047

Table GM-4
Overall Model Mass Balance

Stress Type	Daily Rate (ft^3/d)	Total	
Recharge	899905.9	899905.9	Total Inflow
Stock Well (out)	1123.0		
Drains (out)	898759.4	899882.4	Total Outflow
Difference		23	
% Difference		0.0026%	

Exhibit 8

Table GM-5
Simulated versus Target Head (feet) at Selected Vertical Well Groups
Rosebud Mine Groundwater Model

Well	Target	Simulated	Net Head Difference	
			Observed	Simulated
WO-165	3469.84	3471.08		
WR-115	3465.80	3470.89		
WI-165	3451.81	3449.31		
WM-165	3442.91	3440.62	26.93	30.46
WO-168	3483.15	3472.44		
WR-168	3479.29	3472.27		
WI-168	3444.27	3455.38		
WM-168	3440.85	3447.99	42.30	24.45
WO-156	3457.27	3449.99		
WR-156	3450.62	3448.81		
WI-156	3444.55	3416.93		
WM-156	3421.90	3404.99	35.37	45.00
No overburden well				
WR-154	3465.06	3471.26		
WI-154	3461.68	3445.28		
WM-154	3433.78	3434.38	31.28	36.88
WO-103	3462.95	3462.98		
No Rosebud well				
WI-104	3444.60	3445.63		
WM-108	3429.00	3438.44	33.95	24.55
WO-176	3456.47	3441.01		
WR-112	3434.98	3440.05		
WI-176	3419.40	3409.04		
WM-176	3395.80	3398.57	60.67	42.44
WO-181	3483.20	3489.24		
WR-181	3457.91	3457.99		
WI-181	3452.41	3444.21	30.79	45.03
No McKay well				

Exhibit 8

Table GM-5
Simulated versus Target Head (feet) at Selected Vertical Well Groups
Rosebud Mine Groundwater Model

No overburden well				
WR-237	3477.61	3469.56		
No interburden well				
WM-198	3442.27	3435.52	35.34	34.04
WD-193	3427.62	3402.89	*	*
WO-187	3507.58	3506.84		
WR-234	3496.44	3506.67		
No interburden well				
WM-195	3439.19	3445.81	68.39	61.02
WO-185	3535.27	3552.59		
WR-233	3505.42	3506.92		
No interburden well				
WM-193	3483.86	3478.97	51.41	73.61
WO-101	3386.60	3379.63		
WR-100	3377.50	3379.38		
No interburden well				
WM-100	3364.80	3361.06	21.80	18.57
WO-164	3403.05	3411.28		
WR-164	3404.05	3411.33		
WI-164	3409.22	3402.42		
WM-164	3408.15	3398.44	-5.10	12.84
No overburden well				
WR-101	3304.40	3303.29		
No interburden well				
WM-106	3281.20	3289.86	23.20	13.44
WD-100	3262.00	3274.98	*	*
No overburden well				
WR-161	3333.54	3335.73		
WI-161	3331.27	3323.92		
WM-161	3314.20	3319.30	19.34	16.44

Table GM-5
Simulated versus Target Head (feet) at Selected Vertical Well Groups
Rosebud Mine Groundwater Model

WO-178	3510.84	3500.66		
WR-121	3470.90	3476.74		
WI-178	3435.88	3453.97		
WM-178	3409.06	3443.85	101.78	56.81
WO-179	3467.4	3449.48		
No Rosebud well				
WI-179	3433.78	3417.55		
WM-179	3411.36	3409.58	56.04	39.90
WO-181	3483.2	3489.24		
WR-181	3457.91	3457.99		
WI-181	3452.41	3444.21	30.79	45.03
No McKay well				
WO-169	3462.97	3465.54		
WR-169	3459.82	3465.35		
WI-169	3436.38	3443.77		
WM-169	3424.11	3436.68	38.86	28.86
No overburden well				
WR-173	3480.83	3467.36		
WI-173	3464.41	3451.11		
WM-173	3420.61	3444.93	60.22	22.43
WO-166	3472.81	3463.82		
No Rosebud well				
WI-166	3437.18	3441.59		
WM-113	3433.4	3434.29	39.41	29.53
WO-162	3385.9	3389		
WR-162	3384.34	3388.88		
WI-162	3386.64	3377.07		
WM-162	3386.7	3372.38	-0.80	16.62
No overburden well				
WR-126	3449.1	3469.7		
WI-153	3449.13	3446.83		
WM-153	3432.91	3433.16	16.19	36.54

Table GM-5
Simulated versus Target Head (feet) at Selected Vertical Well Groups
Rosebud Mine Groundwater Model

WO-155	3450.85	3446.96		
WR-122	3444.79	3446.49		
WI-155	3421.17	3424		
WM-155	3418.82	3414.99	32.03	31.97
WO-172	3495.25	3495.68		
WR-103	3490.3	3494.58		
WI-172	3458.82	3470.01	36.43	25.67
No McKay well				
Net average difference (feet)			**36.94**	**33.84**

* Not used for calculations in this table.

Table GM-6
Storativity Analysis Statistics

Target	Year	Difference in observed drawdown and simulated drawdown (a) Scenario 1 (b)	Scenario 2 (b)	Final Model (b)
ROSEBUD COAL TARGETS				
WR-101	1980	-9.90	-9.55	-9.78
	1985	-58.77	-17.04	-27.39
	Average	-34.34	-13.30	-18.58
WR-103	1980	-3.20	-3.20	-3.20
	1985	-0.74	-0.74	-0.74
	1990	-2.33	-2.24	-2.31
	1995	-2.97	-1.46	-2.52
	2000	-2.18	2.47	-0.30
	2005	-4.98	2.96	-1.52
	2010	-6.78	5.65	-0.69
	Average	-3.31	0.49	-1.61
WR-117	1980	-0.40	-0.40	-0.40
	1985	-12.98	-2.47	-5.11
	Average	-6.69	-1.43	-2.75
WR-121	1995	-0.93	-0.84	-0.91
	2000	1.02	1.38	1.11
	2005	-4.86	-0.50	-2.69
	2010	-7.80	1.22	-2.27
	Average	-3.14	0.31	-1.19
WR-124	1990	-0.79	-0.64	-0.75
	1995	-3.21	-1.50	-2.80
	2000	4.51	13.31	7.83
	2005	-4.87	5.82	0.27
	2010	-1.52	10.67	5.14
	Average	-1.18	5.53	1.94
WR-125	1995	0.41	1.10	0.53
	2000	2.17	4.77	2.75
	2005	-0.20	4.98	1.26
	2010	-3.32	5.05	-0.56
	Average	-0.23	3.97	1.00
WR-126	1980	0.00	0.00	0.00
	1985	-0.69	17.34	15.99
	1990	14.19	23.39	21.81

Table GM-6
Storativity Analysis Statistics

Target	Year	Difference in observed drawdown and simulated drawdown (a) Scenario 1 (b)	Scenario 2 (b)	Final Model (b)
	1995	21.67	28.03	26.38
	2000	23.89	29.75	28.13
	2005	24.89	30.48	28.93
	2010	28.28	33.59	32.11
	Average	16.03	23.23	21.91
WR-136	1985	0.00	0.00	0.00
	1990	-2.80	-2.64	-2.76
	1995	-6.68	-2.77	-5.16
	2000	-10.19	11.23	6.49
	2005	-0.73	6.78	2.74
	2010	-2.38	4.54	1.40
	Average	-3.80	2.86	0.45
WR-161	1985	-13.53	-4.44	-9.46
	1990	-35.62	-0.69	-8.78
	1995	-19.69	5.43	-0.97
	2000	-10.46	6.34	1.19
	Average	-19.82	1.66	-4.51
WR-162	1985	-1.09	-1.01	-1.07
	1990	-1.50	-0.36	-1.06
	1995	-2.38	0.43	-1.03
	2000	-8.67	6.25	2.70
	2005	1.51	11.77	8.44
	2010	4.13	9.97	7.95
	Average	-1.33	4.51	2.65
WR-164	1985	1.06	1.07	1.06
	1990	-0.04	0.10	0.02
	1995	-2.08	-1.07	-1.66
	2000	-6.03	1.32	-1.54
	2005	-1.73	5.86	2.89
	2010	-0.61	10.06	7.41
	Average	-1.57	2.89	1.36
WR-168	1990	-0.19	0.89	0.10
	1995	-1.29	10.59	3.67
	2000	1.13	25.99	17.77
	2005	13.28	27.62	22.69
	2010	15.85	31.93	28.47

Table GM-6
Storativity Analysis Statistics

Target	Year	Difference in observed drawdown and simulated drawdown (a) Scenario 1 (b)	Scenario 2 (b)	Final Model (b)
	Average	5.76	19.40	14.54
WR-173	1990	-0.59	-0.52	-0.57
	1995	-1.81	-1.02	-1.61
	2000	-7.26	0.77	-4.43
	2005	-7.28	3.97	-1.00
	2010	-5.36	4.75	0.40
	Average	-4.46	1.59	-1.44
314	1975	0.42	0.42	0.42
	1980	-6.58	3.22	-0.02
	Average	-3.08	1.82	0.20
339	1975	0.25	0.25	0.25
	1980	-0.24	-0.08	-0.20
	1985	-3.89	0.94	-2.36
	1990	-5.24	9.41	1.91
	1995	-2.85	12.50	5.22
	2000	1.27	14.52	8.44
	2005			
	2010	-18.54	2.95	-6.15
	Average	-4.17	5.78	1.01
122762	1975	-0.30	-0.30	-0.30
	1980	1.14	1.15	1.14
	1985	-2.33	-1.08	-1.94
	1990	-4.63	6.37	1.78
	1995	-2.19	8.74	3.80
	2000	0.31	11.20	6.64
	Average	-1.33	4.35	1.85
AVERAGE ROSEBUD COAL		**-2.16**	**5.45**	**2.58**
MCKAY COAL TARGETS				
WM-104	1980	-8.50	-6.28	-6.84
	1985	-6.20	1.17	-0.31
	1990	-13.78	-3.60	-5.25
	1995	-22.32	-10.15	-11.87
	2000	-15.10	-5.36	-6.82

Table GM-6
Storativity Analysis Statistics

Target	Year	Difference in observed drawdown and simulated drawdown (a) Scenario 1 (b)	Scenario 2 (b)	Final Model (b)
	2005	-11.34	-3.57	-4.84
	2010			
	Average	-12.87	-4.63	-5.99
WM-109	1980	0.50	0.50	0.50
	1985	2.48	2.49	2.49
	1990	-1.70	-1.53	-1.58
	1995	-1.85	-0.67	-1.00
	2000	-2.49	0.28	-0.44
	Average	-0.61	0.21	-0.01
WM-111	1995	1.16	1.37	1.31
	2000	1.90	2.46	2.28
	2005	0.13	2.74	2.07
	Average	1.06	2.19	1.89
WM-113	1985	0.40	0.48	0.45
	1990	-0.61	0.15	-0.08
	1995	-3.64	2.33	1.24
	Average	-1.28	0.99	0.54
WM-153	1985	-8.61	-5.40	-5.88
	1990	-10.75	1.00	-0.10
	1995	-7.72	8.19	6.92
	2000	-4.93	10.22	9.01
	2005	-3.22	9.88	8.79
	2010	0.87	12.28	11.24
	Average	-5.73	6.03	5.00
WM-157	1985	15.67	29.95	28.65
	1990	27.60	39.41	38.24
	1995	36.19	44.12	42.93
	Average	26.49	37.83	36.61
WM-162	1985	-2.00	-1.61	-1.71
	1990	-3.12	-0.85	-1.44
	1995	-3.27	1.38	0.38
	2000	-17.36	-7.38	-8.97
	2005	-16.23	-5.22	-6.97
	2010	-19.42	-7.75	-9.62

Table GM-6
Storativity Analysis Statistics

Target	Year	Difference in observed drawdown and simulated drawdown (a) Scenario 1 (b)	Scenario 2 (b)	Final Model (b)
	Average	-10.23	-3.57	-4.72
WM-168	1995	-4.57	6.51	3.87
	2000	-7.84	10.93	7.91
	2005	-4.43	13.02	10.49
	2010	-2.32	14.26	12.01
	Average	-4.79	11.18	8.57
WM-173	1985	1.20	1.23	1.22
	1990	0.46	0.72	0.64
	1995	-1.82	-0.20	-0.70
	2000	-7.85	-1.40	-3.48
	2005	-10.06	0.34	-2.44
	2010	-10.09	1.62	-1.28
	Average	-4.69	0.38	-1.01
WM-178	1985	0.84	0.84	0.84
	1990	0.51	0.55	0.54
	1995	-0.43	-0.19	-0.26
	2000	-0.79	-0.11	-0.36
	2005	-2.22	1.14	0.09
	2010	-5.57	1.61	-0.36
	Average	-1.28	0.64	0.08
WM-186	1985	0.58	3.92	3.40
	1990	0.54	11.42	10.34
	1995	7.04	21.16	20.01
	2000	9.22	22.87	21.74
	2005	9.75	22.11	21.02
	2010	14.41	25.66	24.58
	Average	6.92	17.86	16.85
WM-161	1985	-22.64	-16.14	-17.66
	1990	-27.01	-10.78	-13.30
	1995	-38.90	-22.24	-24.77
	2000	-44.16	-29.77	-32.13
	Average	-33.18	-19.73	-21.97
WM-164	1985	0.36	0.46	0.43
	1990	-2.34	-1.65	-1.83
	1995	-5.94	-3.11	-3.72

Table GM-6
Storativity Analysis Statistics

Target	Year	Difference in observed drawdown and simulated drawdown (a) Scenario 1 (b)	Scenario 2 (b)	Final Model (b)
	2000	-14.36	-7.14	-8.49
	2005	-15.29	-5.88	-7.64
	2010	-19.20	-8.25	-10.22
	Average	-9.46	-4.26	-5.24
311	1975	0.73	0.73	0.73
	1980	-3.04	1.66	0.62
	Average	-1.15	1.20	0.67
337	1975	0.05	0.05	0.05
	1980	-1.13	-0.51	-0.70
	1985	-23.50	-17.02	-18.87
	1990	-22.40	-9.28	-12.52
	1995	-14.34	0.15	-3.29
	2000	-11.31	2.02	-1.20
	2005			
	2010	-39.43	-22.25	-26.27
	Average	-16.01	-6.69	-8.97
123792	1975	1.26	1.26	1.26
	1980	2.40	2.51	2.48
	1985	-5.52	-3.40	-3.99
	1990	-9.19	-0.68	-2.59
	1995	-12.44	-1.43	-3.79
	2000	-13.11	-1.18	-3.70
	Average	-6.10	-0.49	-1.72
AVERAGE MCKAY COAL		**-5.71**	**1.48**	**0.27**
AVERAGE ALL TARGETS		**-3.95**	**3.45**	**1.42**

Notes

(a) If this difference is positive, the model overpredicts drawdown. If the difference is negative the model underpredicts drawdown.

(b) Scenario 1: storativity in all layers was set to 0.01.
Scenario 2: storativity was kept at 0.01 in layer 1 and set to 0.001 in layers 2-5.
Final model: storativity in was set to 0.01 layer 1 and 2 and 0.001 in layer 3 through 5.
The storativity of the spoils in all cases was set to 0.1.

Table GM-7
Simulated Mine Discharge Rates Over Time - Existing Permit Rosebud Mine Area A, B and C

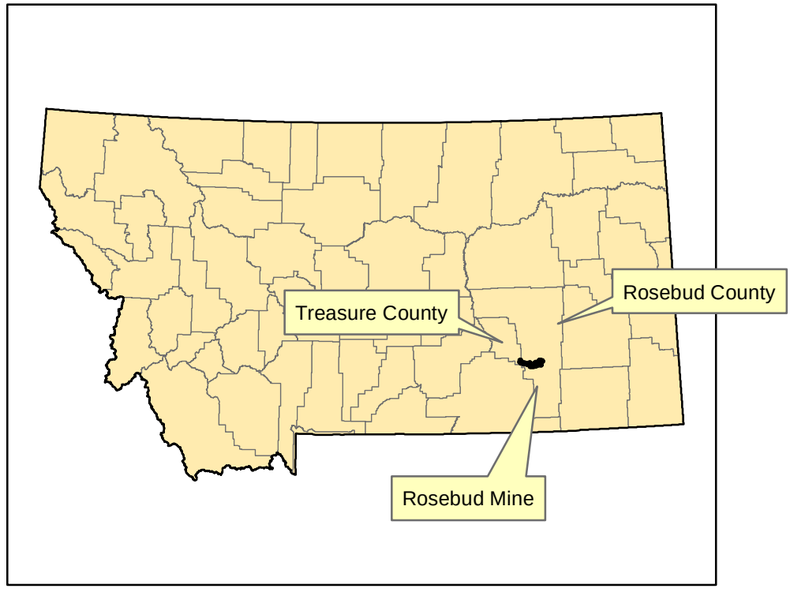
Year	Area A			Area B			Area C		
	Discharge*	Discharge*	Cumulative Average Discharge**	Discharge*	Discharge*	Cumulative Average Discharge**	Discharge*	Discharge*	Cumulative Average Discharge**
	ft^3/d	gpm	gpm	ft^3/d	gpm	gpm	ft^3/d	gpm	gpm
1975	4787	25	25						
1976	7818	41	33						
1977	5937	31	32	19383	101	101			
1978	16540	86	46	11416	59	80			
1979	20245	105	57	8063	42	67			
1980	17186	89	63	5620	29	58			
1981	8428	44	60	43390	225	91			
1982				33750	175	105			
1983				81298	422	151	868	5	5
1984				45948	239	162	21031	109	57
1985	12157	63	60	35791	186	164	6515	34	49
1986	7892	41	58	31176	162	164	13598	71	55
1987	19891	103	63	21044	109	159	18055	94	62
1988	8481	44	61	6751	35	149	29644	154	78
1989	5720	30	58	6597	34	140	33358	173	91
1990	7976	41	57	16493	86	136	41158	214	107
1991	7412	39	56	13378	69	132	37701	196	117
1992	9368	49	55				44046	229	128
1993	7671	40	54				32422	168	131
1994	6657	35	53				33363	173	135
1995	1692	9	51	43450	226	138	27842	145	136
1996				7007	36	132	20859	108	134
1997				12990	67	128	441	2	125
1998				10684	55	124	12624	66	121
1999				24307	126	124	5513	29	116
2000	856	4	48	40229	209	128	10234	53	112
2001				24060	125	128	18750	97	112
2002				11676	61	125	7107	37	108
2003				20275	105	124	7920	41	105
2004				34105	177	127	16412	85	104
2005				36490	190	129	14975	78	103
2006				41256	214	132	26924	140	104

Table GM-7
Simulated Mine Discharge Rates Over Time - Existing Permit Rosebud Mine Area A, B and C

Year	Area A			Area B			Area C		
	Discharge*	Discharge*	Cumulative Average Discharge**	Discharge*	Discharge*	Cumulative Average Discharge**	Discharge*	Discharge*	Cumulative Average Discharge**
	ft^3/d	gpm	gpm	ft^3/d	gpm	gpm	ft^3/d	gpm	gpm
2007				26377	137	132	15676	81	103
2008				25558	133	132	38575	200	107
2009				14635	76	130	19979	104	107
2010				23069	120	130	30363	158	109
2011							14309	74	108
2012							37436	194	110
2013	1823	9	46	22713	118	130	22357	116	111
2014	2779	14	45	35514	184	131	8951	46	109
2015	1768	9	43	31846	165	132	4710	24	106
2016	7918	41	43	41390	215	135	7857	41	104
2017	720	4	41	57550	299	139	35572	185	106
2018	2323	12	40	29513	153	140	22533	117	107
2019	6416	33	40	4732	25	137			
2020	0	0	39	71125	369	143			

Notes
* Mean simulated discharge
**Cumulative is calculated per mine area and does not include non-mining years (or areas of no active mine passes)

Figures



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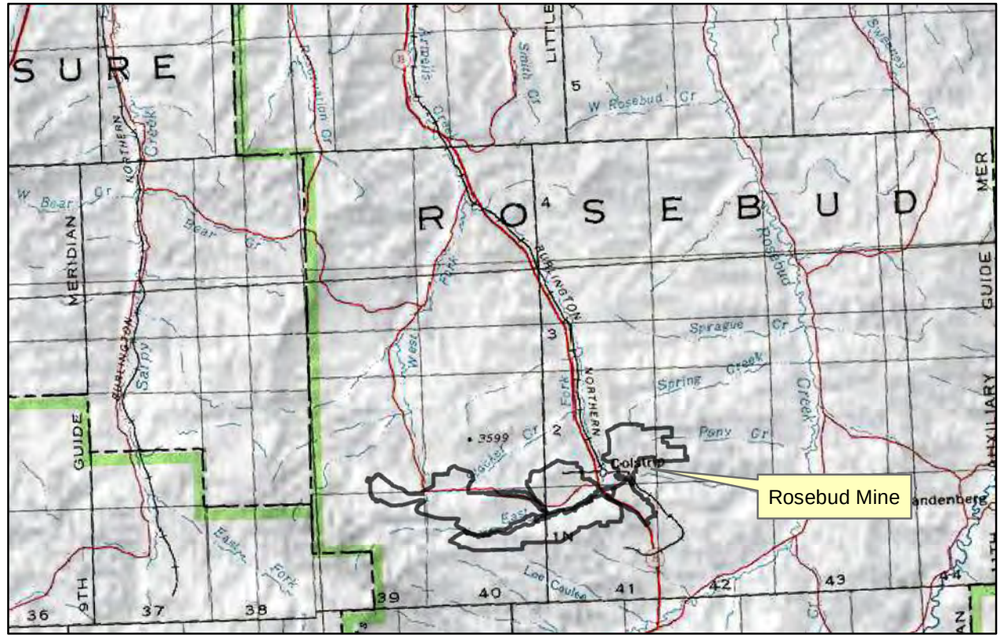

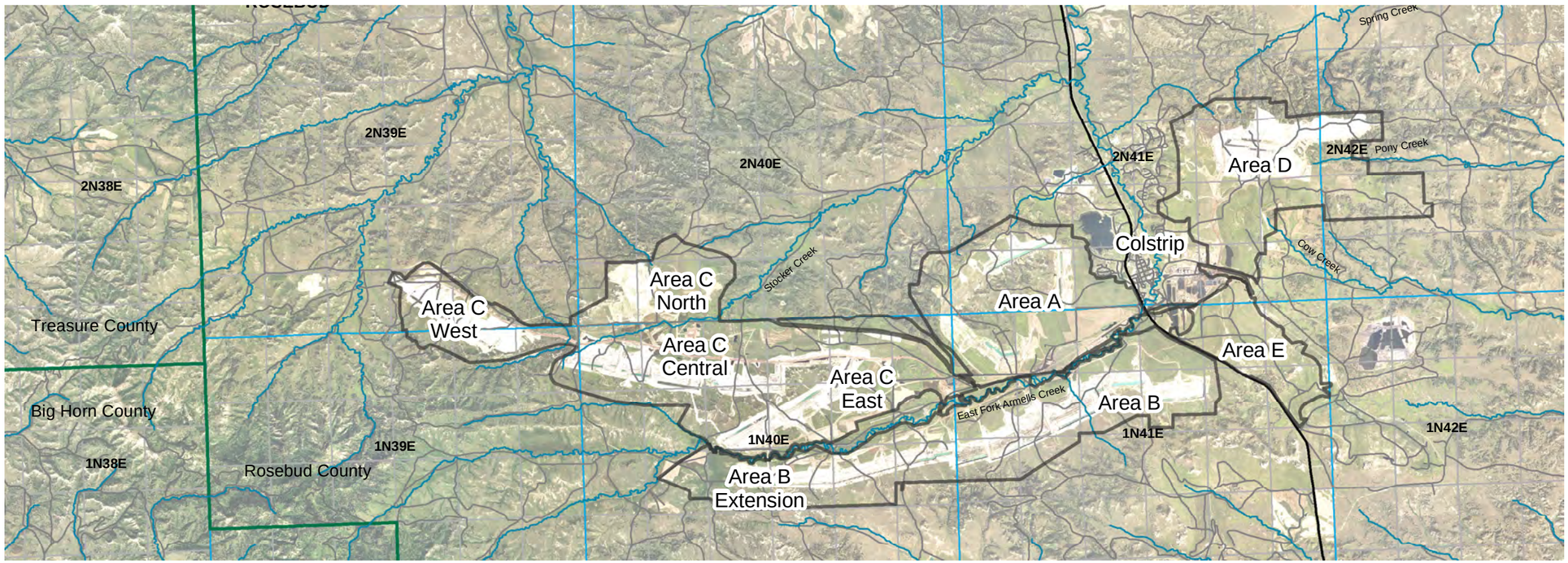

NICKLIN EARTH & WATER, INC.

Date: 2/3/2014 File: Figure GM01 - Site Map

Notes:
1) Aerial Photographs: 2011 NAIP

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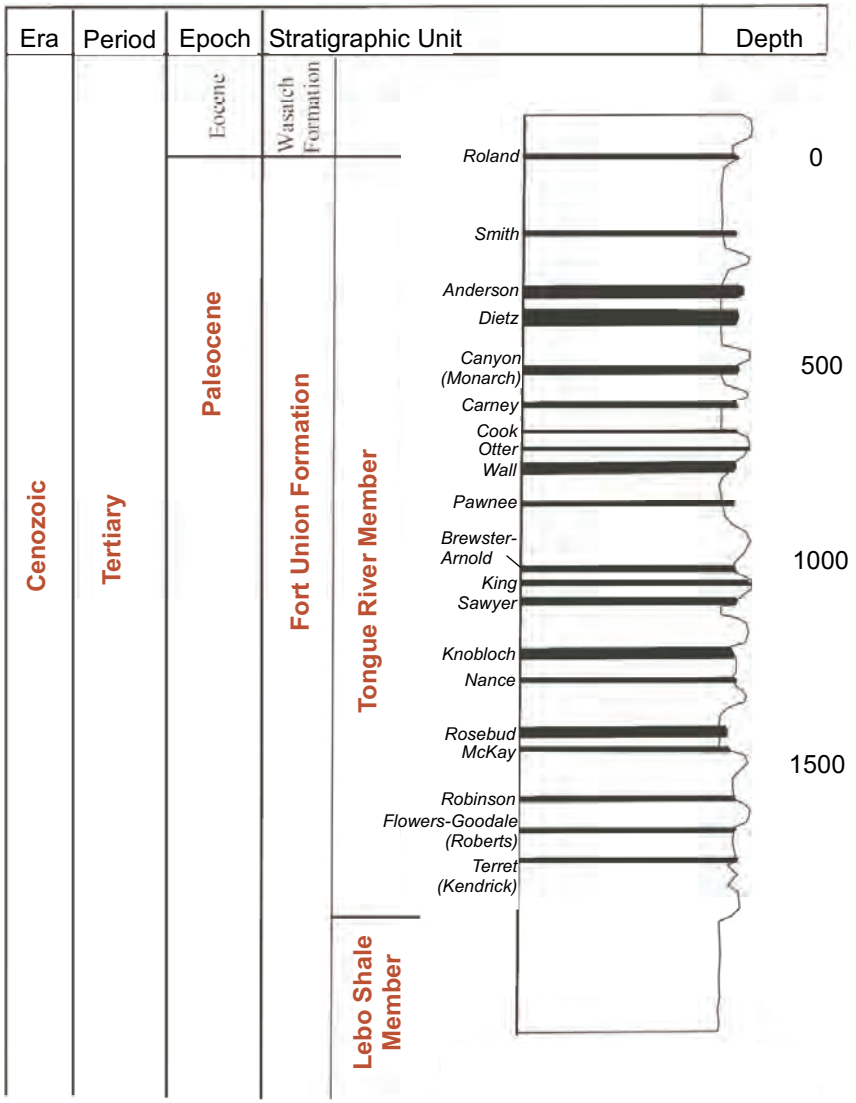
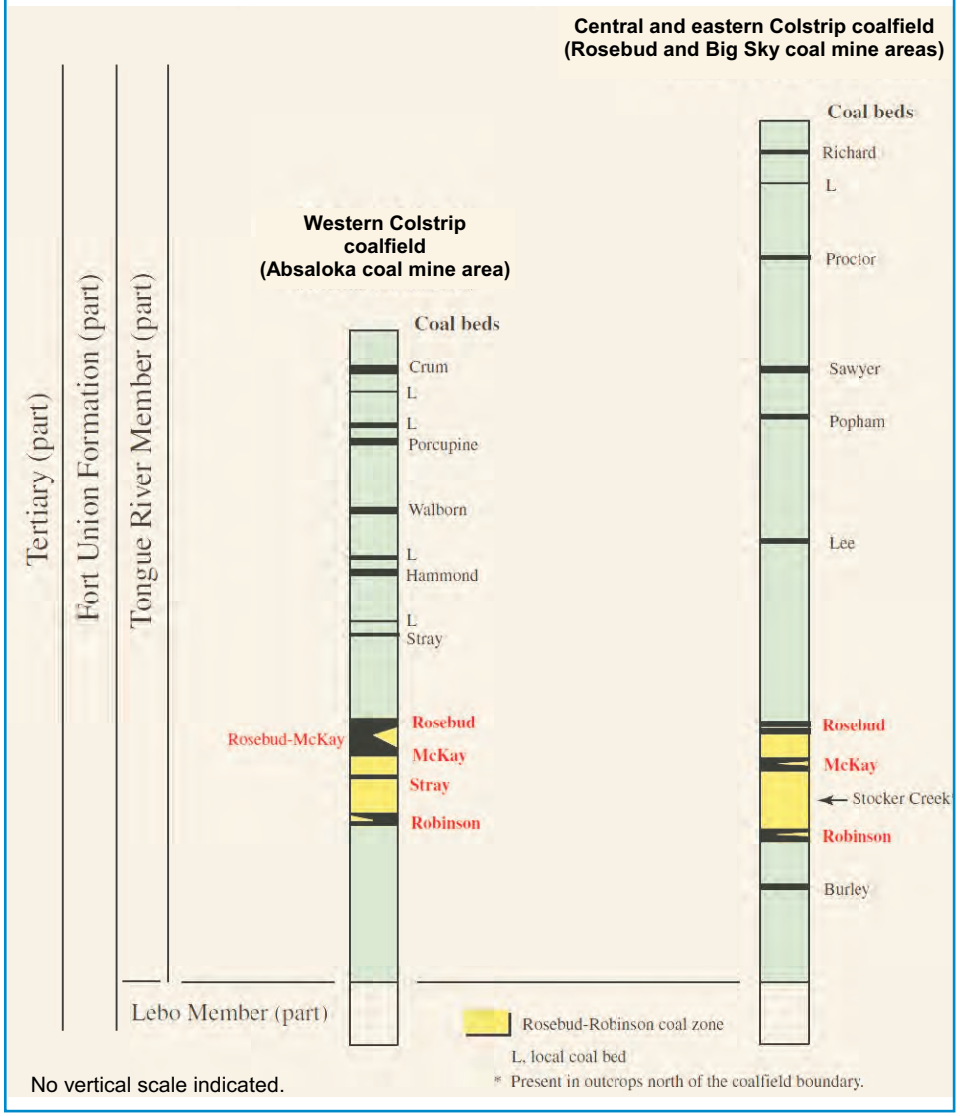
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-1
Site Map
Western Energy Rosebud Mine

Exhibit 8



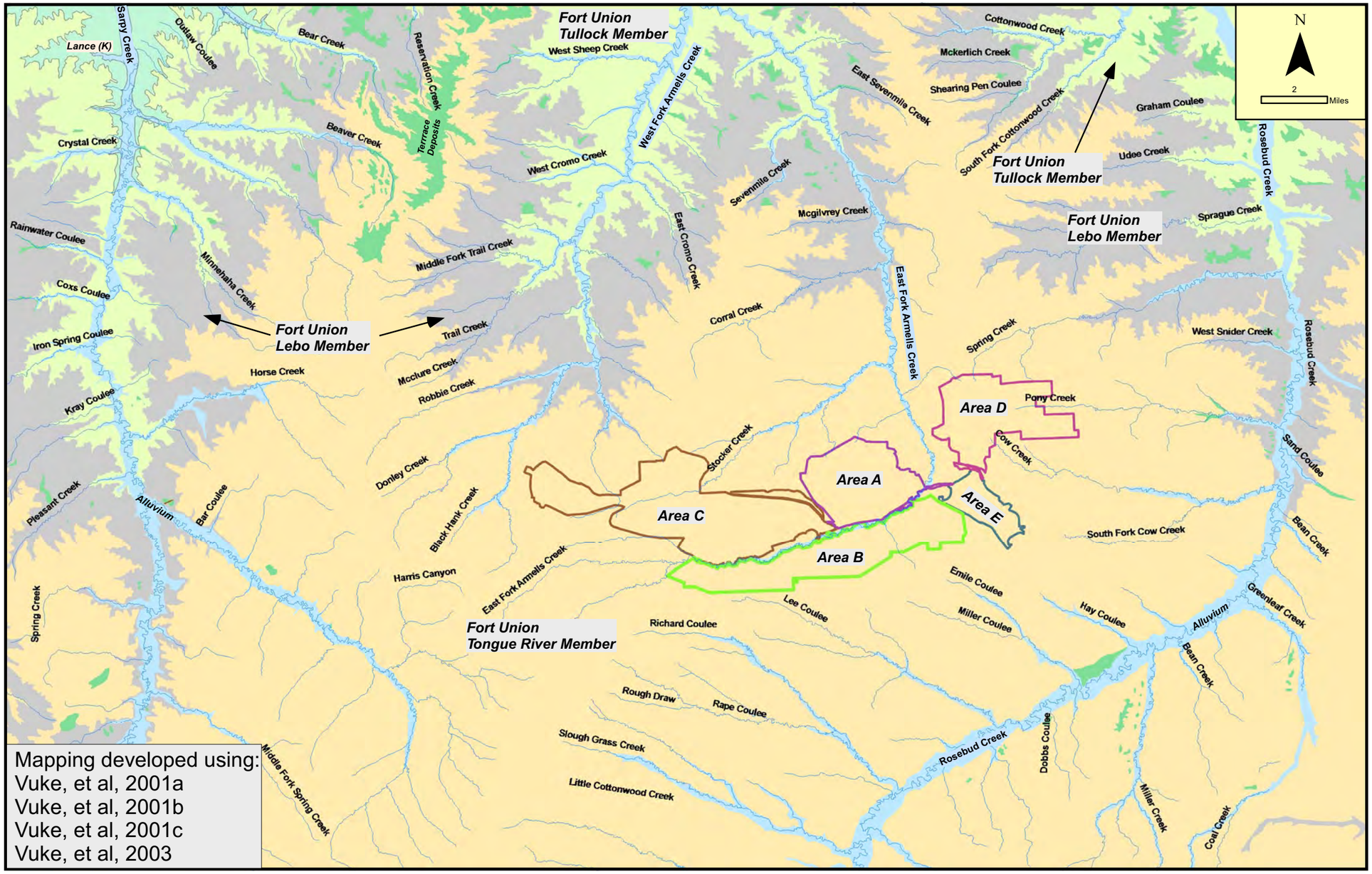
Coal beds of the Tongue River Member - Powder River Basin. Not all coals exist across the entire basin (after Wheaton, et al, 2006).



Coal beds vicinity of Rosebud Mine (from Roberts, et al, 1999).

Date: July 31, 2013 d://figure GM-02 By: MEN Issued for Western Energy	NICKLIN EARTH & WATER, INC.	**Geologic Section Map** **Rosebud Mine**	**Figure GM-2**

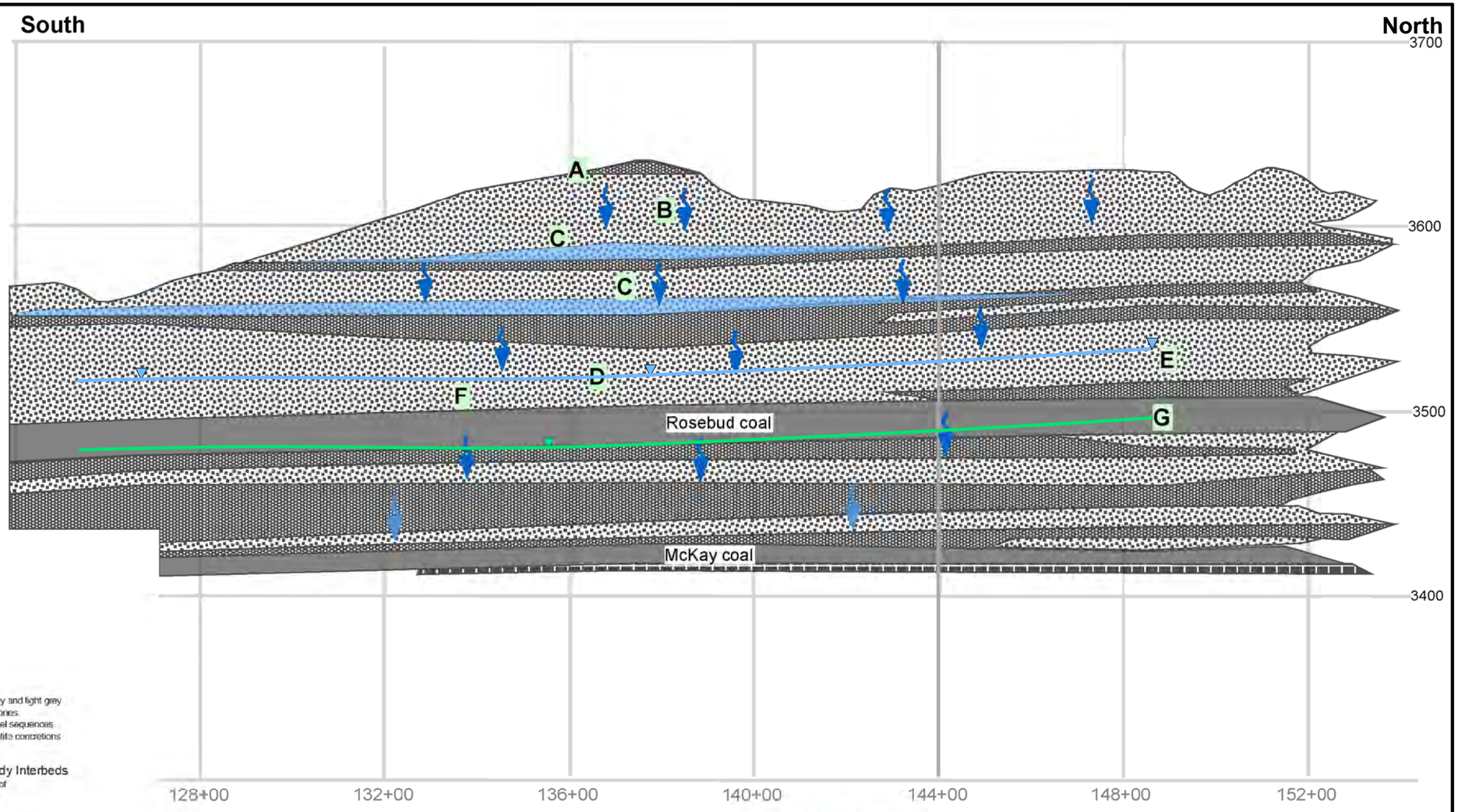
Exhibit 8



Mapping developed using:
Vuke, et al, 2001a
Vuke, et al, 2001b
Vuke, et al, 2001c
Vuke, et al, 2003

Date: July 31, 2013 **D://figure GM-3 By: MEN** **Issued for Western Energy**	**NICKLIN** **EARTH & WATER, INC.**	**Geology Outcrop Map** **Western Energy Company - Rosebud Mine Vicinity**	**Figure GM-3**

Exhibit 8



LEGEND

Fort Union Formation - Sandstone
Predominantly light yellow-brown where weathered to grey and light grey where unweathered. Fine to very fine grained silty sandstones. Frequently massive where numerous crossbedded channel sequences are stacked and interbedded. May contain pyrite or hematite concretions and disseminated pyrite.

Fort Union Formation - Mudstone with Thin Sandy Interbeds
Predominantly sandy mudstone with thin bands to lenses of intercolated very fine sand material representing transition from lower energy to higher energy deposits.

Fort Union Formation - Mudstone
Predominately grey to dark grey, silty to sandy claystone with sparse to moderate carbonaceous content. Commonly includes dark to very dark carbonaceous clay intervals with notable pyrite content.

Fort Union Formation - Coal (Rosebud and McKay Beds)
Predominantly hard, brittle, dull, subbituminous coal with some mudstone bands and laminations. Sparse to abundant secondary pyrite, most common near top and bottom contacts with enclosing sediments. "Where burned near outcrops forms baked and fused material in overlying units." Often poor and soft where exposed to oxidation by near surface weathering.

Adapted from EXHIBIT_Q3_GEO_XSEC_200111026 for conceptual illustration purposes, i.e., the potentiometric heads and perched zones should be considered conceptual only.

A- *Recharge at surface.*
B- *Infiltration/percolation to lower strata.*
C- *Potential perched zones*
D- *Potentiometric head, Rosebud coal (RC).*
E- *RC potentially locally confined by overlying mudstone*
F- *RC potentially locally unconfined by presence of overlying sandstone.*
G- *Potentiometric head, McKay coal.*

Date: May 23, 2013
D://figure GM-04 By: MEN
Issued for Western Energy

NICKLIN
EARTH & WATER, INC.

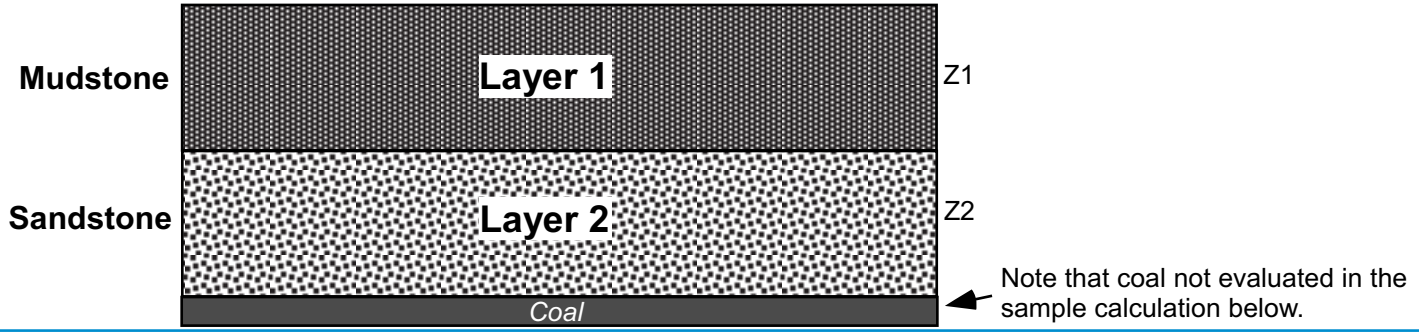
Conceptualization of Vertical Groundwater Leakage Overburden to Rosebud Coal

Figure GM-4

Exhibit 8

A

Conceptual two layer model with layers of identical thickness ($z_1 = z_2$).



Assume that $K_v = 0.1K_h$ **B**

Furthermore, assume that K of mudstone is about the same as shale. According to Delft Design Manual (Hydrology Project, Government of the Netherlands (2003)), a representative value of hydraulic conductivity for shale is 10^{-7} m/day or 3.28×10^{-7} ft/day.

Applying these assumptions yields the following vertical and horizontal conductivity values.

$K_{x1} = 3.28 \times 10^{-7}$ ft/d; ***$K_{z1} = 3.28 \times 10^{-7}$*** ft/d (note that no vertical anisotropy is assumed for the mudstone).

$K_{x2} = 3$ ft/d; ***$K_{z2} = 0.3$*** (note that the vertical to horizontal anisotropy ratio for the sandstone is assumed as 0.1).

According to Todd (1980), a classic groundwater hydraulics reference, the equivalent horizontal hydraulic conductivity of n layer system can be defined as follows:

$$Kx = \frac{K_1z_1 + K_2z_2 + \ldots . K_nz_n}{z_1 + z_2 + \ldots .+ z_n}$$ **C**

Furthermore, according to Todd, the equivalent horizontal hydraulic conductivity of n layer system can be defined as follows:

$$Kz = \frac{z_1 + z_2 + \ldots .+ z_n}{z_1/K_1 + z_2/K_2 + \ldots .+ z_n/K_n}$$ **D**

E===>

For the example above, and assuming a two layer model and applying the relationships from Todd (**C** and **D**), this would yield the following respective effective horizontal and vertical hydraulic conductivities:

K_x = 1.50 feet per day (the effective horizontal hydraulic conductivity of the two-layer system)

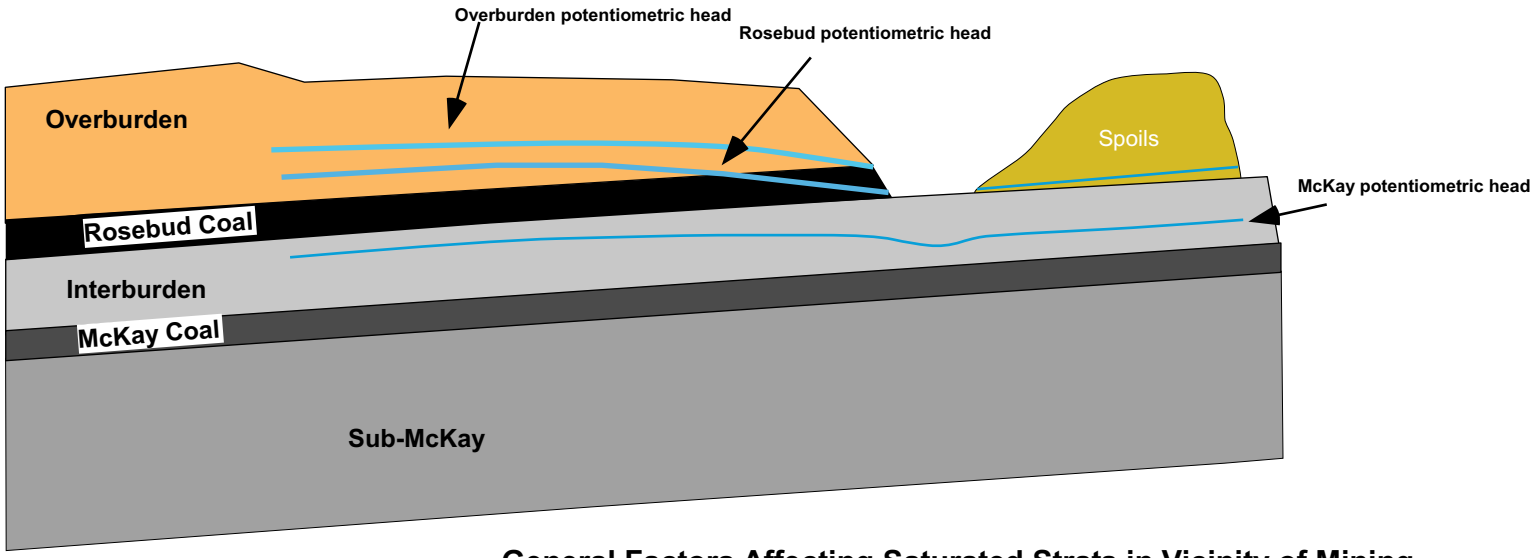
$K_z = 6.56 \times 10^{-7}$ feet per day (the effective vertical hydraulic conductivity of the two-layer system)

or the effective vertical anistropy ratio (K_z/K_x) is 4.37×10^{-7}.

Note that in the event if either of the vertical to horizontal anisotropy ratios exhibited in **A** and **B** were smaller, then each of the latter two values would be smaller accordingly.

Date: April 23, 2013 d://figure GM-5 By: MEN Issued for Western Energy	NICKLIN EARTH & WATER, INC.	**Conceptual Illustration Defining Effective Hydraulic Conductivities and Vertical Anisotropy Ratio Multilayer Geologic Unit**	Figure GM-5

Exhibit 8



General Factors Affecting Saturated Strata in Vicinity of Mining

1. Saturated portions of Overburden and Rosebud Coal are dewatered during mining. Hence, ground-water levels for exposed strata near the mine pass decline.
2. Some change in potentiometric head may be induced in the underlying McKay coal.
3. Any such change is dependent upon the degree of vertical hydraulic conductivity of the interburden which defines the connectivity between the Rosebud Coal and the McKay Coal.
4. Ground-water levels will begin to recover in the remaining spoils after mining proceeds onward.

Hydrogeologic Unit	Discharge Capacity	Transmissivity (ft^2/d)				Storage Coefficient
		Low	High	Mean	Median	
Alluvium (Armells Creek)	Moderate yields	0.8	10,000	1,680	1,324	[0.1 to 0.3]
Overburden	Low to very low yields	0.13	10,600	1,200	7.6	[.006 to 0.03]
Rosebud Coal	Low to very low yields	0.4	1,700	70	4	[0.000015; inapplicable for gravity drainage].
Interburden	Low to very low yields	0.13	28	5.75	0.94	[no data in EIS]
McKay Overburden		30.8	348	201	76	[no data in EIS]
McKay Coal	Low yields	0.13	74.9	19.65	13.9	[no data in EIS]
Sub-McKay	Low yields	12	428	115	62.3	[no data in EIS]
Spoils	Low to very low yields	0.2	3,130	267	8.2	[no data in EIS, assume from 0.1 to 03.]

Parameter values in table adapted from Environmental Impact Statement for Area C, Block I Mine (Montana Department of State Lands, August 2, 1982).

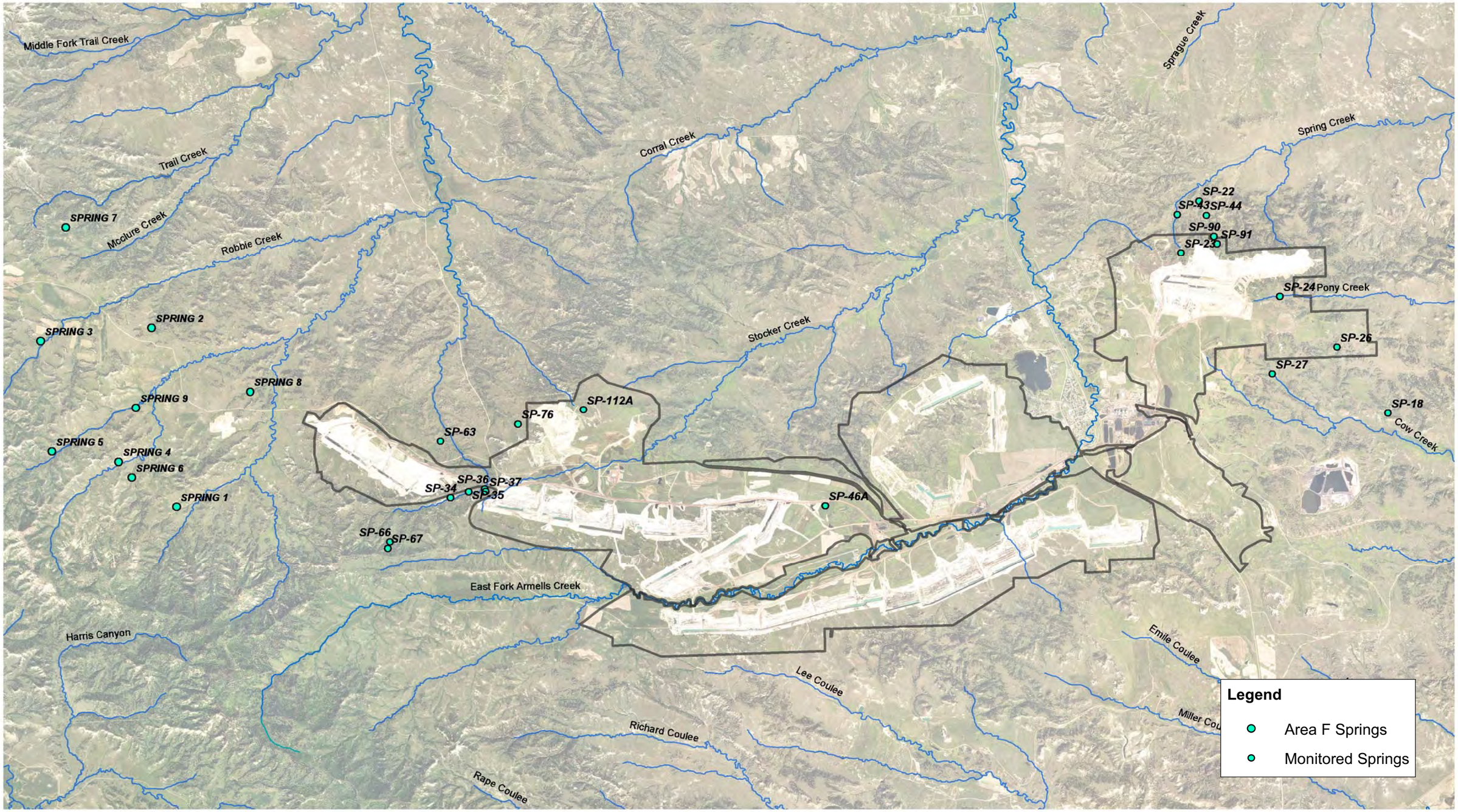
Date: March 31, 2013
C://figure GM-06 By: MEN
Issued for Western Energy

NICKLIN EARTH & WATER, INC.

Mining Process as it Affects Hydrogeologic Units and Typical Hydraulic Characteristics of Strata Rosebud Mine

Figure GM-6

Exhibit 8



NICKLIN EARTH & WATER, INC.

Miles
0 0.55 1.1

Date: 5/23/2013

Name: Figure GM07 - Springs

N

Notes:
1) Aerial Photographs: 2011 NAIP

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A Subsidiary of WESTMORELAND COAL COMPANY
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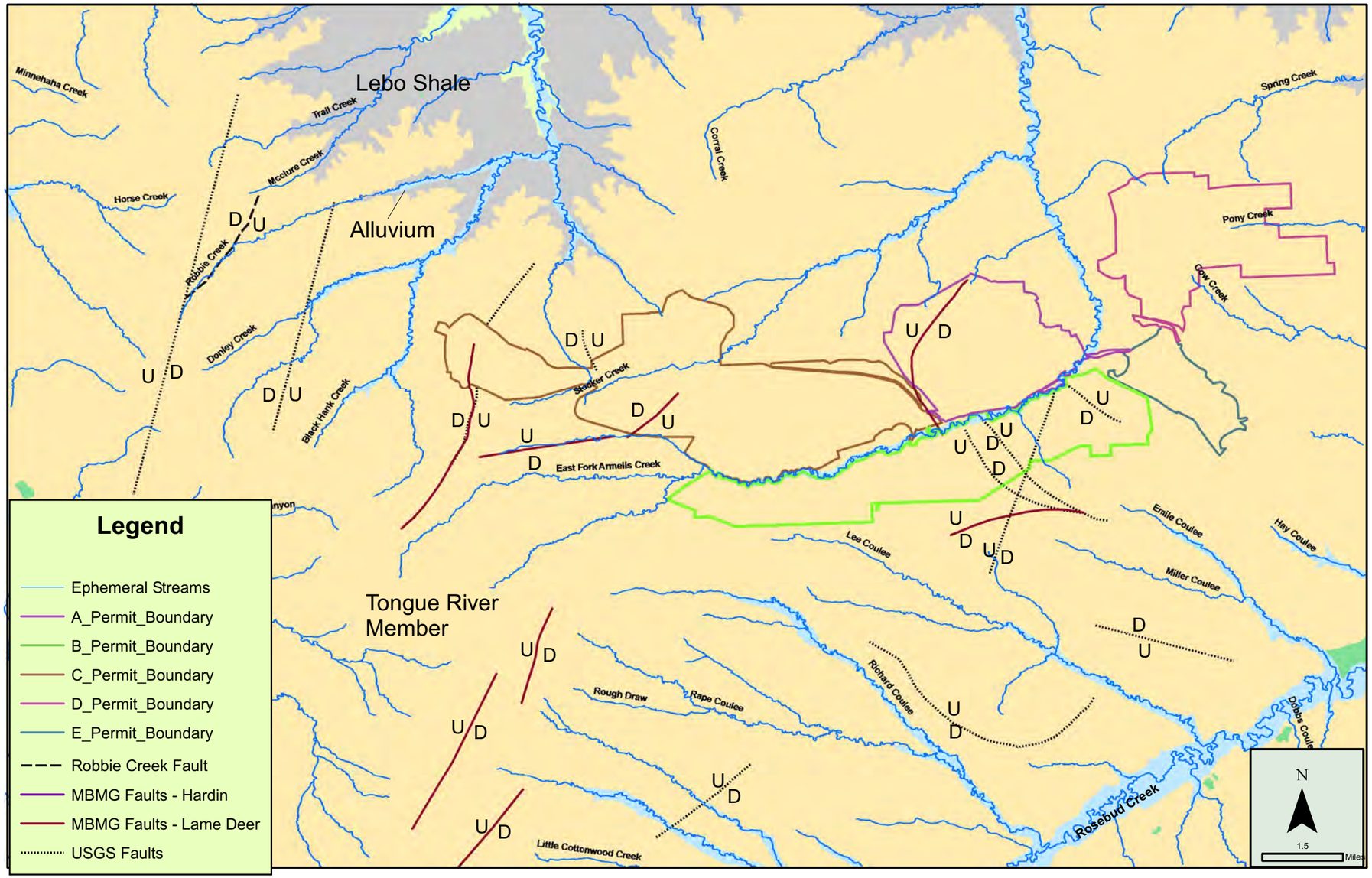
Figure GM-7
Monitored Springs
Western Energy Rosebud Mine

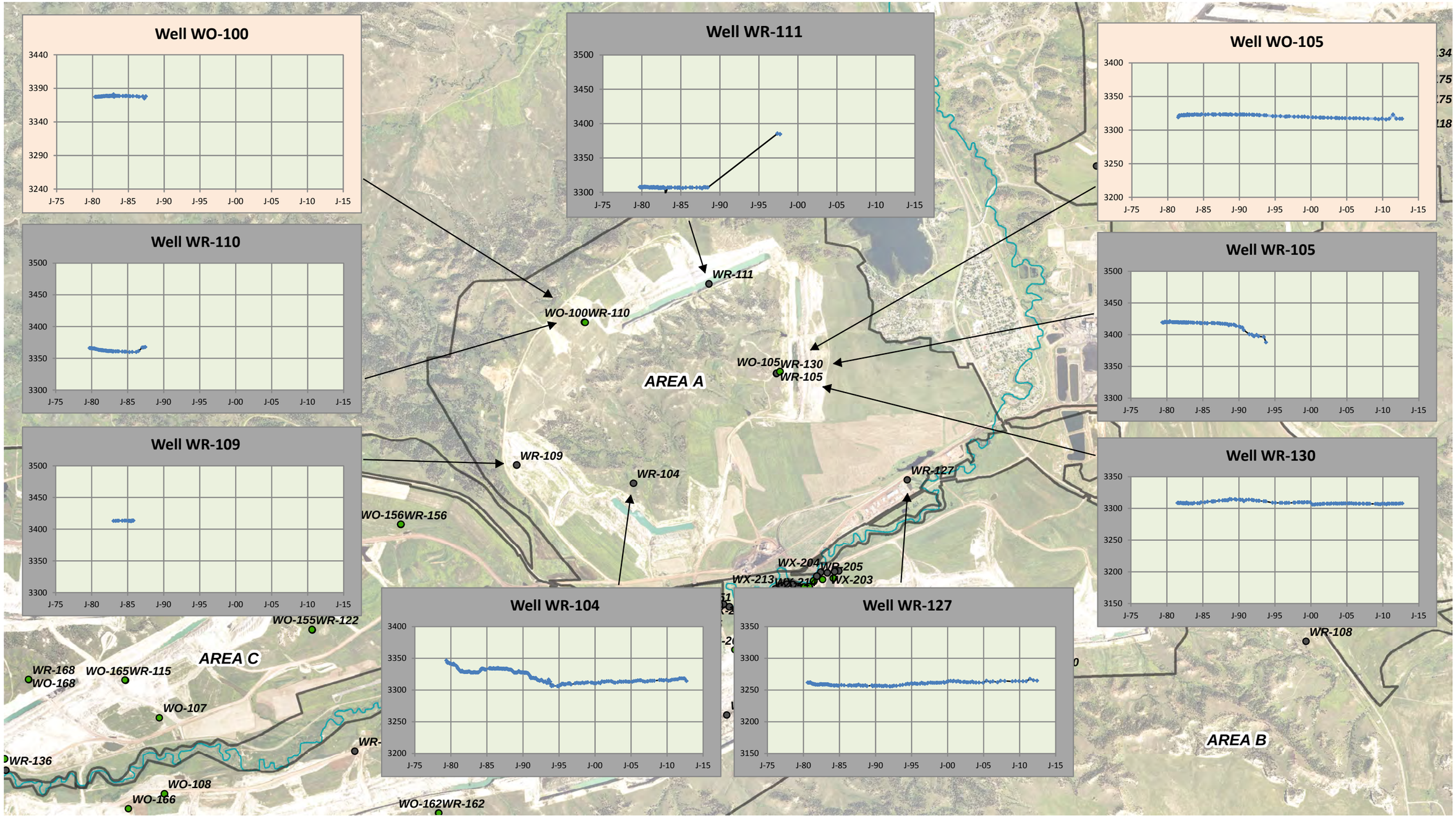
Exhibit 8



Note: Dashed where inferred.

Date: July 31, 2013 **D://figure GM-08 By: MEN** **Issued for Western Energy**	**NICKLIN** **EARTH & WATER, INC.**	**Fault Alignments** **Western Energy Company - Rosebud Mine Vicinity**	**Figure GM-8**

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

Date: 5/21/2013

Name: Fgure GM09_ P1 - Area A Hydrographs - Overburden and Rosebud Coal

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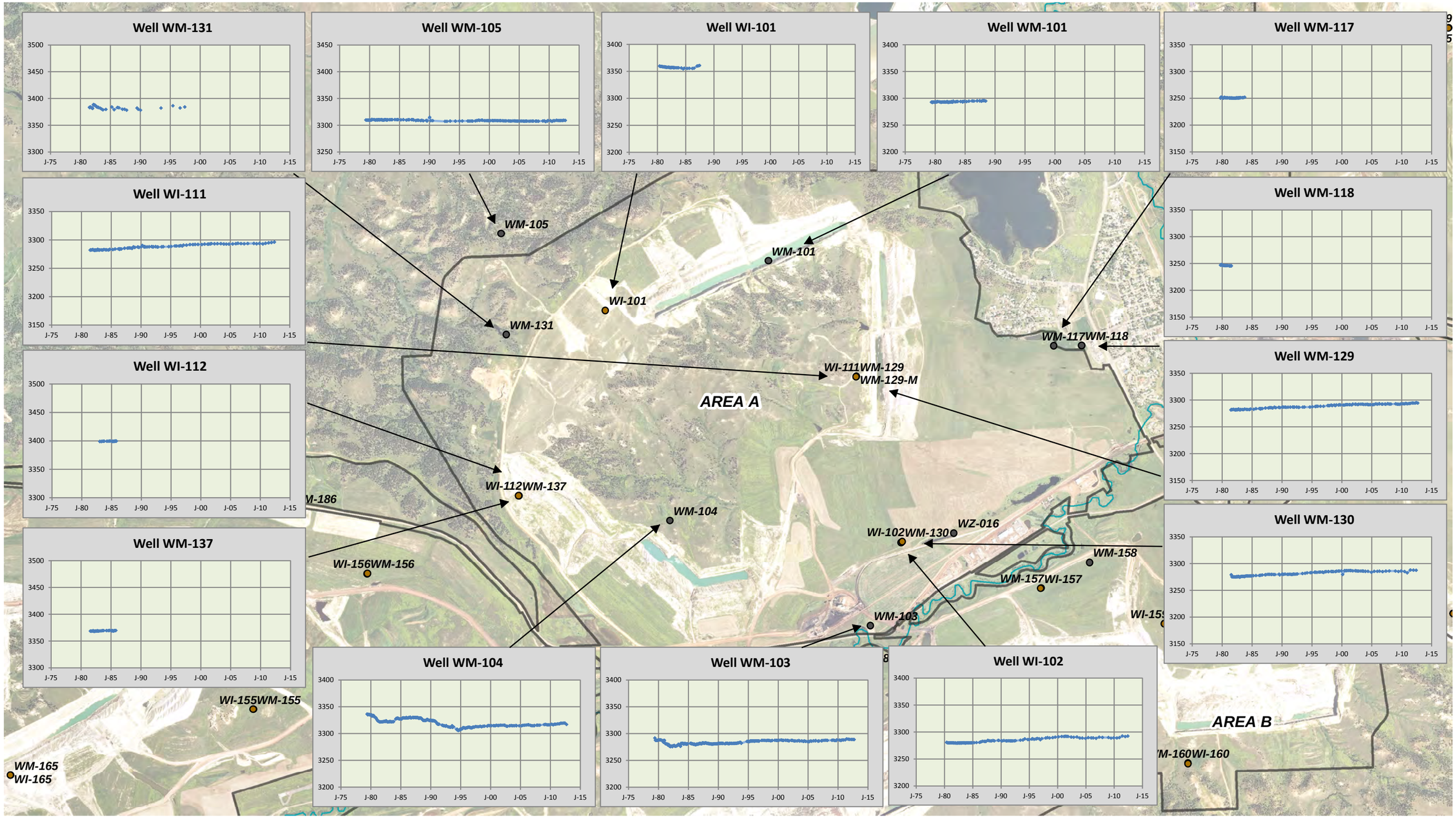
Figure GM-9 - Page 1
Area A - Hydrographs
Overburden and Rosebud Coal
Western Energy Rosebud Mine

Exhibit 8



NICKLIN EARTH & WATER, INC.

Miles
0 0.25 0.5

N

Notes:
1) Aerial Photographs: 2011 NAIP

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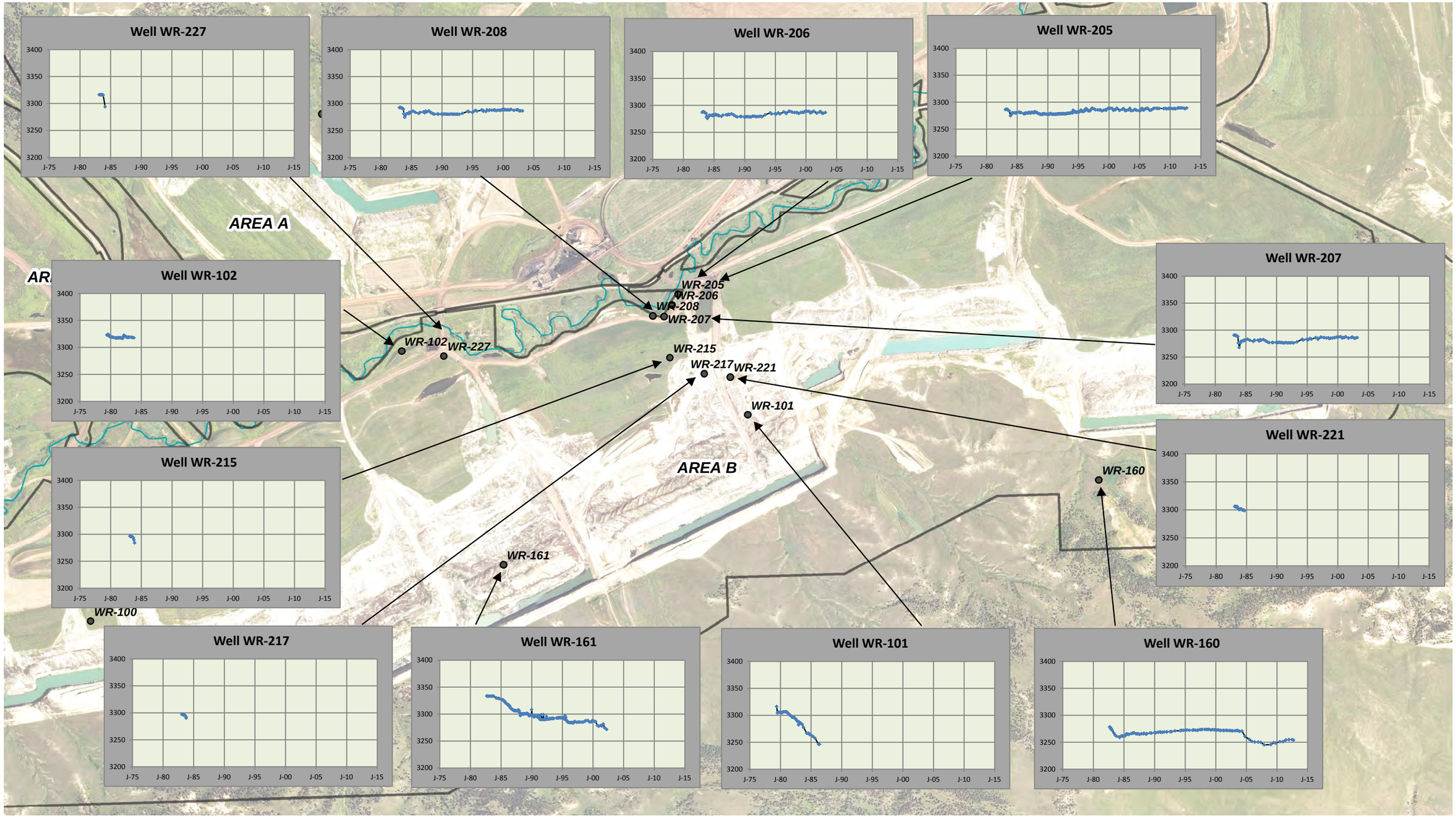
Figure GM-9 - Page 2
Area A - Hydrographs
Interburden and McKay Coal
Western Energy Rosebud Mine

Exhibit 8

Date: 5/21/2013

Name: Figure GM09_P2 - Area A Hydrographs - Interburden and McKay Coal



NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

Date: 5/23/2013

Name: Figure GM10_P1 - Area B Hydrographs - Rosebud coal

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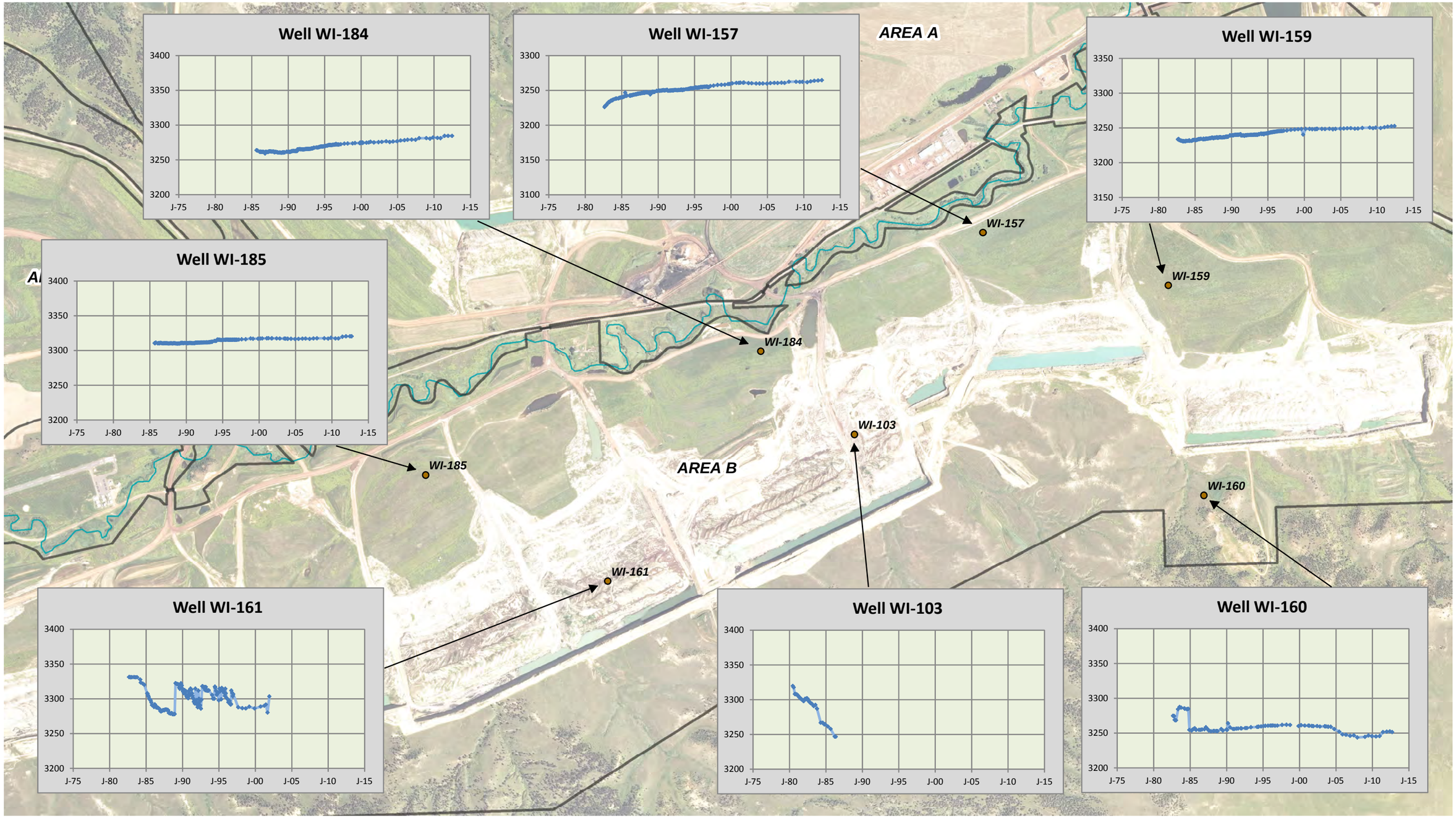
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-10 - Page 1
Area B - Hydrographs
Rosebud Coal
Western Energy Rosebud Mine

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

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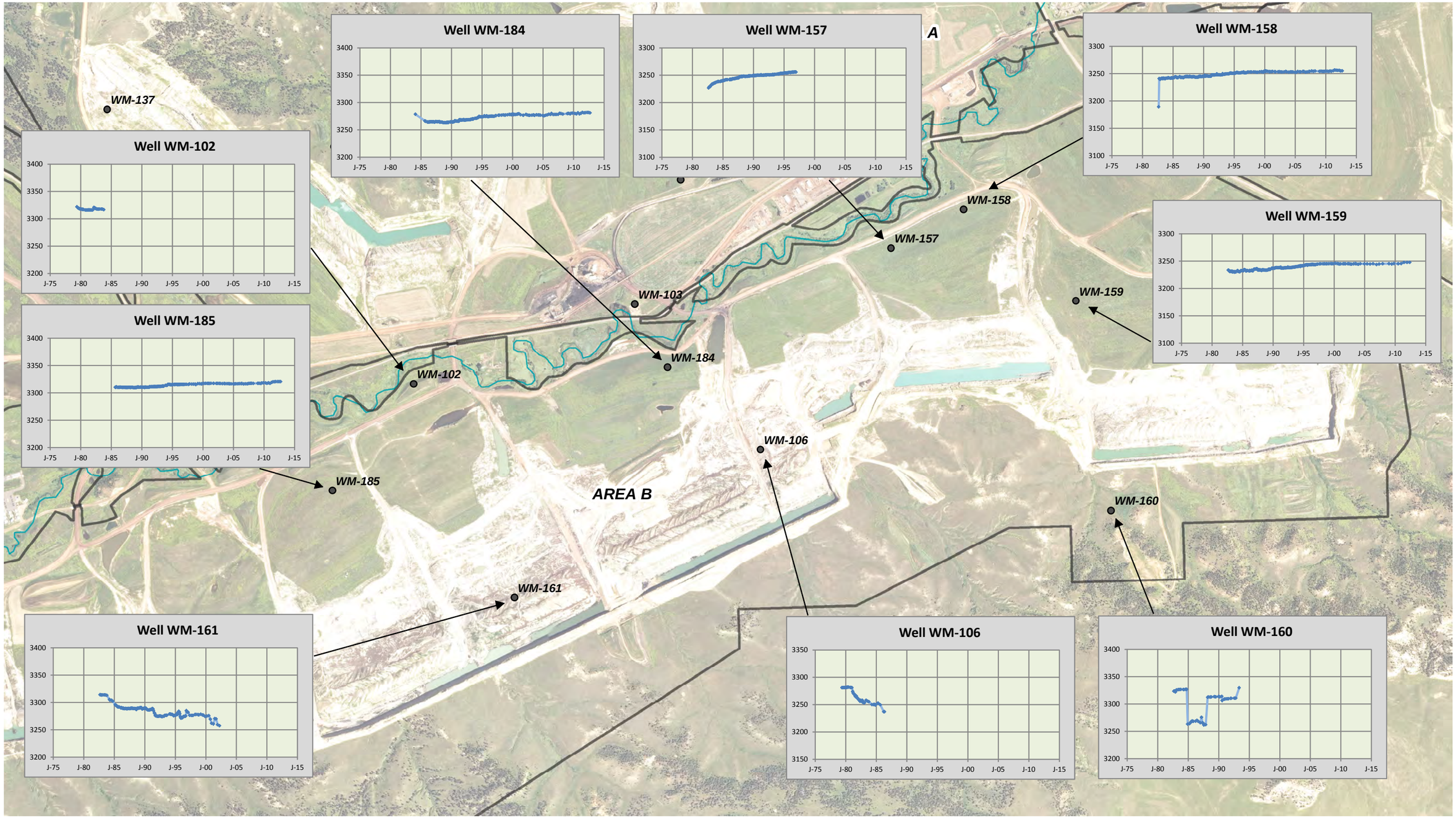
Figure GM-10 - Page 2
Area B - Hydrographs
Interburden
Western Energy Rosebud Mine

Exhibit 8

Date: 5/23/2013

Name: Figure GM10_P2 - Area B Hydrographs - Interburden



NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

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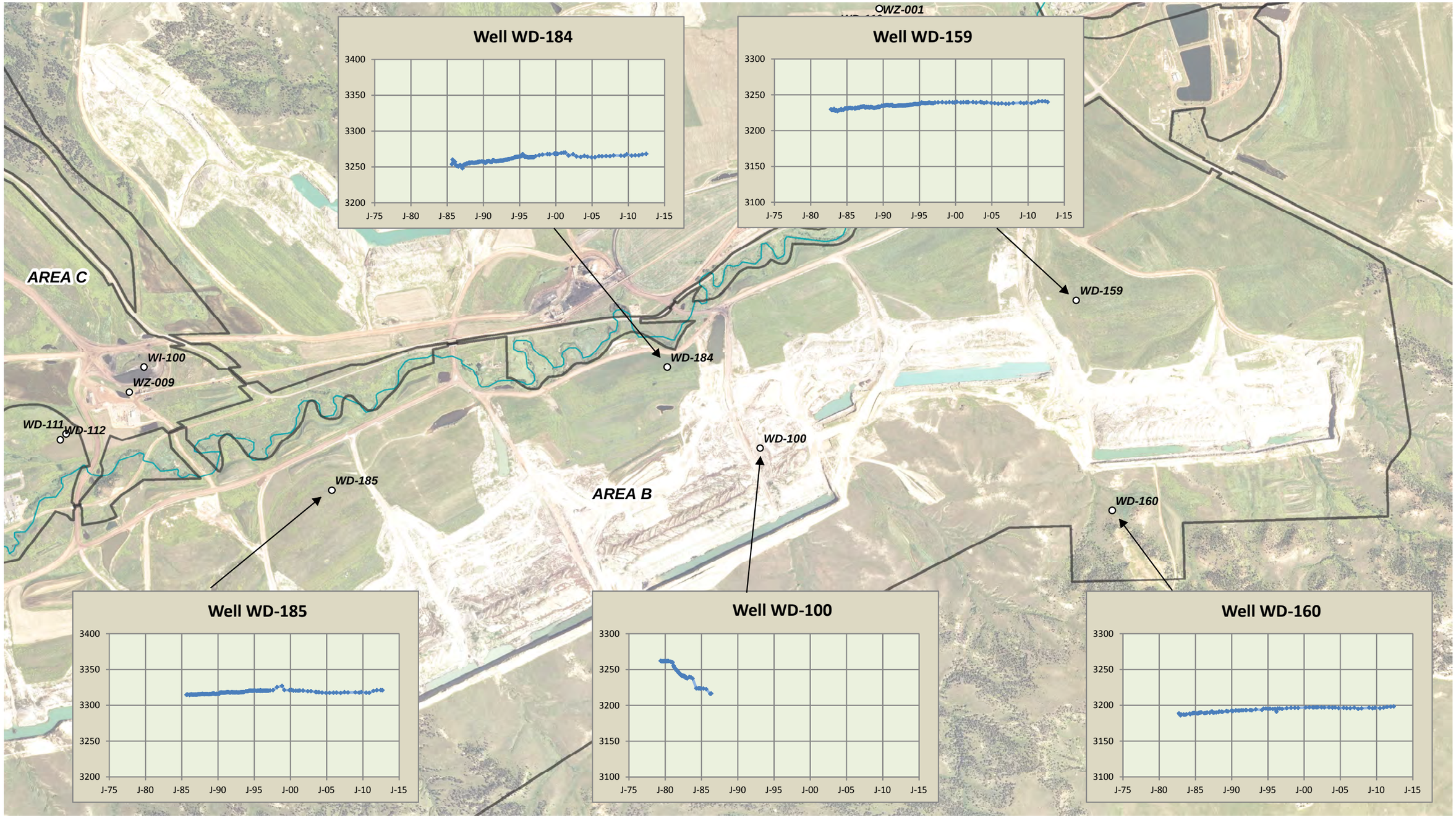
Figure GM-10 - Page 3
Area B - Hydrographs
McKay Coal
Western Energy Rosebud Mine

Date: 4/1/2013

Name: Figure GM10_P3 - Area B Hydrographs - McKay Coal

Exhibit 8



NICKLIN EARTH & WATER, INC.

Miles
0 0.25 0.5

N

Notes:
1) Aerial Photographs: 2011 NAIP

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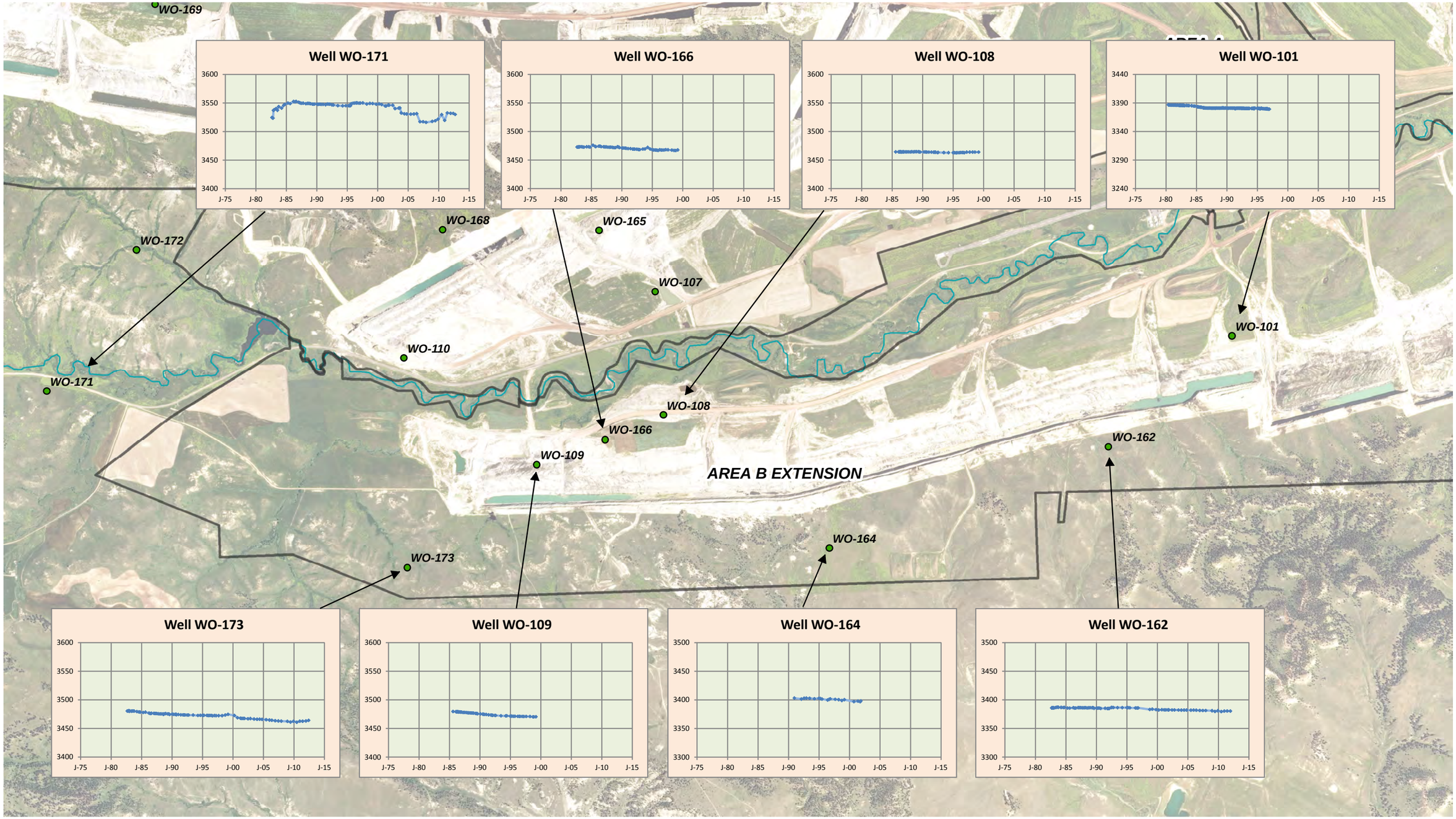
Figure GM-10 - Page 4
Area B - Hydrographs
SubMcKay
Western Energy Rosebud Mine

Date: 5/23/2013

Name: Figure GM10_P4 - Area B Hydrographs - SubMcKay

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

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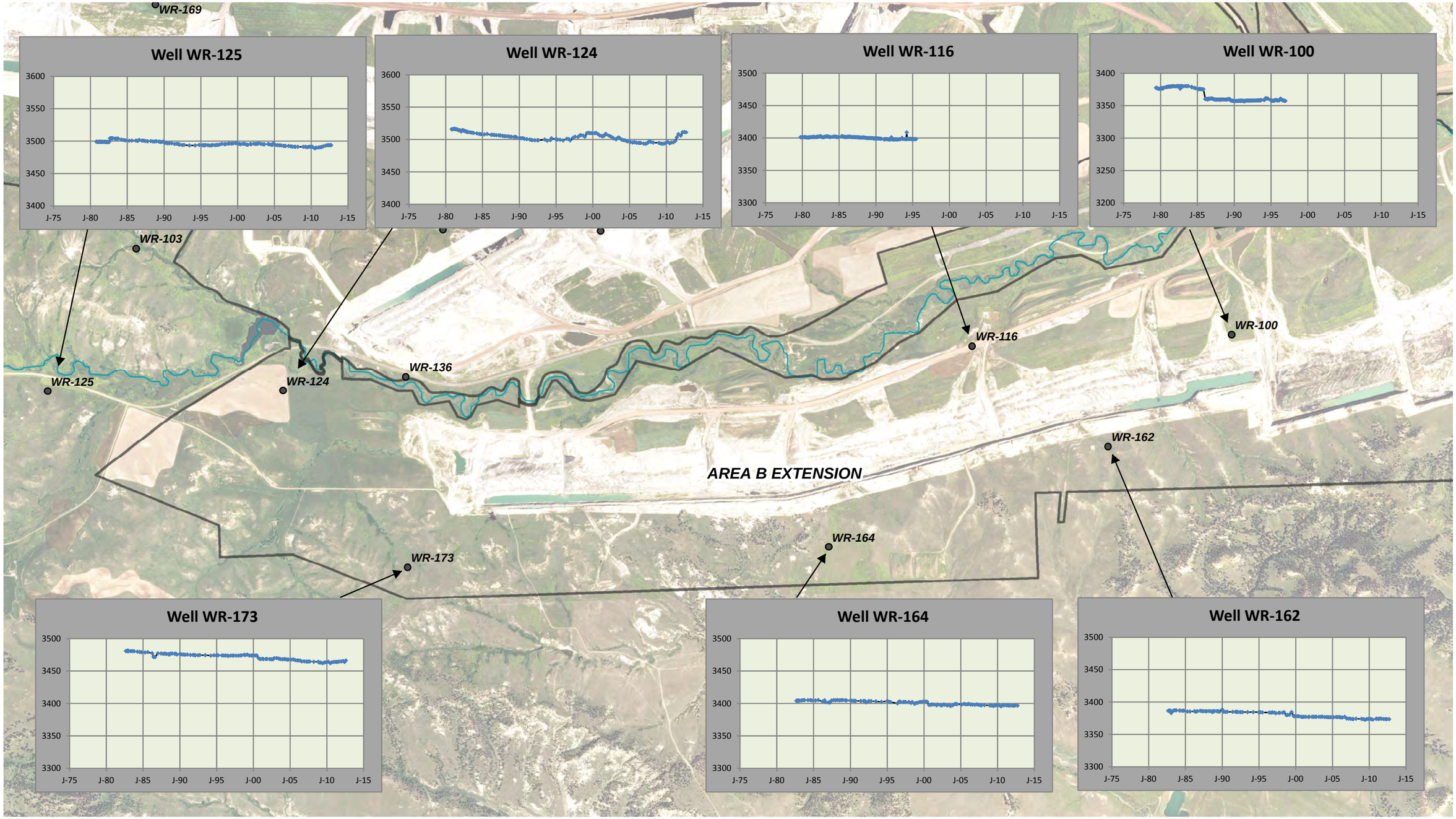
Figure GM-11 - Page 1
Area B Extension- Hydrographs
Overburden
Western Energy Rosebud Mine

Exhibit 8

Date: 5/21/2013

Name: Figure GM11_P1 - Area B Extension Hydrographs - Overburden



Note: The well log for WR-100 indicates this well is screened in the overburden.

NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

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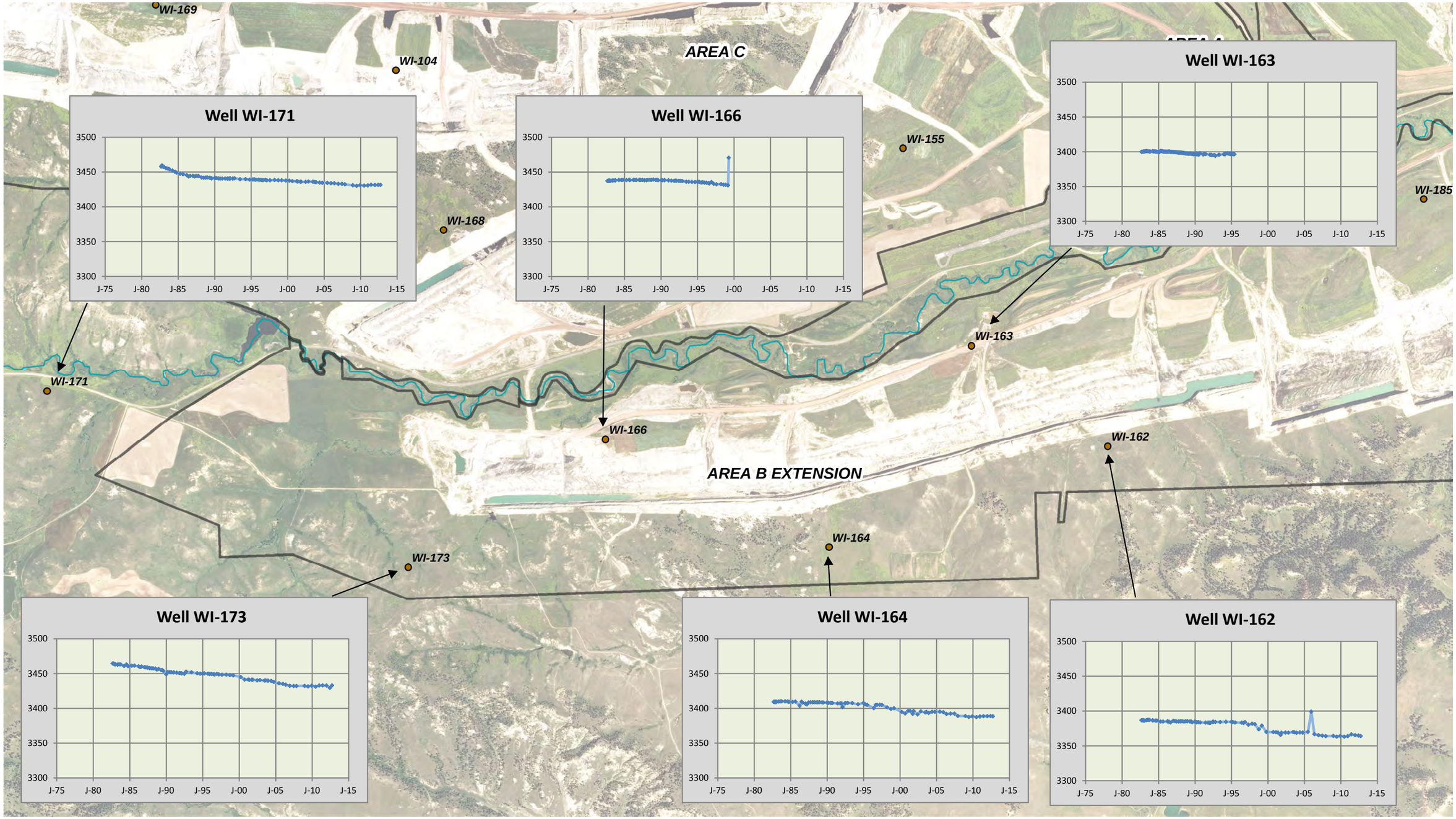
Figure GM-11 - Page 2
Area B Extension- Hydrographs
Rosebud Coal
Western Energy Rosebud Mine

Date: 5/21/2013

Name: Figure GM11_P2 - Area B Extension Hydrographs - Rosebud Coal

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

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A Subsidiary of WESTMORELAND COAL COMPANY
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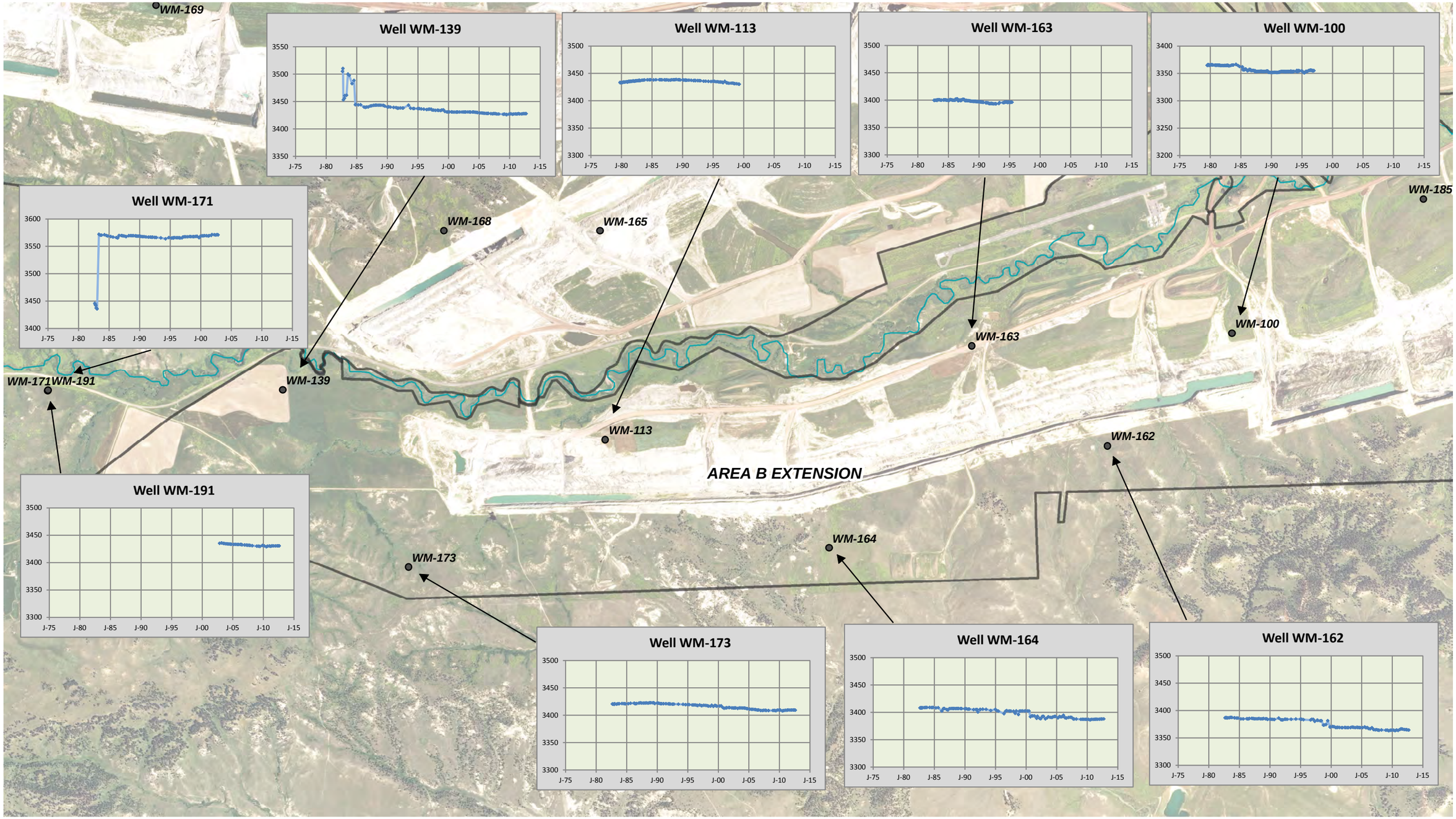
Figure GM-11 - Page 3
Area B Extension- Hydrographs
Interburden
Western Energy Rosebud Mine

Exhibit 8

Date: 5/21/2013

Name: Figure GM11_P3 - Area B Extension Hydrographs - Interburden



NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
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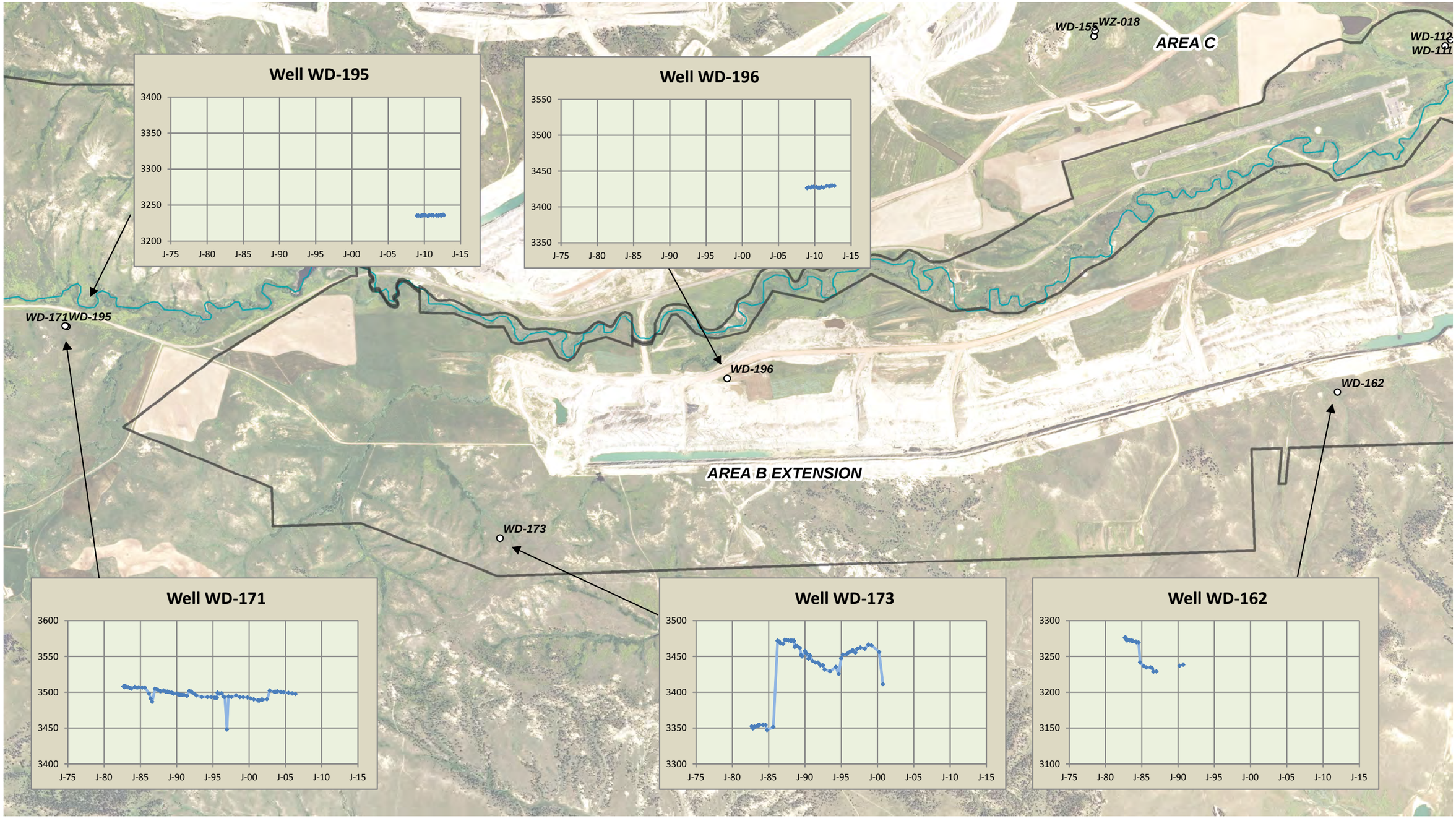
Figure GM-11 - Page 4
Area B Extension- Hydrographs
McKay Coal
Western Energy Rosebud Mine

Date: 5/21/2013

Name: Figure GM11_P4 - Area B Extension Hydrographs - McKay Coal

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

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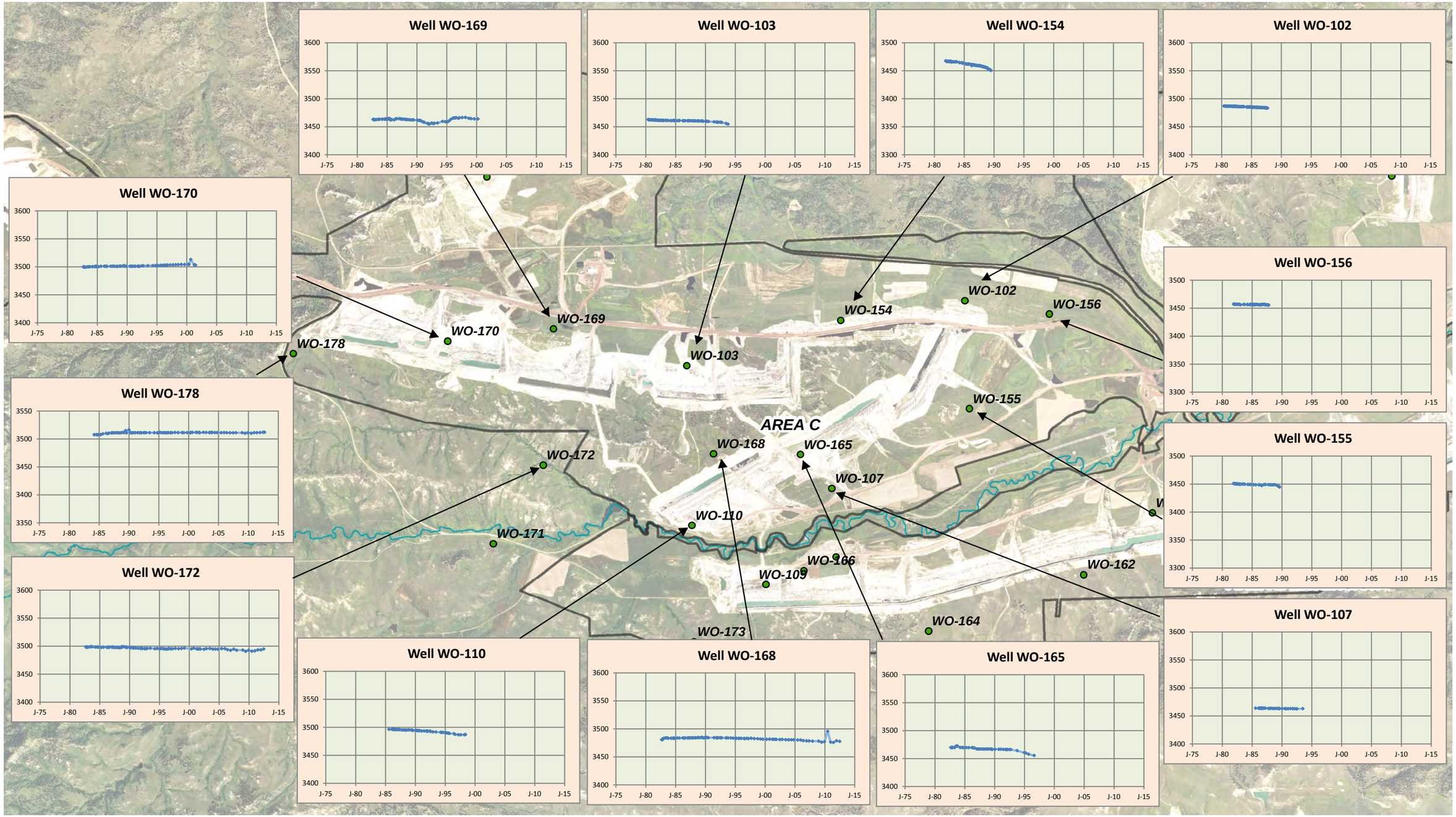
Figure GM-11 - Page 5
Area B Extension- Hydrographs
SubMcKay
Western Energy Rosebud Mine

Date: 5/21/2013

Name: Figure GM11_P5 - Area B Extension Hydrographs - SubMcKay Coal

Exhibit 8



NICKLIN EARTH & WATER, INC.

Miles
0 0.5 1

N

Notes:
1) Aerial Photographs: 2011 NAIP

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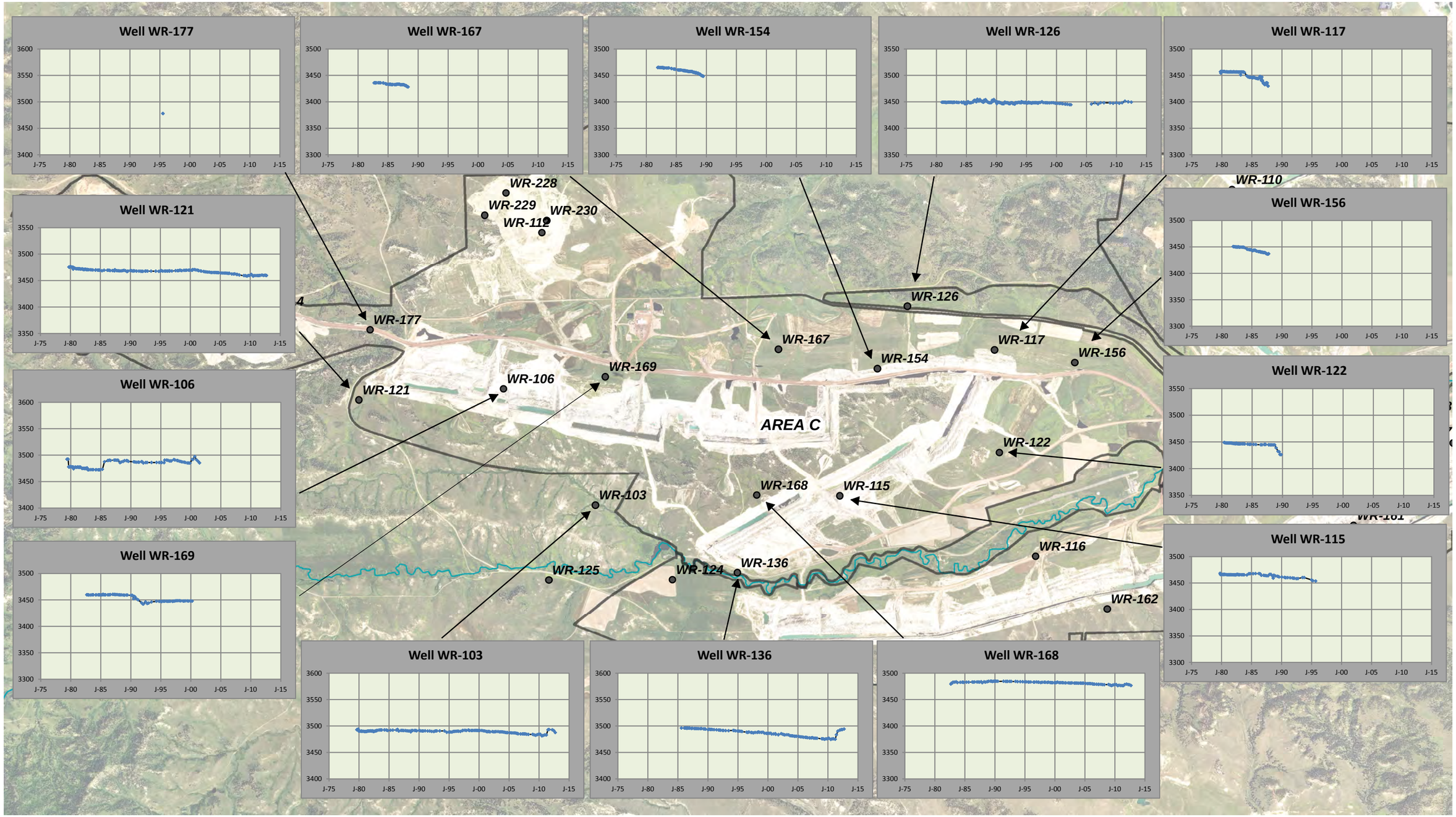
Figure GM-12 - Page 1
Area C Central / East Hydrographs
Overburden
Western Energy Rosebud Mine

Exhibit 8

Date: 5/21/2013

Name: Figure GM12_P1 - Area C Central East Hydrographs - Overburden



NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

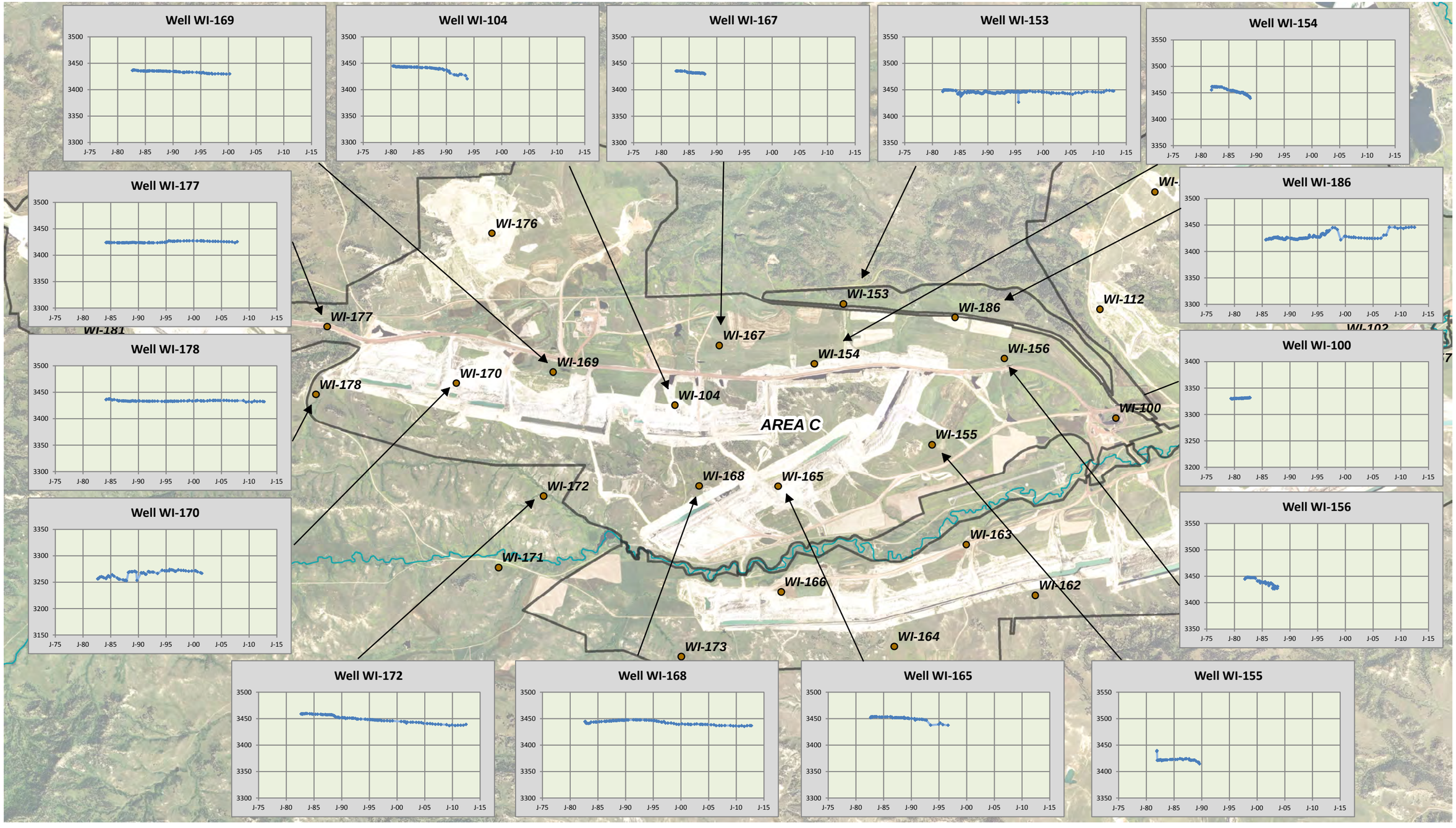
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-12 - Page 2
Area C Central / East Hydrographs
Rosebud Coal
Western Energy Rosebud Mine

Date: 2/3/2014

Name: Figure GM12_P2 - Area C Central East Hydrographs - Rosebud Coal

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

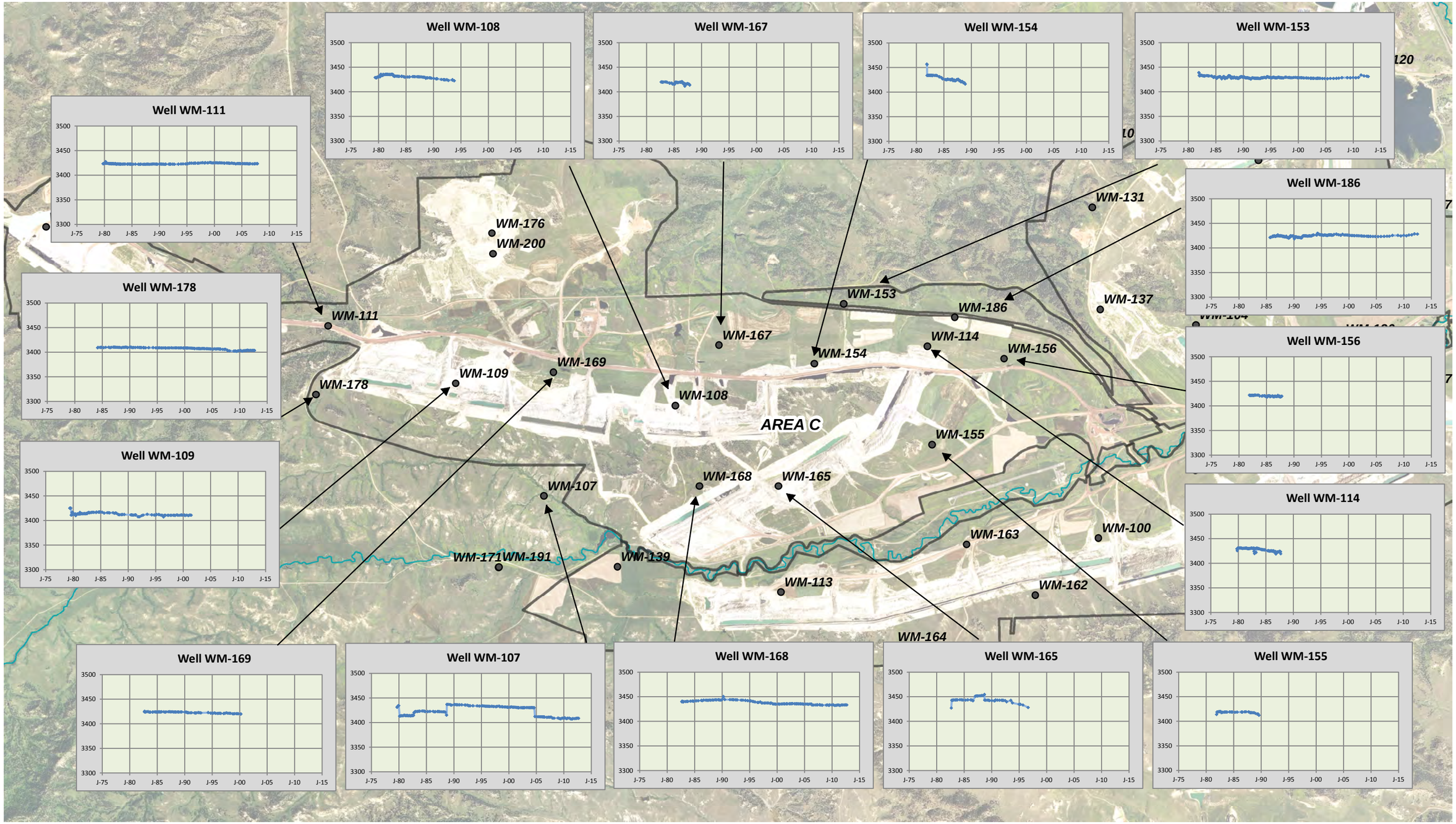
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-12 - Page 3
Area C Central / East Hydrographs
Interburden
Western Energy Rosebud Mine

Date: 2/3/2014

Name: Figure GM12_P3 - Area C Central East Hydrographs - Interburden

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

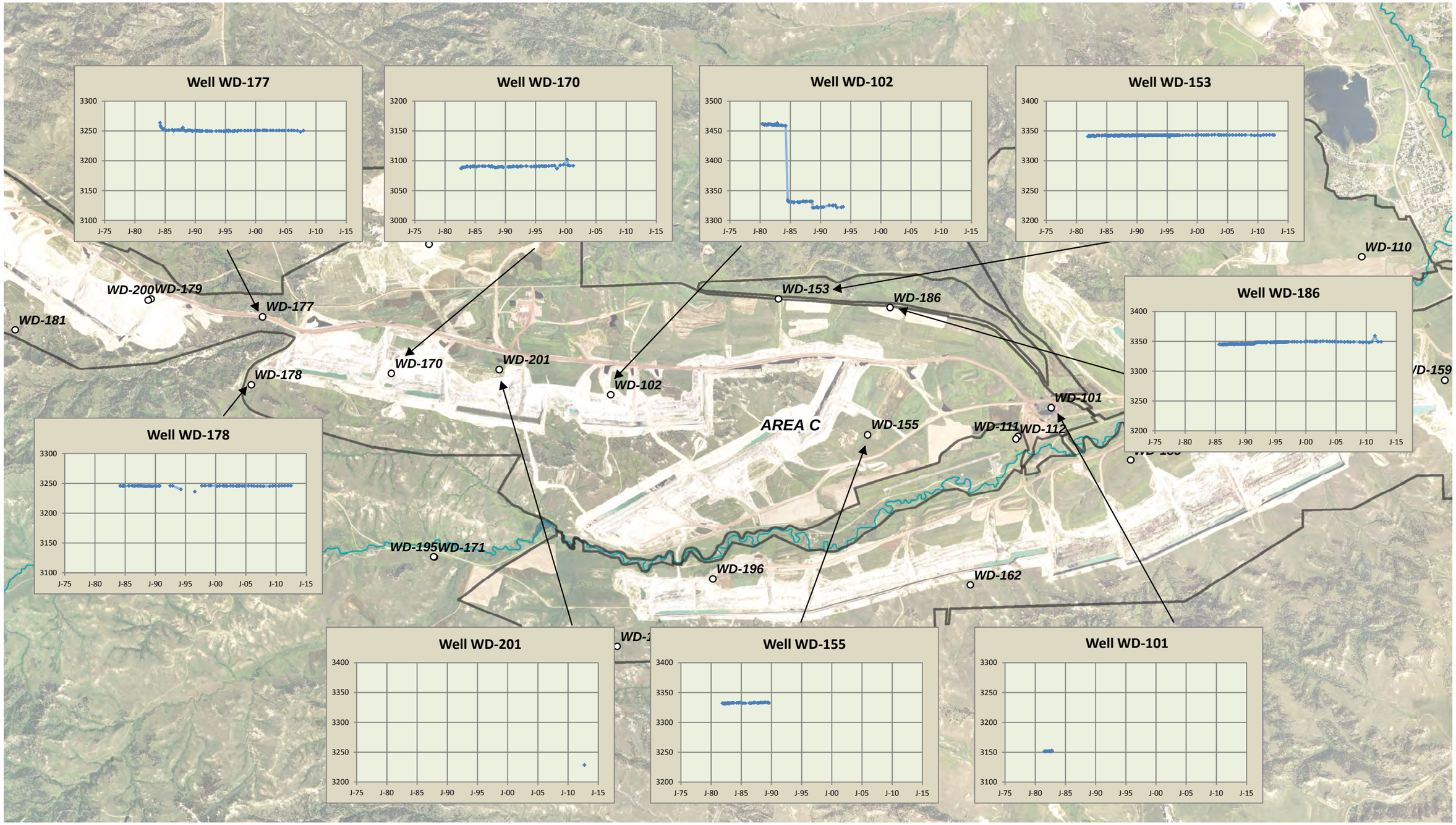
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-12 - Page 4
Area C Central / East Hydrographs
McKay Coal
Western Energy Rosebud Mine

Date: 5/21/2013

Name: Figure GM12_P4 - Area C Central East Hydrographs - McKay Coal

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

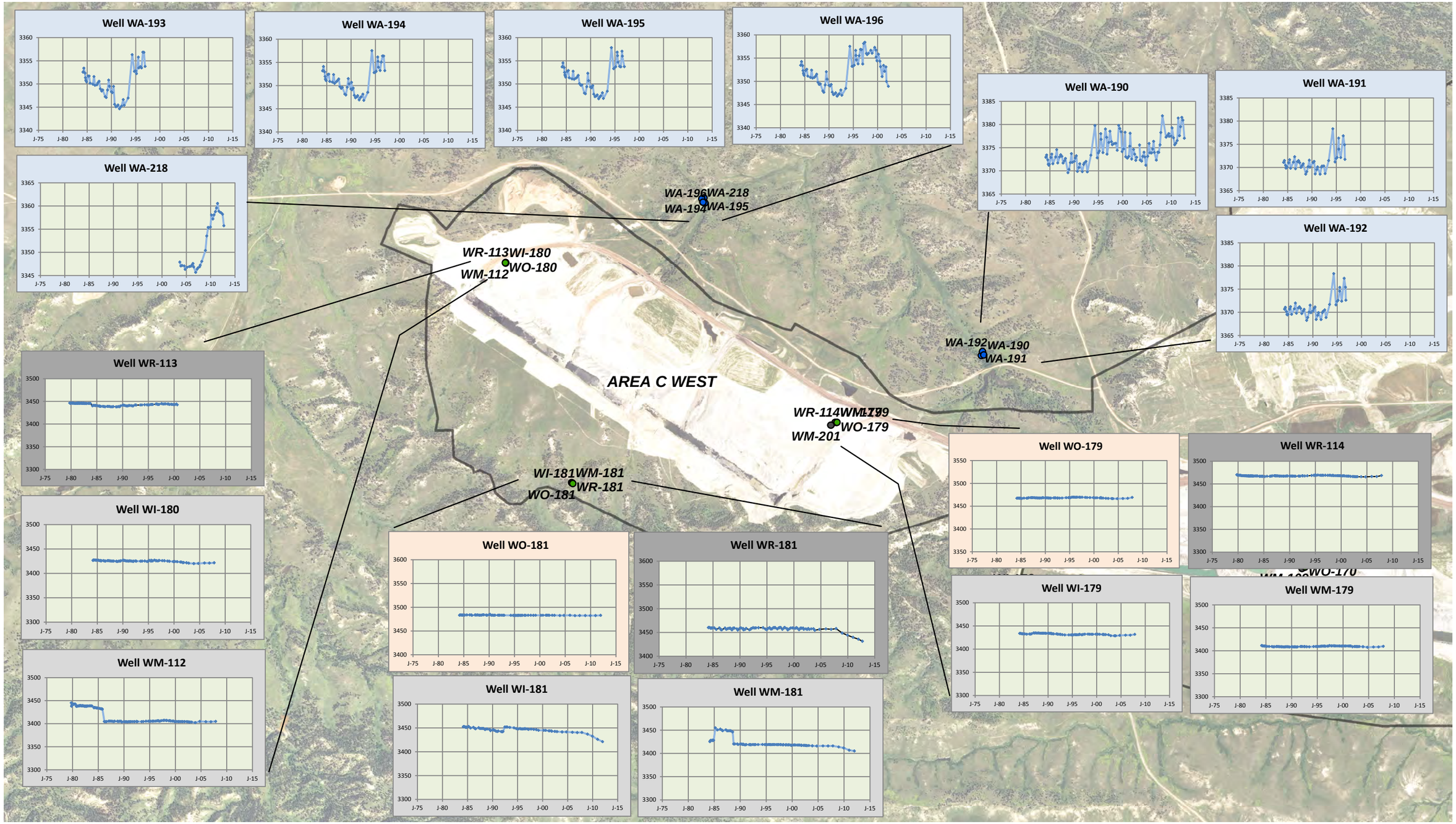
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-12 - Page 5
Area C Central / East Hydrographs
SubMckKay
Western Energy Rosebud Mine

Date: 2/3/2014

Name: Figure GM12_P5 - Area C Central East Hydrographs - SubMcKay

Exhibit 8



Note: WO-180 is a dry well, WM-201 was installed in WY 2012, WL on September 2012 was 3407.19 ft

NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

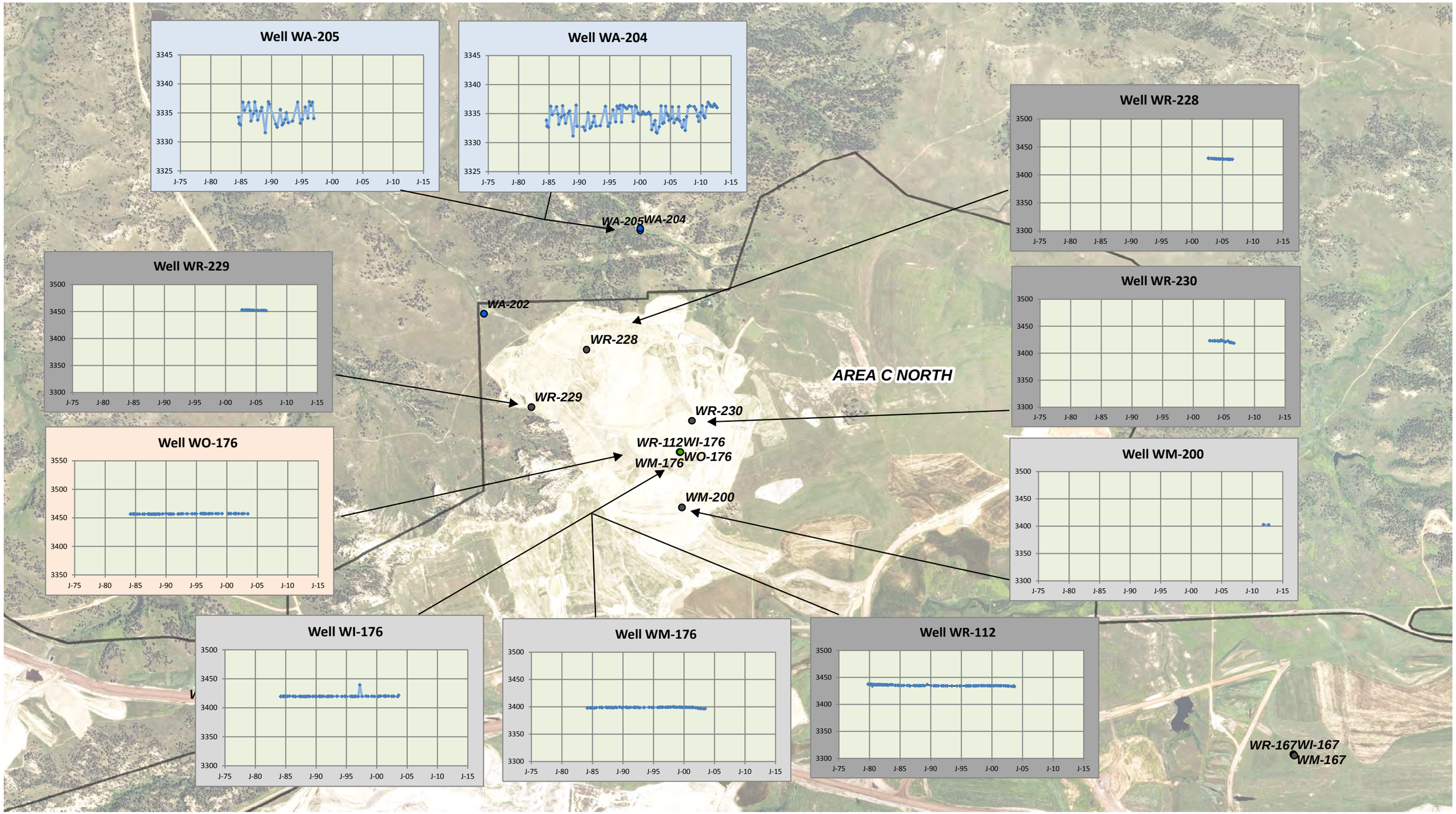
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-13
Area C West Hydrographs
Western Energy Rosebud Mine

Date: 2/3/2014

Name: Figure GM13 - Area C West Hydrographs

Exhibit 8



Note: WA-202 is a dry well.

NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

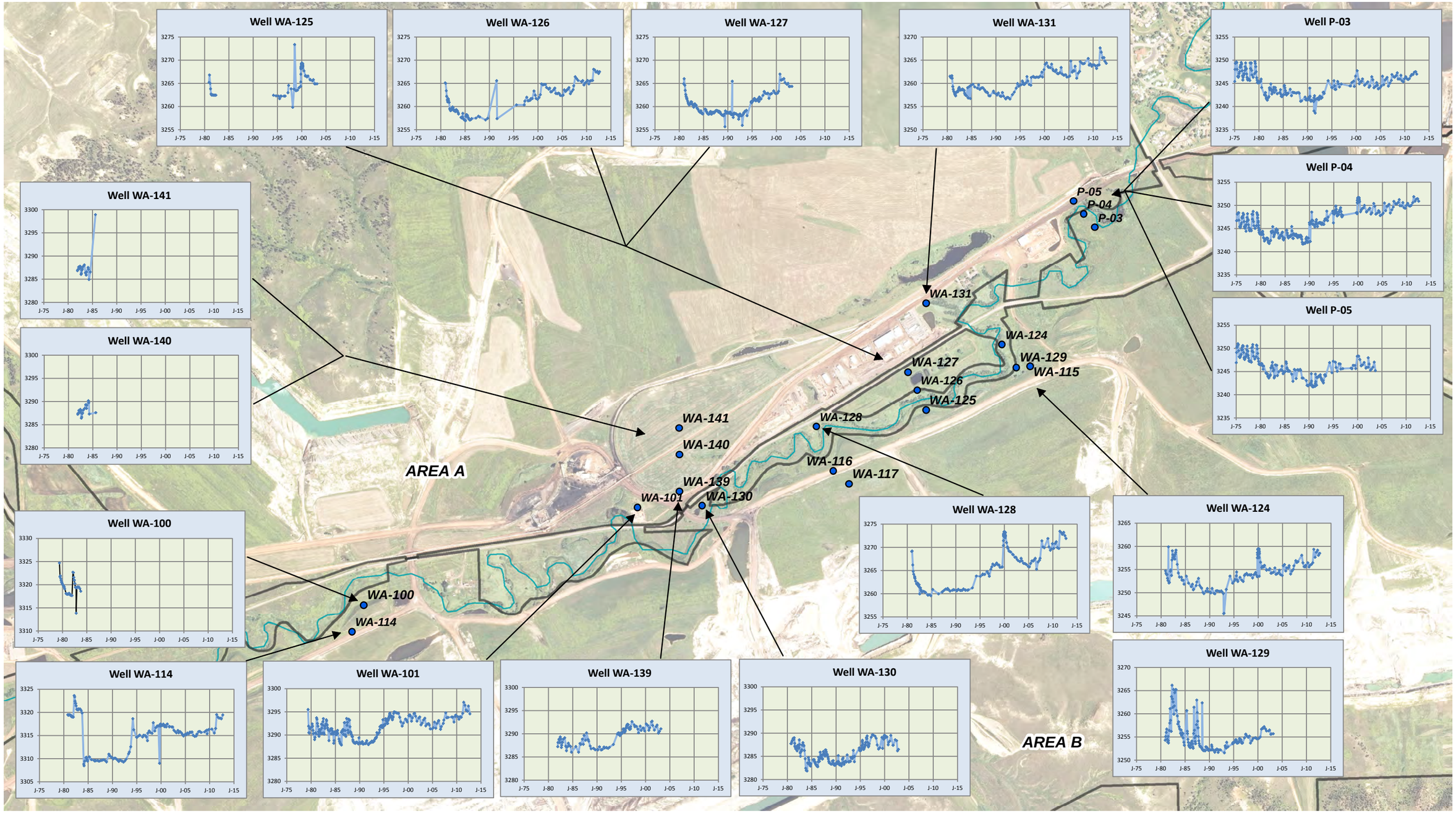
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-14
Area C North Hydrographs
Western Energy Rosebud Mine

Exhibit 8

Date: 5/21/2013

Name: Figure GM14 - Area C North Hydrographs



Note: Only six readings are available for WA-116 and WA-117. WA-115 was generally dry over period of record.

NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

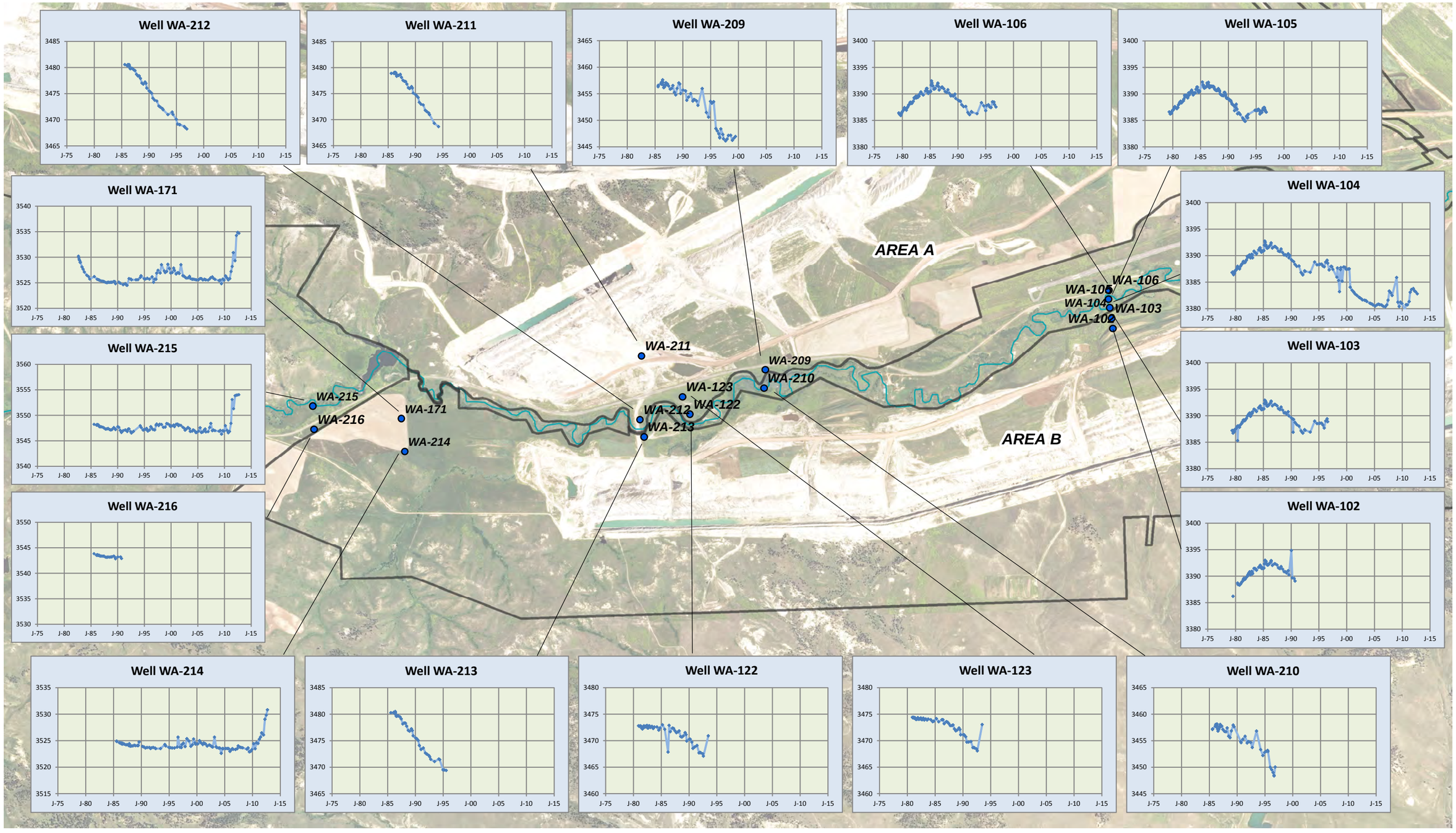
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-15 - Page 1
Hydrographs
Alluvial Wells between Area A and B
Western Energy Rosebud Mine

Exhibit 8

Date: 5/21/2013

Name: Figure GM15_P1 - Alluvial Wells Between A and B Hydrographs



NICKLIN EARTH & WATER, INC.

Miles
0 0.25 0.5

N

Notes:
1) Aerial Photographs: 2011 NAIP

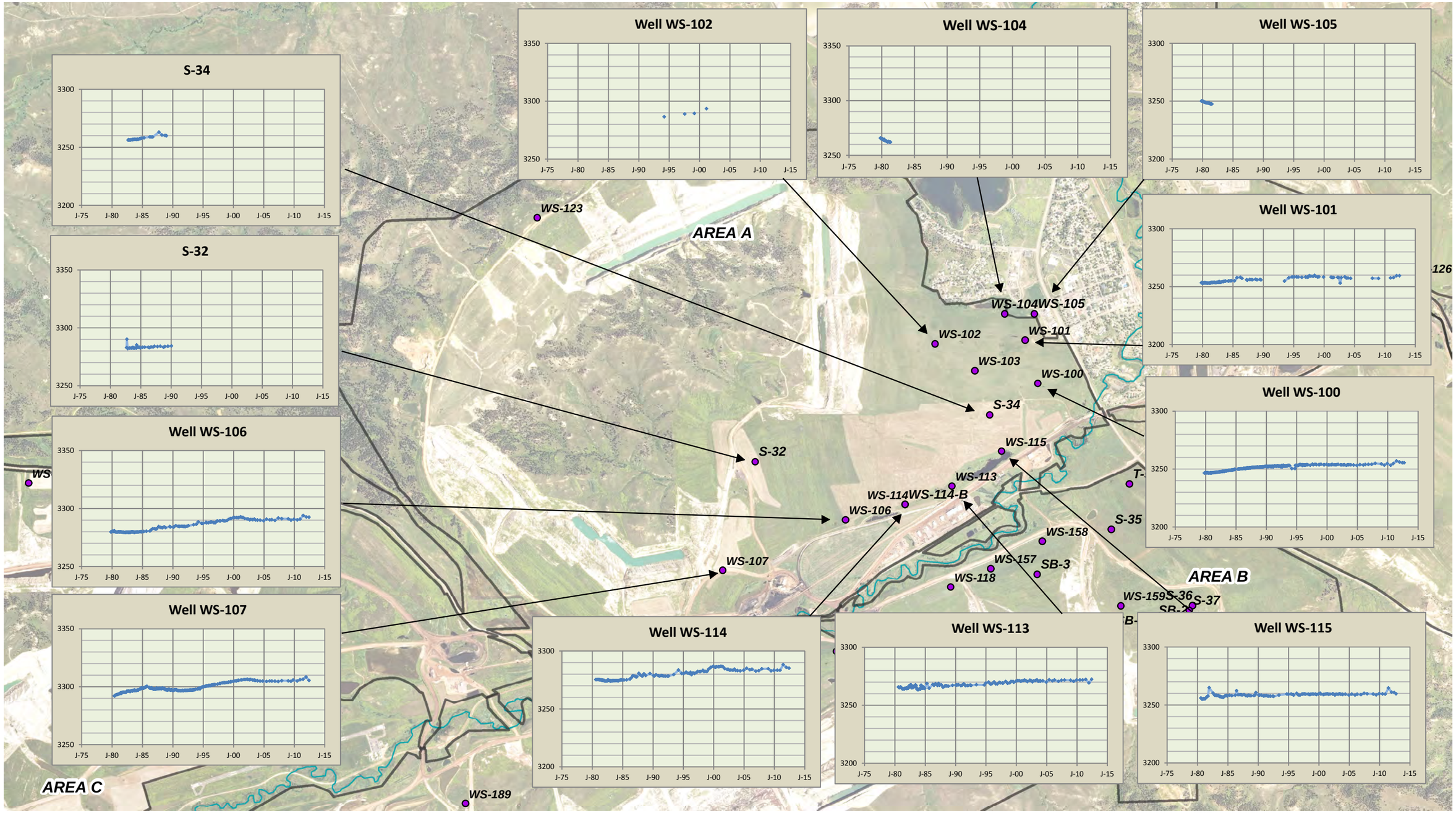
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-15 - Page 2
Hydrographs
Alluvial Wells between B-ext and C
Western Energy Rosebud Mine

Exhibit 8

Date: 4/1/2013

Name: Figure GM15_P2 - Alluvial Wells Between B-ext and C Hydrographs



Note: WS-103 and WS-123 are dry wells.

NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

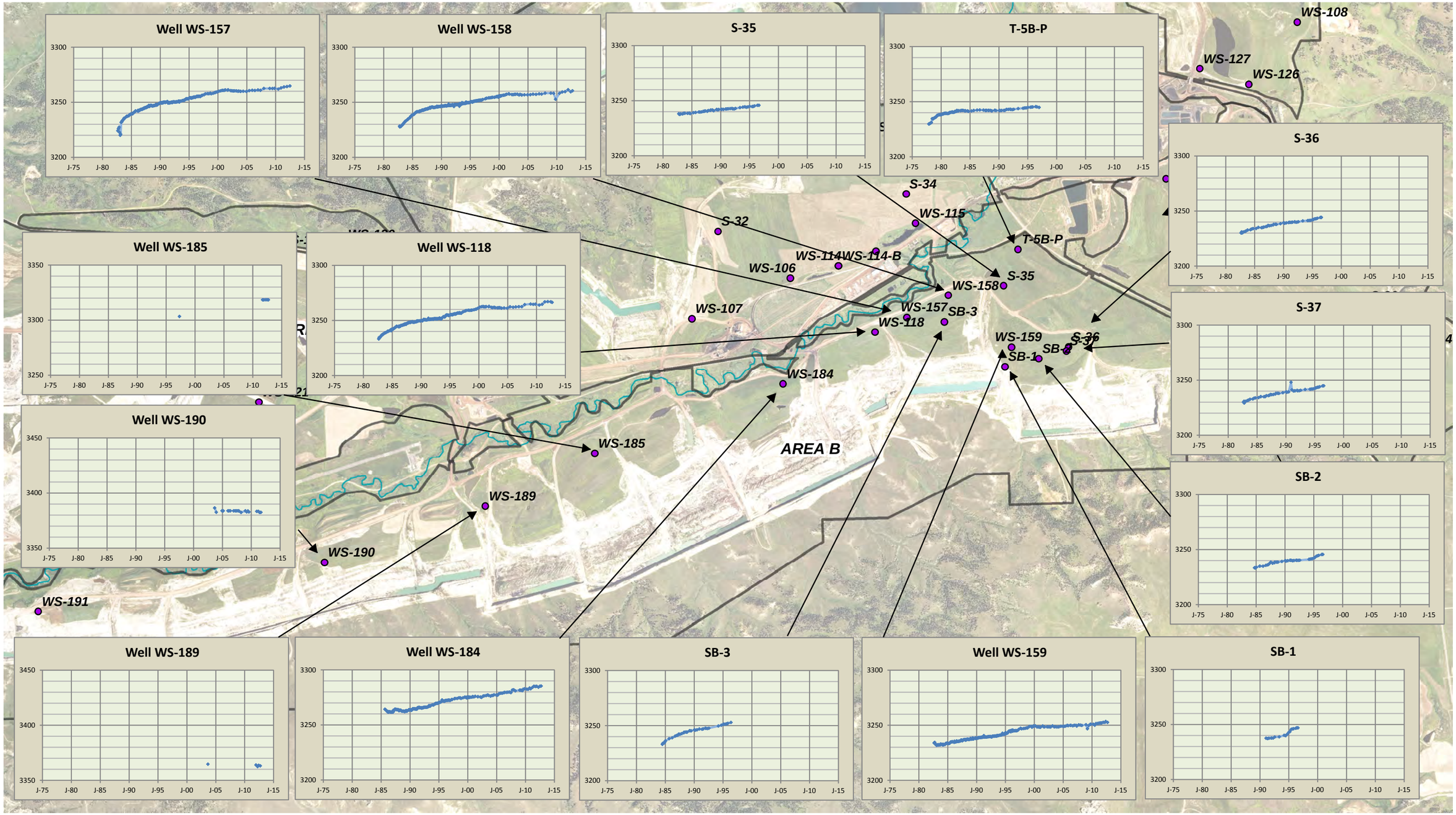
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-16 - Page 1
Area A Hydrographs
Spoils
Western Energy Rosebud Mine

Exhibit 8

Date: 2/3/2014

Name: Figure GM16_P1 - Area A Hydrographs - Spoils Wells



Note: WS-191 is a dry well.

NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

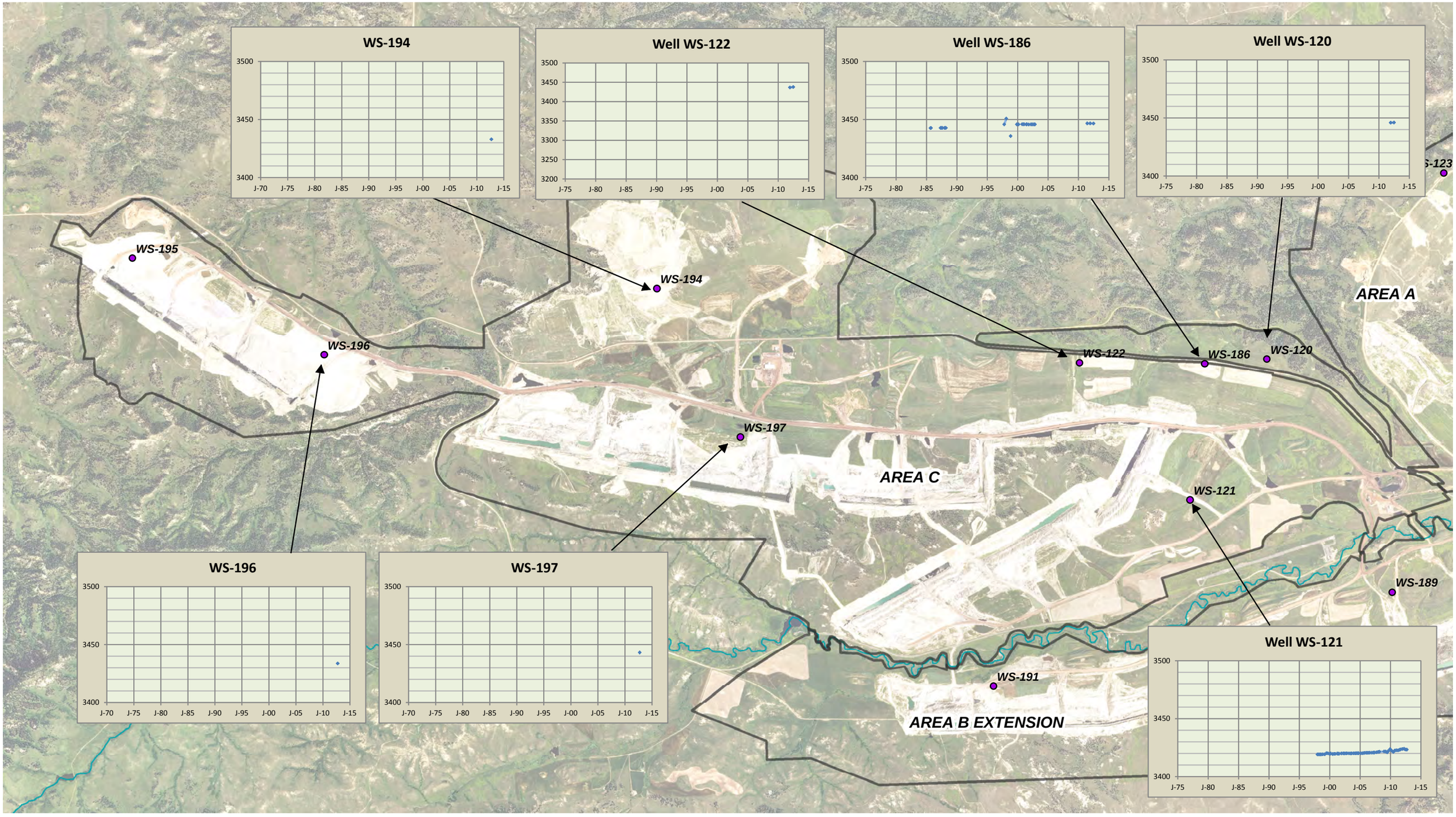
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-16 - Page 2
Area B and B Extension Hydrographs
Spoils
Western Energy Rosebud Mine

Exhibit 8

Date: 5/21/2013

Name: Figure GM16_P2 - Area B Hydrographs - Spoils Wells



Note: WS-195 is a dry well.

NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

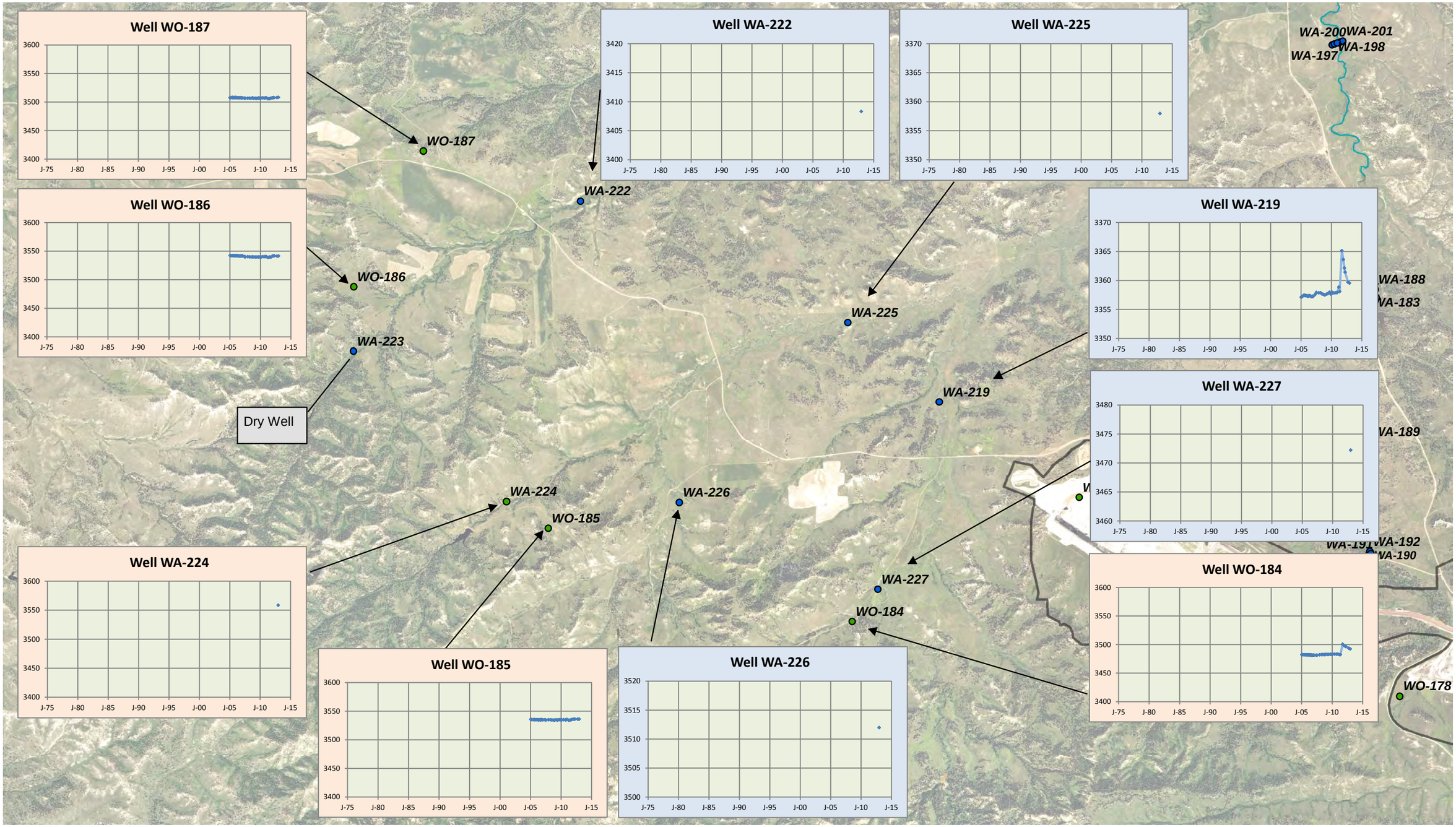
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-16 - Page 3
Area C Hydrographs
Spoils
Western Energy Rosebud Mine

Exhibit 8

Date: 2/3/2014

Name: Figure GM16_P3 - Area C Hydrographs - Spoils Wells



Note: WA-224 is a colluvium, overburden well. WA-223 was dry on 12/20/2012.

NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

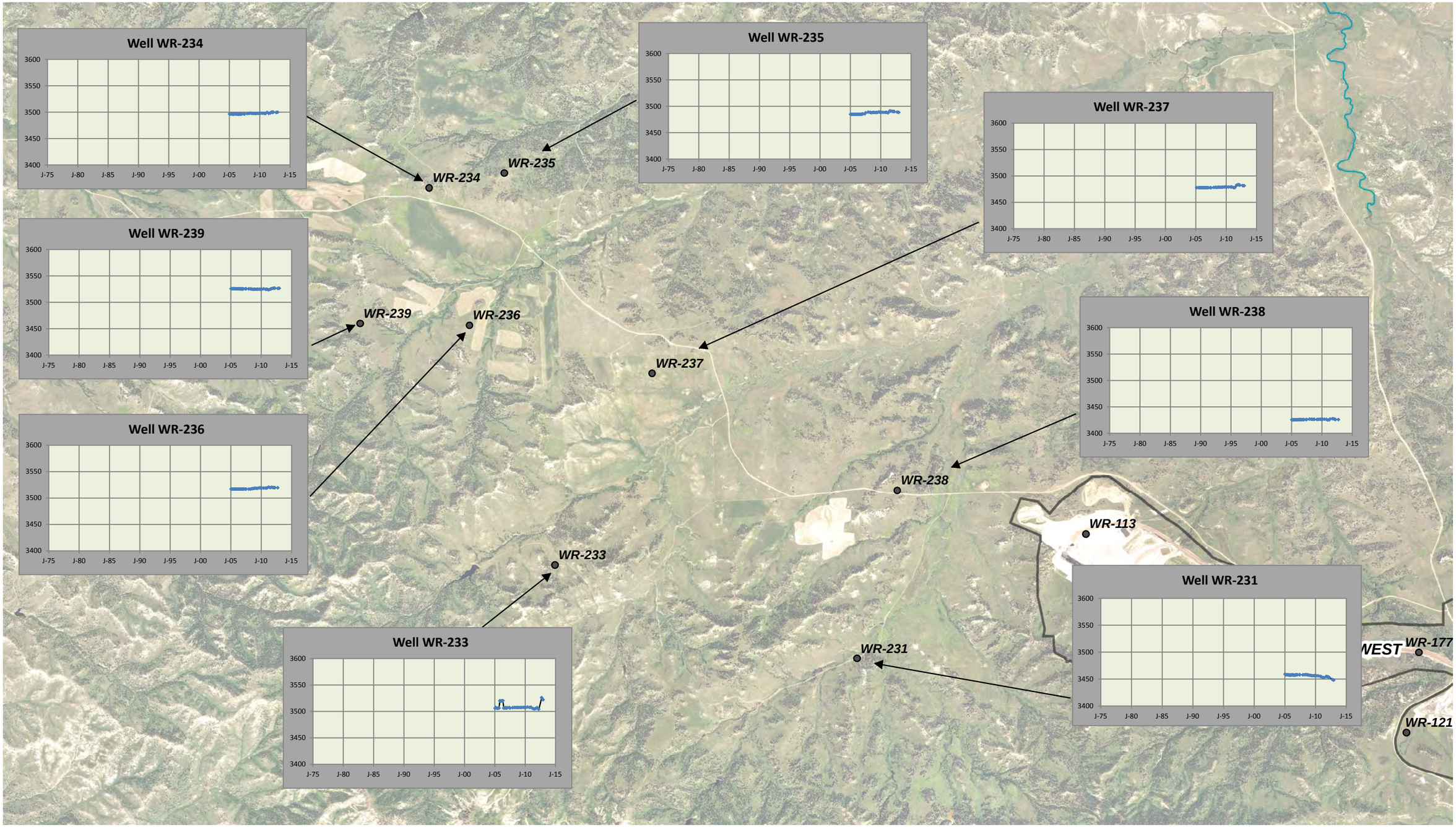
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-17 - Page 1
Hydrographs West of C
Alluvium and Overburden
Western Energy Rosebud Mine

Date: 2/3/2014

Name: Figure GM17_P1 - Hydrographs West of C - Alluvium and Overburden

Exhibit 8



NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

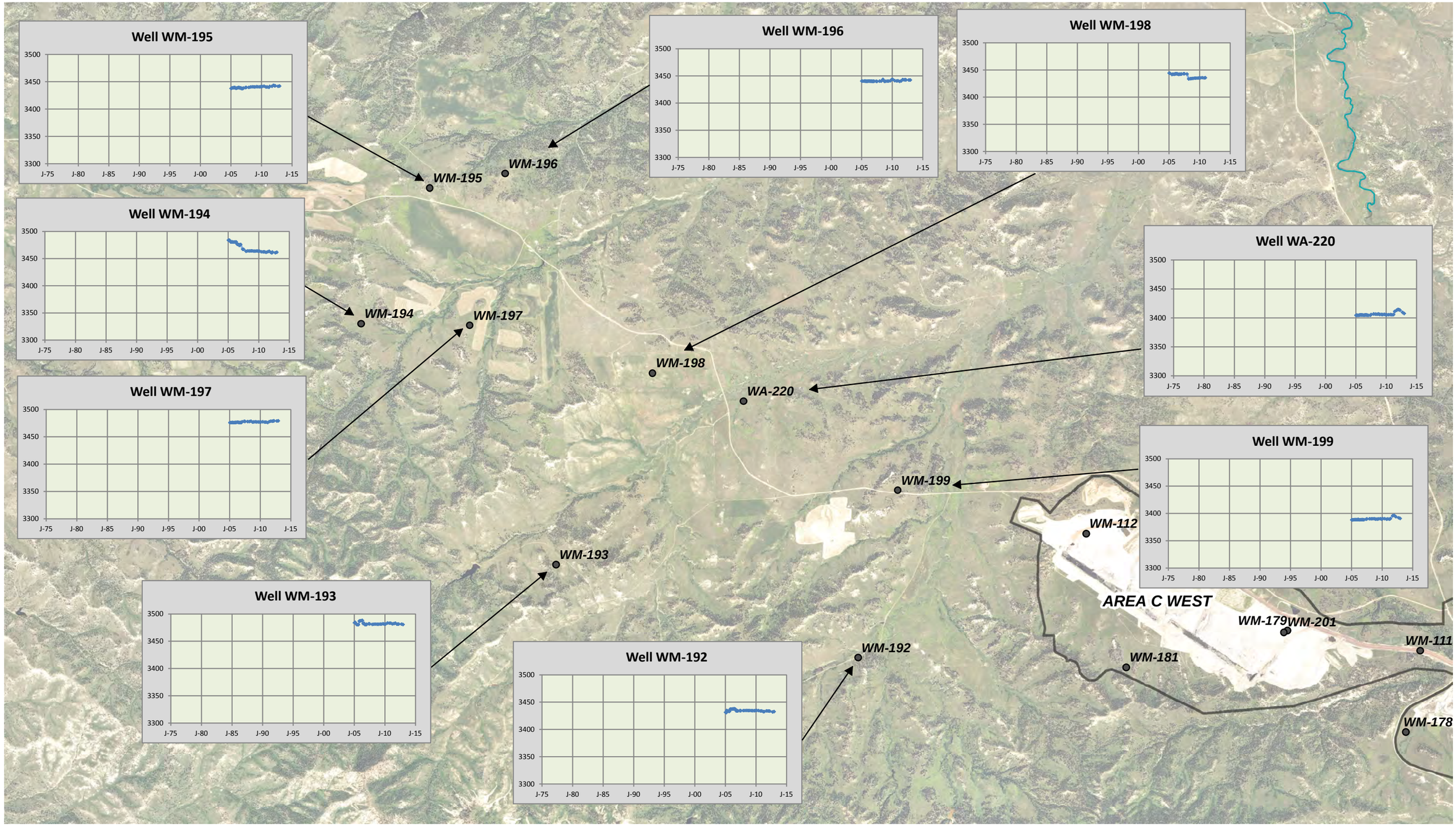
WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-17 - Page 2
Hydrographs West of Area C
Rosebud Coal
Western Energy Rosebud Mine

Exhibit 8

Date: 9/30/2013

Name: Figure GM17_P2 - Hydrographs West of C- Rosebud Coal



Note: Based on the well log WA-220 should be classified as an interburden / McKay coal well.

NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

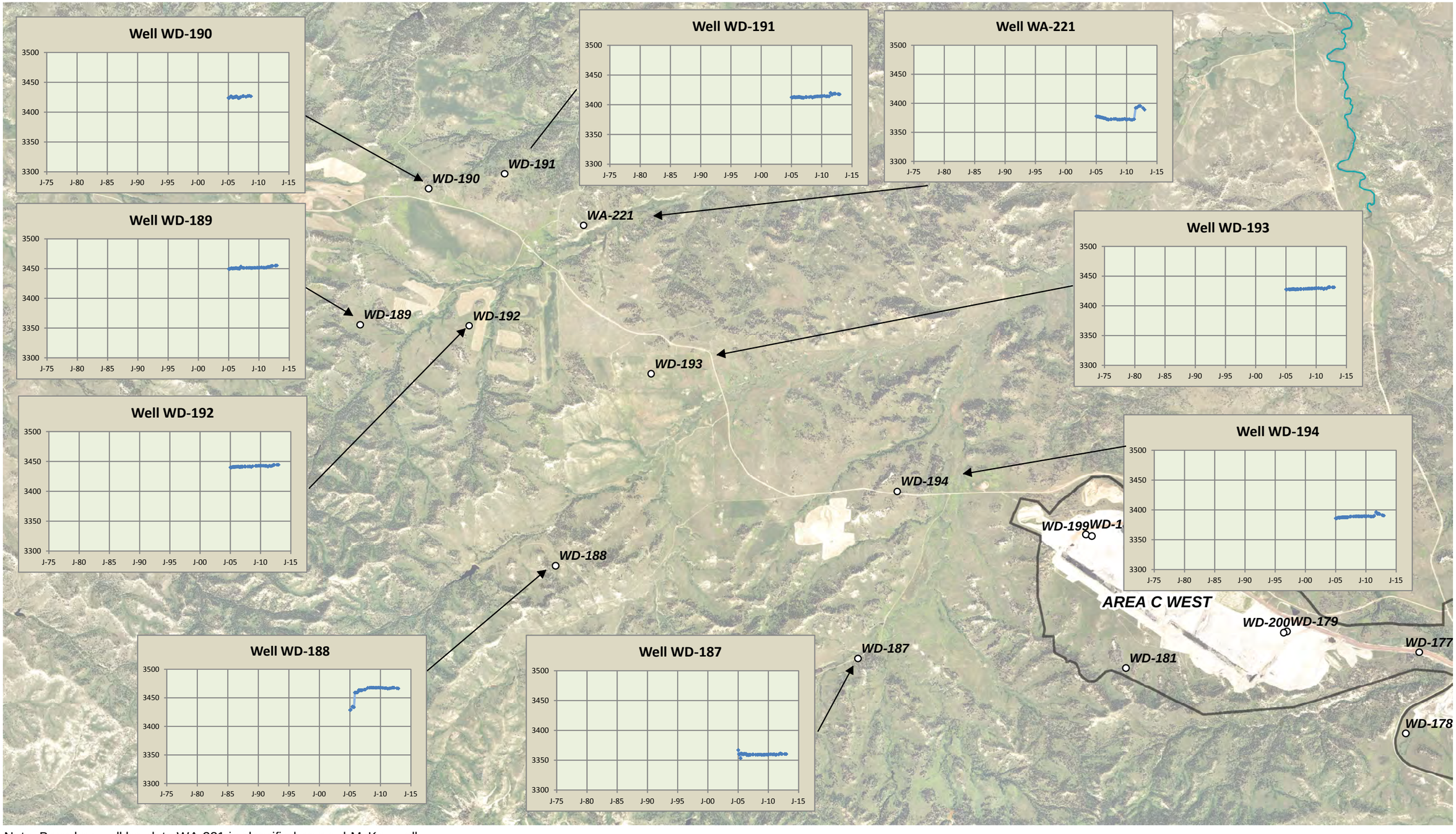
Date: 9/30/2013

Name: Figure GM17_P3 - Hydrographs West of C- McKay Coal

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-17 - Page 3
Hydrographs West of Area C
McKay Coal
Western Energy Rosebud Mine

Exhibit 8



Note: Based on well log data WA-221 is classified as a subMcKay well.

NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

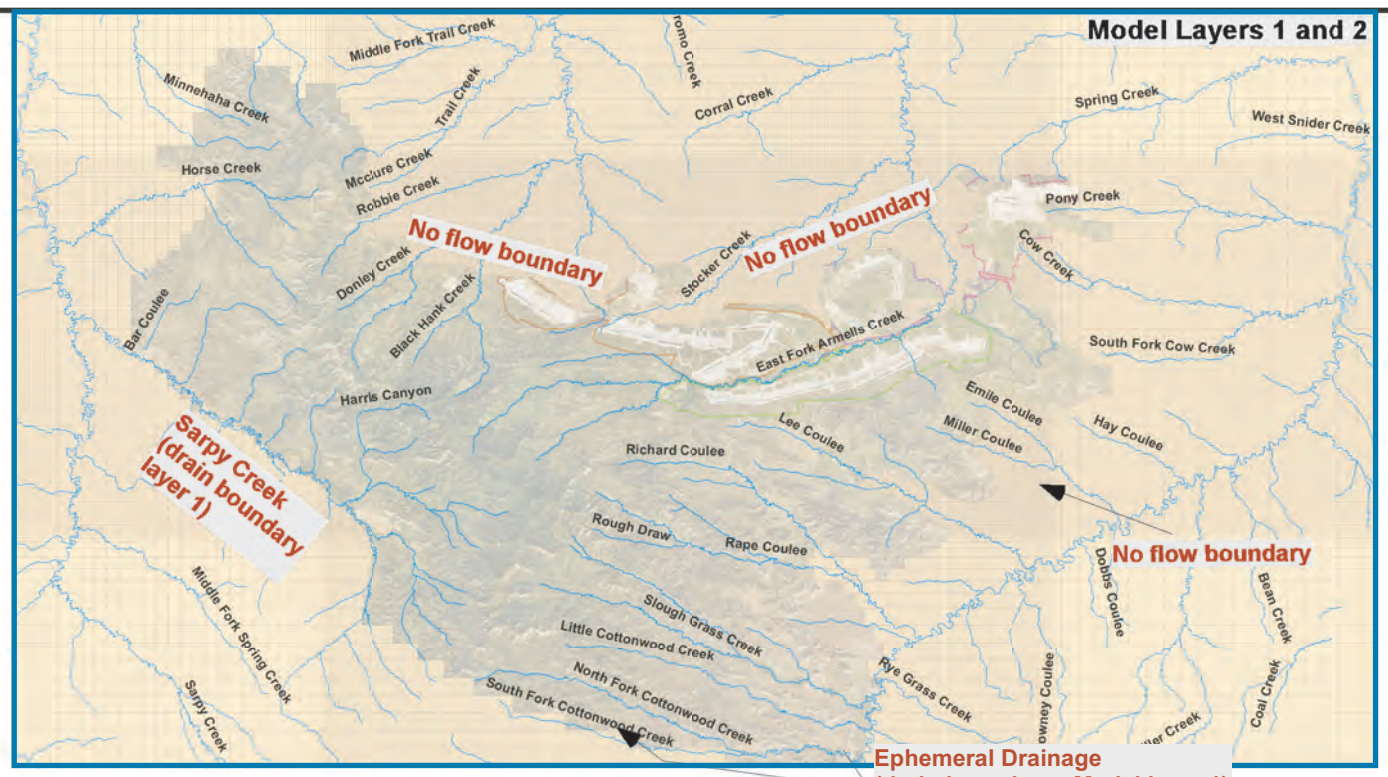
Figure GM-17 - Page 4
Hydrographs West of Area C
SubMcKay
Western Energy Rosebud Mine

Date: 9/30/2013

Name: Figure GM17_P4 - Hydrographs West of C- SubMcKay

Exhibit 8

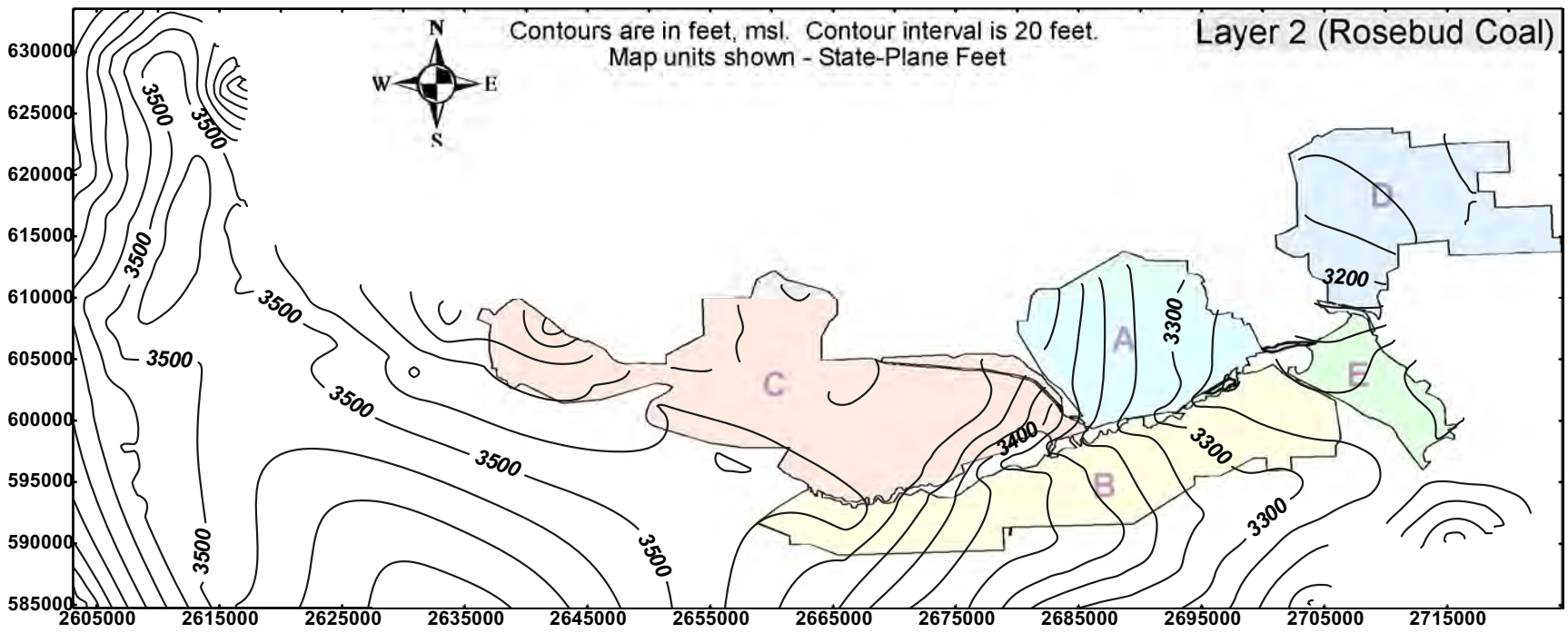
Partial Grid Shown for Layers 1 and 2

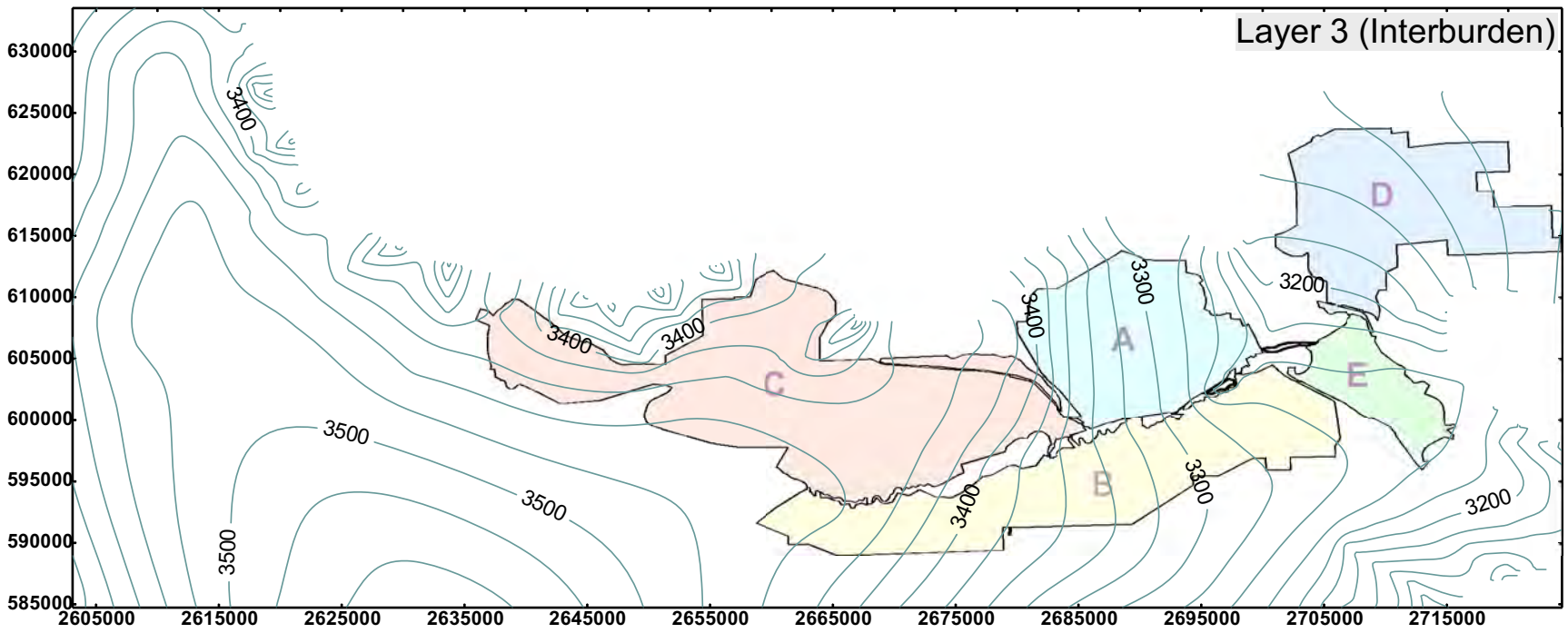


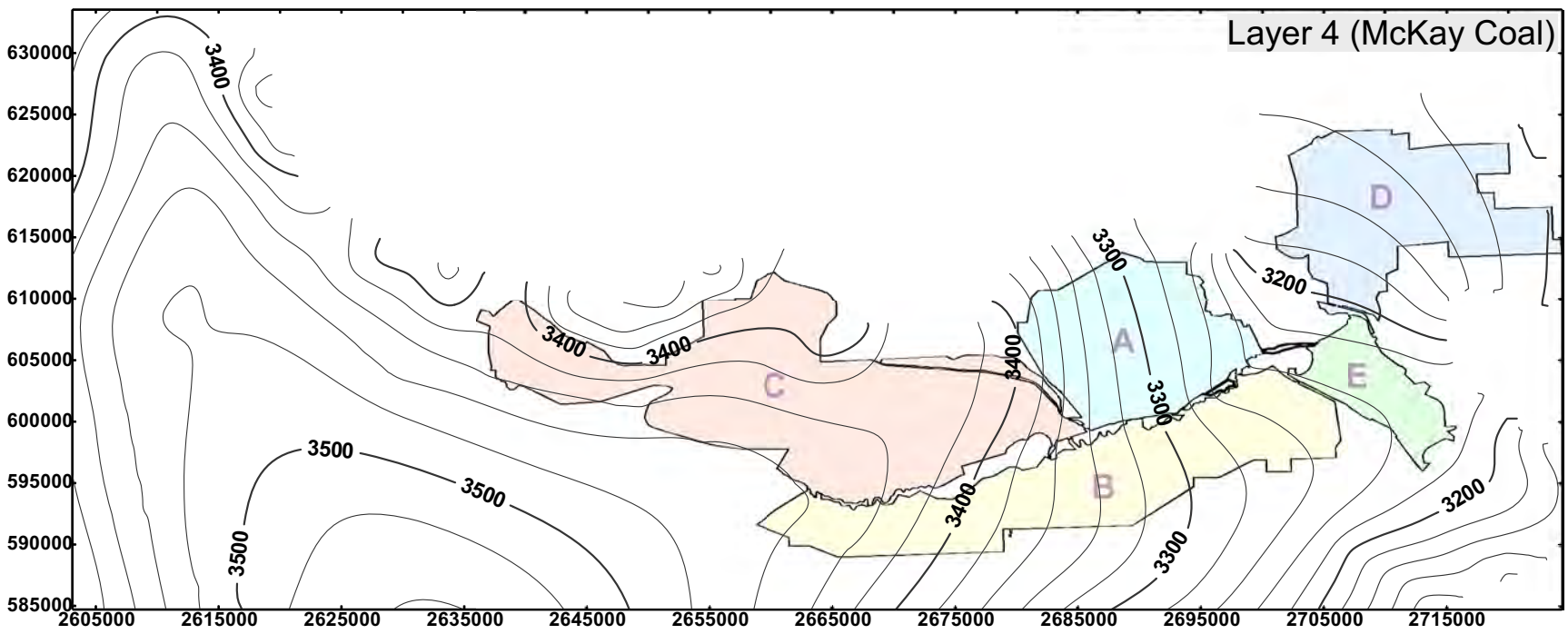
*A limited number of no flow cells were added at this portion of model domain boundary.

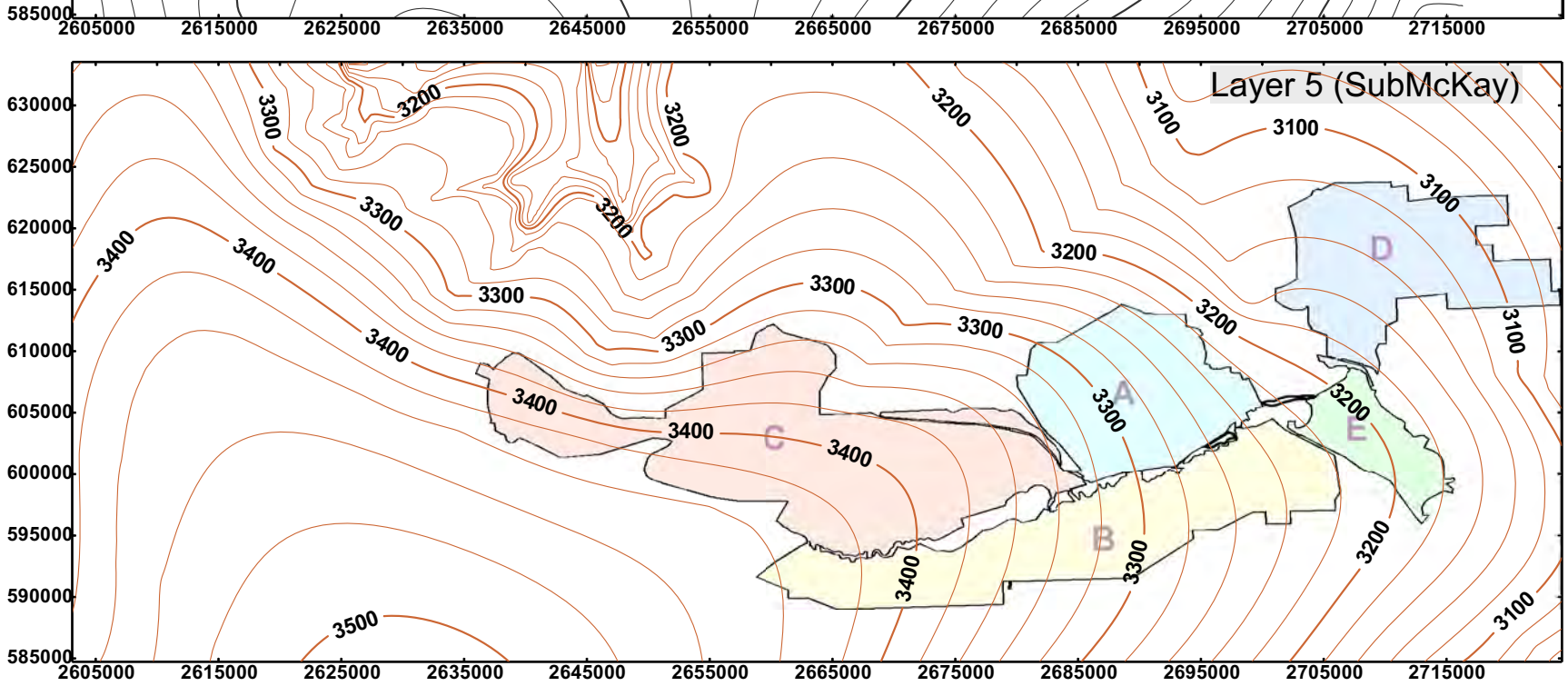
Date: August 1, 2013 d://figure GM-18 By: MEN Issued for Western Energy	NICKLIN EARTH & WATER, INC.	**Groundwater Model Domain by Layer Generalization of Perimeter Boundary Conditions Rosebud Mine**	**Figure GM-18**

Exhibit 8



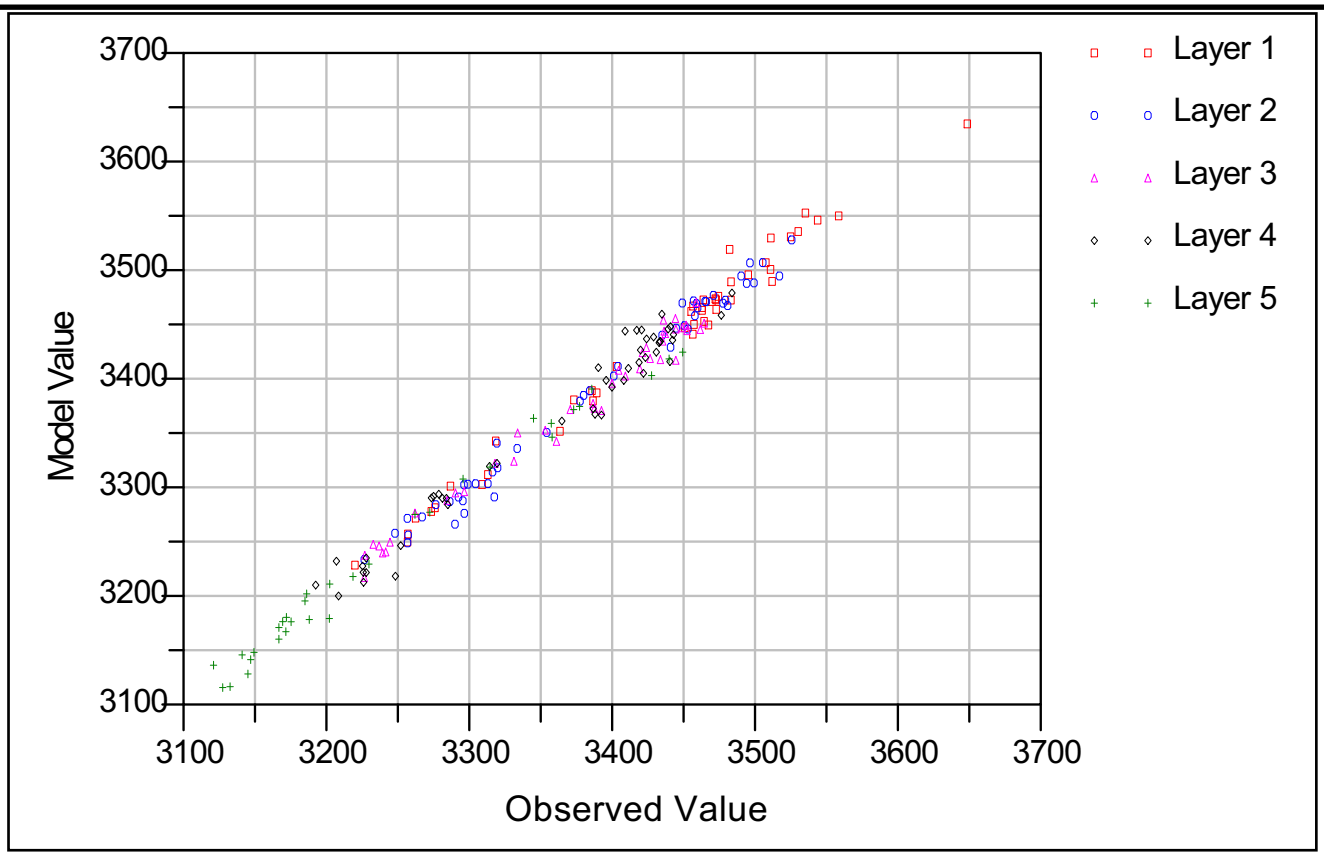


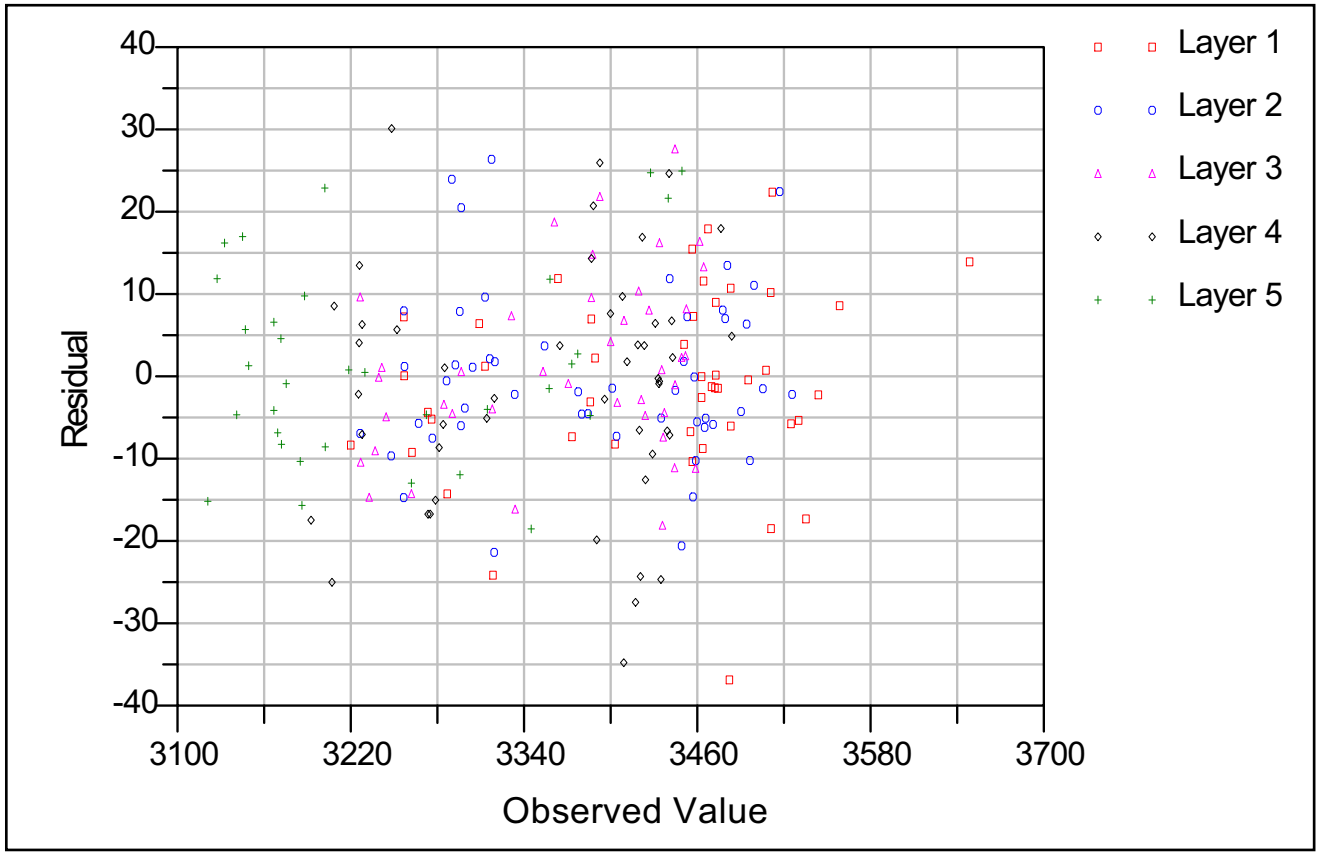




Date: July 31, 2013 d://figure GM-19 By: MEN Issued for Western Energy	NICKLIN EARTH & WATER, INC.	Simulated Potentiometric Heads Pre-Mine Conditions Rosebud Mine Ground-water Model	Figure GM-19

Exhibit 8



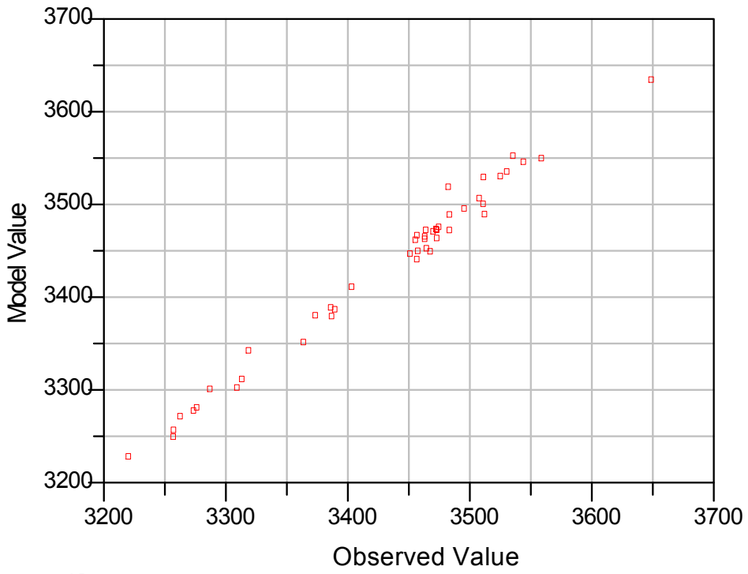


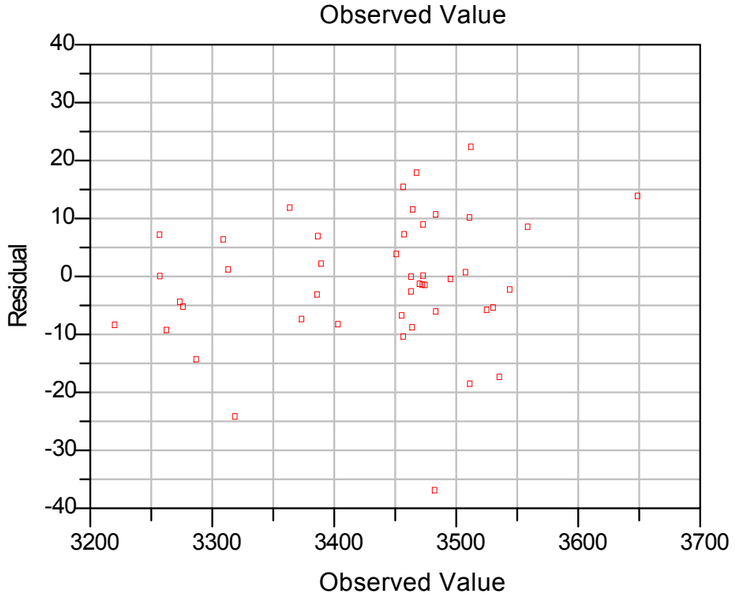
See Table I-2 for specific calibration results. Units are in feet.

Date: May 18, 2013 d://figure GM-20 By: MEN Issued for Western Energy	NICKLIN EARTH & WATER, INC.	Groundwater Model Calibration Plots All Model Layers	Figure GM-20

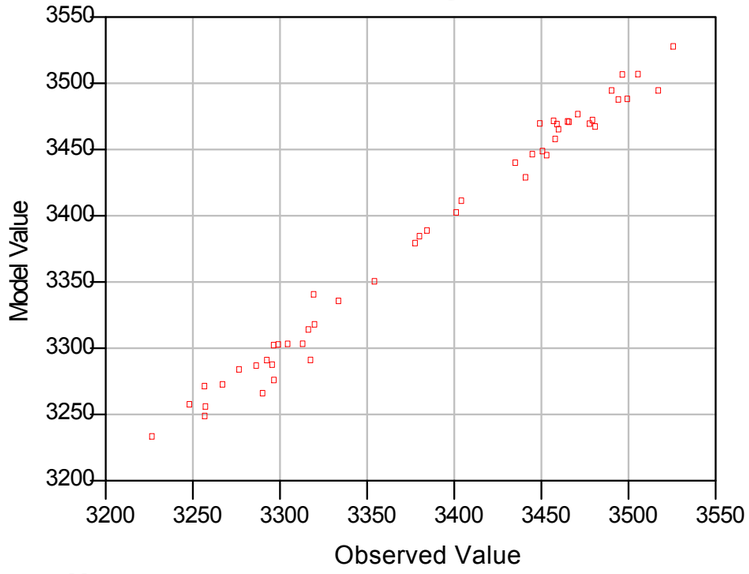
Exhibit 8

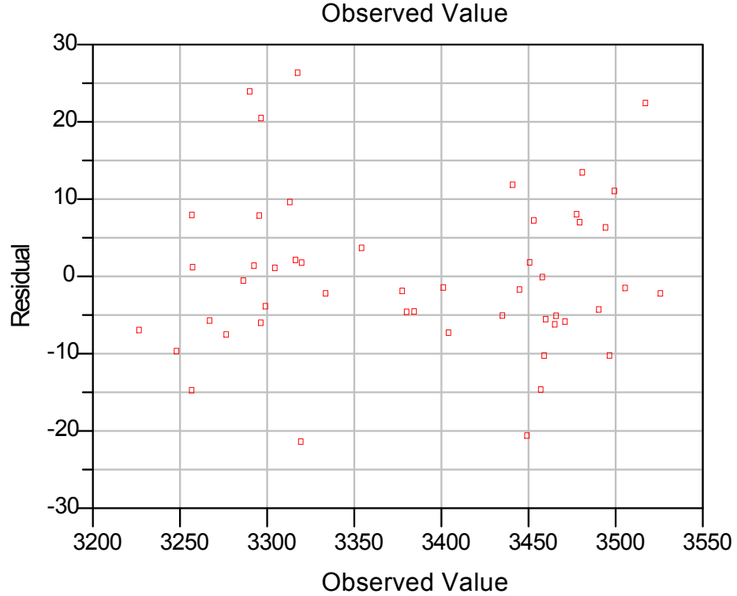
Model Layer 1



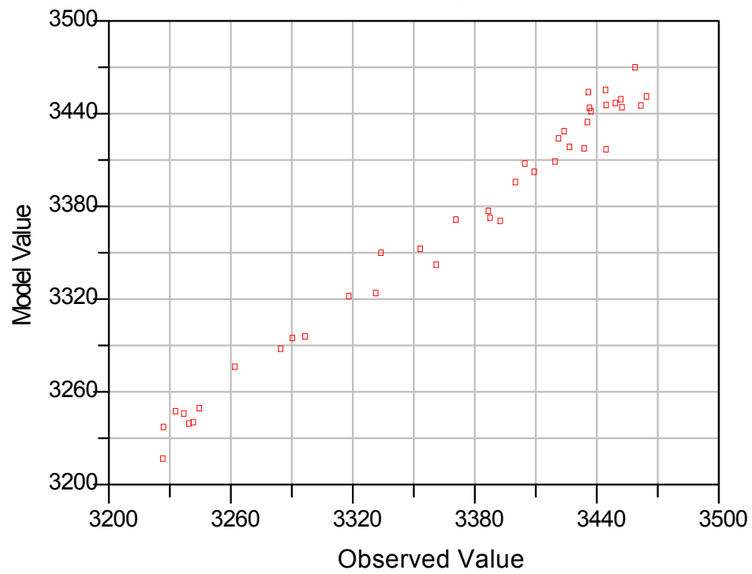


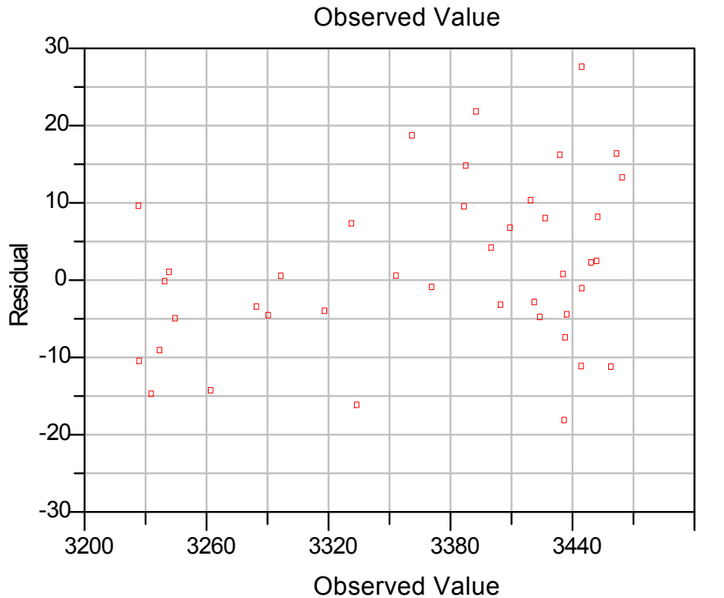
Model Layer 2





Model Layer 3



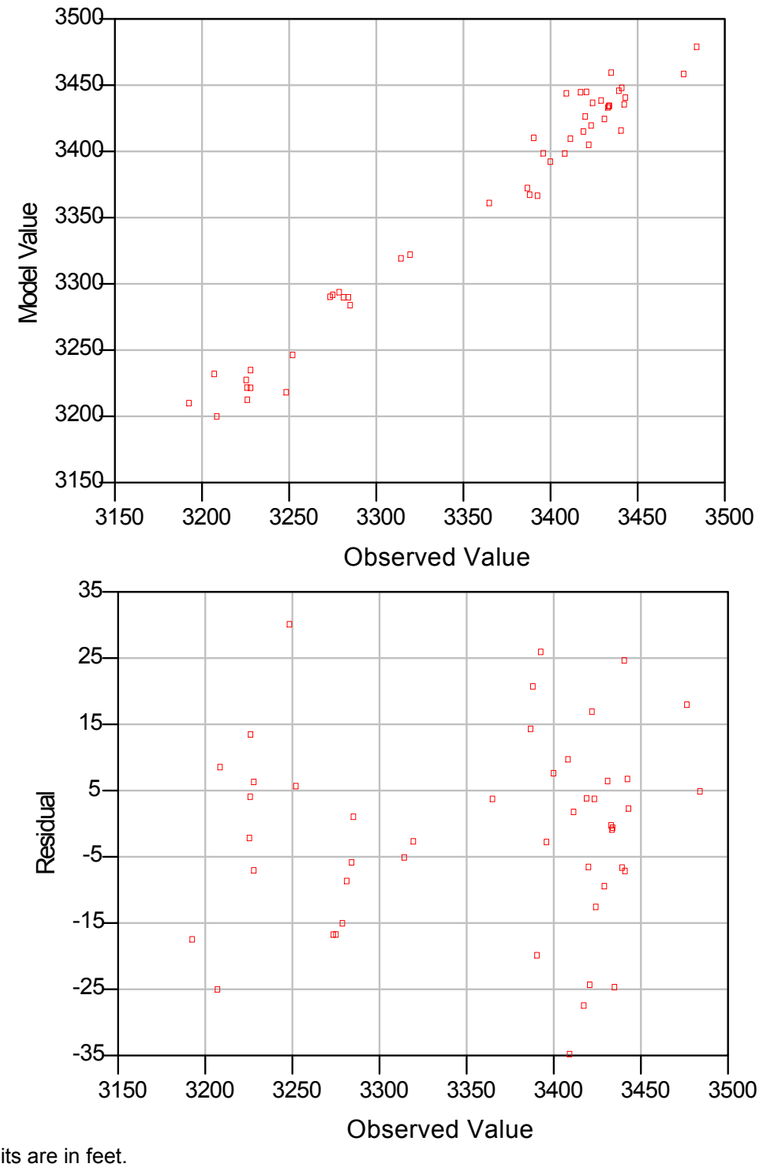


Units are in feet.

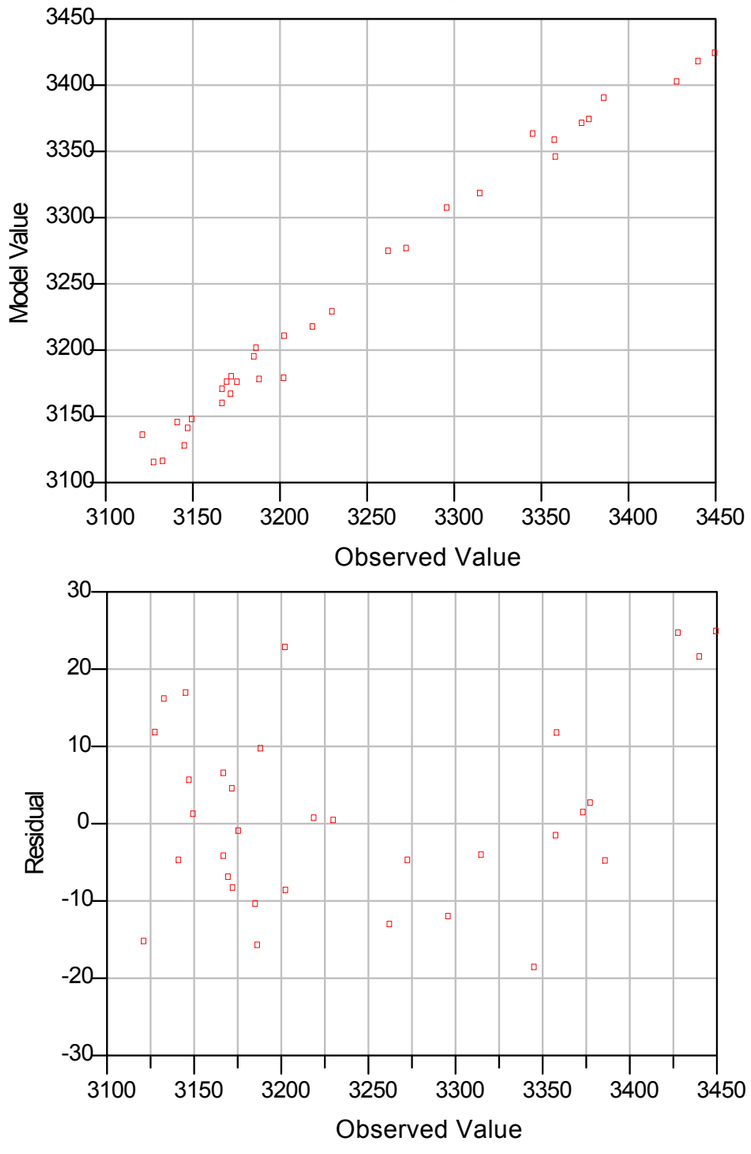
Date: September 27, 2013 **D://figure GM-21 By: MEN** **Issued for Western Energy**	**NICKLIN** **EARTH & WATER, INC.**	**Groundwater Model** **Calibration Plots** **By Model Layer**	**Figure GM-21** **Page 1**

Exhibit 8

Model Layer 4



Model Layer 5



Units are in feet.

Date: September 27, 2013 **D://figure GM-21 By: MEN** **Issued for Western Energy**	**NICKLIN** **EARTH & WATER, INC.**	**Groundwater Model Calibration Plots By Model Layer**	**Figure GM-21** **Page 2**

Exhibit 8

Layer 1 (Overburden)

Contours are in feet, msl. Residuals are in Feet.
Map units shown - State-Plane Feet.
Red symbols imply over-prediction,
blue symbols show under-prediction.

N W E S

A B C D E

630000 620000 610000 600000 590000 580000

2605000 2615000 2625000 2635000 2645000 2655000 2665000 2675000 2685000 2695000 2705000 2715000

Layer 2 (Rosebud Coal)

A B C D E

630000 620000 610000 600000 590000 580000

2605000 2615000 2625000 2635000 2645000 2655000 2665000 2675000 2685000 2695000 2705000 2715000

Layer 3 (Interburden)

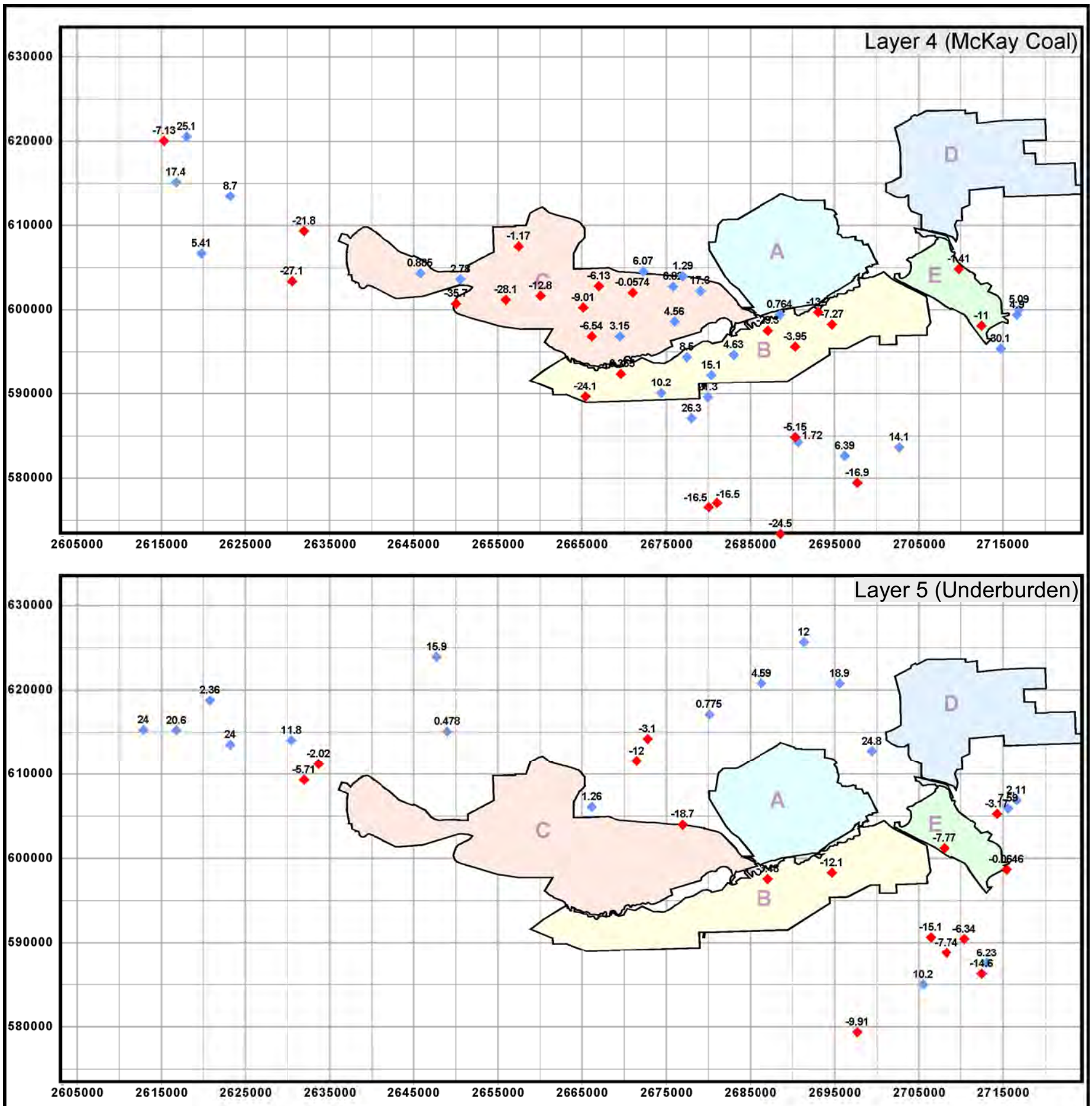
A B C D E

630000 620000 610000 600000 590000 580000

2605000 2615000 2625000 2635000 2645000 2655000 2665000 2675000 2685000 2695000 2705000 2715000

Date: August 20, 2013 d://figure GM-22 By: MEN Issued for Western Energy	NICKLIN EARTH & WATER, INC.	Steady-State Model Residual Plots Rosebud Mine Ground-water Model	Figure GM-22 Page 1

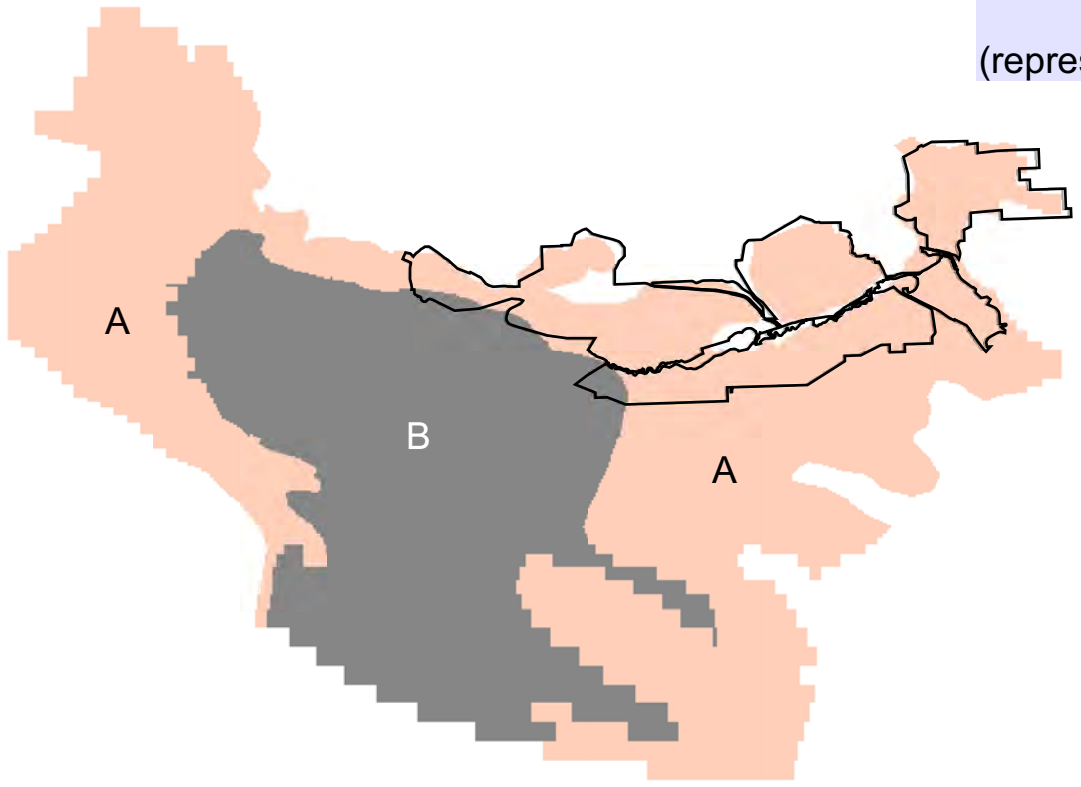
Exhibit 8



Date: August 20, 2013 d://figure GM-22 By: MEN Issued for Western Energy	NICKLIN EARTH & WATER, INC.	Steady-State Model Residual Plots Rosebud Mine Ground-water Model	Figure GM-22 Page 2

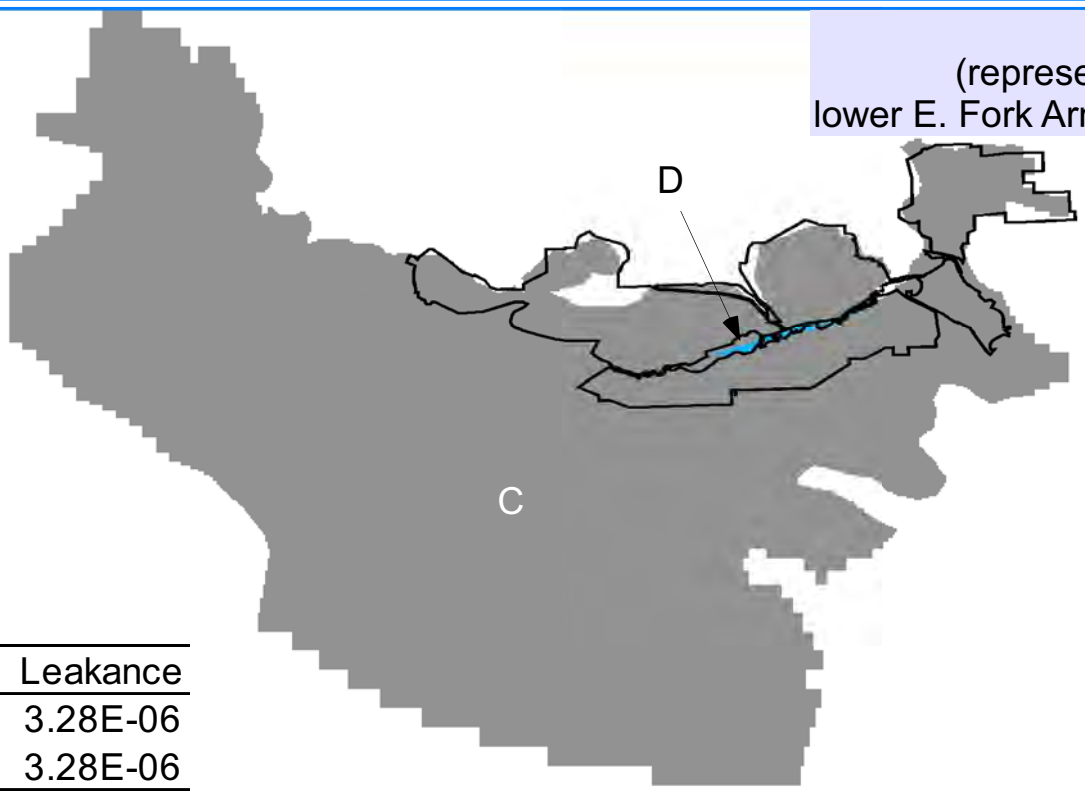
Exhibit 8

Layer 1
(represents overburden)



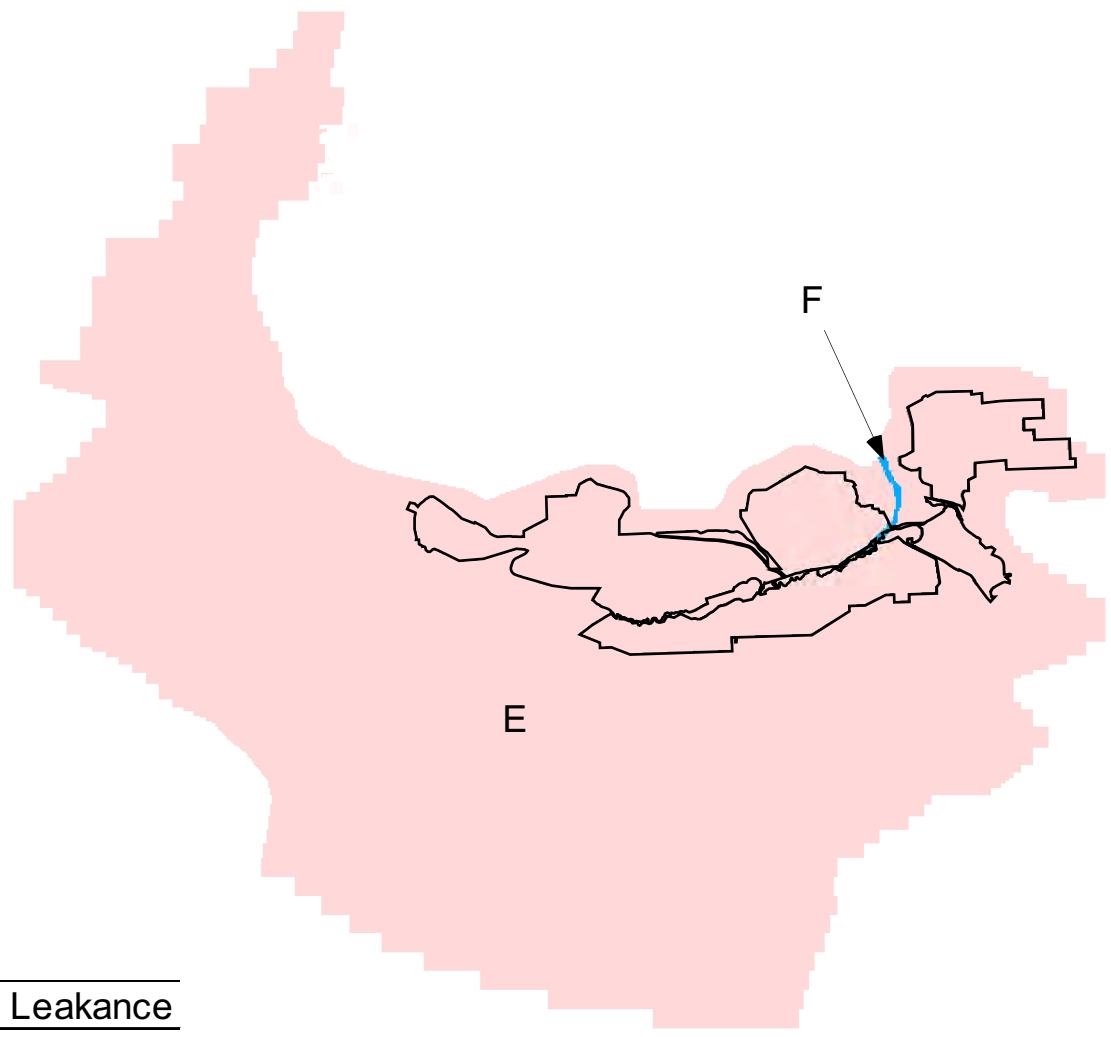
Zone	Transmissivity
A	4.31
B	9.79

Layer 2
(represents Rosebud coal
lower E. Fork Armells Cr. alluvium)



Zone	Transmissivity	Leakance
C	19.02	3.28E-06
D	1,040	3.28E-06

Layer 3
(represents interburden)

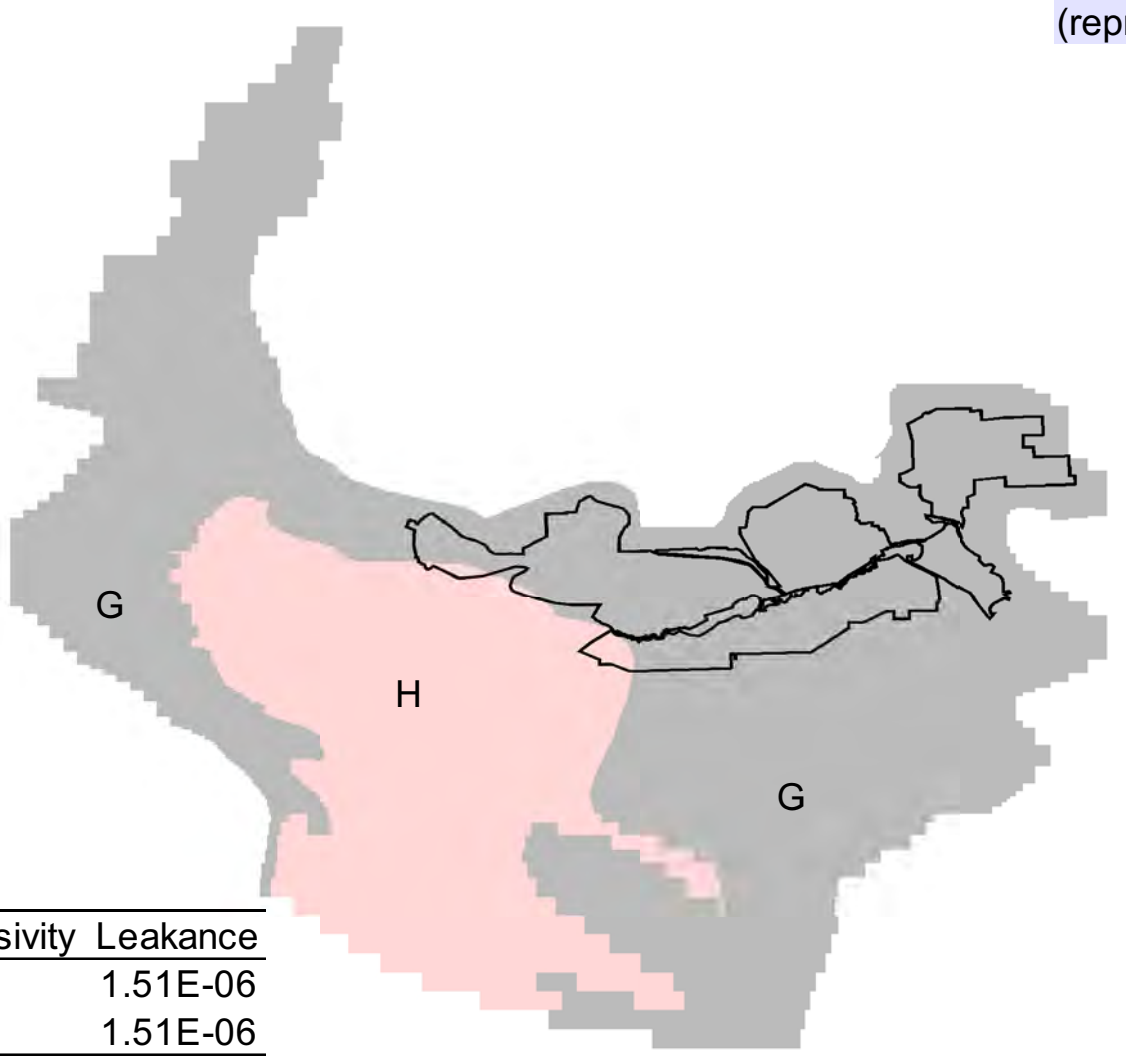


Zone	Transmissivity	Leakance
E	11.55	7.24E-06
F	2,000	7.24E-06

Date: August 1, 2013 **d://figure GM-23 By: MEN** **Issued for Western Energy**	**NICKLIN** **EARTH & WATER, INC.**	**Transmissivity (ft^2/d) and Leakance Zonation** **Rosebud Mine Groundwater Model**	**Figure GM-23** **Page 1**

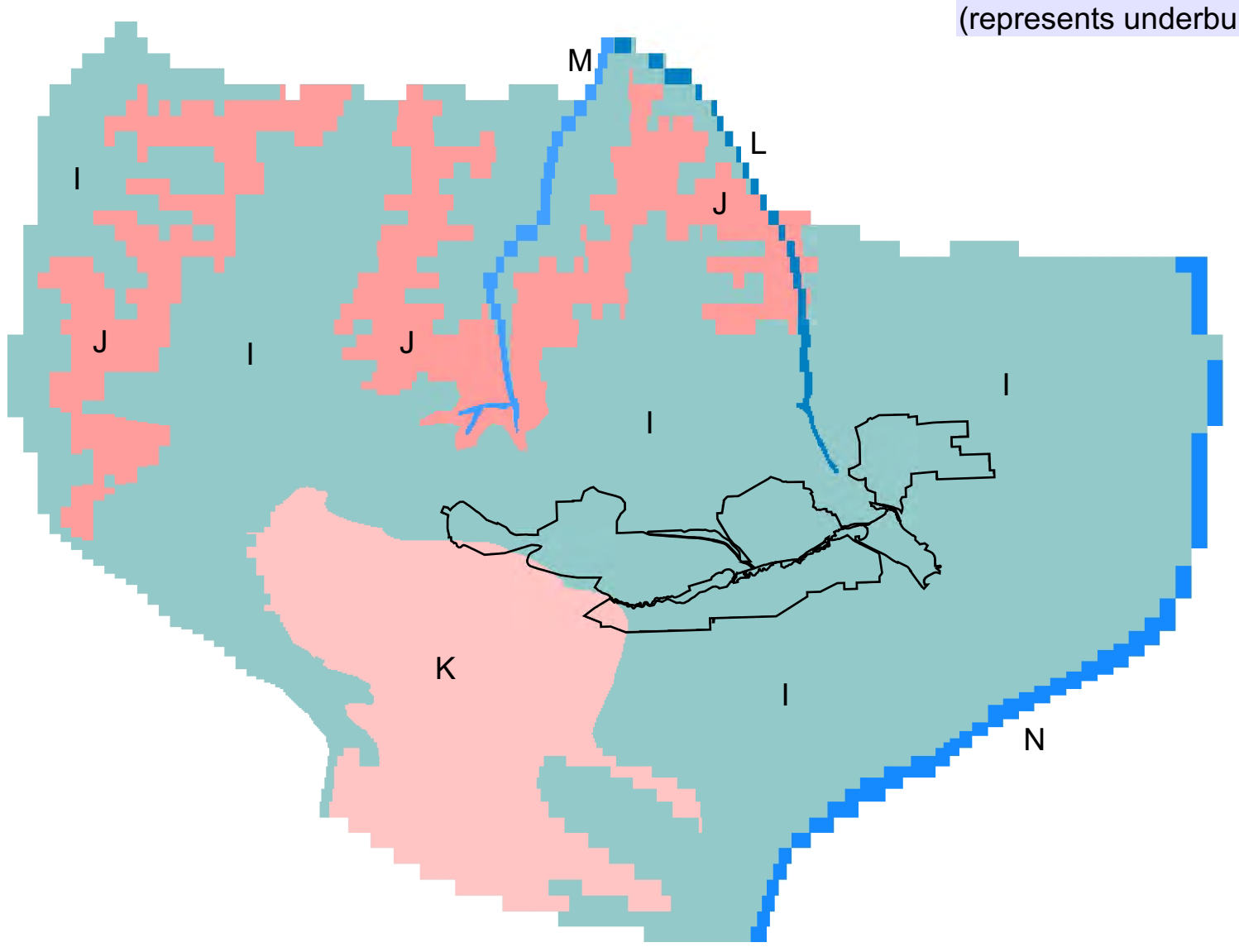
Exhibit 8

Layer 4
(represents McKay coal)



Zone	Transmissivity	Leakance
G	13.43	1.51E-06
H	2.4	1.51E-06

Layer 5
(represents underburden)

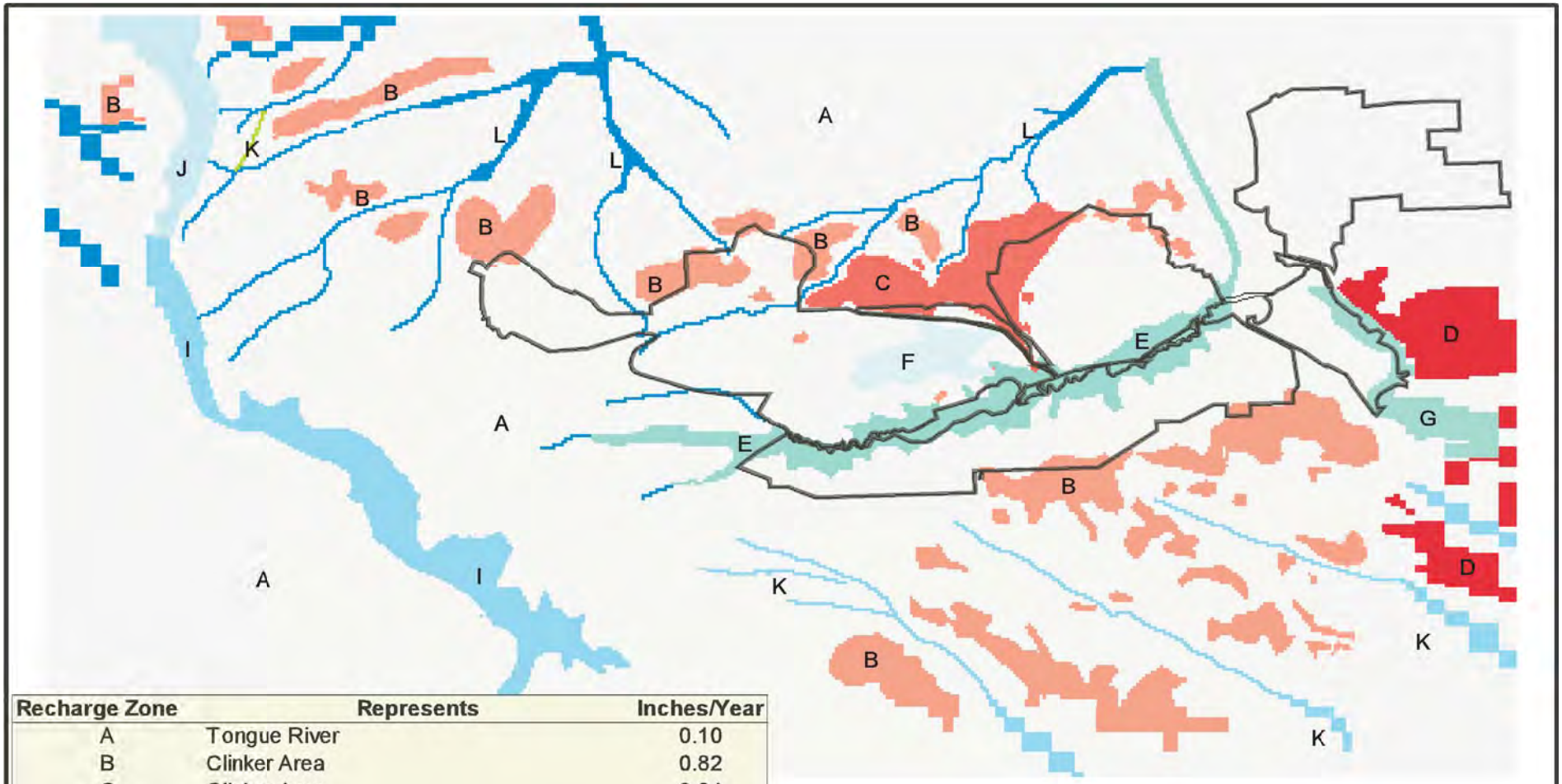


Zone	Transmissivity	Leakance
I	70.8	
J	5	
K	94 *	
L	4,000	
M	2,000	
N	4,000	

* Zone could be assigned to I with little change in calibration.

Date: August 1, 2013 d://figure GM-23 By: MEN Issued for Western Energy	NICKLIN EARTH & WATER, INC.	Transmissivity (ft^2/d) and Leakance Zonation Rosebud Mine Groundwater Model	Figure GM-23 Page 2

Exhibit 8



Recharge Zone	Represents	Inches/Year
A	Tongue River	0.10
B	Clinker Area	0.82
C	Clinker Area	0.84
D	Clinker Area	0.54
E	E Fork Alluvium/Colluvium	1.54
F	Probable Clinker Area	1.08
G	Pre-Mining Clinker As Spoil Backfill?	1.06
H	Alluvium - Drainages to Rosebud Creek	0.13
I	Little Wolf Mountain Divide	1.51
J	Little Wolf Mountain Divide	1.99
K	Fault - Robbie Creek	2.50
L	Alluvium - W. Fork Armells/Stocker Creek	1.93

Date: August 1, 2013
d://figure GM-24 By: MEN
Issued for Western Energy

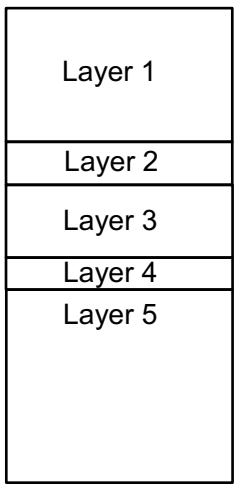
NICKLIN
EARTH & WATER, INC.

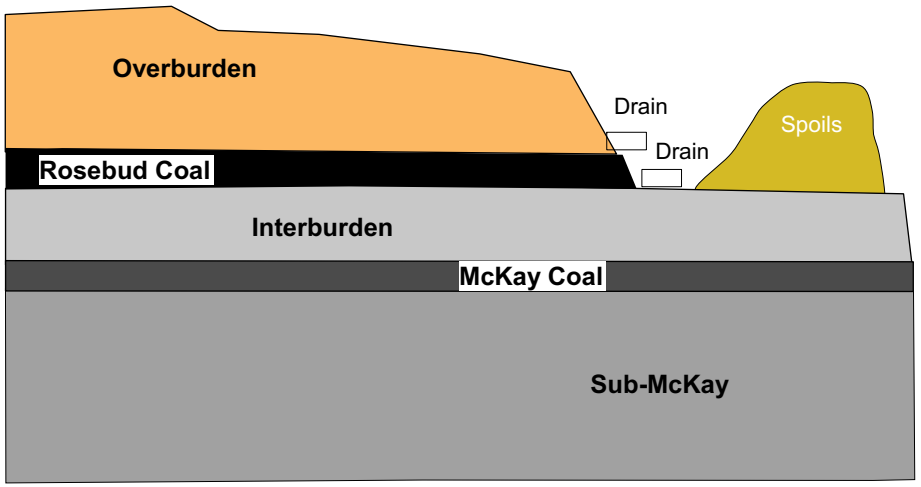
Groundwater Model Recharge Zonation
Vicinity of Rosebud Mine

Figure GM-24

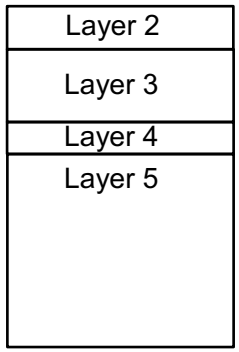
Exhibit 8

Model Layers Representation
Before Mining





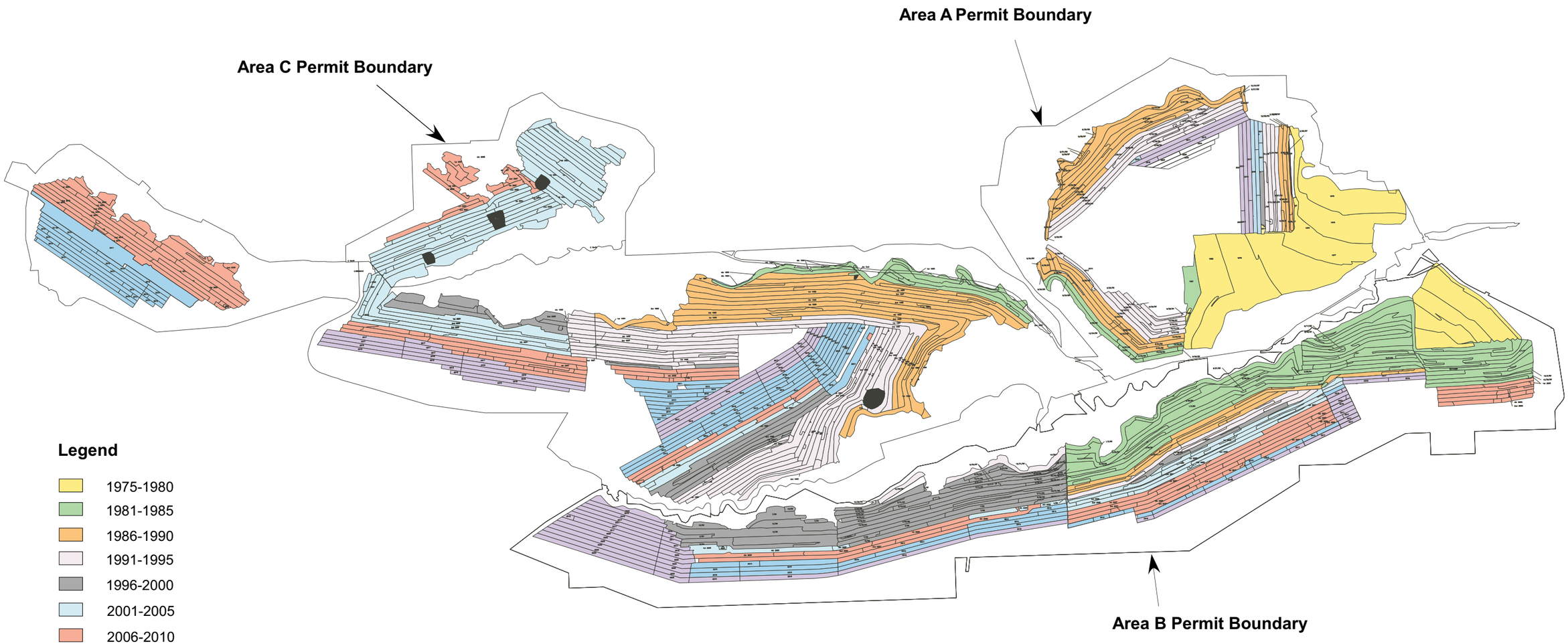
Model Layers Representation
After Mining



1. Model drains are imposed on Layers 1 and 2 during active mine passes.
2. Layer 1 was inactivated following mining passes as spoils are placed.
3. The model drains are removed for the active pass that was completed.
4. Storage coefficients for the spoils were assigned to be 0.1.
5. Transmissivity for the spoils was assigned as 13 ft^2/day.
6. Recharge in the vicinity of the spoils was assigned at 0.22 inches/year.

Date: May 23, 2013 d://figure GM-25 By: MEN Issued for Western Energy	NICKLIN EARTH & WATER, INC.	**Changes in Model Structure and Parameterization Used to Represent Mining Progression Rosebud Mine Model**	**Figure GM-25**

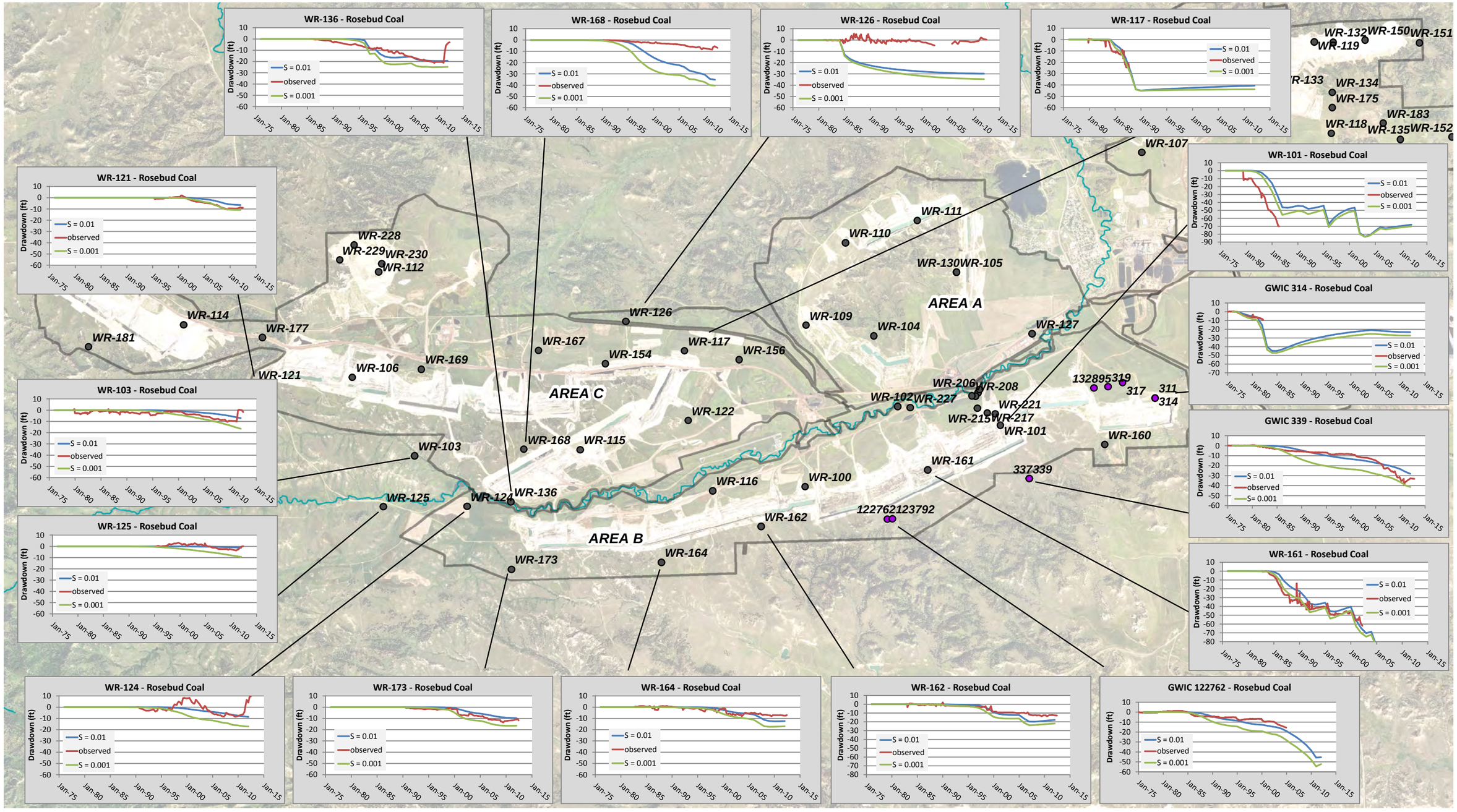
Exhibit 8



Actual mining progress can vary depending upon coal demand and other factor.

Date: May 23, 2013 **D://GM26P1 By: SV** **Issued for Western Energy**	NICKLIN EARTH & WATER, INC.	**Simplified Mining Sequence - Existing Permit (1975-2020)** **Western Energy - Rosebud Mine**	**Figure GM-26**

Exhibit 8



Two storativity values (S) were tested. In the first scenario (blue line) S was set to 0.01 in all layers. In the second scenario (green line), S was kept at 0.01 in layer 1 and set to 0.001 in layer 2 through 5. The storativity of the spoils in both scenarios was set to 0.1.

NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

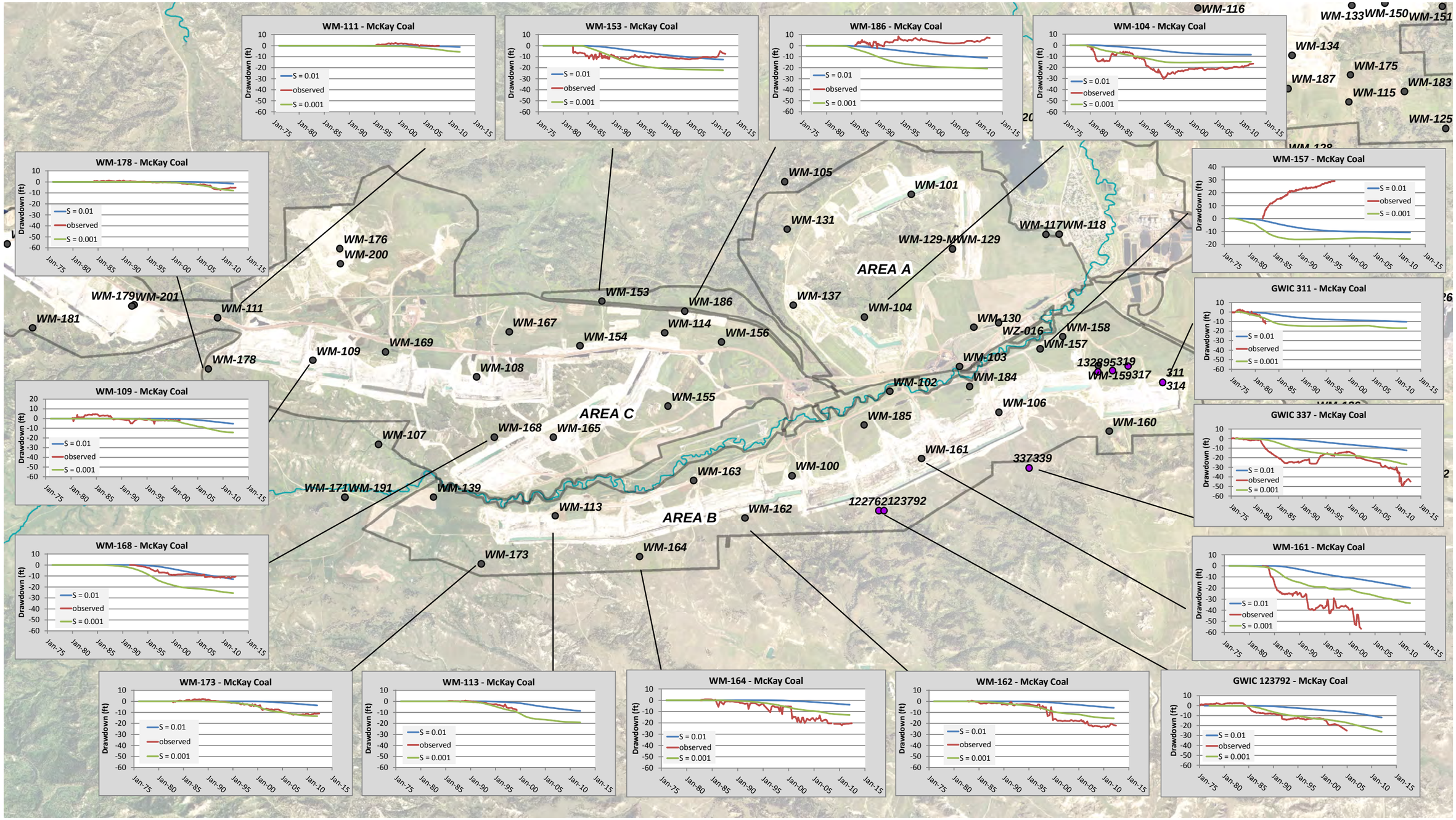
Date: 5/23/2013

Name: Figure GM27P1 - Storativity Analysis - Rosebud Coal

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-27 - Page 1
Storativity Analysis
Observed vs Simulated Drawdown
Selected Rosebud Coal Wells
Western Energy Rosebud Mine

Exhibit 8



Two storativity values (S) were tested. In the first scenario (blue line) S was set to 0.01 in all layers. In the second scenario (green line), S was kept at 0.01 in layer 1 and set to 0.001 in layer 2 through 5. The storativity of the spoils in both scenarios was set to 0.1.

NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

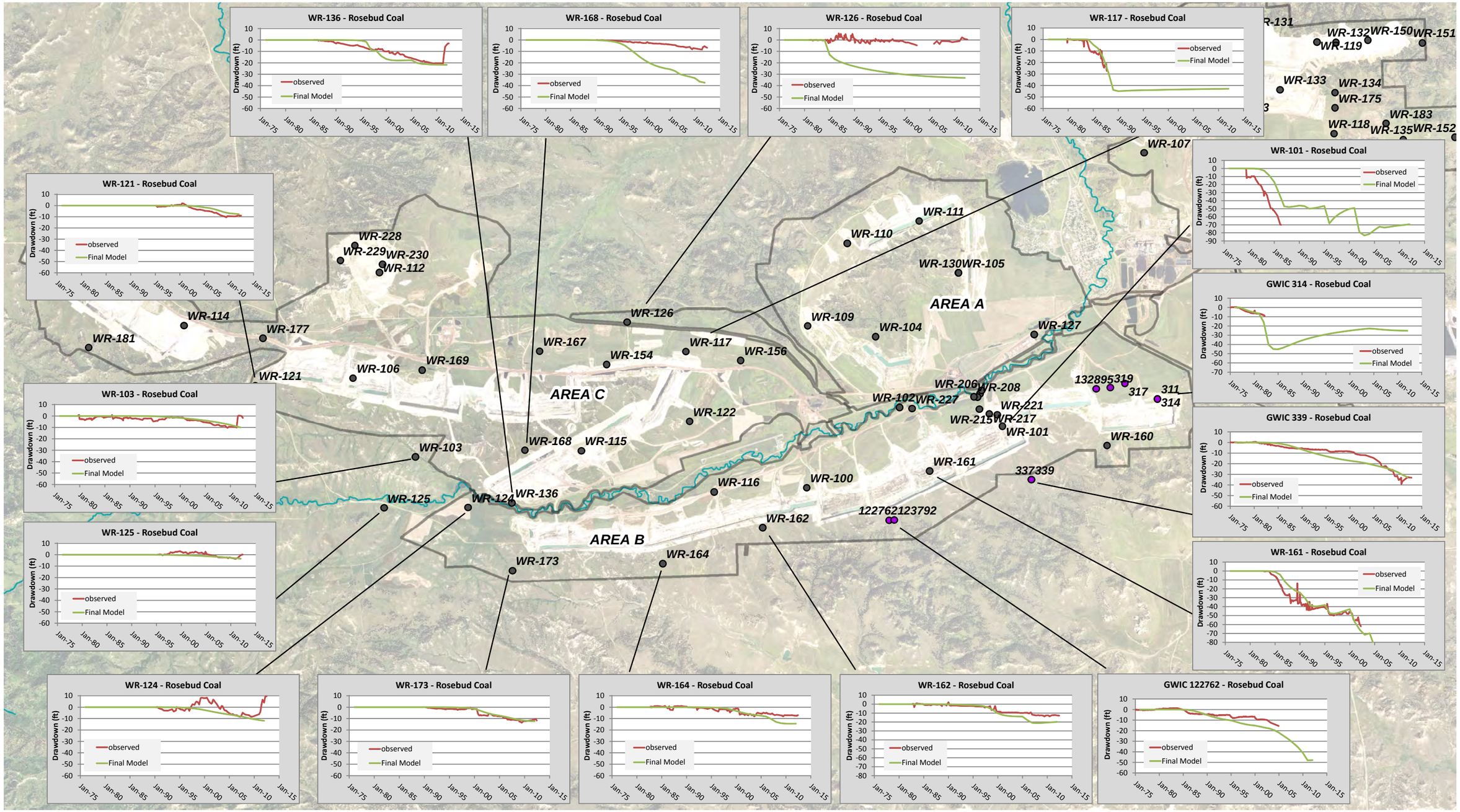
Date: 5/23/2013

Name: Figure GM27P2 - Storativity Analysis - McKay Coal

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-27 - Page 2
Storativity Analysis
Observed vs Simulated Drawdown
Selected McKay Coal Wells
Western Energy Rosebud Mine

Exhibit 8



The storativity values for the final model were assigned as follows: S was set to 0.01 in layer 1 and 2 and set to 0.001 in layer 3 through 5. The storativity of the spoils was set to 0.1.

NICKLIN EARTH & WATER, INC.

Notes:
1) Aerial Photographs: 2011 NAIP

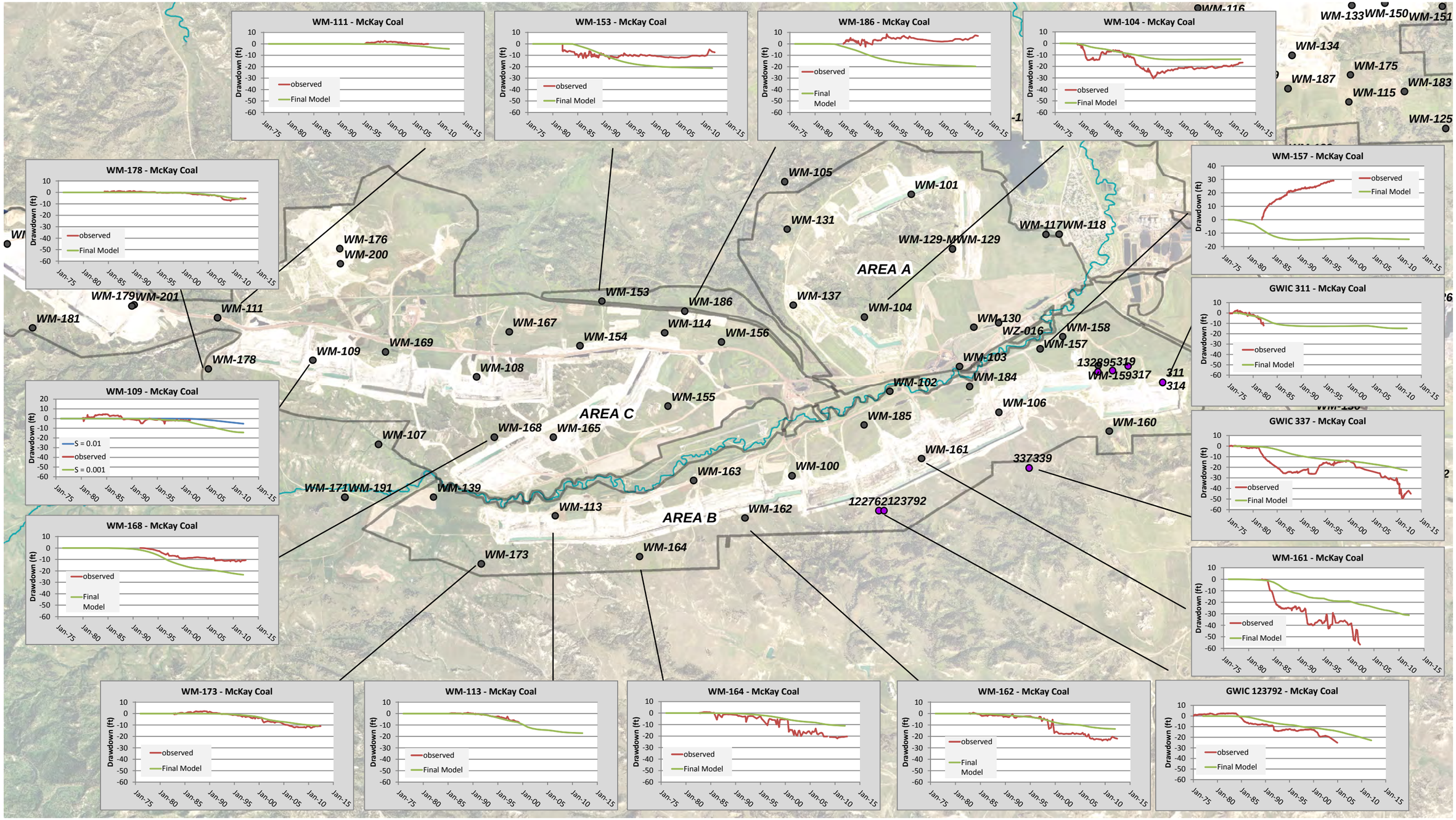
Date: 5/23/2013

Name: Figure GM27P3 - Storativity Analysis - Rosebud Coal - Final Model

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-27 - Page 3
Observed vs Simulated Drawdown
Selected Rosebud Coal Wells
Final model
Western Energy Rosebud Mine

Exhibit 8



The storativity values for the final model were assigned as follows: S was set to 0.01 in layer 1 and 2 and set to 0.001 in layer 3 through 5. The storativity of the spoils was set to 0.1.

NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2011 NAIP

Date: 5/23/2013

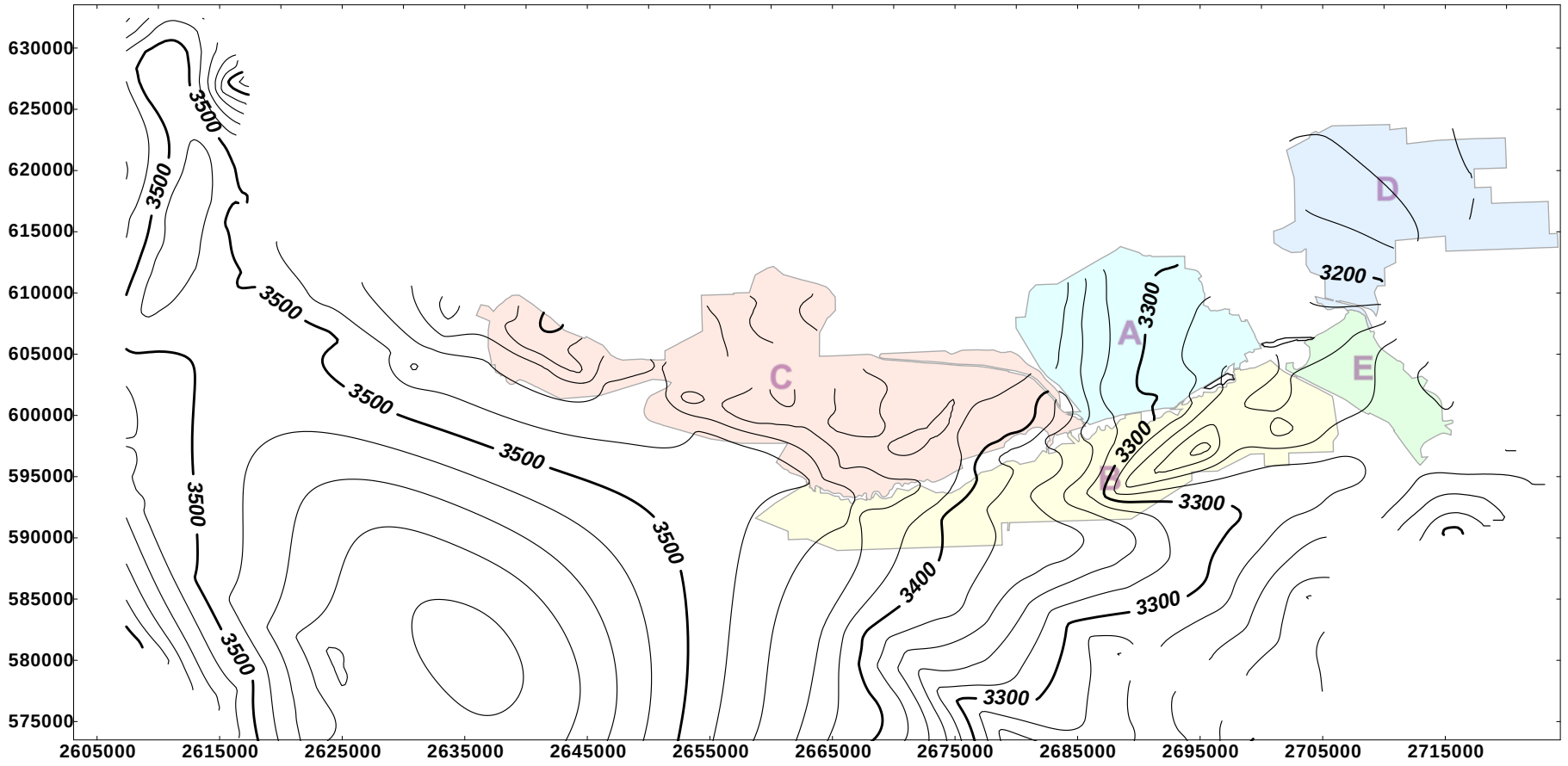
Name: Figure GM27P4 - Storativity Analysis - McKay Coal - Final Model

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure GM-27 - Page 4
Observed vs Simulated Drawdown
Selected McKay Coal Wells
Final Model
Western Energy Rosebud Mine

Exhibit 8

Layer 2 - Rosebud Coal and Spoils

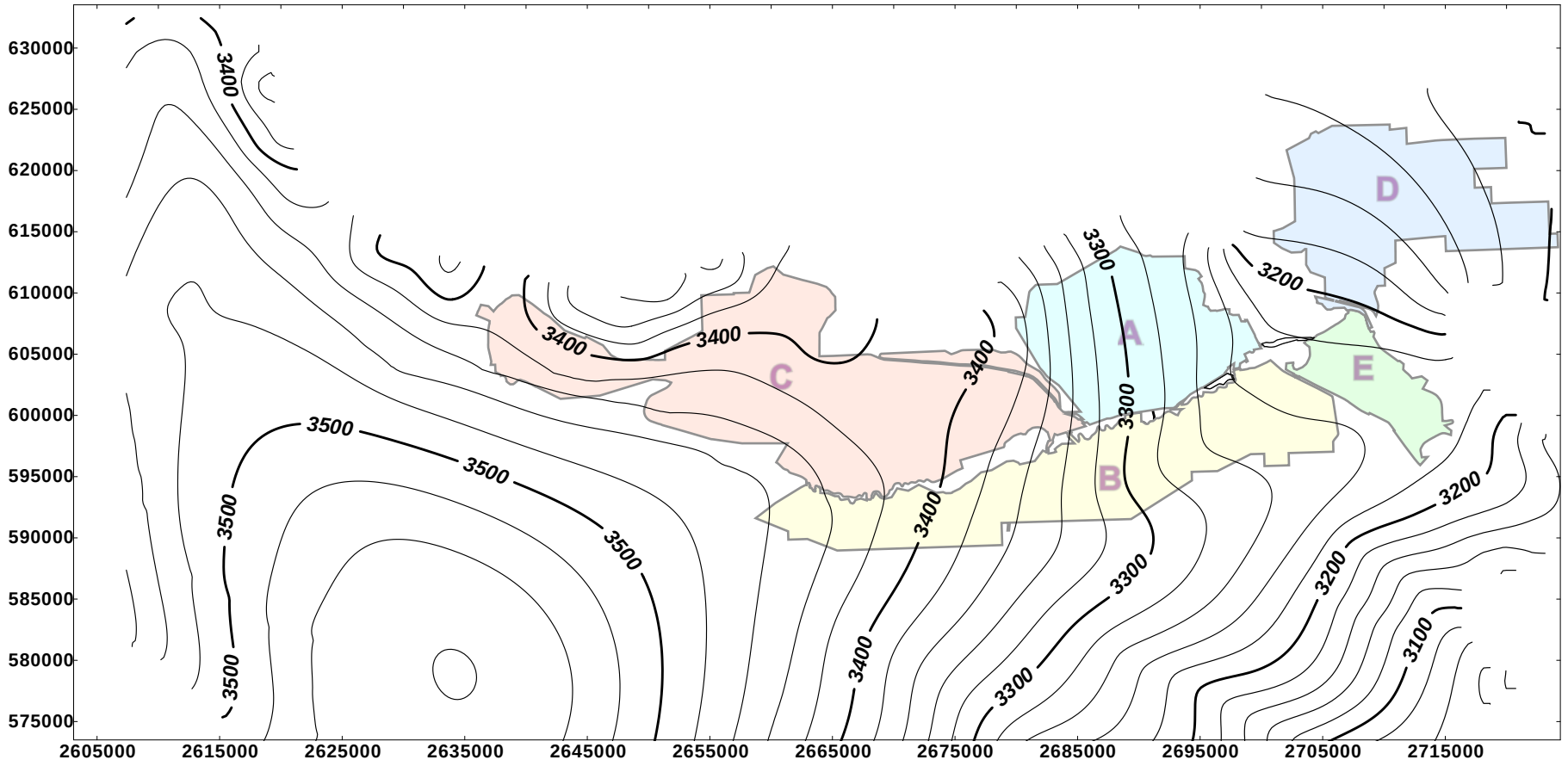


Contours are in feet, msl. Contour interval is 20 feet. Map units shown - State-Plane Feet.

Date: 09/27/13 FGM28P1.cvx Issued for Western Energy	NICKLIN EARTH & WATER, INC.	**Simulated Potentiometric Head - 2011 Layer 2 - Rosebud Coal and Spoils Western Energy - Rosebud Mine**	**Figure GM-28 Page 1**

Exhibit 8

Layer 4 - McKay Coal

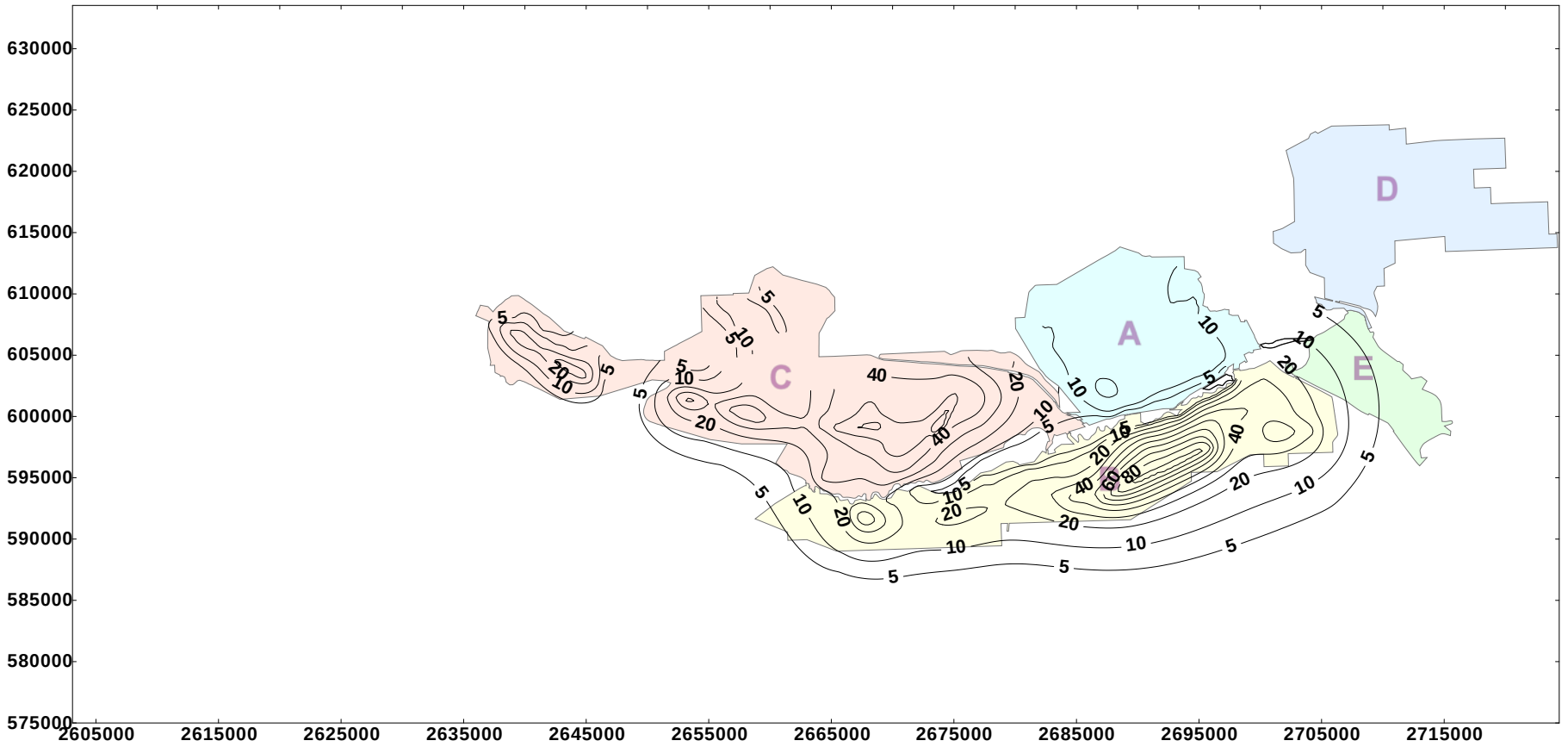


Contours are in feet, msl. Contour interval is 20 feet. Map units shown - State-Plane Feet.

Date: 05/23/13 FGM28P2.cvx Issued for Western Energy	NICKLIN EARTH & WATER, INC.	**Simulated Potentiometric Head - 2011** **Layer 4 - McKay Coal** **Western Energy - Rosebud Mine**	**Figure GM-28** **Page 2**

Exhibit 8

Layer 2 - Rosebud Coal

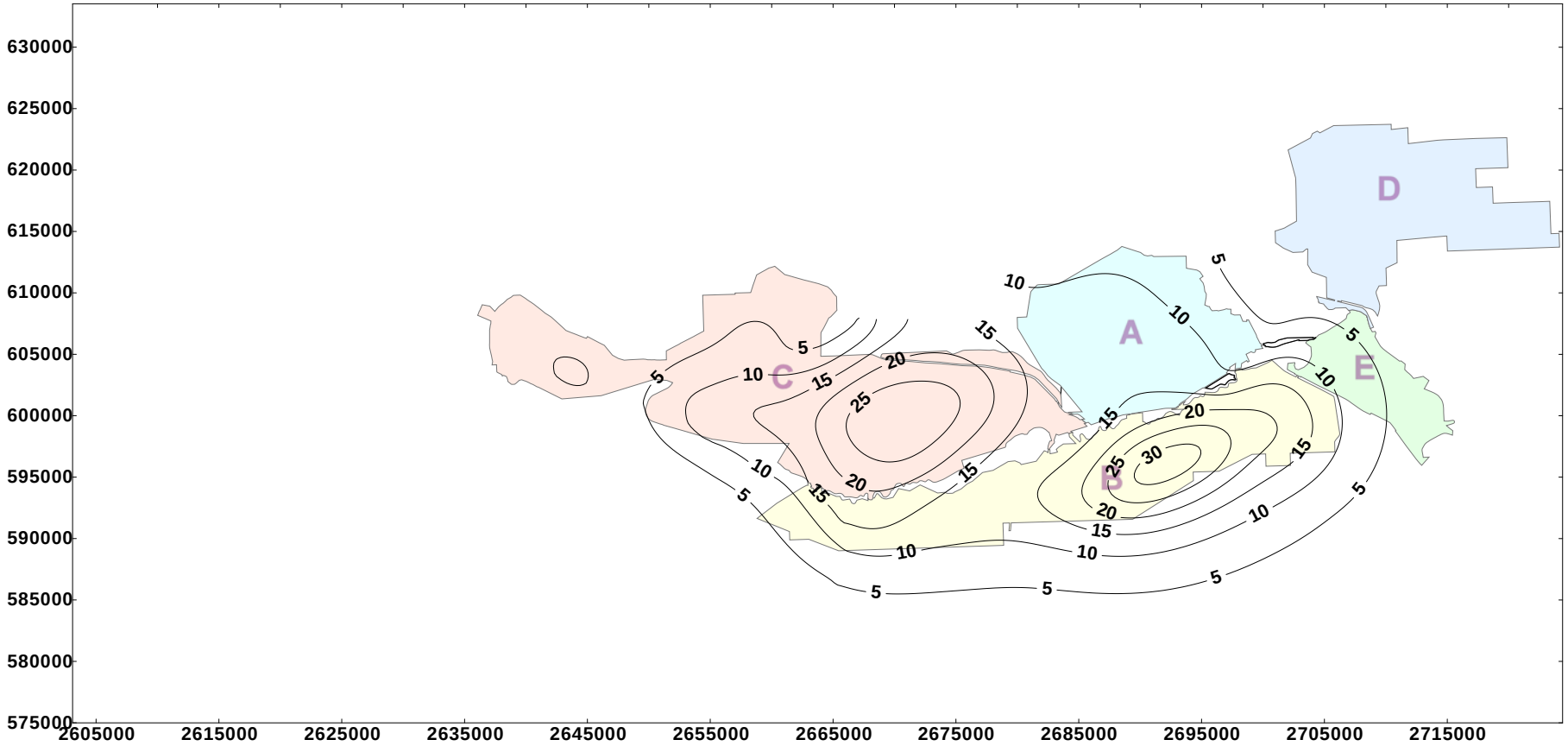


Drawdown contours are in feet. Contour interval is 10 feet. In addition, the 5 foot drawdown contour is shown. Map units shown - State-Plane Feet.

Date: 05/23/13 FGM29P1.cvx Issued for Western Energy	NICKLIN EARTH & WATER, INC.	**Simulated Drawdown - Existing Permit 2011** **Layer 2 - Rosebud Coal** **Western Energy - Rosebud Mine**	**Figure GM-29** **Page 1**

Exhibit 8

Layer 4 - McKay Coal

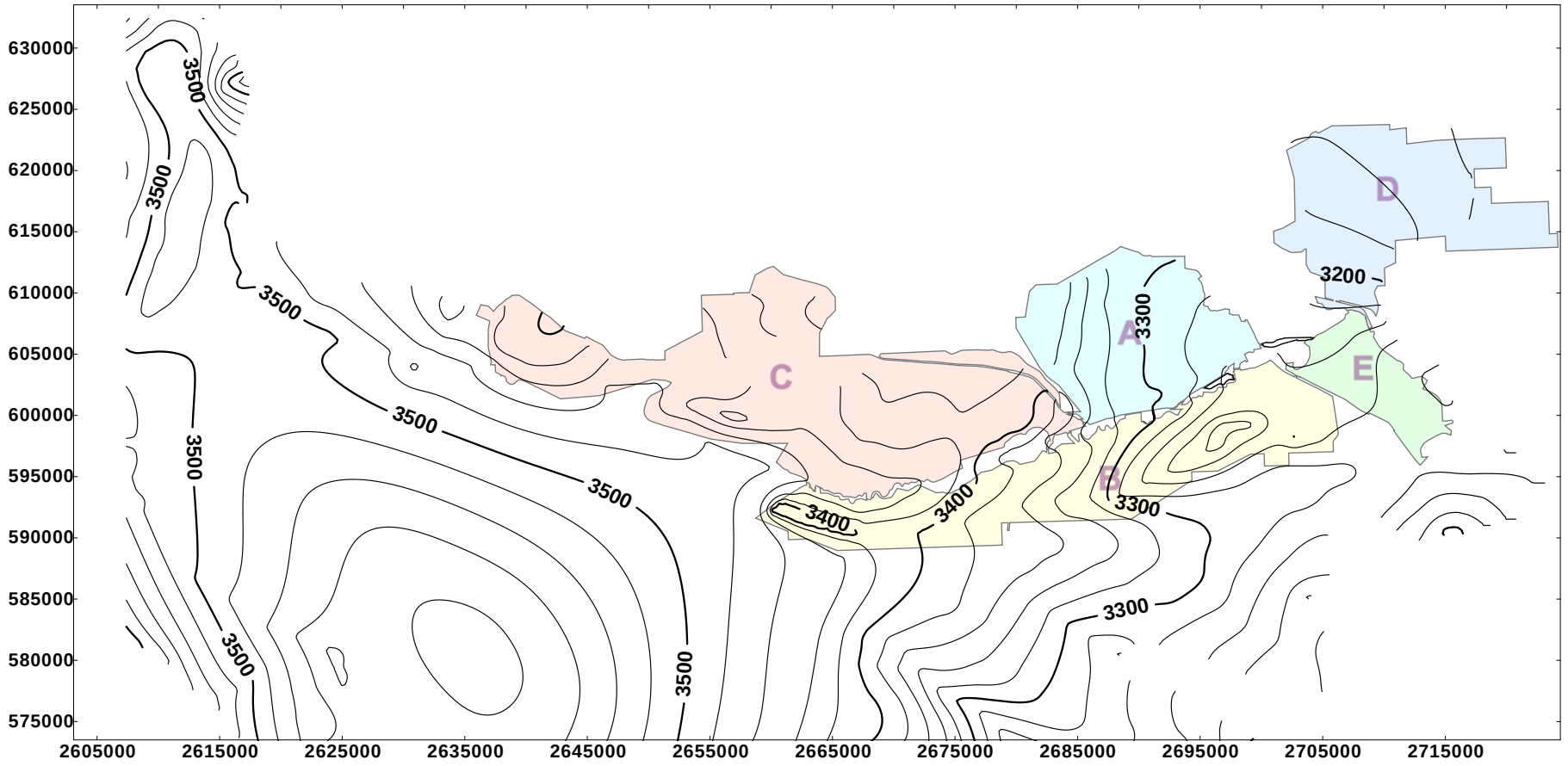


Drawdown contours are in feet. Contour interval is 5 feet. Map units shown - State-Plane Feet.

Date: 05/23/13 FGM29P2.cvx Issued for Western Energy	NICKLIN EARTH & WATER, INC.	**Simulated Drawdown - Existing Permit 2011** **Layer 4 - McKay Coal** **Western Energy - Rosebud Mine**	**Figure GM-29** **Page 2**

Exhibit 8

Layer 2 - Rosebud Coal

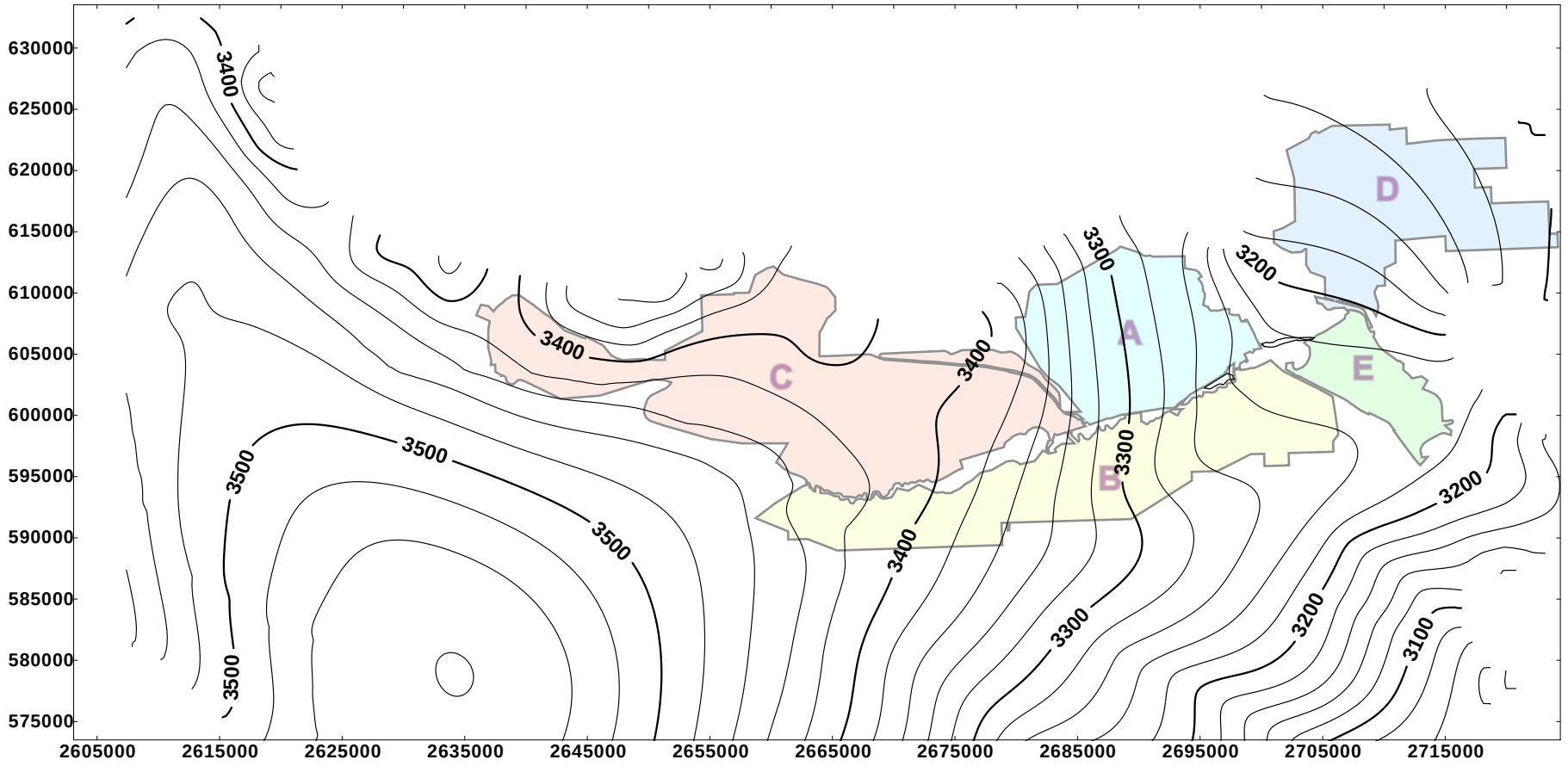


Contours are in feet, msl. Contour interval is 20 feet. Map units shown - State-Plane Feet.

Date: 05/23/13 FI30P1.cvx Issued for Western Energy	NICKLIN EARTH & WATER, INC.	**Simulated Potentiometric Head - Existing Permit 2020** **Layer 2 - Rosebud Coal** **Western Energy - Rosebud Mine**	**Figure GM-30** **Page 1**

Exhibit 8

Layer 4 - McKay Coal

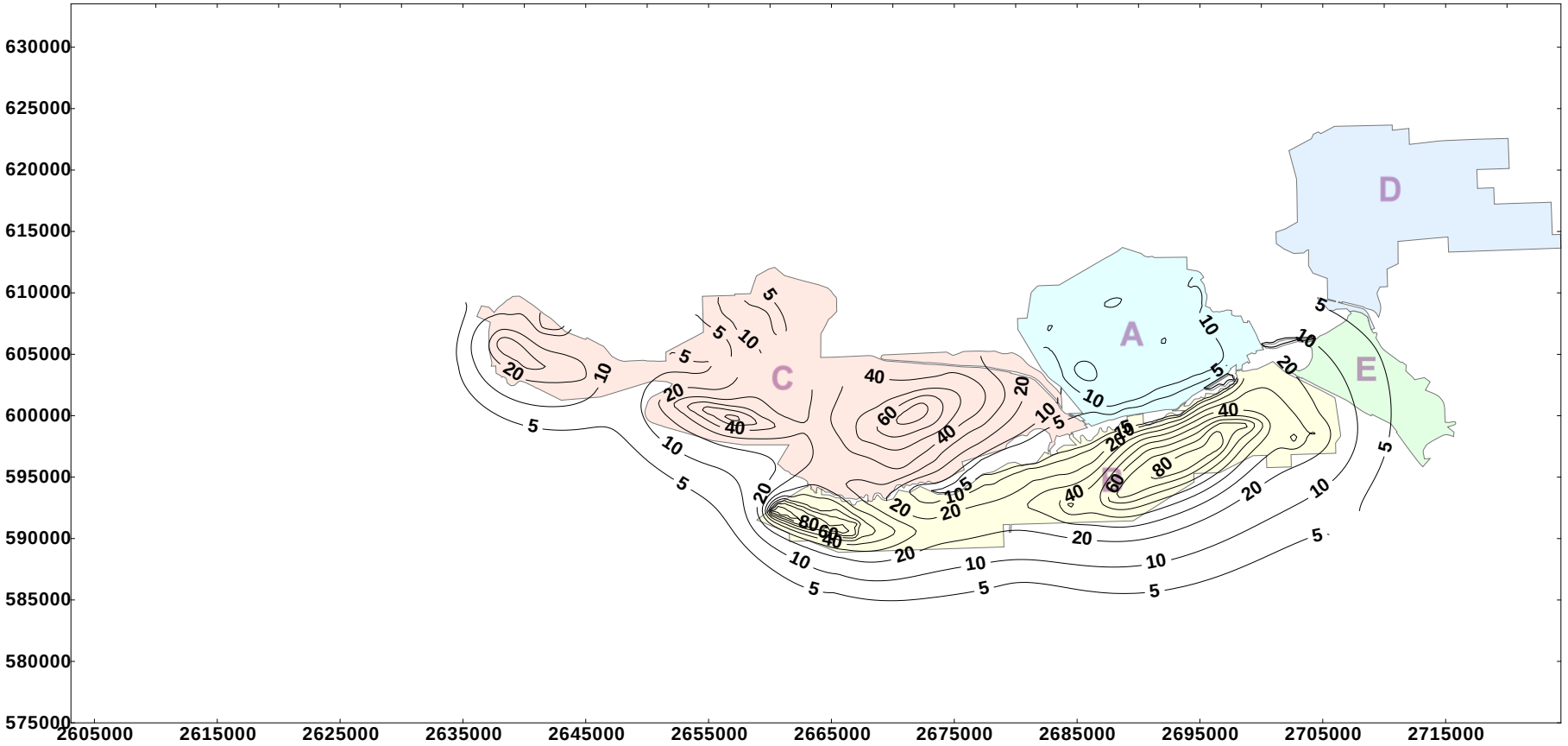


Contours are in feet, msl. Contour interval is 20 feet. Map units shown - State-Plane Feet.

Date: 05/23/13 FGM30P2.cvx Issued for Western Energy	NICKLIN EARTH & WATER, INC.	**Simulated Potentiometric Head - Existing Permit 2020** **Layer 4 - McKay Coal** **Western Energy - Rosebud Mine**	**Figure GM-30** **Page 2**

Exhibit 8

Layer 2 - Rosebud Coal

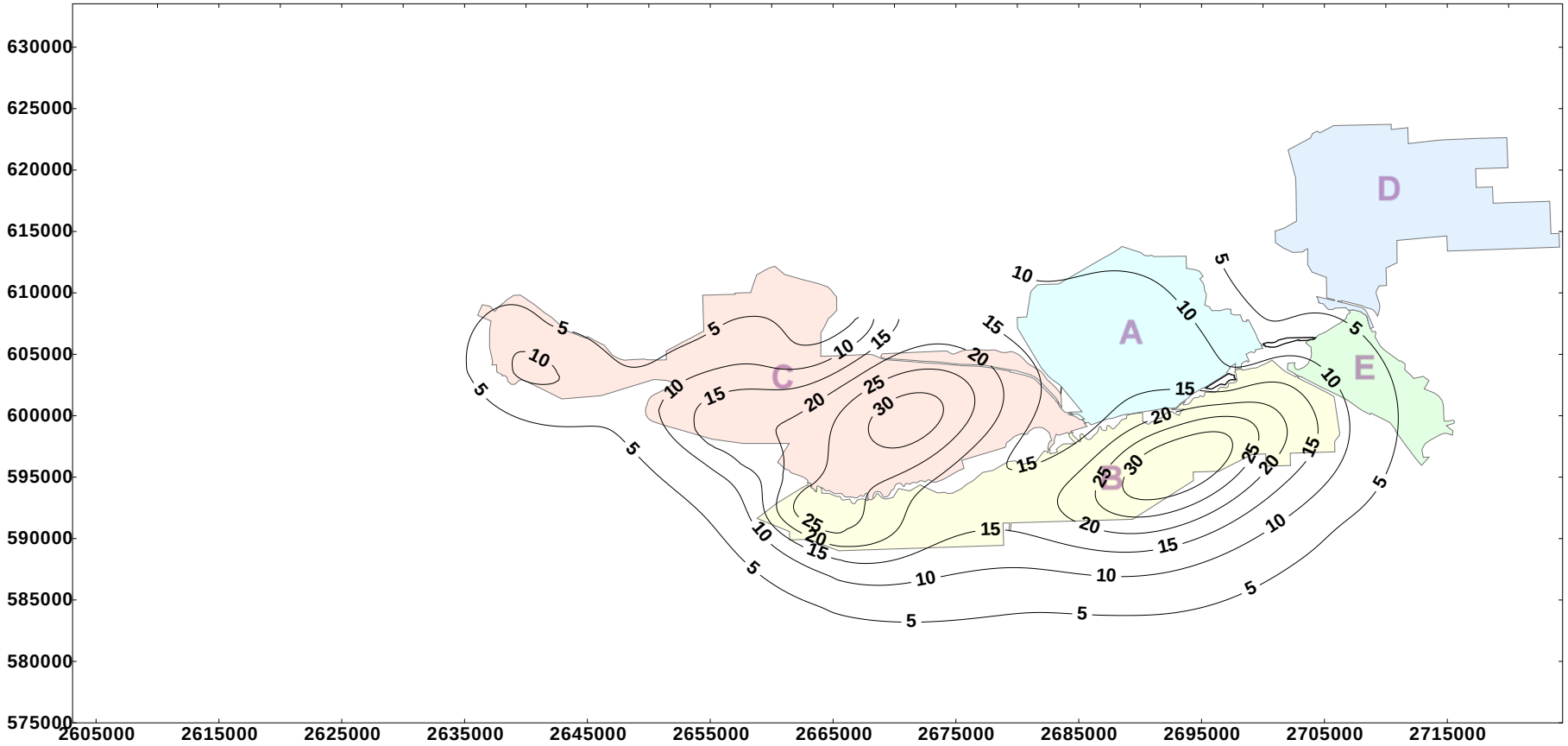


Drawdown contours are in feet. Contour interval is 10 feet. In addition, the 5 foot drawdown contour is shown. Map units shown - State-Plane Feet.

Date: 05/31/13 FGM31P1.cvx Issued for Western Energy	NICKLIN EARTH & WATER, INC.	**Simulated Drawdown - Existing Permit 2020** **Layer 2 - Rosebud Coal** **Western Energy - Rosebud Mine**	**Figure GM-31** **Page 1**

Exhibit 8

Layer 4 - McKay Coal



Drawdown contours are in feet. Contour interval is 5 feet. Map units shown - State-Plane Feet.

Date: 05/23/13 FGM31P2.cvx Issued for Western Energy	NICKLIN EARTH & WATER, INC.	**Simulated Drawdown - Existing Permit 2020** **Layer 4 - McKay Coal** **Western Energy - Rosebud Mine**	**Figure GM-31** **Page 2**

Exhibit 8

Model Attachments

Exhibit 8

Model Attachment GM-A
Target Rationale Summary

Exhibit 8

Attachmenta GM-A
Steady-State Calibration Targets - Rationale of Individual Target
Rosebud Mine

Name	Layer	Observed	Date	Rationale
AAL51	1	3220.00		*
AOVM73	1	3309.00		*
BOV1012	1	3256.80		*
BOV112	1	3373.20		*
BOV1712	1	3257.00		*
BOV212	1	3363.50		*
BOV512	1	3318.50		*
BOV612	1	3313.00		*
WA-103	1	3389.20	7/25/1979	Selected as representative of series WA-102 through WA-106
WA-116	1	3273.40	22-May-80	First readings predated mining.
WA-117	1	3276.00	22-May-80	First readings predated mining.
WA-118	1	3648.59	22-Aug-85	Remote from mining - representative of WA-119 through WA-121
WA-122	1	3472.80	4-Dec-80	Early water levels stable until mining encroached nearer area.
WA-123	1	3474.40	4-Dec-80	Early water levels stable until mining encroached nearer area.
WA-171	1	3530.21	1-Sep-82	Well is drought responsive. Has not responded to mining and is upgradient from mining. Likely vertically isolated from Rosebud coal with underlying overburden strata.
WA-209	1	3456.55	21-Mar-88	Early record is pre-date mining. Mining began in area in 1992 and the well responded to this mining.
WA-210	1	3455.56	22-Sep-88	Early record is pre-date mining. Mining began in area in 1992 and the well responded to this mining.
WA-214	1	3524.91	26-Jul-85	Outside vicinity of mining. Dramatic increase in water levels observed in response to 2011 major precipitation event. Note that initial modeling pre-dated the later observations.
WA-216	1	3543.83	8/5/1985	Observations pre-date mining. Could have selected WA-215 as an alternative target as has longer period of record, or could have employed both.
WA-224	1	3558.56	12/21/2012	New well. Far from any mining activity. Added after initial modeling effort.
WA-226	1	3511.97	12/21/2012	New well. Far from any mining activity. Added after initial modeling effort.
WA-227	1	3472.21	12/21/2012	New well. Far from any mining activity. Added after initial modeling effort.
WO-101	1	3386.60	22-May-80	Water level data before any mining in area of this well.
WO-103	1	3462.95	22-May-80	Water levels showing some decline before mining in area but not as pronounced as WO-102.
WO-107	1	3463.79	5-Aug-85	Water levels predate mining in the vicinity of this well.
WO-108	1	3464.33	5-Aug-85	Water levels predate mining in the vicinity of this well.
WO-155	1	3450.85	24-Nov-81	Water levels showing some limited decline before mining in area occurred.
WO-156	1	3457.27	23-Nov-81	Water levels stable before mining in vicinity.
WO-162	1	3385.90	1-Sep-82	First water levels predate mining in vicinity. This observation well appears to have responded to mining indicating that it is hydraulically connected to the Rosebud coal.
WO-164	1	3403.05	15-Dec-90	First water levels predate mining in vicinity. This observation well appears to have responded to mining indicating that it is hydraulically connected to the Rosebud coal.
WO-165	1	3469.84	1-Sep-82	First water levels predate mining in vicinity. This observation well appears to have responded to mining indicating that it is hydraulically connected to the Rosebud coal.
WO-166	1	3472.81	1-Sep-82	First water levels predate mining in vicinity. This observation well appears to have responded to mining indicating that it is hydraulically connected to the Rosebud coal.
WO-168	1	3483.15	1-Sep-82	First water levels predate mining in vicinity. This observation well appears to have responded to mining indicating that it is hydraulically connected to the Rosebud coal.
WO-169	1	3462.97	1-Sep-82	First water levels predate mining in vicinity. This observation well appears to have responded to mining indicating that it is hydraulically connected to the Rosebud coal.
WO-172	1	3495.25	1-Sep-82	First water levels predate mining activity. This well may be drought responsive as long term declines observed before mining in vicinity.
WO-176	1	3456.47	5-Mar-84	Well stable and nonresponsive to mining.
WO-178	1	3510.84	5-Mar-84	Early readings showed slight increasing trend over time. This may indicate a very low yield well. Water levels stablized just above 3510 as time progressed.
WO-179	1	3467.40	2-Mar-84	First water levels predate mining activity. This well may be drought responsive.
WO-181	1	3483.20	2-Mar-84	First water levels predate mining activity. This well has been unresponsive to mining to date.
WO-184	1	3482.23	15-Jan-05	First readings predate mining in area. Dramatic increase in water level in association with 2011 precipitation, runoff and recharge event.
WO-185	1	3535.27	14-Feb-05	First readings predate mining in area. Slight increase in water level in association with 2011 precipitation event.
WO-186	1	3542.34	12-Jan-05	No mining in area. Well showed some response to 2011 precipitation event.
WO-187	1	3507.58	15-Jan-05	No mining in area.
ARC30	2	3226.50		*
ARC44	2	3276.50		*
ARC52	2	3296.50		*
ARC53	2	3290.00		*
ARC66	2	3248.00		*
ARCM63	2	3295.50		*

Attachmenta GM-A
Steady-State Calibration Targets - Rationale of Individual Target
Rosebud Mine

Name	Layer	Observed	Date	Rationale
ARCM67	2	3317.50		*
BRC1013	2	3256.80		*
BRC1313	2	3380.00		*
BRC1413	2	3313.00		*
BRC1513	2	3267.00		*
BRC1713	2	3257.20		*
BRC213	2	3354.20		*
BRC513	2	3319.30		*
BRC9163	2	3299.00		*
WR-101	2	3304.40	30-Jun-79	First readings before mining in this well's vicinity. First value is highly anomalous.
WR-102	2	3319.80	21-Dec-79	First readings before mining in Area B. Showed seasonal variation in association with E. Fork Armell's Creek alluvium.
WR-103	2	3490.30	13-Jul-81	First readings before mining in vicinity. Readings beginning just after 2000 may be indicating a resonse to mining in Area C and Area B.
WR-112	2	3434.98	29-Sep-88	Observations predate mining in area. Well appears to be drought responsive.
WR-113	2	3440.88	30-Aug-84	Observations predate mining in area. Well appears to be drought responsive.
WR-115	2	3465.80	4-Dec-80	Observations predate mining in area.
WR-116	2	3401.10	5-Oct-79	Observations predate mining in area.
WR-117	2	3457.00	5-Oct-79	Observations predate mining in area.
WR-121	2	3470.91	28-Apr-82	Drought responsive well. Many wells in thsi portion of the system are drought responsive.
WR-122	2	3444.79	28-Sep-87	Observations predate mining in area. Well appears to be drought responsive.
WR-124	2	3499.28	3-Sep-91	Observations predate mining in area. Well appears to be drought responsive.
WR-125	2	3494.15	22-Sep-92	Observations predate mining in area and well about one mile upgradient of any current mining. Well appears to be drought responsive.
WR-126	2	3449.10	21-Oct-80	First observations predate mining in area and well about one mile upgradient of any current mining. Well appears to be drought responsive.
WR-154	2	3465.06	24-Nov-81	Very first observations predate mining in area.
WR-156	2	3450.62	23-Nov-81	Very first observations predate mining in area.
WR-161	2	3333.54	27-Aug-82	Very first observations predate mining in area.
WR-162	2	3384.34	30-Aug-82	Very first observations predate mining in area.
WR-164	2	3404.05	1-Sep-82	Very first observations predate mining in area.
WR-168	2	3483.01	8-Apr-85	Revaluate the target value for this well. More representative values may be from about 1985.
WR-169	2	3459.82	1-Sep-82	First observations predate mining in area.
WR-173	2	3480.83	1-Sep-82	Observations predate mining in area and well about one mile upgradient of any current mining. Well appears to be drought responsive. Re-evaluate target value in future modeling.
WR-181	2	3457.91	25-Sep-87	First observations predate mining in area.
WR-205	2	3286.33	26-Jan-83	Mining commenced near this well after first readings. Possible some very limited drawdown from mining to the east of this well.
WR-208	2	3292.44	26-Jan-83	Mining commenced near this well after first readings. Possible some very limited drawdown from mining to the east of this well.
WR-215	2	3296.33	26-Jan-83	Mining commenced after very first observations at this well.
WR-227	2	3316.26	25-Jan-83	Very first observations predate mining in Area B.
WR-229	2	3453.01	4-Sep-02	Observations predate mining in Area.
WR-231	2	3458.94	15-Jan-05	No mining in area at time of construction. Later readings may be responding to mining in Area C.
WR-233	2	3505.42	15-Jan-05	No mining in area. Well appears to be drought responsive. Reacts significantly to major precipitation/runoff events.
WR-234	2	3496.44	15-Jan-05	No mining in area. Well appears to be drought responsive. More recent data indicate an increase in water levels with increase in precipitation.
WR-236	2	3517.06	15-Jan-05	No mining in area. Well appears to be drought responsive. More recent data indicate an increase in water levels with increase in precipitation. Well adjacent to model no-flow boundary
WR-237	2	3477.61	14-Feb-05	No mining in area. Well appears to be drought responsive. More recent data indicate an increase in water levels with increase in precipitation. Well adjacent to model no-flow boundary
WR-239	2	3525.66	15-Jan-05	No mining in area. Well appears to be drought responsive. Reacts significantly to major precipitation/runoff events.
BAL9031	3	3284.50		*
BAL9041	3	3262.00		*
BIN1017	3	3226.50		*
BIN117	3	3392.50		*
BIN1317	3	3387.50		*
BIN217	3	3361.00		*
BIN417	3	3290.30		*

Attachmenta GM-A
Steady-State Calibration Targets - Rationale of Individual Target
Rosebud Mine

Name	Layer	Observed	Date	Rationale
BIN517	3	3318.00		*
BIN617	3	3296.50		*
BIN717	3	3241.50		*
WA-192	3	3370.66	5-Mar-84	Well is remote from mining. It is likely that this well is drought responsive. Representative of Wel WA-191.
WA-194	3	3353.16	2-Mar-84	Well is remote from mining. It is likely that this well is drought responsive. Representative of wells WA-193 through WA-196 and WA-218.
WA-204	3	3333.85	31-Jul-84	Well is remote from early mining. Did not respond to mining in later period of observations. Representative of WA-205 which possesses a shorter period of record.
WI-104	3	3444.60	22-May-80	Mining began near this well about two years after mining began.
WI-107	3	3239.54	07/07/88	East of Area E. No obvious overall upward or downward trend.
WI-153	3	3449.13	18-Dec-81	First observations before mining began in 1984. Very first reading appears to be anomalous.
WI-154	3	3461.68	18-Dec-81	First observations before mining began in area. Very first reading appears to be anomalous.
WI-155	3	3421.17	22-Dec-81	First observations before mining began in area. Very two readings appear to be anomalous.
WI-156	3	3444.55	23-Nov-81	First observations before mining began in area.
WI-161	3	3331.27	~~30-Aug-82~~	Early readings pre-date mining.
WI-162	3	3386.64	1-Sep-82	Early readings pre-date mining.
WI-163	3	3399.98	1-Sep-82	Early readings pre-date mining in this vicinity of Area B.
WI-164	3	3409.22	1-Sep-82	Early readings pre-date mining in this vicinity of Area B.
WI-165	3	3451.81	1-Sep-82	Early readings pre-date mining in this vicinity of Area C.
WI-166	3	3437.18	1-Sep-82	Early readings pre-date mining in this vicinity of Area B.
WI-167	3	3435.36	1-Sep-82	Early readings pre-date mining in this vicinity of Area C.
WI-168	3	3444.27	1-Sep-82	Early readings pre-date mining in this vicinity of Area C.
WI-169	3	3436.38	1-Sep-82	Early readings pre-date mining in this vicinity of Area C.
WI-172	3	3458.82	1-Sep-82	Early readings pre-date mining in Area C and Area B. Long trem decline especially beginning in late 1980s a concern in using this well as a target. Re-evaluate in future model simulations.
WI-173	3	3464.41	1-Sep-82	Early readings pre-date mining in Area B to the north. Long-term declines for all wells in this cluster. Potentially drought responsive series.
WI-176	3	3419.40	5-Mar-84	Unresponsive to mining.
WI-177	3	3423.92	2-Mar-84	Monitored well before any mining in vicinity.
WI-178	3	3435.88	5-Mar-84	Monitored well before any mining in vicinity. Possibly a drought responsive well.
WI-179	3	3433.78	03/02/84	Monitored well before any mining in vicinity.
WI-180	3	3426.58	03/02/84	Monitored well before any mining in vicinity.
WI-181	3	3452.41	2-Mar-84	Monitored well before any mining in vicinity. Possibly a drought responsive well.
AMC20	4	3226.00		*
BMC1014	4	3192.50		*
BMC114	4	3392.50		*
BMC1314	4	3388.00		*
BMC1414	4	3285.00		*
BMC1514	4	3252.00		*
BMC414	4	3275.00		*
BMC614	4	3284.00		*
BMC714	4	3207.00		*
BMC9154	4	3273.50		*
WA-220	4	3404.58	1/12/2005	New well. Far from any mining activity. Added after initial modeling effort.
WM-100	4	3364.80	30-Jun-79	First observations predate mining.
WM-102	4	3319.40	19-May-79	Well predates mining in general vicinity. Well also exhibits a "dampened" correlation to changing water levels in E. Fork Armells Creek alluvium (see WA-101).
WM-106	4	3281.20	19-May-79	First observations predate mining.
WM-108	4	3429.00	19-May-79	First observations predate mining. Alternative steady state target values could be employed.
WM-109	4	3417.22	24-Oct-84	First observations predate mining. Alternative steady state target values could be employed. Note that first values appear as anomalous and hence not used as target value.
WM-111	4	3423.30	5-Oct-79	First observations pre-date mining. Well appears to be drought responsive.
WM-113	4	3438.40	22-Aug-95	First observations pre-date mining. It is reasonable to use a higher target, say 3438.40 associated with August 22. 1985.
WM-114	4	3430.90	17-Nov-79	First observations predate mining.
WM-122	4	3208.50	11-Jun-09	Mining before well installed. Distance to well greater so post-mine recovery is very limited and also indicates a limited radius of influence to Area E mining. Re-evaluate in future simulations.

Attachmenta GM-A
Steady-State Calibration Targets - Rationale of Individual Target
Rosebud Mine

Name	Layer	Observed	Date	Rationale
WM-127	4	3226.35	8/16/1995	Historic mining before well installed. Assumed recovery is full.
WM-136	4	3228.12	28-Aug-85	Near mined area but well seemed to have recovered by mid to late 1980s. Adjusted to slightly higher target value.
WM-138	4	3226.58	8/16/1995	Historic mining before well installed. Assumed recovery is full.
WM-153	4	3432.91	18-Dec-81	First two years of readings predate mining in Area.
WM-154	4	3433.78	18-Dec-81	First two years of readings predate mining in Area. First two readings anomalous
WM-155	4	3418.82	22-Dec-81	First observations predate mining in well vicinity. Note that first observation is anomalous.
WM-156	4	3421.90	23-Nov-81	First two years of readings predate mining in Area.
WM-161	4	3314.20	30-Aug-82	Very first observations predate mining in this portion of Area B.
WM-162	4	3386.70	1-Sep-82	Very first observations predate mining in this portion of Area B.
WM-163	4	3399.86	1-Sep-82	First observations predate mining.
WM-164	4	3408.15	1-Sep-82	First observations predate mining. Possible combined effects of drawdown associated with mining Area B and Peabody coal.
WM-165	4	3442.91	28-Sep-82	First observations predate mining in vicinity. First observation anomalous and readings in 1987 and 1988 anomalously high.
WM-167	4	3419.89	1-Sep-82	First observations predate mining in Area.
WM-168	4	3440.85	28-Sep-82	First observations predate mining in Area.
WM-169	4	3424.11	1-Sep-82	First observations predate mining in Area.
WM-173	4	3420.61	1-Sep-82	First observations predate mining in Area.
WM-176	4	3399.09	20-Apr-94	Most observations predate mining in Area.
WM-178	4	3409.06	5-Mar-84	Most observations predate mining in Area.
WM-179	4	3411.36	2-Mar-84	First observations predate mining in Area.
WM-192	4	3434.81	27-Jun-08	Observations predate mining.
WM-193	4	3483.86	15-Jan-05	Observations predate mining.
WM-195	4	3439.19	30-Aug-05	Observations predate mining.
WM-196	4	3440.44	15-Jan-05	Observations predate mining.
WM-197	4	3476.37	27-Dec-05	Observations predate mining.
WM-198	4	3442.27	7-Sep-05	Observations predate mining. Anomalous drop in 2008.
WM-199	4	3390.34	24-Sep-08	Observations predate mining. Responded to 2011 precipitation/runoff event.
AAL12	5	3141.00		*
AAL14	5	3147.00		*
AALM70	5	3121.00		*
ASM2	5	3188.00		*
ASMM27	5	3172.00		*
ASMM32	5	3169.40		*
ASMM69	5	3186.20		*
BSM1015	5	3185.00		*
WA-109	5	3218.60	26-Sep-79	Selected as representative of series WA-107 through WA-109
WA-135	5	3149.30	21-Apr-81	Target is remote and in Cow Creek drainage
WA-142	5	3166.74	28-Jan-83	Target is remote and in Cow Creek drainage
WA-145	5	3187.50	17-Sep-82	Target is remote and in Cow Creek drainage
WA-152	5	3202.05	25-Aug-82	Water level is stable - outside of immediate mining area - representative of wells WA-149 through WA-152.
WA-153	5	3145.08	25-Aug-82	Water level is stable - outside of immediate mining area. Redundant well is WA-154.
WA-156	5	3127.44	27-Sep-82	Water level is stable - outside of immediate mining area - representative of wells WA-155 through WA-158.
WA-161	5	3171.63	25-Aug-82	Early water levels stable - outside immediate mining area - representative of wells WA-159 through WA-161.
WA-165	5	3272.37	5-Oct-83	Well is drought responsive - outside of mining area for early readings - possible response to mining beginning in late 1980s. Represents WA-164 through WA-166.
WA-168	5	3295.64	27-Jul-84	Well is drought responseive. Outside of mining for early readings. Representative of response at WA-167 which has a much shorter period of record.
WA-169	5	3373.07	30-Aug-82	Well is drought responsive. Response of nearby well WA-170 is nearly identical with shorter period of record.
WA-183	5	3229.78	2-Mar-84	Early readings relatively steady. Likely a drought responsive well. Representative of wells WA-182 through WA-188.
WA-198	5	3132.60	2-Mar-84	Well was remote from mining during observation period. It is likley that this well is drought responsive. Representative of wells WA-197 through WA-201.
WA-219	5	3357.40	5/31/2005	New well. Far from any mining activity. Added after initial modeling effort.
WA-221	5	3377.71	1/12/2005	New well. Far from any mining activity. Added after initial modeling effort.

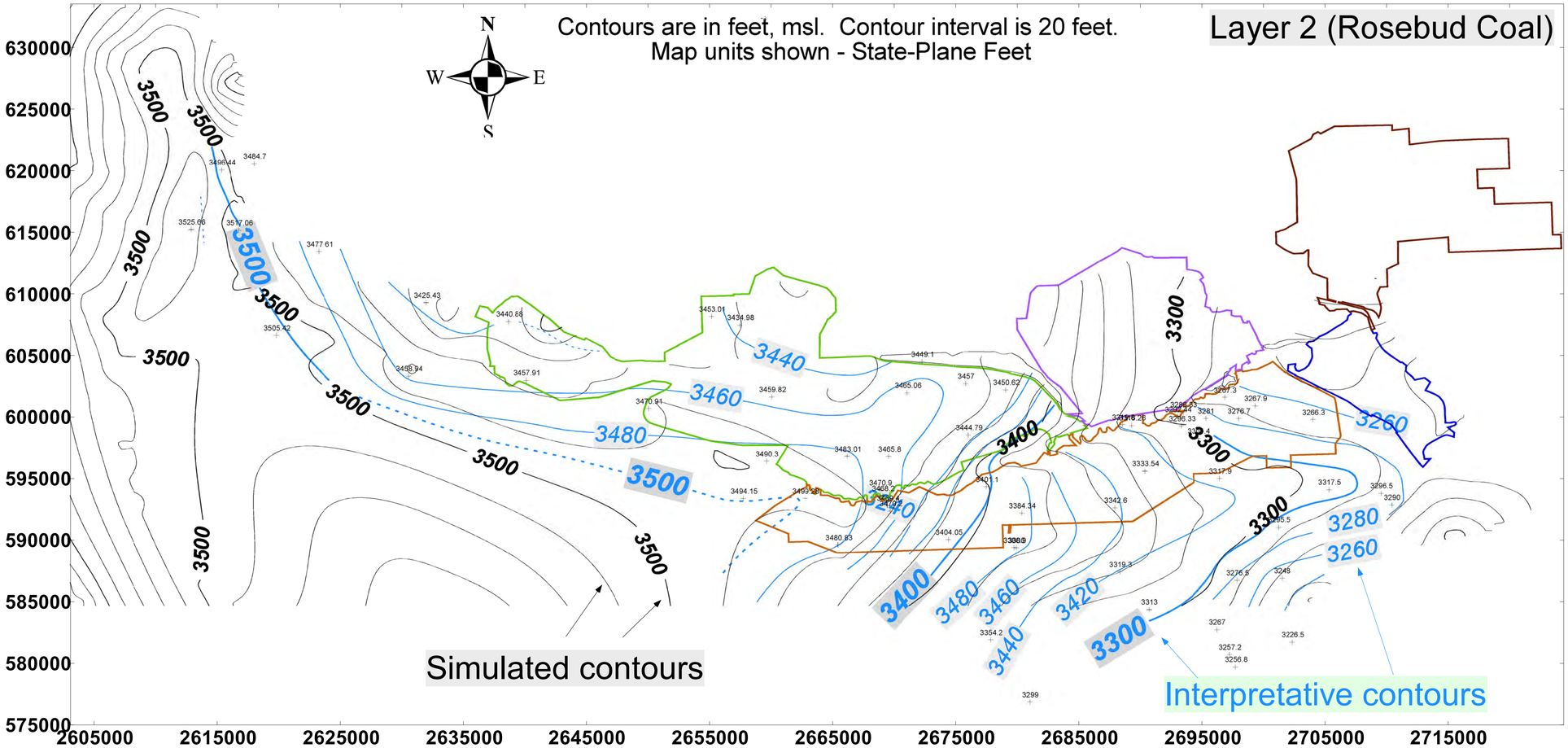
Attachmenta GM-A
Steady-State Calibration Targets - Rationale of Individual Target
Rosebud Mine

Name	Layer	Observed	Date	Rationale
WA-225	5	3357.97	12/20/2012	New well. Far from any mining activity. Added after initial modeling effort.
WD-100	5	3262.00	19-May-79	Water level data before mining in area. Responded to mining - fault may be a factor.
WD-104	5	3175.30	15-May-80	Well appears to be unresponsive to mining in Area E. It is possible that later readings are showing signs of recovery. Re-evaluate in future model simulations.
WD-174	5	3202.35	28-Sep-01	Later value used assuming nearly full recovery. Revaluate for future model simulations.
WD-189	5	3449.39	15-Jan-05	Water levels show slight increasing trend, especially after major precipitation event in 2011.
WD-192	5	3439.87	15-Jan-05	Well remote from mining activity. Considered pre-mine well.
WD-193	5	3427.62	15-Jan-05	Well remote from mining activity. Considered pre-mine well.
WD-194	5	3385.77	15-Jan-05	Well remote from mining activity for first observations. Considered pre-mine well.
WA-131		3262.41	13-Sep-05	Later water level used assuming recovery. Re-evaluate this well for future simulations.
WA-141		3286.83	3-Dec-81	Well assumed as unresponsive to mining. Re-evaluate this well for future simulations for potential of mining impacts.
WD-185		3314.61	29-Aug-85	Installed after historic mining. Revaluate this well for future simulations for potential of mining impacts.
WD-186		3344.97	29-Sep-85	Installed after historic mining. Revaluate this well for future simulations.
WI-106		3226.86	3-Jun-09	Later value used assuming nearly full recovery. Revaluate for future model simulations.
WI-117		3286.87	06/11/09	Used a later value assuming nearly full recovery. Revaluate with future modeling efforts.
WI-174		3244.50	24-Nov-82	Earliest readings pre-date permitted mining in Area E. Re-evaluate for future model simulation efforts.
WI-182		3232.96	12-Dec-08	Used a later value assuming nearly full recovery. Revaluate with future modeling efforts.
WM-120		3225.34	30-Jun-09	Used a later value assuming nearly full recovery. Revaluate with future modeling efforts.
WM-121		3248.30	30-Jun-09	Used a later value assuming nearly full recovery. Revaluate with future modeling efforts.
WM-184		3278.68	24-Jan-00	Mining before well installed. Note that a later value used after hydrograph stabilized indicating recovery had occurred. Re-evaluate with future modeling efforts.
WR-100		3277.50	19-Mar-79	Well sceened just above Rosebud Coal in sandstone. Re-evaluate will in future model simulations.

* Target derived graphically from Big Sky Mine monitoring report hydrographs.

Model Attachment GM-B
Simulated versus Observed Water Levels

Exhibit 8



Area A

Area B

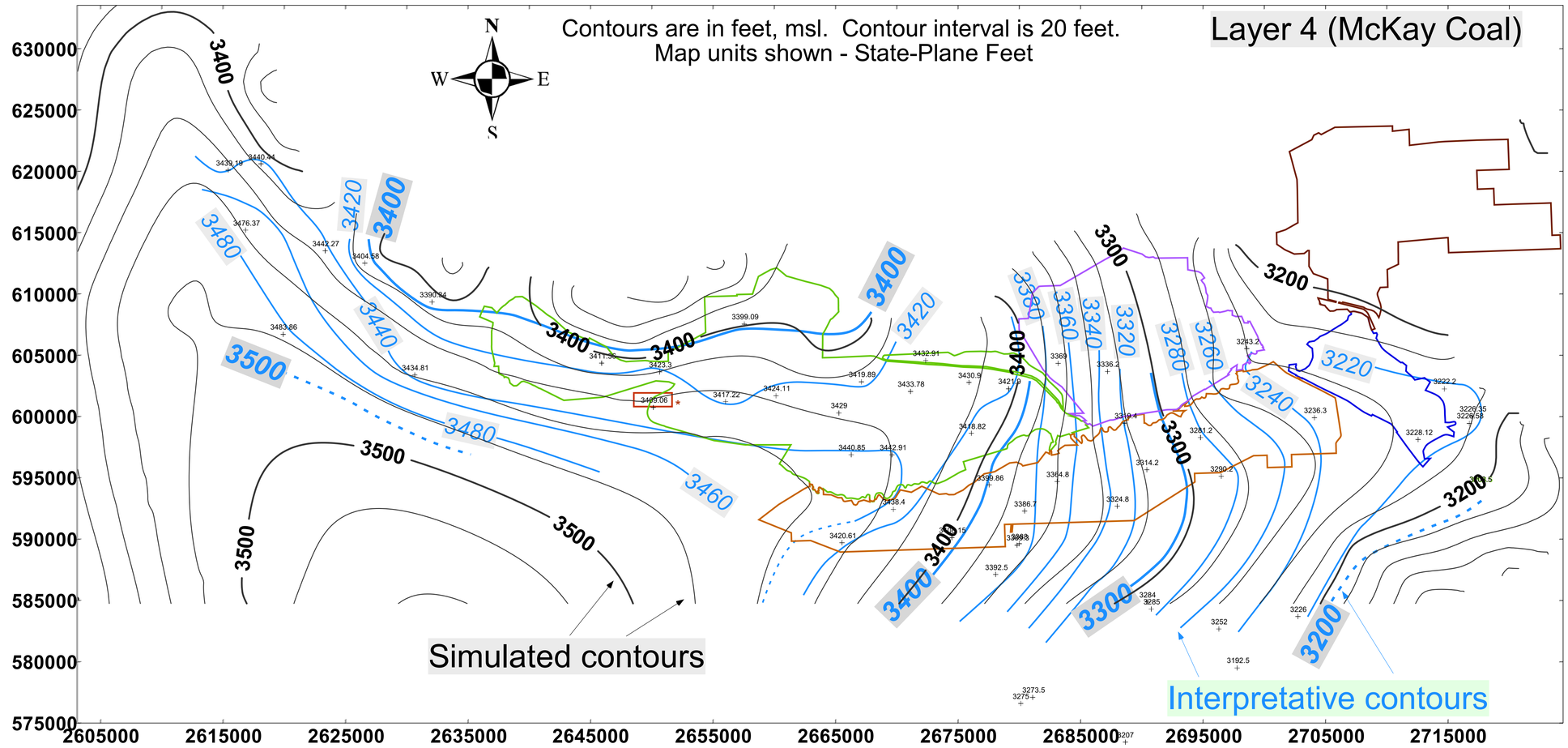
Area C

Area D

Area E

3477.61 Interpreted Pre-Mine Water Level - Rosebud Coal (interpretative contours dashed where inferred).

Date: September 19, 2013 **D://Plate GM-1 By: MEN** **Issued for Western Energy**	**NICKLIN** **EARTH & WATER, INC.**	**Comparison of Simulated Steady-State Water Levels vs Interpretative Pre-Mine Water Levels - Rosebud Coal**	**Plate GM-1**



Area A

Area B

Area C

Area D

Area E

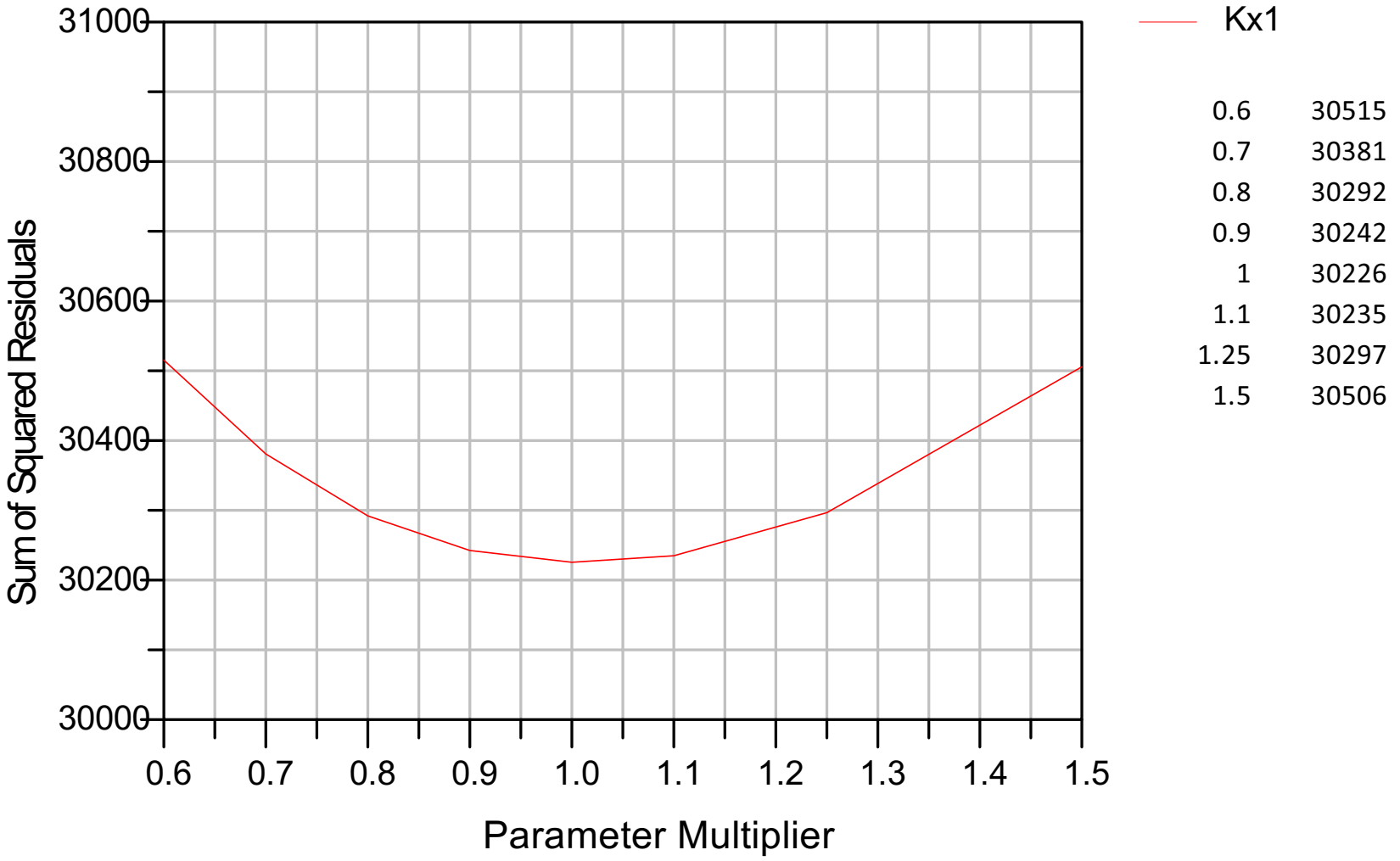
3477.61 Interpreted Pre-Mine Water Level - McKay Coal (interpretative contours dashed where inferred).

* Anomlaous value not used for interpretative contour.

Date: September 19, 2013 **D://Plate GM-2 By: MEN** **Issued for Western Energy**	**NICKLIN** **EARTH & WATER, INC.**	**Comparison of Simulated Steady-State Water Levels vs Interpretative Pre-Mine Water Levels - McKay Coal**	**Plate GM-2**

Model Attachment GM-C
Sensitivity Analysis

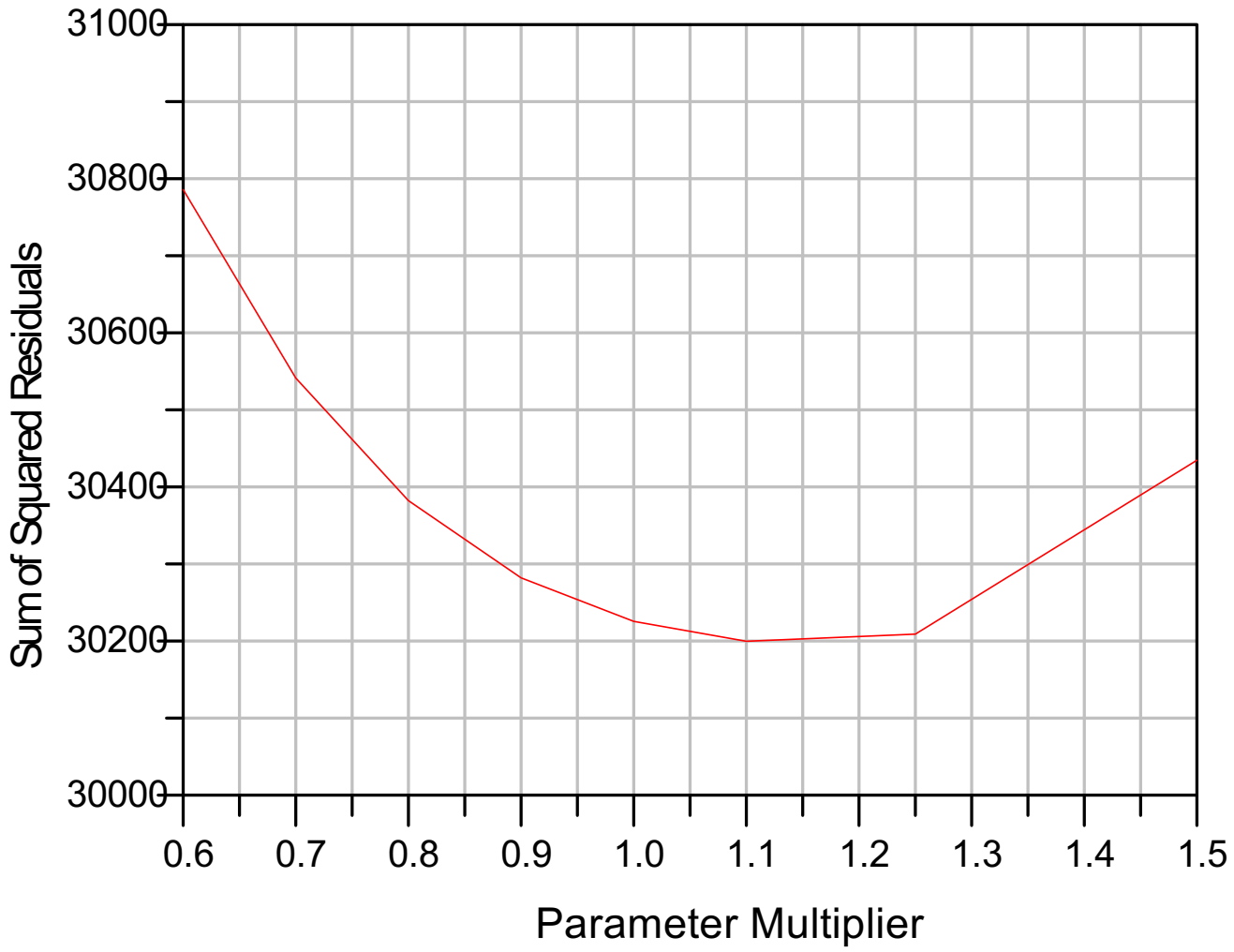
Exhibit 8



0.6	30515
0.7	30381
0.8	30292
0.9	30242
1	30226
1.1	30235
1.25	30297
1.5	30506

Transmissivity Zone A (note that Transmissivity is computed as 30 times Kx1).

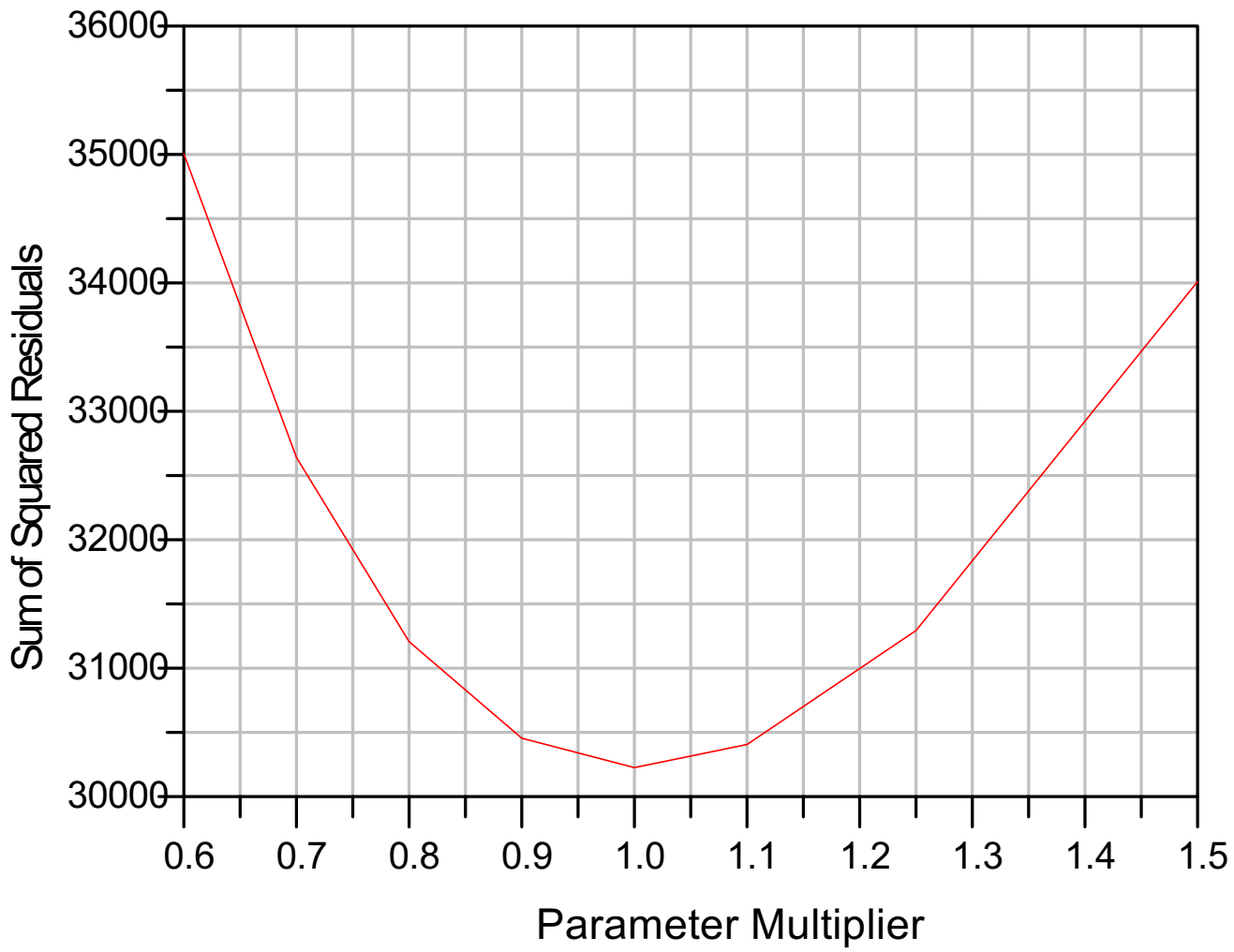
Exhibit 8



Multiplier	SSR
0.6	30786
0.7	30541
0.8	30382
0.9	30282
1	30226
1.1	30200
1.25	30209
1.5	30435

Transmissivity Zone B (note that Transmissivity is computed as 30 times Kx11).

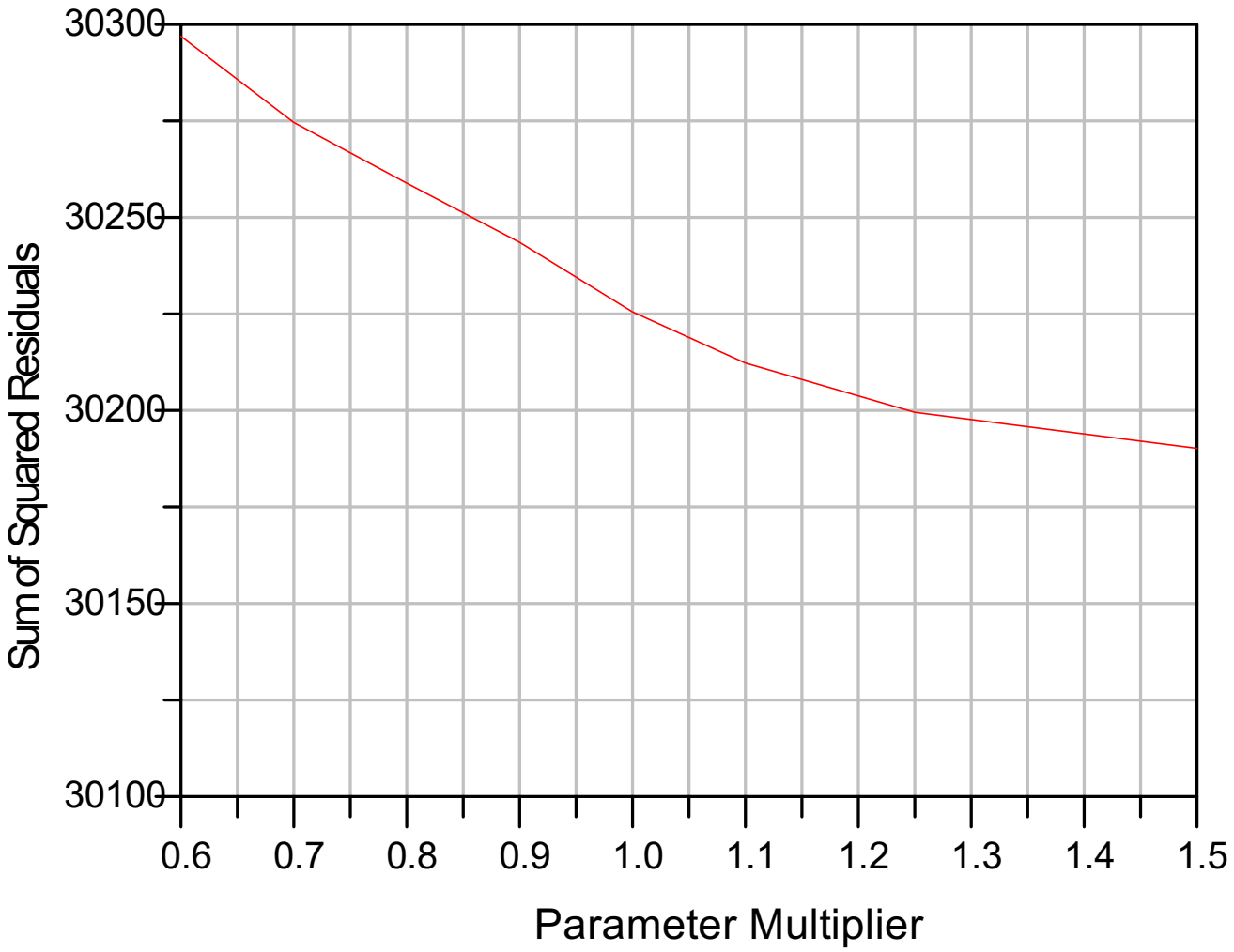
Exhibit 8



Multiplier	SSR
0.6	35005
0.7	32641
0.8	31206
0.9	30455
1	30226
1.1	30405
1.25	31293
1.5	34010

Transmissivity Zone C (note that Transmissivity is computed as 26 times Kx2).

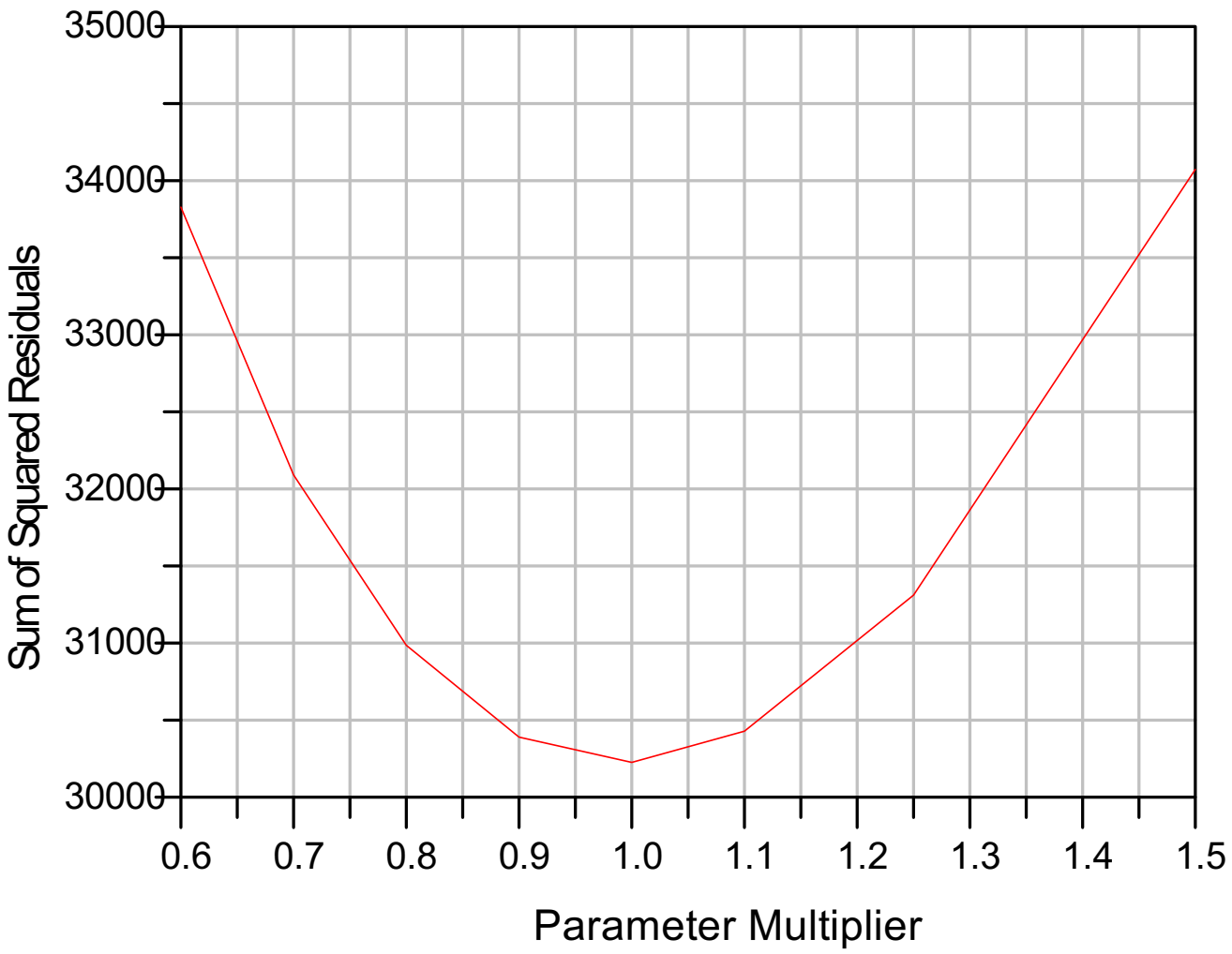
Exhibit 8



Multiplier	SSR
0.6	30297
0.7	30275
0.8	30259
0.9	30244
1	30226
1.1	30212
1.25	30200
1.5	30190

Transmissivity Zone D (note that Transmissivity is computed as 26 times Kx25)

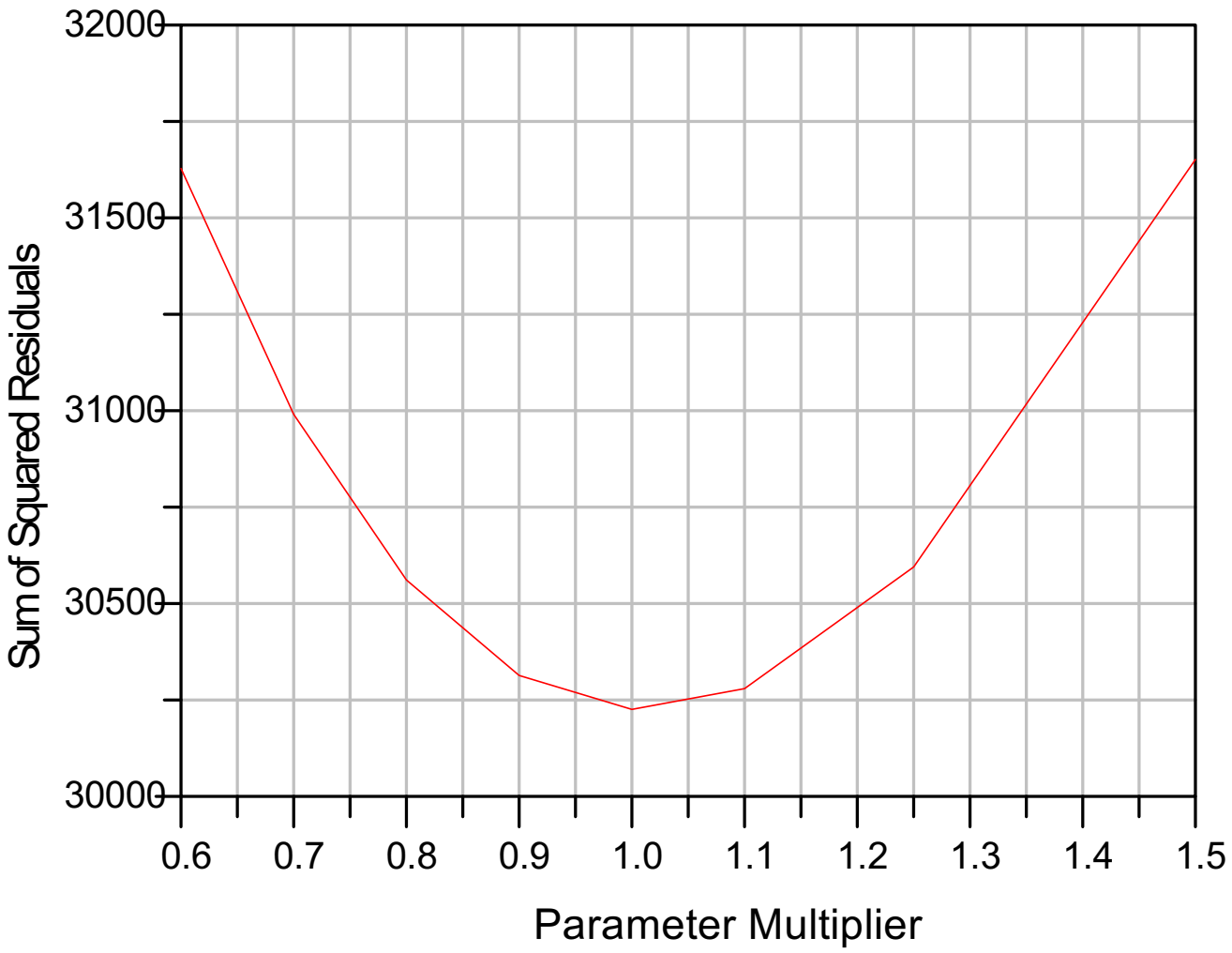
Exhibit 8



Multiplier	SSR
0.6	33828
0.7	32090
0.8	30985
0.9	30390
1	30226
1.1	30428
1.25	31311
1.5	34073

Transmissivity Zone E (note that Transmissivity is computed as 26 times Kx3)

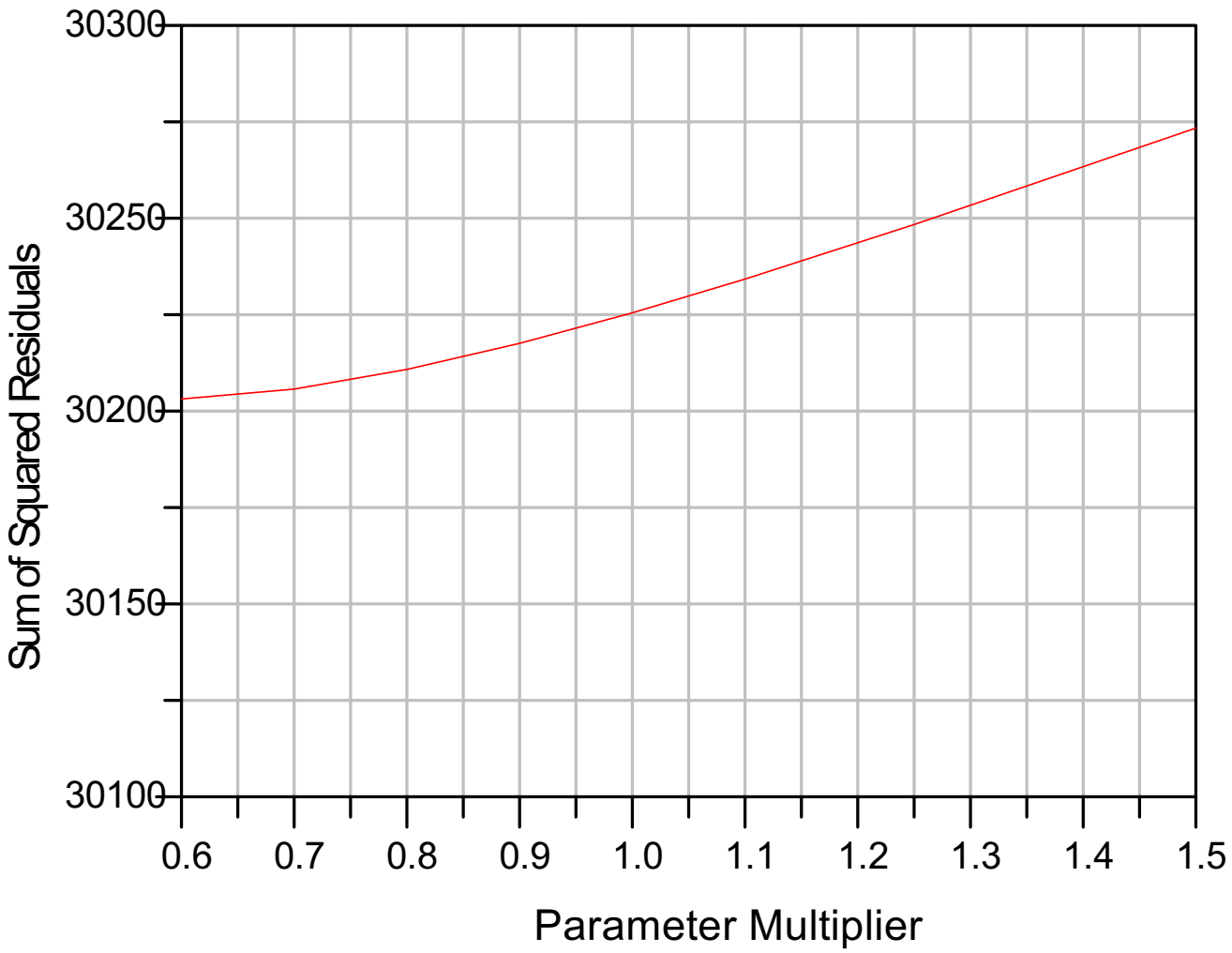
Exhibit 8



Multiplier	SSR
0.6	31628
0.7	30991
0.8	30561
0.9	30314
1	30226
1.1	30279
1.25	30595
1.5	31651

Transmissivity Zone G (note that Transmissivity is computed as 8 times Kx4)

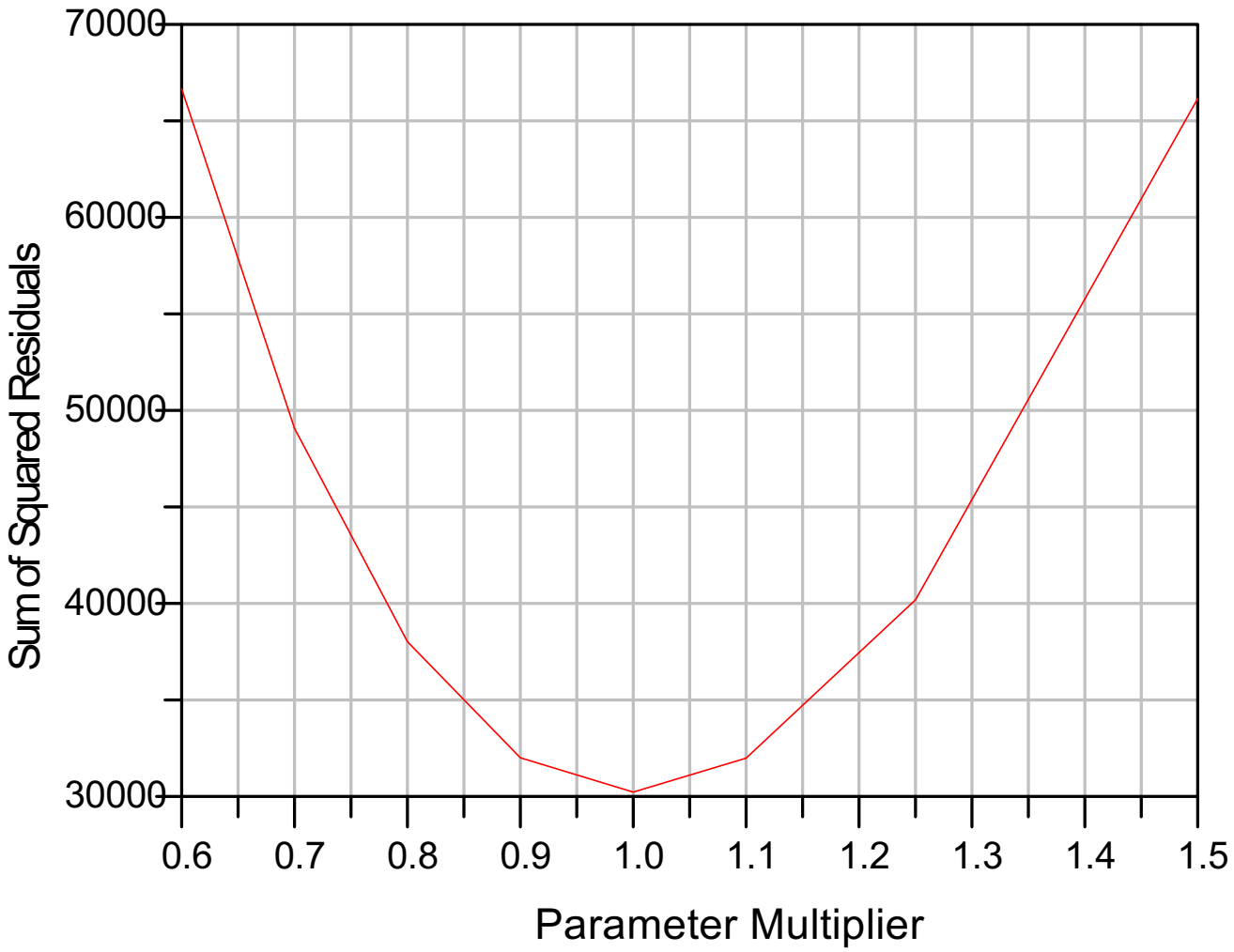
Exhibit 8



Multiplier	SSR
0.6	30203
0.7	30206
0.8	30211
0.9	30218
1	30225
1.1	30234
1.25	30248
1.5	30273

Transmissivity Zone H (note that Transmissivity is computed as 8 times Kx42)

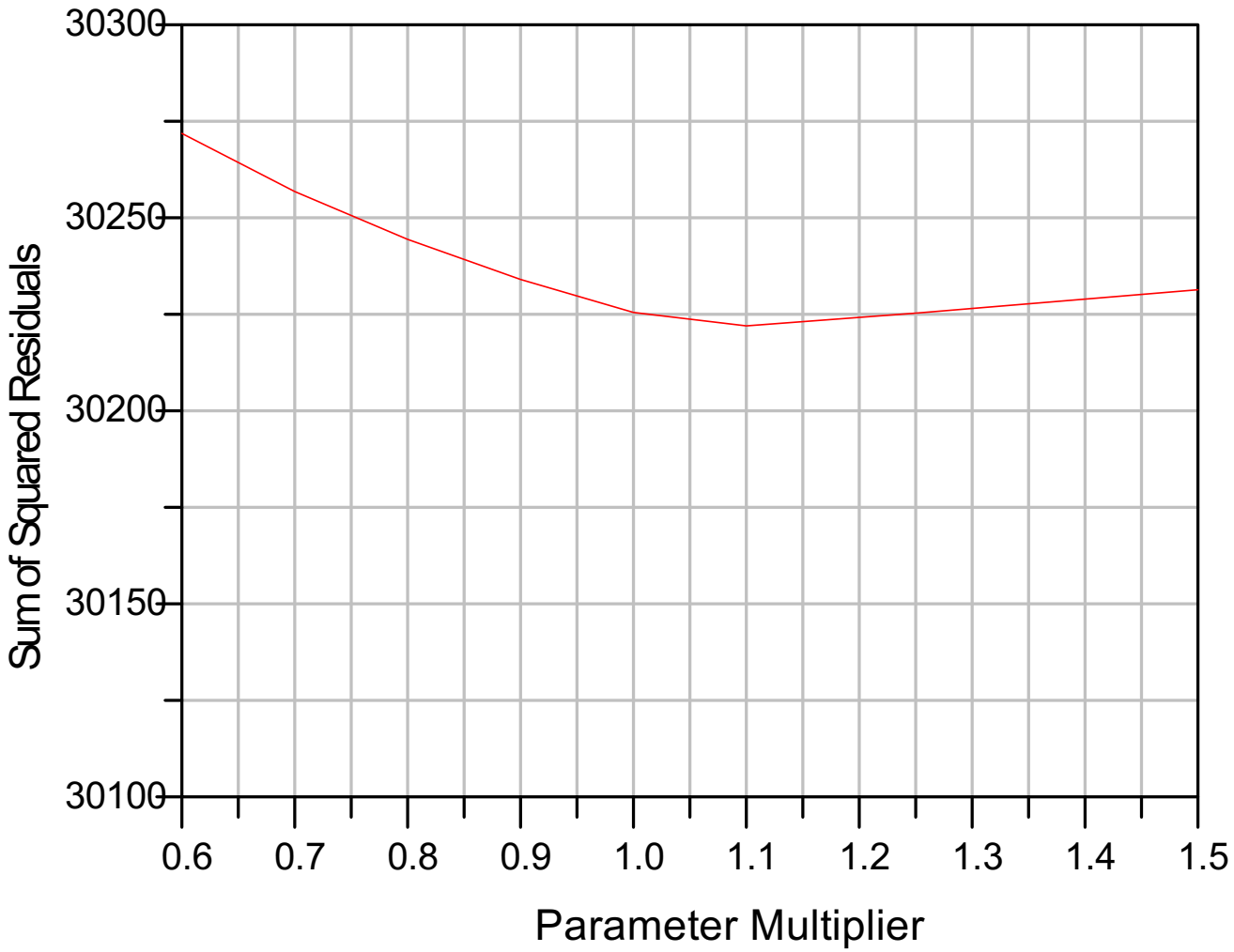
Exhibit 8



Multiplier	SSR
0.6	66663
0.7	49070
0.8	38021
0.9	32003
1	30225
1.1	31985
1.25	40187
1.5	66157

Transmissivity Zone I (note that Transmissivity is computed as 50 times Kx5)

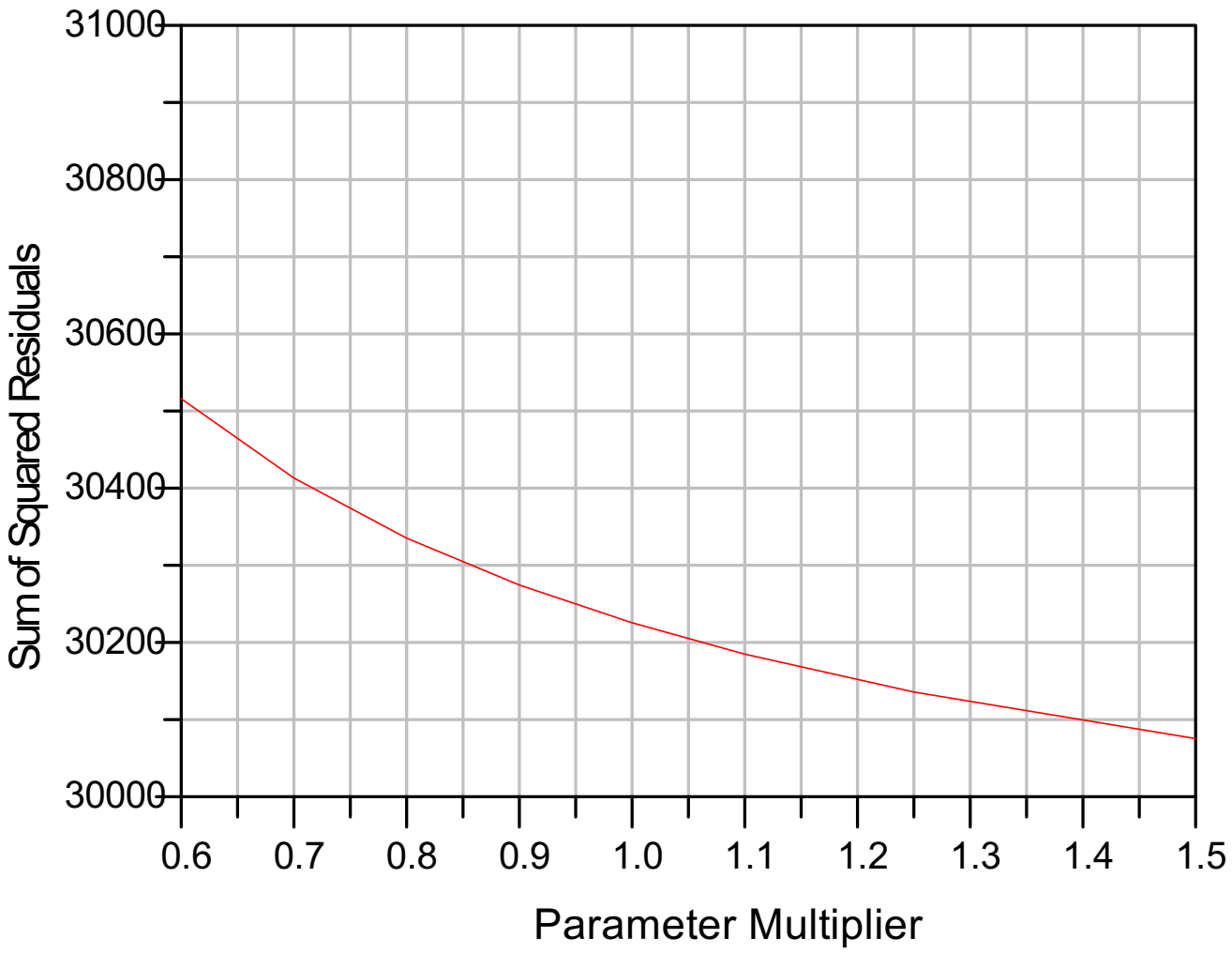
Exhibit 8



Multiplier	SSR
0.6	30516
0.7	30413
0.8	30335
0.9	30274
1	30225
1.1	30185
1.25	30136
1.5	30075

Transmissivity Zone K (note that Transmissivity is computed as 50 times Kx5)

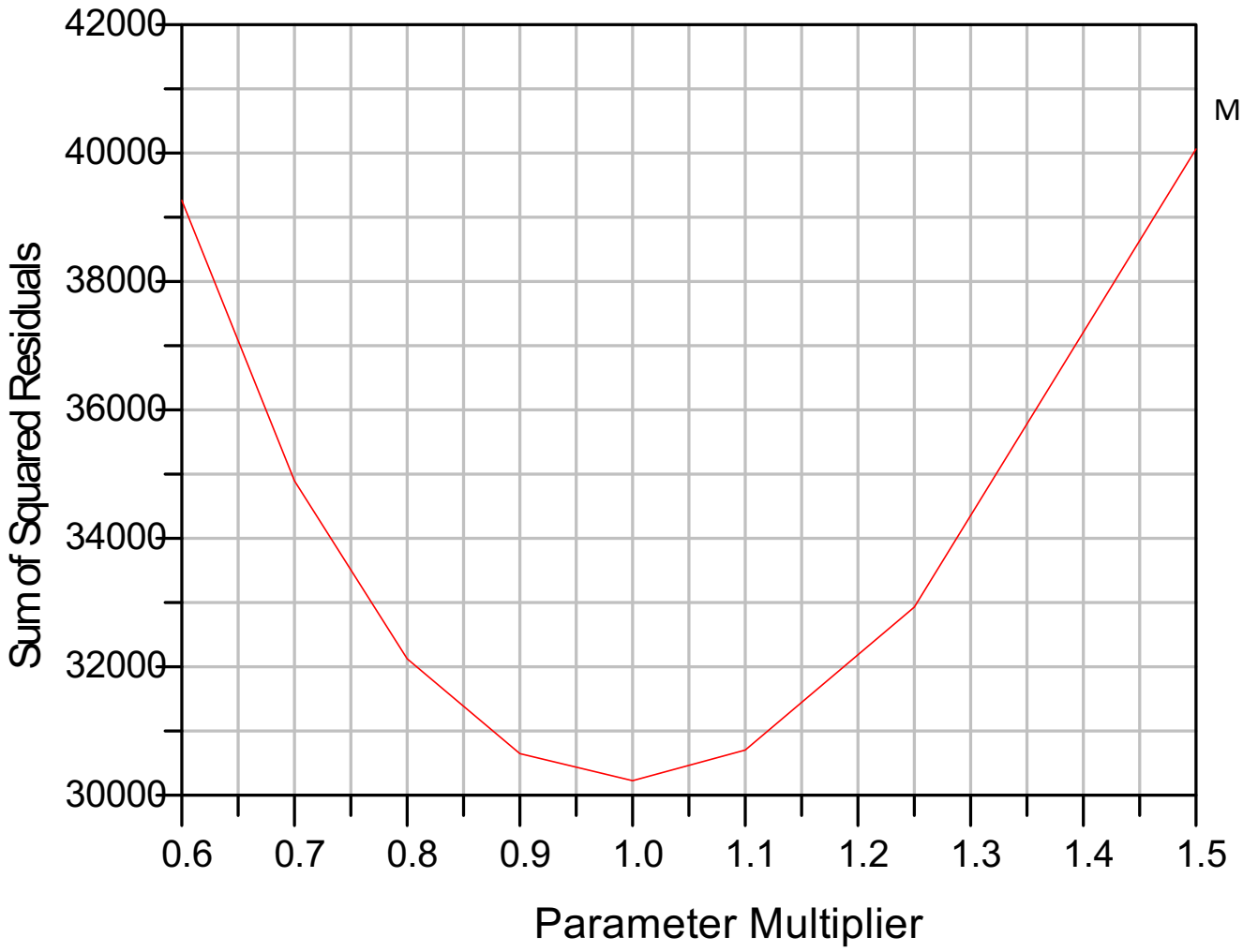
Exhibit 8



Multiplier	SSR
0.6	30272
0.7	30257
0.8	30244
0.9	30234
1	30225
1.1	30222
1.25	30225
1.5	30231

Transmissivity Zone J (note that Transmissivity is computed as 50 times Kx5)

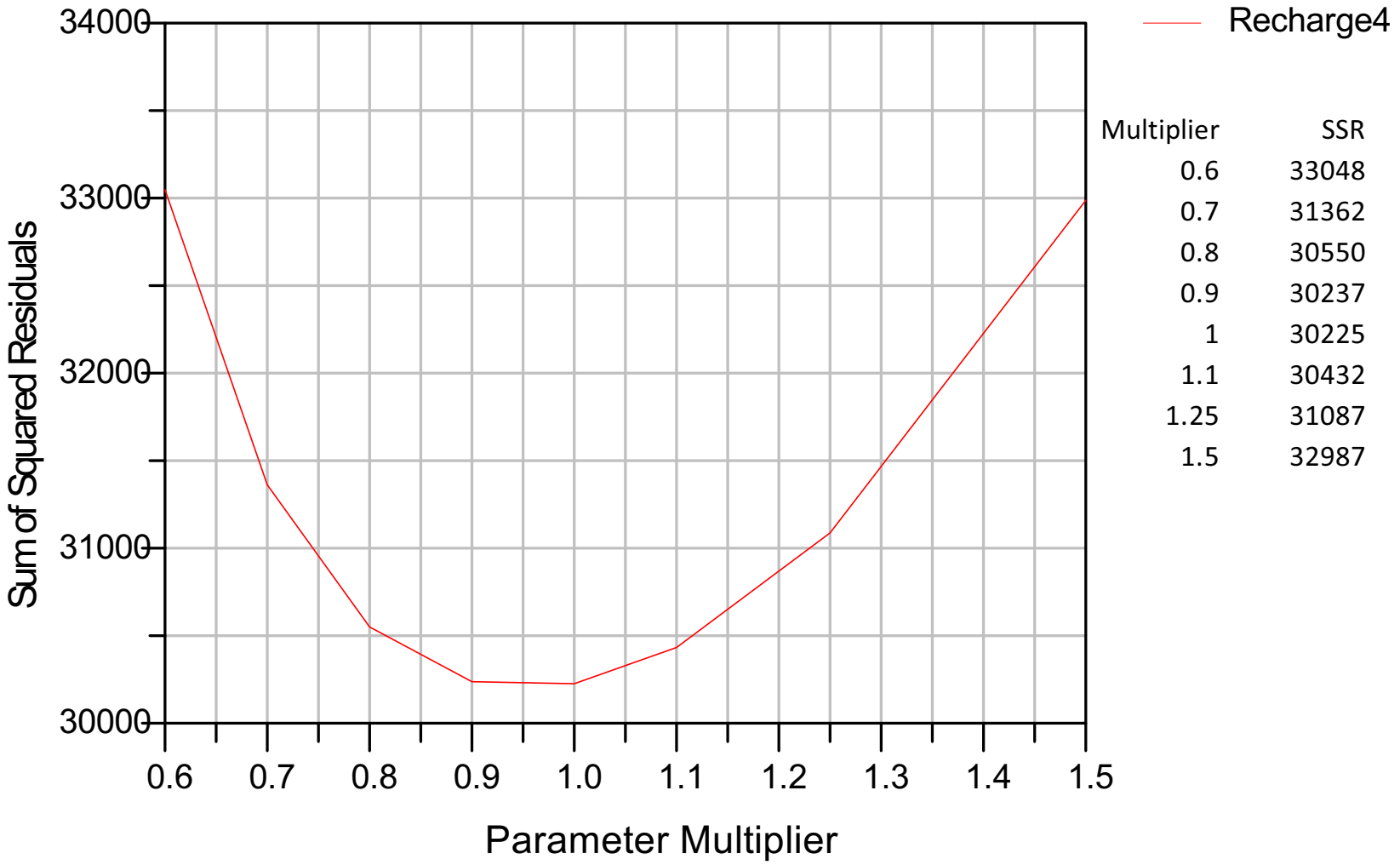
Exhibit 8



Multiplier	SSR
0.6	39263
0.7	34895
0.8	32124
0.9	30647
1	30225
1.1	30703
1.25	32929
1.5	40062

Recharge Zone A

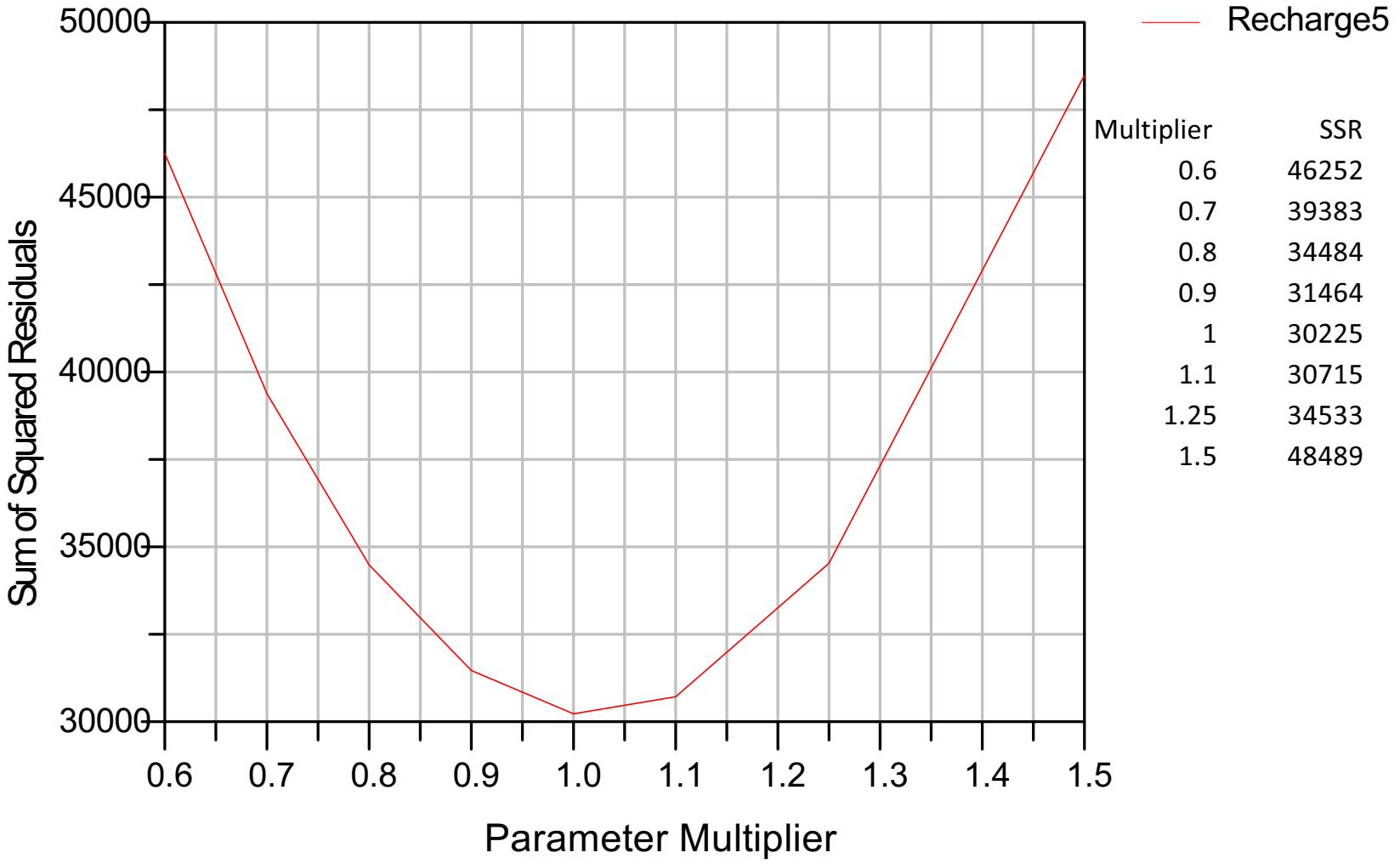
Exhibit 8



Multiplier	SSR
0.6	33048
0.7	31362
0.8	30550
0.9	30237
1	30225
1.1	30432
1.25	31087
1.5	32987

Recharge Zone E

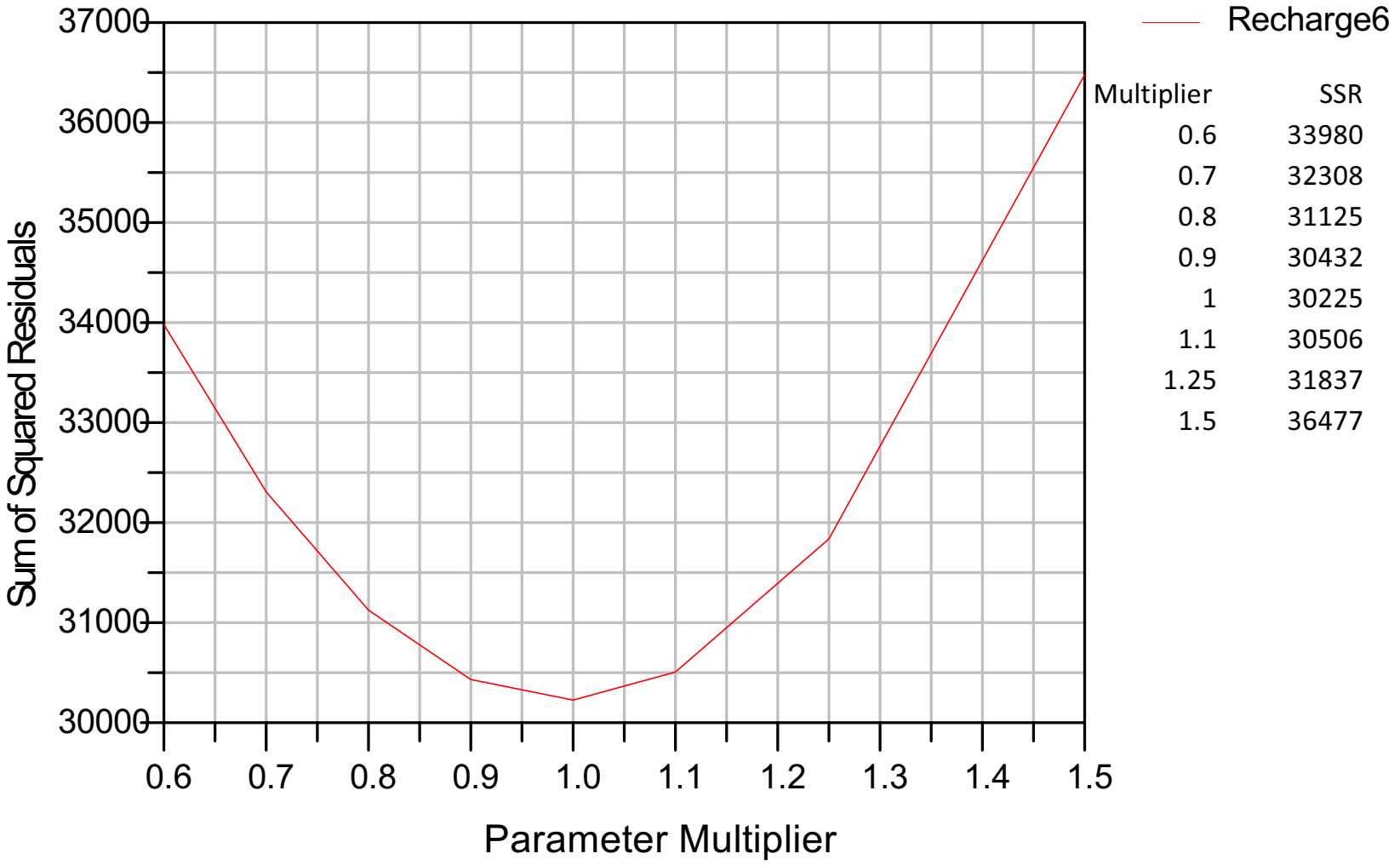
Exhibit 8



Multiplier	SSR
0.6	46252
0.7	39383
0.8	34484
0.9	31464
1	30225
1.1	30715
1.25	34533
1.5	48489

Recharge Zone B

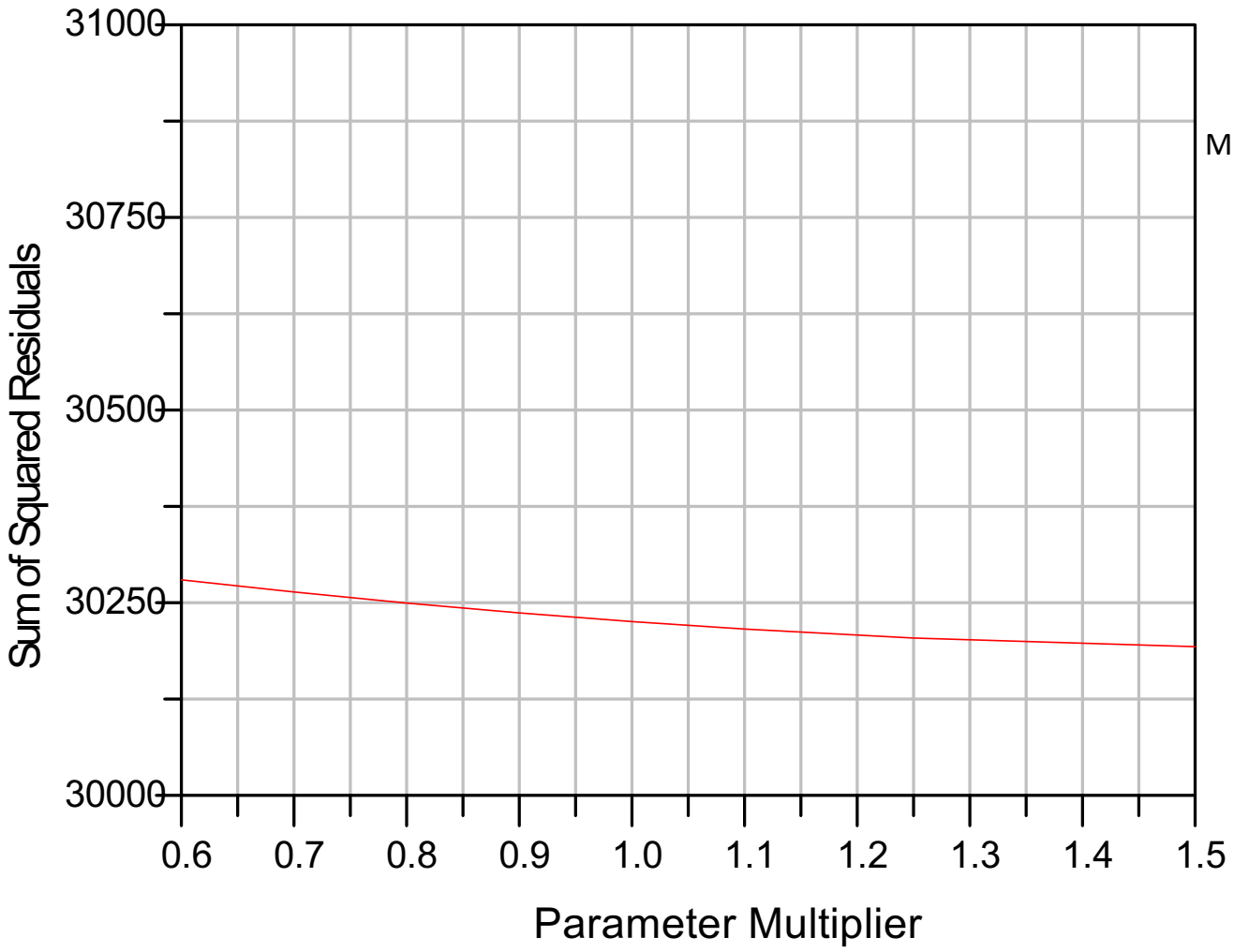
Exhibit 8



Multiplier	SSR
0.6	33980
0.7	32308
0.8	31125
0.9	30432
1	30225
1.1	30506
1.25	31837
1.5	36477

Recharge Zone F

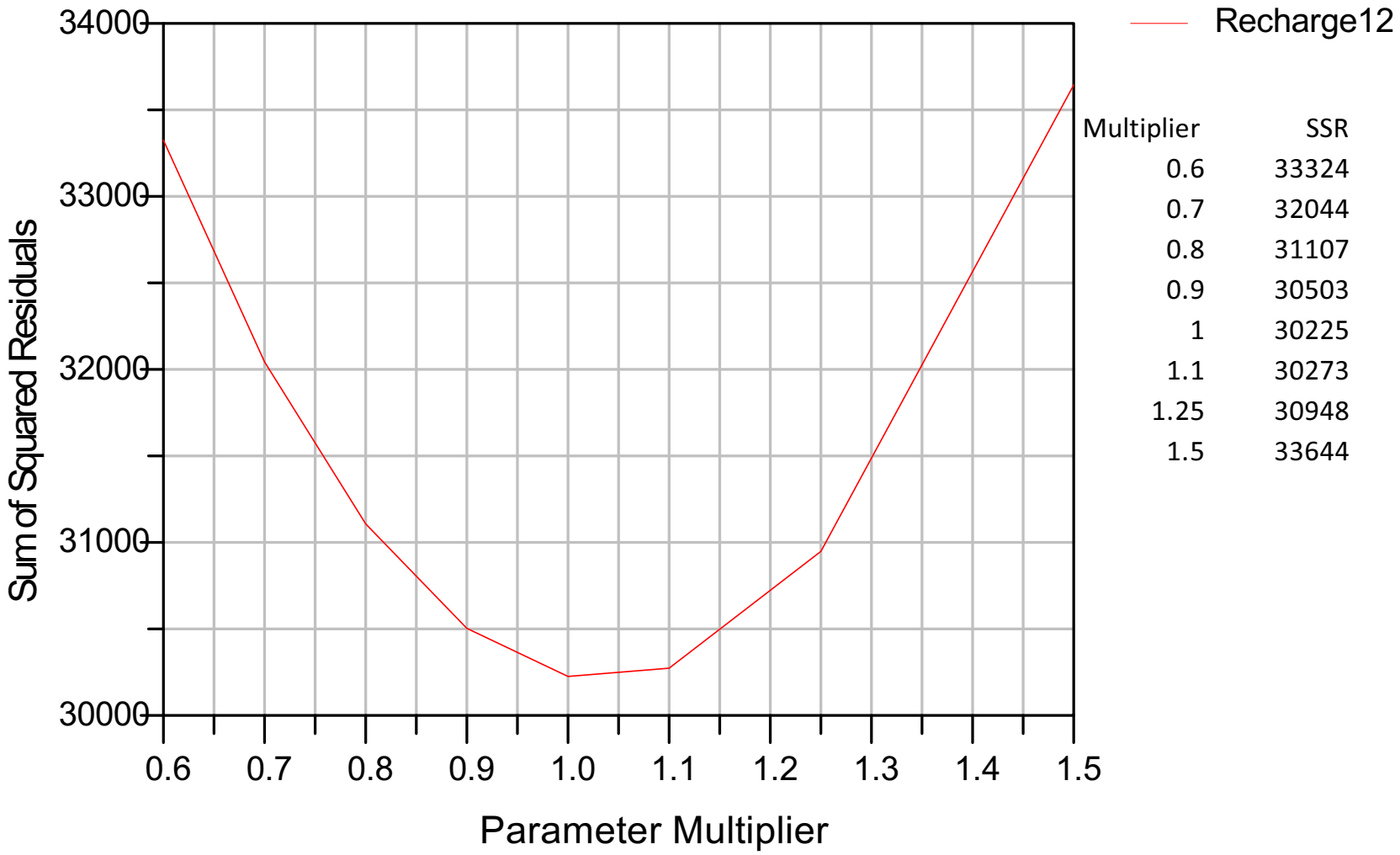
Exhibit 8



Multiplier	SSR
0.6	30280
0.7	30264
0.8	30250
0.9	30237
1	30225
1.1	30216
1.25	30204
1.5	30193

Recharge Zone K

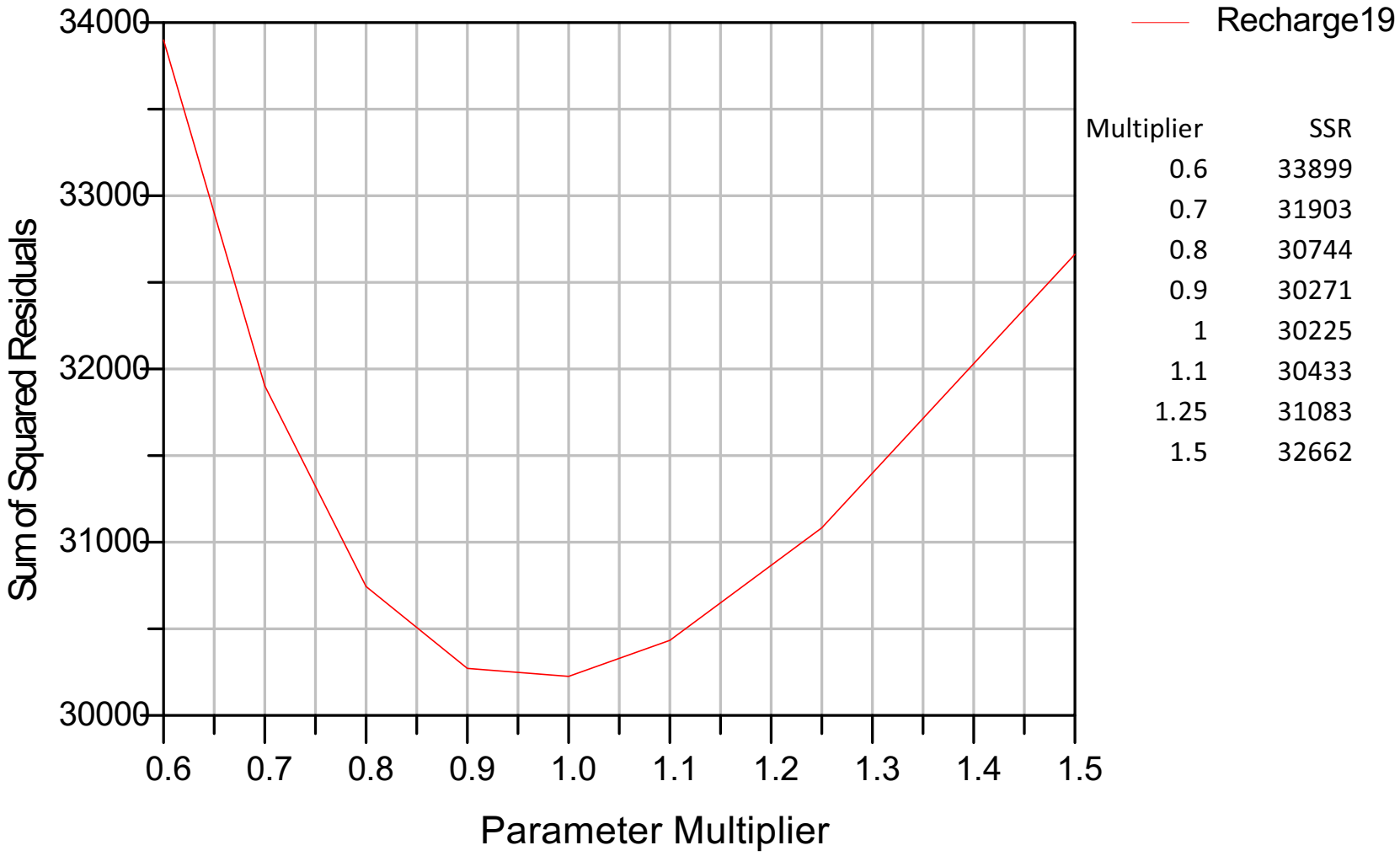
Exhibit 8



Multiplier	SSR
0.6	33324
0.7	32044
0.8	31107
0.9	30503
1	30225
1.1	30273
1.25	30948
1.5	33644

Recharge Zone G

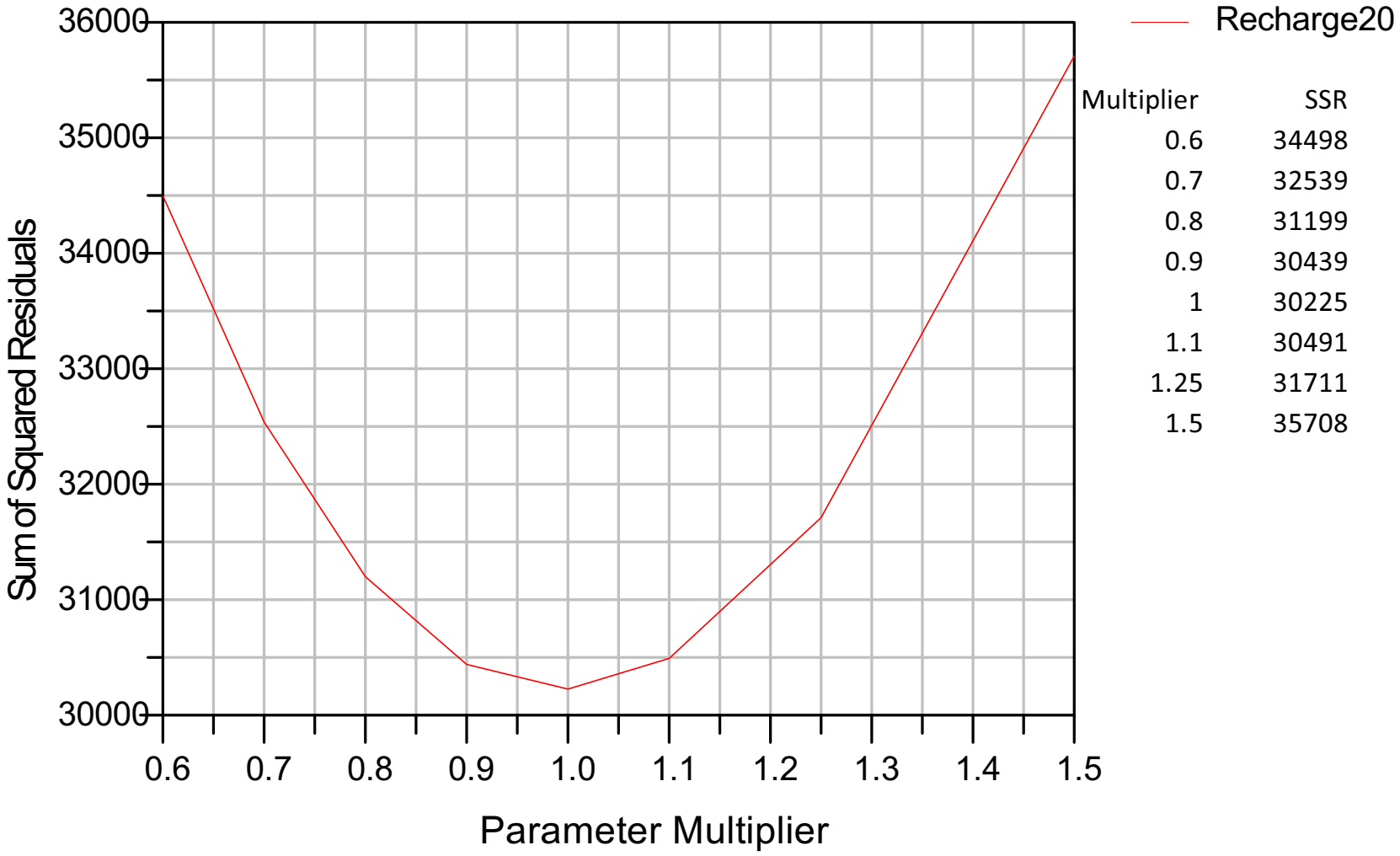
Exhibit 8



Multiplier	SSR
0.6	33899
0.7	31903
0.8	30744
0.9	30271
1	30225
1.1	30433
1.25	31083
1.5	32662

Recharge Zone I

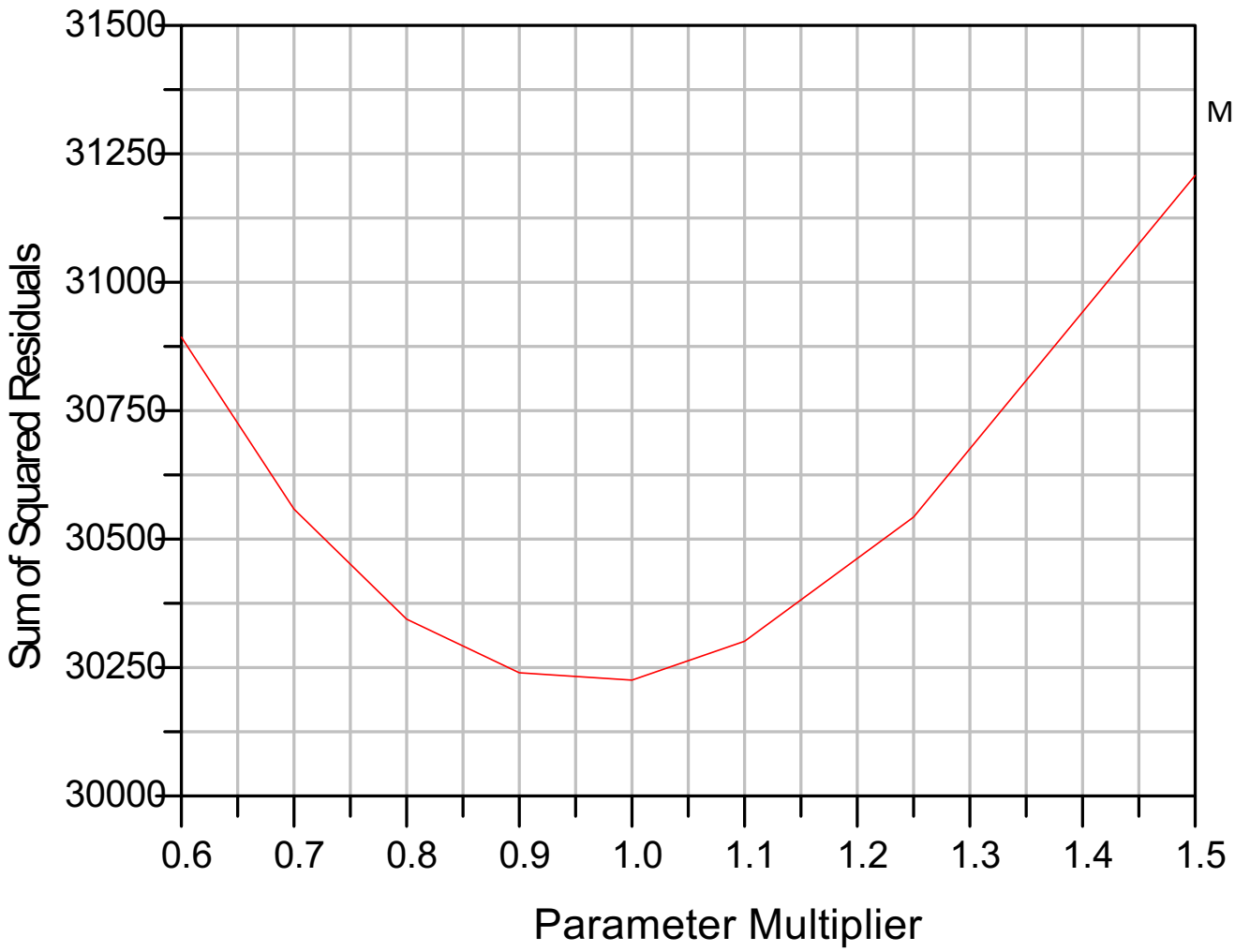
Exhibit 8



Multiplier	SSR
0.6	34498
0.7	32539
0.8	31199
0.9	30439
1	30225
1.1	30491
1.25	31711
1.5	35708

Recharge Zone J

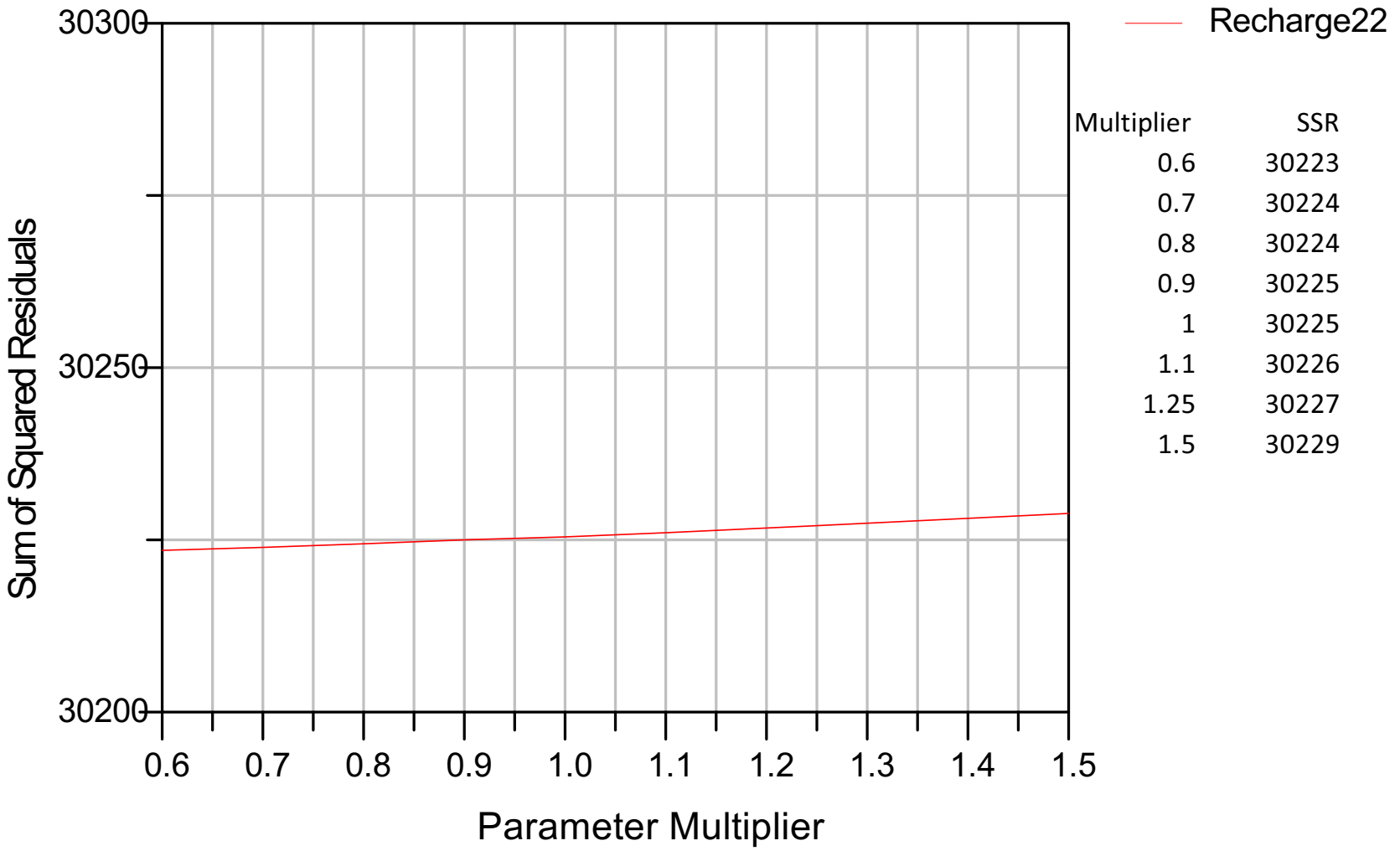
Exhibit 8



Multiplier	SSR
0.6	30893
0.7	30558
0.8	30344
0.9	30240
1	30225
1.1	30301
1.25	30543
1.5	31208

Recharge Zone L

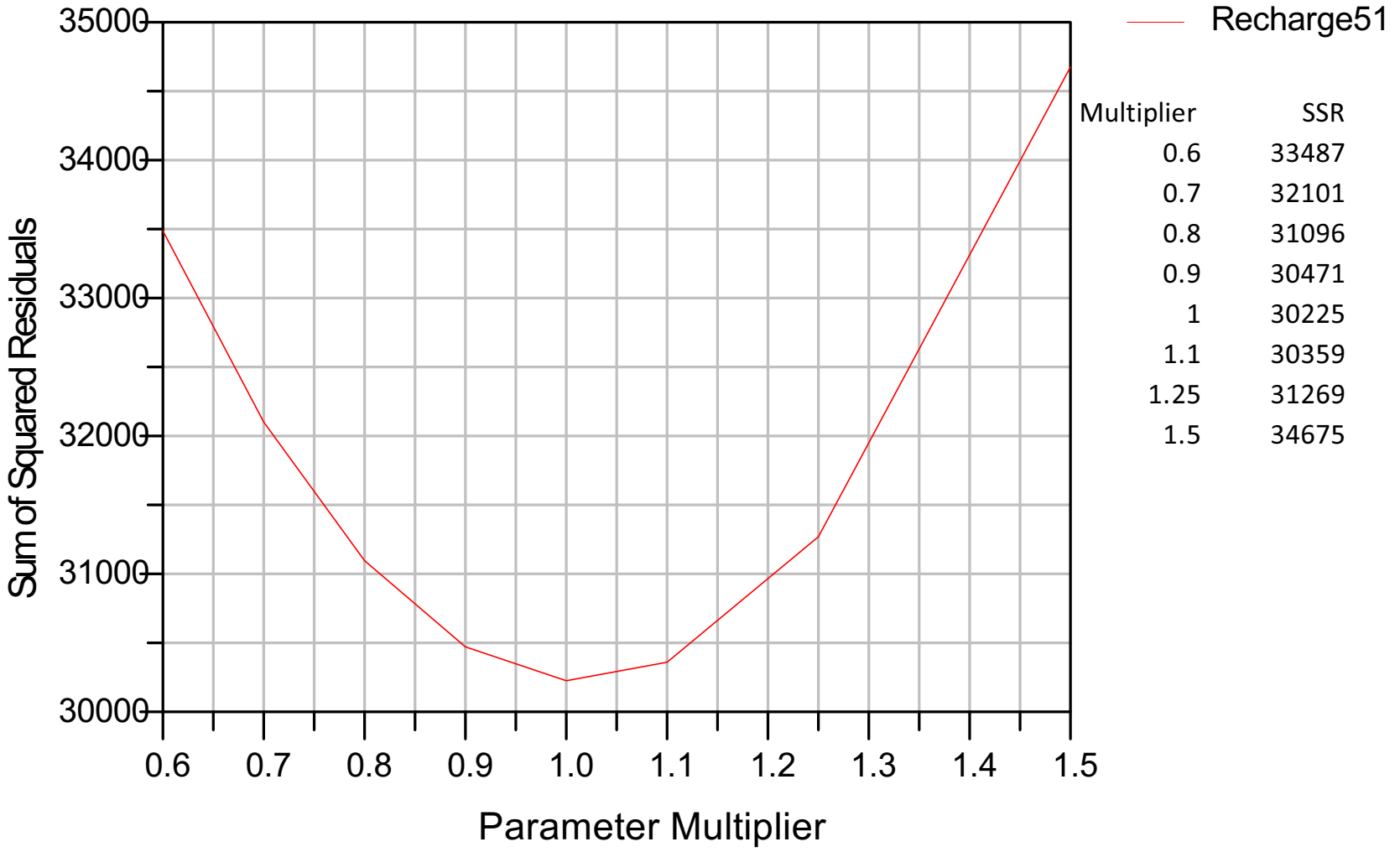
Exhibit 8



Multiplier	SSR
0.6	30223
0.7	30224
0.8	30224
0.9	30225
1	30225
1.1	30226
1.25	30227
1.5	30229

Recharge Zone K

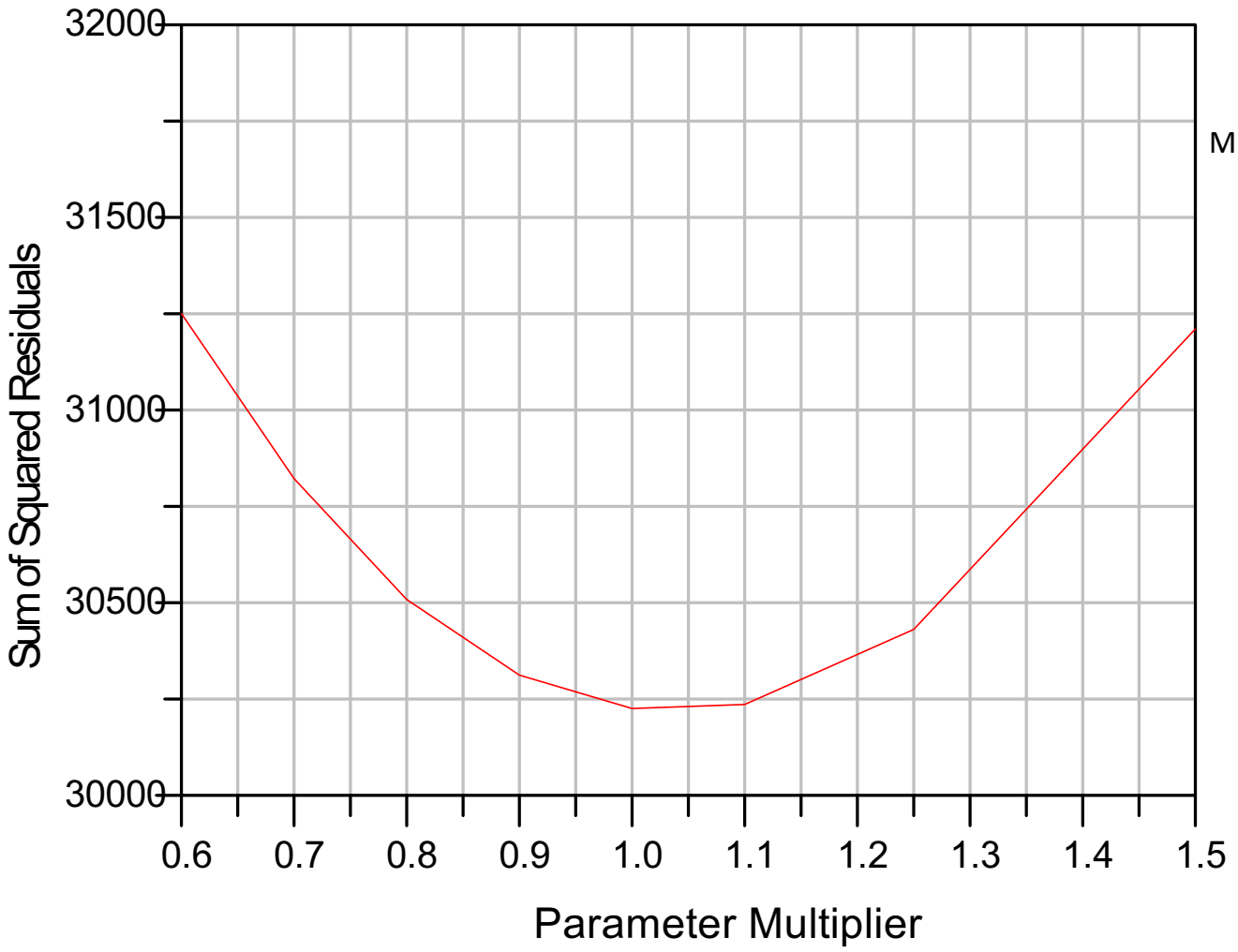
Exhibit 8



Multiplier	SSR
0.6	33487
0.7	32101
0.8	31096
0.9	30471
1	30225
1.1	30359
1.25	31269
1.5	34675

Recharge Zone C

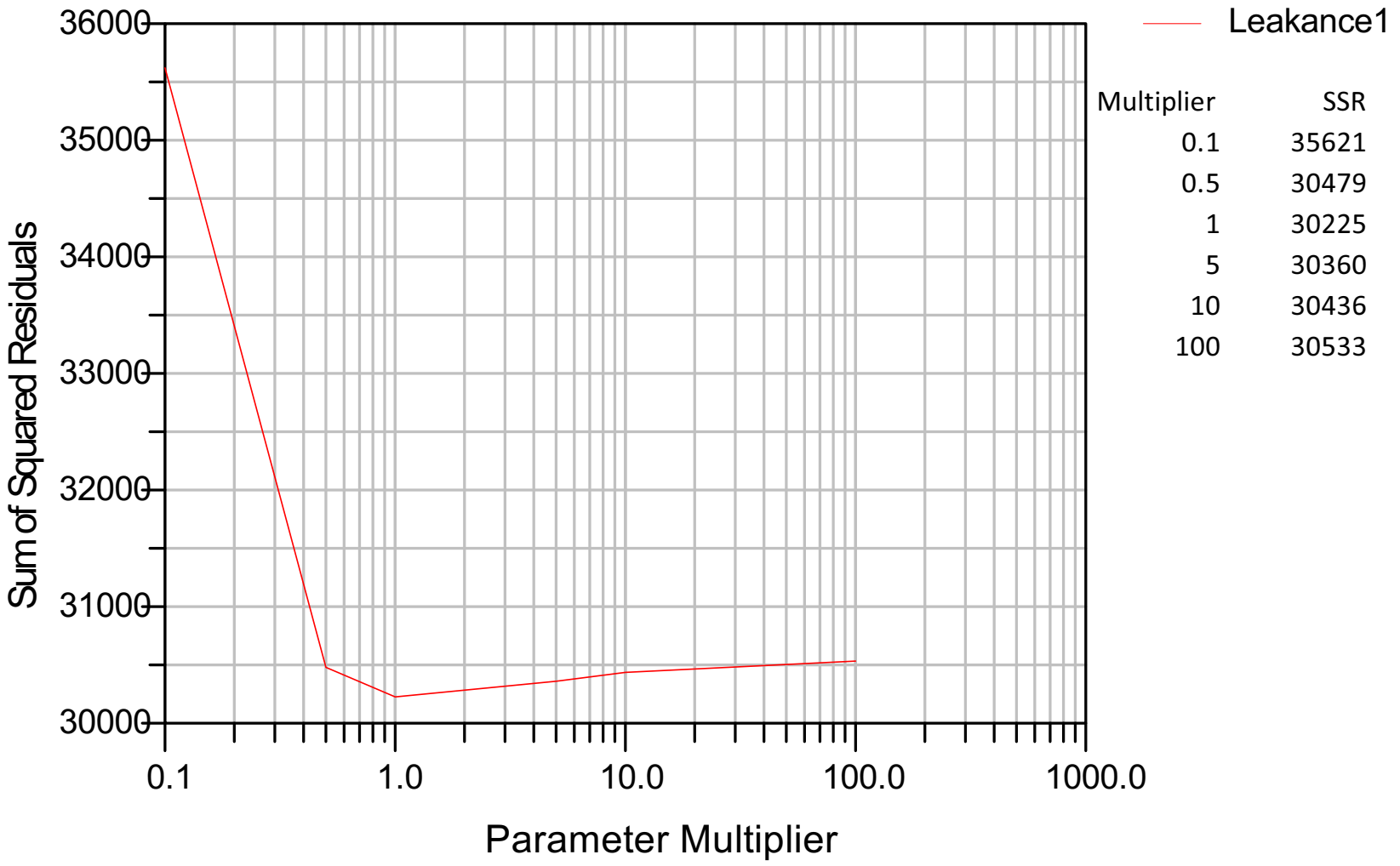
Exhibit 8



Multiplier	SSR
0.6	31250
0.7	30822
0.8	30508
0.9	30312
1	30225
1.1	30236
1.25	30431
1.5	31210

Recharge Zone D

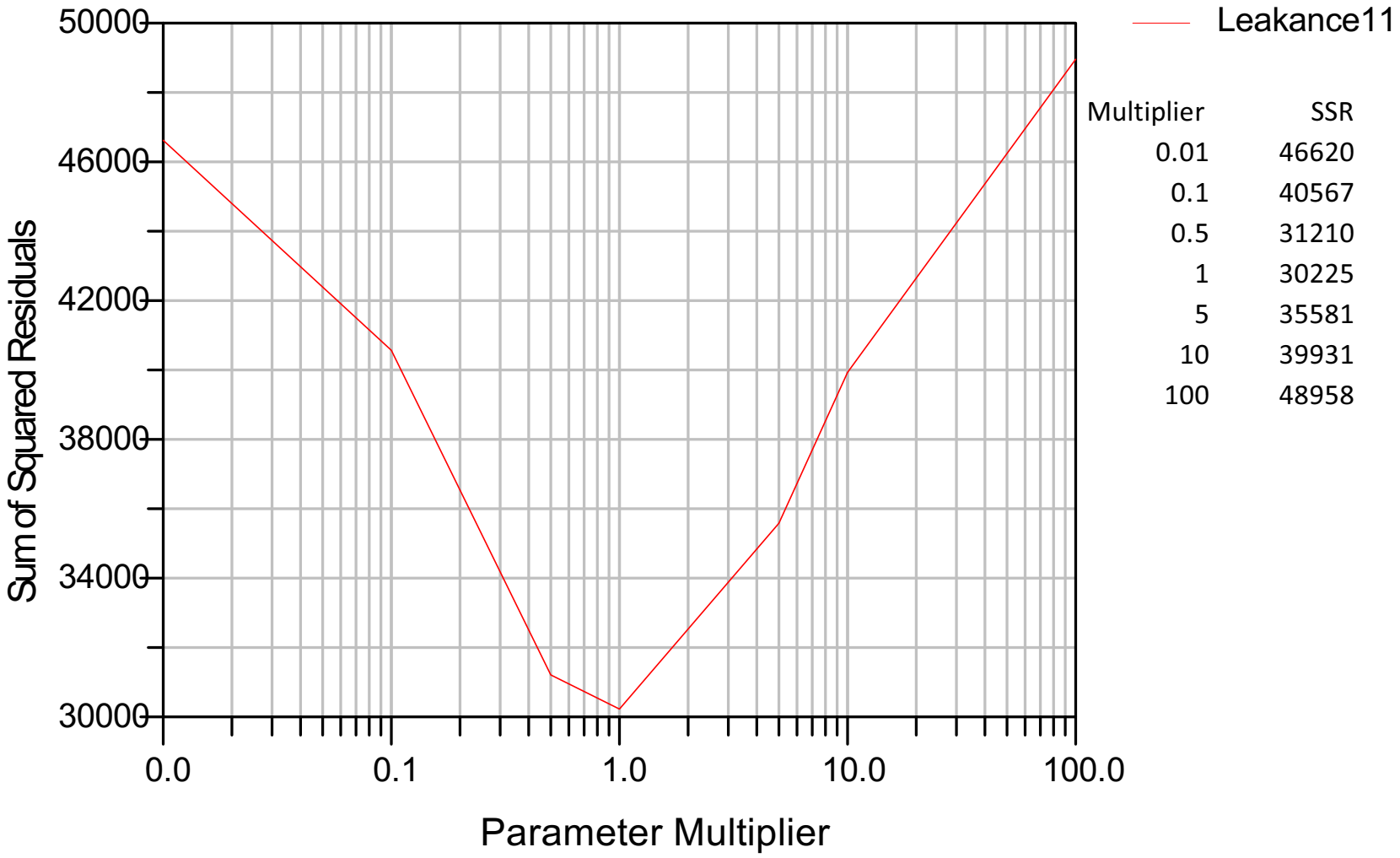
Exhibit 8



Multiplier	SSR
0.1	35621
0.5	30479
1	30225
5	30360
10	30436
100	30533

Leakance Zone A

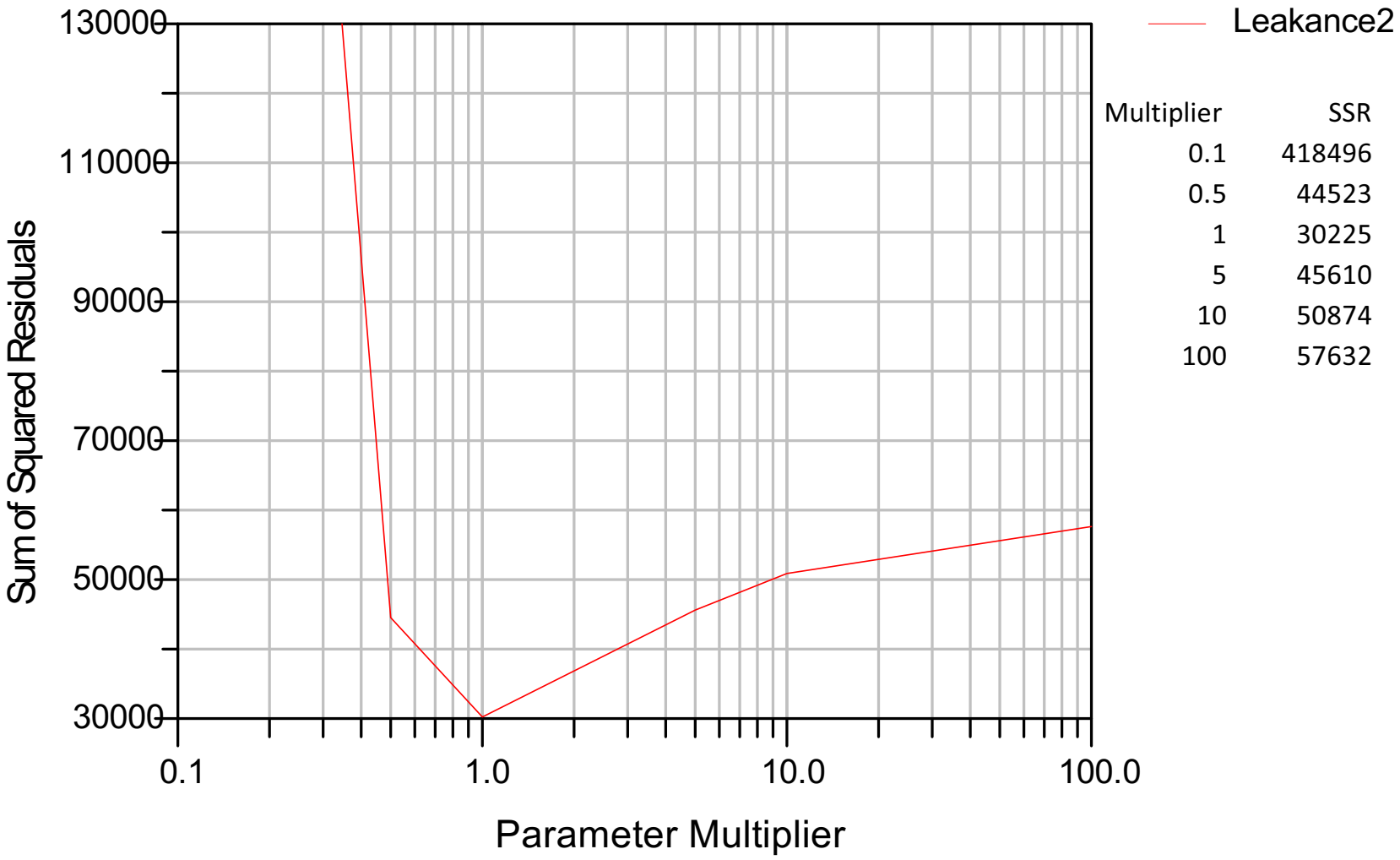
Exhibit 8



Multiplier	SSR
0.01	46620
0.1	40567
0.5	31210
1	30225
5	35581
10	39931
100	48958

Leakance Zone B

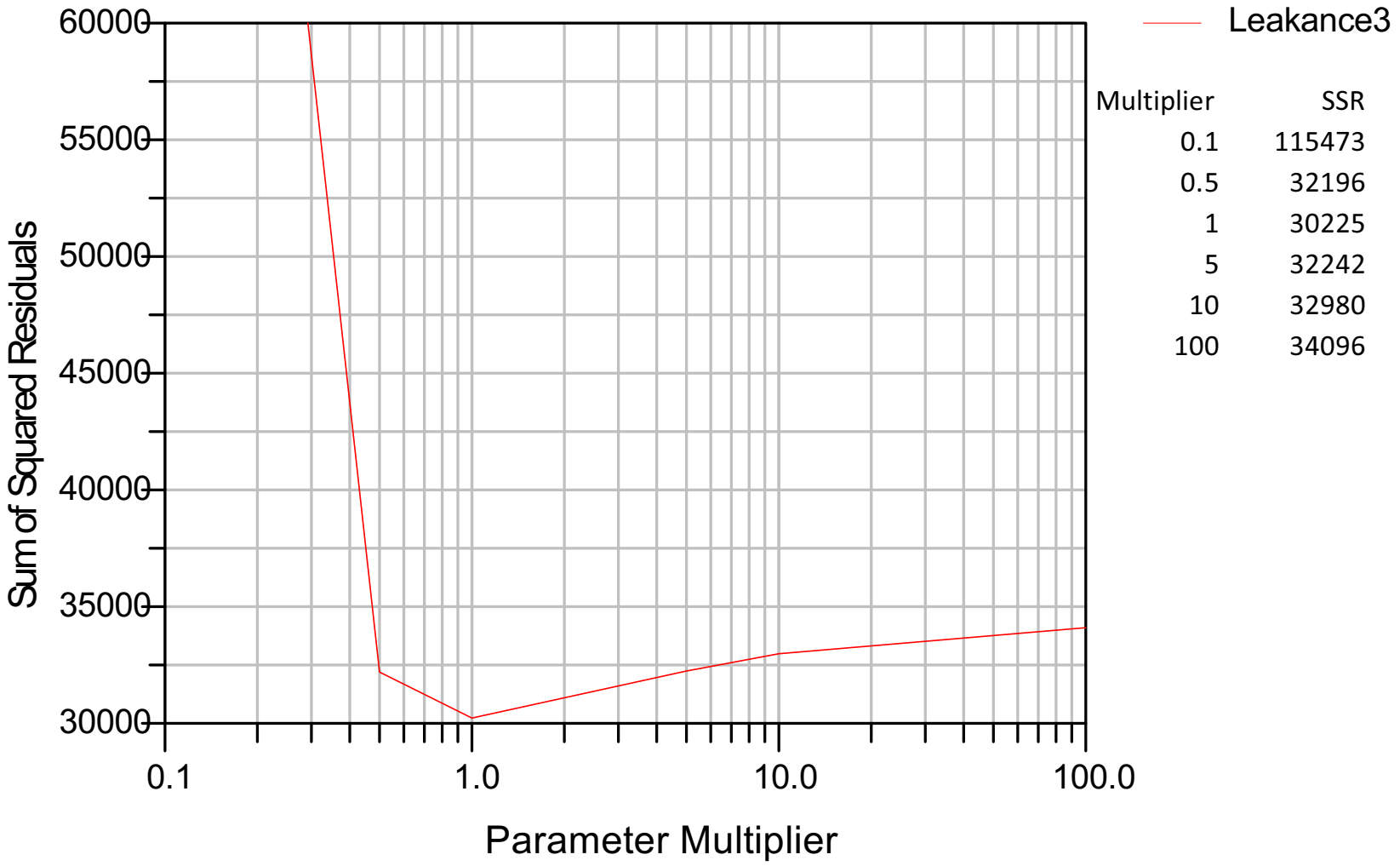
Exhibit 8



Multiplier	SSR
0.1	418496
0.5	44523
1	30225
5	45610
10	50874
100	57632

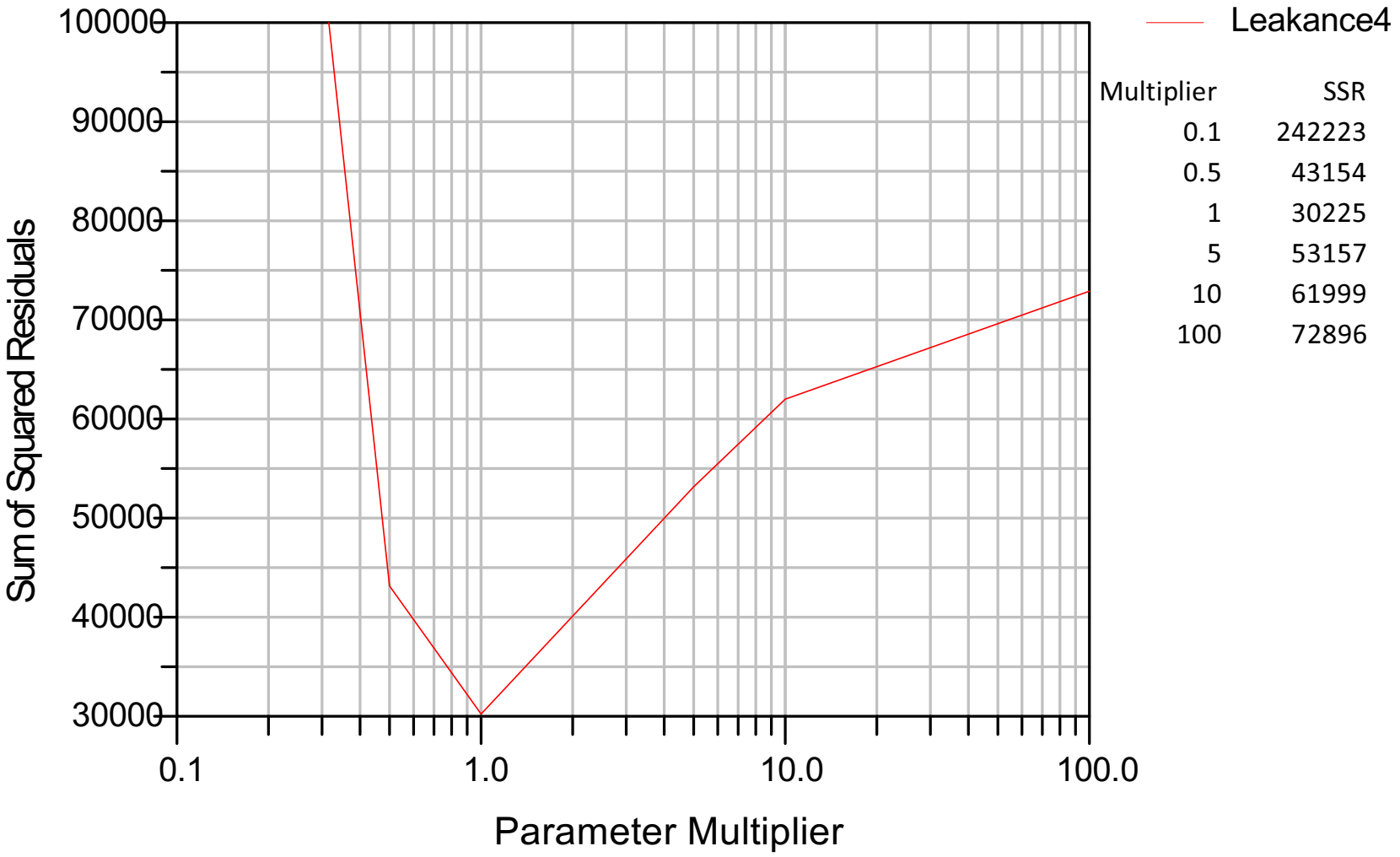
Leakance Zone C

Exhibit 8



Leakance Zone E

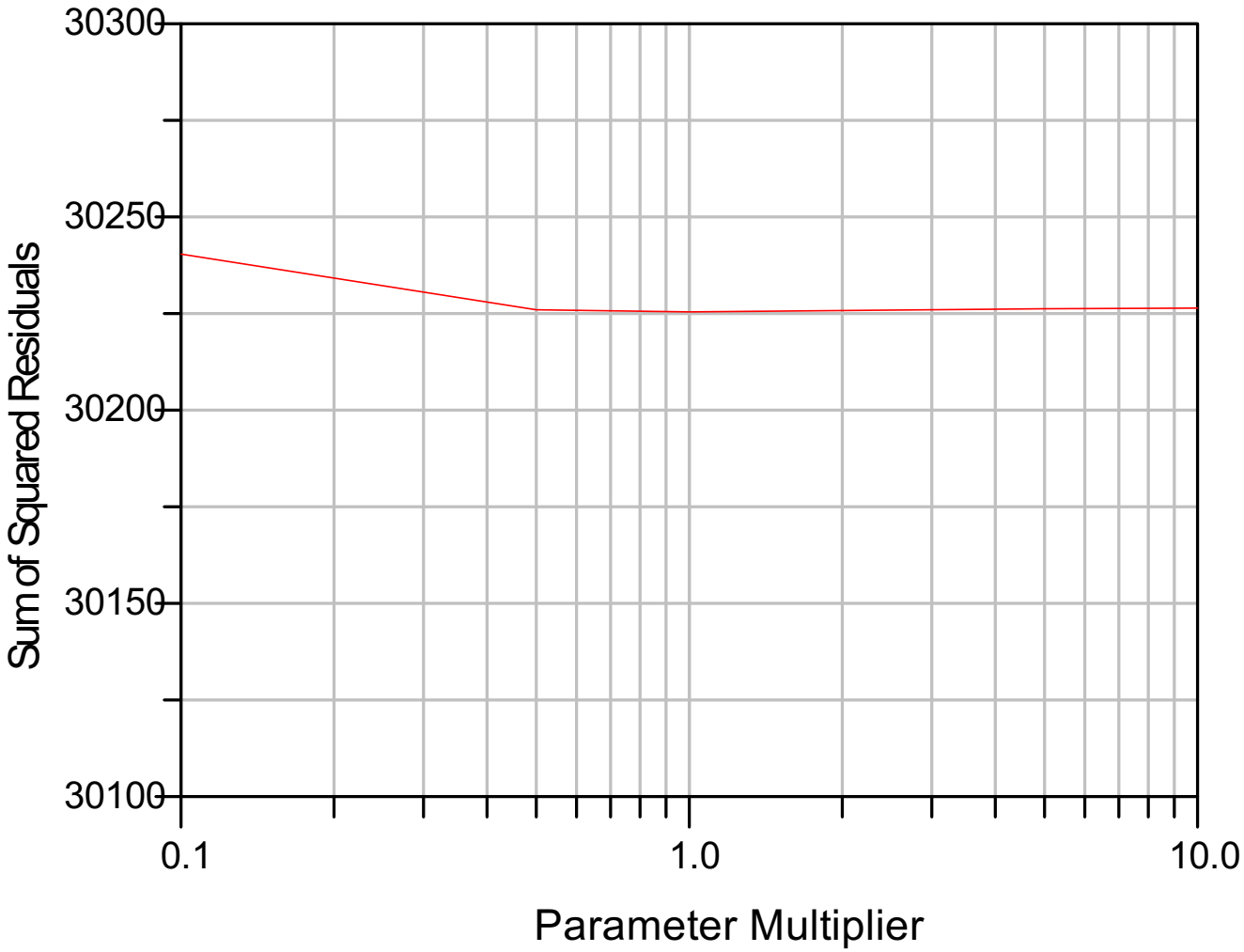
Exhibit 8



Multiplier	SSR
0.1	242223
0.5	43154
1	30225
5	53157
10	61999
100	72896

Leakance Zone G/H

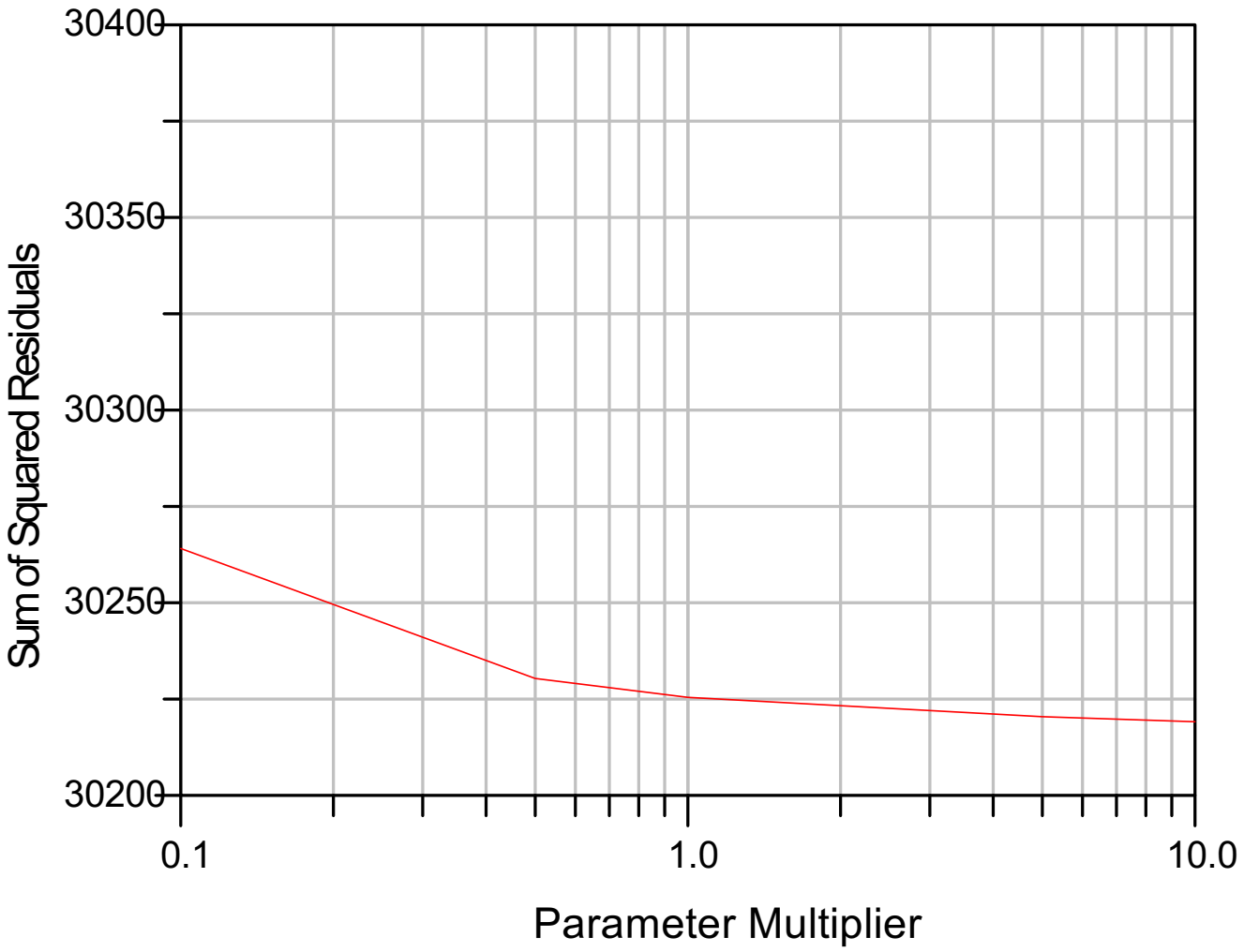
Exhibit 8



Multiplier	SSR
0.1	30240
0.5	30226
1	30225
5	30226
10	30226

Drain Represents E. Fork Armells Creek

See Drain Cross-reference at End of Model Attachment GM-C

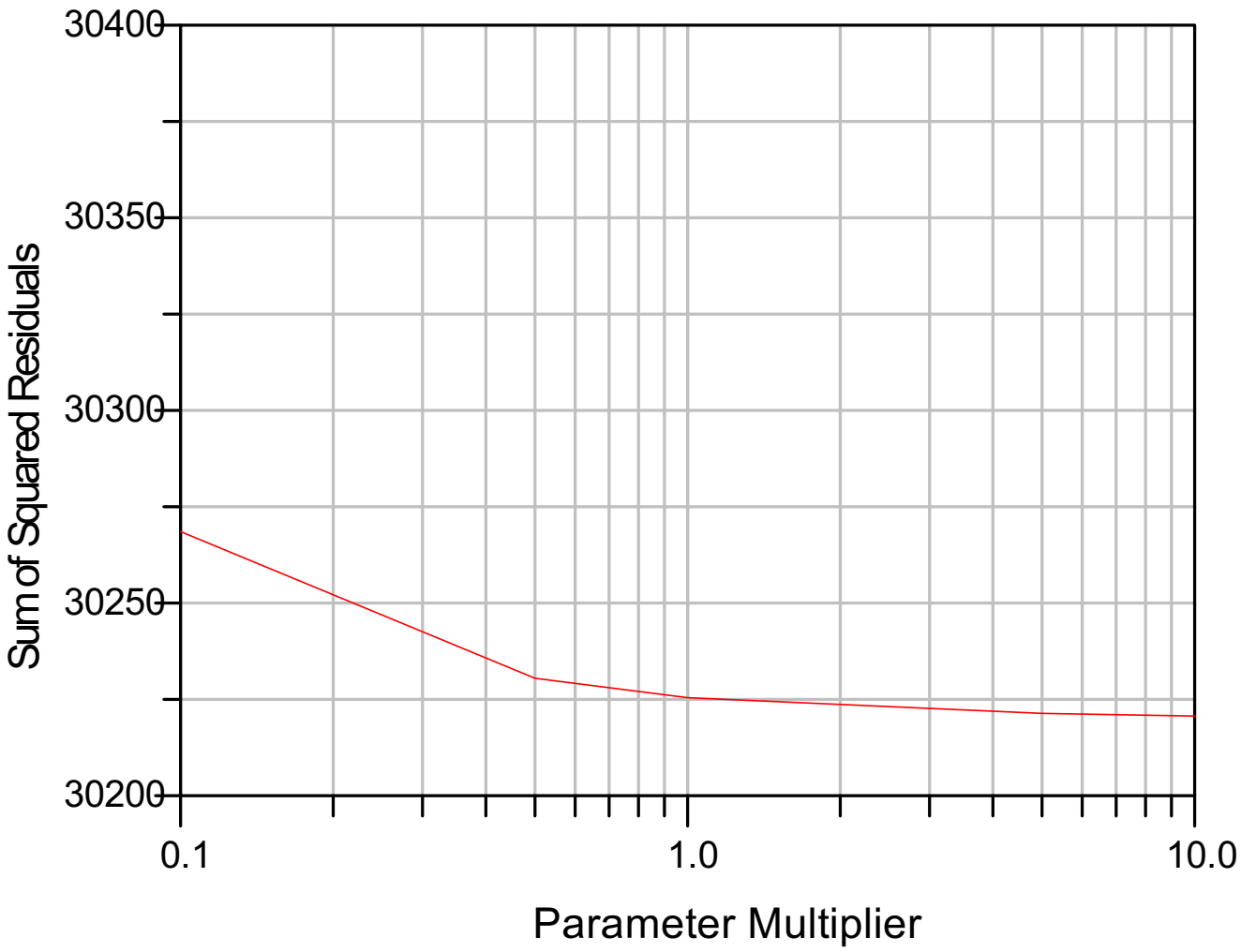


Multiplier	SSR
0.1	30264
0.5	30230
1	30225
5	30220
10	30219

Drain Represents Stocker Creek

See Drain Cross-reference at End of Model Attachment GM-C

Exhibit 8

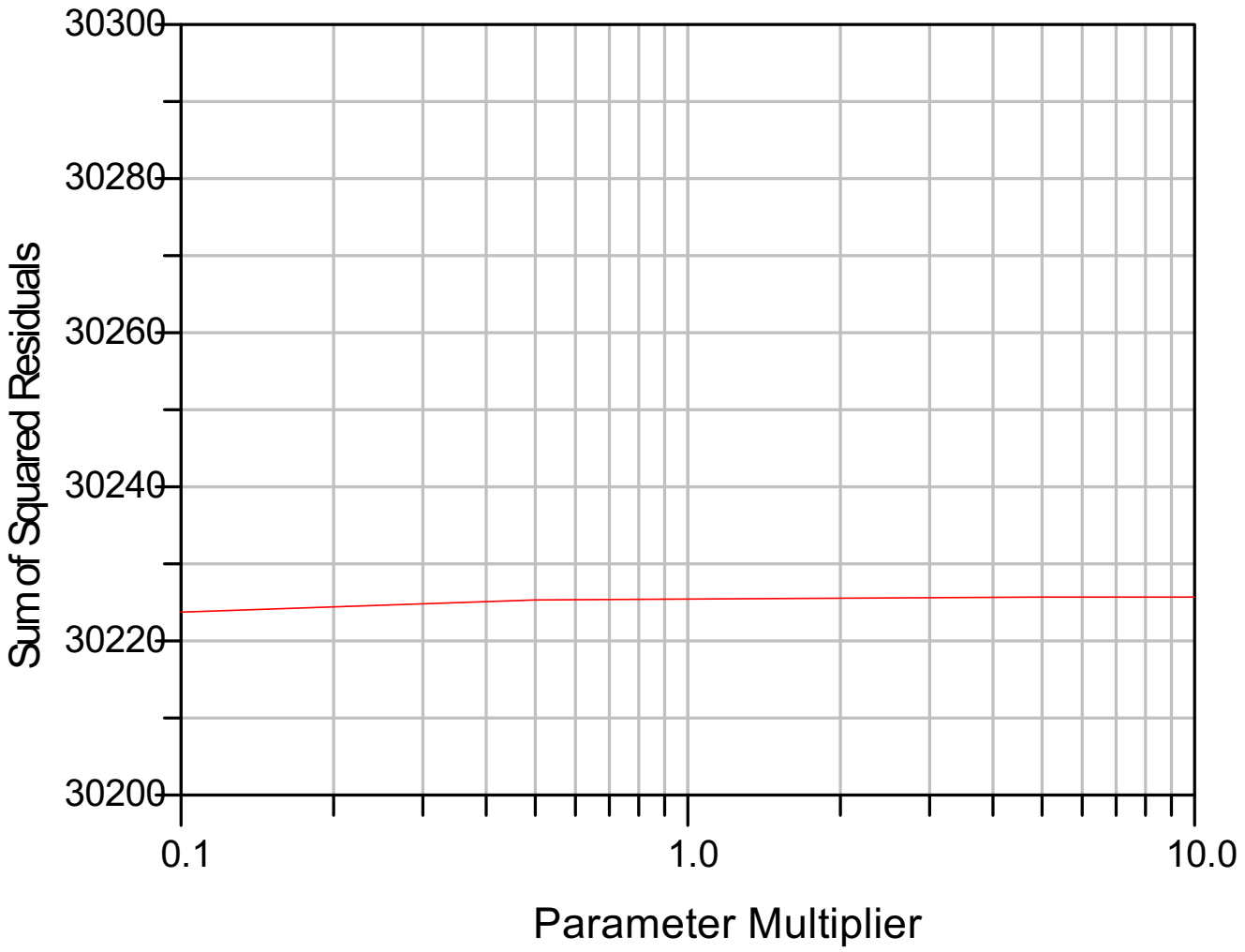


Multiplier	SSR
0.1	30269
0.5	30230
1	30225
5	30221
10	30221

Drain Represents Black Hank Creek

See Drain Cross-reference at End of Model Attachment GM-C

Exhibit 8

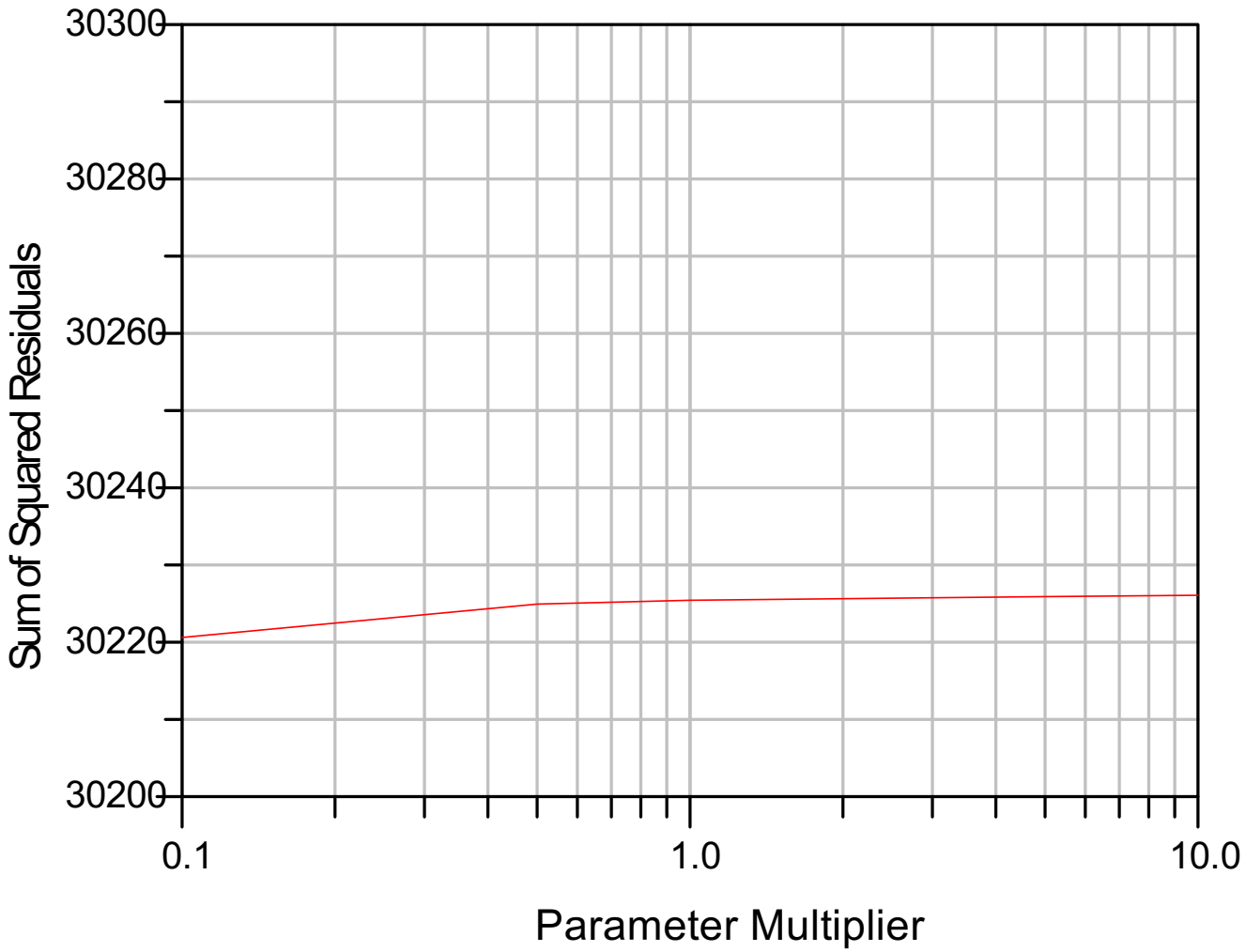


Multiplier	SSR
0.1	30224
0.5	30225
1	30225
5	30226
10	30226

Drain Represents a Donley Creek Reach

See Drain Cross-reference at End of Model Attachment GM-C

Exhibit 8

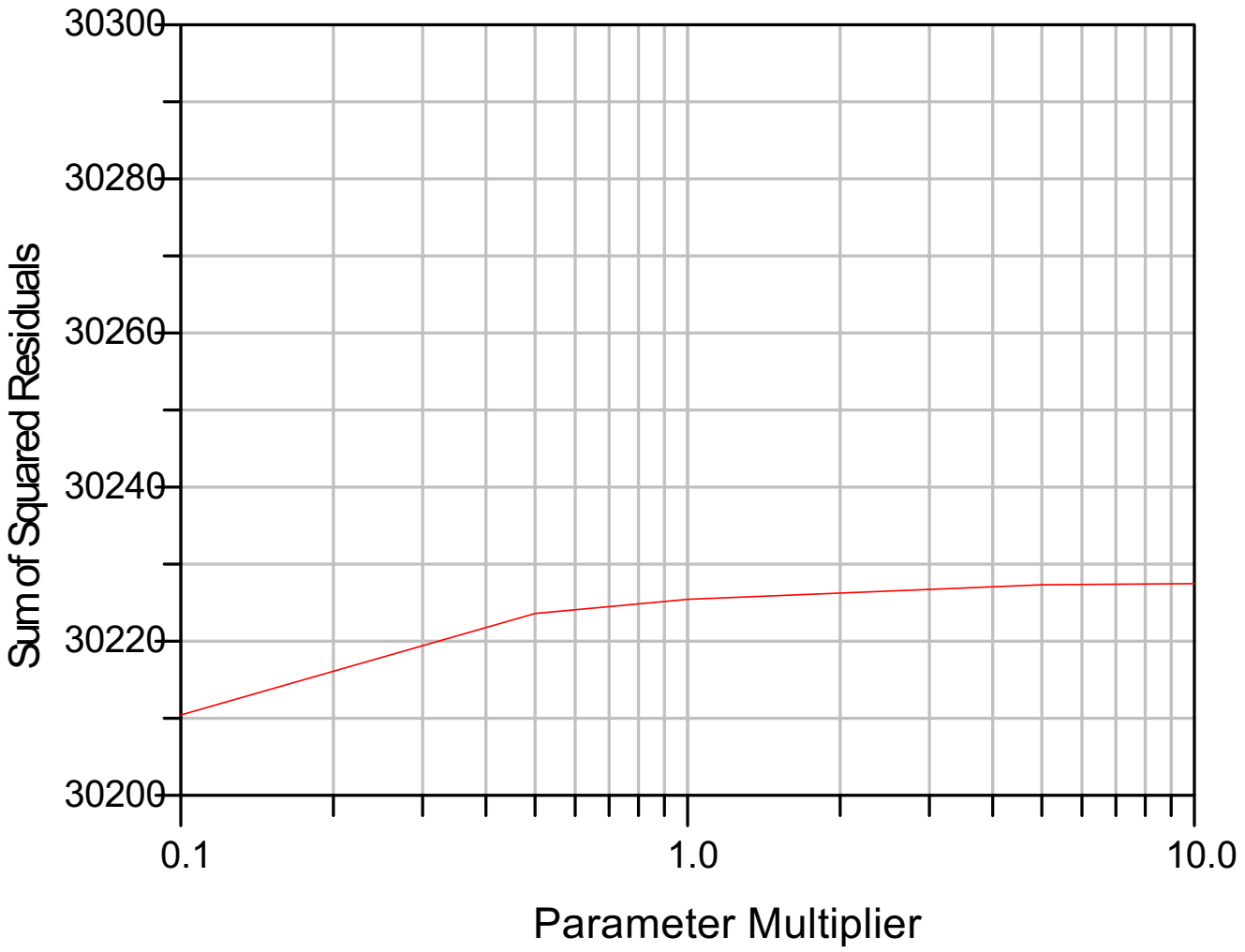


Multiplier	SSR
0.1	30221
0.5	30225
1	30225
5	30226
10	30226

Drain Represents a Donley Creek Reach

See Drain Cross-reference at End of Model Attachment GM-C

Exhibit 8

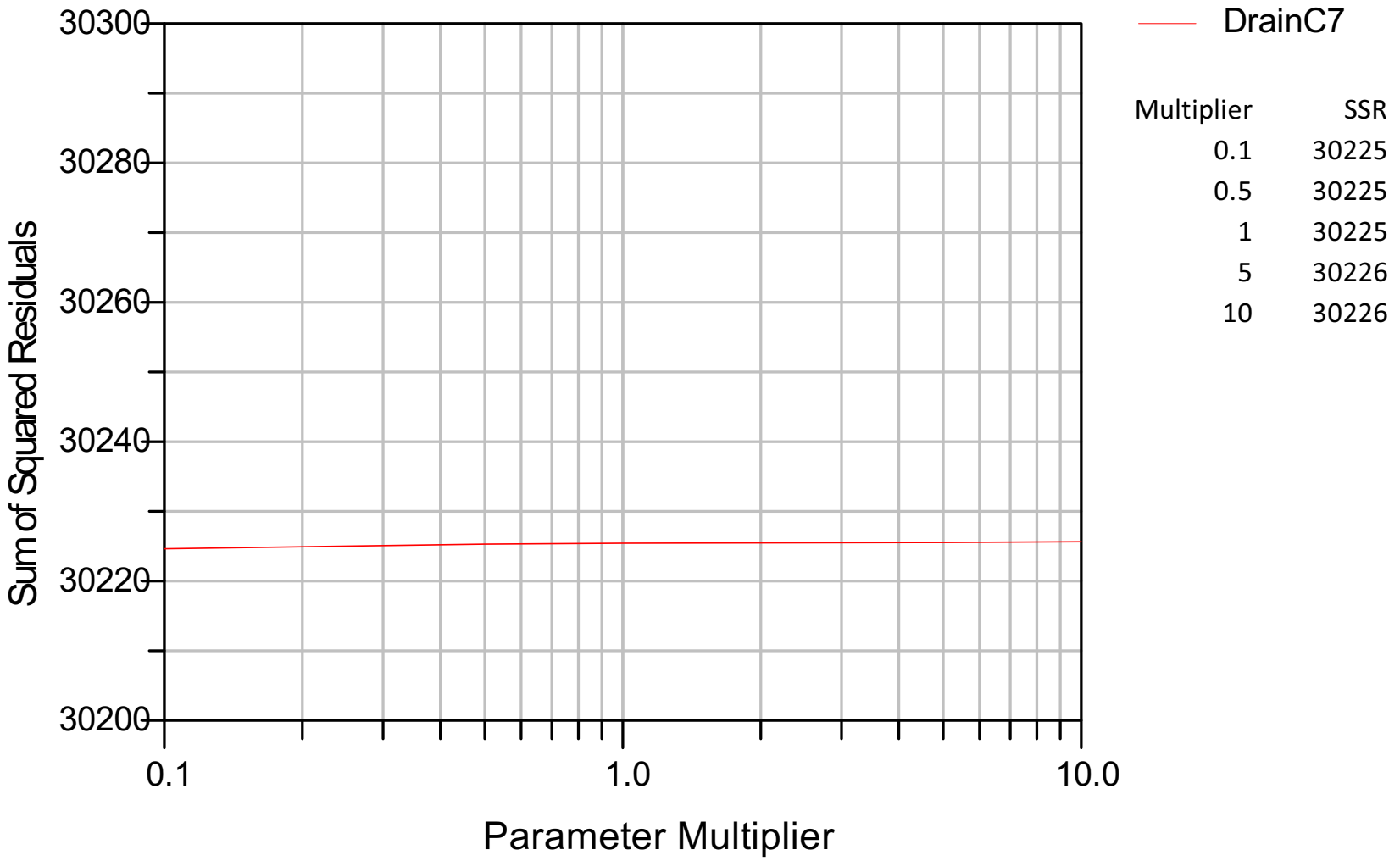


Multiplier	SSR
0.1	30210
0.5	30224
1	30225
5	30227
10	30227

Drain Represents a Donley Creek Reach

See Drain Cross-reference at End of Model Attachment GM-C

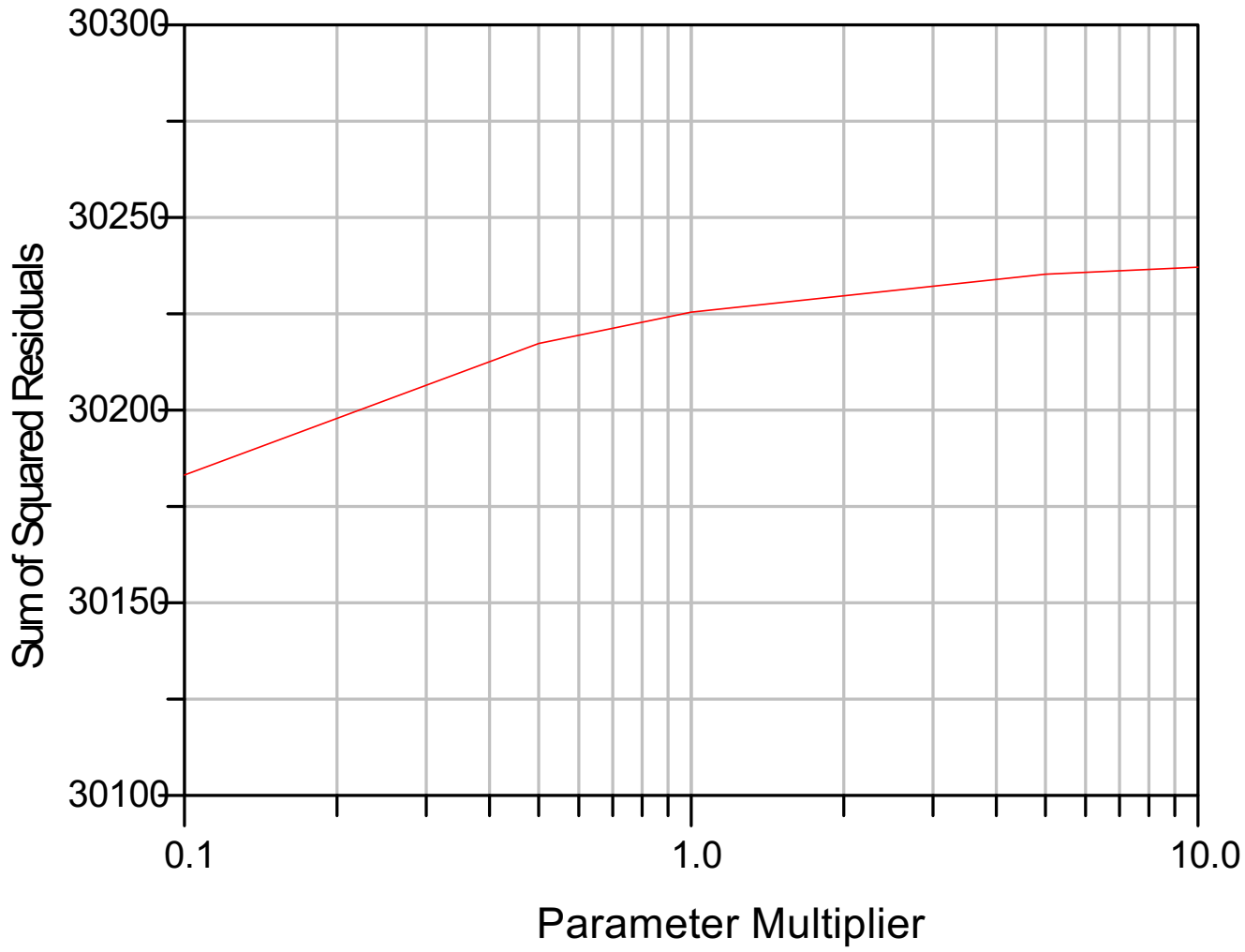
Exhibit 8



Drain Represents a Reach below Confluence of Donley and Robbie Creek

See Drain Cross-reference at End of Model Attachment GM-C

Exhibit 8

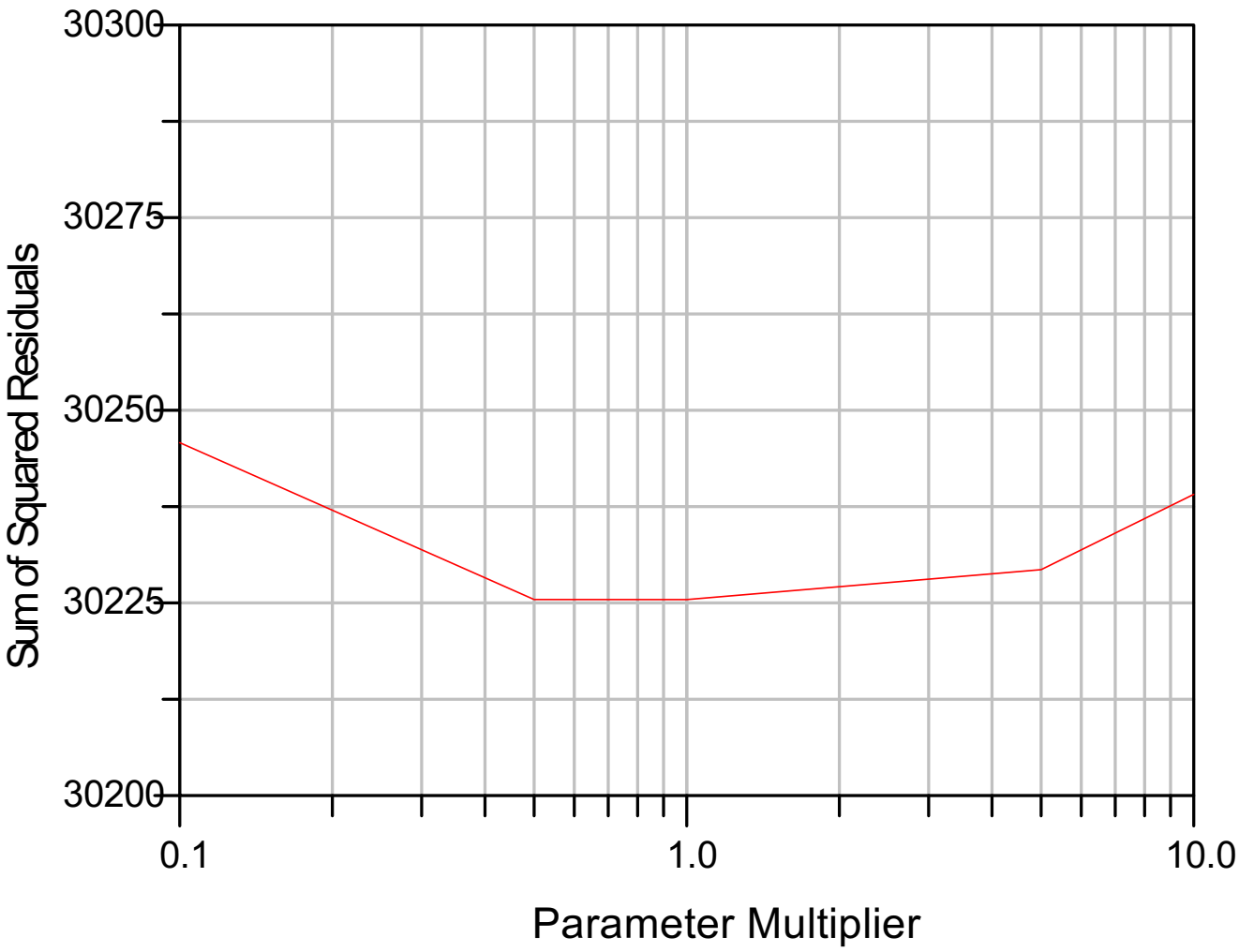


Multiplier	SSR
0.1	30183
0.5	30217
1	30225
5	30235
10	30237

Drain Represents a Robbie Creek Reach

See Drain Cross-reference at End of Model Attachment GM-C

Exhibit 8

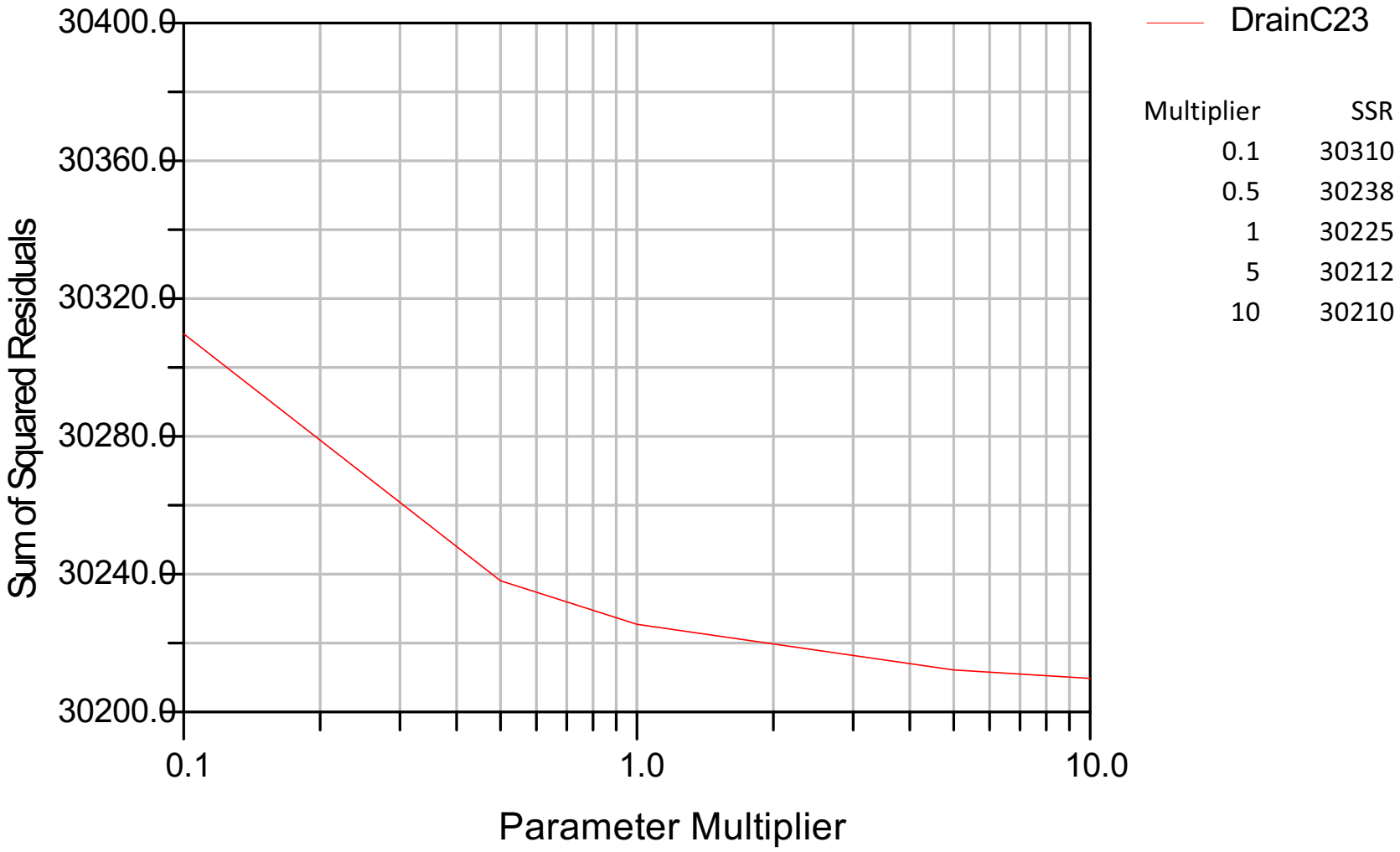


Multiplier	SSR
0.1	30246
0.5	30225
1	30225
5	30229
10	30239

Drain Represents a West Fork Armells Creek

See Drain Cross-reference at End of Model Attachment GM-C

Exhibit 8

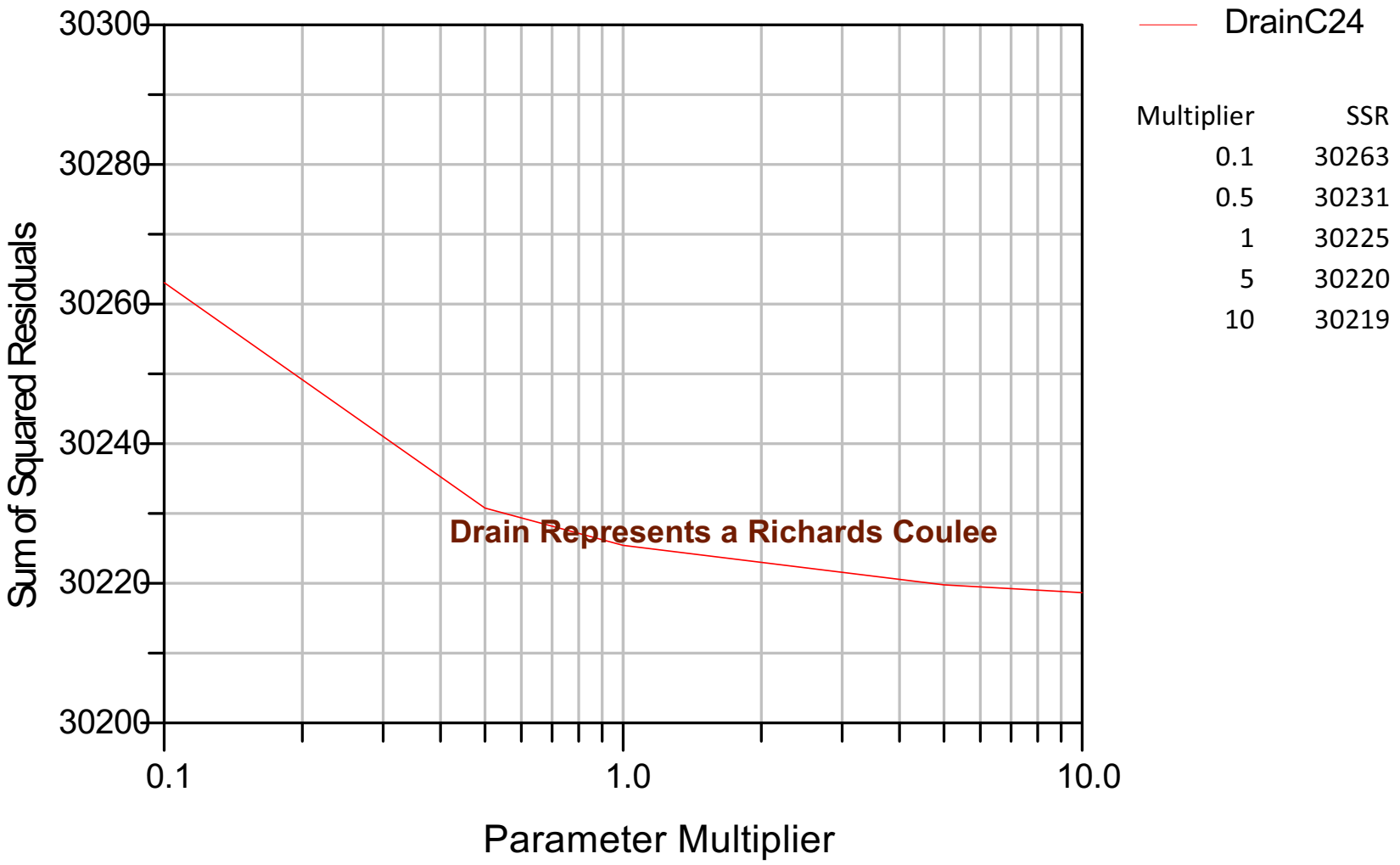


Multiplier	SSR
0.1	30310
0.5	30238
1	30225
5	30212
10	30210

Drain Represents a Richards Coulee

See Drain Cross-reference at End of Model Attachment GM-C

Exhibit 8

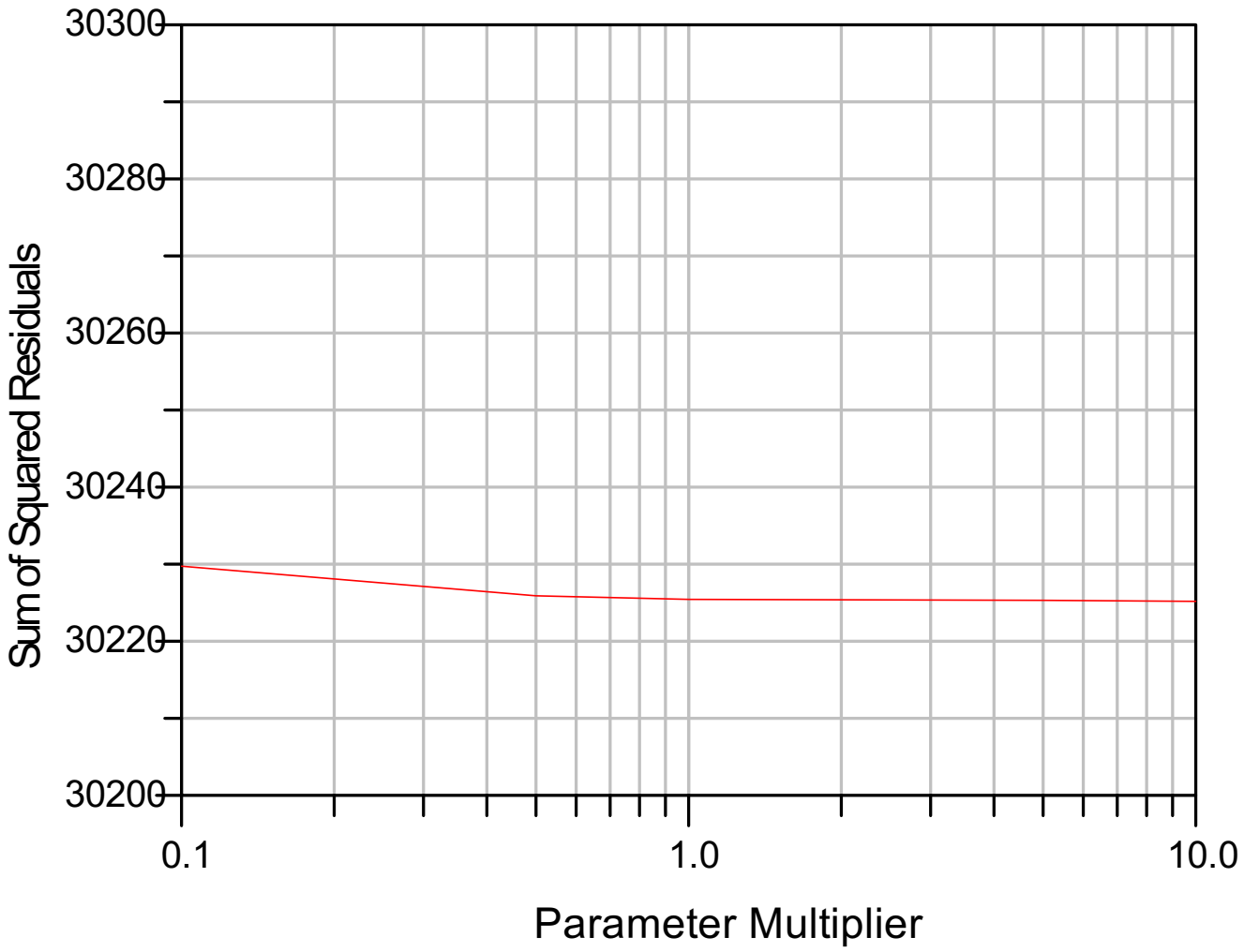


Multiplier	SSR
0.1	30263
0.5	30231
1	30225
5	30220
10	30219

Drain Represents a Lee Coulee

See Drain Cross-reference at End of Model Attachment GM-C

Exhibit 8

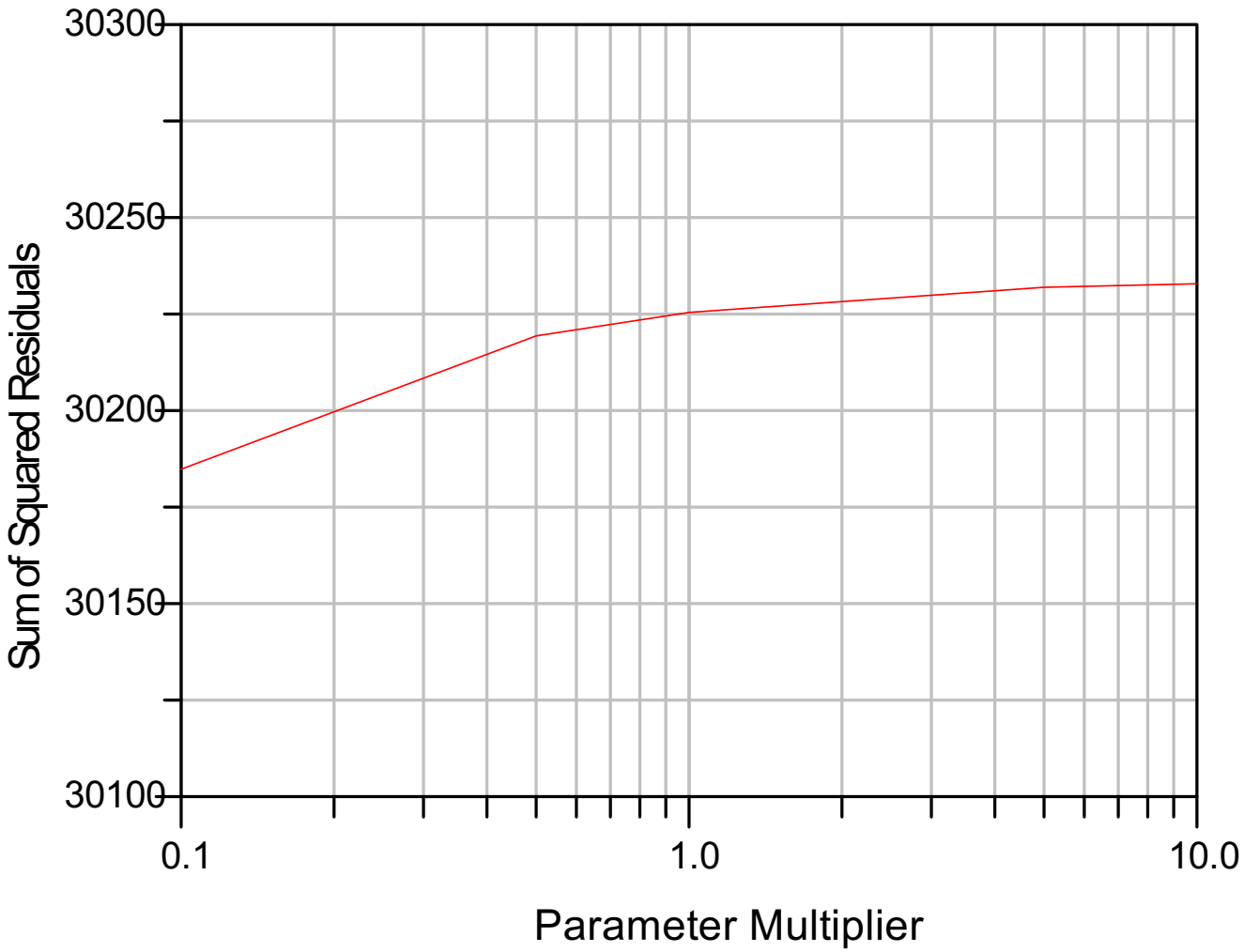


Multiplier	SSR
0.1	30230
0.5	30226
1	30225
5	30225
10	30225

Drain Represents Miller/Emily Coulees

See Drain Cross-reference at End of Model Attachment GM-C

Exhibit 8

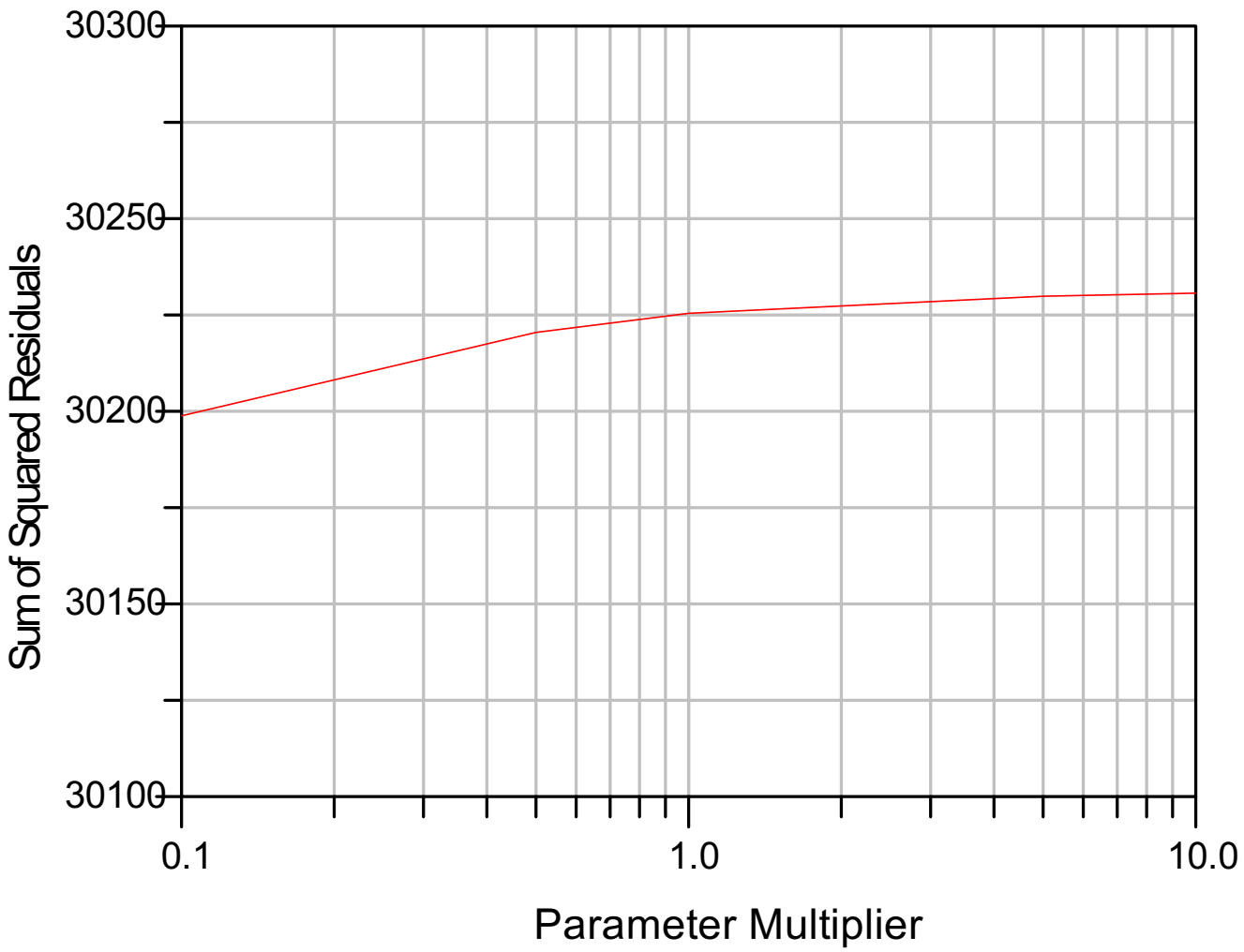


Multiplier	SSR
0.1	30185
0.5	30219
1	30225
5	30232
10	30233

Drain Represents Hay Coulee

See Drain Cross-reference at End of Model Attachment GM-C

Exhibit 8



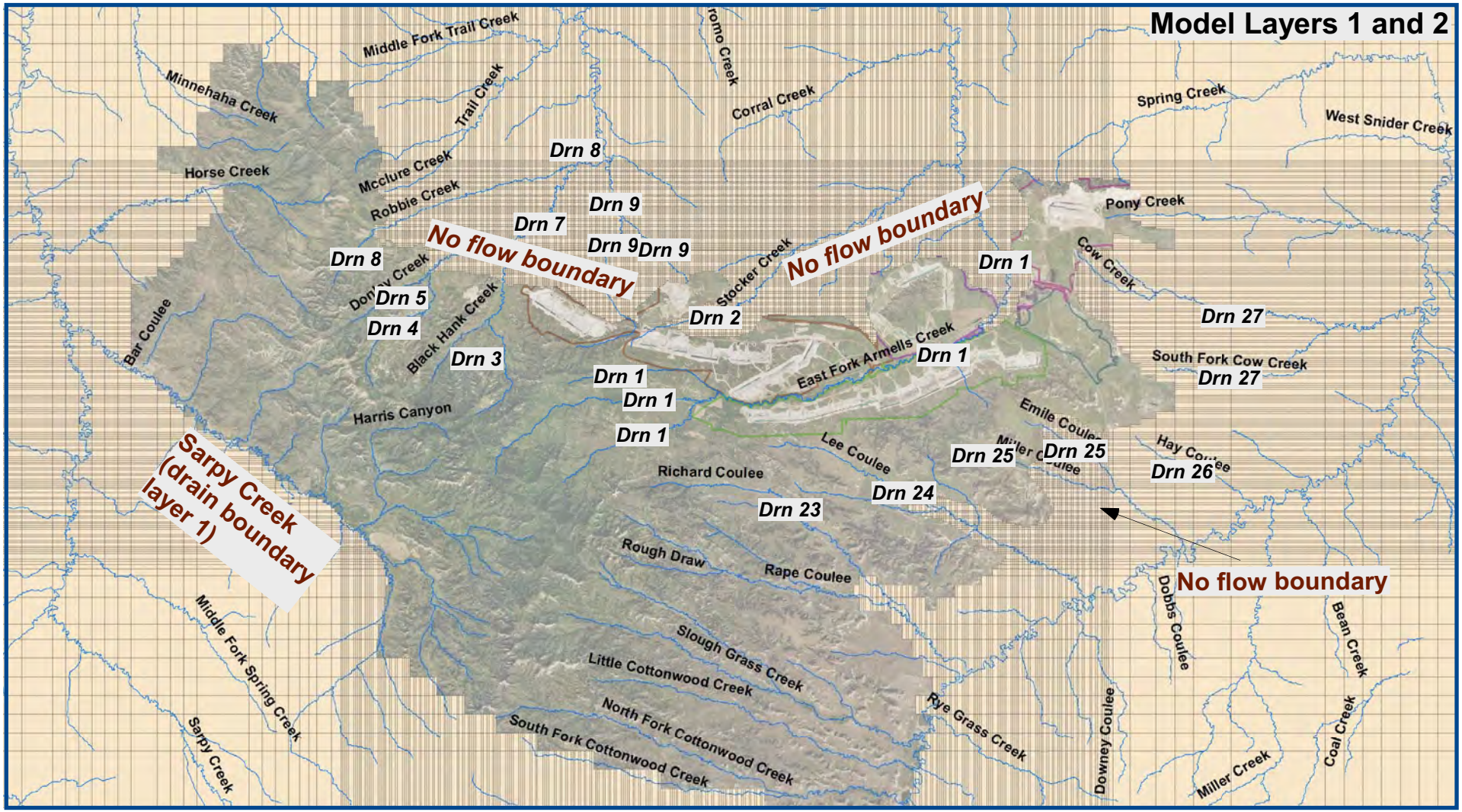
Multiplier	SSR
0.1	30199
0.5	30220
1	30225
5	30230
10	30231

Drain Represents Cow Coulee

See Drain Cross-reference at End of Model Attachment GM-C

Exhibit 8

Drain Cross-Reference - Drains near Areas A, B and C.



See Table that follows

Exhibit 8

Drain Cross Reference

Reach	Creek Associated with Drain Reach	Assigned Drain		
		Width (ft)	Thickness (ft)	Hydraulic Conductivity (ft/d)
1	*E Fork Armells Creek*	*8*	*2*	*10*
2	*Stocker Creek*	*4*	*2*	*5*
3	*Black Hank Creek*	*4*	*2*	*5*
4	*Donley Creek*	*4*	*2*	*5*
5	*Donley Creek*	*4*	*2*	*5*
6	*Donley Creek*	*4*	*2*	*5*
7	*Donley Creek downgradient*	*4*	*2*	*5*
8	*Robbie Creek*	*4*	*2*	*5*
9	*West Fork Armells Creek-upgradient*	*4*	*2*	*5*
9	*West Fork Armells Creek-downgradient*	*8*	*2*	*10*
10	McClure Creek	4	2	5
12	West Cromo Creek	4	2	5
13	West Sheep Creek	4	2	5
20	Rosebud Creek	8	2	10
21	Cottonwood Creek	4	2	5
22	Slough Grass Creek	4	2	5
23	*Richard Coulee*	*4*	*2*	*5*
24	*Lee Coulee*	*4*	*2*	*5*
25	*Miller Coulee*	*4*	*2*	*5*
26	*Hay Coulee*	*4*	*2*	*5*
27	*Cow Creek*	*4*	*2*	*5*
28	Pony Creek	4	2	5
29	Spring Creek	4	2	5
30	Sprague Creek	4	2	5
31	Unnamed Tributary to E. Fork Armells Cr	4	2	5
32	West Sheep Creek	4	2	5
40	Sarpy Creek	8	2	10
41-1	Unnamed Tributary to Sarpy Creek	4	2	5
41-2	Corral Creek	4	2	5
42-1	Unnamed Tributary to Sarpy Creek	4	2	5
42-2	Unnamed Tributary to WF Armells Creek	4	2	5
43-1	Minehaha Creek	4	2	5
43-2	E. Cromo Creek	4	2	5
44	S. Fork Beaver Creek	4	2	5
45	Bear Creek	4	2	5
46	Reservation Creek	4	2	5
47	Seven Mile Creek	4	2	5

Italicized/shaded were subject to steady-state sensitivity analysis.

Attachment E

Groundwater Model Report

Area B – AM4 (Amendment Application 00184)

Permit C1984003B

Western Energy Rosebud Mine

Prepared for

WESTERN ENERGY COMPANY – *Rosebud Mine*

A Subsidiary of WESTMORELAND COAL COMPANY

PO Box 99 Rosebud Lane Colstrip, MT 59323 (406) 748 5100

Prepared by:

Nicklin Earth & Water

670 S Ferguson Ave, Suite 1

Bozeman, MT 59718

406.582.0413

June 2013

Exhibit 8

Contents

Attachment E – Groundwater Model Report
Area B – AM4 (Application Amendment 00184)
Western Energy Rosebud Mine

Exhibit 8

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E-10 Difference in Simulated Potentiometric Head in McKay Coal (2076) – Existing Permit versus Proposed Permit

Report

Attachment E – Groundwater Model Report
Area B – AM4 (Application Amendment 00184)
Western Energy Rosebud Mine

Exhibit 8

Groundwater Model Report
Area B - AM4 (Amendment Application 00184) – Permit C1984003B
Western Energy Rosebud Mine

1.0 INTRODUCTION

1.1 Background

The Rosebud Mine in southeastern Montana has been in operation since 1975 (Figure E-1). Western Energy Coal Company (WECo) is proposing an expansion of the existing mining permit in the eastern portion of Area B, designated as AM4 (Amendment Application 00184). Figure E-2 presents the historical and projected timing of the mine passes for both the existing permit and the proposed amendment. The figure shows that mining within the existing permit of Area B is projected to conclude in 2020. The proposed AM4 mining cuts are anticipated to be mined from 2013 to 2026. This report presents the results of a groundwater modeling effort to evaluate potential changes in groundwater quantity associated with the AM4 Amendment.

In 2011, Nicklin Earth & Water developed a regional groundwater model for the Rosebud Mine area. The model was updated and revised in 2013 and is hereafter designated as the "Rosebud Mine Groundwater Model". A brief overview of the model is given below; however, refer to the Rosebud Mine Groundwater Model Report, provided as Attachment D, for a detailed description of model development, calibration and structure, as well as the hydrologic, geologic and hydrogeologic data used to develop the model.

The current modeling effort makes use of the regional Rosebud Mine model to simulate historical and planned mining within the existing permit in Areas A, B and C. More specifically, mining progression is simulated using a set of cascading transient models for which the regional Rosebud Mine model is the basis.

1.2 Model Overview

The Rosebud Mine groundwater model was developed using MODFLOW: "A modular three-dimensional finite difference ground-water flow model developed by the United States Geological Survey [USGS]" (McDonald and Harbaugh, 1988).

The model domain encompasses an area of approximately 27 miles (N-S) by 36 miles (E-W). The model uses a variable spaced grid, however, a uniform grid density was applied to areas of permitted mining.

The hydrogeology was represented in the model using five layers assigned a constant saturated thickness. The model layers generally represent the following geologic strata:

- Layer 1: Alluvium and overburden
- Layer 2: Rosebud coal
- Layer 3: Interburden
- Layer 4: McKay coal
- Layer 5: SubMcKay

The model parameters (transmissivity, recharge and leakance) were modified areally during calibration to achieve as reasonable an approximation to pre-mining potentiometric head as feasible. Generally, the calibrated transmissivity values for the Rosebud mine model are reasonably consistent with data collected during the EIS (1982). For a detailed overview of steady-state model parameters, refer to the Rosebud Mine Groundwater Model Report.

1.3 Model Application Procedure / Transient Evaluation

The calibrated steady-state model described above was used as the basis of a series of cascading, annual MODFLOW models. The series of models was developed to represent the following mining phases in Areas A, B and C:

- Historic mining from 1975 through 2012 for Areas A, B and C. These models were created as part of the Rosebud Mine Groundwater Model (Attachment D).
- Scenario 1: existing permits

  - Future mining of the existing permits for Areas A, B and C, starting with the year 2013 through 2026. Mining of the existing permit in Area B is projected to conclude in 2020.

  - Post mining starting at the end of mining in 2026 and extending to 2076. This post-mine model simulation was run to 50 years in the future to evaluate the long-term response following mining completion.

- Scenario 2: proposed permit

  - Future mining of the proposed permit from 2013 through 2026. The proposed permit consists of mining of the AM4 Amendment passes in addition to the existing permits for Areas A, B and C. The AM4 revision passes are projected to be mined from 2013 through 2026 (see Figure E-2).

  - Post mining starting at the end of mining in 2026 and extending to 2076 for the existing permit and proposed AM4 Amendment. This post-mine model simulation was run to 50 years in the future to evaluate the long-term response following proposed mining in Area B in addition to mining of existing permits.

A detailed description of the transient modeling process is presented in the Rosebud Mine Groundwater Model Report (Attachment D). In essence, the mine dewatering process in any given year is simulated by inserting drains at the location of the planned mining passes for that year. In the next year's model, these drains are removed and a new series of drains are added.

In addition to the use of drains to simulate the mining progression, changes are made in model formation parameters. Mining in Areas A, B and C includes the removal of the Rosebud coal seam (model layer 2) which is generally overlain by overburden (model layer 1). Once an area is mined, the top layer of the model is inactivated in the corresponding mining footprint. Next, the model parameters of the second model layer in the same area are changed to represent the spoils which replace the mined overburden and coal. The model formation parameters that change are hydraulic conductivity, storativity and recharge.

2.0 RESULTS

2.1 Pre-mining

The pre-mine potentiometric heads as simulated by the steady-state model are presented in Figure GM-19 of the Rosebud Mine Groundwater Model Report. Generally, the direction of groundwater flow within Area B is southeast to northeast. Simulated pre-mine steady-state potentiometric heads in the Rosebud coal (layer 2) and McKay coal (layer 4) were used as a reference to calculate the drawdowns presented in Figures E-3, E-4, E-7 and E-8 of this report.

2.2 During Mining

Simulated mean annual discharge rates and cumulative average discharge rates from 1977 through 2026 for Area B for both the existing and proposed permit are presented in Table E-1. The cumulative average discharge in Area B for the proposed permit is 141 gpm. Comparison of discharge rates for the proposed permit with discharge rates for the existing permit shows that the proposed permit is predicted to increase the average annual discharge rate in Area B during the 2013-2020 period by 44 gpm.

The Rosebud Mine Groundwater Model Report stated that the following should be noted with respect to the discharges calculated by the models:

- Actual flow rates will vary depending on how the mine manages the water that enters the pits. In some instances, water may be pumped from one pit to another.
- Discharge rates during actual pumping may be much higher, and last for relatively shorter durations than a year.
- Some portion of the discharge likely enters the spoils during the mining process.
- There are likely to be anomalies, such as the presence of alluvium that bounds the projected mine cuts or faults that are not easily represented in this regional model.
- There are climatic factors, including evaporation, and impacts of major precipitation/runoff events which can add water to these pits.

2.3 End of Proposed AM4 Mining - 2026

The AM4 Amendment is projected to be mined from 2013 through 2026. This section discusses drawdown simulation results at the end of 2026.

Figures E-3 and E-4 show the simulated drawdown in the vicinity of Area B in 2026 as a result of mining the existing permit and proposed AM4 Amendment, for the Rosebud coal and McKay coal, respectively. The model projects that the most substantial drawdown as a result of mining in Area B will occur within the existing permit boundary and its immediate vicinity. The largest simulated drawdown at the end of the proposed permit is about 110 feet and is projected to occur in the Rosebud coal in the eastern part of Area B, near the southern permit boundary. As is to be expected, the maximum projected drawdown in the Rosebud coal is higher than the maximum projected drawdown in the McKay coal.

Figures E-5 and E-6 present the difference in simulated potentiometric head in 2026 between the existing and proposed permit for the Rosebud coal and McKay coal, respectively. The figures show that the additional drawdown in Area B as a result of the addition of the AM4 passes is expected to occur within the Area B permit boundary and immediately south of the permit boundary.

2.4 Post Mining - 2076

The simulated residual drawdown 50 years after proposed permit mining in Area B has ceased is shown in Figures E-7 and E-8. In the Rosebud coal in Area B, the maximum residual drawdown is projected to be about 50 feet, whereas the highest simulated residual drawdown in the McKay coal is projected to be about 25 feet, in the eastern portion of Area B, near the southern permit boundary.

Figures E-9 and E-10 present the difference in simulated potentiometric head in 2076, between the existing and proposed permit for the Rosebud coal and McKay coal, respectively. The figures show that the additional drawdown as a result of the addition of the AM4 expansion is localized within the Area B permit boundary and its immediate vicinity. In 2076, the maximum difference in drawdown between the existing and proposed permit is projected to be about fifteen feet and 5 feet for the Rosebud coal and McKay coal, respectively.

3.0 SUMMARY AND CONCLUSIONS

The following summarizes the results of this groundwater modeling effort:

- As stated in the Rosebud Mine Groundwater Model Report, the Rosebud Model provides a conservative and consistent basis for comparing the hydrologic response of the relative impacts to groundwater associated with mining in the proposed disturbance area.

- The projected cumulative average discharges over the period of mining (1977-2026) in Area B are 143 gpm (2020) and 141 gpm (2026) for the existing and proposed permit, respectively.

- The maximum drawdown projected outside of the mine boundary at the end of the proposed permit mining is between 80 and 90 feet in the Rosebud coal just south of the eastern portion of Area B. The five foot drawdown is projected to extend up to 1.8 miles south of Area B.

- Significant residual drawdown is predicted to remain 50 years after proposed mining is completed in Area B. Outside of the mine permit boundary, the maximum residual drawdown is between 40 and 50 feet in the Rosebud Coal just south of the eastern portion of Area B. The residual five foot drawdown contour is projected to extend up to 2.3 miles south of Area B.

- The groundwater model simulations predict that the addition of the AM4 revision will result in additional drawdown of about 40 feet in the Rosebud coal and about five feet in the McKay coal, as evaluated at the end of 2026. In 2076 the maximum difference in drawdown between the existing and proposed permit is projected to be about fifteen feet and five feet for the Rosebud coal and McKay coal, respectively.

4.0 REFERENCES

McDonald, M.G. and Harbaugh, A.W., 1988. A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, Book 6, Chapter A1. Techniques of Water-Resources Investigations of the USGS.

Montana Department of State Lands, US Office of Surface Mining, 1982. Final Environmental Impact Statement, Western Energy Company's Rosebud Mine, Area C, Block 1, DSL/OSM EIS-8.

Tables

Attachment E – Groundwater Model Report
Area B – AM4 (Application Amendment 00184)
Western Energy Rosebud Mine

Exhibit 8

Table E-1
Simulated Mine Discharge Rates Over Time
Rosebud Mine - Area B

Year	Area B - Existing Permit			Area B - Proposed Permit		
	Discharge*	Discharge*	Cumulative Average Discharge**	Discharge*	Discharge*	Cumulative Average Discharge**
	ft^3/d	gpm	gpm	ft^3/d	gpm	gpm
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1979	8063	42	67	8063	42	67
1980	5620	29	58	5620	29	58
1981	43390	225	91	43390	225	91
1982	33750	175	105	33750	175	105
1983	81298	422	151	81298	422	151
1984	45948	239	162	45948	239	162
1985	35791	186	164	35791	186	164
1986	31176	162	164	31176	162	164
1987	21044	109	159	21044	109	159
1988	6751	35	149	6751	35	149
1989	6597	34	140	6597	34	140
1990	16493	86	136	16493	86	136
1991	13378	69	132	13378	69	132
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1996	7007	36	132	7007	36	132
1997	12990	67	128	12990	67	128
1998	10684	55	124	10684	55	124
1999	24307	126	124	24307	126	124
2000	40229	209	128	40229	209	128
2001	24060	125	128	24060	125	128
2002	11676	61	125	11676	61	125
2003	20275	105	124	20275	105	124
2004	34105	177	127	34105	177	127
2005	36490	190	129	36490	190	129
2006	41256	214	132	41256	214	132
2007	26377	137	132	26377	137	132
2008	25558	133	132	25558	133	132
2009	14635	76	130	14635	76	130
2010	23069	120	130	23069	120	130
2013	22713	118	130	38562	200	132
2014	35514	184	131	47060	244	136
2015	31846	165	132	44176	229	138
2016	41390	215	135	43511	226	141
2017	57550	299	139	57028	296	145
2018	29513	153	140	29104	151	145
2019	4732	25	137	13012	68	143
2020	71125	369	143	89477	465	152

Exhibit 8

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Rosebud Mine - Area B

Year	Area B - Existing Permit			Area B - Proposed Permit		
	Discharge*	Discharge*	Cumulative Average Discharge**	Discharge*	Discharge*	Cumulative Average Discharge**
	ft^3/d	gpm	gpm	ft^3/d	gpm	gpm
2021				18840	98	150
2022				14290	74	148
2023				14306	74	147
2024				13767	72	145
2025				17832	93	144
2026				4452	23	141

Notes
The bold and italicized years are the years during which the proposed changes occur.
No data are given for years during which no discharge occurred in the area.

* Mean simulated discharge
**Cumulative is calculated per mine area and does not include non-mining years (or areas of no active mine passes).

Figures

Attachment E
Area B – AM4 (Amendment Application 00184) Groundwater Model Report

Area B – AM4 (Application Amendment 00184)
Comprehensive Evaluation of Probable Hydrologic Consequences
Areas A, B and C
Western Energy Rosebud Mine

Exhibit 8

Attachment E

Groundwater Model Report

Area B – AM4 (Amendment Application 00184)

Permit C1984003B

Western Energy Rosebud Mine

Prepared for

WESTERN ENERGY COMPANY – *Rosebud Mine*

A Subsidiary of WESTMORELAND COAL COMPANY

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Prepared by:

Nicklin Earth & Water

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Bozeman, MT 59718

406.582.0413

June 2013

Exhibit 8

Contents

Attachment E – Groundwater Model Report
Area B – AM4 (Application Amendment 00184)
Western Energy Rosebud Mine

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E-2 Mining Sequence – Area B
E-3 Simulated Drawdown in Rosebud Coal (2026) – Existing Permit and AM4 Amendment
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E-5 Difference in Simulated Potentiometric Head in Rosebud Coal (2026) – Existing Permit versus Proposed Permit
E-6 Difference in Simulated Potentiometric Head in McKay Coal (2026) – Existing Permit versus Proposed Permit
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E-8 Simulated Drawdown in McKay Coal (2076) – Existing Permit and AM4 Amendment
E-9 Difference in Simulated Potentiometric Head in Rosebud Coal (2076) – Existing Permit versus Proposed Permit
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Report

Attachment E – Groundwater Model Report
Area B – AM4 (Application Amendment 00184)
Western Energy Rosebud Mine

Exhibit 8

Groundwater Model Report
Area B - AM4 (Amendment Application 00184) – Permit C1984003B
Western Energy Rosebud Mine

1.0 INTRODUCTION

1.1 Background

The Rosebud Mine in southeastern Montana has been in operation since 1975 (Figure E-1). Western Energy Coal Company (WECo) is proposing an expansion of the existing mining permit in the eastern portion of Area B, designated as AM4 (Amendment Application 00184). Figure E-2 presents the historical and projected timing of the mine passes for both the existing permit and the proposed amendment. The figure shows that mining within the existing permit of Area B is projected to conclude in 2020. The proposed AM4 mining cuts are anticipated to be mined from 2013 to 2026. This report presents the results of a groundwater modeling effort to evaluate potential changes in groundwater quantity associated with the AM4 Amendment.

In 2011, Nicklin Earth & Water developed a regional groundwater model for the Rosebud Mine area. The model was updated and revised in 2013 and is hereafter designated as the "Rosebud Mine Groundwater Model". A brief overview of the model is given below; however, refer to the Rosebud Mine Groundwater Model Report, provided as Attachment D, for a detailed description of model development, calibration and structure, as well as the hydrologic, geologic and hydrogeologic data used to develop the model.

The current modeling effort makes use of the regional Rosebud Mine model to simulate historical and planned mining within the existing permit in Areas A, B and C. More specifically, mining progression is simulated using a set of cascading transient models for which the regional Rosebud Mine model is the basis.

1.2 Model Overview

The Rosebud Mine groundwater model was developed using MODFLOW: "A modular three-dimensional finite difference ground-water flow model developed by the United States Geological Survey [USGS]" (McDonald and Harbaugh, 1988).

The model domain encompasses an area of approximately 27 miles (N-S) by 36 miles (E-W). The model uses a variable spaced grid, however, a uniform grid density was applied to areas of permitted mining.

The hydrogeology was represented in the model using five layers assigned a constant saturated thickness. The model layers generally represent the following geologic strata:

- Layer 1: Alluvium and overburden
- Layer 2: Rosebud coal
- Layer 3: Interburden
- Layer 4: McKay coal
- Layer 5: SubMcKay

The model parameters (transmissivity, recharge and leakance) were modified areally during calibration to achieve as reasonable an approximation to pre-mining potentiometric head as feasible. Generally, the calibrated transmissivity values for the Rosebud mine model are reasonably consistent with data collected during the EIS (1982). For a detailed overview of steady-state model parameters, refer to the Rosebud Mine Groundwater Model Report.

1.3 Model Application Procedure / Transient Evaluation

The calibrated steady-state model described above was used as the basis of a series of cascading, annual MODFLOW models. The series of models was developed to represent the following mining phases in Areas A, B and C:

- Historic mining from 1975 through 2012 for Areas A, B and C. These models were created as part of the Rosebud Mine Groundwater Model (Attachment D).
- Scenario 1: existing permits

  - Future mining of the existing permits for Areas A, B and C, starting with the year 2013 through 2026. Mining of the existing permit in Area B is projected to conclude in 2020.

  - Post mining starting at the end of mining in 2026 and extending to 2076. This post-mine model simulation was run to 50 years in the future to evaluate the long-term response following mining completion.

- Scenario 2: proposed permit

  - Future mining of the proposed permit from 2013 through 2026. The proposed permit consists of mining of the AM4 Amendment passes in addition to the existing permits for Areas A, B and C. The AM4 revision passes are projected to be mined from 2013 through 2026 (see Figure E-2).

  - Post mining starting at the end of mining in 2026 and extending to 2076 for the existing permit and proposed AM4 Amendment. This post-mine model simulation was run to 50 years in the future to evaluate the long-term response following proposed mining in Area B in addition to mining of existing permits.

A detailed description of the transient modeling process is presented in the Rosebud Mine Groundwater Model Report (Attachment D). In essence, the mine dewatering process in any given year is simulated by inserting drains at the location of the planned mining passes for that year. In the next year's model, these drains are removed and a new series of drains are added.

In addition to the use of drains to simulate the mining progression, changes are made in model formation parameters. Mining in Areas A, B and C includes the removal of the Rosebud coal seam (model layer 2) which is generally overlain by overburden (model layer 1). Once an area is mined, the top layer of the model is inactivated in the corresponding mining footprint. Next, the model parameters of the second model layer in the same area are changed to represent the spoils which replace the mined overburden and coal. The model formation parameters that change are hydraulic conductivity, storativity and recharge.

2.0 RESULTS

2.1 Pre-mining

The pre-mine potentiometric heads as simulated by the steady-state model are presented in Figure GM-19 of the Rosebud Mine Groundwater Model Report. Generally, the direction of groundwater flow within Area B is southeast to northeast. Simulated pre-mine steady-state potentiometric heads in the Rosebud coal (layer 2) and McKay coal (layer 4) were used as a reference to calculate the drawdowns presented in Figures E-3, E-4, E-7 and E-8 of this report.

2.2 During Mining

Simulated mean annual discharge rates and cumulative average discharge rates from 1977 through 2026 for Area B for both the existing and proposed permit are presented in Table E-1. The cumulative average discharge in Area B for the proposed permit is 141 gpm. Comparison of discharge rates for the proposed permit with discharge rates for the existing permit shows that the proposed permit is predicted to increase the average annual discharge rate in Area B during the 2013-2020 period by 44 gpm.

The Rosebud Mine Groundwater Model Report stated that the following should be noted with respect to the discharges calculated by the models:

- Actual flow rates will vary depending on how the mine manages the water that enters the pits. In some instances, water may be pumped from one pit to another.
- Discharge rates during actual pumping may be much higher, and last for relatively shorter durations than a year.
- Some portion of the discharge likely enters the spoils during the mining process.
- There are likely to be anomalies, such as the presence of alluvium that bounds the projected mine cuts or faults that are not easily represented in this regional model.
- There are climatic factors, including evaporation, and impacts of major precipitation/runoff events which can add water to these pits.

2.3 End of Proposed AM4 Mining - 2026

The AM4 Amendment is projected to be mined from 2013 through 2026. This section discusses drawdown simulation results at the end of 2026.

Figures E-3 and E-4 show the simulated drawdown in the vicinity of Area B in 2026 as a result of mining the existing permit and proposed AM4 Amendment, for the Rosebud coal and McKay coal, respectively. The model projects that the most substantial drawdown as a result of mining in Area B will occur within the existing permit boundary and its immediate vicinity. The largest simulated drawdown at the end of the proposed permit is about 110 feet and is projected to occur in the Rosebud coal in the eastern part of Area B, near the southern permit boundary. As is to be expected, the maximum projected drawdown in the Rosebud coal is higher than the maximum projected drawdown in the McKay coal.

Figures E-5 and E-6 present the difference in simulated potentiometric head in 2026 between the existing and proposed permit for the Rosebud coal and McKay coal, respectively. The figures show that the additional drawdown in Area B as a result of the addition of the AM4 passes is expected to occur within the Area B permit boundary and immediately south of the permit boundary.

2.4 Post Mining - 2076

The simulated residual drawdown 50 years after proposed permit mining in Area B has ceased is shown in Figures E-7 and E-8. In the Rosebud coal in Area B, the maximum residual drawdown is projected to be about 50 feet, whereas the highest simulated residual drawdown in the McKay coal is projected to be about 25 feet, in the eastern portion of Area B, near the southern permit boundary.

Figures E-9 and E-10 present the difference in simulated potentiometric head in 2076, between the existing and proposed permit for the Rosebud coal and McKay coal, respectively. The figures show that the additional drawdown as a result of the addition of the AM4 expansion is localized within the Area B permit boundary and its immediate vicinity. In 2076, the maximum difference in drawdown between the existing and proposed permit is projected to be about fifteen feet and 5 feet for the Rosebud coal and McKay coal, respectively.

3.0 SUMMARY AND CONCLUSIONS

The following summarizes the results of this groundwater modeling effort:

- As stated in the Rosebud Mine Groundwater Model Report, the Rosebud Model provides a conservative and consistent basis for comparing the hydrologic response of the relative impacts to groundwater associated with mining in the proposed disturbance area.

- The projected cumulative average discharges over the period of mining (1977-2026) in Area B are 143 gpm (2020) and 141 gpm (2026) for the existing and proposed permit, respectively.

- The maximum drawdown projected outside of the mine boundary at the end of the proposed permit mining is between 80 and 90 feet in the Rosebud coal just south of the eastern portion of Area B. The five foot drawdown is projected to extend up to 1.8 miles south of Area B.

- Significant residual drawdown is predicted to remain 50 years after proposed mining is completed in Area B. Outside of the mine permit boundary, the maximum residual drawdown is between 40 and 50 feet in the Rosebud Coal just south of the eastern portion of Area B. The residual five foot drawdown contour is projected to extend up to 2.3 miles south of Area B.

- The groundwater model simulations predict that the addition of the AM4 revision will result in additional drawdown of about 40 feet in the Rosebud coal and about five feet in the McKay coal, as evaluated at the end of 2026. In 2076 the maximum difference in drawdown between the existing and proposed permit is projected to be about fifteen feet and five feet for the Rosebud coal and McKay coal, respectively.

4.0 REFERENCES

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Tables

Attachment E – Groundwater Model Report
Area B – AM4 (Application Amendment 00184)
Western Energy Rosebud Mine

Exhibit 8

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Rosebud Mine - Area B

Year	Area B - Existing Permit			Area B - Proposed Permit		
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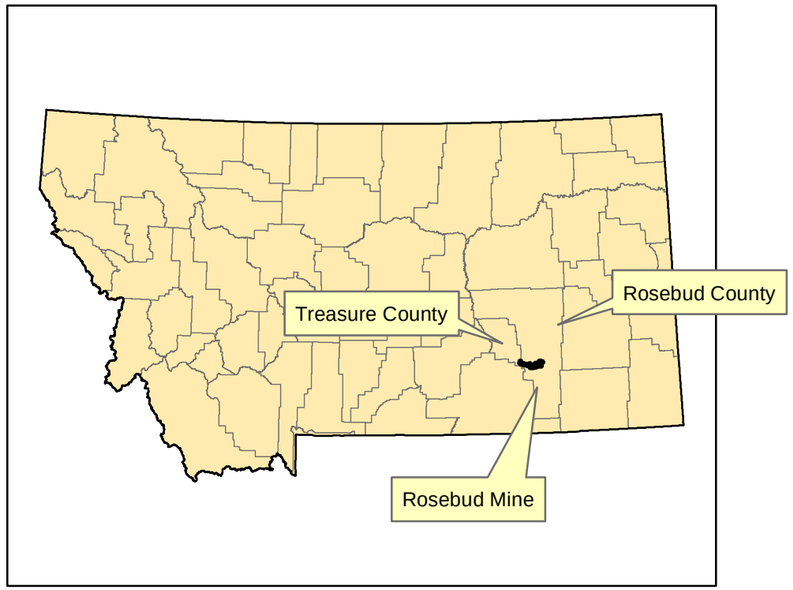
2025				17832	93	144
2026				4452	23	141

Notes
The bold and italicized years are the years during which the proposed changes occur.
No data are given for years during which no discharge occurred in the area.

* Mean simulated discharge
**Cumulative is calculated per mine area and does not include non-mining years (or areas of no active mine passes).

Figures



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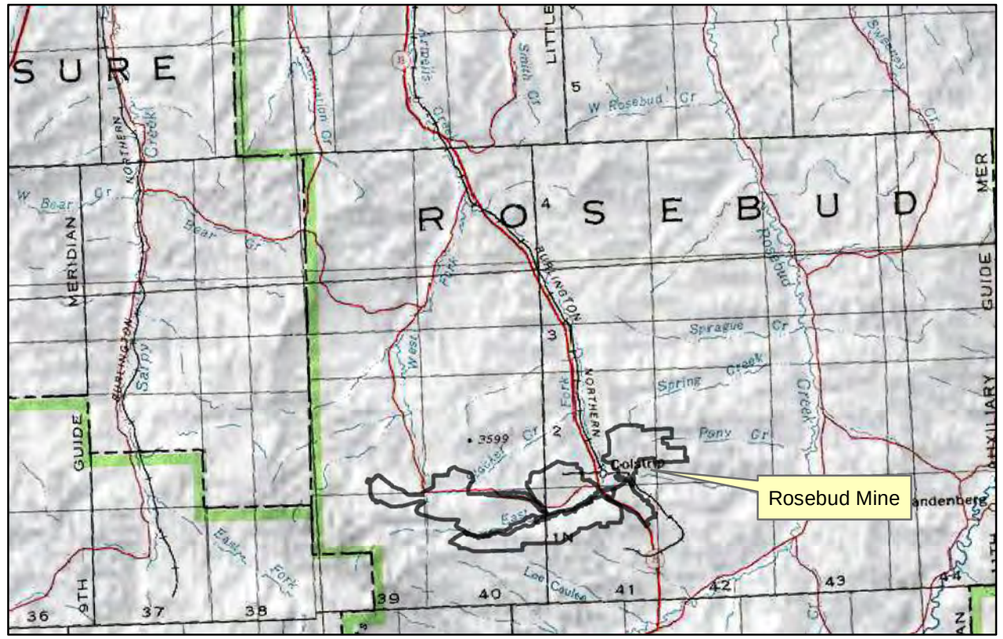
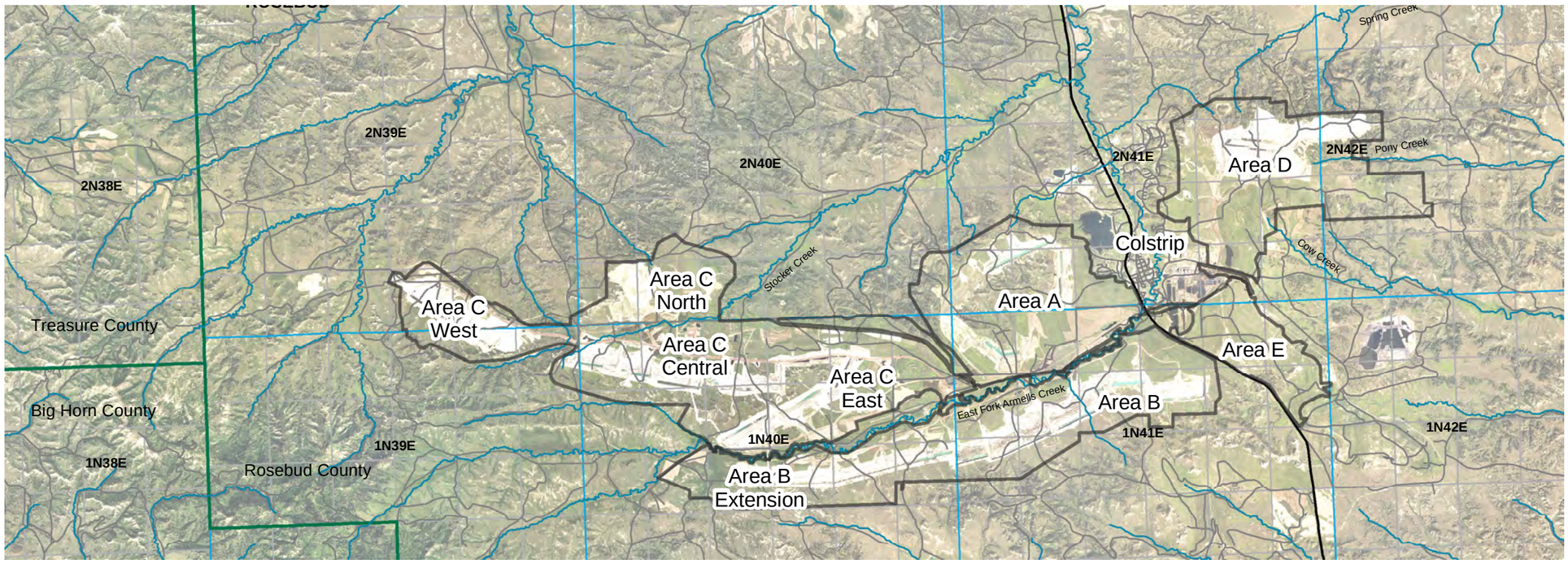




NICKLIN EARTH & WATER, INC.

Date: 7/23/2013 File: F01 - Site Map

Notes:
1) Aerial Photographs: 2011 NAIP

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure E-1
Site Map
Western Energy Rosebud Mine

Exhibit 8

AREA A

AREA C

AREA B EAST

6/27/85

5/29/84

LEGEND

Existing Permit - Area B

Proposed Permit - AM4 Amendment

0.5 mile

NICKLIN
EARTH & WATER, INC.

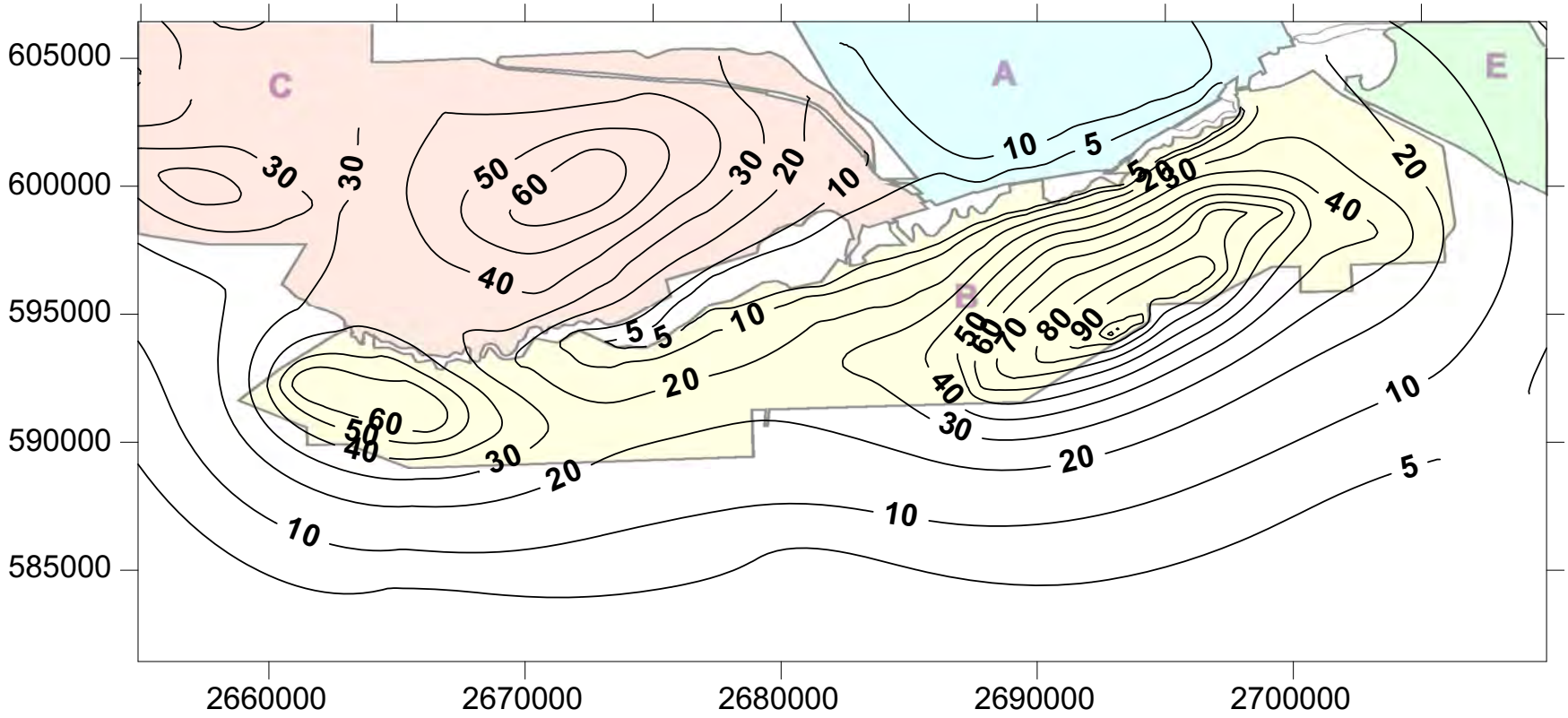
Date: 05/17/13 Name: F02 - Mining Sequence B East.cvx

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY

Figure E-2
Mining Sequence - Area B
Existing and Proposed Permit

Exhibit 8

Layer 2 - Rosebud Coal



Drawdown contours are in feet. Contour interval is 10 feet. In addition, the 5 foot drawdown contour is shown. Map units shown - NAD83 State-Plane Feet. Drawdown in other areas is associated with existing permits in those areas.

NICKLIN EARTH & WATER, INC.

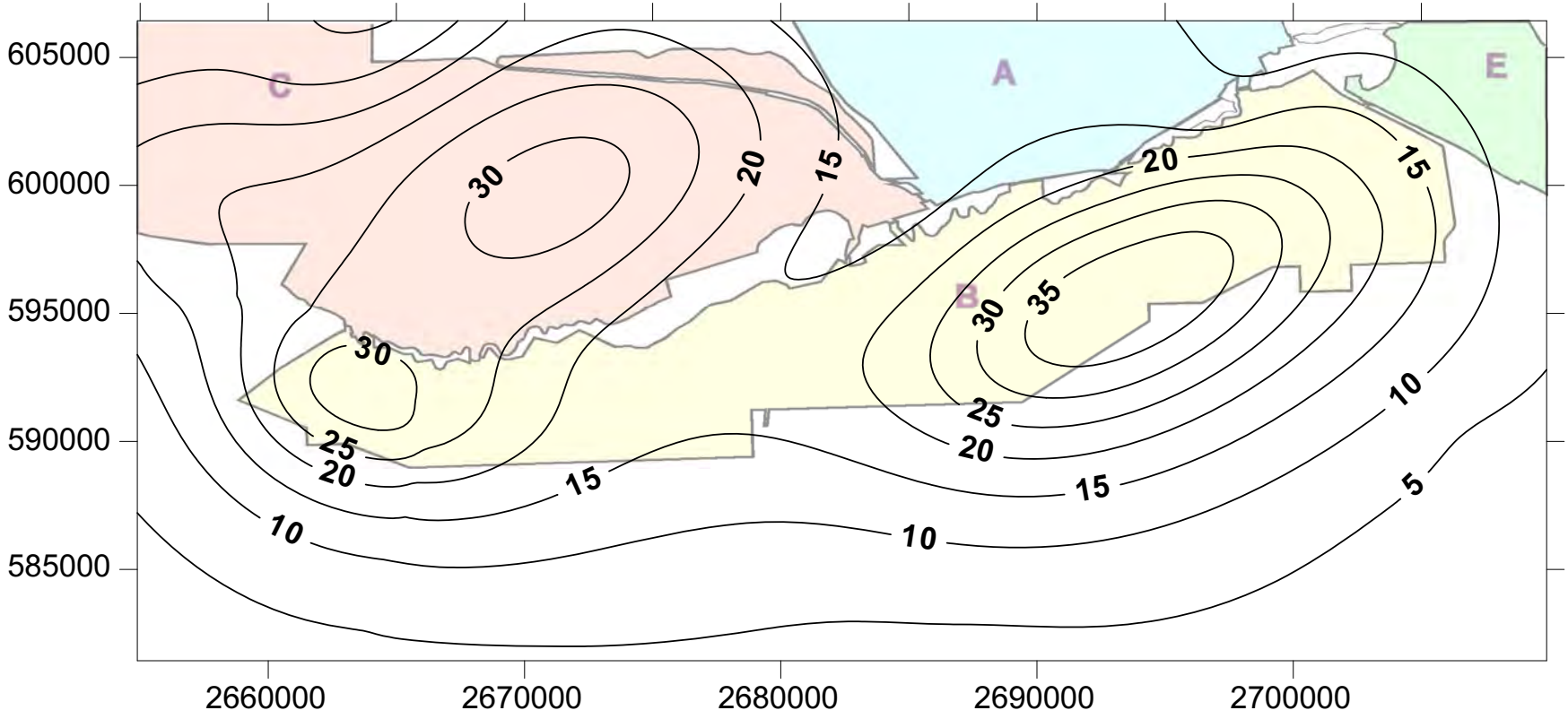
Date: 05/17/13 Name: F03.cvx

WESTERN ENERGY COMPANY - *Rosebud Mine*
A Subsidiary of WESTMORELAND COAL COMPANY

Figure E-3
Simulated Drawdown 2026
Existing Permit and AM4 Amendment
Layer 2 - Rosebud Coal

Exhibit 8

Layer 4 - McKay Coal



Drawdown contours are in feet. Contour interval is 5 feet. Map units shown - NAD83 State-Plane Feet.
Drawdown in other areas is associated with existing permits in those areas.

NICKLIN EARTH & WATER, INC.

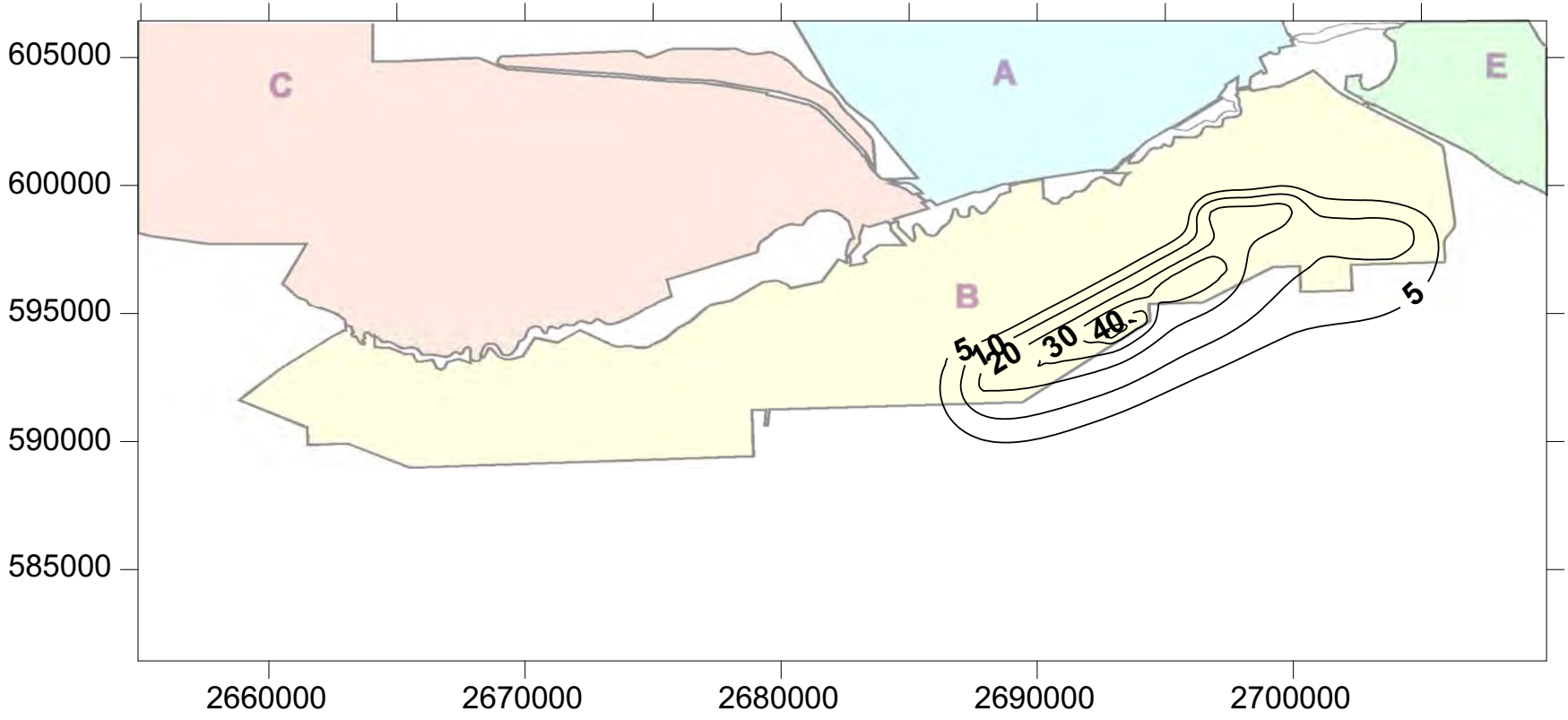
Date: 05/17/13 Name: F04.cvx

WESTERN ENERGY COMPANY - *Rosebud Mine*
A Subsidiary of WESTMORELAND COAL COMPANY

Figure E-4
Simulated Drawdown 2026
Existing Permit and AM4 Amendment
Layer 4 - McKay Coal

Exhibit 8

Layer 2 - Rosebud Coal



Contours were calculated by subtracting simulated potentiometric heads for proposed permit from simulated potentiometric heads for existing permit. Drawdown contours are in feet. Contour interval is 10 feet. In addition, the 5 foot drawdown contour is shown. Map units shown - NAD83 State-Plane Feet.

NICKLIN EARTH & WATER, INC.

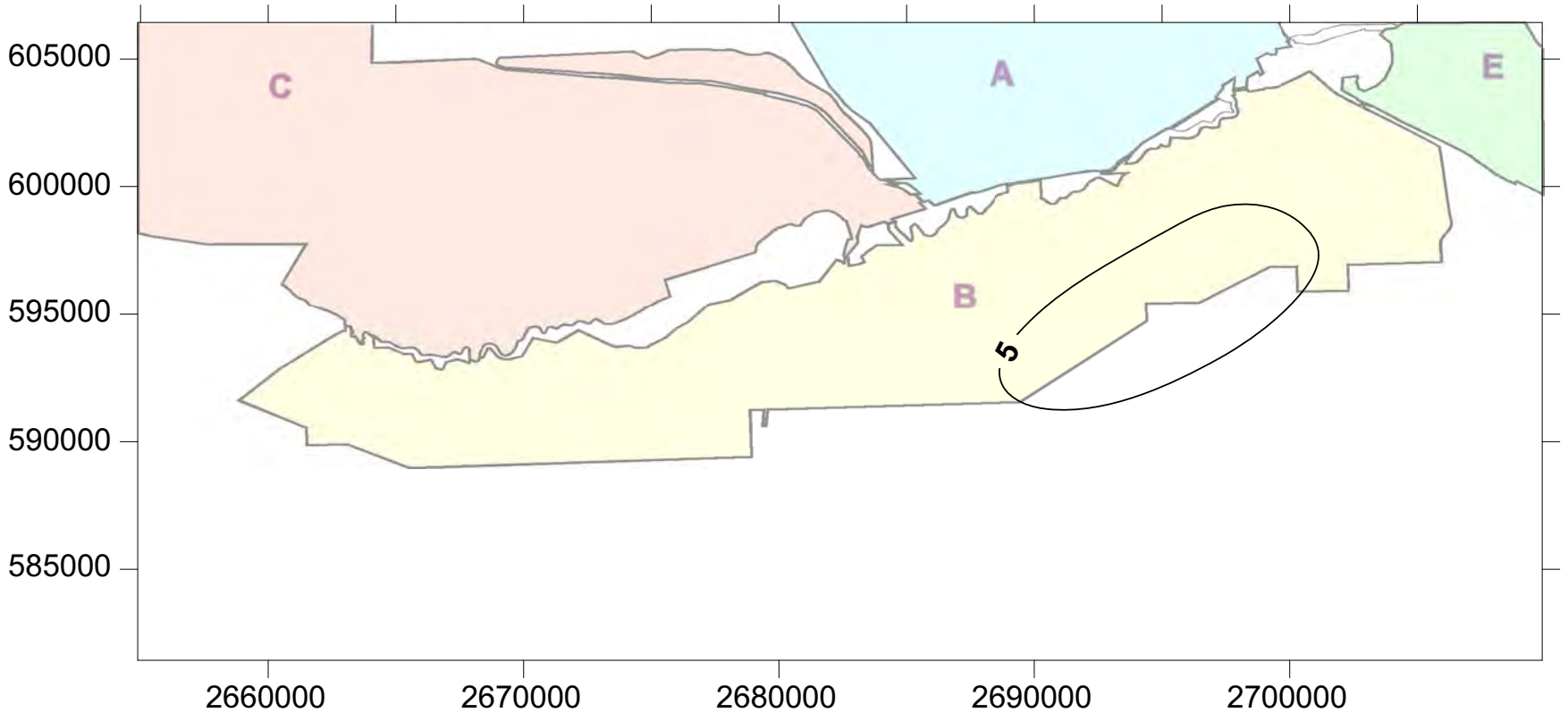
Date: 05/17/13 Name: F05.cvx

WESTERN ENERGY COMPANY - *Rosebud Mine*
A Subsidiary of WESTMORELAND COAL COMPANY

Figure E-5
Difference in Simulated Potentiometric Head - 2026
Existing Permit versus Proposed Permit
Layer 2 - Rosebud Coal

Exhibit 8

Layer 4 - McKay Coal



Contours were calculated by subtracting simulated potentiometric heads for proposed permit from simulated potentiometric heads for existing permit. Drawdown contours are in feet. Contour interval is 0.5 feet. Map units shown - NAD83 State-Plane Feet.

NICKLIN EARTH & WATER, INC.

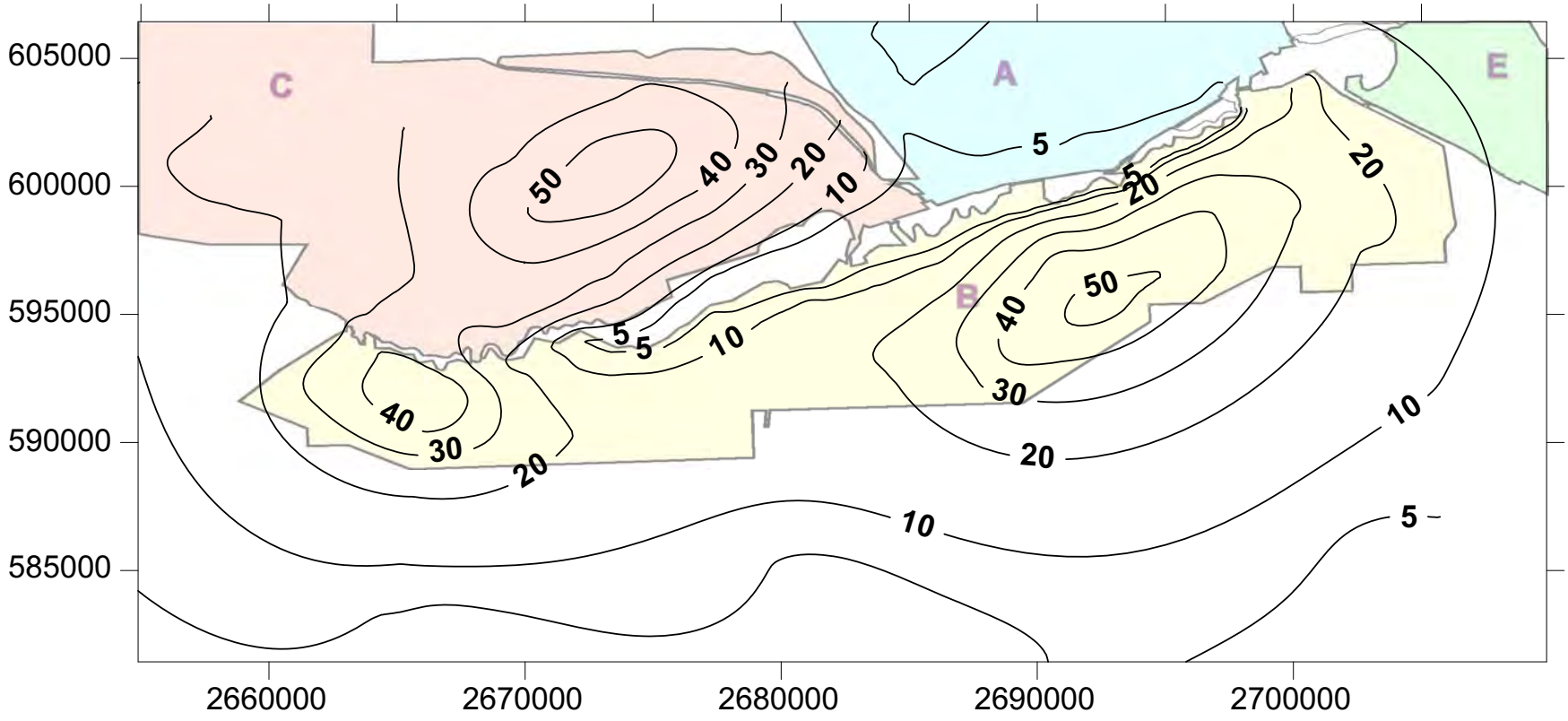
Date: 05/17/13 Name: F06.cvx

WESTERN ENERGY COMPANY - *Rosebud Mine*
A Subsidiary of WESTMORELAND COAL COMPANY

Figure E-6
Difference in Simulated Potentiometric Head - 2026
Existing Permit versus Proposed Permit
Layer 4 - McKay Coal

Exhibit 8

Layer 2 - Rosebud Coal



Drawdown contours are in feet. Contour interval is 10 feet. In addition, the 5 foot drawdown contour is shown. Map units shown - NAD83 State-Plane Feet. Drawdown in other areas is associated with existing permits in those areas.

NICKLIN EARTH & WATER, INC.

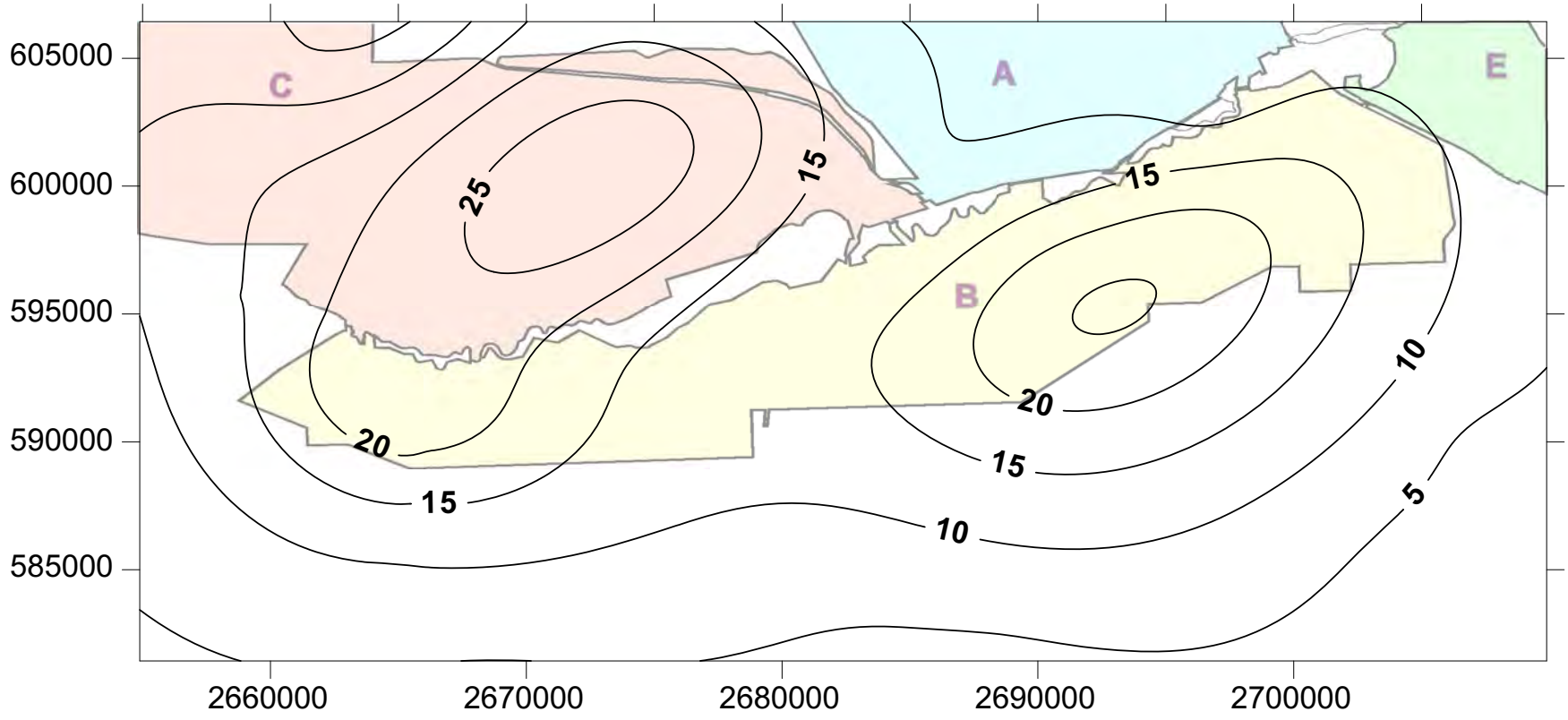
Date: 05/17/13 Name: F07.cvx

WESTERN ENERGY COMPANY - *Rosebud Mine*
A Subsidiary of WESTMORELAND COAL COMPANY

Figure E-7
Simulated Residual Drawdown 2076
Existing Permit and AM4 Amendment
Layer 2 - Rosebud Coal

Exhibit 8

Layer 4 - McKay Coal



Drawdown contours are in feet. Contour interval is 5 feet. Map units shown - NAD83 State-Plane Feet.
Drawdown in other areas is associated with existing permits in those areas.

NICKLIN EARTH & WATER, INC.

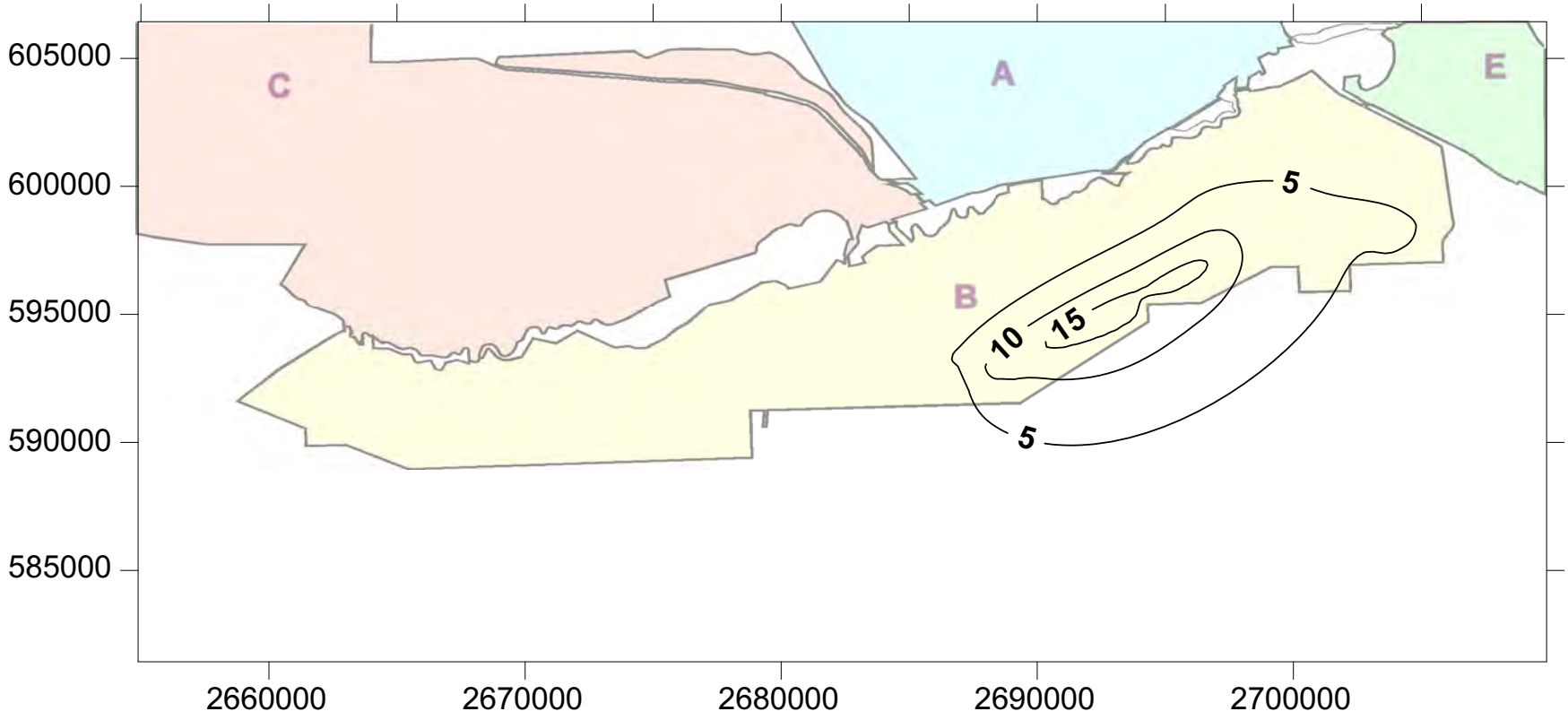
Date: 05/17/13 Name: F08.cvx

WESTERN ENERGY COMPANY - *Rosebud Mine*
A Subsidiary of WESTMORELAND COAL COMPANY

Figure E-8
Simulated Residual Drawdown 2076
Existing Permit and AM4 Amendment
Layer 4 - McKay Coal

Exhibit 8

Layer 2 - Rosebud Coal



Contours were calculated by subtracting simulated potentiometric heads for proposed permit from simulated potentiometric heads for existing permit. Drawdown contours are in feet. Contour interval is 1 foot. Map units shown - NAD83 State-Plane Feet.

NICKLIN EARTH & WATER, INC.

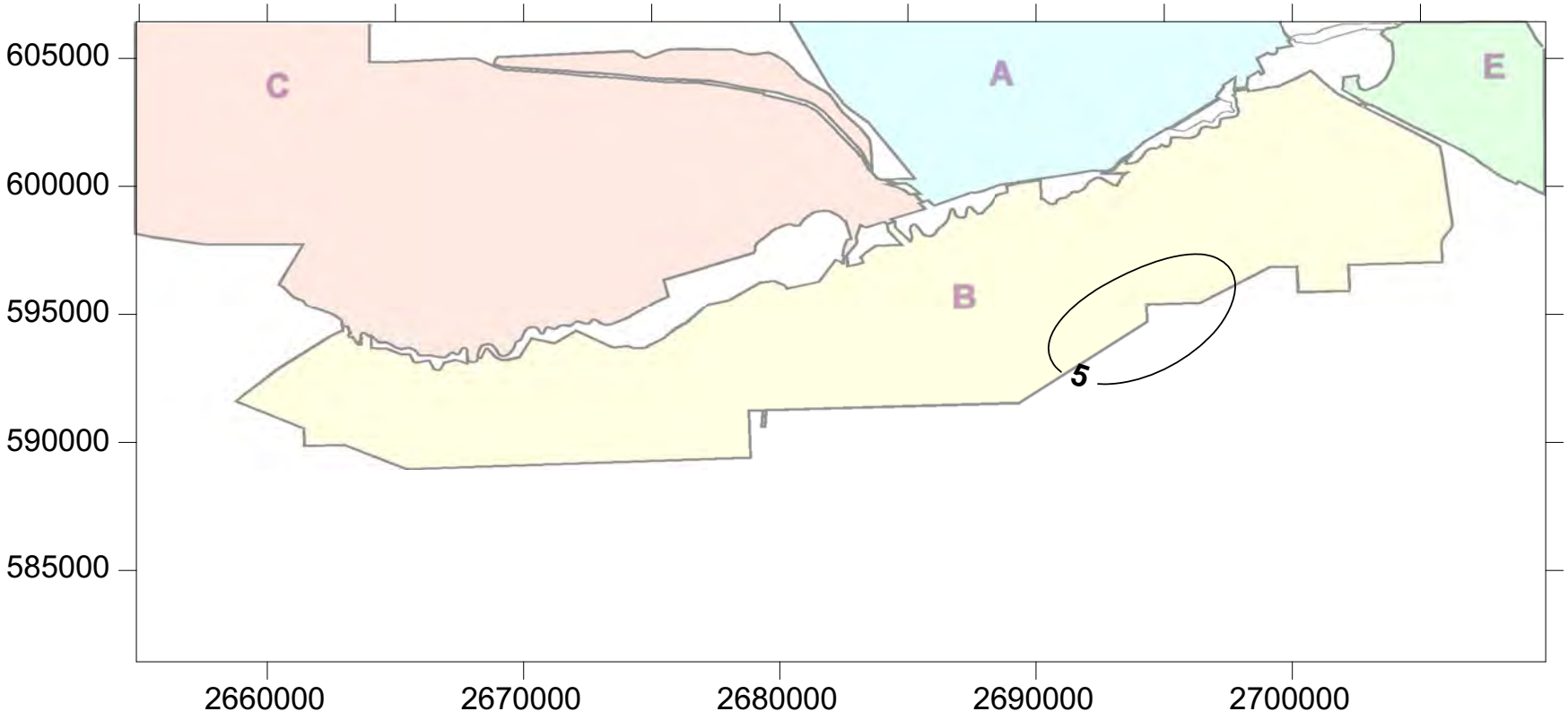
Date: 05/17/13 Name: F09.cvx

WESTERN ENERGY COMPANY - *Rosebud Mine*
A Subsidiary of WESTMORELAND COAL COMPANY

Figure E-9
Difference in Simulated Potentiometric Head - 2076
Existing Permit versus Proposed Permit
Layer 2 - Rosebud Coal

Exhibit 8

Layer 4 - McKay Coal



Contours were calculated by subtracting simulated potentiometric heads for proposed permit from simulated potentiometric heads for existing permit. Drawdown contours are in feet. Contour interval is 0.5 feet. Map units shown - NAD83 State-Plane Feet.

NICKLIN EARTH & WATER, INC.

Date: 05/17/13 Name: F10.cvx

WESTERN ENERGY COMPANY - *Rosebud Mine*
A Subsidiary of WESTMORELAND COAL COMPANY

Figure E-10
Difference in Simulated Potentiometric Head - 2076
Existing Permit versus Proposed Permit
Layer 4 - McKay Coal

Exhibit 8

Attachment F
Private Water Users

Area B – AM4 (Application Amentment 00184)
Comprehensive Evaluation of Probable Hydrologic Consequences
Areas A, B and C
Western Energy Rosebud Mine

Exhibit 8

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
P/O	GWIC	204		2679305.1	597133.7	Farley B	40	9		18991230
MW	GWIC	206		2679705.2	589484.7	MBMG Monitoring Well	225	100	MBMG	19741212
MW	GWIC	208		2679857.9	589493.8	MBMG Monitoring Well	195	100	MBMG	19741212
MW	GWIC	210		2679704.6	589503.0	MBMG Monitoring Well	149	107	MBMG	19741213
P/O	GWIC	212		2673950.4	594317.4	Farley Ranch		0		18991230
P/O	GWIC	213		2673797.7	594312.0	Farley Inc		20		18991230
MW	GWIC	215		2669342.4	594154.9	MBMG Monitoring Well	59	20	MBMG	19741218
P/O	GWIC	216		2668375.0	593391.5	Farley Inc		0		18991230
MW	GWIC	218		2669527.1	593249.6	MBMG Monitoring Well	40	8	MBMG	19741218
MW	GWIC	234		2711079.7	604930.6	MBMG Monitoring	38	35		19730920
MW	GWIC	237		2711078.3	604967.0	MBMG Monitoring	59	37		19730920
MW	GWIC	241		2710251.5	603221.8	MBMG Monitoring	100	78	Teton Drilling	19820707
MW	GWIC	248		2711646.7	601340.6	MBMG Monitoring	115	95	Askin Drilling	19840521
MW	GWIC	253		2714848.8	602262.7	MBMG Monitoring	85	22		19730919
MW	GWIC	254		2715135.6	602091.0	MBMG Monitoring	26.5	23		19730921
MW	GWIC	260		2703827.6	606047.8	MBMG Monitoring Well W-04	32	0		18991230
MW	GWIC	267		2700247.9	602925.0	MBMG Monitoring	49	34	Teton Drilling	19820708
MW	GWIC	275		2702306.6	600994.5	MBMG Monitoring	155	126	Teton Drilling	19820708
MW	GWIC	281		2698724.0	605568.3	MBMG Monitoring	50	17		19741205
MW	GWIC	286		2698962.4	605321.7	MBMG Monitoring	40	10		19741205
MW	GWIC	288		2699077.6	604957.5	MBMG Monitoring	40	12		19741204
MW	GWIC	290		2698969.2	605136.0	MBMG Monitoring	25	6		19741204
MW	GWIC	292		2699263.8	604745.5	MBMG Monitoring	40	19		19741203
MW	GWIC	296		2699423.0	604572.6	MBMG Monitoring	40	19		19740524
MW	GWIC	303		2698379.3	601762.2	MBMG Monitoring	159.5	117	Askin Drilling	19840523
P/O	GWIC	307		2685214.1	601503.4	Kimball L.S.	50	6		18991230
MW	GWIC	311		2704179.3	599969.3	MBMG Monitoring	149	113		19750109
MW	GWIC	317		2702234.2	600882.5	MBMG Monitoring	146	118	Teton Drilling	19820710
MW	GWIC	319		2701351.5	600631.1	MBMG Monitoring	125	119	Askin Drilling	19840523
MW	GWIC	328		2715477.9	599076.3	MBMG Monitoring	50	40	MHD	19730918
MW	GWIC	329		2715593.4	598715.8	MBMG Monitoring	21.5	20	MHD	19730918
P/O	GWIC	331		2711356.6	597499.7	Mcrae	51	0		18991230
P/O	GWIC	332		2714396.6	597321.4	Hafter C.A.	65	54		18991230
P/O	GWIC	333		2712322.0	590751.0	Snider J W	200	107		18991230
MW	GWIC	336		2704291.6	590708.5	MBMG Monitoring	40	28		19810827
MW	GWIC	337		2696455.4	595129.9	MBMG Monitoring	248	128	MHD	19740516
MW	GWIC	339		2696457.4	595075.3	MBMG Monitoring	225	98	MHD	19740523
MW	GWIC	341		2699923.4	586754.3	USGS Research Well	95	67		18991230
MW	GWIC	342		2699920.8	586827.2	USGS Research Well	98	66		18991230
MW	GWIC	343		2699847.0	586751.5	USGS Research Well	104	69		18991230
MW	GWIC	346		2698497.2	586702.1	USGS Obs Well	130.5	72		18991230
MW	GWIC	347		2698570.9	586777.8	USGS Obs Well	128.5	71		18991230
MW	GWIC	353		2701503.8	586082.9	MBMG Monitoring Well BS-46	72	15		18991230
MW	GWIC	354		2701431.4	585970.7	MBMG Monitoring Well BS-47	72	15		18991230
MW	GWIC	364		2704908.4	587813.2	MBMG Monitoring	57	46		19770321
I/C	GWIC	370		2705951.1	588581.2	Peabody Coal Co	60	45		18991230
I/C	GWIC	371		2706108.1	587784.6	Peabody Coal Co	297	145		18991230
MW	GWIC	373		2712975.7	587583.7	MBMG Monitoring	31	19	H & H Drilling	19750709
MW	GWIC	375		2712442.9	587509.1	MBMG Monitoring	23	13	H & H Drilling	19750708
MW	GWIC	376		2712290.1	587503.5	MBMG Monitoring	22	10	H & H Drilling	19750709
MW	GWIC	377		2710876.4	586429.4	MBMG Monitoring	22	15	H & H Drilling	19750708
MW	GWIC	382		2704893.7	584066.5	MBMG Monitoring	40	27	Montana Highway Dept.	19730924
MW	GWIC	394		2704892.6	584095.7	MBMG Monitoring	16	11	Montana Highway Dept.	19730924
MW	GWIC	396		2703975.7	584751.3	MBMG Monitoring Well BS-50	35	14		19810827
MW	GWIC	402		2703052.1	584206.5	MBMG Monitoring	97	55	H & H Drilling	19750722
MW	GWIC	413		2703288.0	584032.9	MBMG Monitoring	97	52	Western Drilling Co.	19750723
MW	GWIC	426		2703288.0	584032.9	MBMG Monitoring	58	46	Western Drilling Co.	19750723
MW	GWIC	427		2703985.3	583799.6	MBMG Monitoring	64	42	Western Drilling Co.	19770318
MW	GWIC	435		2705217.3	583593.4	USGS Research Well	62	41		18991230
MW	GWIC	436		2705217.3	583593.4	USGS Research Well	22	20		18991230
MW	GWIC	437		2705079.2	583187.0	USGS Research Well	44.5	33		18991230

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
MW	GWIC	438		2705151.6	583299.1	USGS Research Well	40.5	33		18991230
MW	GWIC	439		2705148.9	583372.0	USGS Research Well	37	34		18991230
MW	GWIC	442		2705014.9	582856.3	MBMG Monitoring	52	35	Western Drilling Co.	19770318
MW	GWIC	447		2704200.8	582797.1	MBMG Monitoring	80	22	Western Drilling Co.	19770318
MW	GWIC	452		2705010.9	582965.6	USGS Research Well	52.5	36		18991230
MW	GWIC	453		2705083.2	583077.7	USGS Research Well	51	34		18991230
MW	GWIC	457		2702651.2	584009.4	MBMG Monitoring	122	94	Western Drilling Co.	19750710
MW	GWIC	461		2703135.2	584027.2	MBMG Monitoring	107	80	Western Drilling Co.	19750717
MW	GWIC	464		2702567.4	583513.9	MBMG Monitoring	83	56	Western Drilling Co.	19750721
MW	GWIC	471		2702651.2	584009.4	MBMG Monitoring	63	60	Western Drilling Co.	19750724
MW	GWIC	474		2702371.0	583999.1	MBMG Monitoring	160	123	Western Drilling Co.	19750725
MW	GWIC	479		2702389.8	583489.1	MBMG Monitoring	128	94	Western Drilling Co.	19750711
MW	GWIC	480		2702027.0	583643.6	MBMG Monitoring	134	108	Western Drilling Co.	19750715
MW	GWIC	481		2702160.5	583480.7	MBMG Monitoring	76	73	Western Drilling Co.	19750724
MW	GWIC	488		2702372.5	581879.9	MBMG Monitoring	155	124	Western Drilling Co.	19770311
MW	GWIC	490		2705052.4	581840.0	MBMG Monitoring	51	29	Montana Highway Dept.	19730921
MW	GWIC	504		2705026.8	581842.7	MBMG Monitoring	34	28	Montana Highway Dept.	19730924
MW	GWIC	510		2704171.8	582201.5	MBMG Monitoring	144	45	Montana Highway Dept.	19760803
MW	GWIC	514		2704862.2	581464.6	MBMG Monitoring Well TW-01	75	34		18991230
MW	GWIC	517		2705371.7	581483.4	MBMG Monitoring	70	26	Western Drilling Co.	19770316
MW	GWIC	531		2703932.5	581773.2	MBMG Monitoring	88	35	Montana Highway Dept.	19760728
MW	GWIC	536		2703891.6	581498.1	MBMG Monitoring	84	46	Western Drilling Co.	19770321
MW	GWIC	539		2703796.9	581297.7	MBMG Monitoring	106	44	Montana Highway Dept.	19760728
MW	GWIC	548		2703251.8	580168.7	MBMG Monitoring	145	136	Western Drilling Co.	19770312
MW	GWIC	553		2705252.5	580567.1	MBMG Monitoring	62	48	Montana Highway Dept.	19760727
MW	GWIC	556		2705252.5	580567.1	MBMG Monitoring	100	43		19770314
MW	GWIC	568		2704768.4	580549.2	MBMG Monitoring	100	35	Western Drilling Co.	19770316
MW	GWIC	574		2716698.8	598465.5	MBMG Monitoring	33	25	Montana Highway Dept.	19730917
MW	GWIC	635		2720682.5	596244.4	MBMG Monitoring Well	48	41	MHD	19730911
MW	GWIC	660		2720682.5	596244.4	MBMG Monitoring Well	76	47	MHD	19730914
MW	GWIC	673		2720916.9	593408.0	MBMG Monitoring Well	57	16	Montana Highway Dept.	19741202
MW	GWIC	676		2720916.9	593408.0	MBMG Monitoring Well	33	10	Valgamore	19741203
MW	GWIC	680		2703827.6	606047.8	MBMG Monitoring Well	56	16	MHD	18991230
MW	GWIC	683		2703827.6	606047.8	MBMG Monitoring Well	31	8	Valgamore	19741202
MW	GWIC	686		2721158.4	593088.8	MBMG Monitoring Well	28	21	Valgamore	19741125
MW	GWIC	691		2720445.5	593061.9	MBMG Monitoring Well	27	3		18991230
MW	GWIC	693		2720445.5	593061.9	MBMG Monitoring Well	47	19	Montana Highway Dept.	18991230
MW	GWIC	694		2720445.5	593061.9	MBMG Monitoring Well	24	6	Montana Highway Dept.	18991230
P/O	GWIC	1052		2641808.8	615424.9	Fulmer, Genie / Dowlin, Mary Genie	100	45		18991230
P/O	GWIC	1053		2648913.7	616133.2	Fulmer, Genie / Dowlin, Mary Genie	140	50		18991230
P/O	GWIC	1063		2667563.6	614335.3	Lovelace C/O Hendicks	146	76		18991230

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
P/O	GWIC	1064		2657830.5	610086.2	Lovelace C/O Hendicks		-1		18991230
P/O	GWIC	1065		2654198.0	614990.4	Fulmer, Genie / Dowlin, Mary Genie	246	49		19560228
P/O	GWIC	1067		2657886.2	609949.6	Hinrichs W.		0		18991230
P/O	GWIC	1068		2677584.0	605388.6	Fadhl George	252	75		19590101
P/O	GWIC	1077		2696224.0	618206.7	Seward I. * 1.5 MI NW Colstrip MT.	122	35		18991230
P/O	GWIC	1078		2696435.1	616609.6	McDonald	120	40		18991230
MW	GWIC	1089		2698295.5	615875.2	MBMG Monitoring Well	23	7	Montana Highway Dept.	19750110
MW	GWIC	1091		2698025.2	615606.3	MBMG Monitoring Well	26	6	Montana Highway Dept.	19750110
I/C	GWIC	1098		2700084.8	609448.2	Northern Pacific Railroad * Colstrip MT		0		18991230
I/C	GWIC	1099		2700008.5	609445.4	Northern Pacific Railroad * Colstrip MT	40	0		18991230
MW	GWIC	1103		2708752.0	608601.0	MBMG	45.5	27		19730921
MW	GWIC	1115		2708726.6	608600.1	MBMG	24	17	MHD	19730921
I/C	GWIC	11946		2647429.9	603634.6	Northern Pacific Railway Company	84	30		19590101
P/O	GWIC	11953		2636023.8	598095.9	Ashland Lumber Co		245		19580401
I/C	GWIC	11969		2679259.7	600549.8	Northern Pacific Railway Company	80	25		19560101
I/C	GWIC	11973		2658135.4	599800.5	Northern Pacific Railway Company	115	85		19540101
I/C	GWIC	11974		2655342.3	603949.5	Northern Pacific Railway Company	128	40		19580101
I/C	GWIC	11975		2652957.6	596977.8	Northern Pacific Railway Company	143	80		19430101
P/O	GWIC	11979		2680284.9	598244.7	Farley's INC.	150	20		19140101
P/O	GWIC	11980		2679206.5	597039.0	Farley's INC.	100	20		19500101
P/O	GWIC	11981		2673698.0	594246.5	Farley's INC.		20		19140101
P/O	GWIC	11982		2658364.3	593184.9	Farleys, INC.	145	70	Askin Drilling	19840209
P/O	GWIC	11983		2655579.8	593358.7	Farleys INC.	20	0		19300101
P/O	GWIC	11984		2655602.9	592688.4	Farleys INC.	20	0		19630101
P/O	GWIC	11985		2654917.9	593335.9	Farleys INC.	225	0		19300101
P/O	GWIC	11988		2656698.1	589020.5	Farleys INC.	225	0		19630101
I/C	GWIC	11992		2700072.2	605628.7	N.P.R.R.	55	45		19580612
P/O	GWIC	12002		2689271.5	599231.4	Farleys INC.	381	144		19470101
P/O	GWIC	12003		2689921.3	599586.8	Farleys INC.	50	0		19470101
I/C	GWIC	12008		2706007.5	588433.8	Peabody Coal Co	80	65		19730330
I/C	GWIC	12009		2706204.1	587945.0	Peabody Coal Co	60	44		19730329
I/C	GWIC	12010		2705885.5	587597.6	Big Sky Coal Company	297	145	H & H Drilling	19731213
I/C	GWIC	12011		2706105.5	585785.5	Peabody Coal Co	300	190		19700315
I/C	GWIC	12012		2706448.9	585466.3	Peabody Coal Co	300	160	H & H Drilling	19830325
P/O	GWIC	12013		2712579.8	589991.0	Snyder, J.	420	250	Woelich Drilling	19720601
P/O	GWIC	12014		2712579.8	589991.0	Snyder, James W.	300	60	Woelich Drilling	19720523
P/O	GWIC	12015		2712579.8	589991.0	Snyder, James W.	395	225		19700901
P/O	GWIC	12016		2712579.8	589991.0	Snyder, James W.	380	235		19700915
I/C	GWIC	12018		2687682.6	582504.9	Peabody Coal Co	17.5	6	H & H Drilling	19890805
I/C	GWIC	12020		2689716.8	578445.7	Northern Pacific Railway Company	150	40		19470101
I/C	GWIC	12021		2695477.3	577192.1	Northern Pacific Railway Company	70	15		19490101
I/C	GWIC	12026		2715885.8	598394.9	Montana Power Co.	925	378		19510219
P/O	GWIC	12035		2716283.7	587780.4	Parkins, Charles F.	120	0		19250101
P/O	GWIC	14193		2648432.1	618308.7	Farley Inc	90	50	Digger Drilling	19741122
P/O	GWIC	14195		2650925.4	615381.4	Fulmer, Genie / Dowlin, Mary Genie	46	32		19590206
I/C	GWIC	14216		2660429.9	624699.8	Northern Pacific Railway Company	185	80		19580101
P/O	GWIC	14217		2660429.9	624699.8	Fulmer, Genie / Dowlin, Mary Genie	184	165		19590514
P/O	GWIC	14219		2681894.1	617356.4	MacDonald, Lena F	30	22		19110101
P/O	GWIC	14220		2681894.1	617356.4	MacDonald, Lena F	85	60		19461106
I/C	GWIC	14223		2667062.8	608281.4	Northern Pacific Railway Company	140	100		19570101
I/C	GWIC	14225		2673938.2	606185.6	Round-Up Powder Co	355	315	Higgins Drilling Company	19860521

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
P/O	GWIC	14226		2677402.8	605469.7	N.P.R.R. & Fadhl G.	252	146	B & H Drilling	19590412
P/O	GWIC	14239		2696320.2	619056.5	Colstrip Church of Christ	810	360	Ronald L Askin Drilling	19850223
P/O	GWIC	14243		2695733.5	616996.1	MT Dept. of Highway	208	50	Dept of Highways, Core Drill Sec.	19780920
P/O	GWIC	14244		2697692.1	617749.8	Beck, Allen	180	70	Ronald L Askin Drilling	19800327
P/O	GWIC	14245		2696503.8	618213.3	Seward, Ivan	140	70	Ronald L Askin Drilling	19741130
P/O	GWIC	14246		2697349.2	618072.8	MT.Power Co Housing	22	7	Ronald L Askin Drilling	19810330
P/O	GWIC	14248		2701168.3	621543.1	Snider, James	68	57		19290101
I/C	GWIC	14251		2697072.3	614506.3	Northern Pacific Railway Company	85	20		19550101
P/O	GWIC	14252		2688488.8	612425.3	MacDonald, Duncan		0		19590101
I/C	GWIC	14257		2698975.0	608451.8	Montana Power Co.	596	0		19360831
I/C	GWIC	14258		2698975.0	608451.8	Montana Power Co.	519	315		19430202
I/C	GWIC	14262		2699566.7	609684.5	Montana Power Co.	614	0		19450101
P/O	GWIC	14270		2716321.1	613279.1	Egan Joe		200		19550101
MW	GWIC	121145		2704024.0	584826.0	MBMG Monitoring	30	8	J C Drilling	19810827
MW	GWIC	121535		2696394.2	582831.8	MBMG Monitoring	168	104	Western Drilling Co.	19750701
I/C	GWIC	122395		2696688.1	618048.6	B & R Bar	260	120	Askin Drilling	19840914
MW	GWIC	122762		2688130.6	592708.6	MBMG Monitoring	185	124	MHD	19741211
MW	GWIC	122765		2705907.5	584932.0	MBMG Monitoring	108	45	H & H Drilling	19750623
MW	GWIC	123790		2690721.5	584522.4	MBMG Monitoring	177	96	Western Drilling Co.	19750630
MW	GWIC	123791		2690721.5	584522.4	MBMG Monitoring	209	133	Western Drilling Co.	19750627
MW	GWIC	123792		2688436.2	592719.6	MBMG Monitoring	209	151	MHD	19741210
MW	GWIC	123793		2705907.5	584932.0	MBMG Monitoring	220	154	H & H Drilling	19750618
MW	GWIC	123794		2703275.9	585053.8	MBMG Monitoring Well BS-50A	33	10		18991230
I/C	GWIC	124259		2716178.3	604865.9	Montana Power Company	73	0	Gordon Drilling Inc	19830610
I/C	GWIC	124294		2720766.0	606862.4	Montana Power Company	30	11	Askin Drilling	19881021
I/C	GWIC	124295		2720772.9	606680.2	Montana Power Company	40	36	Askin Drilling	19871022
I/C	GWIC	124296		2720781.1	606461.7	Montana Power Company	16	13	Askin Drilling	19871022
I/C	GWIC	124297		2720728.2	605839.6	Montana Power Company	70	45	Askin Drilling	19881021
I/C	GWIC	124298		2720730.9	605766.7	Montana Power Company	100	66	Askin Drilling	19881021
I/C	GWIC	124299		2720592.7	606053.3	Montana Power Company	40	12	Askin Drilling	19881021
I/C	GWIC	124300		2720673.2	605946.9	Montana Power Company	25	14	Askin Drilling	19881021
I/C	GWIC	124304		2720876.7	605954.6	Montana Power Company	75	0	Gordon Drilling Inc	19830610
I/C	GWIC	124309		2717925.8	605150.4	Montana Power Company	131	117	Gordon Drilling Inc	19820626
I/C	GWIC	124310		2718006.2	605044.0	Montana Power Company	78	71	Gordon Drilling Inc	19820626
I/C	GWIC	124412		2720792.1	606170.3	Montana Power Company	22	15	Gordon Drilling Inc	19831117
I/C	GWIC	124424		2719903.6	605407.2	Montana Power Company	20	12	Gordon Drilling Inc	19820627
I/C	GWIC	124432		2717691.4	601895.1	Montana Power Company	165	123	Askin Drilling	19851016
I/C	GWIC	124433		2718327.6	601919.0	Montana Power Company	127	110	Gordon Drilling Inc	19820629
I/C	GWIC	124434		2720699.2	601205.9	Montana Power Company	159	123	Gordon Drilling Inc	19820624
I/C	GWIC	124435		2720620.1	601275.9	Montana Power Company	101	82	Gordon Drilling Inc	19820625
I/C	GWIC	124436		2720336.0	601374.6	Montana Power Company	176	136	Askin Drilling	19851017
I/C	GWIC	124437		2720492.8	601271.1	Montana Power Company	99	74	Askin Drilling	19851017
I/C	GWIC	124467		2719117.0	599906.0	Montana Power Company	138	77	Gordon Drilling Inc	19820628
I/C	GWIC	124476		2721711.0	600733.4	Montana Power Company	221	0	Gordon Drilling Inc	19831122
I/C	GWIC	124484		2721860.9	600812.1	Montana Power Company	101	0	Gordon Drilling Inc	19831121

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
P/O	GWIC	128355		2655145.9	591155.4	Eernisse, Gary	120	64	Sunrise Drilling Inc	19920514
MW	GWIC	129758		2680964.8	577055.3	MBMG Monitoring Well	200	0		19801118
MW	GWIC	132803		2711790.9	602257.9	MBMG Monitoring	140	0	Tenton Drilling	19820707
MW	GWIC	132805		2696898.1	606034.1	MBMG Monitoring	44	0	Teton Drilling	19820708
MW	GWIC	132806		2712614.6	592476.4	MBMG Monitoring	134	0	MHD	19750108
MW	GWIC	132807		2712614.6	592476.4	MBMG Monitoring	119	106	MHD	19750108
MW	GWIC	132808		2693201.0	604710.2	MBMG Monitoring	99	0	Tenton Drilling	19820708
MW	GWIC	132809		2691038.3	604628.0	MBMG Monitoring	105	0	Tenton Drilling	19820707
MW	GWIC	132823		2699855.1	586533.0	MBMG Monitoring	156	70	Western	19750624
MW	GWIC	132824		2699855.1	586533.0	MBMG Monitoring	121	0	Western	19750625
MW	GWIC	132825		2704959.1	589894.2	MBMG Monitoring	45	0		19770322
MW	GWIC	132826		2703637.8	587693.3	MBMG Monitoring	177	0	E.H.	19770322
MW	GWIC	132827		2703637.8	587693.3	MBMG Monitoring	146	0	E.H.	19770324
MW	GWIC	132865		2704892.2	584106.6	MBMG Monitoring	14	0	H & H Drilling	19770324
MW	GWIC	132867		2720954.5	593088.4	MBMG Monitoring Well	61	21	Montana Highway Dept.	19741121
MW	GWIC	132868		2720954.5	593088.4	MBMG Monitoring Well	27	20	Montana Highway Dept.	19741125
MW	GWIC	132870		2720929.3	593080.2	MBMG Monitoring Well	29	21		19741126
MW	GWIC	132871		2720292.5	593063.4	MBMG Monitoring Well	25.5	0		18991230
MW	GWIC	132874		2696394.2	582831.8	MBMG Monitoring	131	73	Western Drilling Co.	19750702
MW	GWIC	132892		2680964.8	577055.3	MBMG Monitoring Well	265	0	MBMG	19801118
MW	GWIC	132893		2705905.9	606343.4	MBMG Monitoring	113	0	Askin Drilling	19840521
MW	GWIC	132894		2705398.4	606288.2	MBMG Monitoring	94	0	Askin Drilling	19841021
MW	GWIC	132895		2700513.0	600563.8	MBMG Monitoring	153	0	Askin Drilling	19840523
MW	GWIC	133089		2712324.8	592042.4	MBMG Monitoring	79	69		19930512
I/C	GWIC	133682		2696967.6	609009.3	MPC-Cimarron	20	0	ADT	19921001
I/C	GWIC	133683		2696967.6	609009.3	MPC-Cimarron	40	27	ADT	19921006
I/C	GWIC	133688		2696280.7	608984.2	MPC - Cimarron	25	0	ADT	19921001
I/C	GWIC	133689		2696280.7	608984.2	MPC - Cimarron	20	0	ADT	19921001
I/C	GWIC	133691		2695619.3	608960.1	MPC - Cimarron	18.5	0	ADT	19921001
I/C	GWIC	133692		2695619.3	608960.1	MPC - Cimarron	25	0	ADT	19921005
I/C	GWIC	133693		2696280.7	608984.2	MPC - Cimarron	23.5	20	ADT	19921005
I/C	GWIC	133695		2696280.7	608984.2	MPC - Cimarron	25	0	ADT	19921005
I/C	GWIC	133698		2696990.7	608379.2	MPC - Cimarron	29	0	ADT	19921005
I/C	GWIC	133700		2696967.6	609009.3	MPC-Cimarron	25	0	ADT	19921005
I/C	GWIC	133703		2697606.0	609663.7	MPC - Cimarron	25	20	ADT	19921006
I/C	GWIC	133706		2696234.6	610248.3	MPC - Cimarron	15	13	ADT	19921006
I/C	GWIC	133708		2696234.6	610248.3	MPC - Cimarron	30	22	ADT	19921006
I/C	GWIC	133709		2696234.6	610248.3	MPC - Cimarron	15	0	ADT	19921006
I/C	GWIC	133710		2717864.3	609496.1	MPC - Colstrip	55	28	H & H Drilling	19911119
I/C	GWIC	133711		2717864.3	609496.1	MPC - Colstrip	18	13	H & H Drilling	19911119
I/C	GWIC	137794		2701755.2	613897.6	MPC Original Townsite	18.5	0	Pro Pump & Equipment Inc.	19930616
I/C	GWIC	137799		2701755.2	613897.6	MPC Original Townsite	20.6	0	Pro Pump & Equipment Inc.	19930606
I/C	GWIC	137800		2701755.2	613897.6	MPC Original Townsite	50	13	Pro Pump & Equipment Inc.	19930606
P/O	GWIC	137801		2703126.4	612627.7	Colstrip Landfill	72	65	Sharp Drilling Inc	19930929
P/O	GWIC	137802		2703126.4	612627.7	Colstrip Landfill	18	12	Sharp Drilling Inc	19930928
P/O	GWIC	137803		2703126.4	612627.7	Colstrip Landfill	20	11	Sharp Drilling Inc	19930929
P/O	GWIC	137804		2703126.4	612627.7	Colstrip Landfill	16	8	Sharp Drilling Inc	19930929
I/C	GWIC	137805		2696435.1	613822.9	MPC Original Townsite	35	0	Pro Pump & Equipment Inc.	19930616
I/C	GWIC	137826		2701942.9	608797.9	MPC Original Townsite	20	0	Pro Pump & Equipment Inc.	19930617
I/C	GWIC	137827		2701942.9	608797.9	MPC Old Town Site	42.5	0	Pro Pump & Equipment Inc.	19930617
I/C	GWIC	137828		2701942.9	608797.9	MPC Original Townsite	15	0	Pro Pump & Equipment Inc.	19930622
I/C	GWIC	137829		2701942.9	608797.9	MPC Original Townsite	15	0	Pro Pump & Equipment Inc.	19930621
I/C	GWIC	137905		2701942.9	608797.9	MPC Original Townsite	30	0	Pro Pump & Equipment Inc.	19930621
I/C	GWIC	137906		2701942.9	608797.9	MPC Original Townsite	16.5	0	Pro Pump & Equipment Inc.	19930621

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
I/C	GWIC	137907		2701942.9	608797.9	MPC Original Townsite	15	0	Pro Pump & Equipment Inc.	19930621
I/C	GWIC	137908		2701942.9	608797.9	MPC Original Townsite	11.4	0	Pro Pump & Equipment Inc.	19930618
I/C	GWIC	137909		2701942.9	608797.9	MPC Original Townsite	25	0	Pro Pump & Equipment Inc.	19930618
I/C	GWIC	137910		2701942.9	608797.9	MPC Original Townsite	20.8	0	Pro Pump & Equipment Inc.	19930618
I/C	GWIC	137911		2701942.9	608797.9	MPC Original Townsite	10	0	Pro Pump & Equipment Inc.	19930621
I/C	GWIC	137912		2701942.9	608797.9	MPC Original Townsite	15	0	Pro Pump & Equipment Inc.	19930618
I/C	GWIC	137914		2701942.9	608797.9	MPC Original Townsite	8	0	Pro Pump & Equipment Inc.	19930618
I/C	GWIC	138117		2708384.7	605457.7	MPC Colstrip-Process Ponds	113	0	Gordon Drilling Inc	19930804
I/C	GWIC	138122		2708435.1	604099.1	MPC Colstrip-Process Ponds	141	0	Gordon Drilling Inc	19930805
I/C	GWIC	138126		2708435.1	604099.1	MPC Colstrip-Process Ponds	105	0	Gordon Drilling Inc	19930806
I/C	GWIC	138128		2709096.7	604123.6	MPC Colstrip-Process Ponds	113	0	Gordon Drilling Inc	19930807
I/C	GWIC	138131		2709096.7	604123.6	MPC Colstrip-Process Ponds	56	0	Gordon Drilling Inc	19930807
I/C	GWIC	138341		2708219.2	609916.3	MPC Colstrip - Process Ponds	57	0	Gordon Drilling Inc	19930806
I/C	GWIC	138344		2712770.0	611522.9	MPC Colstrip - Process Ponds	91	0	Gordon Drilling Inc	19930808
I/C	GWIC	138347		2710905.7	607550.4	MPC Colstrip - Process Ponds	125	0	Gordon Drilling Inc	19930806
P/O	GWIC	139748		2692792.1	589306.4	Mcrea Doug	320	0	Askin Drilling	19910801
P/O	GWIC	144690		2696320.2	619056.5	Pontues, Don	415	120	Higgins Drilling Company	19920818
P/O	GWIC	145092		2678886.5	606014.9	State Lands	100	14	Sunrise Drilling Inc	19921119
I/C	GWIC	145362		2685912.1	582087.4	Peabody Coal Co	140	0		18991230
I/C	GWIC	145363		2689729.7	580911.9	Peabody Coal Co	96	0		18991230
I/C	GWIC	145364		2688744.1	580657.5	Peabody Coal Co	40	0		18991230
I/C	GWIC	145365		2691481.8	579023.9	Peabody Coal Co	80	0		18991230
I/C	GWIC	145366		2697123.5	578226.0	Peabody Coal Co	121	0		18991230
MW	GWIC	146778		2689143.0	616869.6	Hydrometrics * 9404	140	0	Gordon Drilling Inc	19940517
MW	GWIC	146783		2694108.7	614066.3	Hydrometrics	100	0	Gordon Drilling Inc	19940512
MW	GWIC	146785		2694132.6	613410.6	Hydrometrics	16.5	10	Gordon Drilling Inc	19940512
MW	GWIC	146786		2694132.6	613410.6	Hydrometrics	50	12	Gordon Drilling Inc	19940512
MW	GWIC	146787		2694841.9	612116.0	Hydrometrics	40	0	H & H Drilling	19940816
MW	GWIC	146789		2689138.0	615600.1	Hydrometrics	63	44	Gordon Drilling Inc	19940518
MW	GWIC	146790		2689528.8	613951.0	Hydrometrics	58	0	H & H Drilling	19940815
MW	GWIC	146797		2688313.4	615869.4	Hydrometrics	108	0	H & H Drilling	19940816
MW	GWIC	146800		2697559.8	610927.7	Hydrometrics	33	2	Gordon Drilling Inc	19940503
MW	GWIC	146802		2697559.8	610927.7	Hydrometrics	48	5	Gordon Drilling Inc	19940503
MW	GWIC	146803		2697559.8	610927.7	Hydrometrics	21	4	Gordon Drilling Inc	19940504
MW	GWIC	146804		2697559.8	610927.7	Hydrometrics	34	5	Gordon Drilling Inc	19940504
MW	GWIC	146805		2698221.1	610951.9	Hydrometrics	16	2	Gordon Drilling Inc	19940509
MW	GWIC	146806		2697606.0	609663.7	Hydrometrics	20	17	Gordon Drilling Inc	19940511
MW	GWIC	146807		2698313.6	608427.6	Hydrometrics	35	31	Gordon Drilling Inc	19940511
MW	GWIC	146808		2697559.8	610927.7	Hydrometrics	48	11	Gordon Drilling Inc	19940503

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
MW	GWIC	146809		2694296.4	608911.9	Hydrometrics	18.5	12	Gordon Drilling Inc	19940511
MW	GWIC	146810		2699637.9	607742.9	Hydrometrics-MPOT01	20	0	Gordon Drilling Inc	19940511
MW	GWIC	146811		2699637.9	607742.9	Hydrometrics-MPOT01	56	21	Gordon Drilling Inc	19940511
MW	GWIC	146812		2701305.1	608128.8	Hydrometrics-MPPP01	20	0	H & H Drilling	19940817
MW	GWIC	146813		2698221.1	610951.9	Hydrometrics	36.5	8	Gordon Drilling Inc	19940509
MW	GWIC	146814		2703928.7	609520.4	Hydrometrics	24.5	17	H & H Drilling	19940817
MW	GWIC	146815		2703928.7	609520.4	Hydrometrics	27	0	H & H Drilling	19940817
MW	GWIC	146816		2697582.8	610297.5	Hydrometrics	35	12	Gordon Drilling Inc	19940510
MW	GWIC	146817		2697582.8	610297.5	Hydrometrics	56	17	Gordon Drilling Inc	19940509
MW	GWIC	146818		2701257.6	609421.9	Hydrometrics	25	0	H & H Drilling	19940817
MW	GWIC	146819		2698313.6	608427.6	Hydrometrics	45	22	Gordon Drilling Inc	19940510
MW	GWIC	146820		2698313.6	608427.6	Hydrometrics	60	25	Gordon Drilling Inc	19940510
MW	GWIC	146823		2698290.5	609057.7	Hydrometrics	27	13	Gordon Drilling Inc	19940510
MW	GWIC	146827		2698290.5	609057.7	Hydrometrics	47	19	Gordon Drilling Inc	19940510
MW	GWIC	146829		2698975.0	608451.8	Hydrometrics	40	23	Gordon Drilling Inc	19940511
MW	GWIC	146833		2698336.7	607797.4	Hydrometrics	40	0	Gordon Drilling Inc	19940518
MW	GWIC	146835		2698290.5	609057.7	Hydrometrics	31	21	Gordon Drilling Inc	19940511
MW	GWIC	146894		2694108.7	614066.3	Hydrometrics	100	0	Gordon Drilling Inc	19940512
MW	GWIC	146896		2694132.6	613410.6	Hydrometrics	50	12	Gordon Drilling Inc	19940512
MW	GWIC	146897		2694132.6	613410.6	Hydrometrics	16.5	10	Gordon Drilling Inc	19940512
MW	GWIC	146899		2689143.0	616869.6	Hydrometrics * 367D	140	0	Gordon Drilling Inc	19940517
MW	GWIC	146902		2693202.1	613084.9	Hydrometrics	65	0	Gordon Drilling Inc	19940517
MW	GWIC	146904		2689138.0	615600.1	Hydrometrics	63	44	Gordon Drilling Inc	19940518
MW	GWIC	146906		2688184.8	615904.9	Hydrometrics	100	41	Gordon Drilling Inc	19940519
MW	GWIC	146908		2689528.8	613951.0	Hydrometrics	58	0	H & H Drilling	19940815
MW	GWIC	146909		2692198.1	613380.3	Hydrometrics	87	0	H & H Drilling	19940815
MW	GWIC	146912		2688313.4	615869.4	Hydrometrics	108	0	H & H Drilling	19940816
MW	GWIC	146914		2701305.1	608128.8	Hydrometrics-MPPP01	20	0	H & H Drilling	19940817
MW	GWIC	146916		2703928.7	609520.4	Hydrometrics	24.5	17	H & H Drilling	19940817
MW	GWIC	146917		2703928.7	609520.4	Hydrometrics	27	0	H & H Drilling	19940817
MW	GWIC	146919		2701257.6	609421.9	Hydrometrics	25	20	H & H Drilling	19940817
MW	GWIC	148160		2712569.0	586178.8	MBMG Monitoring Well MSU-70	12	0		18991230
MW	GWIC	154404		2702605.9	609471.6	Hydrometrics-MPPP02	35.5	11	Braun	19950926
MW	GWIC	154406		2702605.9	609471.6	Hydrometrics-MPPP02	34.5	9	Braun	19950926
MW	GWIC	154407		2702605.9	609471.6	Hydrometrics-MPPP02	35	15	Braun	19950926
MW	GWIC	154413		2702605.9	609471.6	Hydrometrics-MPPP02	34.25	14	American Drilling & Supply	19951116
MW	GWIC	154417		2702605.9	609471.6	Hydrometrics-MPPP02	34.5	13	American Drilling & Supply	19951116
MW	GWIC	154423		2701257.6	609421.9	Hydrometrics-MPPP02	15	10	American Drilling & Supply	19951115
MW	GWIC	154427		2701257.6	609421.9	Hydrometrics-MPPP02	18.5	10	American Drilling & Supply	19951115
MW	GWIC	154431		2701257.6	609421.9	Hydrometrics-MPPP02	32	13	American Drilling & Supply	19951115
MW	GWIC	154436		2701257.6	609421.9	Hydrometrics-MPPP02	15.5	9	Braun	19950925
MW	GWIC	154442		2701257.6	609421.9	Hydrometrics-MPPP02	26.5	10	Braun	19950925

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
MW	GWIC	159668		2659162.2	615019.7	Hydrometrics Inc	100	57	Gordon Drilling Inc	19950726
MW	GWIC	159676		2659162.2	615019.7	Hydrometrics Inc	100	56	Gordon Drilling Inc	19950926
MW	GWIC	159796		2700938.8	609085.6	Hydrometrics-MPPP02	26.5	0	Braun	19950925
MW	GWIC	159797		2699685.4	606449.8	Hydrometrics-MPPP02	15.5	9	Braun	19950925
MW	GWIC	159798		2701624.1	608461.5	Hydrometrics Inc-MPPP02	35.5	2	Braun	19950925
MW	GWIC	162321		2700251.9	609060.4	Hydrometrics-0728	33	13	Hydrometrics Inc	19960824
MW	GWIC	162322		2700251.9	609060.4	Hydrometrics-0728	28	12	Hydrometrics Inc	19960824
MW	GWIC	162323		2700251.9	609060.4	Hydrometrics-0728	32.5	10	Hydrometrics Inc	19960824
MW	GWIC	162324		2700299.4	607767.2	Hydrometrics-0728	37.5	18	Hydrometrics Inc	19960821
MW	GWIC	162325		2700299.4	607767.2	Hydrometrics-0728	37.5	17	Hydrometrics Inc	19960821
MW	GWIC	162336		2700299.4	607767.2	Hydrometrics-0728	44	22	Hydrometrics Inc	19960820
MW	GWIC	162337		2700299.4	607767.2	Hydrometrics-0728	41.5	28	Hydrometrics Inc	19960823
MW	GWIC	162338		2700299.4	607767.2	Hydrometrics-0728	44	26	Hydrometrics Inc	19960823
MW	GWIC	162339		2700299.4	607767.2	Hydrometrics Inc-0728	46.5	29	Hydrometrics Inc	19960819
MW	GWIC	162346		2700299.4	607767.2	Hydrometrics Inc-0728	36.5	27	Hydrometrics Inc	19960825
MW	GWIC	162347		2703657.7	607890.8	Hydrometrics-0728	49	29	Hydrometrics Inc	19960825
MW	GWIC	162348		2700346.9	606474.1	Hydrometrics Inc-0728	36.5	33	Hydrometrics Inc	19960822
MW	GWIC	162351		2700251.9	609060.4	Hydrometrics Inc-0728	35	34	Hydrometrics Inc	19960822
MW	GWIC	162353		2700251.9	609060.4	Hydrometrics Inc-0728	38	34	Hydrometrics Inc	19960822
MW	GWIC	162360		2702996.2	607866.4	Hydrometrics-0728	16.5	9	Hydrometrics Inc	19960826
MW	GWIC	162370		2702996.2	607866.4	Hydrometrics-0728	11	5	Hydrometrics Inc	19960826
MW	GWIC	162371		2702996.2	607866.4	Hydrometrics-0728	14	4	Hydrometrics Inc	19960826
MW	GWIC	162372		2700204.4	610353.5	Hydrometrics Inc-0728	10	8	Hydrometrics Inc	19960826
MW	GWIC	162373		2700204.4	610353.5	Hydrometrics Inc-0728	11.5	7	Hydrometrics Inc	19960827
MW	GWIC	162384		2700204.4	610353.5	Hydrometrics-0728	15	10	Hydrometrics Inc	19960827
MW	GWIC	162385		2700204.4	610353.5	Hydrometrics-0728	17.5	11	Hydrometrics Inc	19960827
MW	GWIC	162913		2703657.7	607890.8	Hydrometrics-0728	21.5	11	Hydrometrics Inc	19960904
MW	GWIC	162916		2703610.0	609184.0	Hydrometrics-0728	20	11	Hydrometrics Inc	19960905
MW	GWIC	162920		2703610.0	609184.0	Hydrometrics-0728	25.7	11	Hydrometrics Inc	19960905
MW	GWIC	163760		2703610.0	609184.0	Hydrometrics-0795	26	0	American Drilling & Supply	19970721
MW	GWIC	163762		2703657.7	607890.8	Hydrometrics-0795	27	0	American Drilling & Supply	19970721
MW	GWIC	163764		2703705.4	606597.7	Hydrometrics-0795	28	0	American Drilling & Supply	19970721
P/O	GWIC	165964		2710987.0	588939.5	David, Boyd	426	220	Higgins Drilling Company	19970616
MW	GWIC	167396		2703843.2	581427.0	MBMG Monitoring Well PAW-3	10.9	5	ÿ	18991230
I/C	GWIC	167712		2694379.3	615724.8	Montana Power Co	200	0	Gordon Drilling Inc	19980406
I/C	GWIC	167713		2695733.5	616996.1	MPC-1998 Stage 2 Area Investigation	85	60	Gordon Drilling Inc	19980407
I/C	GWIC	167714		2694379.3	615724.8	MPC-1998 Stage 2 Area Investigation	30	21	Gordon Drilling Inc	19980408
I/C	GWIC	167715		2695733.5	616996.1	MPC-1998 Stage 2 Area Investigation	57	38	Gordon Drilling Inc	19980406
I/C	GWIC	167716		2695733.5	616996.1	MPC-1998 Stage 2 Area Investigation	55	33	Gordon Drilling Inc	19980406
I/C	GWIC	167717		2695733.5	616996.1	MPC-1998 Stage 2 Area Investigation	60	31	Gordon Drilling Inc	19980405
MW	GWIC	168395		2706561.8	612021.5	MBMG Monitoring Well S-40	14.95	0	MBMG	19981014
MW	GWIC	168396		2707939.0	609227.4	MBMG	51.9	0	MBMG	19981013
MW	GWIC	168397		2706419.2	609681.8	MBMG	60.6	0	MBMG	19981013
MW	GWIC	168398		2703695.2	614468.8	MBMG Monitoring Well S-43	41	0	MBMG	19981014
MW	GWIC	168399		2709158.7	612737.9	MBMG Monitoring Well S-44	17	0	MBMG	19981015
P/O	GWIC	168413		2703792.2	581425.1	MBMG Final Pit	5	0		18991230
MW	GWIC	168414		2703739.9	582845.8	MBMG Monitoring Well MSU-01	22.4	0		18991230
MW	GWIC	168421		2703061.2	581186.7	MBMG Monitoring	146	0	MBMG	19981007
MW	GWIC	168422		2703866.8	581479.0	MBMG Monitoring	140	0	MBMG	19981006
I/C	GWIC	168795		2697055.8	617044.4	MPC-1998 Stage 2 Area Investigation	40	20	Gordon Drilling Inc	19980410
I/C	GWIC	171708		2703087.5	605389.5	MPC	84	35	Gordon Drilling Inc	19981120

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
I/C	GWIC	171868		2697024.2	615821.3	Montana Power Company-1998 Area 5-6/Stage II Investigation	79	37	Gordon Drilling Inc	19981114
I/C	GWIC	171869		2695749.8	614458.0	Montana Power Company-1998 Area 5-6/Stage II Investigation	116	78	Gordon Drilling Inc	19981113
I/C	GWIC	171870		2689138.0	615600.1	Montana Power Company-1998 Area 5-6/Stage II Investigation	60	43	Gordon Drilling Inc	19981121
I/C	GWIC	171871		2695749.8	614458.0	Montana Power Company-1998 Area 5-6/Stage II Investigation	80	40	Gordon Drilling Inc	19981105
I/C	GWIC	173226		2693202.1	613084.9	Montana Power Company-1998 Area 5-6/Stage II Investigation	50	19	Gordon Drilling Inc	19981119
I/C	GWIC	173227		2693202.1	613084.9	Montana Power Company-1998 Area 5-6/Stage II Investigation	105	0	Gordon Drilling Inc	19981119
I/C	GWIC	173228		2693202.1	613084.9	Montana Power Company-1998 Area 5-6/Stage II Investigation	100	20	Gordon Drilling Inc	19981118
P/O	GWIC	173231		2699418.4	608865.6	Colstrip Public School-Bus Garage	30	21	Haz Tech Drilling Inc	19980717
P/O	GWIC	173234		2699418.4	608865.6	Colstrip Public School-Bus Garage	21.5	18	Haz Tech Drilling Inc	19980717
P/O	GWIC	173235		2699418.4	608865.6	Colstrip Public School-Bus Garage	31.5	17	Haz Tech Drilling Inc	19980717
P/O	GWIC	173236		2699418.4	608865.6	Colstrip Public School-Bus Garage	30	17	Haz Tech Drilling Inc	19900720
I/C	GWIC	177216		2695733.5	616996.1	MPC-1999 Area 3 & 4 EHP/Stage II Investigation	55	17	Askin Drilling	19990923
I/C	GWIC	177217		2697055.8	617044.4	MPC-1999 Area 3 & 4 EHP/Stage II Investigation	28	15	Askin Drilling	19990924
I/C	GWIC	177218		2697055.8	617044.4	MPC -1999 Area 3 & 4 EHP/Stage II Investigation	31	16	Askin Drilling	19990924
I/C	GWIC	177219		2697006.3	618399.5	MPC-1999 Area 3 & 4 EHP/Stage II Investigation	36	21	Askin Drilling	19990924
I/C	GWIC	177220		2695684.0	618351.2	MPC-1999 Area 3 & 4 EHP/Stage II Investigation	40	25	Askin Drilling	19991011
I/C	GWIC	177221		2695684.0	618351.2	MPC-1999 Area 3 & 4 EHP/Stage II Investigation	72	48	Askin Drilling	19991011
I/C	GWIC	177222		2695733.5	616996.1	MPC-1999 Area 3 & 4 EHP/Stage II Investigation	61	36	Askin Drilling	19991011
I/C	GWIC	177225		2695733.5	616996.1	MPC-1999 Area 3 & 4 EHP/Stage II Investigation	85	53	Askin Drilling	19990924
I/C	GWIC	177226		2701257.6	609421.9	MPC	20	12	Maxim Technologies	19990825
P/O	GWIC	177227		2701257.6	609421.9	Loveridge, Ray Sr	19	13	Maxim Technologies	19990824
P/O	GWIC	177229		2701257.6	609421.9	City of Colstrip	20	15	Maxim Technologies	19990824
P/O	GWIC	177230		2701257.6	609421.9	Loveridge, Ray Sr	20	14	Maxim Technologies	19990824
I/C	GWIC	177231		2719999.9	607584.9	MPC	17	10	Askin Drilling	19990915
I/C	GWIC	177232		2719999.9	607584.9	MPC	18	10	Askin Drilling	19990915
I/C	GWIC	177402		2720024.4	606258.0	Montana Power Area	65	45	Askin Drilling	19990915
I/C	GWIC	177403		2718675.9	606207.2	Montana Power Company	50	33	Askin Drilling	19990915
I/C	GWIC	177408		2691640.8	621012.5	Montana Power Area 900D	260	165	Askin Drilling	19990921
I/C	GWIC	177409		2691640.8	621012.5	Montana Power Area 901D	140	111	Askin Drilling	19990921
I/C	GWIC	180053		2720024.4	606258.0	Montana Power Company	18	9	Gordon Drilling Inc	19990216
I/C	GWIC	180085		2720024.4	606258.0	Montana Power Company	65	45	Askin Drilling	19990915
I/C	GWIC	180086		2718726.6	604859.5	Montana Power Company	75	55	Gordon Drilling Inc	19990217
I/C	GWIC	180208		2695733.5	616996.1	MPC-1998 Area 3 & 4 EHP/Stage II Investigation	90	57	Gordon Drilling Inc	19990216
I/C	GWIC	180319		2695701.7	615773.0	MPC-1998 Area 3 & 4 EHP/Stage II Investigation	90	57	Gordon Drilling Inc	19990210

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
I/C	GWIC	180320		2695701.7	615773.0	MPC-1998 Area 3 & 4 EHP/Stage II Investigation	88	82	Gordon Drilling Inc	19990209
I/C	GWIC	180343		2719999.9	607584.9	MPC	18	10	Askin Drilling	19990915
I/C	GWIC	180611		2709565.4	609335.3	PPL Montana LLC	19	13	Gordon Drilling Inc	20000207
I/C	GWIC	180612		2712891.3	608273.8	PPL Montana LLC	14	5	Gordon Drilling Inc	20000205
I/C	GWIC	181417		2718726.6	604859.5	Montana Power Company	50	26	Gordon Drilling Inc	19990217
I/C	GWIC	181418		2718726.6	604859.5	Montana Power Company	76	45	Gordon Drilling Inc	19990212
I/C	GWIC	181419		2718726.6	604859.5	Montana Power Company	120	102	Gordon Drilling Inc	19990211
I/C	GWIC	181840		2695733.5	616996.1	MPC-1998 Area 3 & 4 EHP/Stage II Investigation	70	41	Gordon Drilling Inc	19990216
I/C	GWIC	181841		2695733.5	616996.1	MPC-1998 Area 3 & 4 EHP/Stage II Investigation	80	53	Gordon Drilling Inc	19990209
I/C	GWIC	181842		2709635.9	607441.1	PPL Montana LLC	19	13	Gordon Drilling Inc	20000207
I/C	GWIC	181843		2711518.7	608875.5	PPL Montana LLC	74	29	Gordon Drilling Inc	20000208
I/C	GWIC	181844		2710881.5	608198.8	PPL Montana LLC	14	5	Gordon Drilling Inc	20000205
I/C	GWIC	182889		2701942.9	608797.9	BNSF	1520	0		19260401
I/C	GWIC	182890		2701942.9	608797.9	BNSF	518.5	0		19430115
I/C	GWIC	182891		2701942.9	608797.9	BNSF	595.5	203		19360830
I/C	GWIC	186070		2695585.1	621061.3	PPL Montana LLC-0831	35	7	Askin Drilling	20000725
I/C	GWIC	186071		2695634.5	619706.2	PPL Montana LLC-0831	17.5	4	Askin Drilling	20000725
P/O	GWIC	186072		2695733.5	616996.1	State of Montana	208	0	Dept of Highways, Core Drill Sec.	19780920
I/C	GWIC	186073		2697006.3	618399.5	PPL Montana LLC-0831	26	10	Askin Drilling	20000725
I/C	GWIC	186075		2697006.3	618399.5	PPL Montana LLC-0831	88	24	Askin Drilling	20000726
I/C	GWIC	186077		2697055.8	617044.4	PPL Montana LLC-0831	35	11	Askin Drilling	20000725
I/C	GWIC	190008		2716933.8	607137.6	PPL Montana LLC	13.5	13	Oftedal Construction	20000907
I/C	GWIC	190009		2716933.8	607137.6	PPL Montana LLC	20	21	Oftedal Construction	20000907
I/C	GWIC	190010		2716933.8	607137.6	PPL Montana LLC	15.5	14	Oftedal Construction	20000907
I/C	GWIC	190011		2716933.8	607137.6	PPL Montana LLC	15	0		20000907
I/C	GWIC	191171		2698975.0	608451.8	Montana Power Co	700	0		18991230
I/C	GWIC	191181		2719095.6	603859.3	PPL Montana	51.5	34	Hansen Environmental Drilling	20010627
I/C	GWIC	191182		2719095.6	603859.3	PPL Montana	36	19	Hansen Environmental Drilling	20010626
I/C	GWIC	191183		2718408.5	603833.5	PPL Montana	75	52	Hansen Environmental Drilling	20010626
I/C	GWIC	191184		2718408.5	603833.5	PPL Montana	67.5	45	Hansen Environmental Drilling	20010622
P/O	GWIC	192519		2684087.4	610169.4	Anderson, Joe and Marlene	150	74	Corveau Drilling	20010605
P/O	GWIC	192751		2661847.6	604433.7	Great Northern Properties	400	220	Sharp Drilling Inc	20010428
I/C	GWIC	198266		2719095.6	603859.3	PPL Montana	94	0	Hansen Environmental Drilling	20020515
I/C	GWIC	198267		2719095.6	603859.3	PPL Montana	91	0	Hansen Environmental Drilling	20020517
P/O	GWIC	199242		2696320.2	619056.5	Don Pontius Construction - Well 1	130	34	Higgins Drilling Company	20020222
P/O	GWIC	199243		2696320.2	619056.5	Don Pontius Construction - Well 2	130	34	Higgins Drilling Company	20020222
I/C	GWIC	203157		2703431.0	605055.6	MPC Units 3 and 4	91	49	Gordon Drilling Inc	19830708

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
I/C	GWIC	203158		2703431.0	605055.6	MPC Units 3 and 4	40	40	Gordon Drilling Inc	19830708
I/C	GWIC	203159		2703431.0	605055.6	MPC Units 3 and 4	131	53	Gordon Drilling Inc	19830708
I/C	GWIC	203160		2703431.0	605055.6	MPC Units 3 and 4	84	41	Gordon Drilling Inc	19830712
I/C	GWIC	203161		2703431.0	605055.6	MPC Units 3 and 4	74	42	Gordon Drilling Inc	19830712
I/C	GWIC	203162		2703431.0	605055.6	MPC Units 3 and 4	50	36	Gordon Drilling Inc	19830712
I/C	GWIC	203168		2694679.2	617975.3	Montana Power Stage 2 Pond	241	96	Gordon Drilling Inc	19831116
I/C	GWIC	203171		2694385.7	616946.9	PPL Montana LLC-831	93	49	Hansen Environmental Drilling	20000819
I/C	GWIC	203173		2694385.7	616946.9	PPL Montana LLC-831	90	47	Hansen Environmental Drilling	20000821
I/C	GWIC	203176		2694385.7	616946.9	PPL Montana LLC-831	40	0	Hansen Environmental Drilling	20000820
I/C	GWIC	203184		2697055.8	617044.4	PPL Montana-PPL Groundwater Capture Study	100	56	Askin Drilling	20010702
I/C	GWIC	203190		2697055.8	617044.4	PPL Montana-PPL Groundwater Capture Study	100	42	Askin Drilling	20010629
I/C	GWIC	203211		2695701.7	615773.0	Montana Power Company-1998 Area 5-6/Stage II Investigation	90	61	Gordon Drilling Inc	19981030
I/C	GWIC	203214		2695701.7	615773.0	Montana Power Company-1998 Area 5-6/Stage II Investigation	160	86	Gordon Drilling Inc	19981105
I/C	GWIC	203227		2694475.3	613091.1	PPL Montana-PPL Groundwater Capture Study	60	22	Askin Drilling	20010629
I/C	GWIC	203230		2691782.9	615696.0	Montana Power Company-MPPP03	100	57	Gordon Drilling Inc	19950726
I/C	GWIC	203232		2691782.9	615696.0	Montana Power Company-MPPP03	100	56	Gordon Drilling Inc	19950926
I/C	GWIC	203233		2691782.9	615696.0	PPL Montana LLC-831	90	80	Hansen Environmental Drilling	20000815
I/C	GWIC	203235		2693202.1	613084.9	Montana Power Company-1998 Area 5-6/Stage II Investigation	105	28	Gordon Drilling Inc	19981117
MW	GWIC	203272		2704366.9	606622.1	Hydrometrics-MPC units I and II	42.5	0	Gordon Drilling Inc	19850522
I/C	GWIC	203277		2706505.2	610797.5	PPL Montana LLC	100	61	Askin Drilling	20010629
P/O	GWIC	203836		2717470.7	589448.2	Greenleaf Lands and Livestock	50	25	Askin Drilling	20030501
I/C	GWIC	205504		2696406.4	620183.1	PPL Montana LLC	13	0	Hydrometrics Inc	20030722
I/C	GWIC	205505		2695884.5	620528.7	PPL Montana LLC	17	0	Hydrometrics Inc	20030721
I/C	GWIC	205507		2695986.1	619839.4	PPL Montana LLC	13	0	Hydrometrics Inc	20030721
P/O	GWIC	210087		2711255.7	589941.7	Harbuck, Scott	310	120	Askin Drilling	20031208
I/C	GWIC	210271		2700004.2	606786.2	PPL	30	0	Hansen Environmental Drilling	20040121
I/C	GWIC	210401		2702333.0	607196.4	PPL	26	0	Hansen Environmental Drilling	20040121
P/O	GWIC	212086		2673087.8	588429.2	Ashenhurst Ranch Inc	480	340	Ronald L Askin Drilling	20040518
I/C	GWIC	213584		2718240.3	598818.8	PPL Co	101	82	H & H Drilling	20040701
I/C	GWIC	216108		2705618.1	607923.1	PPL Montana LLC	87	0	Askin Drilling	20040826
I/C	GWIC	216117		2715660.4	604405.1	PPL Montana	45	34	Askin Drilling	20040824
I/C	GWIC	216124		2715660.4	604405.1	PPL Montana	20	6	Askin Drilling	20040823
I/C	GWIC	216126		2718383.1	604507.3	PPL Montana	138	100	Askin Drilling	20040823
I/C	GWIC	216142		2717009.2	605130.5	PPL Montana, INC.	47	41	Askin Drilling	20040823

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
I/C	GWIC	216148		2717110.4	602435.0	PPL Montana	170	110	Askin Drilling	20040722
I/C	GWIC	216172		2717721.6	604482.5	PPL Montana, INC.	300	210	Askin Drilling	20040722
I/C	GWIC	216184		2693452.9	616690.5	PPL Montana *958D	160	62	Askin Drilling	20040816
I/C	GWIC	216202		2695952.7	620057.1	PPL Montana-Stage II Area	260	66	Askin Drilling	20040812
I/C	GWIC	216203		2694728.6	616620.2	PPL Montana-Stage II Area	50	23	Askin Drilling	20040813
I/C	GWIC	216207		2695359.0	616092.4	PPL Montana-Stage II Area	120	48	Askin Drilling	20040813
I/C	GWIC	216208		2695359.0	616092.4	PPL Montana-Stage II Area	140	69	Askin Drilling	20040813
I/C	GWIC	216212		2695359.0	616092.4	PPL Montana-Stage II Area	100	55	Askin Drilling	20040812
I/C	GWIC	216215		2694036.6	616044.2	PPL Montana-Stage II Area	90	46	Askin Drilling	20040813
I/C	GWIC	216216		2694084.7	614725.6	PPL Montana-Stage II Area	156	119	Askin Drilling	20040810
I/C	GWIC	216221		2693496.4	614095.0	PPL Montana-Stage II Area	60	29	Askin Drilling	20040810
I/C	GWIC	216237		2694132.6	613410.6	PPL Montana-Stage II Area	140	42	Askin Drilling	20040811
I/C	GWIC	216240		2693448.0	615424.6	PPL Montana-Stage II Area	46	41	Askin Drilling	20040816
I/C	GWIC	216247		2700915.0	609734.0	PPL Montana-Stage II Area	60	9	Askin Drilling	20040809
I/C	GWIC	217151		2720519.2	600571.7	PPL Montana	56	51	Askin Drilling	20041103
I/C	GWIC	217152		2720494.2	601234.6	PPL Montana	60	59	Askin Drilling	20041102
I/C	GWIC	217155		2720519.2	600571.7	PPL Montana	99	26	Askin Drilling	20041102
I/C	GWIC	217227		2721942.7	597973.5	PPL Montana	11	8	Askin Drilling	20041029
I/C	GWIC	217767		2716423.3	602409.2	PPL Montana	70	57	Askin Drilling	20050106
I/C	GWIC	217768		2717822.9	601787.0	PPL Montana	56	0	Askin Drilling	20050104
I/C	GWIC	217770		2715736.2	602383.5	PPL Montana	36	19	Askin Drilling	20050124
I/C	GWIC	217771		2716398.0	603083.1	PPL Montana	77	0	Askin Drilling	20041229
I/C	GWIC	217772		2717135.8	601761.2	PPL Montana	89	70	Askin Drilling	20041222
I/C	GWIC	217823		2716423.3	602409.2	PPL Montana	47	28	Askin Drilling	20041221
I/C	GWIC	217840		2716448.6	601735.4	PPL Montana	59	33	Askin Drilling	20041221
I/C	GWIC	217855		2717796.5	601133.0	PPL Montana	80	73	Askin Drilling	20050108
I/C	GWIC	217868		2716473.1	601083.3	PPL Montana	96	65	Askin Drilling	20050119
I/C	GWIC	217869		2719145.3	601183.8	PPL Montana	220	149	Askin Drilling	20050121
I/C	GWIC	217925		2720494.2	601234.6	PPL Montana	160	102	Askin Drilling	20050120
I/C	GWIC	217932		2716473.1	601083.3	PPL Montana	56	46	Askin Drilling	20050119
I/C	GWIC	217936		2720494.2	601234.6	PPL Montana	71	52	Askin Drilling	20050118
I/C	GWIC	217940		2720494.2	601234.6	PPL Montana	104	55	Askin Drilling	20050118
I/C	GWIC	218008		2719145.3	601183.8	PPL Montana	92	52	Askin Drilling	20050111
I/C	GWIC	218010		2719145.3	601183.8	PPL Montana	58	58	Askin Drilling	20050125
I/C	GWIC	218013		2718508.6	600495.9	PPL Montana	98	59	Askin Drilling	20040125
I/C	GWIC	218021		2717796.5	601133.0	PPL Montana	57	48	Askin Drilling	20041228
I/C	GWIC	218066		2694018.1	617951.2	PPL Montana	66	49	Askin Drilling	20050126
I/C	GWIC	225865		2721280.9	597948.5	PPL Montana	20	17	Askin Drilling	20050626
I/C	GWIC	225870		2718583.8	598496.2	PPL Montana	19	17	Askin Drilling	20050626
I/C	GWIC	225881		2719882.3	599212.6	PPL Montana	70	41	Askin Drilling	20050625
I/C	GWIC	225890		2721255.6	598618.8	PPL Montana	18	14	Askin Drilling	20050625
I/C	GWIC	225895		2721942.7	597973.5	PPL Montana	91	16	Askin Drilling	20050725
I/C	GWIC	226007		2718608.8	597833.3	PPL Montana	180	129	Askin Drilling	20050727
I/C	GWIC	226014		2694679.2	617975.3	PPL Montana-Stage 2	155	74	Askin Drilling	20051213
I/C	GWIC	226018		2694679.2	617975.3	PPL Montana-Stage 2	160	85	Askin Drilling	20051213
I/C	GWIC	226557		2693403.8	618038.3	PPL Montana, LLC* 974D	40	33	Askin Drilling	20060501
I/C	GWIC	226558		2693403.8	618038.3	PPL Montana, LLC* 975 D	145.5	73	Askin Drilling	20060501
I/C	GWIC	226559		2716908.9	607800.5	PPL Montana, LLC	11	11	Askin Drilling	20060501
I/C	GWIC	226560		2716908.9	607800.5	PPL Montana, LLC	21	17	Askin Drilling	20060501
I/C	GWIC	227766		2701755.2	613897.6	PPL Montana	34	0	SK Geotechnical Co	20040722
I/C	GWIC	227768		2701755.2	613897.6	PPL Montana	24	0	SK Geotechnical Co	20030723
I/C	GWIC	227770		2701755.2	613897.6	PPL Montana	59	0	SK Geotechnical Co	20040722
I/C	GWIC	227771		2701755.2	613897.6	PPL Montana	34	0	SK Geotechnical Co	20040722
I/C	GWIC	232197		2693202.1	613084.9	PPL Montana-CSES	70	0	Askin Drilling	20061120
I/C	GWIC	232198		2701257.6	609421.9	PPL Montana-CSES	59	0	Askin Drilling	20061120
I/C	GWIC	232199		2701257.6	609421.9	PPL Montana-CSES	31	4	Askin Drilling	20061120
I/C	GWIC	232200		2701257.6	609421.9	PPL Montana-CSES	31.5	0	Askin Drilling	20061116
I/C	GWIC	232201		2701257.6	609421.9	PPL Montana-CSES	50	0	Askin Drilling	20061116
I/C	GWIC	232202		2701257.6	609421.9	PPL Montana-CSES	29	0	Askin Drilling	20061116
I/C	GWIC	232204		2701257.6	609421.9	PPL Montana-CSES	40	7	Askin Drilling	20061115
I/C	GWIC	232207		2701257.6	609421.9	PPL Montana-CSES	32	9	Askin Drilling	20061115
I/C	GWIC	232209		2701257.6	609421.9	PPL Montana-CSES	36	4	Askin Drilling	20061115
I/C	GWIC	238193		2701210.2	610711.4	PPL Montana	37	9	Clayton Larson	20070821
I/C	GWIC	238215		2695938.4	609289.1	PPL Montana	40	25	Clayton Larson	20070823
I/C	GWIC	240955		2696320.2	619056.5	PPL Montana-7088	103	84	Askin Drilling	20071010

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
I/C	GWIC	240956		2696320.2	619056.5	PPL Montana-7088	74	40	Askin Drilling	20071010
I/C	GWIC	240957		2696320.2	619056.5	PPL Montana-7088	54	29	Askin Drilling	20071010
I/C	GWIC	240958		2696320.2	619056.5	PPL Montana-7088	42	35	Askin Drilling	20071011
I/C	GWIC	240965		2696320.2	619056.5	PPL Montana-7088	36	34	Askin Drilling	20071011
I/C	GWIC	240975		2696320.2	619056.5	PPL Montana-7088	90	48	Askin Drilling	20071011
I/C	GWIC	240977		2696320.2	619056.5	PPL Montana-7088	92	50	Askin Drilling	20071011
I/C	GWIC	240978		2696320.2	619056.5	PPL Montana-7088	66	49	Askin Drilling	20071012
I/C	GWIC	240979		2696320.2	619056.5	PPL Montana-7088	56	49	Askin Drilling	20071012
I/C	GWIC	240980		2718065.0	604159.8	PPL Montana INC.	66	53	Askin Drilling	20071012
I/C	GWIC	240981		2718065.0	604159.8	PPL Montana INC.	76	63	Askin Drilling	20071015
I/C	GWIC	240982		2718065.0	604159.8	PPL Montana INC.	58	57	Askin Drilling	20071015
I/C	GWIC	240983		2718065.0	604159.8	PPL Montana INC.	64	51	Askin Drilling	20071016
I/C	GWIC	240984		2718065.0	604159.8	PPL Montana INC.	72	64	Askin Drilling	20071016
I/C	GWIC	240985		2718065.0	604159.8	PPL Montana INC.	69	62	Askin Drilling	20071017
I/C	GWIC	240986		2718065.0	604159.8	PPL Montana INC.	63	54	Askin Drilling	20071017
I/C	GWIC	240997		2718065.0	604159.8	PPL Montana INC.	88	79	Askin Drilling	20071023
P/O	GWIC	242581		2695510.7	619610.5	Burton, Brent	60	36	Askin Drilling	20080423
P/O	GWIC	246645		2642769.5	601324.6	Booth Land & Livestock	375	265	Gordon Drilling Inc	20080612
I/C	GWIC	247121		2718065.0	604159.8	PPL Montana INC.	38	0	Askin Drilling	20080326
I/C	GWIC	247230		2704907.9	608527.9	PPL Montana LLC	60	45	Askin Drilling	20080617
I/C	GWIC	247231		2704931.2	607897.7	PPL Montana LLC	63	48	Askin Drilling	20080617
I/C	GWIC	247237		2696320.2	619056.5	PPL Montana-8012	420	91	Askin Drilling	20080402
I/C	GWIC	247238		2696320.2	619056.5	PPL Montana-8012	45	27	Askin Drilling	20080401
I/C	GWIC	247239		2696320.2	619056.5	PPL Montana-8012	100	55	Askin Drilling	20080401
I/C	GWIC	247240		2696320.2	619056.5	PPL Montana-8012	50	32	Askin Drilling	20080327
I/C	GWIC	247241		2696320.2	619056.5	PPL Montana-8012	65	28	Askin Drilling	20080401
I/C	GWIC	247242		2696320.2	619056.5	PPL Montana-8012	100	56	Askin Drilling	20080327
I/C	GWIC	247247		2702356.9	606548.0	PPL Montana, INC-8047	70	46	Askin Drilling	20080618
I/C	GWIC	247273		2704366.9	606622.1	PPL Montana, INC-8047	60	26	Askin Drilling	20080618
I/C	GWIC	247274		2705594.9	608553.3	PPL Montana LLC	69	0	Askin Drilling	20080619
I/C	GWIC	247277		2704907.9	608527.9	PPL Montana LLC	43	38	Askin Drilling	20080617
I/C	GWIC	248899		2701942.9	608797.9	PPL Montana, INC-8090	37	17	Askin Drilling	20081120
I/C	GWIC	248900		2719878.1	606084.7	PPL Montana, LLC	80	51	Ronald L Askin Drilling	20081117
I/C	GWIC	248901		2696320.2	619056.5	PPL Montana, INC-8012	100	56	Ronald L Askin Drilling	20080827
I/C	GWIC	248902		2696320.2	619056.5	PPL Montana, INC-8012	40	24	Ronald L Askin Drilling	20080828
I/C	GWIC	248903		2696320.2	619056.5	PPL Montana-8012	31	23	Ronald L Askin Drilling	20080828
I/C	GWIC	248904		2696320.2	619056.5	PPL Montana, INC-8012	52	26	Ronald L Askin Drilling	20080828
I/C	GWIC	248906		2716150.5	605605.3	PPL Montana, INC.	63	56	Ronald L Askin Drilling	20081117
I/C	GWIC	248907		2715832.3	604579.3	PPL Montana, INC.	72	48	Ronald L Askin Drilling	20081118
I/C	GWIC	248908		2715844.9	604244.2	PPL Montana, INC.	32	23	Ronald L Askin Drilling	20081118
I/C	GWIC	248909		2715844.9	604244.2	PPL Montana, INC.	92	54	Ronald L Askin Drilling	20081119
I/C	GWIC	248910		2715223.7	603819.7	PPL Montana	80	55	Ronald L Askin Drilling	20081119
I/C	GWIC	248911		2716201.1	604257.6	PPL Montana, INC.	49	35	Askin Drilling	20081119
I/C	GWIC	248912		2715844.9	604244.2	PPL Montana, INC.	83	63	Askin Drilling	20081119
I/C	GWIC	248913		2696435.1	613822.9	PPL Montana-8012	43	28	Ronald L Askin Drilling	20080828
P/O	GWIC	250613		2648241.4	602250.8	N49E1	200	0	Teton	19831104
P/O	GWIC	250616		2640606.8	601991.9	N49.5W 6000	320	0	Teton	19831103
I/C	GWIC	250823		2696435.1	613822.9	PPL Montana-Colstrip	85	0		19760913
I/C	GWIC	251683		2696320.2	619056.5	PPL Montana, INC-PPL SOEP	63	36	SK Geotechnical Co	20090624
I/C	GWIC	251687		2696320.2	619056.5	PPL, Montana-PPL Soep	60.5	33	SK Geotechnical Co	20090626
I/C	GWIC	251980		2701352.7	606835.7	PPL Montana, INC-8019	38	18	Askin Drilling	20090427
I/C	GWIC	251983		2701352.7	606835.7	PPL Montana, INC-8019	45	15	Askin Drilling	20090427
I/C	GWIC	251984		2701352.7	606835.7	PPL Montana, INC-8019	43	11	Askin Drilling	20090427
I/C	GWIC	251985		2700004.2	606786.2	PPL Montana, INC-8019	75	5	Askin Drilling	20090505
I/C	GWIC	251986		2700004.2	606786.2	PPL Montana, INC-8019	25	4	Askin Drilling	20090429

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
I/C	GWIC	251987		2701352.7	606835.7	PPL Montana, INC-8019	39	8	Askin Drilling	20090429
I/C	GWIC	251988		2701352.7	606835.7	PPL Montana, INC-8019	43	20	Askin Drilling	20090430
I/C	GWIC	251989		2701352.7	606835.7	PPL Montana, INC-8019	40	7	Askin Drilling	20090430
I/C	GWIC	251991		2701352.7	606835.7	PPL Montana, INC-8019	31.5	6	Askin Drilling	20090430
I/C	GWIC	251992		2701352.7	606835.7	PPL Montana, INC-8019	40	11	Askin Drilling	20090505
I/C	GWIC	251993		2701305.1	608128.8	PPL Montana, INC-8019	22	4	Askin Drilling	20090505
I/C	GWIC	251995		2700072.2	605628.7	PPL Montana, INC	80	0	Askin Drilling	20090505
I/C	GWIC	251996		2700072.2	605628.7	PPL Montana, INC	36	11	Askin Drilling	20090506
I/C	GWIC	251997		2701942.9	608797.9	PPL Montana, INC-8019	36	0	Askin Drilling	20090616
I/C	GWIC	251998		2701942.9	608797.9	PPL Montana, INC-8019	34	0	Askin Drilling	20090615
I/C	GWIC	252000		2701942.9	608797.9	PPL Montana, INC-8019	40	0	Askin Drilling	20090616
I/C	GWIC	252001		2701942.9	608797.9	PPL Montana, INC-8019	38	0	Askin Drilling	20090616
I/C	GWIC	252002		2701942.9	608797.9	PPL Montana, INC-8019	46	0	Askin Drilling	20090615
I/C	GWIC	252017		2718065.0	604159.8	PPL Montana INC.	48	40	Askin Drilling	20090618
P/O	GWIC	256898		2709344.6	589217.7	Ellison, Pete	210	50	Ronald L Askin Drilling	19760412
P/O	GWIC	256900		2716283.7	587780.4	Parkins, Charles F.	90	0		19250101
I/C	GWIC	257022		2695733.5	616996.1	Montana Power Co.	57	0	Gordon Drilling Inc	19980406
I/C	GWIC	258529		2703243.5	610140.7	Montana Power Company-UNITS 3 & 4	35	16	Gordon Drilling Inc	19830711
I/C	GWIC	258530		2703243.5	610140.7	Montana Power Company-UNITS 3 & 4	26	15	Gordon Drilling Inc	19830711
I/C	GWIC	258531		2703243.5	610140.7	Montana Power Company-UNITS 3 & 4	46	14	Gordon Drilling Inc	19830712
I/C	GWIC	259656		2692748.5	619254.6	PPL Montana, LLC	154	114	Askin Drilling	20101018
I/C	GWIC	259658		2693394.8	618986.3	PPL Montana, LLC	154	101	Askin Drilling	20101018
I/C	GWIC	259737		2695701.7	615773.0	PPL Montana, LLC	60	45	Askin Drilling	20101213
I/C	GWIC	262103		2695733.5	616996.1	PPL MT, LLC-2002 377A Well Replacement	48	31	Hansen Environmental Drilling	20020312
I/C	GWIC	262142		2696435.1	613822.9	PPL Montana-Colstrip	85	0	Ronald L Askin Drilling	20090420
I/C	GWIC	262191		2695938.4	609289.1	PPL Montana		0	Clayton Larson	20070823
I/C	GWIC	262193		2695938.4	609289.1	PPL Montana		0	Clayton Larson	20070823
I/C	GWIC	262203		2701942.9	608797.9	PPL Montana, INC-8019	35	0	Askin Drilling	20090615
I/C	GWIC	262386		2694728.6	616620.2	PPL Montana, LLC	50	23	Hydrometrics Inc	20110712
I/C	GWIC	262387		2694036.6	616044.2	PPL Montana, LLC	90	46	Hydrometrics Inc	20110712
I/C	GWIC	262390		2694379.3	615724.8	PPL Montana, LLC	40	21	Hydrometrics Inc	20110712
I/C	GWIC	262391		2695359.0	616092.4	PPL Montana, LLC	120	48	Hydrometrics Inc	20110712
I/C	GWIC	262586		2695684.0	618351.2	PPL Montana LLC	26	12	Askin Drilling	20110720
I/C	GWIC	262587		2695684.0	618351.2	PPL Montana LLC	26	9	Askin Drilling	20110720
I/C	GWIC	262588		2695585.1	621061.3	PPL Montana LLC	24	11	Askin Drilling	20110720
I/C	GWIC	262590		2694379.3	615724.8	PPL Montana LLC	100	54	Askin Drilling	20110721
I/C	GWIC	262599		2702743.8	605727.0	PPL Montana LLC	40	14	Askin Drilling	20110721
I/C	GWIC	262661		2695684.0	618351.2	PPL	10	0	Ronald L Askin Drilling	20110721
I/C	GWIC	263115		2695879.8	617172.9	PPL Montana, LLC	44	33	Askin Drilling	20110720
I/C	GWIC	263118		2695879.8	617172.9	PPL Montana, LLC	25	0	Askin Drilling	20110721
I/C	GWIC	263119		2696051.7	617346.9	PPL Montana, LLC	29	23	Askin Drilling	20110721
I/C	GWIC	263697		2715976.2	608214.1	PPL Montana, INC.	40	13	Askin Drilling	20111110
I/C	GWIC	264101		2719513.8	600198.2	PPL Montana LLC	195	118	Askin Drilling	20111107
I/C	GWIC	264102		2719513.8	600198.2	PPL Montana LLC	109	71	Askin Drilling	20111108
I/C	GWIC	264104		2720276.3	598228.0	PPL Montana LLC	18	13	Askin Drilling	20111109
I/C	GWIC	264105		2720276.3	598228.0	PPL Montana LLC	42	25	Askin Drilling	20111109
I/C	GWIC	264106		2718927.2	598177.2	PPL Montana LLC	75	31	Askin Drilling	20111109
I/C	GWIC	264109		2695022.0	617652.2	PPL Montana LLC	71	56	Askin Drilling	20111110
I/C	GWIC	264112		2695684.0	618351.2	PPL Montana LLC	26	13	Askin Drilling	20111110
I/C	GWIC	264114		2695684.0	618351.2	PPL Montana LLC	49	36	Askin Drilling	20111110
P/O	GWIC	268380		2694138.4	620939.2	Burton, Brent	100	70	Askin Drilling	20120928
I/C	GWIC	268973		2692672.2	617851.2	PPL Montana LLC	80	68	Ronald L Askin Drilling	20120809
I/C	GWIC	268974		2693105.3	615744.0	PPL Montana LLC	83	61	Ronald L Askin Drilling	20120809
I/C	GWIC	268976		2689306.0	617291.4	PPL Montana LLC	105	75	Ronald L Askin Drilling	20120810
I/C	GWIC	268978		2689720.0	617109.4	PPL Montana LLC	142	104	Ronald L Askin Drilling	20120810

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
I/C	GWIC	268980		2690542.9	616887.5	PPL Montana LLC	155	89	Ronald L Askin Drilling	20120809
I/C	GWIC	269070		2716478.1	606383.6	PPL Montana, INC	56	26	Askin Drilling	20120807
I/C	GWIC	269093		2714852.4	604889.1	PPL Montana, INC	46	29	Askin Drilling	20120808
I/C	GWIC	269094		2715154.2	604313.2	PPL Montana, INC	86	33	Askin Drilling	20120808
I/C	GWIC	269096		2715711.1	605092.8	PPL Montana, INC	58	44	Askin Drilling	20120808
I/C	GWIC	269139		2715081.5	605576.2	PPL Montana, INC	58	26	Askin Drilling	20120807
I/C	GWIC	269491		2694923.3	620358.7	PPL Montana LLC	48	29	Askin Drilling	20121016
I/C	GWIC	269494		2694923.3	620358.7	PPL Montana LLC	36	28	Askin Drilling	20121016
I/C	GWIC	269498		2697593.0	620456.3	PPL Montana LLC	57	36	Askin Drilling	20121016
I/C	GWIC	269503		2697593.0	620456.3	PPL Montana LLC	44	37	Askin Drilling	20121016
I/C	GWIC	269513		2696320.2	619056.5	PPL Montana LLC	215	58	Askin Drilling	20121017
I/C	GWIC	269519		2696320.2	619056.5	PPL Montana LLC	80	48	Askin Drilling	20121017
I/C	GWIC	271509		2720276.3	598228.0	PPL Montana LLC	23	19	Askin Drilling	20121116
I/C	GWIC	271557		2701352.7	606835.7	PPL Montana LLC	38	18	Askin Drilling	20121119
I/C	GWIC	271560		2701352.7	606835.7	PPL Montana LLC	25	19	Askin Drilling	20121119
I/C	GWIC	271563		2701305.1	608128.8	PPL Montana LLC	39	16	Askin Drilling	20121118
I/C	GWIC	271565		2701305.1	608128.8	PPL Montana LLC	37	15	Askin Drilling	20121119
I/C	GWIC	271566		2701305.1	608128.8	PPL Montana LLC	25	16	Askin Drilling	20121119
I/C	GWIC	271568		2701305.1	608128.8	PPL Montana LLC	25	16	Askin Drilling	20121119
I/C	GWIC	271570		2701305.1	608128.8	PPL Montana LLC	35	18	Askin Drilling	20121121
I/C	GWIC	271573		2701305.1	608128.8	PPL Montana LLC	41	14	Askin Drilling	20121128
I/C	GWIC	271623		2701941.8	608827.0	PPL Montana, LLC	41	13	Ronald L Askin Drilling	20121128
I/C	GWIC	271626		2701941.8	608827.0	PPL Montana, LLC	50	17	Askin Drilling	20121128
I/C	GWIC	271627		2718215.2	598810.6	PPL Montana LLC	22	16	Askin Drilling	20121117
I/C	GWIC	271628		2718215.2	598810.6	PPL Montana LLC	30	23	Askin Drilling	20121116
S	GWIC, NRIS	379	42A 27336 00	2706504.4	583537.8	Mcrea, D.	195	36		19480901
S	GWIC, NRIS	1054	42KJ 108368 00	2650153.8	612775.0	Snider D * FU-069	136	58	Rosebud Drilling Co	19640612
I/C	GWIC, NRIS	1096	42KJ 94428 00	2701504.8	610412.8	Montana Power Company	9336	560		19710907
S	GWIC, NRIS	11947	42KJ 162827 00	2635180.0	603578.8	Pinkerton, Bill	83	60		19570501
I/C	GWIC, NRIS	11972	42KJ 94831 00	2661571.9	604465.7	Ervin, Jack F.	105	28	Davis Drilling	19850619
D	GWIC, NRIS	11987	42KJ 68082 00	2655809.4	589172.1	Rhodes, Ronald & Michele	300	220	Ronald L Askin Drilling	19880407
I/C	GWIC, NRIS	11989	42A 108358 00	2675758.8	587170.5	Northern Pacific Railway Company	100	30		19570101
I/C	GWIC, NRIS	12007	42A 63135 00	2705747.7	586147.0	Peabody Coal Company	1670	373	Sargent Irrigation Co.	19860713
S	GWIC, NRIS	12019	42A 27337 00	2685332.2	583445.9	Greenleaf Land & Liv	90	30		19460901
S	GWIC, NRIS	14197	42KJ 162799 00	2638962.2	611715.7	Pinkerton, Bill	156	89		19670101
S	GWIC, NRIS	14214	42KJ 56521 00	2670010.7	624011.2	McDonald, Janet	120	70	Ronald L Askin Drilling	19840621
S	GWIC, NRIS	14215	42KJ 63106 00	2665452.2	622549.7	Dowlin, Floyd	418	300	Askin Drilling	19860521
S	GWIC, NRIS	14218	42KJ 162842 00	2679536.7	615682.8	MacDonald, Lena F	80	0		19470910
D	GWIC, NRIS	14237	42KJ 41189 00	2696297.3	619149.4	Childers, Pat & Mike	380	190	Drane Drilling Service	19810906
I/C	GWIC, NRIS	14238	42KJ 27491 00	2696297.3	619149.4	Premier Homes	332	70	Barrus Drilling and Pump Co	19800327
I/C	GWIC, NRIS	14240	42KJ 58886 00	2697058.3	615882.4	Penn, Bill	800	360	Ronald L Askin Drilling	19841120
D	GWIC, NRIS	14241	42KJ 18630 00	2695660.6	618463.4	Childers, Pat	220	50	Drane Drilling Service	19780407
I/C	GWIC, NRIS	14242	42KJ 22277 00	2694360.0	617109.8	Seward, Ivan	300	110	Ronald L Askin Drilling	19781216
P/O	GWIC, NRIS	14247	42KJ 56661 00	2696685.9	617508.0	Alder, Eugene	180	105	Drane Drilling Service	19841022
I/C	GWIC, NRIS	14254	42KJ 5632 00	2698510.9	610741.1	Frontier Village	175	40	Ronald L Askin Drilling	19731125
I/C	GWIC, NRIS	14255	42KJ 25025 00	2698510.9	610741.1	Montana Frontier	460	200	Ronald L Askin Drilling	19791018
I/C	GWIC, NRIS	14256	42KJ 142733 00	2698332.1	607812.4	Montana Power Co.	1520	60		19260401
S	GWIC, NRIS	14271	42A 173935 00	2717653.8	607834.9	Egan Joe	110	80	ÿ	19471001
I/C	GWIC, NRIS	126402	42A 80567 00	2705702.8	587463.2	Peabody Coal Co	400	137	H & H Drilling	19910726
I/C	GWIC, NRIS	136771	42KJ 85507 00	2681648.1	597006.3	County of Rosebud	141	70	Higgins Drilling Company	19930514
D	GWIC, NRIS	154780	42KJ 96586 00	2696022.7	617488.5	Childers, Mike	320	157	Drane Drilling Service	19940808

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
S	GWIC, NRIS	172113	42KJ 108379 00	2659633.2	623705.7	Moose Lodge	420	45	Gordon Drilling Inc	19980929
S	GWIC, NRIS	203270	42A 30007829	2717915.2	588976.9	Aberle, Joe	320	80		19780101
S	NRIS		42A 108301 00	2695464.0	577234.7					19491231
S	NRIS		42A 146426 00	2716842.9	611766.5					19550101
S	NRIS		42A 27339 00	2680091.6	584379.4					19451231
S	NRIS		42A 27702 00	2718083.2	593280.4		140			19800513
S	NRIS		42A 30007851	2707965.4	615133.6		260			20030915
I/C	NRIS		42A 30010169	2683188.8	598053.2					20040325
S	NRIS		42A 30052376	2716281.1	608444.8					20111214
S	NRIS		42A 30052440	2715308.9	615020.0		280			20111228
S	NRIS		42A 37975 00	2716294.7	587928.1					19250615
S	NRIS		42A 42807 00	2711289.7	597570.5					19820319
S	NRIS		42A 48616 00	2717710.3	604533.7					19820720
S	NRIS		42A 52220 00	2673974.6	589469.9					19830321
I/C	NRIS		42A 52443 00	2706432.0	585518.3		300			19830706
S	NRIS		42A 54847 00	2712179.5	608824.6		63			19831129
S	NRIS		42A 54878 00	2719287.3	596628.5		130			19831223
I/C	NRIS		42A 56520 00	2701109.6	585971.3		67			19840716
S	NRIS		42A 58905 00	2686489.3	579851.9		120			19850322
I/C	NRIS		42A 58906 00	2689057.9	581251.0		97			19850322
I/C	NRIS		42A 5968 00	2706342.5	588148.1		297			19750715
I/C	NRIS		42A 5969 00	2706432.0	585518.3					19750715
I/C	NRIS		42A 63110 00	2707093.8	585547.3		320			19860707
D	NRIS		42A 8398 00	2709284.6	589256.4		220			19760521
S	NRIS		42KJ 106423 00	2678897.5	600217.1		80			19561231
S	NRIS		42KJ 106449 00	2652565.3	597322.5		143			19431231
S	NRIS		42KJ 106451 00	2657776.3	599475.2		115			19541231
S	NRIS		42KJ 106456 00	2667278.4	607367.3		140			19571231
S	NRIS		42KJ 106458 00	2677180.4	605691.4		252			19591231
S	NRIS		42KJ 108298 00	2686800.2	598037.0		125			19631206
S	NRIS		42KJ 108360 00	2650153.8	612775.0					19650218
S	NRIS		42KJ 108382 00	2646607.4	597113.8		325			19601231
S	NRIS		42KJ 108499 00	2668557.1	593253.4					19811230
S	NRIS		42KJ 108508 00	2636571.7	601411.6					19811230
S	NRIS		42KJ 108525 00	2662232.1	604483.3					19811230
I/C	NRIS		42KJ 108793 00	2697025.0	617189.0		420			19990713
D	NRIS		42KJ 113990 00	2660939.6	603631.2		395			20010403
I/C	NRIS		42KJ 142734 00	2698300.7	608470.5		595			19360830
I/C	NRIS		42KJ 142735 00	2697635.6	608440.6		518			19430115
I/C	NRIS		42KJ 142736 00	2699630.5	608516.4		514			19460731
D	NRIS		42KJ 15835 00	2690036.5	599959.0		280			19771026
S	NRIS		42KJ 162807 00	2667088.6	613952.3					19601231
S	NRIS		42KJ 162817 00	2681476.8	617079.3		86			19461106
S	NRIS		42KJ 162836 00	2633979.8	600001.9		115			19580519
S	NRIS		42KJ 162839 00	2681455.9	617740.9					19111231
S	NRIS		42KJ 162840 00	2658044.4	609729.3					19451231
S	NRIS		42KJ 177104 00	2654046.3	614881.5					19560228
S	NRIS		42KJ 177107 00	2647407.2	615985.3					19470807
S	NRIS		42KJ 177109 00	2648747.6	615366.0					19590206
D	NRIS		42KJ 177153 00	2690053.3	599464.4					19471231
D	NRIS		42KJ 177605 00	2690053.3	599464.4					19471130
D	NRIS		42KJ 177606 00	2644965.9	609950.6					19501231
D	NRIS		42KJ 177608 00	2658044.4	609729.3					19381231
S	NRIS		42KJ 177609 00	2690053.3	599464.4					19471231
S	NRIS		42KJ 177610 00	2690053.3	599464.4					19471130
S	NRIS		42KJ 183220 00	2684693.0	601276.6					19321031
S	NRIS		42KJ 183243 00	2654018.4	593405.3					19300630
S	NRIS		42KJ 183263 00	2686800.2	598037.0					19600508
S	NRIS		42KJ 183290 00	2659960.8	593604.7		145			19460930
S	NRIS		42KJ 183295 00	2636681.0	598111.7					19580430
S	NRIS		42KJ 183300 00	2642118.8	603404.8		150			19460628
S	NRIS		42KJ 183311 00	2652565.3	597322.5					19470410
S	NRIS		42KJ 183323 00	2683426.4	599715.7					19600831
S	NRIS		42KJ 183328 00	2673816.4	594089.7					19141231
S	NRIS		42KJ 183330 00	2647267.9	597136.2					19551231
S	NRIS		42KJ 183336 00	2678897.5	600217.1					19460404
S	NRIS		42KJ 183471 00	2667278.4	607367.3					19490430
S	NRIS		42KJ 183487 00	2657468.5	588896.5		220			19541220

Attachment F
Groundwater Users (a)

Type (b)	Source (c)	GWIC ID	WR Number	NAD83 St Plane Easting	NAD83 St. Plane Northing	Name	Well Depth	SWL	Driller	Date yyyymmdd (d)
S	NRIS		42KJ 183506 00	2679646.1	597596.7					19141231
S	NRIS		42KJ 183511 00	2632371.0	611480.8					19540831
S	NRIS		42KJ 183535 00	2654677.8	593426.4		110			19470702
D	NRIS		42KJ 183536 00	2673816.4	594089.7					19141231
S	NRIS		42KJ 30007772	2692821.4	612138.5		120			20030729
S	NRIS		42KJ 30007849	2676304.7	598806.4		247			20030915
S	NRIS		42KJ 30011414	2666770.6	613615.6		293			20040712
S	NRIS		42KJ 30015552	2678733.1	605018.3		280			20050620
S	NRIS		42KJ 30052441	2642504.6	601597.2		298			20120103
S	NRIS		42KJ 30052533	2655463.4	605016.1		155			20120117
D	NRIS		42KJ 39568 00	2690053.3	599464.4					19471231
D	NRIS		42KJ 39570 00	2690053.3	599464.4					19471231
I/C	NRIS		42KJ 42049 00	2701912.7	608812.6					19820304
S	NRIS		42KJ 42797 00	2636571.7	601411.6					19820319
S	NRIS		42KJ 42801 00	2661571.9	604465.7		380			19820319
S	NRIS		42KJ 42802 00	2668557.1	593253.4					19820319
S	NRIS		42KJ 42810 00	2663677.7	617852.0					19820319
S	NRIS		42KJ 44176 00	2654677.8	593426.4					19820406
S	NRIS		42KJ 45734 00	2643383.4	617824.4					19820415
S	NRIS		42KJ 46519 00	2636389.4	609638.6					19820427
S	NRIS		42KJ 52501 00	2703166.8	602558.9		120			19830622
I/C	NRIS		42KJ 52502 00	2683470.9	598393.9		120			19830622
I/C	NRIS		42KJ 52503 00	2683448.4	599054.8		140			19830622
I/C	NRIS		42KJ 52504 00	2683470.9	598393.9		38			19830622
S	NRIS		42KJ 52505 00	2696440.1	605731.8		145			19830622
I/C	NRIS		42KJ 52531 00	2693963.2	600922.1					19830812
I/C	NRIS		42KJ 52532 00	2691985.7	600850.6					19830812
S	NRIS		42KJ 54877 00	2694529.8	603586.6		47			19831223
I/C	NRIS		42KJ 55013 00	2696330.1	617830.0		180			19840509
D	NRIS		42KJ 56662 00	2696685.9	617508.0					19841204
I/C	NRIS		42KJ 589 00	2692256.2	602514.1		84			19731003
I/C	NRIS		42KJ 58918 00	2696330.1	617830.0		820			19850503
I/C	NRIS		42KJ 63113 00	2673883.6	606244.6		355			19860716
S	NRIS		42KJ 78675 00	2661098.3	626747.8		68			19910912
D	NRIS		42KJ 80635 00	2656150.0	588853.3		120			19920615
S	NRIS		42KJ 8210 00	2667874.5	593891.0					19400415
I/C	NRIS		42KJ 870 00	2699906.3	609483.9		653			19731030
I/C	NRIS		42KJ 871 00	2699753.7	613358.5		795			19731030
I/C	NRIS		42KJ 872 00	2698808.5	604074.3		84			19731030
I/C	NRIS		42KJ 94426 00	2699753.7	613358.5					19820422
M	NRIS		42KJ 94430 00	2700254.0	609157.2		450			19820422

Notes

(a) Groundwater users within 3 miles downgradient and one mile upgradient from A, B, C permit boundaries

(b) Types
D = Domestic
I/C = Industrial or Commercial
M = Municipal
MW = Monitoring Well
P/O = Private or Other
S = Stock

(c) Two public datasets from the National Resource Information System (NRIS) were consulted: GWIC wells and Water Rights Data
Mined out wells were removed from the selection. When enough data was available (well depth and completion/priority date) duplicate entries were merged.

(d) Completion or priority date.

Attachment G
Area B Hydrology

Area B – AM4 (Application Amendment 00184)
Comprehensive Evaluation of Probable Hydrologic Consequences
Areas A, B and C
Western Energy Rosebud Mine

Exhibit 8

East Fork Armells Creek Hydrological Model

The hydrologic model inputs for Tables G-1, G-2, G-3, G-4, and G-5 are for a single basin model of East Fork Armells Creek from the headwater to the Highway 39 overpass with the characteristics shown in Exhibits 1 and 2. Contours and channels for the premine model were created from premine Digital Terrain Model (DTM) for Mine Areas A, B, and C from their respective approved permits tied to contours and channels digitized from USGS outside the bounds of the DTM. Contours and channels for the post mine were created from DTM for Mine Areas A, B, and C from their respective approved permits tied to premine DTM and digitized USGS contours and channels outside the bounds of the DTM.

TABLE G-1

PREMINE AND POSTMINE GEOMORPHIC CHARACTERISTICS FOR EAST FORK ARMELLS CREEK FROM HEADWATER TO HIGHWAY 39 CROSSING

Drainage Basin	Drainage Area (sq-mi)	Basin Slope[1] (ft/mi)	Drainage Basin Length[2] (ft)	Elon-gation Ratio[3]	Basin Relief[4] (ft)	Basin Perimeter (ft)	Basin Relief Ratio[5] (ft/ft)	Relative Relief[6] (ft/ft)	Total Stream Length[7] (mi)	Drainage Density[8] (mi/sq-mi)	Main Channel Length (ft)	Channel Sinuosity[9] (ft/ft)	Elevation Difference[10] (ft)	Channel Slope[11] (%)	Valley Length (ft)
Armells Creek Pre	34.412	687	74517	0.019	1530	196403	0.021	0.008	115.26	3.35	127634	1.87	1350	1.06	68394
Armells Creek Post	34.560	685	74517	0.019	1530	205919	0.021	0.007	120.08	3.47	127634	1.87	1350	1.06	68394

Notes:

1 Mean basin slope (ft/mi) = [contour interval(ft)][length of contours (mi)] / [drainage area (sq-mi)].
2 Drainage basin length represents the straight line distance from the divide above the dominant channel to the basin mouth.
3 Elongation ratio = (diameter of a circle having the same area as the drainage basin) / (drainage basin length).
4 Basin relief represents the elevation difference between the highest point on the basin boundary and the basin mouth.
5 Basin relief ratio = (basin relief) / (drainage basin length).
6 Relative relief = (basin relief) / (basin perimeter).
7 Total stream length represents the total discernible channel length within the individual drainage, as determined from base and postmine topography interpretation
8 Drainage density = (total stream length) / (drainage area).
9 Channel sinuosity = (channel length) / (valley length).
10 Channel slope represents the overall slope of the main channel as determined by: channel slope = (elevation difference) / (channel length).
11 Valley length represents the length of the surveyed main channel from its surveyed head to the basin mouth, excluding meanders.

TABLE G-2

COMPARISON OF PREMINE AND POSTMINE DRAINAGE BASIN CHARACTERISTICS AND FLOOD RESULTS FOR EAST FORK ARMELLS CREEK FROM HEADWATER TO HIGHWAY 39 CROSSING

Drainage	Drainage Area (sq-mi)		Watercourse Length (ft)		Elevation Difference (ft)		100-yr, 24-hr Peak Discharge [1] (cfs)		100-yr, 24-hr Runoff Volume [1] (ac-ft)		100-yr, 6-hr Peak Discharge [1] (cfs)		100-yr, 6-hr Runoff Volume [1] (ac-ft)	
Basin	Premine	Postmine	Premine	Postmine	Premine	Postmine	Premine	Postmine	Premine	Postmine	Premine	Postmine	Premine	Postmine
Armells Creek	34.41	34.56	127,634	127,634	1350	1350	801.6	805.1	2092.0	2101.1	274.2	275.4	691.1	694.1

Notes:

1 Runoff volumes and peak discharges were computed by the Hydrology Module for SurvCADD Software using the SCS Type II precipitation distribution.

TABLE G-3

PREMINE AND POSTMINE RUNOFF CALCULATIONS FOR EAST FORK ARMELLS CREEK FROM HEADWATER TO HIGHWAY 39 CROSSING

Drainage	Drainage Area (sq-mi)		2-yr, 24-hr Peak Discharge [1] (cfs)		2-yr, 24-hr Runoff Volume [1] (ac-ft)		10-yr, 24-hr Peak Discharge [1] (cfs)		10-yr, 24-hr Runoff Volume [1] (ac-ft)		25-yr, 24-hr Peak Discharge [1] (cfs)		25-yr, 24-hr Runoff Volume [1] (ac-ft)	
Basin	Premine	Postmine	Premine	Postmine	Premine	Postmine	Premine	Postmine	Premine	Postmine	Premine	Postmine	Premine	Postmine
Armells Creek	34.41	34.5600	46.7	49.9	130.5	131.1	278.8	280.0	731.8	734.9	462.6	464.6	1210.9	1216.2

Notes:

1 Runoff volumes and peak discharges were computed by the Hydrology Module for SurvCADD Software using the SCS Type II precipitation

Exhibit 8

TABLE G-4

PEAK PREMINE DISCHARGES OF EAST FORK ARMELLS CREEK FROM HEADWATER TO HIGHWAY 39 CROSSING, CALCULATED FROM OMANG (1992) REGIONAL FLOOD FREQUENCY EQUATIONS

Drainage Basin	Drainage Area (sq-mi)	Mean Basin Elev, E [1] (ft)	Premine Peak Flows (in cfs) for the Given Flood Recurrence Interval Below [2]					
			2 yrs	5 yrs	10 yrs	25 yrs	50 yrs	100 yrs
Postmine								
Armells Creek	34.41	3715	82.5	238.5	403.8	693.2	954.2	1273.3
Postmine								
Armells Creek	34.56	3711	83.0	239.7	405.8	696.7	958.8	1279.4

Notes:

1 Mean basin elevation was determined from a 25-ft grid using SurvCADD software.

2 Taken from: Omang (1992). USGS Water-Resources Investigation Report 92-4048.

FLOOD FREQUENCY EQUATIONS BASED ON BASIN CHARACTERISTICS

Recurrence Interval	Mathematical Equation	Standard Error
2 years	$537\ A^{0.55}(E/1000)^{-2.91}$	128
5 years	$1350\ A^{0.53}(E/1000)^{-2.75}$	85
10 years	$2050\ A^{0.52}(E/1000)^{-2.64}$	70
25 years	$3240\ A^{0.51}(E/1000)^{-2.55}$	59
50 years	$4160\ A^{0.50}(E/1000)^{-2.47}$	56
100 years	$5850\ A^{0.50}(E/1000)^{-2.51}$	58

A = Drainage Area
E = Mean Basin Elevation

TABLE G-5

COMPARISON OF RUNOFF ESTIMATING TECHNIQUES FOR EAST FORK ARMELLS CREEK FROM HEADWATER TO HIGHWAY 39 CROSSING

Drainage Basin	CN [1]	2-yr, 24-hr Peak Discharge (cfs)			10-yr, 24-hr Peak Discharge (cfs)			25-yr, 24-hr Peak Discharge (cfs)		
		SCS [2]	Omang [3]	% Change	SCS [2]	Omang [3]	% Change	SCS [2]	Omang [3]	% Change
Premine										
Armells Creek	69	46.7	82.5	76.9	278.8	403.8	44.8	462.6	693.2	49.9
Postmine										
Armells Creek	69	49.9	83.0	66.4	280.0	405.8	44.9	462.6	696.7	50.6

Notes

1 This is the curve number that was used in the SCS method of runoff determination.

2 These values were calculating using the Hydrology Module for SurvCADD Software, a computer adaptation of the SCS triangular hydrograph method of runoff calculation. See Table 3.

3 These values were calculated using Omang (1992), which estimates peak flow magnitude using regional flood-frequency equations based on drainage basin characteristics. See Table 4.

T 1 N

R 39 E

R 40 E

R 41 E

Legend

- Armels Drainage Boundary
- Armels Drainage
- Armels Drainage Tributary
- Section Lines

REVISIONS	DESCRIPTION	DATE	CAD DESIGNER	CHECKER

Western Energy Company -*Rosebud Mine*
A Subsidiary of WESTMORELAND COAL COMPANY
P.O. 99 Colstrip, MT 59323 (406)748-5100

EXHIBIT 1

East Fork Armells
Premine Drainage Boundary

GRAPHICS DESIGNER: DM	DATE COMPLETED: 2014/01
DESIGNED BY: WS	Base:
SCALE: NOT TO SCALE	Date:
CAD DRAWING: Area B Hydro Study 2014-01.dwg	

Exhibit 8

T 1 N

R 39 E

R 40 E

R 41 E

Legend

- Armels Drainage Boundary
- Armels Drainage
- Armels Drainage Tributary
- Section Lines

REVISIONS	DESCRIPTION	DATE	CAD DESIGNER	CHECKER
.		.	.	.
.		.	.	.

Western Energy Company -*Rosebud Mine*
A Subsidiary of WESTMORELAND COAL COMPANY
P.O. 99 Colstrip, MT 59323 (406)748-5100

EXHIBIT 2

East Fork Armells
PMT Drainage Boundary

GRAPHICS DESIGNER: DM	DATE COMPLETED: 2014/01
DESIGNED BY: WS	Base:
SCALE: NOT TO SCALE	Contour:
CAD DRAWING: Area B Hydro Study PMT 2014-01.dwg	

Exhibit 8

Montana DEQ - Water Quality Standards Attainment Record

Reporting Cycle: 2014 **Assessment Record:** MT42K002_110.pdf **Status:** Unassigned

ASSESSMENT UNIT INFORMATION

Reporting Cycle:	2014
Assessment Unit:	MT42K002_110
Waterbody Name:	East Fork Armells Creek
Location Description:	EAST FORK ARMELLS CREEK, Colstrip to mouth (Armells Creek)

Water Type:	**Size (Miles/Acres)**	**Use Class:**
RIVER	32.36 MILES	C-3

Hydrologic Unit Code:	10100001
HUC Name:	Lower Yellowstone-Sunday
Watershed:	Lower Yellowstone
Basin:	Yellowstone
TMDL Planning Area:	Middle Yellowstone Tributaries
Ecoregion:	Northwestern Great Plains
County:	ROSEBUD CO
Lat/Long AU Start (U/S):	45.886051 / -106.622164
Lat/Long AU End (D/S):	46.092603 / -106.761847

MONITORING INFORMATION

Date Assessment Started: 03/28/2008 **Assessed By:** Stermitz, Mike

Next Scheduled Monitoring Date:

Reporting Cycle: 2014 **Assessment Record:** MT42K002_110.pdf **Status:** Unassigned

CITATIONS

Citation	Location	Biological Data	Habitat Data	Chemistry Data
Van Voast, Wayne A. ; Hedges, Robert B. ; McDermott, John J. (1977), Hydrogeologic Conditions and Projections Related to Mining Near Colstrip, Southeastern Montana, Bulletin 102	DEQ Metcalf Stacks			common ions, pH, conductivity, miscellaneous; metals
Botz, Maxwell K. (1978), Characteristics and Potential Impact of Wastewaters from a Coal-Fired Power Plant at Colstrip, Montana	DEQ Metcalf Stacks			common ions, pH, conductivity, miscellaneous; major nutrients; metals
Melancon, Susan ; Hess, B.C. ; Thomas, Robert B. (1979), Assessment of Energy Resource Development Impact on Water Quality: The Tongue and Powder River Basins, EPA-600/7-79-249	DEQ Metcalf Stacks	fish	riparian &/or instream surveys & physical features	common ions, pH, conductivity, miscellaneous; major nutrients; metals
Bahls, Loren L. (1980), Salinity and the Structure of Benthic Algae (Periphyton) Communities in Streams of the Southern Fort Union Region, Montana, USGS Research Grant #14-08-0001-G-503	DEQ Metcalf Stacks	algae	riparian &/or instream surveys & physical features	common ions, pH, conductivity, miscellaneous; major nutrients
Klarich, Duane A. ; Regele, Stephen M. ; Bahls, Loren L. (1980), Data Report for the Benthic Macroinvertebrate and Periphyton Community Inventory of Streams Draining the Southern Fort Union Coalfield Region of Southeastern Montana, USGS Research grant #14-08-0001-G-503	DEQ Metcalf Stacks	algae; fecal coliforms; macroinvertebrates		common ions, pH, conductivity, miscellaneous; major nutrients; metals; quantitative physical data
Klarich, Duane A. ; Regele, Stephen M. (1980), Structure, General Characteristics, and Salinity Relationships of Benthic Macroinvertebrate Associations in Streams Draining the Southern Fort Union Coalfield Region of Southeastern Montana, USGS Grant #14-08-0001-G-503	DEQ Metcalf Stacks	algae; fecal coliforms; macroinvertebrates	riparian &/or instream surveys & physical features	common ions, pH, conductivity, miscellaneous; metals; quantitative physical data
(1981), Field Notes and Data Collected for "Biological Water Quality Monitoring Eastern Montana 1979"	DEQ PPA Data Archive			

Reporting Cycle: 2014 **Assessment Record:** MT42K002_110.pdf **Status:** Unassigned

Citation	Location	Biological Data	Habitat Data	Chemistry Data
Montana Standard (1981), Order Issued on Colstrip Seep : Montana Standard Newspaper Article 6/06/1981	Assessment Record			common ions, pH, conductivity, miscellaneous
(1997), Pre 1997 Field Assessments	Assessment Record	algae; chlorophyll; fecal coliforms; fish; macroinvertebrates	Land use; photo points; riparian &/or instream surveys & physical features	Rosgen type; benthic sediment data; bioaccumulation; common ions, pH, conductivity, miscellaneous; major nutrients; metals; quantitative physical data
Erbes, Dan (1998), Montana Dept. of Environmental Quality Letter to Office of Surface Mining and Reclaimation	Assessment Record			common ions, pH, conductivity, miscellaneous; quantitative physical data
Montana Department of Fish, Wildlife, and Parks (1999), Montana Rivers Information System (MRIS)	Assessment Record	algae; fish; macroinvertebrates; wildlife	Land use; riparian &/or instream surveys & physical features	common ions, pH, conductivity, miscellaneous; quantitative physical data
(2005), DEQ Field Assessment Form	Assessment Record	algae; chlorophyll; fecal coliforms; fish; macroinvertebrates	Land use; photo points; riparian &/or instream surveys & physical features	Rosgen type; benthic sediment data; bioaccumulation; common ions, pH, conductivity, miscellaneous; major nutrients; metals; organics; quantitative physical data

Reporting Cycle: 2014 **Assessment Record:** MT42K002_110.pdf **Status:** Unassigned

Citation	Location	Biological Data	Habitat Data	Chemistry Data
Suplee, Michael W. (2005), Best Use of the June 2005 Nutrient Data Statistical Summaries	DEQ Metcalf Stacks	algae		major nutrients
Berscheid, Jolene (2006), STORET/Storease Data Archive [Electronic Resource]	DEQ Metcalf Multimedia Case	General; algae; chlorophyll; fecal coliforms; fish; macroinvertebrates; other bacteriological data	General; Land use; riparian &/or instream surveys & physical features	General; Rosgen type; benthic sediment data; common ions, pH, conductivity, miscellaneous; imagery data; major nutrients; metals; organics; quantitative physical data
Montana Department of Fish, Wildlife, and Parks (2006), Montana Rivers Information System (MRIS): Montana Fisheries Information System (MFISH) - http://maps2.nris.mt.gov/scripts/esrimap.dll?name=MFISH&Cmd=INST	Assessment Record	fish; wildlife	Land use; riparian &/or instream surveys & physical features	benthic sediment data; common ions, pH, conductivity, miscellaneous; quantitative physical data
Montana Bureau of Mines and Geology (nnnn), GWIC Data from http://mbmggwic.mtech.edu/	Assessment Record	algae	Land use; riparian &/or instream surveys & physical features	benthic sediment data; common ions, pH, conductivity, miscellaneous; major nutrients; metals; quantitative physical data

Comments:

DATA MATRIX
Biological Data

Comments: Not enough data available to conclude anything about the fishery. Macroinvertebrates sampled at 3 sites in 2005. Very few animals were collected at the lower site, indicating thermal extremes or periodic dewatering. The dominant taxon was a tolerant dragonfly. Emergent macrophytes probably provided a significant portion of the habitat space. Nutrient enrichment was suggested at the middle and upper sites. Periodic dewatering may have influenced the biology at the middle site. Blackfly larvae made up 52% of the sample at the middle site, while midges made up 44% of the upper site. Filamentous algae may have been prevalent at the upper site. At least 2 sites suggested poor biotic communities. The chlorophyll a value at all 3 sites was below criteria.

From Colstrip to mouth (Armells Creek)

Data Type	Comments	Catalog Number	Citation
fish	No fishery data.	Common.General.DR 8	Montana Department of Fish, Wildlife, and Parks (1999), Montana Rivers Information System (MRIS)
fish	2005: 2 sites visited in 2003 were dry (RM 7.2 and 42.8). RM 24.8 to 24.9 sampled in 2003, no fish captured. RM 19.2 to 19.3 sampled in 2001, 2 Plains Killifish captured.	Common.General.DR 8	Montana Department of Fish, Wildlife, and Parks (2006), Montana Rivers Information System (MRIS): Montana Fisheries Information System (MFISH) - http://maps2.nris.mt.gov/scripts/esrimap.dll?name=MFISH&Cmd=INST

Upper

Data Type	Comments	Catalog Number	Citation
chlorophyll	Upper: 0.30 mg/m^2.	Common.General.DR 8	(2005), DEQ Field Assessment Form
macroinvertebrates	Upper: Midges (44%) dominated the sample. Orthocladius sp. was also among the taxa here; together, these midges suggest that filamentous algae may have been prevalent. Nutrient enrichment is implied. Overall taxa richness (28) was marginal; instream habitat diversity may have been limited. 4 specimens of Dubiraphia sp. were collected, making it less likely that dewatering or thermal extremes affected the biota. Bramlett's IBI score = 33.75%,	Common.General.DR 8	(2005), DEQ Field Assessment Form

Data Type	Comments	Catalog Number	Citation
	indicating poor water quality.		

Lower and Middle

Data Type	Comments	Catalog Number	Citation
chlorophyll	Lower: 0.50 mg/m^2. Middle: 0.50 mg/m^2.	Common.General.DR 8	(2005), DEQ Field Assessment Form
macroinvertebrates	Lower: Very few animals collected here. Low abundance of invertebrates can be an indication of severe habitat disturbance, toxic pollutants, frequent dewatering, or thermal extremes. While metrics may not be used, a few observations about the composition can be ventured. The dominant taxon was the dragonfly Lestes sp., considered a tolerant ordinate. The mayfly Callibaetis sp. was present at the site, suggesting that emergent macrophytes probably provided a significant proportion of instream habitat space. Middle: Blackfly larvae (Simulium sp.) were the dominant taxon collected, accounting for 52% of the animals. The abundance of these animals suggests lotic conditions. Another tolerant taxon, Physa sp., was also present in significant numbers. These taxa suggest that nutrient-rich particulates and algal films were a major energy source in the reach; nutrient enrichment may be indicated. Periodic dewatering may influence the biology, since no less-mobile semivoltine taxa were collected. Bramlett's IBI score = 24.71%, indicating poor water quality.	Common.General.DR 8	(2005), DEQ Field Assessment Form

Reporting Cycle: 2014 **Assessment Record:** MT42K002_110.pdf **Status:** Unassigned

DATA MATRIX

Habitat Data

Comments: Site visits in 1979 reported stable banks and a channel covered with macrophytes (cattails). 3 sites visited in 2005. The banks were stable vertically and horizontally, and were well vegetated with deep-rooted grasses. The stream had access to a floodplain, and active erosion was minimal. Long, deep glides were prevalent, and the substrate was mostly silt. Macrophyte growth (cattails) is common. Where cattails are not present, sediment moves during major storm events. A lack of trees was noted, but they probably are not required for sustainability. Some rip rap, culverts, and garbage was noted through town. The overall habitat is least or slightly impaired.

From Colstrip to mouth (Armells Creek)

Data Type	Comments	Catalog Number	Citation
photo points	19 reach photos.	Common.General.DR8	(2005), DEQ Field Assessment Form
riparian &/or instream surveys & physical features	Visited twice in 1979, below Colstrip. 7/79: Banks vegetated and stable. Substrate 40% detritus, 30% muck, 10% gravel, 20% sand/silt. 99% pools. Substrate 90% covered with macrophytes. 3/70: Banks vegetated and stable. Substrate 30% detritus, 30% muck, 40% sand/silt. Substrate 0% covered with macrophytes, mostly bare shifting silt and muck. Lots of cattails.	Lower Missouri.General.DATA	(1981), Field Notes and Data Collected for "Biological Water Quality Monitoring Eastern Montana 1979"
riparian &/or instream surveys & physical features	Stream Reach Assessment: Assessment includes the town of Colstrip. Water first starts "flowing" at Hwy 39, at the So. end of Colstrip, below the mine. The stream appears intermittent through town. No land disturbances were observed from Colstrip to the mouth. In town there were several road crossing, culverts, rip-rap, and bank encroachment. The stream runs through a golf course below town. Stream bottom all silt/clay, abundant submerged vegetation. Long deep glides are prevalent. The lack of trees probably contributes slightly to elevated water temps. There were no noticeable alterations to flow. Aquatic plants consist of rush, sedge, cattails.	Common.General.DR8	(2005), DEQ Field Assessment Form

Data Type	Comments	Catalog Number	Citation
	Some algae growing on submerged veg. Banks appear to be grazed seasonally. Riparian Assessment: Stream appears stable vertically and horizontally. The amount of riparian vegetation is optimal, although the kind of vegetation is sub-optimal (lacks trees and brush). Only a few mature trees are present, although they are probably not required for sustainability. Little erosion observed, the stream has adequate characteristics to dissipate energy. Overall the habitat is in good shape.		

Upper

Data Type	Comments	Catalog Number	Citation
riparian &/or instream surveys & physical features	Upper: Site fairly pristine and appealing. Site is basically a wetland, with a small discernable channel. Water is flowing through cattails. Heavy macrophyte growth, sparse filamentous algae. Substrate 100% silt. No "pools", but channel is deep. No alteration present. Sediment does not move, but covers bottom. Bank stability optimal, only eroded at cow paths, then very little. Bank vegetation protection optimal on RB, sub-optimal on LB (lacking age classes of trees).	Common.General.DR 8	(2005), DEQ Field Assessment Form

Lower and Middle

Data Type	Comments	Catalog Number	Citation
riparian &/or instream surveys & physical features	Lower: Site fairly pristine and appealing. Many minnows observed. Macroinvertebrate Habitat Assessment: Substrate mostly silt, some woody debris, grass, rush. Site is 1 long, deep glide or pool. Channel alteration absent. Banks stable, but	Common.General.DR 8	(2005), DEQ Field Assessment Form

Data Type	Comments	Catalog Number	Citation
	sediment moves w/in channel during major storm events. Bank stability and vegetation protection optimal; grass, brush, scattered adult and young adult trees, forbs. Little evidence of erosion except for a few cow paths. Stream appears to be recovering and a new riparian zone is establishing. Middle: Site somewhat disturbed. Moderate filamentous algae and macrophyte growth. Heavy sedge growth and lots of submerged veg. Macroinvertebrate Habitat Assessment: Substrate mostly silt, some small pebbles; lots of sedge, grass. No "pools" present, reach is a long, narrow, deep glide. Channel alteration absent. Little sediment movement, though the bottom is silt. Bank stability and vegetation protection optimal; no trees or woody vegetation, but good grass cover. With the exception of trees, "as good as it gets" on a prairie stream.		

Reporting Cycle: 2014 **Assessment Record:** MT42K002_110.pdf **Status:** Unassigned

DATA MATRIX

Chemistry Data

Comments: East Fork Armells is typical of most streams in this region. The water is very hard, saline, and high in sulfates. Where TSS data was available (2005), concentrations were low. Mining activities (including water pumped from the Yellowstone River to seeping ponds) likely have contributed to increased TDS concentrations and "water logging" below Colstrip. Water logging may not currently be ocurring. The elevated SC concentrations make this water unsuitable for irrigation under ordinary circumstances. The soils must be permeable, drainage must be adequate, water must be applied in excess, and very salt-tolerant crops should be selected. This water is acceptable for use with livestock accustomed to its use, but is not recommended for pregnant or lactating cows. Data from the 1970's show that NO2+NO3 regularly exceeded criteria, although this was not the case in 2005. In 2005, TKN at the lower site moderately exceeded the contact recreation criteria, and slightly exceeded the aquatic life criteria. At the middle site, contact recreation and aquatic life criteria were slightly exceeded. The most reliable metals data is from the 2005 assessment, which showed no exceedences.

From 1/2 mile above highway 39 to mouth (Armells Creek)

Data Type	Comments	Catalog Number	Citation
common ions, pH, conductivity, miscellaneous	Water in the creek is less mineralized upstream from Colstrip than it is downstream from the town. The water downstream from the town chemically resembles water from ponds in the former Rosebud mine pits. Pre mining data are not adequate for specific comparisons between the past and the present, but statistical tests of variances and means indicate that no significant changes in water quality have occurred since 1923.	Yellowstone.General.gm398	Van Voast, Wayne A. ; Hedges, Robert B. ; McDermott, John J. (1977), Hydrogeologic Conditions and Projections Related to Mining Near Colstrip, Southeastern Montana, Bulletin 102
common ions, pH, conductivity, miscellaneous	Water in the East Fork Armells Creek is very hard, alkaline, magnesium sulfate type and has a high concentration of dissolved minerals. Water quality in this stream is poor and is not suited for irrigation, water supply, or most uses. The stream, in its natural state, does not meet States requirement for B-D3 streams to be suitable for growth and propagation of non-salmonid fishes. If the Colstrip flyash pond leaked, it would eventually reach the East Fork of Armells. No measurable impacts are expected due to the stream's poor quality and high flow relative to	Yellowstone.Lower Yellowstone-Sunday.pu130	Botz, Maxwell K. (1978), Characteristics and Potential Impact of Wastewaters from a Coal-Fired Power Plant at Colstrip, Montana

Data Type	Comments	Catalog Number	Citation
	expected groundwater seepage. Calcium=377 mg/L; Sodium=295 mg/L; Chloride=61 mg/L; Magnesium=381 mg/L; Bicarbonate=449 mg/L; Carbonate=<1.0 mg/L; Sulfate=2362 mg/L; Alkalinity=368 mg/L.		
common ions, pH, conductivity, miscellaneous	1974-1977: Sulfates exceeded recommended levels in 29 out of 30 samples.	Yellowstone.General.wq075	Melancon, Susan ; Hess, B.C. ; Thomas, Robert B. (1979), Assessment of Energy Resource Development Impact on Water Quality: The Tongue and Powder River Basins, EPA-600/7-79-249
common ions, pH, conductivity, miscellaneous	1978, 1979: One site in lower segment sampled each year. 1978: Calcium=330 mg/L; Sodium=665 mg/L; Chloride=54.6 mg/L; Magnesium=605 mg/L; Bicarbonate=594 mg/L; Carbonate=<1.0 mg/L; Sulfate=4038 mg/L; Alkalinity=487 mg/L; Total Hardness as CaCO3=3316 mg/L. 1979: Calcium=236 mg/L; Sodium=385 mg/L; Chloride=36 mg/L; Magnesium=416 mg/L; Bicarbonate=427 mg/L; Carbonate=<1.0 mg/L; Sulfate=2590 mg/L; Alkalinity=350 mg/L.	Yellowstone.General.wr104	Klarich, Duane A. ; Regele, Stephen M. ; Bahls, Loren L. (1980), Data Report for the Benthic Macroinvertebrate and Periphyton Community Inventory of Streams Draining the Southern Fort Union Coalfield Region of Southeastern Montana, USGS Research grant #14-08-0001-G-503
common ions, pH, conductivity, miscellaneous	1978, 1979: SC (µmho/cm) measured 3 times. Min= 4200, Max= 6400, Mean= 5080.	Yellowstone.General.mb784	Klarich, Duane A. ; Regele, Stephen M. (1980), Structure, General Characteristics, and Salinity Relationships of Benthic Macroinvertebrate Associations in Streams Draining the Southern Fort Union Coalfield Region of Southeastern Montana, USGS Grant #14-08-0001-G-503
common ions, pH, conductivity,	One site approx. 1.5 mi. below Colstrip. 3/22/79: pH= 8; Alkalinity= 380 mg/L; TSS= 7.8 mg/L. 10/7/79:	Lower Missouri.General.DAT	(1981), Field Notes and Data Collected for "Biological Water Quality Monitoring Eastern

Data Type	Comments	Catalog Number	Citation
miscellaneous	Stream dry, no sample.	A	Montana 1979"
common ions, pH, conductivity, miscellaneous	Water and pollutants are reportedly seeping from sludge ponds, most significantly the fly ash evaporation pond.	Yellowstone.Lower Yellowstone-Sunday.DR8	Montana Standard (1981), Order Issued on Colstrip Seep : Montana Standard Newspaper Article 6/06/1981
major nutrients	1979: NO2+NO3= 0.37 mg/L; TP= .07 mg/L; TKN= 1.1 mg/L. One site approx. 1.5 mi. below Colstrip. 3/22/79: Ammonia (mg/L as N)= .57;	Lower Missouri.General.DATA	(1981), Field Notes and Data Collected for "Biological Water Quality Monitoring Eastern Montana 1979"
major nutrients	The criteria used for these sites (with the exception of TKN) are from the level lV Central Grassland ecoregion, growing season. All values in mg/L. Contact recreation (80th percentile of reference): NO2+ NO3 = 0.16; TP = 0.13; TN = 1.04; TKN = Unavailable. Aquatic life uses the 90th percentile of reference condition: NO2+ NO3 = 0.19; TP = 0.15; TN = 1.29; TKN = Unavailable. The criteria used for TKN is from the level lll Northwestern Great Plains ecoregion, growing season. All values in mg/L. Contact recreation (80th percentile of reference): TKN = 0.82. Aquatic life uses the 90th percentile of reference condition: TKN = 0.93.	Common.General.pg027	Suplee, Michael W. (2005), Best Use of the June 2005 Nutrient Data Statistical Summaries
major nutrients	Several sites were sampled between 1974 and 1979. Near colstrip, NO2+NO3 (mg/L), 1975: 9 samples, max= .13, min= .02, mean= .07. 1976, 10 samples, max= .88, min= .02, mean= .28. 1977, 10 samples, max= .64, min= .01, mean= .13. 1978, 9 samples, max= .85, min= .01, mean= .18. 1979, 6 samples, max= .87, min= .00, mean= .23. NO2+NO3, 11 samples, separate from those above: Mean= 0.19 mg/L. TP, 6 samples. Mean=0.11 mg/L. TKN, 3 samples. Mean= 1.0 mg/L.	Common.General.0609	Berscheid, Jolene (2006), STORET/Storease Data Archive [Electronic Resource]

Data Type	Comments	Catalog Number	Citation
metals	10 samples between 1974-1977. Cd exceeded aquatic life and drinking water criteria 10 times. Fe exceeded aquatic life criteria once and drinking water criteria 7 times. Pb exceeded both criteria 10 times, and Hg exceeded aquatic life criteria 5 times. This data is from well water.	Yellowstone.General.wq075	Melancon, Susan ; Hess, B.C. ; Thomas, Robert B. (1979), Assessment of Energy Resource Development Impact on Water Quality: The Tongue and Powder River Basins, EPA-600/7-79-249
metals	1973-1979: Most of data is over 30 years old and detection limits too high. Cannot use data.	Common.General.0609	Berscheid, Jolene (2006), STORET/Storease Data Archive [Electronic Resource]
metals	1973, 1999, 2000: Detection level too high to use data.	Common.General.WEB	Montana Bureau of Mines and Geology (nnnn), GWIC Data from http://mbmggwic.mtech.edu/
quantitative physical data	One sample = 3510 µmho/cm.	Yellowstone.Lower Yellowstone-Sunday.pu130	Botz, Maxwell K. (1978), Characteristics and Potential Impact of Wastewaters from a Coal-Fired Power Plant at Colstrip, Montana
quantitative physical data	1978-1979: 3 SC samples taken, expressed as µmho/cm. Min = 4200, Max = 6400, Mean = 5080.	Yellowstone.General.mb784	Klarich, Duane A. ; Regele, Stephen M. (1980), Structure, General Characteristics, and Salinity Relationships of Benthic Macroinvertebrate Associations in Streams Draining the Southern Fort Union Coalfield Region of Southeastern Montana, USGS Grant #14-08-0001-G-503
quantitative physical data	More than 8,000 acre-feet per year of Yellowstone river water is pumped to the MPC storage pond to supply the MPC power plant and Colstrip municipal uses. It is evident that a 70% increase in discharges from the Colstrip area have likely resulted in "water logging" problems downstream along EFAC over the past 20 years. Mining activities at this time do not appear to be a contributor to the problem of inundation because mine dewatering has resulted in a reduction of inflow. TDS samples from alluvium	Yellowstone.Lower Yellowstone-Sunday.DR8	Erbes, Dan (1998), Montana Dept. of Environmental Quality Letter to Office of Surface Mining and Reclaimation

Data Type	Comments	Catalog Number	Citation
	wells in the EFAC alluvium increased 50% from 1977 to 1997, since the advent of significant mining disturbance, and seepage and discharges from facility and municipal sources.		

Upper

Data Type	Comments	Catalog Number	Citation
common ions, pH, conductivity, miscellaneous	Upper: pH=7.98; Calcium=313 mg/L; Sodium=296 mg/L; Chloride=68.1 mg/L; Magnesium=425 mg/L; Bicarbonate=484 mg/L; Carbonate=<2.0 mg/L; Sulfate=2360 mg/L; Alkalinity=484 mg/L; Total Hardness as CaCO3=2530 mg/L; SAR=2.6.	Common.General.DR 8	(2005), DEQ Field Assessment Form
major nutrients	Upper: NO2+NO3= 0.011 mg/L; TKN=0.70 mg/L; TP=0.251 mg/L.	Common.General.DR 8	(2005), DEQ Field Assessment Form
metals	No standards exceedences.	Common.General.DR 8	(2005), DEQ Field Assessment Form
quantitative physical data	Upper: 6/5/05: Flow= 5 (est.) cfs; Temp=20.76°C; SC=3376 µmho/cm; DO=7.80 mg/L; turbidity=clear; TSS=2.50 mg/L; Substrate: 100% silt.	Common.General.DR 8	(2005), DEQ Field Assessment Form

Lower and Middle

Data Type	Comments	Catalog Number	Citation
common ions, pH, conductivity, miscellaneous	Lower: pH=7.68; Calcium=303 mg/L; Sodium=756 mg/L; Chloride=76.8 mg/L; Magnesium=542 mg/L; Bicarbonate=480 mg/L; Carbonate=<2.0 mg/L; Sulfate=3920 mg/L; Alkalinity=480 mg/L; Total Hardness as CaCO3=2990 mg/L; SAR=6.0. Middle: pH=7.97; Calcium=315 mg/L; Sodium=543 mg/L; Chloride=69.4 mg/L; Magnesium=543 mg/L; Bicarbonate=536 mg/L; Carbonate=<2.0 mg/L;	Common.General.DR 8	(2005), DEQ Field Assessment Form

Reporting Cycle: 2014 **Assessment Record:** MT42K002_110.pdf **Status:** Unassigned

Data Type	Comments	Catalog Number	Citation
	Sulfate=3440 mg/L; Alkalinity=536 mg/L; Total Hardness as CaCO3=3020 mg/L; SAR=4.3.		
major nutrients	Lower: NO2+NO3= 0.009 mg/L; TKN=1.06 mg/L; TP=0.029 mg/L. Middle: NO2+NO3= 0.012 mg/L; TKN=0.97 mg/L; TP=0.018 mg/L.	Common.General.DR 8	(2005), DEQ Field Assessment Form
metals	No standards exceedences at either site.	Common.General.DR 8	(2005), DEQ Field Assessment Form
quantitative physical data	Lower, 6/5/05: Flow=1.25 cfs; Temp=18.43°C; SC=4757 µmho/cm; DO=4.15 mg/L; turbidity=turbid; TSS=10.3 mg/L; Substrate: 100% silt. Middle, 6/7/05: Flow= 2.44 cfs; Temp=18.54°C; SC=4594 µmho/cm; DO=9.20 mg/L; turbidity=clear; TSS=11.5 mg/L; Substrate: 100% silt.	Common.General.DR 8	(2005), DEQ Field Assessment Form

ASSESSMENT HISTORY

Cycle 2006

1996- 19 miles listed as partially supporting agriculture, aquatic life, swimmable, and warm water fishery. The causes were nutrients, salinity/TDS/chlorides, and suspended solids. The sources were agriculture, natural sources, and range land. Listed for assessment in 2004 due to insufficient credible data.

Cycle 2008

Not assessed this cycle

Cycle 2010

Not assessed this cycle

Cycle 2012

TKN listing is being changed to a TN listing

Reporting Cycle: 2014 **Assessment Record:** MT42K002_110.pdf **Status:** Unassigned

Cycle 2014

Not assessed this cycle

Overall Condition of Segment

Biology: 1 site was sampled in 2001, and 2 fish were captured. Macroinvertebrates were sampled at 3 sites in 2005. At the lower site, too few animals were collected apply matrices. Of those collected, a tolerant dragonfly was dominant, and heavy macrophyte growth was suggested. The middle and upper sites indicated poor and very poor biotic communities, respectivly. Blackfly larvae made up 52% of the middle site, while midges made up 44% of the upper site. Nutrient enrichment was suggested at both sites. The chlorophyll a value at all 3 sites was below criteria. Habitat: The banks are stable vertically and horizontally. Very little active erosion was noted in 1979 and 2005 assessments. The banks are well-vegetated with deep rooted grasses, and cattail stands are common. Trees are generally lacking, but are not required for sustainability. The substrate is 100% silt. Some channel disturbance was noted through town (culverts, rip rap, a golf course) but not enough to impact the overall impairment level. With the exception of "water logging" (see physical/chemical), the habitat is only slightly impaired.

Physical/Chemical: East Fork Armells is typical of most streams in this region. The water is very hard, saline, and high in sulfates. Where TSS data was available (2005), concentrations were low. Mining activities (including water pumped from the Yellowstone River to seeping ponds) likely have contributed to increased TDS concentrations and "water logging" below Colstrip. DEQ correspondence in 1998 estimated a 50% increase in TDS concentrations in the EFAC alluvium from 1977 to 1997. Water logging may not currently be occurring. The elevated SC concentrations make this water unsuitable for irrigation under ordinary circumstances. This water is acceptable for use with livestock accustomed to its use, but is not recommended for pregnant or lactating cows. Data from the 1970's show that NO2+NO3 regularly exceeded criteria, although this was not the case in 2005.

In 2005, TKN at the lower site moderately exceeded the contact recreation criteria, and slightly exceeded the aquatic life criteria. At the middle site, contact recreation and aquatic life criteria were slightly exceeded. The most reliable metals data is from the 2005 assessment, which showed no exceedences.

Other: TSS does not appear to be an accurate cause of impairment. The macroinvertebrate samples, field observations, and historical and 2005 water chemistry data indicate that nutrients may be a source of impairment. The SC values do not appear to be vastly different from other drainages in the region; however, the probable impact from municipal sources and industrial pond seepage cannot be ignored. The past and present impacts from changes in groundwater chemistry, surface flow, and atmospheric deposition merits further investigation. Salinity/TDS/chlorides will remain a cause of impairment.

Montana DEQ - Water Quality Standards Attainment Record

Reporting Cycle: 2014 **Assessment Record:** MT42K002_110.pdf **Status:** Unassigned

USE SUPPORT DECISION

Use Class C-3

Trophic Status: **Trophic Trend:**

Uses	DQA	Method, Data, and Information Used	Assessment Type and Confidence	Use Support	Partial Flag	Use Support Certainty	Threatened
Aquatic Life		110, 120, 240, 310, 320, 375, 860	BIOLOGICAL-FAIR, HABITAT-GOOD, PHYSICAL/CHEMICAL-GOOD	Not Supporting	Yes	Low	No
Primary Contact Recreation		240, 860	BIOLOGICAL-FAIR, HABITAT-FAIR, PHYSICAL/CHEMICAL-FAIR	Fully Supporting	No	High	No

Method Number and Description

110-Information from local residents
120-Surveys of fish and game biologists/other professionals
240-Non-fixed station physical/chemical (conventional + toxicants)
310-Ecological/habitat surveys
320-Benthic macroinvertebrate surveys
375-Visual observation, may not quantify some parameters; single season; by prof.
860-Other Agencies/Organizations provided monitoring data

Montana DEQ - Water Quality Standards Attainment Record

Reporting Cycle: 2014 **Assessment Record:** MT42K002_110.pdf **Status:** Unassigned

IMPAIRMENT INFORMATION

Uses	Cause (Confidence): Source(Confirmed)	Observed Effects
Aquatic Life	379 (Low): 152 (N), 165 (N) 399 (Low): 152 (N), 165 (N) 456 (Low): 156 (N) 458 (Low): 156 (N)	
Primary Contact Recreation		

Cause Number and Description	Source Number and Description	Observed Effect Number and Description
379-Specific Conductance 399-Total Dissolved Solids 456-Nitrate/Nitrite (Nitrite + Nitrate as N) 458-Nitrogen (Total)	152-Transfer of Water from an Outside Watershed 156-Agriculture 165-Coal Mining	

DELISTINGS

Cause	Delisting Reason	Delisting Date
Total Kjehldahl Nitrogen (TKN)	Data and/or information lacking to determine water quality status; original basis for listing was incorrect (Category 3)	11/10/2011

Reporting Cycle: 2014 **Assessment Record:** MT42K002_110.pdf **Status:** Unassigned

CATEGORY INFORMATION

Previous Cycle	
Cycle	2012
Category	5 - Waters where one or more applicable beneficial uses have been assessed as being impaired or threatened, and a TMDL is required to address the factors causing the impairment or threat.
User Defined Category	N/A

Current Cycle	
Cycle	2014
Category	5 - Waters where one or more applicable beneficial uses have been assessed as being impaired or threatened, and a TMDL is required to address the factors causing the impairment or threat.
User Defined Category	N/A

Montana DEQ - Water Quality Standards Attainment Record

Reporting Cycle: 2014 **Assessment Record:** MT42K002_170.pdf **Status:** Completed

ASSESSMENT UNIT INFORMATION

Reporting Cycle:	2014
Assessment Unit:	MT42K002_170
Waterbody Name:	East Fork Armells Creek
Location Description:	EAST FORK ARMELLS CREEK, headwaters to Colstrip

Water Type:	**Size (Miles/Acres)**	**Use Class:**
RIVER	24.67 MILES	C-3

Hydrologic Unit Code:	10100001
HUC Name:	Lower Yellowstone-Sunday
Watershed:	Lower Yellowstone
Basin:	Yellowstone
TMDL Planning Area:	Middle Yellowstone Tributaries
Ecoregion:	Northwestern Great Plains
County:	BIG HORN CO, ROSEBUD CO
Lat/Long AU Start (U/S):	45.813191 / -106.881882
Lat/Long AU End (D/S):	45.886051 / -106.622164

MONITORING INFORMATION

Date Assessment Started: 03/30/2006 **Assessed By:** Stermitz, Mike

Next Scheduled Monitoring Date:

Reporting Cycle: 2014 **Assessment Record:** MT42K002_170.pdf **Status:** Completed

CITATIONS

Citation	Location	Biological Data	Habitat Data	Chemistry Data
(1997), Pre 1997 Field Assessments	Assessment Record	algae; chlorophyll; fecal coliforms; fish; macroinvertebrates	Land use; photo points; riparian &/or instream surveys & physical features	Rosgen type; benthic sediment data; bioaccumulation; common ions, pH, conductivity, miscellaneous; major nutrients; metals; quantitative physical data
Erbes, Dan (1998), Montana Dept. of Environmental Quality Letter to Office of Surface Mining and Reclaimation	Assessment Record			common ions, pH, conductivity, miscellaneous; quantitative physical data
Montana Department of Fish, Wildlife, and Parks (1999), Montana Rivers Information System (MRIS)	Assessment Record	algae; fish; macroinvertebrates; wildlife	Land use; riparian &/or instream surveys & physical features	common ions, pH, conductivity, miscellaneous; quantitative physical data
(2005), DEQ Field Assessment Form	Assessment Record	algae; chlorophyll; fecal coliforms; fish; macroinvertebrates	Land use; photo points; riparian &/or instream surveys & physical features	Rosgen type; benthic sediment data; bioaccumulation; common ions, pH, conductivity, miscellaneous; major nutrients; metals; organics; quantitative physical data
Berscheid, Jolene (2006), STORET/Storease Data Archive [Electronic Resource]	DEQ Metcalf Multimedia Case	General; algae; chlorophyll; fecal coliforms; fish;	General; Land use; riparian &/or instream surveys & physical	General; Rosgen type; benthic sediment data; common ions, pH,

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Citation	Location	Biological Data	Habitat Data	Chemistry Data
		macroinvertebrates; other bacteriological data	features	conductivity, miscellaneous; imagery data; major nutrients; metals; organics; quantitative physical data
Montana Department of Fish, Wildlife, and Parks (2006), Montana Rivers Information System (MRIS): Montana Fisheries Information System (MFISH) - http://maps2.nris.mt.gov/scripts/esrimap.dll?name=MFISH&Cmd=INST	Assessment Record	fish; wildlife	Land use; riparian &/or instream surveys & physical features	benthic sediment data; common ions, pH, conductivity, miscellaneous; quantitative physical data
Montana Bureau of Mines and Geology (nnnn), GWIC Data from http://mbmggwic.mtech.edu/	Assessment Record	algae	Land use; riparian &/or instream surveys & physical features	benthic sediment data; common ions, pH, conductivity, miscellaneous; major nutrients; metals; quantitative physical data

Comments: The MBMG is presently doing an assessment to determine the potential impacts of mining to this stream. DEQ will wait until we have the results of that study before making impairment determinations.

Reporting Cycle: 2014 **Assessment Record:** MT42K002_170.pdf **Status:** Completed

DATA MATRIX
Biological Data

Comments: The 1992 and 2005 assessments indicated this segment is ephemeral. Water begins to gather and flow at or near the Hwy 39 bridge, approximately 1/2 mile above the town of Colstrip.

Headwaters to Colstrip

Data Type	Comments	Catalog Number	Citation
fish	No useful data.	Common.General.DR8	Montana Department of Fish, Wildlife, and Parks (1999), Montana Rivers Information System (MRIS)
fish	One dry site in this segment visited in 2003. No other information available.	Common.General.DR8	Montana Department of Fish, Wildlife, and Parks (2006), Montana Rivers Information System (MRIS): Montana Fisheries Information System (MFISH) - http://maps2.nris.mt.gov/scripts/esrimap.dll?name=MFISH&Cmd=INST

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DATA MATRIX

Habitat Data

Comments: Stream is ephemeral. Flow begins at or near hwy. 39. Mining activity (open pit coal) surrounds the stream for much of the reach. A mine employee stated that the mine removed the channel in one section, and may be cutting through another section in the near future. Areas that have been reclaimed are in good condition. The upper 1/4 of the segment is undisturbed pasture land. Bank vegetation consists mostly of grasses and shrubs, trees are mostly missing. There are a number of dikes and road crossings in the channel. Road crossings do not have culverts, apparently due to lack of flow. One pond created by a road crossing is located in the lower section. The affects upon flow from the huge mine pits is unknown, and the mine is continually moving and expanding. Where the mine has not obliterated the channel the stream habitat is not impaired; however, taking into account the mass amount of surrounding land disturbance, the overall habitat is at least moderately impaired. A huge open pit mine cutting through a stream channel is clear evidence of habitat impairment.

Headwaters to Colstrip

Data Type	Comments	Catalog Number	Citation
Land use	The dominant land uses are grazing and mining. Mine activities take place in the lower 3/4's of the stream. The upper 1/4 of the stream is ranch land. Grazing takes place throughout the drainage where land has been reclaimed or is not under construction.	Common.General.DR8	(2005), DEQ Field Assessment Form
photo points	32 photos.	Common.General.DR8	(2005), DEQ Field Assessment Form
riparian &/or instream surveys & physical features	(DR8 Citation: 1992 Stream Reach Assessment Form) Stream ephemeral. Some erosion evident from bank trampling, 10-20% of segment shows erosion. Substrate not measured (no water). Bank vegetation consists of grass with some shrubs and small trees. Little structure in the stream bed to slow water and sediment movement. Some channelization through the town of Colstrip. No flowing or ponded water. Upper reach has dry land farming, with equipment getting as close to banks as possible. Flow began in Colstrip (<1 cfs).	Common.General.DR8	(1997), Pre 1997 Field Assessments
riparian &/or instream surveys & physical	Ephemeral stream. According to locals, stream did not run from top to bottom this year despite the	Common.General.DR8	(2005), DEQ Field Assessment Form

Data Type	Comments	Catalog Number	Citation
features	heavy rains. Some ponded water stands behind a dike in the lower section, which looks to be perennial. This pond is created by the dike and is not natural. There is no culvert in this dike or the many other dikes or road crossings, affirming the ephemeral nature of the stream. There is much land disturbance in the area, but the creek channel itself is undisturbed for the most part. Apparently the mine has bisected the stream in the upper segment. The affects upon flow from this huge open pit mine is unknown. Stream Reach Assessment: Stream is ephemeral from headwaters to near Colstrip (highway 39). Unable to access the upper 2-3 miles of stream (access denied). Could see trees, shrubs, pasture land. A moderate amount of road construction is taking place in the drainage, and the main road crosses the creek in several places. There are numerous dikes in the reach, and there are no culverts at the road crossings or dikes. Most of the drainage is pasture land, and disturbances to the channel are low. A mine employee said the open pit mine cut through the stream channel in one spot, but was unable to confirm on site or through aerial photos. Riparian Assessment: Old downcutting near mouth, but currently stable - stream ephemeral. Laterally stable, and in balance with water and sediment supplied by the watershed. Type and amount of riparian vegetation sub-optimal (lacks trees). Dikes and roads interrupt stream channel. Apparently the flow is not large enough during runoff to require culverts.		

Reporting Cycle: 2014 **Assessment Record:** MT42K002_170.pdf **Status:** Completed

DATA MATRIX

Chemistry Data

Comments: Water chemistry data is limited to a "water hole" and one other site in 1973, a pond in 1980, and one other site in 1985. The "other" sites were located approximately 5 miles above Colstrip. The stream has dried up since 1985, or the samples were taken after a rain event, as this reach is ephemeral. There is nothing in this data to indicate anthropogenic sources of impairment. A 40% increase in TDS in the alluvial aquifer above Colstrip is attributed to mining, and may be impacting the stream below Colstrip.

Headwaters to Colstrip

Data Type	Comments	Catalog Number	Citation
common ions, pH, conductivity, miscellaneous	1980, 1985: Pond approx. 2 mi. above hwy 39 sampled twice in 1980: Calcium=547 and 132 mg/L; Sodium=160 and 66.7 mg/L; Chloride=15.6 and 15.2 mg/L; Magnesium=345 and 185 mg/L; Bicarbonate=547 and 370 mg/L; Carbonate=<1.0 mg/L; Sulfate=1600 and 921 mg/L; Alkalinity=448 and 303 mg/L; Total Hardness as CaCO3=1841 and 1094 mg/L.1985, approx. 5 mi. above town: Calcium=210 mg/L; Sodium=300 mg/L; Chloride=20 mg/L; Magnesium=410 mg/L; Sulfate=2300 mg/L; Alkalinity=457 mg/L; Total Hardness as CaCO3. pH=7.68; Calcium=303 mg/L; Sodium=756 mg/L; Chloride=76.8 mg/L; Magnesium=542 mg/L; Bicarbonate=480 mg/L; Carbonate=<2.0 mg/L; Sulfate=3920 mg/L; Alkalinity=480 mg/L; Total Hardness as CaCO3=2990 mg/L; SAR=6.0.	Common.General.0609	Berscheid, Jolene (2006), STORET/Storease Data Archive [Electronic Resource]
common ions, pH, conductivity, miscellaneous	1973: Water hole approx. 2 mi. above town: Calcium=106 mg/L; Sodium=0 mg/L; Chloride=7 mg/L; Magnesium=35 mg/L; Bicarbonate=497 mg/L; Carbonate=<1.0 mg/L; Sulfate=295 mg/L; Alkalinity=408 mg/L; Total Hardness as CaCO3=409 mg/L. Approx. 5 mi. above town: Calcium=40 mg/L; Sodium=230 mg/L; Chloride=12 mg/L; Magnesium=403 mg/L; Bicarbonate=584 mg/L;	Common.General.WEB	Montana Bureau of Mines and Geology (nnnn), GWIC Data from http://mbmggwic.mtech.edu/

Data Type	Comments	Catalog Number	Citation
	Carbonate=<1.0 mg/L; Sulfate=1722 mg/L; Alkalinity=479 mg/L; Total Hardness as CaCO3=1759 mg/L; SAR=2.39.		
major nutrients	1973: Water hole approx. 2 mi. above town: Nitrate as N= 0 mg/L. Approx. 5 mi. above town: Nitrate as N= 0.97 mg/L.	Common.General.WEB	Montana Bureau of Mines and Geology (nnnn), GWIC Data from http://mbmggwic.mtech.edu/
quantitative physical data	A 40% increase in TDS in the alluvial aquifer observed upstream of Colstrip appears to be directly associated with mining activity.	Yellowstone.Lower Yellowstone-Sunday.DR8	Erbes, Dan (1998), Montana Dept. of Environmental Quality Letter to Office of Surface Mining and Reclaimation
quantitative physical data	1980, 1985: Pond approx. 2 mi. above hwy 39 sampled twice in 1980: Calculated TDS = 2866 and 1725 mg/L. 1985, approx. 5 mi. above town: Flow= 0.22 cfs; Temp= 13.5 °C.	Common.General.0609	Berscheid, Jolene (2006), STORET/Storease Data Archive [Electronic Resource]
quantitative physical data	1973: Water hole approx. 2 mi. above town: TDS= 962 mg/L. Approx. 5 mi. above town: Calculated dissolved solid= 2732.62 mg/L.	Common.General.WEB	Montana Bureau of Mines and Geology (nnnn), GWIC Data from http://mbmggwic.mtech.edu/

ASSESSMENT HISTORY

Cycle 2006

1996 - Listed as partially supporting aquatic life, swimmable, and warm water fishery. The causes were nutrients and suspended solids. The sources were agriculture and range land. Listed for assessment in 2004 due to insufficient credible data.

Cycle 2008

Not assessed this cycle

Cycle 2010

Not assessed this cycle

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Cycle 2012

Not assessed this cycle

Cycle 2014

Removed 2B category during 2014 cycle.

Overall Condition of Segment

This segment is ephemeral. Water begins to surface in the channel near highway 93. The stream did not run continually from the top to bottom in spring 2005, despite the heavy rains. Some outdated water chemistry data is available from a pond, a "water hole", and an upstream site. Either the upstream site has dried up since then or the sample was taken after a rain event. The samples are of little use, although there was nothing to indicate impairment. The stream was assessed in 2004. The entire reach was dry with the exception of a human-induced pond in the lower segment. This water is backed up behind a bermed road crossing with no culvert. There are several dikes and road crossings in the reach with no ponded water, and the area is currently being mined for coal. At least 2 huge open pits are located near the channel, and a mine employee said one pit crossed the channel. DEQ employees were unable to confirm this, despite accessing almost the entire stream. 2005 aerial photos show the mine enroaching upon, but not entering the stream channel. At least one observed part of the stream was once obliterated by the mine, but has been reclaimed. As the mine is expanding and moving, it is reasonable to assume the mine will continue to impact the stream channel.

Grazing is occurring throughout the reach with little impact. The riparian vegetation is mostly grasses and shrubs. Trees are generally missing, but are not required for sustainability. It is not known if this stream was intermittent prior to mining activities, which began in the 1920's. Mining activity has, at a minimum, moderately impaired the habitat in this segment. This segment should remain listed until mining activity has ceased, and the entire drainage is reclaimed. DEQ protocol requires ephemeral streams only to be assessed for habitat. Because the habitat is impaired, aquatic life is partially supporting, despite the fact the stream is ephemeral. There is insufficient information to evaluate the warm water fishery beneficial use; it does not support the use likely due to natural conditions (category 5N).

Other: There is very little useful data available in this reach for suspended solids. The habitat is impaired from overall mining activity, but there were no sources identified in the 2005 assessment for suspended solids. It appears that TSS was listed in 1996 before the stream was separated into two reaches. Almost all of the historical data is from the lower segment which, unlike the upper segment, is not ephemeral. There is "good cause" for delisting suspended solids as a cause of impairment in this segment.

Montana DEQ - Water Quality Standards Attainment Record

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USE SUPPORT DECISION

Use Class C-3

Trophic Status: **Trophic Trend:**

Uses	DQA	Method, Data, and Information Used	Assessment Type and Confidence	Use Support	Partial Flag	Use Support Certainty	Threatened
Aquatic Life		110, 240, 310, 375, 860	HABITAT-GOOD, PHYSICAL/CHEMICAL-LOW	Not Supporting	Yes	High	No
Primary Contact Recreation		110, 310, 375	BIOLOGICAL-FAIR, HABITAT-FAIR, PHYSICAL/CHEMICAL-FAIR	Fully Supporting	No	High	No

Method Number and Description

110-Information from local residents
240-Non-fixed station physical/chemical (conventional + toxicants)
310-Ecological/habitat surveys
375-Visual observation, may not quantify some parameters; single season; by prof.
860-Other Agencies/Organizations provided monitoring data

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IMPAIRMENT INFORMATION

Uses	Cause (Confidence): Source(Confirmed)	Observed Effects
Aquatic Life	84 (Medium): 127 (N)	
Primary Contact Recreation		

Cause Number and Description	Source Number and Description	Observed Effect Number and Description
84-Alteration in stream-side or littoral vegetative covers	127-Surface Mining	

DELISTINGS

Cause	Delisting Reason	Delisting Date

Reporting Cycle: 2014 **Assessment Record:** MT42K002_170.pdf **Status:** Completed

CATEGORY INFORMATION

Previous Cycle	
Cycle	2012
Category	4C - Identified threats or impairments result from pollution categories such as dewatering or habitat modification and, thus, the calculation of a Total Maximum Daily Load (TMDL) is not required
User Defined Category	2B - Available data and/or information indicate that a water quality standard is exceeded due to an apparent natural source in the absence of any identified anthropogenic sources.
Current Cycle	
Cycle	2014
Category	4C - Identified threats or impairments result from pollution categories such as dewatering or habitat modification and, thus, the calculation of a Total Maximum Daily Load (TMDL) is not required
User Defined Category	N/A

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MONTANA BOARD OF ENVIRONMENTAL REVIEW

MONTANA ENVIRONMENTAL INFORMATION CENTER, and SIERRA CLUB, Petitioner, v. MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY, Respondent.	Case No.: BER 2016-03 SM **RESPONDENT'S RESPONSES TO PETITIONERS' FIRST SET OF REQUESTS FOR ADMISSION, INTERROGATORIES AND REQUESTS FOR PRODUCTION**

Respondent Montana Department of Environmental Quality responds to PETITIONERS' FIRST SET OF REQUIESTS FOR ADMISSION, INTERROGATORIES AND REQUESTS FOR PRODUCTION as follows:

INTERROGATORY NO. 1:

Please identify each person who assisted the answering of these interrogatories.

ANSWER:

The following current employees of DEQ's Industrial and Energy Minerals Bureau: Peter Schade, hydrologist; Martin Van Oort, hydrologist; Melissa Sjolund, technical coordinator/MPDES permit coordinator; Adam McMahon, hydrologist; Robert Smith, permit coordinator; Chris Yde, supervisor, Coal and Uranium Section; Ed Coleman, bureau chief,

Exhibit 5

Industrial and Energy Minerals Bureau. John North, Chief Legal Counsel. Emily Hinz, hydrologist, formerly with the Industrial and Energy Minerals Bureau; now with the Department of Fish, Wildlife, and Parks.

INTERROGATORY NO. 2:

Before answering these discovery requests, state whether or not you have:

A. Made a due and diligent search of all related documents within your possession or under your control, in order to obtain information with respect to this appeal. If not, please explain why.

B. Made a due and diligent inquiry of DEQ personnel, Montana state agency staff, consultants, and officials in order to obtain information with respect to this appeal. If not, please explain why.

ANSWER:

(A) Yes.

(B) Yes as to DEQ personnel. No as to other agencies, consultants, and officials because none would have relevant information.

INTERROGATORY NO. 3.

Please identify all DEQ personnel involved in the Amendment AM4 permit review and/or development process.

ANSWER:

The following current employees of DEQ's Industrial and Energy Minerals Bureau: Peter Schade, hydrologist; Martin Van Oort, hydrologist; Sharona Gilbert, administrative assistant; Ashley Eichhorn, fiscal specialist/project manager; Peter Mahrt, engineer; David Adair, engineer; Julian Calabrese, soil scientist; Mike Glenn, vegetative specialist; Robert Smith,

permit coordinator; Chris Yde, supervisor, Coal and Uranium Section; Ed Coleman, bureau chief, Industrial and Energy Minerals Bureau.

The following former employees of DEQ's Industrial and Energy Minerals Bureau: Tom Golnar, hydrologist, retired; Jim Consort, hydrologist, retired; Emily Hinz, hydrologist, now with the Department of Fish, Wildlife, and Parks; Angela McDannel, hydrologist, retired; Samantha Gundlach, vegetation specialist, now homemaker; Chris Bardash, GIS analyst, now with Texas Department of Transportation; Eric Urban, technical coordinator, now bureau chief, Water Quality Planning Bureau.

INTERROGATORY NO. 4:

Please identify all other Montana state agency staff and officials, not employed by DEQ, and consultants who were involved in the Amendment AM4 permit review and/or development process.

ANSWER: None.

INTERROGATORY NO. 5:

Please identify all documentary evidence relevant to this appeal.

ANSWER: DEQ objects to this interrogatory on grounds it is vague, overly burdensome, and calls for information that is subject to attorney client communication or attorney work product privileges. Furthermore, DEQ cannot determine what documents Petitioner's may assert or the Board of Environmental Review may determine are relevant to this appeal, and Petitioners or the Board may disagree with DEQ's relevance determinations.

REQUEST FOR ADMISSION NO. 1:

You are requested to admit that WECo submitted its Area F permit application in 2011.

ANSWER: Admit.

REQUEST FOR ADMISSION NO. 2:

You are requested to admit that WECo's Area F permit application was pending before DEQ at the time DEQ approved WECo's Amendment AM4 application.

ANSWER: Admit.

REQUEST FOR ADMISSION NO. 3:

You are requested to admit that portions the proposed Area F permit area are within the cumulative hydrologic impact area identified in DEQ's CHIA for Amendment AM4.

ANSWER: DEQ objects to this request for admission to the extent it requires DEQ to characterize the CHIA, a document which speaks for itself. DEQ admits without waiving this objection.

REQUEST FOR ADMISSION NO. 4:

You are requested to admit that DEQ's CHIA for Amendment AM4 did not address any of the potential hydrologic impacts expected from the proposed Area F operation.

ANSWER: DEQ objects to this request for admission to the extent it requires DEQ to characterize the CHIA, a document which speaks for itself. DEQ admits without waiving this objection.

INTERROGATORY NO. 6:

Please state whether any portion of the proposed Area F operation is within the cumulative hydrologic impact area identified in DEQ's CHIA for Amendment AM4.

ANSWER: A portion of the currently proposed Area F operation is within the cumulative hydrologic impact area identified in DEQ's CHIA for Amendment AM4.

INTERROGATORY NO. 7:

Please state whether any hydrologic impacts from the proposed Area F operation may occur within the cumulative hydrologic impact area identified in DEQ's CHIA for Amendment AM4.

ANSWER: Hydrologic impacts from the proposed Area F operation may occur within the cumulative hydrologic impact area identified in DEQ's CHIA for Amendment AM4.

INTERROGATORY NO. 8:

A. Please state whether any person identified in your answers to INTERROGATORY NO. 1, INTERROGATORY NO. 3 or INTERROGATORY NO. 4 has discussed or considered the propriety of considering potential hydrologic impacts from the proposed Area F operation in DEQ's CHIA for Amendment AM4.

B. Please identify any and all documents in which any person identified above in your answers to INTERROGATORY NO. 1, INTERROGATORY NO. 3 or INTERROGATORY NO. 4 discussed or considered the propriety of considering potential hydrologic impacts from the proposed Area F operation in DEQ's CHIA for Amendment AM4.

ANSWER: (A) Yes, it has been discussed internally by DEQ Coal Program staff. (B) No documents exist.

REQUEST FOR PRODUCTION NO. 1:

Please produce any and all documents in DEQ's possession or control identified in your response to INTERROGATORY NO. 8.

RESPONSE: None exist.

INTERROGATORY NO. 9:

Please identify any applications for mining operations or prospecting work for or related to the proposed Area G operations of the Rosebud Mine that were pending at the time DEQ approved WECo's Amendment AM4 application.

ANSWER: No applications were pending at that time.

INTERROGATORY NO. 10:

Please state whether any proposed operations or prospecting pertaining to Area G are within the cumulative hydrologic impact area identified in DEQ's CHIA for Amendment AM4.

ANSWER: Prospecting has occurred within the CIA. No mining operations were proposed when the CHIA was issued.

INTERROGATORY NO. 11:

Please identify any and all documents in which any person identified above in your answers to INTERROGATORY NO. 1, INTERROGATORY NO. 3 or INTERROGATORY NO. 4 discussed or considered the propriety of considering potential hydrologic impacts from the proposed Area G operations in DEQ's CHIA for Amendment AM4.

ANSWER: There are none.

REQUEST FOR PRODUCTION NO. 2:

Please produce all documents in DEQ's possession or control that are identified in your answer to INTERROGATORY NO. 11.

ANSWER: None exist.

REQUEST FOR ADMISSION NO. 5:

You are requested to admit that DEQ's CHIA for Amendment AM4 defined "anticipated mining" to include "permitted operations."

ANSWER: DEQ objects to this request for admission to the extent it requires DEQ to characterize the CHIA, a document which speaks for itself. DEQ admits without waiving this objection that page 5-1 of the CHIA states: "'Anticipated mining' includes the entire projected life through bond release of all permitted operations and all operations required to meet diligent development requirements for leased federal coal for which there is actual mine-development information available."

REQUEST FOR ADMISSION NO. 6:

You are requested to admit that DEQ's CHIA for Amendment AM4 did not expressly define "anticipated mining" to include "operations with pending applications."

ANSWER: DEQ objects to this request for admission to the extent it requires DEQ to characterize the CHIA, a document which speaks for itself. DEQ admits without waiving this objection.

INTERROGATORY NO. 12:

Please identify any and all "operations required to meet diligent development requirements for leased federal coal for which there is actual mine-development information available" within the cumulative hydrologic impact area identified in DEQ's CHIA for Amendment AM4.

ANSWER: Within the CIA area, mine Areas A, B, C (currently approved mine plans), and F contain leased federal coal subject to diligent development requirement for which mine-development information is available.

INTERROGATORY NO. 13:

Do you contend that DEQ's failure to include proposed operations or prospecting in Area F or Area G in DEQ's CHIA for Amendment AM4 was justified? If your answer is anything

other than an unqualified, "No," please set for with particularity your basis for such justification.

ANSWER: Yes. The proposed action was determined to have no impacts to mine Area C making it unnecessary to include Area F. Page 9-36 of the CHIA states: "As discussed below, proposed mining in AM4 will remove additional overburden in the east part of Area B but will not affect overburden water levels or water quality in other permit areas of the Rosebud Mine." Page 9-37 of the CHIA states: "Due to its [Area C's] location upgradient, proposed mining in Area B will have no impact on water quality or quantity in Area C overburden." Page 9-42 of the CHIA states: "Due to the direction of groundwater flow, Area B mining, including that proposed in AM4, is not expected to increase drawdown or otherwise impact the Rosebud coal groundwater in or near Area C." Page 9-47 of the CHIA states: "Due to the direction of groundwater flow, Area B mining, including mining proposed in AM4, is not expected to impact Area C interburden." Although impacts from the permitted operation in Area C may interact with potential impacts from Area F, impacts from the proposed operation in Area B AM4 do not interact with any potential impacts from Area F. Thus, no analysis was required. DEQ excluded the prospecting and data collection activities under permits X2004322 and N2006005 in "Area G" from the CHIA analysis for two reasons. First, DEQ is not required to address prospecting impacts in the CHIA. Second, prospecting and data collection have no impact on the hydrologic balance.

REQUEST FOR ADMISSION NO. 7:

You are requested to admit that electrical conductivity (EC) standards from ARM 17.30.670 apply to Rosebud Creek.

ANSWER: Admit that the numeric standards for electrical conductivity (EC) contained in ARM.17.30.670(2)(a) and (3)(a) apply to Rosebud Creek.

REQUEST FOR ADMISSION NO. 8:

You are requested to admit that EC standards from ARM 17.30.670 apply to the following tributaries of Rosebud Creek: Spring Creek, Pony Creek, Cow Creek, South Fork Cow Creek, Emile Coulee, and Lee Coulee.

ANSWER: Admit that the numeric standards for EC contained in ARM 17.30.670(4) apply to the tributaries to Rosebud Creek.

REQUEST FOR ADMISSION NO. 9:

You are requested to admit that a portion of Rosebud Creek is within the cumulative hydrologic impact area identified in the CHIA for Amendment AM4.

ANSWER: Admit.

REQUEST FOR ADMISSION NO. 10:

You are requested to admit that the following tributaries of Rosebud Creek are within the cumulative hydrologic impact area identified in the CHIA for Amendment AM4: Spring Creek, Pony Creek, Cow Creek, South Fork Cow Creek, Emile Coulee, and Lee Coulee.

ANSWER: Admit.

REQUEST FOR ADMISSION NO. 11:

You are requested to admit that DEQ's CHIA for Amendment AM4 did not address whether the cumulative hydrologic impacts of mining and reclamation activities within the cumulative hydrologic impact area would cause violation of EC standards in the following tributaries of Rosebud Creek: Spring Creek, Pony Creek, Cow Creek, South Fork Cow Creek, Emile Coulee, and Lee Coulee.

ANSWER: Deny.

INTERROGATORY NO. 14:

Please state whether WECo (including its agency, representatives, and employees) has expressed concerns or doubts to DEQ personnel about its ability to comply with EC standards from ARM 17.30.670 at any point in the past five years. If your answer is anything other than an unqualified "No," please set forth the following information specifically and in detail:

A. Identify who expressed such concerns or doubts;

B. Identify when and where such concerns or doubts were expressed;

C. Identify any and all documents that contain such concerns or doubts;

D. Identify any and all documents in which DEQ personnel discussed or responded to such concerns or doubts.

ANSWER: Yes

(A) Jesse Noel, former Engineering and Environmental Manager for Western Energy Company

(B) Concerns were expressed in a June 13, 2012, Public Comment letter to Jenny Chambers, former Water Protection Bureau Chief regarding the renewal of MPDES permit No. MT0023965.

(C) June 13, 2012, Public Comment letter from Jesse Noel to Jenny Chambers. (See letter page 12, file name: 061312_Noel_Chambers_Public_Comment.pdf)

(D) September 14, 2012, Final decision letter containing DEQ Response to Comments from Jenny Chambers to Kent Salitros, Vice President and General Manager of Western Energy Company (See Response to Comments, Comment 60 on page 19 of 23; file name 091412_Chambers_Salitros_FinalDecsion.pdf).

REQUEST FOR PRODUCTION NO. 3:

Please produce any and all documents in DEQ's possession or control that are identified in your answer to INTERROGATORY NO. 14.

RESPONSE:

- 061312_Noel_Chambers_Public_Comment.pdf, which is attached as Exhibit 1.
- 091412_Chambers_Salitros_FinalDeicsion.pdf, which is attached as Exhibit 2.

INTERROGATORY NO. 15:

Please state whether any DEQ personnel have raised questions or concerns at any point in the last five years about WECo's ability to comply with the EC standards from ARM 17.30.670. If your answer is anything other than an unqualified "No," please set forth the following information specifically and in detail:

A. Identify who raised such questions or concerns;

B. Identify when and where the questions or concerns were raised;

C. Identify any and all documents in which the questions or concerns were raised.

ANSWER: No.

REQUESTION FOR PRODUCTION NO. 4:

Please produce any and all documents in DEQ's possession or control that are identified in your answer to INTERROGATORY NO. 15.

RESPONSE: None identified.

INTERROGATORY NO. 16:

Please identify all water bodies or segments of water bodies within the cumulative hydrologic impact area that are subject to EC standards from ARM 17.30.670.

ANSWER: The EC standards in ARM 17.30.670(2)(a) and (3)(a) apply to Rosebud Creek. The EC standards in ARM 17.30.670(4) apply to all tributaries and other surface waters in the Rosebud Creek watershed.

INTERROGATORY NO. 17:

Do you contend that the failure of DEQ's CHIA for Amendment AM4 to address the potential for violations of EC standards in the Rosebud Tributaries within the cumulative hydrologic impact area was justified? If your answer is anything other than an unqualified, "No," please set for with particularity your basis for such justification.

ANSWER: DEQ disagrees that the CHIA failed to address the potential for these violations.

REQUEST FOR ADMISSION NO. 12:

You are requested to admit that Rosebud Creek is a Class C-3 water under ARM 17.30.629.

ANSWER: Partially admitted. DEQ admits that Rosebud Creek is classified as a C-3 water but denies that it is so classified by ARM 17.30.629. It is classified C-3 by ARM 17.30.611(1)(c).

REQUEST FOR ADMISSION NO. 13:

You are requested to admit that the following tributaries of Rosebud Creek are Class C-3 waters under ARM 17.30.629: Spring Creek, Pony Creek, Cow Creek, South Fork Cow Creek, Emile Coulee, and Lee Coulee.

ANSWER: Admit that all tributaries to Rosebud Creek are classified as C-3 waters but deny that they are so classified by ARM 17.30.629. They are classified C-3 by ARM 17.30.611(1)(c).

REQUEST FOR ADMISSION NO. 14:

You are requested to admit that Rosebud Creek is subject to the water quality standards provided in ARM 17.30.629.

ANSWER: Admit.

REQUEST FOR ADMISSION NO. 15:

You are requested to admit that Spring Creek, Pony Creek, Cow Creek, South Fork Cow Creek, Emile Coulee, and Lee Coulee are subject to the water quality standards provided in ARM 17.30.629.

ANSWER: Admit that the intermittent reaches of these streams are subject to the standard in ARM 17.30.629. Deny that other reaches of these streams are subject to those standards.

REQUEST FOR ADMISSION NO. 16:

You are requested to admit that East Fork Armells Creek is a Class C-3 water under ARM 17.30.629.

ANSWER: Partially admitted. DEQ admits that East Fork Armells is classified as a C-3 water but denies that it is so classified by ARM 17.30.629. It is classified C-3 by ARM 17.30.611(1)(c).

REQUEST FOR ADMISSION NO. 17.

You are requested to admit that East Fork Armells Creek is subject to the water quality standards provided in ARM 17.30.629.

ANSWER: Partially admitted. Where East Fork Armells Creek is ephemeral, it is not subject to the water quality standards of 17.30.629 (see ARM 17.30.637(4)). Where East Fork Armells Creek is perennial or intermittent, it is subject to the standards in ARM 17.30.629.

REQUEST FOR ADMISSION NO. 18:

You are requested to admit that all Class C-3 waters in the cumulative hydrologic impact area are subject to numeric nutrient standards in DEQ Circular DEQ-12A.

ANSWER: Deny. The numeric nutrient standards in DEQ-12A apply to all wadeable streams. Any C-3 waters in the CIA which meet the definition of a wadeable stream in DEQ-12A are subject to the standards in DEQ-12A. Additionally, ephemeral streams are not subject to the water quality standards of 17.30.620 through 17.30.629 (see ARM 17.30.637(4)). Because the numeric nutrient standards in Circular DEQ-12A are referenced in 17.30.629(2)(h), they do not apply to ephemeral streams.

REQUEST FOR ADMISSION NO. 19.

You are requested to admit that DEQ's CHIA for Amendment AM4 did not address or discuss whether the cumulative hydrologic impacts would cause violations of the nutrient standards in DEQ Circular DEQ-12A.

ANSWER: DEQ objects to this request for admission to the extent it requires DEQ to characterize the CHIA, a document which speaks for itself. DEQ admits without waiving this objection.

REQUEST FOR ADMISSION NO. 20:

You are requested to admit that the nutrient standard for total nitrogen, which includes nitrate + nitrite, from DEQ Circular DEQ-12A that applies to the Class C-3 waters in the cumulative hydrologic impact area is more stringent than the human health standard for nitrate + nitrite in DEQ Circular-7.

ANSWER: DEQ objects to this request for admission to the extent it requires DEQ to characterize the CHIA, a document which speaks for itself. DEQ admits without waiving this objection.

REQUEST FOR ADMISSION NO. 21:

You are requested to admit that pursuant to the review required by section 303(d) of the federal Clean Water Act, 33 U.S.C. § 1313(d), DEQ has determined that the lower segment of East Fork Armells Creek is not meeting applicable water quality standards for aquatic life.

ANSWER: Admit.

REQUEST FOR ADMISSION NO. 22:

You are requested to admit that pursuant to the review required by section 303(d) of the federal Clean Water Act, 33 U.S.C. § 1313(d), DEQ has determined that the lower segment of East Fork Armells Creek is not meeting applicable water quality standards for aquatic life because of, among other things, nitrate + nitrite as nitrogen pollution.

ANSWER: Deny. The 2014 DEQ Water Quality Standards Attainment Record for lower East Fork Armells Creek (MT42K002_110-Colstrip to the mouth) identifies nitrate-nitrite as a cause of impairment of aquatic-life-uses with a low level of confidence. This is not a determination that nitrate +nitrite as nitrogen is a cause.

REQUEST FOR ADMISSION NO. 23:

You are requested to admit that pursuant to the review required by section 303(d) of the federal Clean Water Act, 33 U.S.C. § 1313(d), DEQ has determined that the lower segment of East Fork Armells Creek is not meeting applicable water quality standards for aquatic life because of, among other things, nitrogen pollution.

ANSWER: Deny. The 2014 DEQ Water Quality Standards Attainment Record for lower East Fork Armells Creek (MT42K002_110-Colstrip to the mouth) identifies Nitrogen (Total) as a cause of impairment of aquatic-life-uses with a low level of confidence. This is not a determination that nitrogen is a source.

REQUEST FOR ADMISSION NO. 24:

You are requested to admit that pursuant to the review required by section 303(d) of the federal Clean Water Act, 33 U.S.C. § 1313(d), DEQ has determined that coal mining is one source of the pollution causing the lower segment of East Fork Armells Creek to not meet applicable water quality standards for aquatic life.

ANSWER: Deny. The 2014 DEQ Water Quality Standards Attainment Record for lower East Fork Armells Creek (MT42K002_110-Colstrip to the mouth) identifies coal mining as an unconfirmed source of the pollutants. The 2014 DEQ Water Quality Standards Attainment Record lists the confidence in these causes of impairment to aquatic-life-uses as low. This is not a determination that coal mining is a source of this pollution.

INTERROGATORY NO. 18:

Please identify all waters in the cumulative hydrologic impact area identified in DEQ's CHIA for Amendment AM4 that are subject to the nutrient standards in DEQ Circular DEQ-12A.

ANSWER: Perennial and intermittent streams within the cumulative hydrologic impact area are subject to the nutrient standard in DEQ Circular DEQ-12A. West Fork Armells Creek, Stocker Creek, East Fork Armells Creek, unnamed tributaries of East Fork Armells Creek, Spring Creek, Cow Creek, Hay Coulee, Emile Coulee, Lee Coulee, and Rosebud Creek have intermittent or perennial stretches.

INTERROGATORY NO. 19:

Please state whether the nutrient standard for total nitrogen, which includes nitrate + nitrite, from DEQ Circular DEQ-12A that applies to the Class C-3 waters in the cumulative

hydrologic impact area is more stringent than the human health standard for nitrate + nitrite in DEQ Circular-7.

ANSWER: DEQ objects to this request for admission to the extent it requires DEQ to characterize the CHIA, a document which speaks for itself. DEQ admits without waiving this objection.

INTERROGATORY NO. 20:

Please state whether DEQ personnel have considered, addressed, or raised concerns about whether the nutrient standards for total nitrogen from DEQ Circular DEQ-12A apply to surface waters in the cumulative hydrologic impact area. If your answer is anything other than an unqualified "No," please set forth the following information specifically and in detail:

A. Identify who considered, addressed, or raised concerns about the applicability of these standards;

B. Identify when and where the applicability of these standards was considered, addressed, or concerns about their applicability were raised;

C. Identify any and all documents in which the applicability of these standards was considered, addressed, or concerns about their applicability were raised.

ANSWER: Yes

(A) Melissa Sjolund, technical coordinator/MPDES coordinator, Industrial and Energy Minerals Bureau.

(B) DEQ-12A nutrient standards were considered in the Fact Sheet accompanying Major Modification 2 to MPDES permit No. MT0023965 (file name MT0023965_FS_MOD2.pdf)

(C) See p. 6 of the Fact Sheet accompanying Major Modification 2 to MPDES permit No. MT0023965 (file name MT0023965_FS_MOD2.pdf)

REQUEST FOR PRODUCTION NO. 5:

Please produce any and all documents in DEQ's possession or control that are identified in your answer to INTERROGATORY NO. 20.

RESPONSE: The Fact Sheet is attached as Exhibit 3

REQUEST FOR PRODUCTION NO. 6:

Please produce any and all documents that address, discuss, or consider WECo's compliance with DEQ's Circular DEQ-12A at the Rosebud Mine.

RESPONSE: None exist.

INTERROGATORY NO. 21:

Do you contend that the failure of DEQ's CHIA for Amendment AM4 to consider potential violation of total nitrogen standards from DEQ's Circular DEQ-12A was justified? If your answer is anything other than an unqualified, "No," please set for with particularity your basis for such justification.

ANSWER: Yes. There was not enough data available on Total Nitrogen concentrations in waters in the CIA area to make a reasonable determination of the significance of any impacts. In addition, the proposed mining in AM4 is located over one mile from EFAC and is not expected to contribute a measureable amount of additional nitrogen to EFAC via either groundwater or surface water pathways. Finally, compliance with the nutrient standards is addressed in MPDES MT0023965.

REQUEST FOR ADMISSION NO. 25:

You are requested to admit that the dewatering of an intermittent stream outside the mine permit area but within the cumulative hydrologic impact area identified in DEQ's CHIA for Amendment AM4 to the degree that it becomes ephemeral constitutes material damage.

ANSWER: Admit that this dewatering would constitute material damage if a land use or beneficial use of water were adversely affected and deny if the dewatering would not have this adverse effect.

INTERROGATORY NO. 22:

Please state whether in the last five years any person identified your answers to INTERROGATORY NO. 1, INTERROGATORY NO. 3 or INTERROGATORY NO. 4 has considered, addressed, or discussed the intermittent character of any length in the upper segment of East Fork Armells Creek. If your answer is anything other than an unqualified "No," please set forth the following information specifically and in detail:

A. Identify who considered, addressed, or discussed the intermittent nature of any length of the upper segment of East Fork Armells Creek;

B. Identify when and where the intermittent nature of any length of the upper segment of East Fork Armells Creek was considered, addressed, or discussed;

C. Identify any and all documents in which the intermittent nature of any length of the upper segment of East Fork Armells Creek was considered, addressed, or discussed.

ANSWER: Yes.

(A) Current employees of DEQ: Melissa Sjolund, technical coordinator/MPDES; Martin Van Oort, hydrologist; Peter Schade, hydrologist; Robert Smith, permit coordinator; Chris Yde, supervisor, Coal and Uranium Section; Ed Coleman, Bureau Chief, Industrial and Energy

Minerals Bureau. Former employees of DEQ: Angela McDannel, hydrologist, retired; Emily Hinz, hydrologist, now with Fish, Wildlife, and Parks; Dana David, attorney, current employer is the State of New Mexico.

(B) This was discussed on multiple occasions during development of the AM4 CHIA. Specific times and locations of discussions aren't available.

(C) Email message, Emily Hinz to Angela McDannel, dated August 20, 2015, entitled "Section 15 Writeup;" The Fact Sheet accompanying Major Modification 2 to MPDES permit No. MT0023965 discusses the intermittent nature of a segment of East Fork Armells Creek. The June 2, 2014, deficiency letter and January 2016 MPDES permit modification-related documents. See the Fact Sheet accompanying Major Modification 2 to MPDES permit No. MT0023965 (file name MT0023965_FS_MOD2.pdf). Two reports are cited in the Fact Sheet and are provided (file names Arcadis_2014.pdf and Nicklin_2014.pdf

REQUEST FOR PRODUCTION NO. 7:

Please produce any and all documents in DEQ's possession or control that are identified in your answer to INTERROGATORY NO. 22.

RESPONSE: See Exhibits 4 through 7.

REQUEST FOR ADMISSION NO. 26:

Please admit that there are no historic records that identify or describe the instream dam in Section 15 described in DEQ's CHIA for Amendment AM4 on pages 9-9 and 9-10.

ANSWER: Deny.

INTERROGATORY NO. 23:

If your response to REQUEST FOR ADMISSION NO. 26 is anything other than an unequivocal admission, please identify any and all historic records that identify or describe the

instream dam in Section 15 described in DEQ's CHIA for Amendment AM4 on Pages 9-9 and 9-10.

ANSWER: The instream dam in Section 15 is visible on aerial photos from many years and is shown in the CHIA in Appendix A, Photos 18 and 19. This dam is also depicted on several Annual Mine Report maps for WECo Area C. Schwehr, 1979, also describes this instream dam on page 10, "Station No. 9 is located immediately below a small impoundment on the creek." 2011 aerial imagery (Google Earth) clearly shows the pooling of East Fork Armells Creek behind this dam.

REQUEST FOR ADMISSION NO. 27:

Please admit that there are no historic records that attribute the intermittent nature of East Fork Armells Creek in Section 15 to the accumulation of runoff behind the instream dam in Section 15 described in DEQ's CHIA for Amendment AM4 on pages 9-9 and 9-10.

ANSWER: Admit that DEQ's personnel are not aware of any such records.

INTERROGATORY NO. 24:

If your response to REQUEST FOR ADMISSION NO. 27 is anything other than an unequivocal admission, please identify any and all historic records that attribute the intermittent nature of East Fork Armells Creek in Section 15 to the accumulation of runoff behind the instream dam in Section 15 described in DEQ's CHIA for Amendment AM4 on pages 9-9 and 9-10.

ANSWER: Request for Admission No. 27 was Admitted.

REQUEST FOR PRODUCTION NO. 8.

Please produce any and all documents identified in INTERROGATORY NO. 23 and INTERROGATORY NO. 24.

RESPONSE: Interrogatory 23: Schwehr, 1979 was provided to Petitioner on February 18, 2016. The photographs are attached as Exhibits 8 and 9. The1990 Annual Mine Report map is attached as Exhibit 10. The 1992 Aerial Photo map is attached as Exhibit 11.

Interrogatory 24: None exist.

REQUEST FOR ADMISSION NO. 28:

You are requested to admit that DEQ's CHIA for Amendment AM4 did not affirmatively find that the ephemeral character of East Fork Armells Creek in Section 15 was not the result of cumulative hydrologic impacts from the Rosebud Mine.

ANSWER: DEQ objects to this request for admission to the extent it requires DEQ to characterize the CHIA, a document which speaks for itself. DEQ admits without waiving this objection.

REQUEST FOR ADMISSION NO. 29:

You are requested to admit that DEQ's CHIA for Amendment AM4 did not make a material damage determination with respect to the cumulative hydrologic impact of all mining operations on surface water quantity in East Fork Armells Creek in Section 15.

ANSWER: DEQ objects to this request for admission to the extent it requires DEQ to characterize the CHIA, a document which speaks for itself. DEQ admits without waiving this objection.

REQUEST FOR ADMISSION NO. 30:

You are requested to admit that baseline measurements of ground water in the Rosebud Coal in Area B identified some groundwater that would classify as Class I groundwater under ARM 17.30.1006(2).

ANSWER: DEQ objects to this request for admission to the extent it requires DEQ to characterize the CHIA, a document which speaks for itself. DEQ admits without waiving this objection.

REQUEST FOR ADMISSION NO 31:

You are requested to admit that baseline measurements of ground water in the Rosebud Coal between the Rosebud Mine and the Big Sky Mine identified some groundwater that would classify as Class I groundwater under ARM 17.30.1006(2).

ANSWER: Deny that baseline measurements in Appendix D of the CHIA in Rosebud Coal wells between the Rosebud Mine and Big Sky Mine have groundwater with conductivity which falls in the Class I range, but admit that the CHIA references an EC of 880µS/cm measured in 1996 in a Rosebud coal well north of Big Sky Mine Area A.

INTERROGATORY NO. 25:

Please identify the average and median concentrations of total dissolved solids (TDS) from baseline samples of ground water in the Rosebud Coal in Area B.

ANSWER: Based on the data contained in Appendix D of the CHIA, the average TDS for Rosebud Coal wells in Area B is 1324 mg/L and the median is 1283 mg/L. For this analysis only, wells located with the current Area B permit boundary were used.

INTERROGATORY NO. 26:

Please identify the average and median concentrations of TDS in base line samples of ground water in the Rosebud Coal between the Rosebud Mine and the Big Sky Mine.

ANSWER: Based on the data contained in Appendix D of the CHIA, the average TDS for Rosebud Coal wells between the Big Sky and Rosebud Mines is 1806 mg/L and the median is

1880 mg/L. All wells located between the Rosebud and Big Sky mined areas were included in this analysis, regardless of their position inside or outside the mines' permit boundaries.

REQUEST FOR ADMISSION NO. 32:

You are requested to admit some of the spoil water from Area B of the Rosebud Mine is expected to migrate to the southeast toward unmined portions of the Rosebud Coal between the Rosebud Mine and the Big Sky Mine.

ANSWER: Admit.

REQUEST FOR ADMISSION NO. 33:

You are requested to admit that the spoil water from Area B of the Rosebud Mine that is expected to migrate to the southeast toward unmined portions of the Rosebud Coal between the Rosebud Mine and the Big Sky Mine is expected to have TDS concentrations that would classify as Class II or Class III ground water under ARM 17.30.1006.

ANSWER: Deny. TDS concentrations are not used to classify groundwater under ARM 17.30.1006. The groundwater classes in ARM 17.30.1006 are defined by natural specific conductance. Admit that the that the spoil water from Area B of the Rosebud Mine that is expected to migrate to the southeast toward unmined portions of the Rosebud Coal between the Rosebud Mine and the Big Sky Mine is expected to have specific conductance concentrations that would classify as Class II or Class III ground water under ARM 17.30.1006.

REQUEST FOR ADMISSION NO. 34:

You are requested to admit that degradation of Class I ground water in the Rosebud Coal outside the mine permit boundary to Class II or Class III ground water would be a violation of water quality standards.

ANSWER: Admit it would be a violation if the specific water quality standards listed for Class I groundwater were violated, but deny that it would be a violation in other instances.

REQUEST FOR ADMISSION NO. 35:

You are requested to admit that the DEQ's CHIA for Amendment AM4 does not address the potential degradation of Class I ground water in the Rosebud Coal between the Rosebud Mine and the Big Sky Mine.

ANSWER: DEQ objects to this request for admission to the extent it requires DEQ to characterize the CHIA, a document which speaks for itself. DEQ asserts without waiving this objection that DEQ's CHIA did not address potential degradation of Class I groundwater in the Rosebud Coal between the Big Sky and Rosebud mines because there is no Class I groundwater in that area.

REQUEST FOR ADMISSION NO. 36:

You are requested to admit that the CHIA does not identify any hydraulic connection between clinker deposits between the Rosebud Mine and the Big Sky Mine and the Rosebud Coal between the Rosebud Mine and the Big Sky Mine.

ANSWER: DEQ objects to this request for admission to the extent it requires DEQ to characterize the CHIA, a document which speaks for itself. DEQ denies without waiving this objection.

REQUEST FOR ADMISSION 37:

You are requested to admit that that Clark, 1995, submitted as Exhibit 3 in public comments submitted by Petitioners MEIC and Sierra Club, found that TDS concentrations were either unchanged or changed only in small amounts as ground water flowed from the Big Sky Mine spoils aquifer to the downgradient coal aquifer.

ANSWER: Admit.

INTERROGATORY NO. 27:

Please identify any and all documents in which DEQ personnel identified in INTERROGATORY NO. 1, INTERROGATORY NO. 3, and INTERROGATORY NO. 4 discuss or address potential impacts of migration of spoils water from Area B of the Rosebud Mine.

ANSWER: None exist.

REQUEST FOR PRODUCTION NO. 9:

Please produce any and all documents identified in INTERROGATORY NO. 24.

RESPONSE: None exist.

REQUEST FOR ADMISSION NO. 38:

You are requested to admit that in 2014 DEQ personnel had concerns about material damage occurring off the Rosebud Mine site that may have been related to the Rosebud Mine.

ANSWER: Admit.

INTERROGATORY NO. 28:

Please state whether any DEQ personnel has raised concerns about material damage occurring off the Rosebud Mine site that may have been related to the Rosebud Mine. If your answer is anything other than an unqualified "No," please set forth the following information specifically and in detail:

A. Identify who raised such concerns;

B. Identify what concerns were raised, including what pollutants or impacts to water quantity were involved;

C. Identify any and all documents in DEQ's possession or control in which such concerns were raised, considered, or discussed.

ANSWER: Yes.

(A) Former employees of DEQ's Industrial and Energy Minerals Bureau: Emily Hinz, hydrologist, now with the Department of Fish, Wildlife, and Parks; and Angela McDannel, hydrologist, retired.

(B) Concerns were raised that potential inputs of additional salinity, sulfate, and chloride to East Fork Armells Creek from the Rosebud Mine may cause material damage to the protected beneficial use aquatic life support for C-3 waters.

(C) See "AM4 Seventh Round Acceptability Deficiency.pdf"

REQUEST FOR PRODUCTION NO. 10:

Please produce any and all documents in DEQ's possession or control that you identified in your response to INTERROGATORY NO. 27.

RESPONSE: None exist.

INTERROGATORY NO. 29:

Please state in detail and with specificity any and all concerns that DEQ personnel have raised about material damage occurring off the Rosebud Mine site that may have been related to the Rosebud Mine.

ANSWER: See answer to Interrogatory No. 28. B.

INTERROGATORY NO. 30:

Please identify any and all documents in DEQ's possession or control in which any individual identified in INTERROGATORY NO. 1, INTERROGATORY NO. 3, or INTERROGATORY NO. 3 discusses the impairment of East Fork Armells Creek, as determined

in DEQ's review required by section 303(d) of the federal Clean Water Act, 33 U.S.C. § 1313(d).

ANSWER: September 8, 2014, Final decision letter containing DEQ Response to Comments from Jon Kenning, Water Protection Bureau Chief, to Kent Salitros, vice president and general manager of Western Energy Company (See Response to Comments, Response 9, page 9; file name 090814_Kenning_Salitros_FinalDeicsion.pdf).

The Fact Sheet accompanying the 2012 renewal of MPDES permit No. MT0023965 (see p. 20 of 73, file name MT0023965_FS_Renewal.pdf). September 14, 2012, Final decision letter containing DEQ Response to Comments from Jenny Chambers to Kent Salitros, Vice President and General Manager of Western Energy Company (See Response 19 on page 8 of 23; file name 091412_Chambers_Salitros_FinalDeicsion.pdf).

REQUEST FOR PRODUCTION NO. 11:

Please produce any and all documents identified in your answer to INTERROGATORY NO. 30.

RESPONSE:

- 090814_Kenning_Salitros_FinalDeicsion.pdf is attached as Exhibit 12.
- MT0023965_FS_Renewal.pdf is attached as Exhibit 13.
- 091412_Chambers_Salitros_FinalDeicsion.pdf is attached as Exhibit 14.

REQUEST FOR ADMISSION NO. 39:

You are requested to admit that Sigler and Bauder, 2012, cited in DEQ's CHIA for Amendment AM4 on page 2-4 is not a peer-reviewed study.

ANSWER: Admit.

REQUEST FOR ADMISSION NO. 40:

You are requested to admit that Hutcheson, 2001, cited in DEQ's CHIA for Amendment AM4 on page 2-4 is not a peer-reviewed study.

ANSWER: Admit.

REQUEST FOR ADMISSION NO. 41:

You are requested to admit that Geomega, 2007, cited DEQ's CHIA for Amendment AM4 on page 6-2 is not a peer-reviewed study.

ANSWER: Admit.

REQUEST FOR ADMISSION NO. 42:

You are requested to admit that Raisbeck et al., which was submitted as Exhibit 4 of Petitioner's comments is a peer-reviewed study.

ANSWER: Deny.

REQUEST FOR ADMISSION NO. 43:

You are requested to admit that the chronic exposure limit for sulfate recommended in Raisbeck et al., is lower than the sulfate limits from Sigler and Bauder, 2012, Hutcheson, 2001, or Geomega, 2007.

ANSWER: Admit that Raisbeck is lower than Sigler and Bauder and Geomega, but deny that Raisbeck is lower than Hutcheson.

INTERROGATORY NO. 31:

Please identify all cumulative hydrologic impact assessments prepared by DEQ for any mining operation at the Rosebud Mine or the Big Sky Mine. Please also identify the particular operation or mining area for which each cumulative hydrologic impact assessment was prepared.

ANSWER: Cumulative Hydrologic Impact Assessments were conducted for the following applications: Big Sky Mine Area A Snider's Amendment, April 1987; Big Sky Mine Area B,

New Permit, November 1988; Big Sky Mine Area B Application 180, June 2007; Rosebud Area C Application 172, August 2006; Rosebud Mine Area D Application 115, November 1985; Rosebud Mine Area C Application 125, January 1989; Rosebud Area D Application 161, October 2001; Rosebud Area Mine B Application 134, January 1995; Rosebud Mine Area B Second Extension, June 1983; and Rosebud Mine Area A Application 107, June 1984.

REQUEST FOR PRODUCTION NO. 12:

Please produce all of the following documents:

A. Schwehr, 1981 (cited in DEQ's CHIA for Amendment AM4 at 9-9);

B. WECo, 1986 (cited in DEQ's CHIA for Amendment AM4 at 9-9);

C. MME, 1995 (cited DEQ's CHIA for Amendment AM4 at 9-9);

D. Van Voast, W.A., Hedges, R. B., McDermott, J.J., 1977 (cited in DEQ's CHIA for Amendment AM4 at 11-4);

E. Slagle et al., 1983 (cited in DEQ's CHIA for Amendment AM4 at 11-3);

F. Montana Department of State Lands (MDSL) Reclamation Division, 1981. Alluvial Valley Floor Decision Document for East Fork Armells Creek (cited in DEQ's CHIA for Amendment AM4 at 11-2);

G. Montana Department of State Lands (MDSL) Reclamation Division, 1982 (1). Memo to Peabody Big Sky Mine from Jeff Hagener and Bob Ringler, regarding Alluvial Valley Floors (cited in DEQ's CHIA for Amendment AM4 at 11-2);

H. Montana Department of State Lands (MDSL) Reclamation Division, 1982 (2). Alluvial Valley Floor Decision Document for a portion of Stocker Creek in the vicinity of Western Energy's Rosebud Mine. Helena, Montana (cited in DEQ's CHIA for Amendment AM4 at 11-2);

I. Montana Department of State Lands (MDSL) Reclamation Division, 1984 (1). Alluvial Valley Floor Decision Document for portions of Stocker and East Fork Armells Creeks in the vicinity of Western Energy's Rosebud Mine. Helena, Montana (cited in DEQ's CHIA for Amendment AM4 at 11-2);

J. Montana Department of State Lands (MDSL) Reclamation Division, 1984 (2). Alluvial Valley Floor Decision Document for East Fork Armells Creek. Helena, Montana (cited in DEQ's CHIA for Amendment AM4 at 11-2);

K. Montana Department of State Lands (MDSL) Reclamation Division, 1984 (3). Alluvial Valley Floor Decision Document for portions of Pony, Spring and Cow Creeks within and adjacent to Western Energy's proposed Area D Mine. Helena, Montana (cited in DEQ's CHIA for Amendment AM4 at 11-2);

L. Montana Department of State Lands (MDSL) Reclamation Division, 1986. Alluvial Valley Floor Decision Document for Lee Coulee in its entirety to its confluence with Rosebud Creek, Helena, Montana (cited in DEQ's CHIA for Amendment AM4 at 11-3);

M. Pacific Northwest National Laboratory (PNNL), 2014. 2013 Hydrologic/Water Quality Study of Cow and Pony Creek Drainages, Rosebud County, Montana. Richland, Washington (cited in DEQ's CHIA for Amendment AM4 at 11-3);

N. Van Voast, W.A. and Reiten, J.C., 1988. Hydrogeologic responses: twenty years of surface coal mining in southeastern Montana. Montana Bureau of Mines and Geology, Mem. 62, 30 p. (cited in DEQ's CHIA for Amendment AM4 at 11-4);

O. Western Energy Company, 1984. Rosebud Mine, Area C Mine Permit. Western Energy Company. Colstrip, Montana (cited in DEQ's CHIA for Amendment AM4 at 11-4);

P. Western Energy Company, 1983. Hydrologic Resource Volumes, Aquifer Test Data (cited in DEQ's CHIA for Amendment AM4 at 11-4);

Q. Western Energy Company, 1984. Cow Creek alluvial valley floor investigation. Prepared by Hydrometrics, Inc., Helena, MT(cited in DEQ's CHIA for Amendment AM4 at 11-4);

R. Any and all emails in DEQ's possession or control between the individuals identified in INTERROGATORY NO. 1, INTERROGATORY NO. 3, INTERROGATORY NO. 4, regarding preparation of DEQ's CHIA for Amendment AM4;

S. Any and all emails in DEQ's possession or control between the individuals identified in INTERROGATORY NO. 1, INTERROGATORY NO. 3, INTERROGATORY NO. 4, regarding preparation of DEQ's "Response to Public Comments" included with DEQ's Written Findings for Amendment AM4 issued on December 4, 2015;

T. Any and all drafts of DEQ's CHIA for Amendment AM4;

U. Any and all drafts of DEQ's "Response to Public Comments" included with DEQ's Written Findings for Amendment AM4 issued on December 4, 2015. The documents requested in items A though Q were provided to Petitioner on February 18, 2016. The documents requested in items R and S are attached as Exhibit 15, except that documents the disclosure of which DEQ objects on the grounds of the attorney-client or attorney work product privileges are not included and are described in the privilege log that is attached as Exhibit 43 (Privilege Log emails numbered 1-31). There are 32 documents that fit the request in item T. Seven are attached as Exhibits 34-40. DEQ objects to production of the others because they are protected by the attorney-client communication and attorney work product privileges. Their description is contained in the privilege log that is attached as Exhibit 42 (Privilege Log

documents numbered 1-25). In response to item U, one document is attached and is labeled Exhibit 41.

VERIFICATION FOR INTERROGATORIES AND REQUESTS FOR PRODUCTION

STATE OF MONTANA)
ss.
County of Lewis & Clark)

I, Chris A. Yde, being first duly sworn, state that I am the supervisor of the Industrial and Energy Minerals Bureau, Coal and Uranium Section, Montana Department of Environmental Quality, and I am authorized to answer the foregoing Interrogatories and Requests for Production and to make this verification. I have read the foregoing Answers to Interrogatories and Responses to Requests for Production, and the information provided in them is true and correct to the best of my knowledge and belief.

Chris A. Yde

Subscribed and sworn to before me by Chris A. Yde, this 26th day of February 2016.

(Seal)

HILLARY HOULE
NOTARY PUBLIC for the
State of Montana
Residing at Helena, Montana
My Commission Expires
May 19, 2019

Signature of Notary

As the attorney for the Department of Environmental Quality, I am signing these Responses to Requests for Admission, Answers to Interrogatories, and Responses to Requests for Production and certify this response in accordance with M. R. Civ. P. Rule 26(g)(1).

STATE OF MONTANA,
DEPARTMENT OF
ENVIRONMENTAL QUALITY

John North, Chief Counsel
Special Assistant Attorney General

CERTIFICATE OF SERVICE

The undersigned certifies that on February 27, 2016, he caused the original or a copy of the foregoing DEQ Responses to MEIC First and Second Discovery Requests delivered or transmitted to the person named below as follows:

Original sent by first class and a copy by electronic mail:

Shiloh Hernandez
Western Environmental Law Center
103 Reeder's Alley
Helena, MT 59601
(406) 204-4861
hernandez@westernlaw.org

By:

Exhibit 5

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1973

STATE DOCUMENTS

MAR 22 1973

F I N A L:

PLEASE RETURN

ENVIRONMENTAL IMPACT STATEMENT ON THE PROPOSED MONTANA POWER COMPANY ELECTRICAL GENERATING PLANT AT COLSTRIP, MONTANA

MONTANA STATE LIBRARY
930 East Lyndale Avenue
Helena, Montana 59601

March, 1973

Department of Health and Environmental Sciences
John S. Anderson, M.D., Director
Environmental Sciences Division
Benjamin F. Wake, Administrator
Air Quality Bureau
Don Holtz, Chief

Exhibit 4

MONTANA STATE LIBRARY
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Final environmental impact statement on
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MSL SEP 25 '74					
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http://archive.org/details/finalenvironmen1973mont_0

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FORWARD

This final environmental impact statement is submitted pursuant to the Montana Environmental Policy Act, (MEPA), Section 69-6504 (b)(3). The statement was prepared by the Environmental Sciences Division of the Montana State Department of Health and Environmental Sciences, regarding a coal-fired electric generating plant proposed for construction near Colstrip, Montana, for which an application has been received for a permit to construct.

Although MEPA requires this agency to assess all forseeable impacts that might result from construction of the proposed plant, issuance of the requested permit is contingent only upon adequate demonstration by the applicant of the ability to prevent illegal air pollution. To date, research by the State and the applicant has not indicated that illegal air pollution would result.

Under MEPA, agencies and individuals have 30 days to comment following publication of a final environmental impact statement. If, within that time, no credible evidence of illegal pollution is received, the permit will be issued as requested.

Comments should be submitted to the Air Quality Bureau, Montana State Department of Health and Environmental Sciences, Cogswell Building, Helena, Montana, by April 20, 1973.

Exhibit 4

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SUMMARY: FINAL ENVIRONMENTAL IMPACT STATEMENT

Coal-Fired Steam Electric Plant, Colstrip, Montana
Prepared by Montana State Department of Health and Environmental Sciences
Environmental Sciences Division

1. TYPE OF ACTION: Administrative

2. DESCRIPTION OF ACTION:

The Montana Power Company and the Puget Sound Power and Light Company have made application for a Construction Permit to the Montana State Department of Health and Environmental Sciences, Environmental Sciences Division, for a 700-megawatt coal-fired steam electric power generating plant to be located just east of Colstrip, Montana. The first unit is scheduled for completion in 1975 and the second in 1976. The Montana Environmental Policy Act required that an impact statement be submitted and evaluated prior to any major action, in this case the granting of a Permit to Construct.

The generating station will burn coal from an adjacent mine. The coal will be transported by truck from the mine to a crusher and from there to the plant by conveyer. Cooling water, boiler make-up water, and scrubber water will be transported by pipeline from the Yellowstone River, about 31 miles to the North. There will be no return to the river.

The companies propose to construct two additional transmission lines from Colstrip to the Billings area.

3. PROBABLE IMPACT OF THE PROPOSED ACTION ON THE ENVIRONMENT

Sulfur oxides, particulate, nitrogen oxides, trace elements, water vapor and heat will exhaust from two 500-foot stacks. Emission and ambient air levels probably will comply with all state and federal standards. Effects of pollutants, including fluorides, on flora and fauna, weather, and aesthetics appear minimal, although subtle long-term effects may be indeterminable.

Construction of the power plant, cooling systems, transmission lines, pipeline, and strip mine development impose primary and secondary impacts on the environment. These will affect flora and fauna, aesthetics, the economy, society and others.

4. PROBABLE ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED, SHOULD THE PROPOSAL BE IMPLEMENTED

Some of the adverse effects include the consumption of a non-renewable resource, air quality degradation, disturbance of land by mining, and aesthetic degradation.

5. ALTERNATIVES TO THE PROPOSED ACTION

The only alternative feasible within the time frame set for construction of the plants is a reduction in the rate of increase of the use of electrical energy.

6. SHORT TERM BENEFITS VS. LONG TERM EFFECTS

The long-term adverse effects may well outweigh the short term gains.

Exhibit 4

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7. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF NATURAL RESOURCES

The proposed plant will consume 90 million tons of coal over the 30-year life of the plant, or three million tons per year of this non-renewable resource.

8. RESPONSE TO THE DRAFT STATEMENT

Over 3000 responses have been received commenting directly or indirectly on the draft statement, mostly in opposition to the construction.

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SUMMARY OF STATISTICS OF COLSTRIP PLANT

Location	One mile east of Colstrip, Montana, 30 miles south of I-94, at Forsyth; Section 34, Township 2 North, Range 41 East, Rosebud County, Montana
Elevation	3200 feet above sea level
Ownership	The Montana Power Company and Puget Sound Power and Light Company
Operation	Montana Power Company
Scheduled Completion	Unit #1, July, 1975; Unit #2, July, 1976
Total Cost	$183,000,000
Steam Generator	Combustion Engineering Company
Capacity	2,520,000 lb steam/hr/unit
Size	206 feet high, 160 feet wide, 238 feet long
Turbines	General Electric
Capacity	350 mw/unit, 700 mw total (nominal)
Cooling Towers	Ecodyne Corporation Wet crossflow induced draft type 65 feet high, 48 feet wide, 252 feet long; 117,200 gal/min inlet water/unit
Stack	Two stacks--each 500 feet high, approximately 30 feet diameter at base
Scrubbers	
Type	Venturi with alkali chemical system
Capacity	1,600,000 cu. ft. per min. @ 293°F
Buildings	300 feet high, 160 feet wide, 238 feet long
Coal	385,000 #/hr; 8,843 BTU/#, 23.87% moisture, 0.77% sulfur, 8.59% ash
Mine	Strip-type, approximately 65 surface acres/year, 3,000,000 tons of coal/year
Transmission Lines	3 lines, 230 kv each, 60 feet high, 800 feet average span, 3 conductors, 2 shield wires per line
Pipeline	22" to 26" diameter, (minimum), approximately 30 miles
Water Consumption	8,000 gals per minute, 4.2×10^9 gal per year
Settling Ponds	30 surface acres, 100 acre feet

Exhibit 4

Exhibit 4

I. DESCRIPTION OF PROPOSED ACTION

Exhibit 4

Exhibit 4

I. DESCRIPTION OF PROPOSED ACTION

Plant and Process

The Montana Power Company (MPC) and the Puget Sound Power and Light Company propose to construct a 700 megawatt electrical generating station near Colstrip, Montana. This complex of two 350 mw units would provide electricity for Montana users and for delivery to the Northwest Power Pool, of which the two companies are members. The plant would burn coal, supplied from deposits in the immediate area of Colstrip. The first unit is scheduled for completion by July, 1975, and the second by July, 1976.

The proposed plant would be the third coal-fired steam electric generating facility and the first "mine-mouth" plant to be constructed in Montana. Montana Dakota Utilities' 44 mw plant at Sidney (1958) and Montana Power's 180 mw Corette plant at Billings (1968) are small by comparison. The applicant (MPC) states that economic, technical and environmental considerations favor locating the plant at Colstrip rather than nearer the load centers. Mine-mouth generation is not always favored, as demonstrated by the large amount of Montana low sulfur coal now being contracted to power plants old and new in the midwest.

In the case of the proposed Colstrip plant, the applicant states that the mine-mouth facility is favored in part because no new transmission lines will be required west of Billings. One line currently is under construction to carry electricity from Billings to the plant until generation begins. The power flow would then be reversed, with electricity produced at Colstrip flowing to Billings.

Two additional lines are in the planning stage. No routes have been selected, the applicant states, although corridors have been selected, as illustrated in the section on impacts.

The alternative of hauling coal to a plant nearer the load centers would leave the applicant open to disruptions from labor disputes, increased costs from increasing railroad rates, and other continuing costs. By contrast, a power line, once built, has relatively little maintenance cost.

Exhibit 4

Environmentally, the Colstrip area was favored for the project because it

> "is remote and the development would affect few people directly . . ."

according to the applicant. Further, the applicant asserts,

> "the weather patterns of eastern Montana are generally less confining than the more mountainous terrain of much of MPC's service area."

Continuing in the words of the applicant:

> "Existing land use levels would be upgraded by the proposed development; i.e., more people would realize more use from the energy available from this land than the values being received by very few people at its present level of use. Also, the land disturbed by the mining activity will be reclaimed, and the extensive research over the past 5 years in WECo's (Western Energy Company) area, indicates the disturbed land will be back in production in 3 to 5 years. The site adjacent to the town of Colstrip minimizes the travel and time of the operating personnel to and from work, as town facilities, including homes, would be provided by expanding the existing village."

A number of other possible sites within the MPC service area were investigated before Colstrip was selected. MPC data indicate two of the sites considered were Cushman, near Ryegate, and Springdale, between Livingston and Big Timber. Economic evaluation found Colstrip was favored on a cost basis by less than one percent. Nevertheless, Colstrip was chosen, for reasons previously mentioned.

Air pollution probably is the most serious environmental effect of coal-fired generating plants. Potential air pollution from the proposed plants would be controlled by venturi wet scrubbers. The scrubbers purchased for the Colstrip plant are designed to remove both SO_2 and particulate matter from the combustion gases. Although venturi scrubbers of various design have long demonstrated a high efficiency in removal of particulate matter larger than 2 micron, their long-term reliability for SO_2 removal still is questioned by the utility industry.

The EPA is convinced that wet scrubbers using lime slurry can effectively control SO_2, and the EPA New Source Performance Standards were formulated on the assumption of their workability.

In justifying its new source standards, the EPA stated as follows:

> "The administrator took into account the following facts in determining that there has been adequate demonstration of the achievability of the standard.

Exhibit 4

"There are at present three SO_2 removal systems in operation at U. S. power stations. Moreover, a total of thirteen electric power companies have contracted for the construction of seventeen additional units, most of which will become operational in the next two years."

The EPA then mentioned three units which have had adequate success in operation. The most successful of the three was a Bahco unit which had no serious operational difficulties between November, 1969, and March 21, 1972, when the EPA justified its standard in the Federal Register.

A number of venturi scrubbers have demonstrated effective removal of SO_2 over a relatively short trial period, but the degree of their efficiency over longer periods is in the test stage.

An article in the December, 1972, Engineering and Mining Journal assessed the state of the art of SO_2 removal as follows:

"It has been independently concluded by a number of investigators that the wet limestone scrubbing process is the closest to commercial availability of the many processes suggested to date. Under pressure from regulatory bodies, commitments have been made by the utilities industry to build large, commercial-prototype installations employing limestone scrubbing. However, despite extensive laboratory and pilot plant research to date, a more realistic view is that considerable development work remains to be done before the process can be considered 'proved.'"

Continuing, "A difficult and perhaps extended period of shakedown can be anticipated for the initial commercial units now being built or started up in the utility industry. And although these units are being installed in commercial systems, they must be regarded as development in nature."

A recent technical conference on the subject revealed a wide range of problems being experienced by operators of venturi scrubbers on power plants.[10] At the conclusion of the conference, the program chairman addressed the assembly as follows:

"Let me say that a lot of what you've heard today sounds pessimistic. You really wonder how these companies stand all of the pains they're going through. But thank God for those who are paying the price to lead us into this important technology.

"There were a lot of pessimistic reports on many of the pioneering nuclear plants in days past. There were continual embarrassments and cost and schedules were often way out. But go back and see how well those plants are running today and compare their capital costs with today's estimates. Those pioneers paid a price to lead us into nuclear technology, but in the end, many got a bargain."

Exhibit 4

"I had a couple of people tell me last night that they're scrambling now to get up to speed on sulfur-removal technology, and that they wish they already had a couple of years' experience in running a scrubber. So I hope there's some analogy here to the early nuclear experience. Gentlemen, I thank you. I'm sure the whole industry thanks you for leading the way."

Recent experience elsewhere indicates venturi scrubbers can be operated reliably and efficiently on large power plants. At the Dave Johnston plant near Casper, Wyoming, for example, gasses from a 320 MW unit have been scrubbed at an efficiency above 99 percent on particulate and about 50 percent on SO_2.[33]

Although the plant does not fall under the EPA New Source Performance Standards, the owner, Pacific Power and Light, intends to spend $30 million installing scrubbers on the other three stacks at the Casper plant, believing them to be more effective in pollution control than electrostatic precipitators.

The scrubbers for the proposed Colstrip plant would be substantially over-designed and operated in parallel with three venturis on each unit. Should one venturi malfunction or require maintenance, the boiler still could operate at 80 percent of full load, with the two operating venturis maintaining the design collection efficiency.

All assumptions made by the State regarding the potential for air pollution are contingent upon operation of the scrubbers at the efficiencies guaranteed to the applicant by the supplier; 99.5 percent on particulate, 39.7 percent SO_2 removal. Performance at these efficiencies would limit SO_2 emissions to 1.0 lb SO_2/million BTU, and fly ash emission to .018 grains per actual cubic foot, at any operational load.

Should the scrubbers malfunction, the operating load of the plant would have to be reduced to whatever load could be handled by the remaining operable scrubbers. There is no bypass for combustion gas to escape around the scrubbers, and the plant will not be allowed to operate in violation of state and federal air pollution laws. Monitoring of ambient air and stack gasses will be performed as the need is seen.

The applicant will follow the requirements of the Environmental Protection Agency by installing in-stack continuous monitoring equipment for particulates, sulfur oxide, and nitrogen oxides. Test ports will be placed in the stack and breaching for source monitoring by the company and state and federal agencies.

Exhibit 4

The state is confident that the system ordered by the applicant for pollution control is as effective as any on the market today.

A study of venturi scrubbers on power plants performed for the EPA indicated a high efficiency on a variety of pollutants generated in coal combustion. Hydrogen fluoride, one of the most worrisome pollutants, was removed, along with other soluble gasses, at an efficiency averaging 90 percent. The lowest removal efficiency of the gasses was 70 percent, the highest 99.7.

Tests at a pilot venturi scrubber operating at the J. E. Corette plant in Billings indicated an average fluoride removal above 90 percent. More specific data is included in the section on Emissions. A description of the scrubber operation follows later in this section.

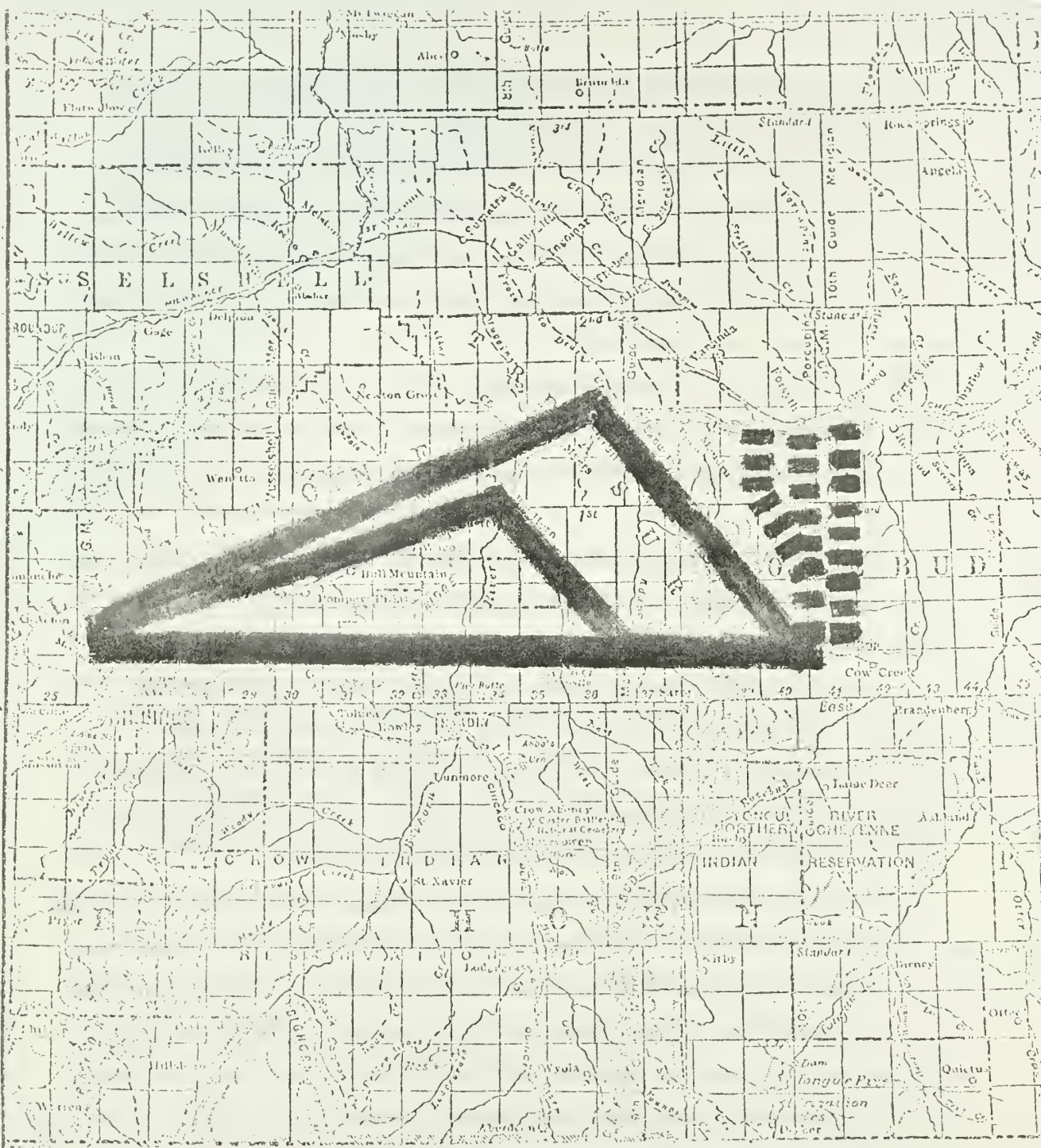
Mechanical draft evaporative cooling towers will be used to cool the plant. There will be no discharge of heated water, except into the air as vapor.

The towers would be

> "supplied by Ecodyne Cooling Products Company. The size and location have been shown in the construction permit application. Each plant unit will have one cooling tower of seven cells. The fans will be powered by 200 hp motors and will use 185.2 hp at rating. The towers are rated at an inlet wet bulb temperature of 60°F and will have a range of 31.7°F and an approach of 21.5°F when cooling 113,000 gpm of 113.2°F water. Actual condenser flow will be 104,000 gpm. Evaporative loss at rating will be 3.17% and guaranteed maximum drift will be 0.02%. Under these conditions, the water consumed by the towers will be 3,323 gpm at the required condenser flow."

The cooling towers will receive hot water from the plant condensers and return cool water to condense steam from the turbines. Blowdown from both the cooling towers and the boiler will be discharged to the ash pond. Pond water will be recirculated to the scrubbers in a closed loop system. Collected flyash from the scrubbers, bottom ash from the boilers, and economizer ash will be sluiced to the ash pond, and periodically removed for disposal in a manner not yet determined. Two ash ponds designed for decanting and draining would aid in the ash disposal. The ponds will be sealed with bentonite or plastic to prevent leaching.

Exhibit 4



LEGEND

WATER LINES

230 KV ELECTRIC TRANSMISSION

FIGURE 1

POSSIBLE CORRIDOR ROUTES

THE MONTANA POWER CO.

BUTTE, MONTANA

DRAWN		SCALE	NTS
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APPROVED		NO.	

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Pipeline and Water Supply

Plant water will be obtained from the Yellowstone River and supplied to the plant by a buried steel pipeline at least 22 inches in diameter. The pipeline will intercept the Yellowstone at one of three possible points illustrated in Fig. 1. It will carry 8,000 gallons of water per minute to a 100 acre-feet surge pond. The pond, covering approximately 30 surface acres, will hold a three-day supply of water for the plant.

Transmission Lines

As previously noted, electricity would be transferred by three 230 KV transmission lines, originating in the plant switchyard and extending west to the Billings area. The line now under construction is routed south of the Yellowstone River Valley through Hardin to the J. E. Corette steam electric generating station in Billings. Two additional lines are scheduled for completion in mid-1975 and 1976. These two lines will share a common corridor where feasible, crossing the Yellowstone River Valley east of Billings at a location yet to be determined. They will terminate at a new substation to be added to the Montana Power Company's integrated system north of Billings. Each line will consist of three conductors and two shield wires supported by two vertical wooden poles with some three pole structures where required. The lines will be approximately 60 feet high with an average of 800 feet between poles.

The Billings substation will be the termination point of six 230 KV lines. Two of these, one from Anaconda and one from the Corette plant, are already operating. An additional line from the Billings plant would be put on the existing double circuit towers. Another of these lines will be the Billings-Great Falls line, construction of which will begin in 1973. The Colstrip lines would be the last two lines to terminate in the substation. No surveying has begun on the two Colstrip lines, according to the applicant. No right-of-way was procured as of January 31, 1973. In the words of the applicant,

> "A July, 1973, completion of preliminary survey is necessary to allow sufficient time to evaluate environmental engineering, right-of-way, and material

Exhibit 4

considerations before construction which must commence in the spring of 1974."

Power lines and pipelines are further noted in the section on Impacts.

Strip Mining and Coal Supply

Western Energy Corporation, a wholly owned subsidiary of Montana Power Company, will supply coal for the generating facility. Approximately 65 surface acres will be mined each year to supply the estimated consumption of three million tons of coal per year. Coal will be trucked from the mine pits to a crusher and taken by conveyor belt to the plant site stockpile. The Montana State Department of Lands will make intensive evaluations of the strip mining and reclamation necessary for this facility. Environmental impact statements will be written, as required by the Montana Environmental Policy Act of 1971. The Department of Lands also requires that permit applications be submitted and the mining will be closely regulated.

The vast quantities of strippable coal in eastern Montana and the Fort Union Region suggest further electrical energy development in the area. The North Central Power Study, funded and supported by the Bureau of Reclamation in collaboration with some 35 interested utilities, proposed development of up to 53,000 mw generating capacity in the Fort Union Region of southeastern Montana and northern Wyoming. The Montana Power Company and Puget Sound Power and Light Company are considering at least two additional 700 mw units at Colstrip.

Construction and Location

The proposed plant will be located immediately east of the company town of Colstrip, about 30 miles south of Interstate 94 at Forsyth and about 90 cross-country miles due east of Billings. Montana Power Company owns and has available 1365 acres for the plant site. This area will contain the two thermal electric generators, cooling towers, surge pond, ash ponds, and a coal storage area.

Employment during construction will peak at 800-900 men. Following construction, approximately 44 persons will be required to operate Unit #1, and 19 more will be

Exhibit 4

required for Unit #2. An additional 55 employees will be needed in the mining operation. Operating personnel and mining employees probably will be housed in Colstrip. The Ken R. White Company of Denver, land-use planners and designers, has developed a town plan.

The total cost of the proposed facility will be in excess of $183 million. The Bechtel Corporation, headquartered in San Francisco, is the engineer-contractor for the generating facility.

Detailed Description of Process

Figure 2 illustrates a material balance for the generating facility as submitted by the applicant.

Following is a more detailed process description1 also submitted by the applicant:

"Coal of approximately 1.5 inch lump size is transported to the plant storage site. It is mechanically conveyed into the plant and fed to coal pulverizers which reduce it in size from 1.5 inches to a size such that 70% of the coal will pass through a 200 mesh sieve. The pulverized coal is then used as combustion fuel for a steam generator. The coal is fed into the steam generator through fuel nozzles, which are located at the four corners of a furnace. The coal is mixed with air in the furnace and ignited. The combustion process gives off energy in the form of heat which is transferred through the furnace walls to water which is converted to steam at 2,400 lbs per sq. inch and 1,000°F. The steam is piped to a turbine which extracts energy by reducing the steam to a low pressure and temperature. The energy is used to rotate the shaft of an electric generator whose output is delivered to an electric transmission system exterior to the plant.

"The low pressure steam exhausted from the turbine is reconverted to water by cooling in a condenser, and then returned to the steam generator for reuse. The cooling is accomplished by supplying water at a lower temperature than the steam to the tube side of a shell and tube heat exchanger (condenser). The cooling water absorbs the heat of the condensing steam through the tube walls and is pumped to a cooling tower where it is exposed in the form of droplets to a flow of atmospheric air. The air evaporates some of the water causing the balance to be cooled so that it can be returned to the condenser for reuse. Fresh water to replace the amount that is evaporated is supplied to the cooling tower from the surge pond or pipeline.

"In the steam generator, the unused portions of the combustion air and the gaseous products of combustion are combined, and along with any suspended fly ash from the burned coal, are conveyed to a flue gas scrubbing system installed for emission control. This is a full stream scrubber system that will simultaneously remove fly ash and sulfur dioxide. The removal is accomplished by scrubbing the flue gas with an alkaline solution of water

Exhibit 4

Exhibit 4

Figure 2

and calcium carbonate, which is generally available from the fly ash. If the alkalinity of the ash varies to a point where additional alkalinity must be added, it is obtained by the addition of soda ash (Na_2CO_3) or lime (CaO). The gaseous sulfur dioxide will react with the calcium carbonate to form solid calcium or sodium salts. At the same time, the mechanical action of the scrubber traps fly ash particles in the water droplets. Recirculation within the scrubber system makes the alkalinity in the ash available for the process. The used scrubber solution, newly formed salts, and trapped fly ash are piped to an ash pond where the solids settle out. The pond water is then recirculated back to the scrubber in a closed loop system from which no water is discharged to any natural bodies. This emission control system is guaranteed to limit the sulfur oxide emissions to 1.0 lb SO_2/million BTU and the fly ash emissions to .018 grains per actual cubic foot, at any operational load of the power plant.

"The coal charged into the process will have the following average composition:

Moisture	23.87%
Fixed Carbon	38.95
Volatile Matter	28.59
Ash	8.59
	100.00%
Sulfur	0.77% (included above)
Heating Value	8,843 BTU/lb

At full load, 385,500 lbs per hour of this fuel will be burned in each unit corresponding to 3,410 million BTU per hour of heat release per unit. The corresponding sulfur oxide production would be 5,650 lbs per hour SO_2 or 1,658 lbs SO_2 per million BTU input. The flyash production would be 26,492 lbs per hour, since 20% of the total input of 33,114 lbs per hour will become attached to the furnace walls and removed as boiler slag while the balance leaves the furnace as fly ash. This corresponds to 7.77 lbs of fly ash per million BTU.

"The guarantees on the emission control systems are equivalent to 99.5% particulate removal and 39.7% SO_2 removal, which will limit particulate emissions to 0.039 lbs per million BTU input and sulfur oxide emissions to 1.0 lbs per million BTU input."

Detailed information on the scrubber system follows:

"The supplier of the system will be Combustion Equipment Associates, Inc., 555 Madison Avenue, New York, New York, 10022. The pollution control system consists of three venturi scrubber trains to handle flue gases from each 361.8 mw (gross) generating units. Each venturi scrubber train consists of a venturi scrubber, reheater, I.D. fan, and associated ductwork and piping. The bleed from three scrubber trains is combined and pumped to an ash pond. Each venturi scrubber provides two contacts between liquor and gas streams for optimum removal of both fly ash and SO_2. The first contact in the venturi throat section is of co-current flow type (both liquor and gas flowing in the same direction) whereas the second contact is counter-current flow type (liquor and gas flowing in the opposite direction) and occurs in the separator section--just below the mist eliminators where the flue gas is exposed to

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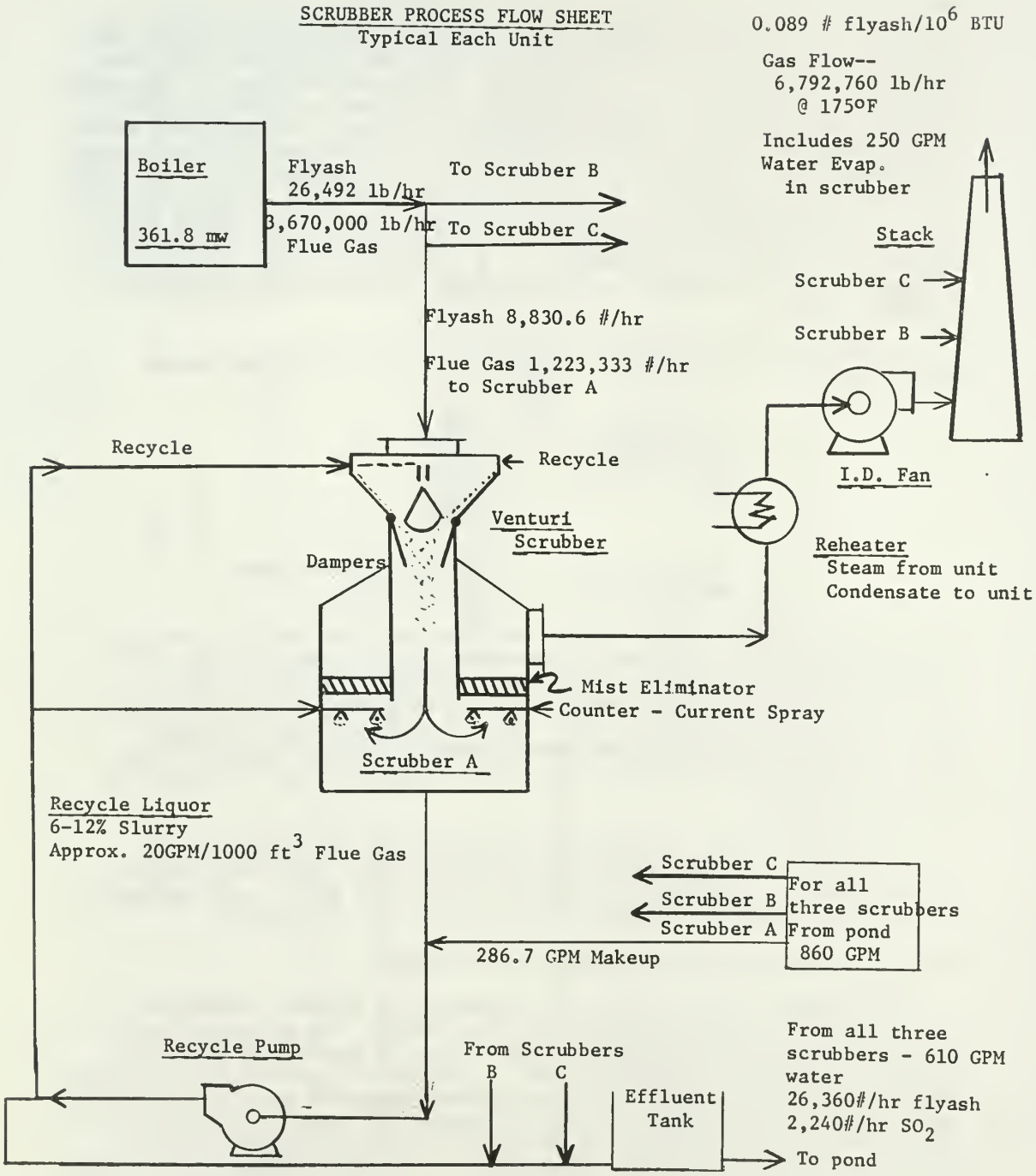

SCRUBBER PROCESS FLOW SHEET
Typical Each Unit
0.089 # flyash/10^6 BTU
Gas Flow--
6,792,760 lb/hr
@ 175°F
Includes 250 GPM
Water Evap.
in scrubber
Boiler
361.8 mw
Flyash
26,492 lb/hr
To Scrubber B
3,670,000 lb/hr
Flue Gas
To Scrubber C
Stack
Scrubber C
Scrubber B
Flyash 8,830.6 #/hr
Flue Gas 1,223,333 #/hr
to Scrubber A
I.D. Fan
Recycle
Recycle
Venturi
Scrubber
Dampers
Reheater
Steam from unit
Condensate to unit
Mist Eliminator
Counter - Current Spray
Scrubber A
Recycle Liquor
6-12% Slurry
Approx. 20GPM/1000 ft3 Flue Gas
Scrubber C
Scrubber B
Scrubber A
For all
three scrubbers
From pond
860 GPM
286.7 GPM Makeup
Recycle Pump
From Scrubbers
B
C
Effluent
Tank
From all three
scrubbers - 610 GPM
water
26,360#/hr flyash
2,240#/hr SO2
To pond

Exhibit 4

sprayed liquor. Essentially all the fly ash removal is attained in the throat section with partial removal of SO_2, and the counter-current spray sections are used to optimize SO_2 removal.

"A portion of the total flue gas containing fly ash and sulfur oxides enters each venturi scrubber, where it is contacted with recycle liquor for fly ash and sulfur oxides removal. The accelerating flue gas shatters the curtain of liquor in the throat into small droplets. These droplets not only trap the dust particles but also provide mass transfer surface for absorption reagent.

"The flue gas and liquor flow downward through the down-comer section. The liquor settles by gravity into the integral recycle tank, whereas the flue gas turns 180 degrees for further contact with the recycle liquor in the counter-current spray zone.

"Each venturi scrubber is provided with recycle pumps (3 - 60% capacity, two operating and one spare) and piping. The bleed from the scrubber is taken from the discharge side of the recycle pumps, and after combining with the bleed from other scrubbers, is sent to the ash pond for final settling. The clear overflow from the ash pond is returned to the scrubber system. The makeup water, equivalent to evaporation plus liquor remaining with the ash pond cake, is added to the scrubber. The makeup water is to be supplied from the plant cooling towers blowdown (CTBD). Part of the CTBD makeup water, treated to the extent of reducing the dissolved solids of Ca ppm as $CaCO_3$ to the river water level, is utilized in the form of sprays to clean any buildup occurring on the mist eliminators.

"The system is designed to use the alkali content of the fly ash for SO_2 removal.

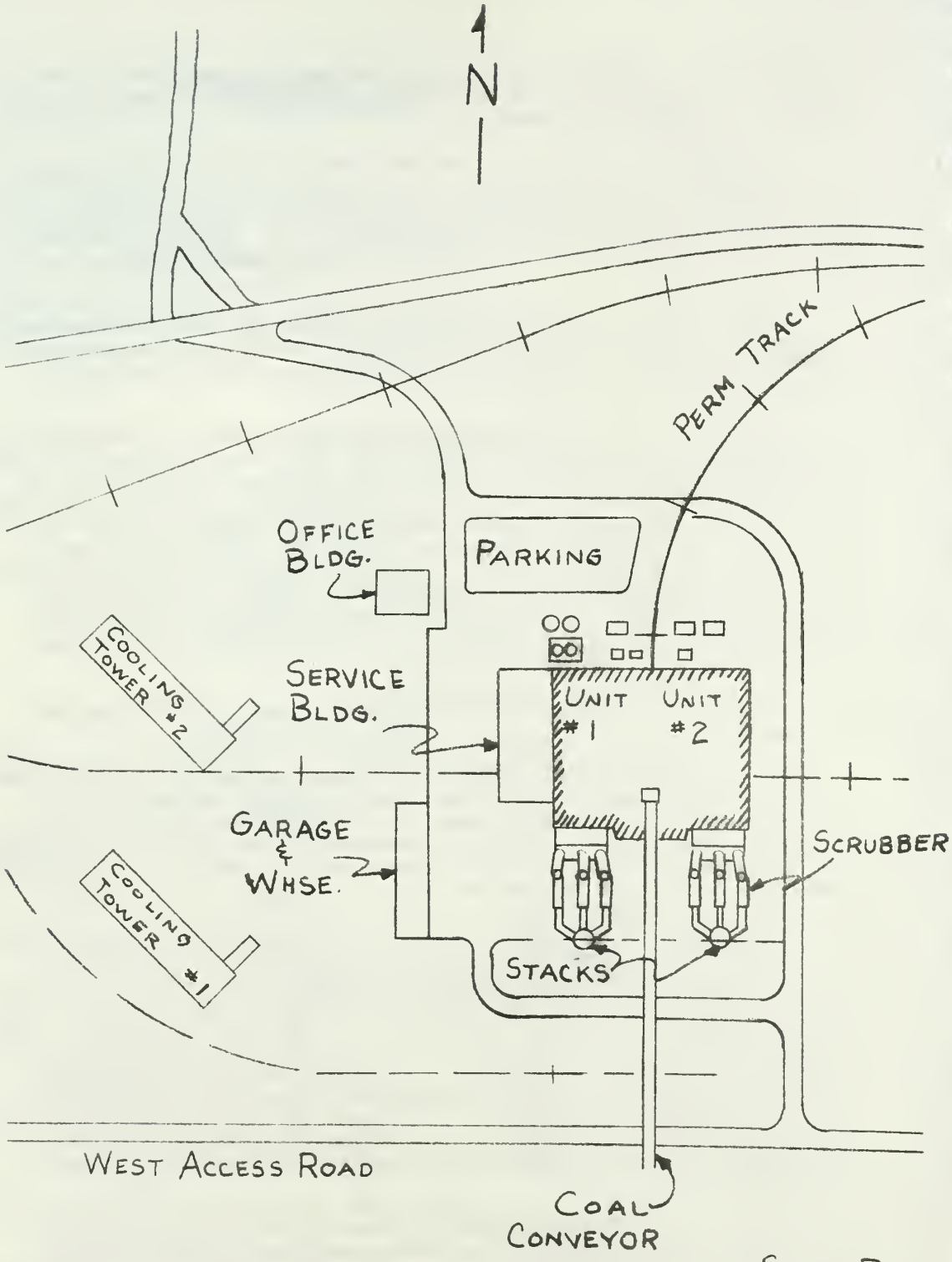
"The materials of construction for all pumps and piping are rubber lined and the system is designed with utmost care to minimize scaling, buildup, erosion and corrosion problems. Using the fly ash as the source of alkali for the process will require a slurry concentration of 6 to 12% in the recycle loop, and this condition will help minimize scaling problems by providing an abundant source of seed crystals for scale to form on.

"The cleaned flue gas then enters the chevron-type mist eliminator where any entrained liquor droplets are efficiently separated and collected from the flue gas. A spray washing system--both above and below the mist eliminator--is provided to prevent any significant buildup on the eliminator section. The entrainment free flue gas is reheated in a steam coil type reheater before entering an induced draft fan. Three sets of plate coil type indirect steam reheaters are provided for reheating the scrubber flue gas by a maximum of 50°F. Soot blowers are included to clean out any possible buildup on the heat exchange surfaces. The dry I.D. fans, one for each scrubber train, handle flue gases leaving the reheaters. The flue gas is combined with the flow from the other scrubber trains and discharged to the atmosphere through a stack.

"The attached scrubber process flow sheet illustrates the foregoing description. The open design of the venturi which will minimize plugging problems and the venturi's relative insensitivity to variations in operating conditions were factors in selecting this equipment."

Figure 3 shows the plant site.

Exhibit 4



SITE PLAN
1" = 200'

COLSTRIP GENERATING PLANT

Exhibit 4

FIGURE 3

II. ENVIRONMENTAL SETTING OF PROPOSED POWER PLANT

Exhibit 4

Exhibit 4

II. ENVIRONMENTAL SETTING OF PROPOSED POWER PLANT

Topography

The power plant is located just outside the town of Colstrip, Rosebud County, in southeastern Montana. The site lies in the Northern Great Plains Province, east of the ranges that make up the Rocky Mountains. The topography is developed on essentially flat lying sediments of the Fort Union Formation which contains most of the coal in eastern Montana and adjacent states. Numerous sandstones and shales are associated with the coal seams.

The Fort Union Formation was laid down as the Rocky Mountains to the west were rising during the Paleocene, about 65 million years ago. The climate was much milder and wetter at that time and the streams carried the sediments from the mountains into the Fort Union Region. In this region, there existed large swamps, producing the many coal seams now found in southeastern Montana and adjacent states. Coal in the Colstrip area is ranked as sub-bituminous and is found in seams about 25 feet thick. During erosion of the Fort Union Formation, coal seams were exposed at the surface where they were sometimes ignited, starting underground coal fires. Many areas in this region have a pink to red rock known as clinker, a direct result of underground fires.

The elevations in the vicinity of Colstrip range from less than 2900 feet (msl) in the Rosebud Creek Valley about 12 miles east of Colstrip to over 4400 feet (msl) as near as 20 miles to the south. The elevation of Colstrip itself is about 3200 feet (msl). The topography exhibits a number of land forms which have been developed on the flat lying sediments of the Fort Union Formation. The rolling upland is dissected by the streams in the area, producing narrow valleys, buttes, and some fairly level land. The level areas are the well-developed flood plains of certain stream valleys.

Colstrip lies within the upper Missouri drainage basin, on the East Fork of Armells Creek, which drains directly into the Yellowstone River. Rosebud Creek also drains an area very close to Colstrip and flows from the southwest of Colstrip to the east and then north into the Yellowstone River. The Yellowstone River flows from west to east

Exhibit 4

and is located about 30 miles north of Colstrip. There are numerous small streams in the area, most of which are intermittent, because of varying frequency and amount of annual precipitation.

Figure 4 shows the Colstrip area.

Population

The present population of Colstrip is 200. The population density in the area immediately surrounding Colstrip is very low, about one to two persons per square mile, mostly ranchers. The town of Lame Deer, population 650, is about 18 miles south of Colstrip, and Forsyth, population 1900, is about 30 miles north of Colstrip in the Yellowstone Valley. Billings, with a population of nearly 80,000, is about 90 miles west of Colstrip. Miles City lies in the Yellowstone Valley about 50 miles to the northeast. The Northern Cheyenne Indian Reservation lies south of Colstrip.

Land Use

Ranching and other agrarian pursuits comprise the bulk of the land usage in the Colstrip area. The ranches are generally a combination of grazing and dry-land crop farming. Soil and moisture are such as to permit some tillaged and irrigated agriculture in the valley bottoms, with crops such as alfalfa hay, wheat, oats, and barley.

There are some forested areas in the vicinity and a portion of the Custer National Forest lies southeast of Colstrip. Some lumbering is done in this area, but the scale is small compared to the lumbering activity in Western Montana. Coal is presently being mined in two places near Colstrip--the Western Energy Mine at Colstrip and the Peabody coal mine a few miles south. In other areas, coal is being mined by the Decker Coal Company at Decker, about 60 miles to the south, and by Knife River Coal Company at Savage, about 150 miles to the northeast.

Historical Values

The Indians were the first inhabitants in southeast Montana and staged some valiant battle efforts in defense of their territory. Custer's Last Stand and the Battle of

Exhibit 4

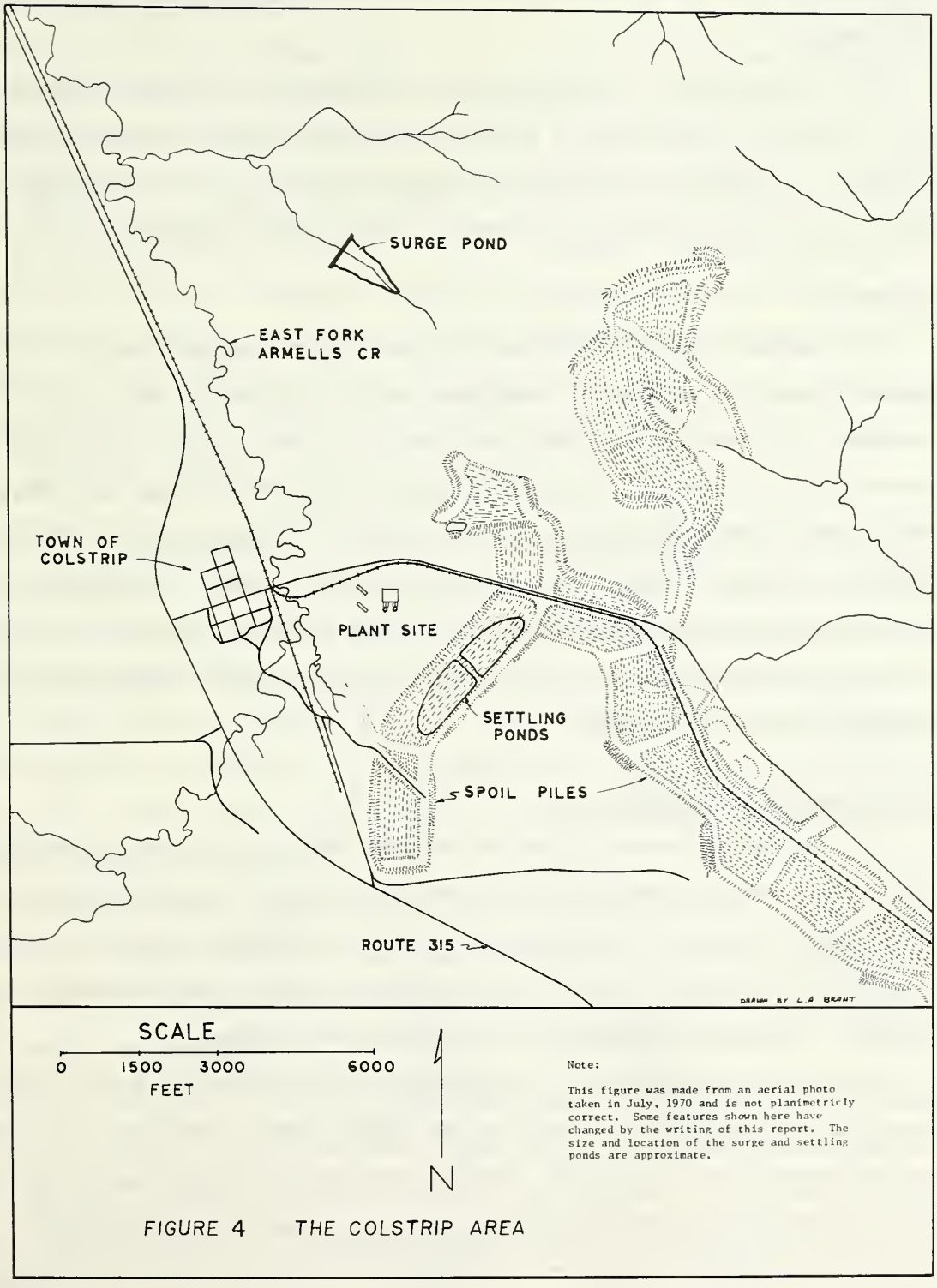


FIGURE 4 THE COLSTRIP AREA

Exhibit 4

the Rosebud are only two examples of the activity during the late 19th century in this area.

The archaeology of the proposed plant and mine site at Colstrip has been studied by a team from the University of Montana, under contract with the Western Energy Company. No significant archaeological material was found, in the opinion of the study team. The relevant portion of the study is included in the appendix.

Recreation

Southeastern Montana offers some excellent recreational opportunities. The Custer National Forest has a number of campgrounds used by local people and tourists. The pronghorn, mule deer, and whitetail deer provide big game hunting to residents and non-residents of Montana. Ring-necked pheasants can be found along the Yellowstone River Valley and Hungarian partridge, sage grouse, and sharptail grouse offer good upland bird hunting. Sport fishermen can find walleye, sauger, and northern pike in the various water courses, especially the Yellowstone River. Ponds near Colstrip have trout and there are reports that a paddlefish spawning ground is developing in the Yellowstone River near Forsyth.

Meteorology and Climatology

Southeastern Montana is in the mid-latitudes which has a prevailing westerly air flow aloft. The major east-west storm track across the U. S. passes through the center of the state. The area is considered semiarid and, as a whole, has what may be termed a modified continental climate. Within the general climate type, topographic effects provide a wide range of temperature and precipitation patterns.

The winters are quite cold, with invasions of cold arctic air from the north being occasionally interrupted by storms from the Pacific Ocean. Spring and early summer are the wettest parts of the year, with the heaviest rains coming from storms involving moisture from the Gulf of Mexico, mostly in May and June. The combination of early-growing season precipitation with rapid temperature warming in May and June, followed

Exhibit 4

by hot, dry summers has helped to produce a stable agricultural base in the arable section of southeastern Montana.

Total precipitation averages about 15 inches per year. The annual mean temperature is 46 degrees with maximum recorded high 110 degrees, and the minimum recorded low -50 degrees. Maximum hourly wind on record is 73 miles an hour, with gusts to 95 observed.

A full year's preliminary meteorological data from a study performed at Colstrip by Montana State University has been received by the state. Included in this data were wind directions, wind speeds and temperature parameters for Colstrip. The study year included the period from November 12, 1971, through November 11, 1972. Most of the wind data were collected at the top of a 307-foot tower. The inversion data were taken from thermocouple positions at the 59 and 294-foot levels on the tower with supplemental information available from aircraft soundings.

Vertical temperature profiles indicate that there were 215 inversions during the year. There were an average of about 17 inversions per month, with durations from 10 to 24 hours and 14 over the year lasting longer than 24 hours. It should be noted that the short inversions normally develop at night when air nearest the ground is radioactively cooled below the temperature of air higher in the atmosphere. These nighttime inversions usually are weak and are broken when the sun warms the ground which in turn warms the lower layers of air. Inversions of this type thus do not normally last beyond the warmest period of the day.

The short inversions, lasting between 10 and 23 hours, were most common in August, September, and October. Also, the data seem to indicate the inversions were strongest during the fall and early winter with over 24 percent of December having extremely stable atmospheric conditions.

There were generally 15 to 50 inversions per month of durations less than 10 hours.

The 14 inversions lasting more than 24 hours occurred during the winter months. There were seven in December, three in January, four in February. The longest inversion lasted 67 hours, and occured in December. Several other inversions lasted more than two days.

Figures 5, 6, 7, 8 and 9 are from the MSU data.

Exhibit 4

FIGURE 5

COLSTRIP WIND ROSE

Compiled from wind data taken at Colstrip, Montana by Montana State University for the Montana Power Company. Instrument was in operation at top of 307 foot tower from November 12, 1971 - November 11, 1972.

Exhibit 4

FIGURE 6

Frequencies of Tops of Early Morning Ground-Based Inversions by Season at Colstrip

(Based on All Morning Aircraft Soundings)

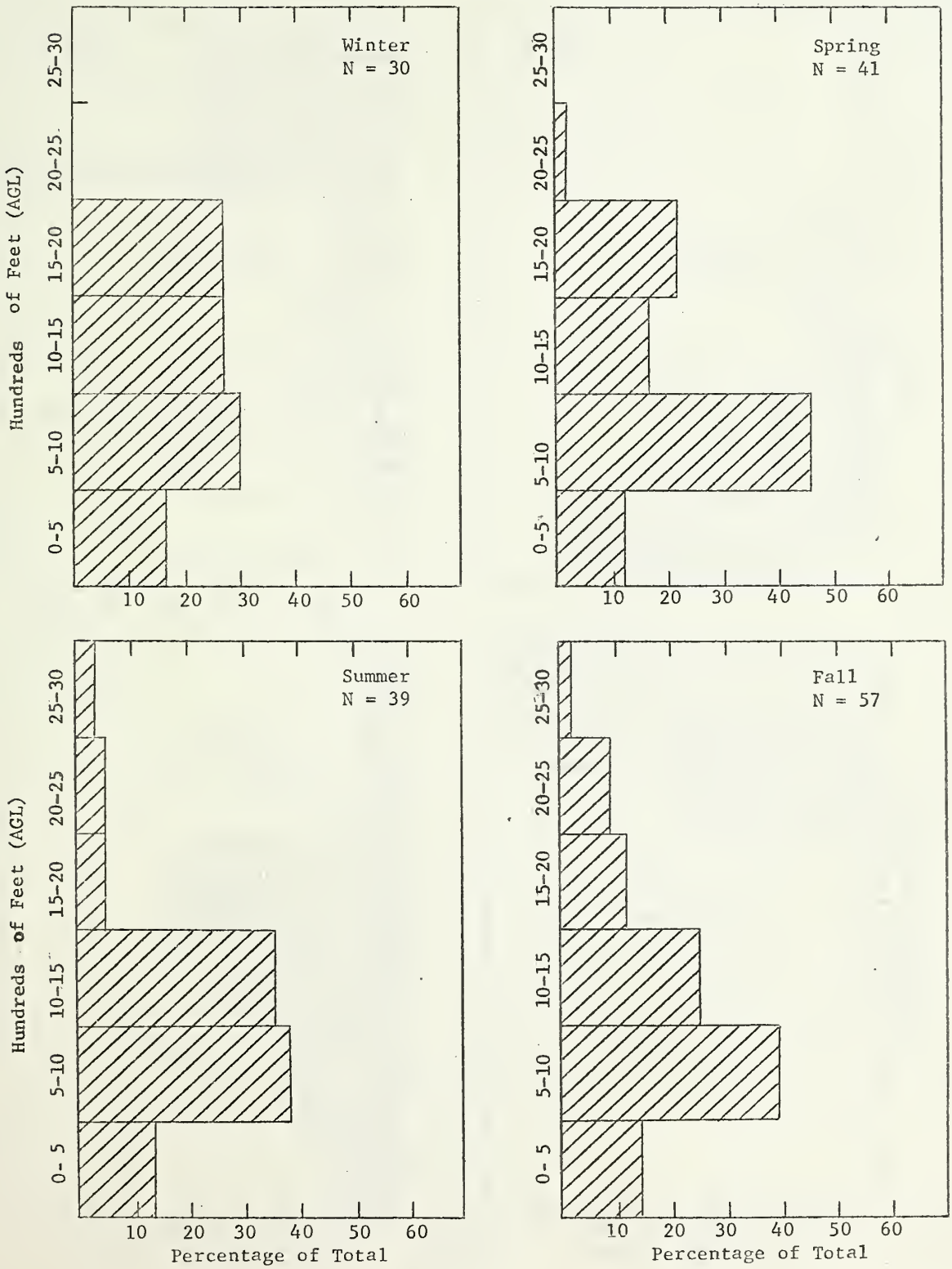


Exhibit 4

FIGURE 7

Frequencies of Maximum Mixing Depths by Season at Colstrip

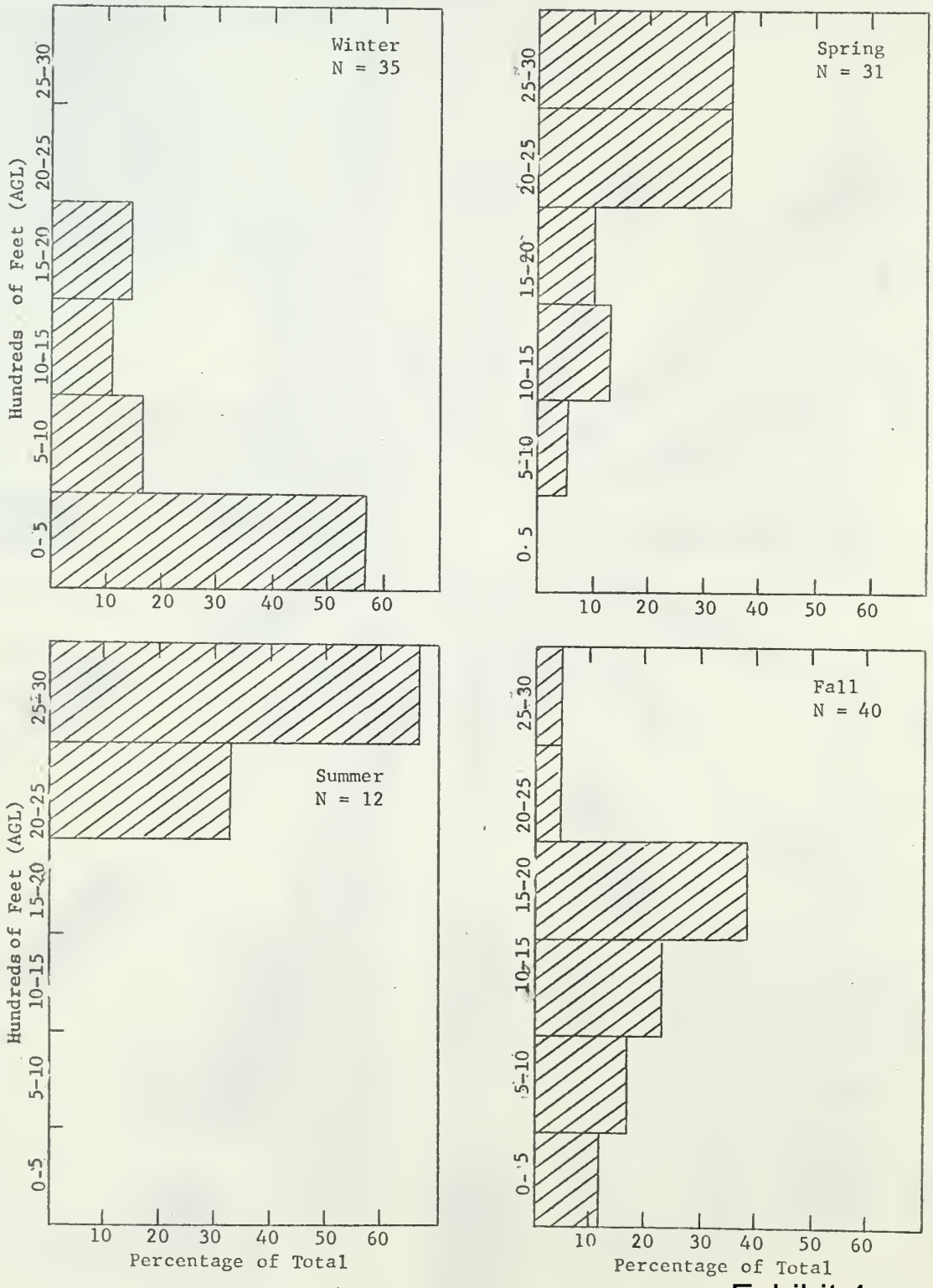


Exhibit 4

Seasonal Wind Roses for 1053 Ft AGL

Based on Near Dawn Pilot Balloon Observations Nov 71 to Nov 72

(Numbers Indicate Mean Wind Speed)

wind blows toward center

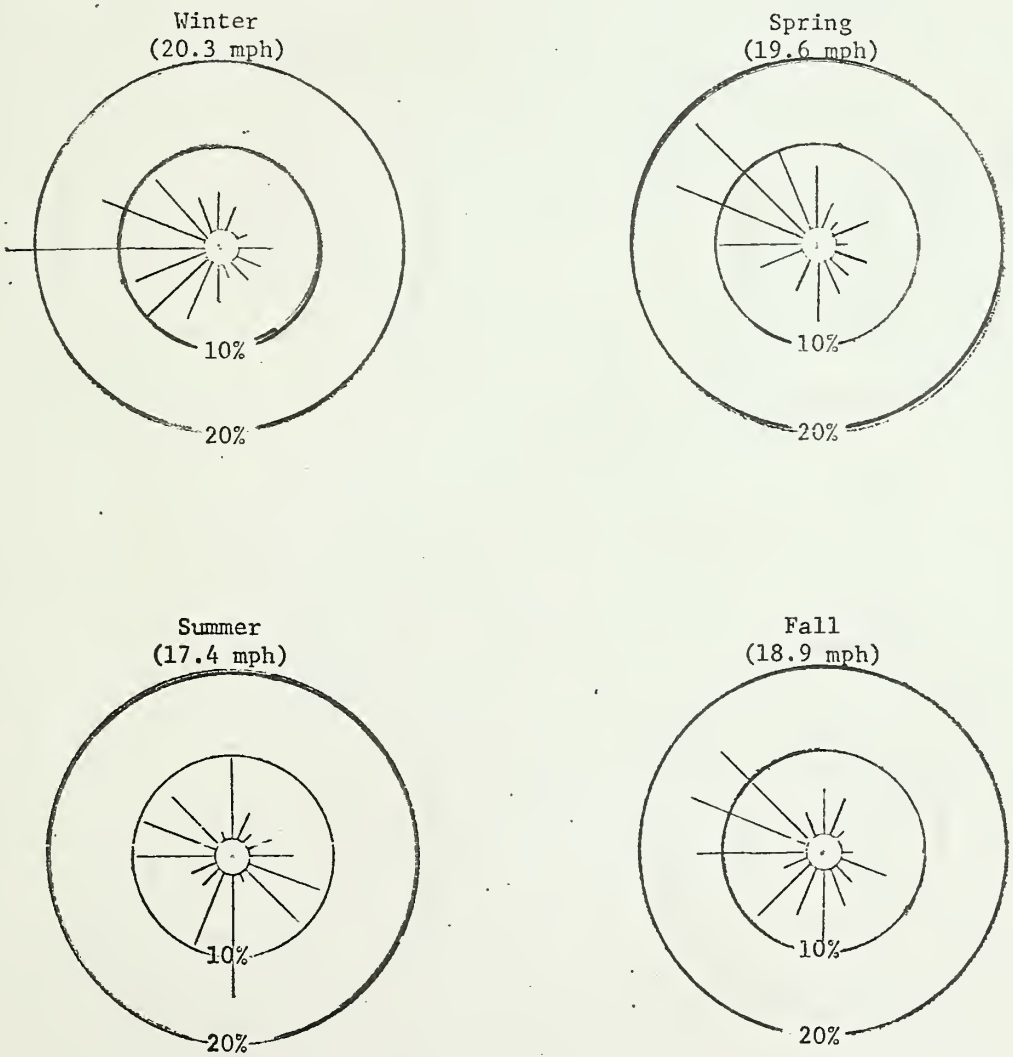


FIGURE 8

Exhibit 4

Seasonal Wind Roses for 1053 Ft AGL

Based on Mid-Afternoon Pilot Balloon Observations Nov 71 to Nov 72

(Numbers Indicate Mean Wind Speed)

Wind blows toward center

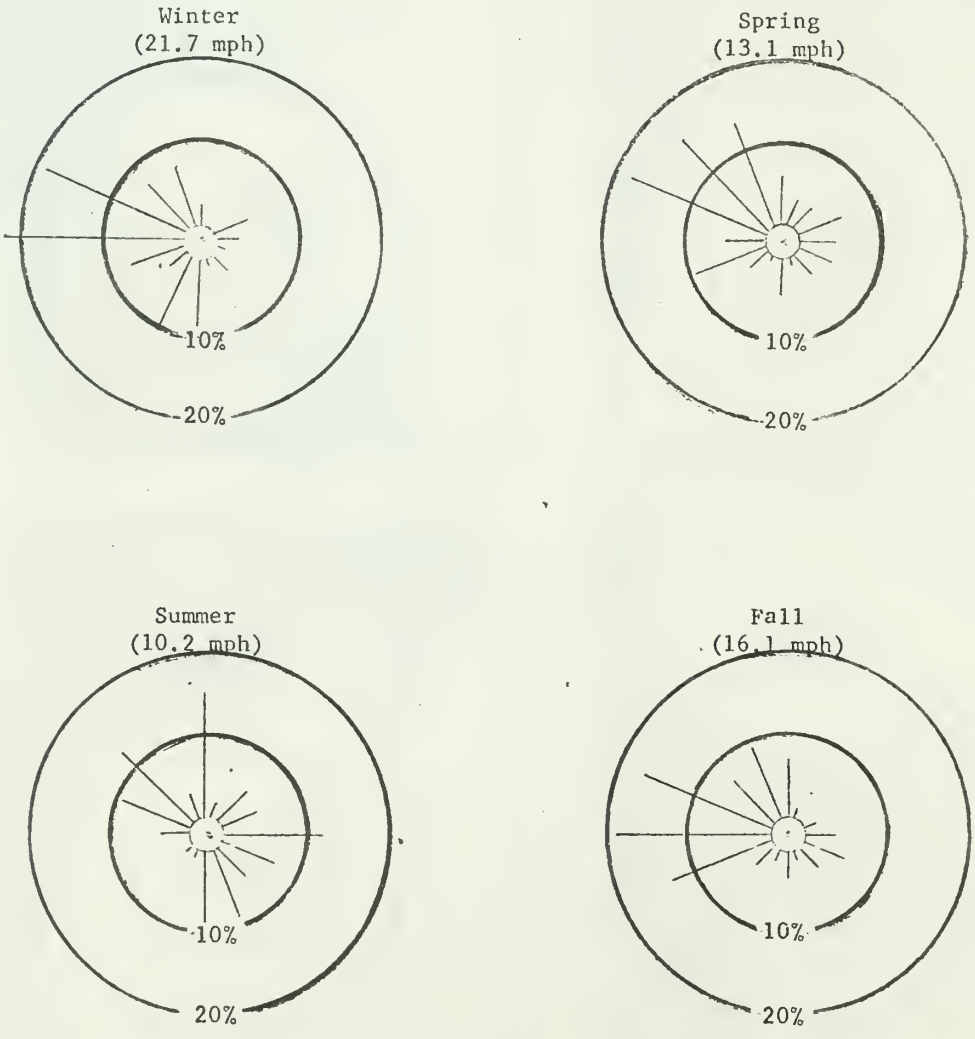


FIGURE 9

Exhibit 4

III. PROBABLE IMPACT ON THE ENVIRONMENT

Exhibit 4

Exhibit 4

III. PROBABLE IMPACT ON THE ENVIRONMENT

Emissions and Effects

Stack emission from the proposed power plant probably poses the greatest potential primary impact on the environment. Other aspects imposing primary impacts are cooling tower emissions to the atmosphere, ash and water discharge onto the land and direct disturbance of the land from mining. These impacts and others are investigated in varying degrees of detail in this section.

From the Final Environmental Statement for the Jim Bridger Thermal Electric Generation Project, submitted by the Bureau of Land Management for the proposed plant in western Wyoming, the following questions were raised:

1. Will the plant comply with state and federal emission and air quality standards?
2. What will be the effects of emission even if the plant complies?
3. What guarantees are there that the equipment will function as designed, and who will monitor companies in operation to see that they carry out their plans?

These questions were developed from responses to the draft environmental impact statement on that project.

The state of Montana is required to enforce federal standards established by the EPA where they are more stringent or more inclusive than state standards. For some pollutants, such as mercury, Montana has established no standards. Table 1 gives state and federal ambient air quality standards and compares them with projected maximum concentrations for the Colstrip area. Particulate, SO_2, and trace metal emissions are functions of coal composition. The estimated emissions listed in Table 2 are compared with state and federal emission standards.

Data for estimated emissions were supplied by the applicant, and projected concentrations are calculated from these figures using a simulation technique known as diffusion modeling.

Exhibit 4

AMBIENT AIR QUALITY STANDARDS AND PROJECTED MAXIMUM CONCENTRATIONS

Pollutant	Montana Standard	EPA Standard	Proposed Plant (Two Units) Contribution
Particulate	75 ug/m^3 (Annual geometric mean) 200 ug/m^3 (24 hr. max)	60 ug/m^3 (Annual geo. mean) 150 ug/m^3 (24 hr. max)	0.1 ug/m^3 (Annual)* 2.0 ug/m^3 (24 hr.)*
Sulfur Dioxide	0.02 ppm (Annual Arith. Mean) 0.10 ppm (24 hr. average)[1] --- 0.25 ppm (1 hr. average)[3]	0.02 ppm (Annual Arith. mean) 0.10 ppm (24 hr. average)[2] 0.50 ppm (3 hr. average)[2] ---	0.001 ppm (Annual max.)* 0.02 (24 hr. max.)* 0.14 ppm (24 hr. max.)* 0.14 ppm (1 hr. max.)*
Nitrogen Oxides	---	0.05 ppm (Annual Arith. Mean)	0.001 ppm (Annual)*
Fluorides	1 PPB (24 hr. average)	---	.020 PPB (24 hr. Max.)* (Uncontrolled)

TABLE 1

*Diffusion Modeling Results
[1]Not to be exceeded over 1% of the days in any 3-month period
[2]Not to be exceeded more than once a year
[3]Not to be exceeded for more than one hour in any four consecutive days

Exhibit 4

EMISSION STANDARDS & ESTIMATED EMISSIONS

Substance	Montana Standard	EPA Standard	Proposed Plant (2 Units)
Particulate	0.154 lb/10^6 BTU input 1050 lb/hr	0.10 lb/10^6 BTU input 682 lb/hr	0.039 lb/10^6 BTU input 266 lb/hr
Sulfur Dioxide	1.0 lb of S/10^6 BTU input 13,640 lb/hr	1.2 lb of SO_2/10^6 BTU input 8160 lb/hr	1.0 lb of SO_2/10^6 BTU input 6820 lb/hr
Nitrogen Oxides	———	0.7 lb/10^6 BTU input 4774 lb/hr	<0.7 lb/10^6 BTU input <4774 lb/hr
Fluorides	———	———	2.0 lb/hr (controlled)
Carbon Dioxide	———	———	1,454,000 lb/hr
H_2O	———	———	710,000 lb/hr

TABLE 2

Exhibit 4

Diffusion modeling

A diffusion model was used to predict downwind, ground level concentrations from the two power plant units at Colstrip. A diffusion model uses various meteorological and emission parameters to predict pollutant concentrations. The modeling techniques used were approved by the EPA.[34,27]

Following are some of the assumptions made in diffusion modeling.

The concentration of emissions remains uniform in time. The material diffused consists of stable gases and aerosoes smaller than 20 microns. No material is removed from the plume when the plume strikes the ground or other object. Pollutants are distributed on a normal statistical curve from the center line of the plume.

Because of the variability of the atmosphere, diffusion modeling is considered accurate only within a factor of two. Thus, actual concentrations may be half or twice values computed.

Diffusion modeling indicates that only in rare cases will either state or federal ambient air standards be approached. That these standards are considered adequate is confirmed by the following statement by the Administrator of the Environmental Protection Agency in establishing the national primary and secondary air quality standards:

> "National secondary ambient air quality standards are those which, in the judgment of the Administrator, based on air quality criteria, are requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of air pollutants in the ambient air."

Emissions from the proposed plant are expected to drift east. The relatively high (500 feet) stacks are expected to disperse the emissions over a wide area.

No other major emission source exists within a 90-mile radius of Colstrip, therefore, no additive effects are foreseen. The Southwest Energy Study, compiled by a Federal Task Force for the Four Corners Region, indicated:

> "No significant additive effects of the concentrations covered by one plant on those of another plant if they are separated by 100 km or more."

Possible additive effects will be investigated in detail should additional plants be proposed for this region.

Exhibit 4

Particulate

Using data furnished by the applicant and quoted in Table 2, combined full load particulate emissions from both units of the plant will not exceed 267 pounds per hour (3.2 tons/day). Some increase in atmospheric particulate loading will result from the plant emissions, but these emission rates are well within both Montana emission regulations and EPA New Source Performance Standards. Control to this degree required a 99.5% collection efficiency, removing 53,200 pounds per hour of particulate from the flue gases at full load.

To give perspective to the maximum emission rate of 267 pounds per hour from the Colstrip generating facility, it can be compared to Montana Power Company's Corette Plant in Billings. The Corette plant, less than 1/3 the size, emits 426 pounds per hour under full load.

In order to determine the background particulate concentration in the Colstrip area, the State has performed sampling for almost a year. Early in April, 1972, a rural sampling site was chosen to define background ambient air values. The data from a location some nine miles east of Colstrip are presented for the period from April 6 to September 3, 1972, as follows:

TABLE 3

	Number of Samples	High Value	Low Value	Geometric Mean	Arithmetic Mean
Total Suspended Particulates (24-hr. average concentrations in ug/m^3)	23	191	3.7	22	35.5

One shortcoming of the sampling resulted from placing hi-vol particulate samplers near dirt or gravel roads because of the need for electricity. The State intends to continue sampling, possibly to the extent of establishing sites an adequate distance from roads to obtain better background data. Of the data in Table 3, the significant

Exhibit 4

value is 22 ug/m^3. For a whole year, it is estimated that the total suspended particulate value will be approximately 15 ug/m^3. The national secondary standard is 60 ug/m^3 which is four times the particulate background value estimated for the Colstrip area.

Maximum ground level concentrations for various pollutants have been obtained from diffusion modeling estimates as presented in the following section on sulfur oxides.

From modeling, a 2 ug/m^3 plant contribution for a 24-hour average (Table 5) was estimated with adverse weather conditions. This value is very low compared to the national 24-hour secondary standard of 60 ug/m^3 for total suspended particulates. Considering the background value of 15 ug/m^3, the addition of the 2 ug/m^3 value results in a total estimate of 17 ug/m^3.

However, one must consider road dust, which will increase due to greater population and mobility of that population, construction, and plant and mining operations. It is anticipated that an annual geometric mean for the area might approach 50 ug/m^3.

TABLE 4

MAXIMUM GROUND LEVEL CONCENTRATIONS FOR TWO 350 MEGAWATT UNITS

Period / Pollutants	10 min.	1 hour	3 hour	24 hour	Annual
Particulates (ug/m^3)	-	-	-	2.0	0.10*
Sulfur Oxides ppm	0.18	0.14	0.11	0.02	0.001*
Nitrogen Oxides ppm as NO_2	-	-	-	0.02	0.001*
Fluorides (PPB)	.183	.14	.11	.020	.0012*

*EPA Diffusion Model

Exhibit 4

Sulfur Oxides

Data submitted by the applicant and listed in Table 2 specify that sulfur oxide emissions from the proposed Colstrip plant will not exceed 1 lb/million BTU input to the system. This totals 6820 lbs/hour for the two units (82 tons per day) representing emission control efficiency of approximately 39%. Coal analysis reveals an average of 0.77% sulfur-in-coal.

Montana regulations limit emissions to 1 lb of sulfur/million BTU input or the equivalent of 2 lbs of sulfur dioxide/million BTU input. Federal New Source Performance Standards for Fossil Fuel-Fired Steam Generators limit sulfur dioxide emissions to less than 1.2 lbs/million BTU input.

The following paragraph, taken from the applicant's permit application, explains the proposed sulfur oxide control system at the plant:

> ". . .This is a full stream scrubber system that will simultaneously remove fly ash and sulfur dioxide. The removal is accomplished by scrubbing the flue gas with an alkaline solution of water and calcium carbonate, which is generally available from the fly ash. If the alkalinity of the ash varies to a point where additional alkalinity must be added, it is obtained by the addition of soda ash (Na_2CO_3) or lime (CaO). The gaseous sulfur dioxide will react with the calcium carbonate to form solid calcium or sodium salts. At the same time, the mechanical action of the scrubber traps fly ash particles in the water droplets. Recirculation within the scrubber system makes the alkalinity in the ash available for the process. The used scrubber solution, newly formed salts, and trapped fly ash are piped to an ash pond where the solids settle out. The pond water is then recirculated back to the scrubber in a closed loop system from which no water is discharged to any natural bodies. This emission control system is guaranteed to limit the sulfur oxide emissions to 1.0 lb SO_2/million BTU and the fly ash emissions to .018 grains per actual cubic foot, at any operational load of the power plant."

Background sulfur dioxide values have been gathered in the Colstrip area for a one-year period (September, 1971, - September, 1972). See Figures 10 and 11, Appendix, for maps of the sampling sites in the general area. The data were obtained from monthly sulfation plate data using the conversion factor (mg $SO_3/100cm^2/day$) x 0.035 = parts per million. See Table 16 in Appendix.

Exhibit 4

TABLE 5

Sulfur Dioxide (ppm)	
Number of Samples	54
Annual Arithmetic Mean	0.003 ppm

This arithmetic mean of 0.003 ppm should be significant as an average background value for the Colstrip area at present. Continued sulfur dioxide monitoring will be carried out by the State Department of Health and Environmental Sciences.

The draft statement estimated a maximum SO_2 concentration of .43 ppm, which would have violated the Montana standard requiring that .25 ppm of SO_2 for one hour not be exceeded more than once every four days.

Following publication of this draft, new information became available that indicated the SO_2 estimate in the draft was erroneous. The model and its results were refined with data from TVA power plants and supplemental meteorological information from Montana State University. Revised figures indicate SO_2 concentrations would not exceed .136 ppm under severe fumigation conditions.

Referring to Table 4, we again find conservative one-hour, three-hour, 24-hour, and annual estimated SO_2 concentrations. The state's annual SO_2 background value of 0.003 ppm is higher than the annual value of 0.001 ppm estimated by the EPA. It is possible that the annual average could be slightly in excess of 0.004 ppm.

The diffusion model was used to estimate particulate, sulfur dioxide, and nitrogen oxide concentrations.

A different model similar in design and theory was used by the EPA to estimate long term (annual) concentrations. Their results listed in Table 4 indicated no violation of the annual standards.

Estimates for oxides of nitrogen and particulate were made by multiplying the SO_2 results by the respective ratios of SO_2 emission to nitrogen oxide and particulate matter.

Exhibit 4

The state's experience in ambient monitoring of other industrial complexes around the state suggests that one-hour SO_2 concentrations approximating one part per million do occasionally occur under adverse weather situations. The terrain surrounding Colstrip does not rule out wind channeling, impingement and other phenomena which might cause higher SO_2 concentrations in the Colstrip area than the above diffusion predictions. A similar discussion could be developed for other emissions.

Nitrogen Oxides (NO_x)

The boiler supplier for the proposed plant guarantees nitrogen oxide emissions will not exceed .7 lbs NO_x/million BTU, the level specified in the Federal New Source Performance Standards. When the Colstrip plant is operating at full load, this amount will total 4750 lbs per hour of nitrogen oxides.

The following information was submitted by the Montana Power Company regarding NO_x emissions:

> "The steam generators at this installation will both be tangentially fired pulverized units.
>
> "In order to insure an absolute minimum of nitrogen oxide formation, we have purchased an overfire air system as part of this equipment. This system takes the normal amount of combustion air and distributes it to a greater volume of the furnace than would normally be used in a tangentially fired unit. The greater distribution of combustion air reduces the maximum flame temperatures and the amount of nitrogen available for combination at any particular location in the flame. As a result, nitrogen oxide products will be substantially reduced below the low levels normally found on a tangentially fired unit.
>
> "With the overfire air system, the supplier, Combustion Engineer, Inc., has guaranteed that the nitrogen oxides leaving the unit will not exceed .7 lbs/million BTU, which we understand is the current federal emission standard."

In its Background Information for New Source Performance Standards, the EPA stated:

> "The NO_x standard for solid fuels is based on results from tangentially fired units burning coal. Four tangentially fired units burning bituminous coal, which were tested by EPA, had emissions of nitrogen oxides that were well below the required level of 0.7 pounds per million BTU. Published data from numerous sources, and other test results from steam generator manufacturers, indicate comparable results for tangential firing . . ."

Exhibit 4

The State has done no background ambient sampling for nitrogen oxides. The EPA AP-84 publication "Air Quality Criteria for Nitrogen Oxides", page 3-1, states that the non-urban North American continental average levels of NO_2 are about 0.004 ppm. The source of this background NO_2 is biologically produced NO which under photochemical oxidation yields the NO_2 variety.

Extrapolation from the SO_2 dispersion model indicate low concentrations of nitrogen dioxide will result from the proposed plant.

Trace Elements

The quantities of most of the trace elements in Montana coal are not well known. The only element that has been analyzed sufficiently to warrant any confidence in the results is fluorine. Table 6 presents the best data that the state has on the elements shown.

TABLE 6

TRACE ELEMENT CONCENTRATIONS OBTAINED FOR COAL
FROM WESTERN ENERGY MINE AT COLSTRIP

(Values in ppm by weight unless otherwise noted)

Al	0.74%	0.74%	Eu	.075	.085
Mg	.20%	.19%	Co	0.48	0.40
Fe	.20%	.069%	Br	9	33
Mn	100.	91.	Sc	1.0	1.0
V	7.4	3.6	Hf	0.77	0.81
Ti	430.	330.	Cr	3.0	2.8
La	3.8	4.0	Tb	.065	0.056
Na	150.	140.	Ta	0.24	0.26
Sm	0.55	0.50	Cu	<100.	<80.
Th	1.5	1.3	3* (Mean of six other Montana coals = 3.16*)		
U	0.7*	(Mean of six other Montana coals = 1.13*)			
R^{226}	2.8	pCi/g* (Mean of six other Montana coals - 3.31*)			

Values obtained by Battelle Northwest for EPA except*
*Values obtained by EPA

Trace element concentrations in the coal only partially determine adverse environmental effects. The form in which a particular element leaves the boiler will

Exhibit 4

partially determine how it is affected in the control devices and its behavior in the environment. There are few plants of the Colstrip type with venturi scrubbers, and how their operation affects trace element emissions are not known at this time.

Certain trace elements are of particular interest and will be dealt with separately.

Fluorine

Values for the concentration of fluorine in the coal at Colstrip have ranged from less than one ppm to 140 ppm. Since the writing of the draft statement, the state has performed a number of analyses for fluorine in the coal according to standard procedures. Since that time, some other laboratories have revised their values and there is now general agreement among two commercial laboratories and the state on a value between 30 to 40 ppm dry weight on splits of seven samples. A third commercial lab reported a mean value of 25 to 30 ppm for these same seven samples. These values correspond with the state's values for other samples of coal also from the Rosebud Seam at Colstrip. Therefore, the very high (>100 ppm) and the very low (<5 ppm) values seem to be in error.

Also, since the writing of the draft supplement to this statement, this Department has analyzed the collected ash from the Corette plant for fluorides and has sampled fluoride emissions from the stack gases also at the Corette plant. The presence of fluoride in the various kinds of ash show that not all of the fluoride in the coal is released into the air. In addition to these data, a series of tests have been run on a pilot venturi scrubber to determine fluoride removal efficiencies. These tests indicate that about 90 percent of the total fluorides will be removed by the wet scrubber. Taking all the data we have regarding fluorine, we can estimate the emission rate of fluorides and use this figure and the diffusion model to arrive at worst possible ambient concentrations.

Assuming 35 ppm fluorine in the coal, 585,300 pounds (dry weight) of coal burned per hour, and only 10 percent of the fluorine emitted into the air, we arrive at an

Exhibit 4

emission rate of 2.05 pounds fluoride per hour (.26 g/sec). At this emission rate, the maximum 24-hour concentration that can be expected is .02 ppb as compared to the state standard of 1.00 ppb for a 24-hour average.

TABLE 7

Fluoride Analysis of Coal and Ash (ppm dry weight)
from Corette Plant

Belt Coal Oven Dry Samples

Laboratory	Truesdale	WAR	Radian	State
No. of Values	7	7	7	7
Min.	11	34	25.1	20
Max.	38	40	38.2	43.5
Mean	26.1	37.3	33.1	29.8
		Pulverized Coal		
No. of Samples	7	7	7	6
Min.	11	36	26.7	25
Max.	45	41	38.2	46
Mean	29.0	38.0	32.4	33.3
		Bottom Ash		
No. of Samples	3	3	3	3
Min.	25	2.4	0.1	0
Max.	33	7	0.1	0
Mean	29	5.0	0.1	0
		Economizer Ash		
No. of Samples	3	3	3	3
Min.	33	41	25	8
Max.	45	102	70	75
Mean	38	64	42	34
		Precipitator Ash		
No. of Samples	3	3	3	3
Min.	51	236	103	162
Max.	65	302	158	216
Mean	57	267	128	181

Mercury

It is difficult to analyze coal for mercury and obtain reliable values. Since mercury is quite volatile, it may evaporate from a coal sample during handling and the sample may easily be contaminated in the laboratory. This problem is difficult to overcome even with the most careful handling. Even samples prepared for use as standards

Exhibit 4

can show variation in the mercury content (Norm Suhr, personal comm.). The author of a recent article in Science which reported 33 ppm Hg in a sample of Montana coal (considered a very high value) has said recently that the value is in error, probably the result of contamination of the sample.[16,17]

A commercial laboratory under contract with Montana Power Company reported that mercury concentrations in the Rosebud Seam are less than 0.1 ppm. Given the difficulties associated with mercury analyses and the unreliable data obtained from this laboratory on another trace element, the mercury value cannot be relied upon.

There are no reliable data concerning mercury in Montana coal. However, the state has no reason, at this time, to think Montana coal has either more or less mercury than coals from other parts of the U. S. (1-3 ppm).[7]

The laboratory working for Montana Power Company reports that 97 percent of the mercury remains in the ash. The Department does not accept this conclusion. Other reports indicate approximately 90 percent of the mercury in the coal is emitted into the atmosphere as a vapor.[8] What effect the wet scrubbers, with their lower temperatures, will have upon the mercury vapor is not known. It is likely, though, that the wet scrubbers will remove a higher percentage of the mercury than other types of control devices in use on most of the coal-fired power plants in the U.S.[11,31]

Selenium

Selenium compounds released in the combusion of coal may be either gaseous or particulate. In either case, they would be collected at a high efficiency by wet scrubbers. The particulate would be expected to be collected at close to 99 percent efficiency, just as other particulate matter. The gaseous portion, probably hydrogen selenide, is extremely soluble in water, thus lending itself to collection in wet scrubbers.[32]

Radioactive Elements

Several of the trace elements are of particular interest because they are radioactive. Uranium is not very abundant in the earth's crust but it is found in many

Exhibit 4

kinds of rocks. Being radioactive, uranium breaks down into lighter elements. At that time, it emits some form of radiation. The new elements which result from a uranium decay are called daughter elements, some of which are also radioactive. The radioactive daughter elements also undergo decay until a stable isotope is formed. There are a number of isotopes in the uranium decay series between uranium and lead. Some isotopes have a very short half-life (time for one half of a given quantity of a radioactive substance to disintegrate) and some have long ones. Uranium^{238} has a half life of about 4.5×10^9 years. This long half-life enables the element to be acted upon by geological processes which may concentrate the element in certain kinds of rocks. Some coal and black shales have anomalously high concentrations of long-lived radioactive isotopes. The isotopes with short half-lives can be formed and undergo decay while in the coal (age of Colstrip coal is about 60 million years). However, these isotopes are continuously being formed by the heavier isotopes.

Natural radioactivity of some of the Colstrip coal has been determined. The small amounts of uranium and thorium with their long half-lives are not likely to pose any threat to the environment. Radium^{226} is the most likely to pose a threat.[21] (The units for radium^{226} in Table 7 are picocuries per gram of coal. The term picocurie (10^{-12} curies) is a unit of activity, not a unit of mass. The activity unit is used here to separate R^{226} from other radioactive isotopes, each having its own level of radioactivity (half-life). The activity units can be treated as mass units in diffusion modeling and since it is activity that is of interest, the exchange of units is acceptable.)

By figuring the amount of activity of R^{226} which goes through the boiler and applying the diffusion model, an ambient activity can be obtained for groundlevel under the worst meteorological conditions expected. Assuming 3.0 pCi/g (dry wt) for an average value of radium activity in the coal, 796×10^6 pCi/hr will be present in the coal going to the boiler. Because the radium will be in the particulates, we will assume 99 percent collection in the scrubber.[12] A level of activity of

Exhibit 4

2210 pCi/sec will be emitted to the atmosphere. Applying the diffusion model, we find a maximum value of 9.2×10^{-4} pCi/m^3 in the ambient air at ground level. The maximum permissible concentration set by the Federal Radiation Council is 1×10^{-12} uCi/ml or 1.0 pCi/m^3, for radium in soluble form (or twice that value if insoluble). Therefore, maximum radium^{226} concentrations are expected to be three orders of magnitude less than those values considered safe. From these figures, the Department concludes that no radiation danger is expected from the proposed power plant; however, sampling for radioactivity will be carried out once the plant goes on line to experimentally ascertain the correctness of this conclusion.

Other Trace Elements

A symposium on trace elements in coal was held at the annual meeting of the Geological Society of America in November, 1972. From the papers presented and the discussions which followed, several conclusions can be tentatively drawn.[1]

First, many trace elements are rather efficiently captured in the plant when good particulate control is in operation. From work done in Australia, it appears that in chain grate and stoker fired boilers, most of the trace elements are collected in the slag, ash, and boiler tube deposits. The boiler tube deposits immediately next to the tube have much higher concentrations of the trace elements, which may be the result of greater cooling in that zone of the deposit. In pulverized coal boilers, such as the proposed Colstrip plant will have, the trace elements collect in the fly ash. These situations hold true even for the more volatile elements such as arsenic, zinc, and lead. No information is available from this study for wet scrubber systems but if cooling is a factor in concentrating trace elements on the boiler tubes, the degree of cooling in the wet scrubber may be expected to make that system more effective in removing trace elements than other kinds of control devices.

Second, a speaker from EPA (Von Lehmden) reported that there are some indications that smaller particles have higher concentrations of the trace elements than the larger

Exhibit 4

ones. He stressed that the data only indicate the possibility of the existence of this phenomenon. If this phenomenon exists, one could not assume the same efficiency of removal of trace elements by the scrubber as the efficiency of particulate matter, since the scrubber is less efficient in removing the smaller particles. However, a concentration factor of two in the uncollected fly ash would reduce the efficiency of trace element collection from 99.5 percent (total particulate collection efficiency) to 99 percent, assuming all of the trace element is in the fly ash. Because the concentration factor in the escaping particulate matter is probably less than two, and because some of the trace elements are collected before they reach the scrubber, an efficiency of 99 percent for particulate trace element removal can be assumed if the overall particulate efficiency of the scrubber is 99.5 percent.

Trace Elements in the Collected Ash

Some concern has been expressed concerning the fate of the trace elements in the collected ash and if these elements can enter ground or surface water. The trace elements in the ash differ from those in the coal in two important ways. First, the burning of the coal recombines the elements into different compounds. Second, the concentrations of the trace elements in the ash may be elevated over those in the coal.

The oxidizing environment and high temperatures in the boiler are generally expected to produce oxides of the elements. Most oxides are quite insoluble and will remain in the ash. This Department is not aware of any trace element contamination existing from leaching of the coal, fly ash that is used in concrete, and other materials, or from leaching of the clinker (the ash and baked country rock resulting from natural underground coal fires.) The clinker perhaps deserves some investigation in this area because of the reducing conditions which probably existed during the combustion of that coal. In this case, the trace elements may exist in less oxidized states and be more soluble than in the power plant ash. If the leaching of trace elements does become a problem, ash disposal methods may be altered to alleviate the problem.

Exhibit 4

Conclusion

Although many questions exist concerning possible trace element contamination from the proposed plant, no significant problems are expected at this time. This situation does not eliminate the state's concern in this area and investigations are continuing to answer some of the questions. Monitoring by the state agencies and research organizations probably would discover any problems that might arise which are not anticipated at this time. Problems related to trace elements, if found, will have to be dealt with on an individual basis.

TABLE 8

Hi-vol analyses at a site 9 miles east of Colstrip are as follows:

Values are 24-hour averages in ug/m^3	No. Samples	High Value	Low Value	Geometric Mean	Arithmetic Mean
Total suspended particulate	23	191	3.7	22	--
Cadmium	20	0.001	0.000	--	0.0002
Lead	20	0.011	0.000	--	0.065
Zinc	20	0.290	0.010	--	0.1235

The above heavy metal data were obtained by chemical analyses of the hi-vol fiber-glass filters.

Exhibit 4

Possible Impacts From Emission

Sulfur Oxides

Many of the effects of sulfur oxide emissions have been documented.[4] Metallic surfaces may be damaged with the damage increasing with increasing humidity and temperature. Other materials affected by SO_2 are limestone, marble, roofing slate, mortar, some textile fibers, such as cotton, rayon and nylon, and leather and paper. Synergistic interactions with particulate matter contribute to the effects. Sulfur oxides can also damage various forms of plant life.[4]

Sulfur oxides generally accelerate corrosion when they are first converted to sulfuric acid, either in the atmosphere or on metallic surface. Tests in Chicago showed that 100 gram mild steel panels exposed to average sulfur oxide concentrations of 0.02 ppm lost about four grams of their weight through corrosion within three months.[4]

Plants vary in their sensitivities to sulfur oxides. Among the plants existing near Colstrip, alfalfa is believed the most sensitive to SO_2. Experiments have shown that 1.25 ppm of SO_2 will cause traces of leaf destruction in one hour. Four ppm caused 50 percent leaf destruction in the same time.[4] It has been suggested that lower concentrations of SO_2 over long periods may slow the growth rate of sensitive plants.[4]

There are two types of visible leaf injury, acute and chronic, associated with SO_2. Acute injury is caused by relatively high SO_2 concentrations over relatively short intervals. Chronic injury results from exposure to relatively low concentrations over a period of days or weeks. It occurs when an excessive amount of sulfate accumulates in leaf tissue. Sulfate formed in leaf tissue from SO_2 in the air is additive to sulfate absorbed through the roots. Absorption through the roots thus increases as SO_2 in the air precipitates sulfate into the soil. It should be noted that sulfates precipitating from airborne SO_2 may enrich sulfate-deficient soil. The sulfate content of soils near Colstrip is not known.

In addition to visible damage, it has been suggested that the growth of alfalfa and other sensitive species might be suppressed at SO_2 concentrations too low to produce visible injury.[4]

Exhibit 4

Another possible source of damage from SO_2 emissions results from the formation of sulfuric acid mist, the combination of airborne sulfur oxides with water. The amount of acid formed depends on the temperature, humidity, and the amount of sulfur oxides in the air.

Some types of pine trees are sensitive to sulfuric acid solutions, and substantial damage to commercial Christmas tree crops has been reported in an area dominated by the Mt. Storm power station at Mt. Storm, West Virginia.[22,14] Although the damage apparently was caused by acid rains, it should be noted that the Mt. Storm plant emits an estimated 120,000 tons of sulfur oxides per year, compared to about 30,000 tons at the proposed Colstrip plant.

Heavy SO_2 emissions also can lead to acidification of soil and water. Studies in Scandinavia indicate that the pH of surface water in that area has extended farther into the acid range over a period of 11 years.[37]

The increasing acidity is believed to result from the heavy industrial pollution drifting over the area from southern England and central Europe. Sulfuric acid in precipitation is believed to cause the acification.

While in England, SO_2 concentrations declined at ground level because of the increasing use of tall stacks. However, downwind in Scandinavia the acidity of rainwater increased. It is assumed that the delivery of the pollutants to higher air levels by taller stacks caused the delivery of the pollutants to stations farther downwind than before.

In 1958, the pH of rain was between 5 and 4.5 in areas of Europe downwind from major pollution sources. One exception was the Netherlands, where the pH was lowered to 4.5 from the buildup of pollutants from southern England, northern France, and the Ruhr. Seven years later, the pH was under 4.5 over most of central Europe and southern Scandinavia, and under 4 in the Netherlands and northern Germany.[37] The trend to acidification apparently is increasing with industrialization.

Exhibit 4

Surface water in Scandinavia became two to three times more acid over a three-year study period. This is expected eventually to affect fish populations. Salmon can tolerate a pH no lower than 5.5, trout 5, pike 4.3, and perch 4.[37] Where acidic precipitation is heavy, important minerals may be washed out of soils.[25]

The amount of SO_2 emitted from the proposed Colstrip project probably would be insignificant compared to that causing the effects noted in the Norwegian study cited. Other coal development facilities known to be under consideration in the area could lead to significant damage from SO_2.[29]

On a worldwide basis, man is believed to be contributing about half as much as nature to the total atmospheric burden of sulfur compounds. By the year 2000 he will match nature's contribution.[18] In industrialized regions the SO_2 concentrations contributed by man are overwhelming natural processes, and causing the dispersal of sulfur compounds for many hundreds of kilometers downwind from industrial sites.

Fluorides

According to the U. S. Department of Commerce, about 155,000 tons of man-made fluoride is emitted to the ambient air annually. Of this, 17 percent, or 27,000 tons, comes from the burning of coal.

Although the State ambient standard of 1 ppb for a 24-hour average is considered adequate, the effects of fluoride emission over the life of the proposed plant are unpredictable. Exposure to low concentrations over long periods can lead to damage in sensitive plants. In studies some plants exposed to .1 ppb for five weeks developed substantial leaf damage and accumulated 150 ppm of fluoride.[30]

Ponderosa pine, which is common around Colstrip, may be damaged by fumigations of hydrogen fluoride at a concentration of .5 ppb.[13]

Also, in some cases it appears that ambient concentrations below 1 ppb may cause fluoride concentrations in vegetation sufficient to harm domestic animals. A recent study by the Washington Department of Ecology found that an aluminum plant near Ferndale,

Exhibit 4

Washington, was causing fluoride concentrations in the ambient air of .4 ppb. Plants in the nearby area accumulated 20 to 180 ppm of fluoride, and cattle were crippled from eating contaminated forage.

Most veterinarians who have studied fluorides agree that at least 35 ppm in forage is necessary to cause harm to domestic animals.[13]

It should be recalled that bunch grasses growing in the Colstrip vicinity have a life cycle lasting from three to five years, allowing more than one growing season for the accumulation of fluorides.

Most studies indicate that domestic animals raised in areas not polluted by fluorides will accumulate in their lifetimes less than 1000 ppm of fluorides in their bones. In polluted areas, animals will accumulate between 1000 and 8000 ppm, depending on the severity of the pollution.

Domestic animals do not exhibit the same fluoride-accumulating propensities as wild animals.[5] Data published by the EPA in 1972 showed the following:

1. Indigenous animals such as mice, rabbits, squirrels, chipmunks, deer, elk, bear, antelope, coyotes, and grouse collected in areas where vegetations contain 10 ppm or less of fluoride will average less than 300 ppm in their bone tissue.

2. Animals of the same species living in a fluoride-polluted area will accumulate two to five times more fluoride in their bones than domestic animals living in the same area.

3. Deer and snowshoe hares feeding upon forage with an average fluoride concentration of 30 ppm will accumulate 2000 to 5000 ppm of fluoride in their bone tissues, while grouse species (blue and ruffed) feeding on forage with 30 ppm of fluoride will accumulate 3000 to 7000 ppm in bone tissues.

There was no attempt to evaluate health effects caused by fluorides in the wild animals.

Exhibit 4

Particulate Matter

The extent of impacts resulting from particulate emission is not completely known. On a worldwide basis, suspended particulate matter is believed to be at least partly responsible for lowering the temperature of the planet, through the refraction of inbound solar energy.

The most obvious impact from particulate matter emitted at Colstrip probably would be visibility. The efficiency of venturi scrubbers is known to be low on particles less than two microns.

A given mass of particulate matter, such as one pound, will refract light in the atmosphere according to the amount of surface presented to the light rays. One pound of particles 2 microns in diameter would have far more surface area, for example, than two much larger particles each having a mass of one-half pound. Thus, even the 99.5 percent efficiency predicted for the scrubbers at Colstrip will not totally prevent visibility reduction. There is reason to think that under stable conditions, with high humidity, visibility may decrease.[3] Visibility will decline as humidity rises.

Another contribution to lowered visibility will be the conversion of sulfur oxides and nitrogen oxides to sulfate and nitrate particles in the air.

The Southwest Energy Study commented thus on visibility reduction:

> "A review of available information on conversion of SO_2 and NO_x to particulate matter in plumes indicates that there is no information on conversion of NO_x to nitrate and the information on conversion of SO_2 is not very reliable and is in quantitative disagreement. However, it is clear from chemical analysis of collected particulate matter that SO_2 and NO_x are converted to particulate sulfate and nitrate.
>
> "If there is significant conversion of SO_2 and NO_x to particulates this will predominate over fly ash in causing visibility reductions.
>
> "Aircraft studies in power plant plumes have reported that as much as 50 percent of the gaseous SO_2 disappears (presumably to particulate sulfate or sulfuric acid) within ¼ mile of the stack exit."

Since the abatement equipment on the proposed plant would be similar to the equipment on the Dave Johnston plant, it is germane to note that there is almost no visible particulate matter in the scrubbed stack gases of that plant.

Exhibit 4

Further possible impacts of particulate emissions will be discussed under health effects.

Mercury

Because of the lack of any reliable analysis of mercury in the Colstrip coal and ignorance regarding the efficiency of venturi scrubbers on mercury vapor, no predictions can be made about possible effects. The movement of small amounts of mercury through the food chain may cause liver or kidney concentrations in range cattle to exceed federal tolerance limits without visible damage to the animals if mercury emissions are high enough.

A concentration of .17 ppb in water appears capable of producing levels in fish flesh of .5 ppm, which is above acceptable levels for human consumption on a regular basis.[19]

Selenium

Selenium is poisonous to men and other animals in high concentrations. At lower concentrations it is a necessary dietary substance. No impact should result from selenium emissions at Colstrip, owing to the high collectability of selenium compounds in wet scrubbers.

Impacts of Emissions in Combination, Health Effects

Although synergistic effects are certain to occur among emissions from the proposed plants, the potential for damage is impossible to assess. It is possible to assert that the combined effects of all the pollutants will be greater than the accumulated effects of each pollutant existing alone. For example, particulate matter acts with sulfur oxides to increase the irritant capabilities of the combination. A threefold to fourfold potentiation of the irritant response to sulfur dioxide is observed in the presence of particulate matter capable of oxidizing sulfur dioxide to sulfuric acid.[3]

Exhibit 4

Both ozone and nitrogen oxide react with SO_2 to cause plant damage at concentrations much lower than those needed for either pollutant to damage plants alone.[4]

Acting alone, nitrogen oxides are an irritant to the human respiratory system. Combined with water in the air, NO can become corrosive nitric acid.[2]

The team hired by the applicant to study emission effects at Colstrip indicated that some plant damage might result at Colstrip if the oxides of nitrogen are released in sufficient quantity during early summer, when plants are growing rapidly. (See Appendix)

In the human body SO_2 acts to cause increased resistance in the airways of the lungs. Most individuals react to SO_2 at concentrations 5 ppm and above, although sensitive persons experience discomfort at 1 ppm. The long-term effects of SO_2, particulate sulfates, and sulfuric acid mist are not agreed upon, although it generally is conceded that sulfur oxides lead to a variety of respiratory ailments.

A letter to the State from Dr. Bruce Anderson, Billings, (see Appendix) indicates that patients with respiratory ailments in Billings get noticeably worse when a temperature inversion traps pollutants.

Dr. Bruce Geer of Durango, Colorado, testified before a U. S. Senate Committee that acute and chronic respiratory ailments in children admitted to Durango hospitals doubled in five years during the operation of the Four Corners coal-fired power plant, although the population of the areas served by the hospitals decreased.[28] Dr. Geer attributed the increased illness to air pollution from the plant. It should be noted that the Four Corners plant emits an estimated 300 tons of SO2 daily, compared to 82 tons per day at the proposed Colstrip plant.

Nevertheless, it is interesting that emphysema and chronic bronchitis are among the fastest growing diseases in the country, doubling every five years since 1945.

The extremely small particulate matter that would be emitted at Colstrip could be more detrimental to health than larger amounts of coarser material.[3] This is because

Exhibit 4

microparticulate matter, smaller than 2 microns, penetrates more deeply into the air passages of the lungs, where it may hinder air exchange. Further, the smaller particles in this range may penetrate the minute air sacs of the lungs where they come into direct contact with the blood. They may then be transmitted throughout the body, along with attached toxic materials. The smaller particles also can carry more toxic material than an equal weight of larger particles because of the greater area of the smaller particles.

There also is evidence that particulate matter may increase precipitation where humidity is sufficient.[23]

Although humidity at Colstrip is low, it likely would be increased by emissions from evaporative cooling towers. Besides possibly increasing precipitation and decreasing visibility, increased humidity from cooling towers could cause increased generation of sulfuric acid if the cooling tower plume were to mix with the stack plume.

Such mixing of the plumes should be infrequent because of the large vertical difference of the emissions, and the probable difference in wind direction between the 65-foot level cooling tower emission and the 500-foot level of the stack plume. Despite the apparent odds against plume mixing, it does happen at existing power plants. Regardless of whether the plumes mix, the cooling towers produce a detectable increase in humidity for many miles downwind.[23]

Under the proper weather conditions, wet cooling towers can produce icing and fog conditions, although this usually does not extend more than one-quarter mile from the towers.[26] Only the power plant will be within one-quarter mile in the prevailing wind direction from the towers. The applicant indicates that the Bechtel Corporation believes fogging or icing will not occur more than 200 feet from the towers.

Noise

The only significant noise at Colstrip will be produced by the cooling towers. Using information furnished by the applicant, the state developed the following chart.

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TABLE 9

Noise level (both towers) in db(A)	distance in feet
84	100
78	200
72	400
66	800
60	1600
54	3200
48	6400

There is no federal or state noise standard, but some Montana towns have noise ordinances. In Billings and Helena, for example, the maximum noise allowed during the day is 55 db(A), with 50 the maximum at night. From information furnished by the applicant, it appears there is a trailer park planned about 1500 feet from the towers. At that distance, the sound level might be bothersome. Even at the far side of Colstrip, about 3000 feet from the towers there will be noise in excess of the municipal ordinances for Billings and Helena. The towers will also be 3000 feet from the applicant's property line.

Cooling tower drift

Information from the applicant on cooling tower drift follows.

> "At an expected drift loss of 0.005 percent of 104,000 GPM (5.2 gpm) the solids carryover would not exceed 10.9 pounds per hour. By analogy . . (with information furnished by Bechtel) all of the material would be deposited within a 2000 foot radius of the towers and 60 percent or 835 pounds/acre/year within a 1000 foot radius. These figures apply to continuous operation at full load, whereas actual operation would average about 70 percent of maximum."

Bechtel estimated the flora damage threshold at 1000 pounds/acre/year. It should be noted that the 2000 foot radius is all company land.

The cooling tower water will have the following maximum composition:

Exhibit 4

Total hardness, ppm as $CaCO_3$	1,859
Calcium, ppm as $CaCO_3$	1,167
Magnesium, ppm as $CaCO_3$	682
Alkalinity, M, ppm as $CaCO_3$	32
Alkalinity, P, ppm as $CaCO_3$	0
Chloride, ppm as Cl	76
Sodium, ppm as Na	483
Silica, ppm as SiO_2	166
Nitrate, ppm as NO_3	6
Sulfate, ppm as SO_4	2,646
Bicarbonate, ppm as HCO_3	39
pH	7.2 ± 0.2
Total dissolved solids, ppm	4,045

Other impacts

Ash and Water Discharge to the Land

Dust from Ash

Fly ash, bottom ash, and economizer ash are sluiced to the ash pond system for settling. When the settled ash fills an individual pond to capacity, the water is drained off to another pond and the ash is removed.

The two possible sources of dust from this operation appear to be of only minor impact. First, dust may be generated from the surface of a dry inactive pond prior to or after ash removal. Second, dust may result from ash handling and disposal.

The applicant has indicated ponds will be kept flooded at all times, especially if it appears a dust problem may arise. The applicant has also indicated measures will be taken to reduce dust from ash handling. Data on physical properties of the ash indicate that the ash does not easily become airborne. This is especially true at the pond where it has a tendency to form a hard crust.

There is some chance of water contamination if the applicant fulfills the stated intention of disposing of ash in worked-out strip mines.[29] The pollution potential has not been determined, and the State Department of Lands indicates that no fill of ash into mines will be allowed until it is proven that water contamination will not occur.

Exhibit 4

Water Contamination - Plant

The closed recycling water system prevents any wastewater discharge to groundwater or streams. All water leaving the plant is discharged directly to the atmosphere from the stack, cooling towers, and ponds. Approximately 6250 gallons per minute of water evaporate from the cooling tower-condenser system, and 500 gallons per minute leave the stack.

Blowdown, consisting of mineral-laden water from the boiler-turbine system, discharges to the ash pond. The minerals eventually are concentrated by evaporation and precipitate in the pond.

Water Contamination - Colstrip Sewage System

An Imhoff Tank, which provides settling and removal of suspended material, is presently used for sewage treatment. On May 8, 1971, the Montana Water Pollution Control Council adopted the following compliance plan for the community of Colstrip:

Begin construction of new sewage treatment facilities by September 1, 1971.

Complete construction of new sewage treatment facilities by January 1, 1972.

Plans and specifications were received for the project during April, 1971, and after requested changes were made, they were approved on October 14, 1971. A county rural improvement district was formally established for the project during October, 1971. Construction of the sewage lagoons began during September, 1972, and was completed in January, 1973. Design of the facility was based on a projected 1990 population of 880.

Because there is essentially no flow in Armells Creek, it is necessary to have a facility which will provide removal of essentially all waste materials contributed by the population or to provide a facility which is capable of treating the sewage adequately, holding it to a time when there is adequate dilution flow in Armells Creek, and discharging it at that time. It may also be possible to discharge the treated water to the Montana Power Company cooling water ponds when they are constructed. It

Exhibit 4

is doubtful that there will be any discharge from the sewage lagoons for several years. Aeration equipment can be easily added to the lagoons if an odor problem arises or if additional treatment is required.

The State recommends that water from the sewage lagoons be used for irrigation after water is available from the pipeline. Water from the deep well, although not harmful to humans, is too highly charged with sodium salts to be used for irrigation.

A more detailed discussion of sewage disposal is presented in "Water Quality Management Interim Plan for Colstrip, Montana" prepared by the Montana State Department of Health and Environmental Sciences.

After reviewing the potential for water pollution from the ash ponds and sewage lagoon, State water pollution authorities concluded the chance of ground or surface water pollution was slight at most. Chemical-charged water will be confined in ash ponds sealed with bentonite, plastic, or whatever other material emerges as most favorable from research now being performed by the applicant.

The new sewage lagoon is adequate for 980 persons. However, according to the town plan developed for the applicant, permanent population of the town would surpass 980 in late 1973, climbing to a total permanent population of 1781 in 1975, and remaining stable until at least 1980. If all these persons live in the town, enlargement of the sewage facilities will be necessary, and the state would require this if necessary to prevent water pollution.

Adequacy of water supply

Colstrip currently is supplied by several shallow wells and a cistern. The supply is deemed "barely adequate" by the state. It is proposed to divert 150 gpm from a new 9000-foot deep well to municipal use. Ample water could be supplied from the pipeline that would supply the proposed plant from the Yellowstone River.

Exhibit 4

Land Use

The construction of the proposed power plant with its associated aqueduct, transmission lines, roads, mine and so forth, represents a major change of land use. The agrarian and wildlife uses of thousands of acres will be converted into industrial use.

The plant, as proposed, will occupy an area of 1365 acres. The mine will disturb an area of approximately 2000 acres over 30 years. The aqueduct and transmission line will temporarily alter approximately 2900 acres. However, most of the area involved in the aqueduct and transmission line rights-of-way will not be out of production. Roads along these rights-of-way may permanently change the land use of about 200 acres.

The greatest land use changes may not come from the proposed activities directly, but from the greater numbers of people in the vicinity. The increased population, especially during construction, will possibly result in trailer parks, subdivisions, drive-in businesses, service stations, and many other features that will alter land use. The growth of the town of Colstrip is being planned but the increase in area will alter land use.

Impact on Flora and Fauna

The construction of the proposed plant, the mine, stack emissions and the general increase in human activity will affect the flora and fauna. The effects would be produced in the following ways:

1. Occupation of land by other than natural habitat.
2. Presence of man-made structures.
3. Increased noise, pollution, and other factors affecting the functioning of the ecosystem.
4. Increased activity of man, including greater hunting pressure by the increased population.
5. Effects on aquatic systems by changes in quality and quantity of water.

All else being equal, the productivity of a region depends upon the amount of land area in production. The land that once supported the plants that fed deer, mice,

Exhibit 4

and birds will be used for the plant site, storage areas, settling ponds, roads, mining, and so on, and will no longer support the living organisms. Therefore, the simple destruction of habitat for other uses will decrease the biota.

The presence of man-made structures directly affects the flora and fauna. Especially to birds, these structures, including transmission lines, are physical hazards that may increase mortality rates significantly. The structures may also provide nesting sites or other accommodations for some species such as the common pigeon. The overall effect of the structures on the native species will probably be to reduce their numbers.

Although the impacts of power lines on game birds and hunting are not well known, one recent study shed some light on the subject.[15]

During the study, in Wisconsin, it was observed that Canada geese in normal flight never flew under power lines. No geese were known to be shot by hunters within one-quarter mile of powerlines. In spring and non-hunting periods in the fall, geese landed within one-fourth mile of powerlines, fed near them, and walked under them, suggesting that the lines hinder goose hunting in season.

Ducks were less wary of powerlines, but the wariness varied with species. Duck shooting success on a private march declined about two-thirds after a powerline crossed the area, and shooting was limited to local birds early in the season. It thus would seem that hunting might be affected if the powerlines from Colstrip were to pass through or near grainfields along the Yellowstone River. No adequate assessment can be made of environmental impact caused by powerlines and pipelines until their actual routes are known.

The noise and pollution from the proposed facility will alter the ecosystem, affecting the flora and fauna. The emissions from the plant will put a stress on some plants which may kill them or reduce their ability to compete with other species. Certain plants may be completely replaced. If such plants are essential to the survival of some animal species, a very significant change in community structure could take

Exhibit 4

place. Likewise, certain pollutants may be very toxic to some species or may interfere with their reproduction, again leading to a major change in community structure. Some other species may be favored by these changes.

The increased activity of vehicular traffic, hikers, hunters, dogs and cats will have a damaging effect upon the flora and fauna in most cases. Greater numbers of people living and working in the Colstrip area will increase the contact between man and the natural ecosystem. This increased activity will be a direct result of the proposed power plant.

The aquatic ecosystems in the area, including the Yellowstone River, will be altered in a number of ways. The diversion of water for the proposed plant will decrease the flow in the Yellowstone. The water quality will also be changed as stack emissions get into the water, and as towns increase in size producing more sewage and urban-type runoff. It is impossible to quantify these changes or predict the major changes in such activities as sport fishing.

It is impossible to determine the impact of water appropriation from the Yellowstone River until the actual volume to be used is known. The applicant has told the state that the pipeline will be 22 to 26 inches in diameter. However, documents dated December 22, 1970, and filed in the Rosebud County Courthouse in Forsyth, record that the applicant has appropriated 250 cubic feet a second, to be transported through a 60-inch pipeline. The applicant indicates the large appropriation was made because at that time it was uncertain how much water was to be needed.

As noted earlier, information on the pipeline is unavailable.

If the applicant were to use the full 250 cfs appropriated, it could have a serious effect on the Yellowstone River below the outlet, as noted in Table 10.

It should be noted that figures supplied by the Environmental Defense Fund show that 250 cfs should supply a sustained generation capacity of 9,875 megawatts. For comparison, a 24-inch pipe supplying 40.1 cfs would sustain generation of up to 1,590 megawatts. Although the applicant has disclosed no plans for more than 700

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megawatts of generating capacity at Colstrip, officials of the Bonneville Power Administration have stated publicly that the applicant is considering construction of two 700-megawatt generators in addition to the development now proposed. The officials said the two additional plants would be expected to go on line in September, 1978, and September, 1979. To get the plants operable by that time, it was indicated, a decision to build would be necessary early in 1973. Such construction would require more water than could be transported in a 26-inch line.

Under Montana law, any water appropriated but not used may be appropriated by another user. Thus, if the applicant does not use the full 250 cfs, it may be appropriated by another consumer.

Considerable interest has been expressed regarding the possible construction of units three and four. The applicant has indicated that if the decision is made to build these additional units, reapplication would be made to the state, considering the increased scope of the operation.

TABLE 10

STATION	DRAINAGE AREA, MI^2	MAX. FLOW cfs	MIN. FLOW cfs	AVG. FLOW cfs
Yellowstone at Billings	11,795	66,100	430	6,754
Bighorn at Bighorn	22,885	26,200	275	3,756
Tongue at Miles City	5,379	13,300	0	405
Yellowstone at Miles City	48,253	96,300	996	11,140
Powder near Locate	13,194	31,000	0	600
Yellowstone near Sidney	69,103	159,000	470	12,910

Records show that between 1931 and 1965 the lowest daily flows of the Yellowstone River at Miles City averaged 1900 cfs. During these low water periods the flow of the Tongue River and Rosebud Creek is nil or nearly so. Therefore, low flows at Forsyth also should average 1900 cfs. Thus, 250 cfs at Forsyth would represent about one-eighth of the river's total flow at low flow in an average year.

In its comments on the draft statement, the Environmental Quality Council commented on consumption of water from the River as follows:

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"Assuming utilization of the total appropriation of 250 cfs, proportionate use of Yellowstone River water would range from 11% to 25% at minimum discharge levels and 2.2% of the 43-year average discharge. For those who would contend that this is an unrealistic figure because appropriations are usually far above what is actually diverted and used, the Appraisal Report on Montana-Wyoming Aqueducts lists approximately 2,350 cfs (1,700,000 acre-feet per year) of Yellowstone River water subject to development as industrial water supplies and a recent newspaper editorial written by a Bureau of Reclamation official indicates that in normal years the flow of the Yellowstone would be reduced one-third and in a dry year the flow would be reduced about one-half as a result of water diversion for industrial use.[29]

"The diversion of water of the magnitude discussed in the paragraph above would have effects on the water quality of the Yellowstone River in the following areas:

1. Temperature. Loss of water volume and buffering capacity would result in more erratic temperature fluctuations, higher temperature maxima and more prolonged periods of freezing, thus affecting:

a. life histories of fish, invertebrates and aquatic plants.
b. growth and reproductive rates of preferred and undesirable fish species, possibly giving the latter a competitive advantage and resulting in changes in
c. relative abundance of preferred and undesirable fish species.
d. growth rates of aquatic plants, including algae; possibly enhancing seasonal production resulting in nuisance blooms and taste and odor problems.
e. diversity of the aquatic community.

2. Concentration of Pollutants. Most water quality management plans are based on the dilution effect afforded by the receiving waters. Once a substantial volume of dilution water is removed polluters may find themselves in a position of noncompliance with existing water quality criteria. Parameters, the concentrations or levels of which may be affected, include:

a. coliforms.
b. biochemical oxygen demand (BOD) and dissolved oxygen.
c. pH
d. turbidity.
e. temperature.
f. residues.
g. sediment or settleable solids.
h. toxic substances (pesticides and heavy metals).

In the extreme case, one or any number of these factors may increase (or decrease) in value or concentration to the point where the tolerance level of fish and bottom organisms is exceeded and community diversity is thereby reduced.

3. Concentration of Nutrients. Nutrients, particularly phosphorus, nitrogen and carbon, are critical to growth of algae and other plants which form the base of the aquatic food chain. Only slight increases

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in the usable concentrations of these three strategic elements, alone or in combination, are often enough to trigger massive algal growths or blooms which could degrade the water aesthetically by causing taste and odor problems and visual unsightliness. The Yellowstone River, however, is not subject to this type of problem except where it or its confluent the Missouri may be impounded.

These are three areas where water quality would be affected by diversion away from the river. These are merely the types of problems that may arise; statements on their extent would be speculation at this time. The severity of the impact would be determined by the magnitude and timing of the withdrawal. Critical parameters should be monitored over a period of years to detect undesirable changes as development progresses and more water is appropriated, withdrawn and consumed."

The Ecological Consulting Service of Helena under contract to the applicant, is studying the possible effects.

Adequacy of air pollution standards

The State in its Ambient Air Quality Standards wrote

"The air quality standards listed describe a level of air quality designed to protect people from adverse effects of air pollution, and they are intended further to promote maximum comfort and enjoyment in the use of property consistent with economic and social well being of the community."

At this time, the State sees no reason to doubt the adequacy of the standards.

The EPA defines its primary standard as adequate to protect the public health to a sufficient degree. The EPA secondary standard is calculated to protect the public welfare from any known or anticipated adverse effects from pollution.

The EPA is believed to be considering new standards, and should these go into effect, provisions are available for backfitting additional pollution control equipment on the Colstrip plant, should it fall under the new standard.

For example, additional SO_2 removal could be accomplished by adding stages to the venturi scrubbers.

Social and economic impacts

The human dimension of the proposed Colstrip development is perhaps the most difficult to assess adequately. The economic aspects are somewhat more clear cut and some of the benefits of increased coal production at Colstrip can be predicted. Some of these follow:

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Tax Returns

Under present tax laws, coal using operations are subject to the following kinds of taxes and fees:

a. Strip Coal Mines License Tax--paid quarterly to the state, based on gross value of tonnage mined, and heat content of the coal. The first 5,000 tons are exempt from taxation, and a credit of up to one cent per ton for land reclamation may be claimed, or else one-half the cost of reclamation, whichever is lower.

b. Corporation License--paid annually to the state, based on 5.75 percent of all net income earned in the state, with a minimum of $50.

c. Net Proceeds--paid to the county, based on tonnage mined. Net proceeds of mines and mining claims fall in Class 1 of taxable property, taxed at 100 percent of "full and true" value. So, although it has the appearance of an advalorem property tax, this is in fact a tax on production.

d. Property, both personal and general (land and improvements)--paid to the county. At the discretion of the Legislature and with the approval of the electorate, a statewide property tax of up to 2 mills paid to the state may also be levied.

Coal-using companies, power generating and distributing firms are subject to the Electrical Energy Producers' License Tax, amounting to 1.438 percent of the gross value of electrical sales, and to corporate income taxes as well as property levies. No taxes peculiar to coal-conversion companies have been enacted.

Rates at which these taxes are levied are based on amount of capital investment, volume and type of coal mined, or net income from operations. From partial figures on coal company operation, it appears that all taxes (not including royalty payments) paid to county and state are currently averaging about 18 cents per ton mined. The three companies on the tax rolls for the calendar year 1971 paid to the state and local governments 1 1/4 million dollars on 7 million tons mined.

For newer generation-plus-mining operations, payrolls are reported to average about $10,000 per employee, with this income subject to state income taxes, local property and special taxes, gasoline taxes, and licenses and fees.

"Value added by manufacture" is a rough measure of the relative tax-yielding character of an industry. But the added value may be due to high capital investment in machinery and equipment, subject to property taxes; or to high investment in personnel

Exhibit 4

and payrolls, subject to income and other taxes. It cannot be assumed, of course, that increased tax returns will lead inevitably to lower taxes per capita. Rosebud County however, has already felt a sharp increase in tax returns per capita as a result of coal-based operations.

Employment

Jobs and population increases from coal development will depend on the number and kinds of enterprises that are established. From present evidence, the number of jobs created per million tons of coal extracted per year are about as follows:

Mining only	10 to 20, depending on scale and efficiency of operations.
Power Generation	40

Multipliers

The relationship between numbers of jobs and the probable general population is calculated by using "multipliers." One of these described the numbers of service and professional occupations ("derivative" jobs) that appear in an economy as a result of a given number of new primary or basic jobs. In Montana, this relationship was derived in the Montana Economic Study by the University of Montana's Bureau of Business and Economic Research in 1970, on the basis of statewide historical figures up to 1969; and the multiplier was 2.7. This meant that in general 1.7 derivative employment positions have developed for every basic job -- defined as jobs based on products or services for export, and therefore creating income to the community or state from "outside." The multiplier was not worked out for different portions of the state, however, and a study of recently acquired figures giving data by counties shows indication that this multiplier is probably lower in the eastern counties, many of them characterized by population decrease and economic decline for decades. Another multiplier is the average size of family or household -- or more accurately, the number of persons supported by each of the income-producing jobs. Use of the average household size (3.1 persons in 1970) to estimate population would give an inflated projection, because it assumes each of the jobs would be filled by a separate breadwinner and would

Exhibit 4

represent a different household. The statewide ratio of population to jobs in 1970 was about 2.8, but this ratio obscures the "true" relationship because it includes a sizeable unemployment figure, which would not be characteristic of an area with expanding job opportunities and increasing employment.

Population increase would be inevitable if coal mining increases and increased numbers of jobs and people mean social impacts of various kinds. But it must be remembered that the eastern counties have already been undergoing considerable social impact from population and employment changes during the past decades. Although not all the counties have been decreasing in total numbers of people, all but one suffered net out-migration during the past decade, and all but one are subject to an "employment-gap" amounting to between 6 and 29 percent of total 1970 employment, and averaging 15 percent for the 14 counties. This employment-gap claculation was used in the Montana Economic Study to describe the amount of additional employment growth that would have been required to prevent out-migration of the labor force. It assumes that stopping net out-migration would have required a growth in employment sufficient to absorb the entire "natural" growth of the labor force (which depends on normal population growth rates in the area) and in addition reduce the unemployment rate to the 1960 national average, which was 5.1 percent and has been both higher and lower in the interim. By this kind of calculation the "employment-gap" still to be filled in 1970 amounted to at least 4,400 jobs in the 14 counties, and probably more.

The town planners hired by the applicant predicted that the population of Colstrip would reach a maximum of 1866 in late 1974, declining in 1976 to a permanent population of 1781.

Not all of this population would work directly for the company, and many or most of them would be the non-working dependents of the workers. As shown in Table 11 the payroll for construction, mining, and operation employees would peak in December, 1974, at $2,493,000 per month declining gradually to $410,000 per month after October, 1976.

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TABLE 11

ESTIMATED MONTHLY PAYROLL AT COLSTRIP PROJECT
UNITS #1 & #2
(THOUSANDS OF DOLLARS)

	1972	1973	1974	1975	1976
January	-	435	1241	2455	1926
February	-	482	1300	2349	1455
March	-	647	1338	2226	1220
April	-	894	1494	2119	995
May	-	1029	1648	2036	807
June	-	1205	1864	1936	589
July	423	1341	2064	1899	622
August	418	1405	2234	1852	463
September	423	1400	2346	1864	416
October	435	1305	2446	1929	410
November	465	1247	2487	1993	410
December	476	1229	2493	2011	410

based on:

Project 1972 costs - no escalation
Includes payroll estimate for construction, operation, and mining labor.

Exhibit 4

It is uncertain whether the tax benefits from the project would adequately offset the social problems that might ensue.

Few predictions can be made about the needs of the increased population. The State Department of Intergovernmental Relations believes the increased needs can be met with the increased revenues.

The Montana Board of Crime Control has developed a concept of what would be needed to enforce the law in the Colstrip area, following the influx of population. Rosebud County will require a new deputy sheriff, deputy probation officer, and secretary. A patrol car and other law enforcement equipment would bring the total estimated initial cost increase in the area to $40,579.69.

A 25-bed hospital under construction in Forsyth is considered adequate for the increased population.

As noted above, the police protection is furnished by the county. Fire protection is the responsibility of the Western Energy Company. Ken R. White recommended construction of a fire station in Colstrip.

Two churches also were recommended. Library service will be furnished through a bookmobile from Billings.

Substantial expansion of housing was recommended, as noted in the summary of the plan furnished in the appendix.

Heavy impact will be felt in the schools at Colstrip. Currently there are nine teachers and 141 students in the Colstrip elementary school, and eight teachers and 128 students in the high school. The superintendent of the Colstrip schools indicates that mobile units will be brought in as the need is felt. Initially, it is planned to add two classrooms, a library, a cloakroom, and a lavatory, to accommodate 55 to 60 students.

Much of the housing to be developed around Colstrip will be trailer units. The Western Energy Company has requested that the state approve a 68 unit mobile home park

Exhibit 4

on the south side of Colstrip. There should be no water pollution potential from the site, as it is proposed to connect to the town sewage system. The municipal water supply also would be utilized. A considerable impact may result from the amount of grading necessary.

It is estimated that 3000 cubic yards of site grading excavation will be required, along with 16,000 yards of site grading borrow material and 9000 cubic yards of topsoil excavation. Storage and replacement of the topsoil is required. Roads in the area will be surfaced, and all disturbed areas not otherwise stabilized will be planted with grass. Drainage and surface runoff will be controlled with landscaping and culverts.

The increase of population in the area will contribute to the impacts expected from the total population increase expected, as noted earlier.

Whether this area is maintained as an attractive housing site will depend on the trend of employment at Colstrip. If as predicted, the population levels off at almost 1800 persons, the area might escape the type of blight that often afflicts temporary housing areas.

Social impacts will be caused by the gradual change of lifestyles from agricultural to industrial. Although the loss of agricultural land is regrettable, the economic impacts may offset the loss. For example, ranch workers, many of them married and with families, ordinarily earn between $300 and $500 per month. With greater job opportunities resulting from coal development, these same men may earn $10,000 a year or more.

The quality of the overall development at Colstrip will depend in large part upon how diligently the applicant follows the town plan. The applicant asserts that architects have already been hired to implement the plan, which will be modified and updated to cope with changing situations.

Some impact also will be felt as subdivisions develop near the town, and as more families buy small acreages of land away from town. Some impacts already are felt on the Northern Cheyenne Indian Reservation from non-Indian workers living on tribal land, and purchasing supplies in Lame Deer. The Northern Cheyenne Indians have mixed feelings about the project. Some believe that the development will bring work to tribal members

Exhibit 4

and increase the standard of living, while others believe that increased contacts between non-Indians and Indians will be detrimental to the tribe.

Plans to Lessen Overall Impact

Efforts by the applicant to assess and minimize the environmental impact of the proposed plant include the financing of a number of special environmental studies, as follows:

1. Archaeological survey by the University of Montana. Completed, results in Appendix.

2. Study by Montana State University of air pollution effects on native vegetation, animals, soils in the vicinity of Colstrip. Preliminary survey results in Appendix.

3. Meteorological data collection and climatalogical interpretation of local weather pattern by MSU. One year's preliminary data used in diffusion modeling. Summary included in statement.

4. Air quality monitoring by the applicant.

5. Town planning for Colstrip growth by the Ken R. White Company, Denver, Colorado. Plan completed, summary in Appendix.

6. Wildlife habitat utilization in the vicinity of the generating station by the Ecological Consulting Service, Helena. In progress, preliminary survey results in the Appendix.

7. Determination of the presence of trace elements in the coal, and their disposition through combustion, by West Associates. No data yet.

All studies performed by MSU for the applicant will be available to persons with a "need to know," according to a spokesman for MSU.

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IV. ADVERSE ENVIRONMENTAL EFFECT WHICH CANNOT BE AVOIDED SHOULD THE PROPOSED BE IMPLEMENTED

Exhibit 4

Exhibit 4

IV. ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED SHOULD THE PROPOSAL BE IMPLEMENTED

There are a number of basic operations and effects that are inherent in a coal-fired power plant of the kind proposed. The impacts of these operations and effects cannot be avoided. The following group of effects is considered unavoidable, should the plant be built:

1. The consumption of about 90 million tons of coal in 30 years.
2. The consumption of 4.2×10^9 gallons of water per year.
3. Some air pollution--the amount of pollutants can be reduced, but not to zero.
4. Occupation of land by plant, mine, aqueduct, transmission lines, and human habitation space.
5. The adverse effects of increased population in Colstrip vicinity.
6. Change of life styles and social values as society is transformed from agrarian to industrial.
7. Aesthetic impact of facilities.

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V. ALTERNATIVES

Montana Power Company and Puget Sound Power and Light Company have decided to build a coal-fired electrical generating plant at Colstrip if given permission to do so. The Department of Health and Environmental Sciences will decide to issue or deny the permit for construction. The decisions made by all parties concerned are choices of a wide range of possible alternative actions. The proposed actions of the companies involved, are alternatives which they presumably believe will be in their best interests. Whether or not the company's chosen actions are in the best interests of the people of Montana remains to be seen. What alternatives exist to the building of this plant other than proposed?

The alternatives that may be considered, include both ones realistically applying to the proposed plant and ones involving this plant's role in the national energy configuration over a longer period of time. The kind of cooling, for instance, which may be applied to this plant, is a real alternative which can be considered at this time. Building a magnetohydrodynamics (MHD) plant instead, is not a real alternative for this plant at this time. MHD is a possible alternative to the conventional type of power plant at some point in the future. The dividing line between these types of alternatives is arbitrary.

Real Alternatives to the Proposed Plant

The first real alternative which must be considered is that of not building a power plant. The decision to build the plant is based on meeting the "demand." "Demand" is a word that is heard a lot these days and perhaps should be discussed a bit further at this time. Demand, when discussing the use of electricity, is that amount of energy that the customers will use if it is available in the wires. To the consumer, the end of the wire is, practically speaking, an unlimited source if instant energy. As long as the voltage in the line is at the prescribed level, the consumer can extract all the

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energy he needs at the moment. He cannot fill bushel measures with it to save for shortages, but neither is he limited in its use--that is until a brownout or total failure occurs. As long as the voltage is maintained in the line, the consumption of electrical energy is independent of the generating capacity at the power plant. Increasing generating capacity alone will not sell more power. However, if inadequate generating capacity exists, brownouts or failures will occur. Since brownouts have not occurred in Montana in the recent past, the growth of the demand is independent of the power companies except that attributable to their extensive advertising. (Even though Montana Power Company claims that their advertising does not increase the demand, this claim must be seriously doubted due to the large advertising budget of the company. They claim that the yard lights which they have promoted for years only serve to even the load during the 24-hour day.[20] Again, this argument can be questioned since such devices as timers on electric water heaters, which are used by other utility companies across the nation, are neither promoted nor available from Montana Power Company. Such timers would be more effective in balancing the load than the increased use of yard lights.) The decision to build a new power plant is a decision to continue to meet the demand. Unfortunately, if the demand on a particular line is not met, all of the users suffer the brownout--there are no preferred or established customers if they are supplied by the same wire.

The applicant has based their decision to construct on projected demands. According to the Bonneville Power Administration, (BPA), the rate of electrical energy use in Montana increases about five percent per year. Elsewhere, the growth rate is about seven percent, which causes a doubling of demand every ten years.

Figures from the National Power Survey, cited by the applicant, projected a demand increase from 1,460 mw in 1970 to 2,590 mw in 1980, in the area comprising Butte, Anaconda, Billings, Helena, Great Falls, Kalispell, and Missoula. The projection for 1990 in the same area is 4,700 mw. These power levels are peak loads, and are not entirely supplied by the applicant.

Exhibit 4

The applicant asserts it has had a deficiency in self-generated power in recent years. The applicant claims its self-generated resources in January, 1973, totaled 768 mw. An additional 263 mw were received from other utility sources.

In the opinion of the applicant, many of these other sources no longer will be available in 1975. The predicted 1975 peak load in the applicant's supply area is 1098 mw. The applicant asserts that brownouts could occur in 1975 if the proposed plants were not built, because the 768 mw capacity could not meet the predicted 1098 peak load.

A variety of new loads is predicted to contribute to the increased power demand. For example, U. S. Plywood and Champion International Paper is expected to need an unspecified but "significant" increase in power for expanded activities in about 1974. The Anaconda Company will need 25 mw for its new Anaconda smelter by 1975, the applicant states.

Further information from the applicant indicates that residential usage of electricity accounted for only about 20 percent of the total MPC output in 1972.

The applicant continues:

> "Several signs of growth, such as population growth, rise in the living standard, rise in recreation and tourism and employment for Montana in the decade 1970-1980, are evidence of the continued growing need for electrical energy in Montana for both residential and industrial use.
>
> "Secondly, in addition to the projection of more people and industry in Montana which will require more energy, the present market of electric energy is not exhausted. For example, only 75 percent of Montana's potential residential customers have electric ranges, only 60 percent have electric dryers, only 14 percent have outdoor lights, and only 9 percent have air conditioning. The percentage of customer growth has been the highest in history in the past two years for the Montana Power Company and is expected to continue."

One source of increased electrical demand is the farmer, who has found it feasible to place more acres under cultivation with the use of electrical sprinkler irrigation. The following is the annual added usage for irrigation purposes, from Montana Power Company information:

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Year	Horsepower Added
1961	1380
1962	1333
1963	1622
1964	2163
1965	2042
1966	1643
1967	2767
1968	2582
1969	2081
1970	2743
1971	4643
1972	4292

It is predicted that the amount of energy used for environmental improvement on a national basis will increase from about two percent of total energy consumption in 1970 to four or five percent in the period 1970-1985.

The applicant indicates that sewage and water treatment facilities in Billings and Great Falls each will use enough electricity to serve an average Montana town with a population of 10,000.

Further information from the applicant notes that the Humble Oil Company in Billings has a water treatment system using four 50 HP electric motors on large aerators in the ameliorating process.

> "Great Western Sugar Company in Billings is constructing a new sewage treatment facility that will require 600 to 700 HP in electrical load. Furthermore, the air pollution equipment to be installed in the Colstrip plant will use approximately 25 mw. . .approximately 1/30 of the total electricity now generated by the Montana Power Company."

Although the applicant states that only 1,483 homes are electrically heated in the MPC service area, peak loads occur in the winter. The stated reason for this is

> "because the temperature is colder and the days are shorter which results in greater uses of electricity. For example, with shorter days more lighting is required. With shorter days and colder weather there is a tendency for people to be indoors and use more electricity for lighting, clothes drying, hot water and heating. In addition to electric heat, forced air and natural gas heating systems use electric thermostats, fans and blowers."

Montana Power Company peak loads are illustrated in Figures 10 and 11 and Table 12.

Exhibit 4

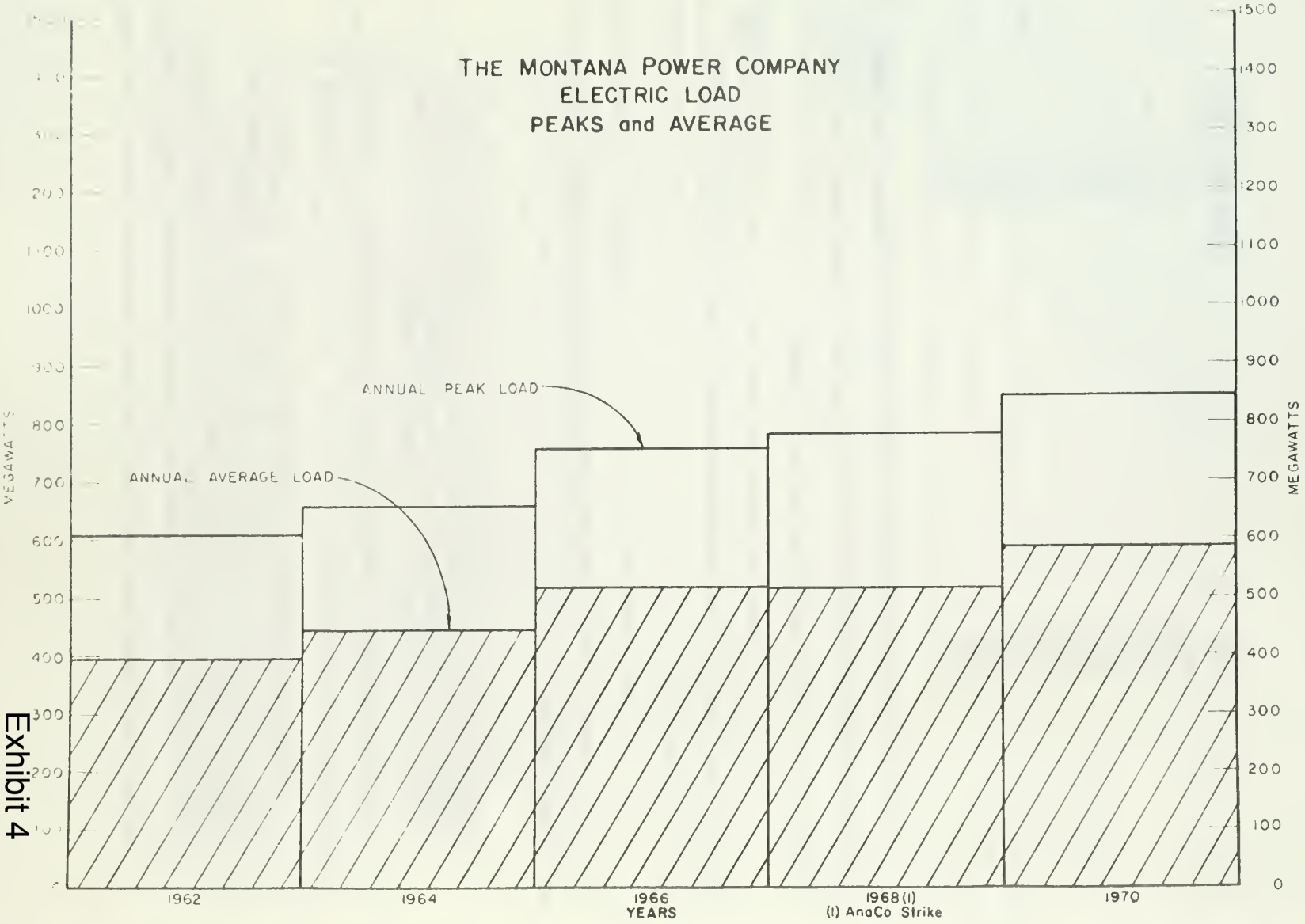

FIGURE 10
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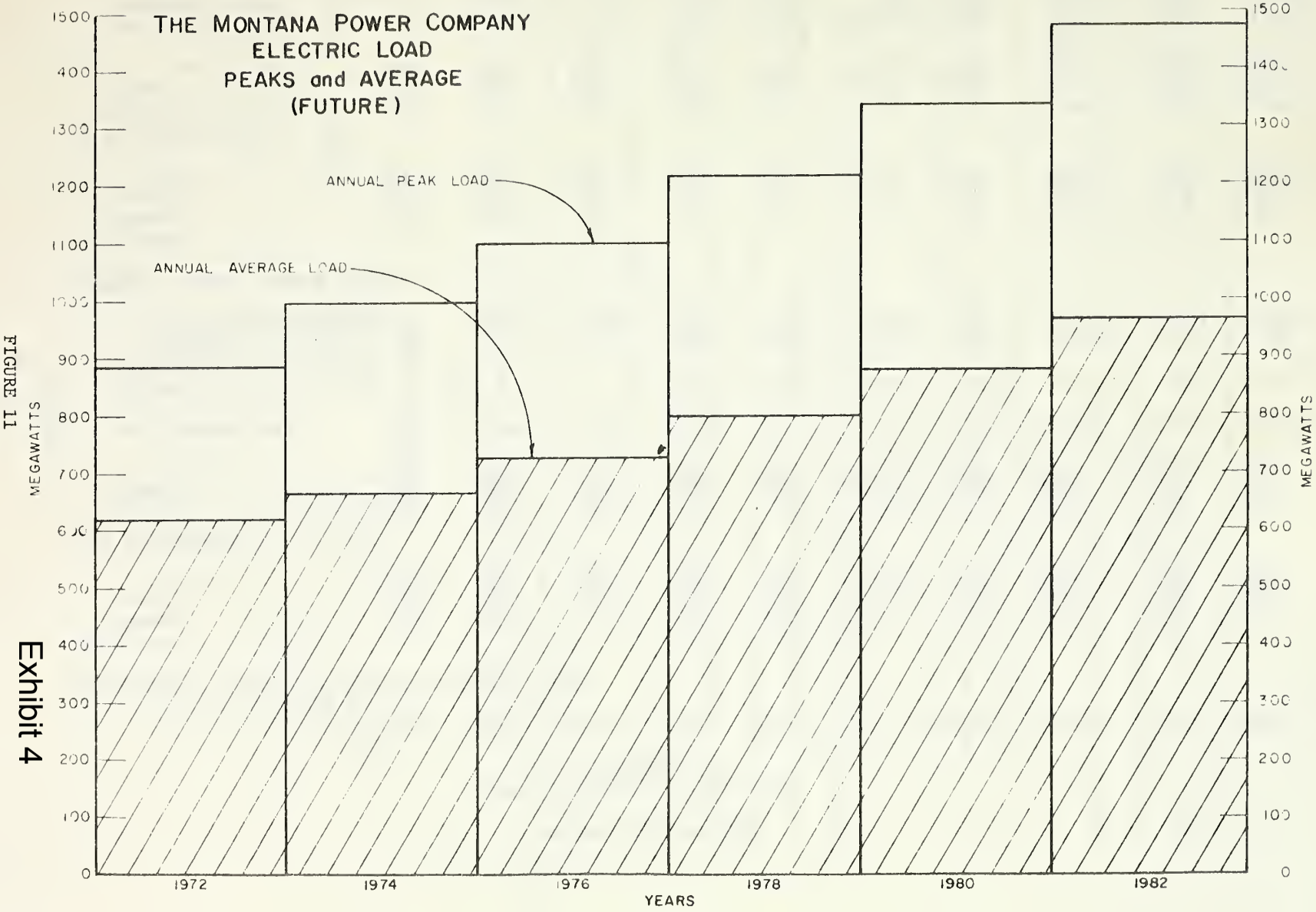

FIGURE 11
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TABLE 12

Montana-Puget Combined

Loads, Resources and Deficiency
Megawatts

	1972-3	1973-4	1974-5	1975-6	1976-7	1977-8	1978-9	1979-80	1980-1	1981-2
PEAK (Energy required at time of heaviest load)										
Firm Load:										
Montana	822	879	926	972	1020	1071	1125	1182	1241	1304
Puget	2022	2175	2341	2514	2719	2937	3177	3423	3716	4018
Total	2844	3054	3267	3486	3739	4008	4302	4605	4957	5322
Net Resources:										
Montana	941	874	940	877	774	774	774	767	811	811
Puget	2052	2151	2184	2430	2438	2465	2605	2542	2387	2373
Total	2993	3025	3124	3307	3212	3239	3379	3309	3198	3184
Net Surplus (Def)	149	(29)	(143)	(179)	(527)	(769)	(923)	(1296)	(1759)	(2138)
Colstrip #1 & #2				330	660	660	660	660	660	660
Less Added Reserve Obligation				-50	-99	-99	-99	-99	-99	-99
Surplus (Deficiency)	149	(29)	(143)	101	34	(208)	(362)	(735)	(1198)	(1577)
ENERGY - 12 mos. annual average										
Firm Load:										
Montana	567	598	629	661	693	726	760	798	837	878
Puget	1210	1270	1363	1464	1576	1701	1836	1980	2139	2315
Total	1777	1868	1992	2125	2269	2427	2596	2778	2976	3193
Net Resources:										
Montana	613	622	663	616	573	596	597	598	657	665
Puget	1210	1338	1280	1375	1315	1350	1399	1344	1282	1272
Total	1823	1960	1943	1991	1888	1946	1996	1942	1939	1937
Net Surplus (Def)	46	92	(49)	(134)	(381)	(481)	(600)	(836)	(1037)	(1256)
Colstrip #1 & #2				280	561	561	561	561	561	561
Surplus (Deficiency)	46	92	(49)	146	180	80	(39)	(275)	(476)	(695)

As noted, at least half the power generated will be delivered to the Northwest Power Pool, which serves Washington, Oregon, Idaho, western Montana, and other areas in the western U. S. through inter-ties with other pools. The BPA has testified at length on the probable need for power increases in the area served by the Northwest Power Pool.

The BPA indicates that the aluminum industry is the single largest power consumer in the Northwest. In 1970, the industry used about 21 billion kilowatt hours of electricity in the region. Individual plant use varied from 1.25 billion kwh to 3.5 billion kwh.[35]

The second largest industrial use is paper manufacturing with 45 pulp and paper plants in the Northwest. No specific data was immediately available on power usage by these plants, although some individual plants are known to demand almost 100 mw. The BPA estimates that pulp and paper plants account for 15 percent of the industrial use of electrical energy in the region. The third largest industrial user is the forest products industry, using over three billion kwh annually.

The following table (Table 13) from the BPA shows electric energy use by the West Group Area of the Northwest Power Pool for calendar 1970 and the percent of total electric energy use for each class compared to these same percentages for the U. S.

TABLE 13

	Pacific Northwest		U. S.
Class of Consumer	Energy Sales (billions of kwh)	% of Total Energy Sales	% of Total Energy Sales
Domestic	27.5	31.4	31.9
Commercial	12.1	13.8	22.4
Industrial	44.1	50.3	41.4
Irrigation	2.6	2.9	(
Other	1.4	1.6	(4.3
TOTALS	87.7	100.0	100.0

Exhibit 4

Electric Power Requirements by Major
Consumer Categories in the Pacific Northwest
(West Group Area)

	Actual			Estimated	
	1950	1960	1970	1980	1990
Population[1]	4,674,671	5,489,729	6,435,000	7,201,000	8,476,000
No. Domestic Consumers	1,072,628	1,406,903	1,985,569	2,451,000	3,066,000
No. Commercial Consumers	140,401	176,807	241,860	314,000	399,000
KWH Per Consumer					
Domestic	5,112	9,841	13,831	19,300	24,600
Commercial	16,799	29,143	50,035	72,600	95,900
Energy Sales (billions of kwh)					
Domestic	5.5	13.8	27.5	47.3	75.4
Commerical	2.4	5.2	12.1	22.8	38.3
Industrial	11.1	22.3	44.1	73.0	117.0
Irrigation	.1	1.0	2.6	5.0	9.0
Other	.6	.8	11.4	2.6	4.9
Total	19.7	43.1	87.7	150.7	244.6
Losses	3.1	4.7	9.6	15.1	24.2
Total Requirements	22.8	47.8	97.3	165.8	268.8
Ten Year Annual Growth Rates		7.7%	7.5%	5.5%	4.9%

[1]States of Washington, Oregon, Idaho, and western Montana.

BPA - Branch of Power Requirements
July 13, 1972

Exhibit 4

PACIFIC NORTHWEST (West Group Area) ELECTRIC UTILITY SALES

(billions kwh)

Year	Total	Industry	Industry % of total	Sales to Aluminum Industry			Total	Industry
				BPA	Chelan	Total		
1950	19.7	11.1	56.3%	6.2	--	6.2	31.5%	55.8%
1960	43.1	22.3	51.7	8.8	.1	8.9	20.6	39.9
1970	87.7	44.1	50.3	20.9	1.3	22.2	25.3	50.3
1980	150.7	73.0	48.4	31.2	1.3	32.5	21.5	44.5
1990	244.6	117.0	47.8	37.0	1.3	38.3	15.6	32.7

TABLE 15

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Branch of Power Requirements

January 10, 1973

Exhibit 4

The West Group area includes Washington, Oregon, Idaho, and the portion of Montana west of the Continental Divide.

Table 14 and Table 15 further illustrate power demand projections in the Northwest.

According to BPA, a significant portion of the energy to be needed in the Northwest will be used for environmental clean up. For example, one pulp mill recently requested 7.5 mw for pollution control. If all 45 pulp plants required a similar amount of power, the demand would be considerable. BPA apparently does not agree with the applicant about the potential for large energy demand by sewage treatment, solid waste disposal and recycling processes. According to the BPA, such operations are "not large consumers of electric power."

Electrical heating units in the power pool region used about nine billion kwh in 1970 or 30 percent of the total residential electric energy use, according to the BPA. Usage of electric heat is expected to triple in the next 20 years "as shortages of fossil fuels and concern for a clean environment in the home and in urban areas accelerate demand."

No estimate was available as to possible increases in electric heating in Montana. However, MPC Executive Vice-President J. A. McElwain stated before the Board of Health on January 12, 1973, that his company does not advertise electric heat because "it's just not practical in Montana."

One BPA official has written a paper on the needs of the Northwest for more power. After detailing many reasons for the need, he summarized:

> "We are, in other words, building an affluent society (provided, of course, there is enough power for industry and commerce to create the necessary jobs and income) which will make it possible for the average consumer not only to purchase new homes and appliances, but to replace older appliances with newer ones which generally require more electricity." [9]

If an ever increasing demand for electricity is to be met in Montana, more generating capacity must be built. The no-build alternative means either the demand will not be met or the growth of the demand must be curbed. To stop the growth of the demand by 1975 would require a number of imaginative, bold, and unpopular steps by the

Exhibit 4

State, or, even less likely, attitude changes by society. Although it is felt by some that the growth of this demand must and will be slowed in the future, its occurrence in Montana within two years seems highly unlikely. The quickest manner in which this slowing could be brought about would be in rationing or taxing the price of power to limit the growth of the use of electricity. The increased cost would tend to cause customers to shift to other sources of energy or do without.[24] The political climate in Montana at this time places real limits on how far the State could proceed in this direction.

It can, therefore, be concluded that the no-build alternative is not feasible for this particular power plant.

Another real alternative involves the method of condensing the steam. Several methods can be used for this function, but since there is no large stream of water near the plant, once-through cooling can be ruled out as a real alternative. Even though the company has elected to install wet cooling towers, dry cooling is a possible choice that may be in the best interests of Montana. The State does not have adequate data to determine which is better at this time. The company claims that dry cooling is less efficient than wet cooling and will result in greater use of coal for the same power. This claim may or may not be true, but even if true, society may decide at some future time that the water is more valuable than the extra coal that would be burned. Another claim for wet cooling is that dry cooling is much more expensive; however, there are indications that if many power plants are built in Montana and Wyoming, it will be cheaper for society at large to insist upon dry cooling.[29] The ultimate decision on which method would be best for Montana would require extensive study. These studies have not been carried out to date, because until March, 1973, the State has not had the authority to affect any decisions on this subject and it still cannot affect decisions on this proposed plant.

The proposed plant will employ a venturi scrubber to remove particulate matter and gases from the stack effluent. Alternative collection devices exist and are in use

Exhibit 4

in other power plants. The most widely applied air pollution control unit for power plants in recent years is the electrostatic precipitator (ESP). The Corette plant in Billings, for instance, uses an ESP. Although ESP's can remove up to 99.5 percent of the particulate matter, they cannot remove gases. The venturi scrubber will remove a significant amount of SO_2 and gaseous fluorides which would otherwise be emitted into the atmosphere. This Department believes that the best available control technology is planned for the Colstrip plant.

The location and size of the proposed plant is also subject to alternatives. The State does not have the authority to insist upon possible changes in these factors for this plant (future plants will come under the jurisdiction of the newly enacted siting authority). As shown above, the size of the plant by itself will not change consumption patterns unless it is inadequate. The size of the plant is then a moot point. As to the best location, no study by the state has been done on this aspect. There are many places in the state that would be a worse location for the plant, but whether better locations exist is not known. The location of future plants will be considered by the State.

The demand for electrical power could possibly be met by a generating facility utilizing some method other than a conventional coal-fired boiler. Other forms of fossil fuel are more limited than coal and would not be acceptable from several environmental aspects. Nuclear plants require a long lead time for design and construction. Substituting a fission plant for coal is not feasible if the 1975 demand is to be met; therefore, is not an acceptable alternative to this particular plant.

This discussion on "real" alternatives is not meant as an excuse to build the plant as proposed. With the authority that the Department has over this particular plant, the alternatives which really exist are voluntary ones. Decisions on these alternatives will not be entirely up to the company for future power plants in Montana.

Exhibit 4

Long Term Alternatives

Many people are concerned about the exponential growth of electrical demand in the U. S. There exists a very definite limit (measured in decades) to the extent that this demand can grow and be met with fossil fuel. Effort should be expended to reduce the energy demand and to find alternate ways of generating power other than the burning of fossil fuels. These alternatives are longer term than those which are real for the proposed Colstrip plant. The reader is referred to Mr. Albert Melcher's discussion of alternatives in the Appendix.

Exhibit 4

VI. RELATIONSHIP BETWEEN LOCAL SHORT TERM USES OF MAN'S ENVIRONMENT AND LONG TERM EFFECTS

Our society's dependence upon electrical energy is growing rapidly. A form of energy developed in less than a century is now used in so many ways in the domestic, industrial, and commercial sectors of our society that our way of life is dependent upon it. The technological and economic changes of this century have been so dependent upon electricity that this form of energy is considered by many as essential to civilization. Others argue that civilizations have existed for many times as long as has electrical energy production and there is little indication that this society is more civilized than ones gone before. Even in existing societies, it is contended that there is no relationship between electrical power consumption and degree of civilization.

The rapid growth of electrical energy consumption in the U. S. at this time is an indication of our dependence on this commodity. This "demand" for electrical energy, and many question whether this is a real or artificially stimulated demand, is presently being met largely by the consumption of non-renewable resources: coal, oil, and gas. This "demand" is presently growing in such a manner that consumption doubles roughly every ten years. This kind of growth is referred to as exponential. At this rate of growth, the "demand" in just three decades will be eight times its present value. Because coal is being used to produce much of this energy, the consumption of this non-renewable resource is also growing exponentially. Although there are large quantities of coal still in the earth, there is considerably less than has been expressed by some. Global reserves are estimated to be 5×10^{12} tons or a 2300-year supply at current rates of consumption. However, at a growth rate of 4.1 percent annually (much less than the growth rate of electrical "demand") there is only a 111-year supply. Even if there is actually five times as much coal as estimated, the supply is only 150 years at a growth rate of 4.1 percent. In addition, the U. S. has about 32 percent of the world supply but presently consumes 44 percent of the world production. (Limits to Growth, Meadows, 1972, Universe Books, New York.) Therefore, if the

Exhibit 4

electrical "demand" continues to grow at its present rate and this growth is met largely by the conversion of coal, the coal reserves in the U. S. will be greatly diminished in a few decades. The coal, once consumed in a power plant, is lost forever. Future uses of the coal, whether to generate power or as a source of chemicals for production of some other commodity, are denied. The future needs of the coal may be more urgent than our present needs for electricity.

The proposed Colstrip generating plant will not consume the reserves in Montana by itself, but it cannot be divorced from the overall energy situation of the country. (The expressed purpose of the plant makes this point clear.) At present, coal is being removed from the area for power production outside of the Fort Union Region and more power plants are being planned within the Region.

Depletion of coal as a resource is not the only long term consideration involved here. An economy based on the exploitation of the coal is developed in the coal fields themselves, as well as where the electrical energy is being consumed. The short term gains to the Colstrip area are made known by the interests involved in building the plant and mining the coal. Jobs are created and money enters the local economy from these jobs. As long as the coal is mined and the power is generated, the flow of money through the community is assured. When the coal is exhausted, or its use for production of electricity becomes obsolete, the economy and way of life dependent upon the exploitation of the coal will suffer. Many feel that this consequence is inevitable; that only its magnitude and timing are in question. Improper reclamation of the land may destroy the original economic base of the region: the land used for agriculture. Numerous examples of boom and bust cycles can be cited. There is little evidence that this sort of thing will not happen in the Fort Union Region.

At the other end of the transmission lines, is a society and economy becoming more and more dependent upon electricity. Not only is the per capita use of electrical energy increasing, but the number of persons kept employed, warmed, and fed by this energy is increasing. Each ton of coal that is used to meet the increased "demand"

Exhibit 4

of electrical energy is increasing the entire society's economic and physical dependence upon electricity. A civil disturbance or war or other sudden interruption of the supply of electricity would be catastrophic. Likewise, a sharp rise in the cost of electricity would put a strain on the economy through businesses, manufacturing, and domestic use. This situation is true today but will be more critical as time goes by and our society becomes more and more dependent upon this energy.

The possible local destruction and regional degradation of the ecosystem by the proposed Colstrip plant also has long term implications. Land use changes adversely affecting food production, modification or loss of recreational areas for present and future generations, and changes in natural species may be more significant to our descendants than our use of electricity over the next several decades. Residents of the area will be subjected to changes in social and psychological pressures from this industrial economy and life style, as the change is made from an agricultural base to a more industrial one. Future residents may encounter the reverse situation; that is, adapting to an agrarian life style should the industrial form be removed or altered.

On the more positive side, one can speculate that both short term uses and long term uses will be beneficial. The short term, while the coal supply lasts and through the life of plant operation, will see increased employment in the Colstrip and Fort Union area, and at the receiving end of the electricity. The tax base for the communities will also increase. Over a longer period, the increased employment resulting from the short term energy use may continue indefinitely, even though coal is no longer available for power generation. Alternate energy sources will probably emerge as economics dictate their practicality. It is even possible, although not probable, that some of these sources may locate in the Colstrip-Fort Union Region, where water supply and transmission systems will already exist. On reclamation of strip mined land, and possibly obsolete power plant sites, it would appear that society's increasing environmental concern will move to disallow any but the most advanced reclamation methods for the time. It is not inconcievable that reclaimed land can be returned to its

Exhibit 4

former levels of productivity. Still on the positive, it can be argued that man continues to accept new challenges as they arise and often prevails, minimizing negative consequences. Few dispute that electricity benefits society, and that a major reduction in per capita energy available would be detrimental. Evaluation of these and other potential consequences, be they boon or bane, is nearly impossible. The factual information necessary to make such determinations is, at best, scarce and few people are willing to make judgments of the relative desirabilities of such alternatives for the future.

The relationship between the short term effects and long term effects is one of space and time. It is so much easier to plan for the short term than for the long term. The effects that occur in the long term are seldom planned or taken into consideration in planning. The long term effects, both good and bad, of the Colstrip plant will be accidents, in that they are not planned. One's concern is greatest for things and persons closest to him in space and time. As situations are removed in time (future) or involve a larger portion of the world, a person spends less time and energy thinking about them. For instance, a person is much more concerned with his family over the next few years than with the nation over the next hundred years. (Limits to Growth, op. cit.) Actions based upon these different levels of concern are often contradictory. It is also much easier to accept decisions that have more personal and quicker results than ones less personal and farther removed in time. It is, therefore, easier to decide in favor of a power plant that will prevent a small power shortage in one's own town in four years than to be concerned with the fate of a large portion of the United States society fifty years from now. Even though some very serious problems for mankind seem to loom in the future if he continues on his present course, he is reluctant to give up his immediate comforts. This concept is well illustrated by our attitude towards energy in this society. When evaluated at some future date, the proposed Colstrip plant may prove to have been very efficient at solving one immediate problem, but in doing so having created other problems of much greater scope and duration.

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VII. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF NATURAL AND ECONOMIC RESOURCES

The consumption of a non-renewable resource is an irreversible commitment. The burning of coal in the proposed power plant would be the major consumption of a non-renewable resource. Approximately 90 million tons will be burned in 30 years, which represents the coal under nearly 2000 acres if present mining methods are used.

Since this coal will be mined by stripping, 2000 acres of land will be disturbed which will put it out of production at least temporarily. If adequate reclamation is not possible, the 2000 acres of land will be permanently degraded.

There are also some of the materials that will be used in the construction of the plant itself plus the aqueduct and transmission lines. Metals and other materials that can be recycled do not fall into this category.

Exhibit 4

VIII. RESPONSE TO THE DRAFT STATEMENT

Exhibit 4

Exhibit 4

VIII. RESPONSE TO THE DRAFT STATEMENT

The Department of Health and Environmental Sciences has received over 3000 responses concerning the Colstrip power plant and general coal development since publication of the draft statement in October. Included in these responses were specific comments on the impact statement. The mail consisted of letters, postcards, petitions for and against development, and coupons from the Billings Gazette which express disfavor with the development.

Approximately 95 percent of the responses opposed development of the plant and coal mining operations. A breakdown of the mail as of January 4, 1973, concerning the proposed plant and coal development follows:

For the plant or coal development:	
Letters	73
Postcards	3
Signatures on Petitions	54
Total	130

Against the plant or coal development:	
Letters	1162
Postcards	55
Coupons	300
Signatures on Petitions	1350
Total	2867

A rush of correspondence arrived in late November and early December, which was probably precipitated by several articles in the Billings Gazette, including a front page editorial. Very few letters were received after January 4, 1973, and their change on the total figures presented above would be very minor.

Exhibit 4

Ranchers, doctors, lawyers, housewives, students, small town and urban dwellers, businessmen, retired persons and many more have written. Most of the writers were from eastern Montana, but included residents from other parts of this state and other states.

The fears most often expressed were:

1. Strip mining will proceed with little, if any, adequate reclamation of the land.
2. Air and water will be polluted significantly.
3. Large scale water consumption will result.
4. Montana will emulate the bad characteristics of other states.
5. Present life styles will be disrupted.

Many letters expressed disfavor with either Montana Power Company in general or with the population centers outside of Montana that would use some of the energy. Many letters and all of the coupons merely ask us to deny the permit for construction without any particular reason being stated.

There were two major misconceptions expressed or implied by the large number of correspondents. First, many people appear to believe that all of the power from the Colstrip plant will be used outside of Montana, and that Montana needs no additional generating capacity to meet its own needs. Second, most letters were written seemingly with the belief that the Air Quality Bureau could decide to issue or deny a permit on the basis of popular opinion or criteria other than the standards established in the regulations. The articles in the Gazette promoted this misconception.

There was a substantial amount of confusion expressed in the letters about the role of the Department of Health. The non-degradation clause from the Air Quality Implementation Plan was cited as evidence that the State should oppose construction of the plant. However, since in its literal interpretation, non-degradation is not possible, and since at the national level, the legality of non-degradation laws and variations thereof is before the U. S. Supreme Court, the Department does not feel it has the authority to enforce a literal interpretation of non-degradation.

Exhibit 4

There was also considerable concern as to why construction of the plant was allowed to begin before a permit to construct was issued. The reason is that the State had no authority to regulate construction except for those portions of the plant that would contribute to air pollution.

All letters commenting directly on the draft statement are included in the Appendix, either verbatim or condensed form. One of these comments worth noting states that all the great civilizations of the past became more technologically complex as they advanced. It was further noted that the great civilizations of the past also share the common characteristic of no longer being around.

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APPENDIX

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ARCHAEOLOGICAL SURVEY

Exhibit 4

Exhibit 4

The following is from an archaeological survey performed in 1971 for the Western Energy Company by Dale E. Fredlund and his team from the University of Montana.

Site Descriptions

Ellison Petroglyph Site (24RB1019). Site 24RB1019 is a rock art site located in the southwest quarter of Sec. 29, T2N, R41E. Four panels of petroglyphs (Figs. 2-5) have been drawn on the northeast vertical face of a stump-like, 25-30 foot high, eroded sandstone remnant that juts up at the end of a pine-covered ridge. Site 24RB1020, a habitation and lookout site, surround the art panels. The two sites, although adjacent, were assigned separate numbers because there is no way of ascertaining any direct association between the inhabitants of 24RB1020 and the individuals responsible for the art work at 24RB1019.

The four panels cover completely a flat, vertical sandstone face approximately 8 feet in height by 15 feet in width, but vary among themselves as to their individual dimensions and height above the present ground surface. Panel 1 covers an area approximately 4 by 2 feet (8 square feet) and is 4 to 8 feet above the surface. Panel 2 is also 4 by 2 feet (8 square feet), but covers an area from 3 to 7 feet above the surface. Panel 3 is smaller, being only 2 by 2 feet (4 square feet), and is at a height of from 4 to 8 feet above the ground. Panel 4 is 2½ feet by 1 foot, and is the lowest of the panels, being at a height of only 0 (surface) to 1½ feet. In addition, one large sandstone boulder, which had fallen face-down from the sandstone wall within the past 10 years, was reported to have exhibited numerous figures. It was impossible to move the boulder in order to verify the lead, but it seems reasonable that the report is valid.

Many motifs are still clearly visible on the panels, despite damage due to weathering. Based on the superimposition of some of the figures and on the various

Exhibit 4

art elements present, it seems very likely that more than one group of people were responsible for this art work. Grooves, lines, and various human and animal figures have been etched and rubbed into the soft sandstone.

Art styles frequently found throughout the Northern Plains occur in Panels 1-3, as follows: 7 shield-bearing warriors; 3 V-necked anthropomorphs, 2 solid body, square-shouldered anthropomorphs; 3 outlines, square-shouldered anthropomorphs; 2 horses with feathered arrows in their backs; 1 tipi; and numerous lines and arrows.

Superimposition occurs on all three panels, but the following should be noted especially: the lines dissecting the V-necked, outlined shield bearer and the square-shouldered anthropomorph in Panel 1 are etched over the figures; the V-shouldered anthropomorph occurs over an incomplete circular design on Panel 2; and a V-shouldered figure is superimposed on a square-shouldered figure in Panel 3.

Art elements similar to those in Panels 1-3 occur at the following sites, as noted by Conner and Conner (1971-17):

Pictograph Cave, pictographs (Mulloy 1958)
Pryor Creek, No. 2, pictographs
Bear Gulch, pictographs (Secrist 1960)
Atherton Canyon, pictographs (Secrist 1960)
Decker Site, petroglyphs
Deer Medicine Rocks, petroglyphs
Nordstrom-Bowen, petroglyphs (Hagen 1963)
Langman Petroglyphs, petroglyphs

In addition, several other sites in the area of Colstrip display these art forms, especially 24RB1027, the Benjamine Hill site, located near the Western Energy survey area on Rosebud Creek.

While the elements on Panels 1, 2, and 3 are fairly common in the Northern Plains, Panel 4 is atypical. The style present is, to my knowledge, not reported from any other site in the state. The art work on Panel 4 (Fig. 5) consists of frequently connecting curved lines, and rotund heads with short "crew-cut" like hair and smiling faces. The low height of this panel above the present ground surface (1½ feet) and the advanced stage of its decomposition suggest that it was

Exhibit 4

the work of a different and earlier group of people than those who were responsible for Panels 1-3. A test pit was excavated below this panel; however, fallen sandstone blocks have sealed off any information which might be gained from the site (see 24RB1020 for the test report).

Ellison Rock Site (24RB1020). Site 24RB1020 is a habitation site which extends 100 yards upslope and away from the sandstone remnant exhibiting the petroglyphs of 24RB1019. The site also includes a high sandstone remnant which had been used prehistorically as a lookout site.

The ridge is covered by native grasses, prickly pear, sage, and sparse ponderosa pines. Various types of brush grow along the bottom of an adjacent dry wash which contains water for at least part of the year.

Three artifacts were found on the surface of the site: a small side-notched projectile point, and two granite-tempered, dark gray plain ware pottery sherds. A small test pit was dug at the base of the sandstone remnant under the rock art panels. The top level of the revealed strata was 2-6 inches deep and consisted of dry, wind-blown sand and surface duff. Below this stratum was a stratum of gray sand which extended to bedrock, at a depth of 19 inches below the surface. The sand stratum was composed of compacted sandy soil and sandstone fragments with scattered charcoal, and evidenced much rodent activity. From the test pit were recovered one projectile point, three scrappers and the remnants of a hearth.

The projectile point is a small side-notched type, 2.6 cm. long by 1.2 cm. wide by 0.3 cm. thick. One of the blade edges is straight, the other convex. Of the three scrapers, two are flake scrapers, both exhibiting fine pressure retouch on one edge only. One scraper is a plano convex end-scraper of tan chalcedony. This scraper is very well made and exhibits controlled primary percussion scars on the dorsal surface. Pressure retouch is evident along the lateral edges and nose of the scraper. Part of one hearth made of fragmented sandstone rock was found resting on the sandstone bedrock. It did not contain sufficient carbon for radiocarbon dating.

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Farley Ridge Site (24RB1022). Site 24RB1022 is located slightly northwest of the Farley ranch building, along the base of a low sandstone outcrop ridge that extends into the basin. Small concentrations of debitage are found intermittently from the base of the sandstone ridge to its junction with the higher pine-covered ridges.

It is possible that because the ridge provided concealment, it was used as an approach route to game animals grazing on the flats.

Western Energy Shelter (24RB1033). Site 24RB1033 is located in the northeast quarter of Sec. 32, R41E, T2N. The shelter faces southward and is slightly above the floor of the east-west extending dry wash that dissects Sec. 32. Ponderosa pine, chokecherry, and native grasses constitute the vegetation of the immediate site surroundings.

Debris from lithic tool manufacture was found on a low sandstone outcrop directly above the rock shelter. Because of the proximity of the debitage, it was felt necessary to test the shelter for subsurface cultural material. The shelter was excavated to a depth of 49 inches below surface at which point bedrock was encountered. The subsurface strata consisted of sand deposited by wind and water, and rock sloughed from the shelter's ceiling.

At a depth of 5 inches below the surface was encountered a fragmented wood floor composed of 2-inch thick, sawed planking, some of which still evidenced green paint. Other historic items recovered included a metal can, glass, and cloth fabric found at 11 inches below the surface. A concentration of charcoal at about 12 inches below the surface suggests that part of the wood sturcture had burned.

Another south-facing rockshelter located during the survey had formed at the base of the sandstone outcrops in the southeast one-quarter of Sec. 8, R41E, T1N. The shelter measured 25 feet wide by 10 feet deep. Cow manure mixed with wind-blown sand covered the entire floor area. No surface indication of human habitation was detected. However, since the shelter would have

Exhibit 4

provided excellent protection and concealment for prehistoric peoples, testing of the floor deposits was warranted. A test location near the center of the cave's length on the outer lip of the floor was selected. Below the surface mixture of sand and cow dung was encountered clean, aeolian-deposited, compacted sand stratum disturbed by occasional rodent holes and with occasional rock that had sloughed from the ceiling. There was no indication of human habitation. Consequently test excavation was terminated 36 inches below surface level, at a point where sloping bedrock was encountered.

The Cattail Site (24RB1015). Site 24RB1015 is located on the second terrace above Armells Creek. Surface debitage extends for approximately 100 yards along the terrace. The vegetation in the immediate area includes cottonwood and chokecherry along the creek, and sage and native grasses on the terraces. Because the cultural deposits are entirely on the surface, cultivation has caused considerable damage to the site. Thus, I felt the site warranted no further study.

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Exhibit 4

Panel 1, Ellison Petroglyph site.

Exhibit 4

Exhibit 4

Panel 2, Ellison Petroglyph site.

Exhibit 4

Exhibit 4

Panel 3, Ellison Petroglyph site.

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Exhibit 4

Panel 4, Ellison Petroglyph site.

Exhibit 4

Exhibit 4

EMISSIONS EFFECTS

Exhibit 4

Exhibit 4

INTRODUCTION

In January, 1972, the Montana Agricultural Experiment Station initiated a preliminary investigation into the effects of coal-fired power plant stack emissions on the range resource in the vicinity of Colstrip, Montana. This study was the initial step of a potential program extending over several years. It was requested and supported by the Montana Power Company through the Endowment & Research Foundation of Montana State University. The objectives of the investigation were to:

1. Gather literature and information on coal-fired generating plant emissions and monitoring systems.
2. Inspect the site of the power plant and the adjacent areas.
3. Prepare a realistic and comprehensive proposal for implementation of a formal study.
4. Submit a budget for the investigation.

Substances Recommended for Study

Of the elements or gases already discussed, arsenic, poly-nuclear hydrocarbons, carbon monoxide, and gaseous hydrocarbons have not been considered in this category. Levels of these substances in the plant emissions will be extremely low or the pollutant may be readily removed from stack gases and hence to not warrant expensive analyses.

An analysis of fly ash for radionuclides should be made. If an estimation of particulate fallout and radionuclides shows a potential accumulation problem, a monitoring program should be initiated. Calculated maximum concentration that could possibly be derived from power plant emissions should always be significantly lower than maximum permissible concentrations in air as established by the Public Health Service.

Sulfur Dioxide:

This gas has been shown to produce toxic symptoms in several sensitive plant species at very dilute concentrations in the atmosphere. Ponderosa pine and alfalfa

Exhibit 4

are very sensitive to sulfur damage and are common in the study area. Atmospheric concentrations as low as 0.1 ppm sulfur dioxide produce injury in sensitive plant species if the fumigation is extended over prolonged periods of time (Hindawi, 1968). Because of the known presence of sulfur sensitive plants near Colstrip, the atmospheric concentration of sulfur will be very critical in this area.

The sulfur content of an individual plant is a poor indicator of plant damage or of environmental sulfur contamination since plant sulfur is quite variable. Vegetative sulfur concentration depends upon the species of plant analyzed and environmental conditions during the growth of the plant in addition to the rate and length of sulfur fumigation. In some instances, sulfur concentrations may be higher in healthy plants than in sulfur damaged ones and sulfur injury, if any occurs, can only be interpreted by visual inspection. Plant damage should be reflected, however, in the average sulfur content of a plant species.

Sulfur contents of vegetation established prior to power plant operation and compared to sulfur levels in the same plant species after operation of the generators will yield valid judgments as to the extent of sulfur fumigation during operation of the generating complex.

Oxides of Nitrogen:

These oxidizing substances are quite damaging to various plant species. Nitrogen dioxide is especially damaging to plants during periods of cloudy skies and high humidity. Some plant damage may occur in early summer at Colstrip if the oxides of nitrogen are released in sufficient quantity during this period of rapid plant growth. The function of nitrogen oxides in the formation of smogs was discussed under the emission of hydrocarbons in the previous section of this proposal.

Because of the wide variation in plant nitrogen concentrations no analytical technique has been developed that will allow interpretation of nitrogen contents of vegetation as an indicator of plant damage. Diagnostic study of affected vegetation

Exhibit 4

can reveal nitrogen oxide damage to vegetation only after it occurs.

At the present time sulfur dioxide and nitrogen dioxide damage are very difficult to describe analytically. To develop a picture of atmospheric concentrations of these two gases, a monitoring of existing air quality is strongly recommended. Data avilable from the sampling sites established by the Montana Power Company to monitor air quality and a diagnostic survey of vegetation should reveal the extent of sulfur and nitrogen oxide damages.

Fluoride:

Reports of the toxicity of this element to cattle are usually associated with aluminum reduction works or phosphate fertilizer plants because of the massive release of fluorides from these operations. Fluoride levels in the coal to be utilized at Colstrip and the rate of coal utilization anticipated at this plant justify close examination of the accumulation of this element in plants and animals on the range near the power plant.

The main route of fluoride accumulation in plants will be by foliar absorption since plant roots absorb little fluoride from the soil. In addition to absorbed fluoride some particulate matter high in fluoride will be found on plant leaves. It is inevitable, therefore, that animals feeding in the area influenced by stack gases from the Colstrip power plant will accumulate fluoride in their tissues. However, the low fluoride level in the coal, the retention of fluoride in fly ash, and the removal of hydrogen fluoride gas by wet scrubbers should reduce fluoride emissions below critical levels and fluoride should not pose an environmental hazard under the present production schedule at Colstrip.

Fluorides accumulate in skeletal tissues of mammals and produce damage by altering the normal molecular structure of these tissues. This action in cattle has been extensively studied and the probability of toxic accumulation because of the Colstrip power plant is remote. Much less is known of the effect of this element on wildlife and this facet of the total fluoride picture will be investigated

Exhibit 4

along with the accumulation in cattle.

Ponderosa pine, the most common tree in this area, is especially sensitive to fluoride damage. If atmospheric fluoride concentrations exceed the limits tolerated by this pine, an early loss of needles can be predicted. A decrease in the vigor of these trees may result in increased insect damage, and die off of most of the trees in the fumigated area will likely follow within a few years.

Mercury:

The toxicity of mercury has been well documented and federal levels in meat have been established. If mercury emissions are high enough, the movement of small amounts of mercury through the food chain may cause liver or kidney levels in range cattle to exceed federal tolerance limits without visible damage to the animals. The resulting economic loss to the ranchers in the study area could be substantial.

Selenium:

Several species of the genera Astragulus and Stanleya are known to accumulate selenium from the soil in which they are growing. Western wheatgrass (Agropyron smithii) has also been identified as a selenium accumulator but at lower levels than the other species. These plants are found in the Colstrip area and western wheatgrass is one of the dominant grasses on parts of the range in this area. Cattle generally avoid selenium accumulators but will not ignore the more common palatable grasses on the range. Thus, high selenium levels in western wheatgrass could be quite damaging on this rangeland.

A selenium concentration in cattle feed as low as 4 ppm is considered by some authorities to be the minimum level in food at which this element may accumulate in animal tissues and ultimately produce the characteristic signs of selenium toxicity (Underwood, 1962). Low levels of selenium, if present in stack emissions, could contribute sufficient quantities of this element to the soils of the area and permit range plants to approach this minimum critical selenium level.

Exhibit 4

Cadmium & Lead

These two elements are accumulative poisons similar to mercury. While neither of these is absorbed by terrestrial plants from the soil in appreciable quantities, foliar absorption and contamination does take place. If low level emissions of either of these elements from the power plant occur, food chain transfer and accumulation will take place and concentrations within the liver or kidneys of range animals will be elevated.

Unlike mercury, federal tolerance levels for cadmium and lead have not been established for foods destined for human consumption. The Environmental Protection Agency is presently considering such levels and long term accumulation in range cattle may pose economic problems for ranchers attempting to market animals from areas contaminated by cadmium or lead.

Beryllium and Chromium:

These elements are relatively unknown in the field of trace metal studies. Their extreme toxicity has been established and their carcinogenic properties substantiated by several investigators. Until the concentration of these two elements in the coal to be utilized at Colstrip has been determined and soil and plant levels analyzed, they should be viewed with caution. If emission of these elements occurs, the movement of the metals in the ecosystem will be carefully monitored.

Recommendations:

The present state of our knowledge of emissions from fossil fuel burning plants is fairly sophisticated. We can analyze the fuel or stack emissions for elemental composition and interpret meteorological data to determine fallout patterns. Unfortunately, our knowledge of the effect of many of these emissions on vegetation and animals or of synergistic effects of combinations of two or more of these emissions is very limited. In view of these facts it is recommended that selenium, cadmium, lead, beryllium, and chromium concentrations in soils, forage and cultivated

Exhibit 4

vegetation and animal tissues be established before the generating plant becomes operational in 1975. Monitoring of these elements after this date will reveal changes in the concentration of these metals in the appropriate compartment. If significant changes in the elemental composition of any trophic level occur, potential damage to the range resource will be implied. Trophic level concentration changes will preceed visible signs of range deterioration by one to several years and corrective action may be implemented before substantial damage to the range resource has taken place.

Plant damage due to sulfur or nitrogen dioxide in the atmosphere has been established but their influence on animals is still the subject of much research and debate. Since there are no present techniques to evaluate plant damage by these emissions other than by visual inspection of damaged vegetation, an air monitoring program for total sulfur and oxides of nitrogen is appropriate. Constant monitoring of atmospheric sulfur and nitrogen oxides will indicate if these atmospheric levels approach minimum toxic limits for the sensitive plants in the area. Furthermore, sulfur levels in dominant vegetation will be established prior to plant operation and monitored after power production has begun. Sulfur accumulation in the dominant species will be established by this procedure and the extent of sulfur dioxide fumigation after 1975 assessed.

Fluoride levels in vegetation and animals should be determined before 1975 and monitored after full plant operation. Cattle, deer, and antelope are found on the ranges near Colstrip throughout the year and will be subjected to increased fluoride uptake if substantial quantities are emitted by the powerplant. Elevated fluoride levels on vegetation of the area could be quite harmful to animals spending their entire life span on these ranges.

Mercury should be monitored in terrestrial animals and aquatic organixms. Although preliminary analyses of the coal to be burned indicate "normal" mercury levels

Exhibit 4

at least one published report has indicated elevated mercury levels in coal from Rosebud County. Until mercury concentrations in indicator organisms have been established before and after plant operation, this toxic substance must be viewed with caution.

Exhibit 4

Exhibit 4

WILDLIFE AND ECOLOGICAL REPORT

Exhibit 4

Exhibit 4

The following is from a preliminary wildlife and ecological report prepared by the Ecological Consulting Service of Helena for the Western Energy Company and Stearns-Roger Corporation.

The survey covers an area 10 by 20 miles, which the consultants believe is the area possibly affected by emissions from the proposed generating plant. Along with the wildlife study, the consulting service will analyze the downstream effects of removing the estimated 8,000 gallons per minute cooling water from the Yellowstone Riber. The effects on fish, irrigation, municipal and recreational uses will be studied.

I. DESCRIPTION OF STUDY AREAS

A. Location and History

The five areas of study are adjacent to Colstrip, Montana. They include A & B, Old Spoils, Experimental and Control areas. Colstrip has an approximate population of 266 persons most of whom have some connection with mining or construction activity in the immediate area. There has been periodic strip mining for coal in the vicinity for more than 50 years.

The study areas were investigated for wildlife species and vegetative communities which support them. Historically, the general Colstrip area has supported a large wildlife population and was used by Indians. With settlement, the area was used for raising livestock with the valley bottoms and other suitable areas cultivated for agricultural use. A comparison of the writings of early explorers and inhabitants of the area reveal an alteration of its vegetative complexes through a century of heavy grazing and other agricultural practices.

However, livestock and agricultural use has co-existed with an abundance of native wildlife and a few exotic species of introduced wildlife. Just prior to the 1900's, wildlife was at a low ebb throughout Montana but good conservation practices and improved range management allowed most wildlife species to build until, in the mid-fifties, deer population reached a peak statewide. By the late sixties, deer and

Exhibit 4

antelope populations and other wildlife species became stabilized with better harvest methods and hunting seasons more closely geared to available winter range.* Today, eastern Montana is one of the better wildlife areas of Montana. Areas A and B amount to approximately 6/10ths of one percent of Deer and Antelope Hunting District 72 in which they are located.

B. Physical Description and Vegetative Communities

1. Area A

2. Area B

These are the two areas proposed for strip mining of coal. They lie adjacent to each other immediately west of Colstrip with State Highway No. 315 as their common eastern boundary. Each area is approximately 3 miles east-west and 1½ to 2½ miles north-south. Each area contains approximately 5½ square miles with a collective total of about 11 square miles, and mining will be done only where the overburden is less than 150' deep.

Area A is bounded on the north and Area B is bounded on the south by higher elevation east-west ridges with Ponderosa Pine-type forests of varying density. The ridges slope to a rolling-type terrain on the valley bottoms, which consist of grassland types where the major portion is under agricultural cultivation. Lands cultivated for wheat and alfalfa in Areas A and B amount to slightly less than 1 square mile.**

An intermittent stream, the East Fork of Armell's Creek, drains the major part of both Areas A and B and serves as the arbitrary east-west dividing line between Area A and B. The East Fork joins the main stream of Armell's Creek at Colstrip. Armell's Creek flows past Colstrip in a northerly direction approximately 35 miles to the Yellowstone River.

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*Montana Fish and Game Department Environmental Statement, "Annual Statewide Harvest of Big Game Animals", Project no. FG-22, July 24, 1972.

**Calculated from Montana Power Company map

Exhibit 4

Two major vegetative zones occur on both Area A and B: Ponderosa Pine and Sagebrush-Grassland. The Ponderosa Pine Zone occupies the northern part of Area A and the southern part of Area B. The elevations of the Ponderosa Pine Zone run from about 3,400 feet to about 3,600 plus feet. The Sagebrush-Grassland Zone occupies the remainder of both areas from an elevation of about 3,300 feet to 3,400 feet. In the total of Areas A and B there are approximately 5 square miles in the Ponderosa Zone and 6 square miles in the Sagebrush-Grassland Zone. The two zones are not clearly defined in all areas and a gradation from one to the other is common. The widest variety of plant species and associated wildlife occurs within the ecotone between Zones.

3. The Old Spoils Area

This area is east and south of Colstrip where spoil banks and piles date from 1921 to the present. The old spoils ridges are characterized by steep slopes and sharp tops. Some faces of the old spoils are nearly barren of vegetation and others are heavily vegetated by volunteer species in complex and radically differing communities and are used by a variety of larger wildlife. Wildlife species in the area were studied to comment on the value of the old spoils to wildlife.

4. Experimental Area

Reclamation experiments are being conducted in various places among the spoils area by Dick Hodder et al.* Experimental areas have been shaped to gentler slope and terrain configuration and carry a variety of planted and volunteer types of vegetation and receive some wildlife use. However, since the areas have only been established for 4 years, it is too early to determine the potential degree of wildlife use which can be expected as vegetation becomes more fully established. The area was studied for some comparison of wildlife use on the untouched spoils areas and "reclaimed" areas.

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*Coal Mine Land Reclamation Research (Reports from 1968 through 1972.)

Exhibit 4

5. Control Area

A control area was established on the Don Bailey Ranch approximately 12 miles south of Colstrip. It was chosen as a place similar to Areas A and B and which was unlikely to be disturbed by major land use changes in the near future. Studies were made on comparable vegetative zones for comparison with Areas A and B and the Spoils Area.

C. Additional Data

1. Climate and Weather

The average annual precipiation in the Colstrip area is about 15 inches, with the number of frost-free days varying from 115 to 120 days. The weather is characterized by sudden and extreme changes with blizzards, hail, high winds, snow and drought being part of the "average". Summers can be extremely hot and winters very cold and severe. Temperatures may vary from 100° F. to minus 40° F. From spring 1972, to date, precipitation has been above average with a periodicity that has produced exceptional plant growth.

II. WILDLIFE

A. Game Birds*

1. Observed or identified:

a. Sharptailed Grouse . . Pedioecetes phasianellus . . . (all)

b. Ring-necked Pheasant . Phasianus colchicus. . . . . (7)

c. Sage Grouse. . . . . Centrocercus urophasianus . . (3)

2. Known to use the area, but not observed:

a. Mallard. . . . . Anas platyrhynchos . . . . . (8)

b. Greenwinged Teal . . . Anas carolinensis . . . . . (8)

c. Bluewinged Teal . . . Anas discors . . . . . (8)

d. Hungarian Partridge . Perdix perdix . . . . . (7)

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*As defined by Montana law.

Exhibit 4

B. Non-game birds

1. Observed or identified:

a. Sp. Sandpiper. . . . . Actitis macularia. . . . . (8)

b. Mourning Dove . . . . . Zenaidura macroura . . . . .(all)

c. Great Horned Owl . . . . . Bubo virginianus . . . . . .(all)

d. Cooper's Hawk . . . . . Accipiter cooperii . . . . .(6,9)

e. Short-eared Owl . . . . . Asio flammeus . . . . . .(all)

f. Red-tailed Hawk . . . . . Buteo jamaicensis . . . . .(all)

g. C. Nighthawk . . . . . Chordeiles minor . . . . . .(all)

h. Marsh Hawk . . . . . Circus cyaneus . . . . . .(4,5,7)

i. Red-shafted Flicker . . . . Colaptes cafer . . . . . .(6,7,9)

j. Pigeon Hawk . . . . . Falco columbarius . . . . .(all)

k. Hairy woodpecker . . . . . Dendrocopos villosus . . . .(6,9)

l. Sparrow Hawk . . . . . Falco sparverius . . . . . .(all)

m. E. Kingbird . . . . . Tyrannus tyrannus. . . . . .(all)

n. Killdeer . . . . . Charadrius vociferus . . . . (7)

o. W. Kingbird . . . . . Tyrannus verticalis . . . . (7)

p. Say's Phoebe . . . . . Sayornis saya . . . . . .(6,7,9)

q. Horned Lark. . . . . Eremophila alpestris . . . .(4.7)

r. Bank Swallow . . . . . Riparia riparia . . . . . (2)

s. Barn Swallow . . . . . Hirundo rustica. . . . . (4,7)

t. Cliff Swallow . . . . . Petrochelidon pyrrhonota . . (all)

u. B-b Magpie . . . . . Pica pica . . . . . (all)

v. Pinon Jay . . . . . Gymnorhinus cyanocephala . . (all)

w. B-c Chickadee . . . . . Parus atricapillus septentrionalis . . (6,7,9)

x. Brown Thraser . . . . . Toxostoma rufum . . . . . (7)

y. Robin . . . . . Turdus migratorius . . . . . (all)

z. M. Bluebird . . . . . Sialia currucoides . . . . . (6,7,9)

Exhibit 4

aa. Loggerhead Shrike . . . . . Lanius ludovicianus . . . . . (4,7)

bb. Starling . . . . . Sturnus vulgaris . . . . . (4,7)

cc. W. Meadowlark . . . . . Sturnella neglecta . . . . . (4,7)

dd. Redwinged Blackbird . . . . . Agelaius phoeniceus . . . . . (4,7)

ee. Brewer's Blackbird . . . . . Euphagus cynocephalus . . . . (4,7)

ff. B-h Cowbird . . . . . Molothrus ater ater . . . . . (4,7)

ff. Lark Bunting . . . . . Calamospiza melanocorys . . . (6.9)

gg. Vesper Sparrow . . . . . Pooecetes gramineus . . . . . (6,9)

hh. Lark Sparrow . . . . . Chondestes grammacus strigatus . . (6,9)

ii. Brewer's Sparrow . . . . . Spizella breweri breweri . . . (3)

jj. White-crowned Sparrow . . . . . Zonotrichia leucophrys . . . . (6,9)

kk. Song Sparrow . . . . . Melospiza melodia . . . . . (6)

ll. Rocky Mountain Nuthatch . . . . Sitta carolinensis nelsonii . (4)

2. Known to be in the area, but not observed:

a. Swainson's Hawk . . . . . Buteo swainsoni . . . . . (all)

b. Ferruginous Hawk . . . . . Buteo regalis . . . . . (all)

c. Golden Eagle . . . . . Aquila chrysaetos canadensis . (all)

d. Prairie Falcon . . . . . Falco mexicanus . . . . . (2,4,5,7)

e. G. Yellowlegs . . . . . Totanus melanoleucus . . . . . (8)

f. Rock Dove . . . . . Columbia livia . . . . . (5,7)

g. Y-b Sapsucker . . . . . Sphyrapicus varius . . . . . (6,9)

h. Downy Woodpecker . . . . . Dendrocopus pubescens subsp. . (6,9)

i. Tree Swallow . . . . . Iridoprocne bicolor . . . . . (7)

j. House Wren . . . . . Troglodytes aedon subsp . . . (7)

k. Catbird . . . . . Dumetella carolinensis . . . . (7)

l. E. Bluebird . . . . . Sailia sialis . . . . . (6,9)

m. W. Bluebird . . . . . Sailia mexicana . . . . . (6,9)

n. Cedar Waxwing . . . . . Bombycilla cedrorum . . . . . (6,9)

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o. Yellow Warbler . . . . . Dendroica petechia subsp . . . (7)

p. Yellowthroat . . . . . Geothlypis trichas subsp . . . (7)

q. Grasshopper Sp . . . . . Ammodramus savannarum . . . . (7)

r. McCown's Longspur . . . . . Rhynchophanes mccownii . . . . (7,9)

3. Rare and endangered species*

Rare and endangered species are defined as those birds which, according to the Committee on Rare and Endangered Wildlife Species of the Bureau of Sport Fisheries and Wildlife, are so few in numbers or are so threatened as to be in danger of extinction.

No endangered bird species was in evidence in either the study area or in the general vicinity. The Prairie Falcon, which is known to be in the area, is classified as a rare bird, but not an endangered species. In the opinion of a qualified ornithologist familiar with the area, Peregrine Falcons will not be found there.**

4. Birds of prey

Birds of prey were found throughout the entire area and also outside the perimeter of Areas A and B, with the exception of the Cooper's Hawk, which was seen only in the Ponderosa Pine Zone. The other raptors were seen over the entire general A and A areas.

5. Mammals -- Game Species***

a. Observed or identified:

1. Mule Deer . . . . . Odocoileus hemionus . . . . . (all)

2. Pronghorn Antelope . . . . . Antilocapra americana . . . . . (all)

6. Mammals -- Non-game Species

a. Observed or identified:

1. Predators:

a. Badger . . . . . Taxidea taxus . . . . . (all)

b. Raccoon . . . . . Procyon lotor . . . . . (all)

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*As defined by the Committee on Rare and Endangered Wildlife Species of the Burau of Sports Fisheries and Wildlife

**Kenneth Walceck, Montana Fish and Game Department

***As defined by Montana law

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c. Red Fox . . . . . Vulpes vulpes . . . . . (all)

d. Coyote . . . . . Canis latrans . . . . . (all)

e. Bobcat . . . . . Lynx rufus . . . . . (all)

2. Others:

a. Thirteen-lined Ground Squirrel . . . . Citellus tridecemlineatus . . (1,7,10,11)

b. Least Chipmunk . . . . . Eutamias minimus . . . . . (6,9)

c. Northern Pocket Gopher . Thomomys talpoides . . . . . (all)

d. Western Deer Mouse . . . Peromyscus maniculatus . . . . (all)

e. White-footed Mouse . . . Peromyscus leucopus . . . . . (6,9)

f. Porcupine . . . . . Erethizon dorsatum . . . . . (all)

g. Eastern Cottontail . . . Sylvilagus floidanus . . . . . (all)

h. White-tailed Jack Rabbit Lepus townsendii . . . . . (all)

i. Little Brown Bat . . . . . Myotis lucifugus . . . . . (4,6,7,9)

j. Striped Skunk . . . . . Mephitis mephitis . . . . . (all)

k. Mink* . . . . . Mustela vison . . . . . (4,7)

b. Known to be in the area, but not observed:

1. Predator:

a. Long-tailed Weasel . . . Mustela frenata . . . . . (6,9)

2. Others:

a. Richardson Ground Squirrel Citellus richardsonii . . . . . (1,7,10,11)

b. Ord Kangaroo Rat . . . . Dipodomys ordii . . . . . (2,6,9)

c. Northern Grasshopper Mouse-Onychomys leucogaster . . . . . (2,6,9)

d. Western Harvest Mouse . . Reithrodontomys megalotis . . . (7,Ag.)

e. Meadow Vole . . . . . Microtus pennsylvanicus . . . . (4,7,Ag.)

f. Meadow Jumping Mouse . . Zapus hudsonius . . . . . (4,7,Ag.)

7. Rare and endangered species

Rare and endangered species are defined as those animals which, according to the Committee on Rare and Endangered Wildlife Species of the Bureau of Sport Fisheries and

*Furbearer, according to Montana law.

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Wildlife, are so few in numbers or are so threatened by circumstances as to be in danger of extinction.

No endangered animals were in evidence in either the study area or in the general vicinity. The Black-footed Ferret, an endangered species, which is closely associated with Prairie Dog towns, could not be expected to be in the vicinity as no Prairie Dog towns were found in the area. However, there are Prairie Dog towns within 50 airline miles of Areas A and B. Wherever there are Prairie Dog towns, the possibility exists that the Black-footed Ferret is also present. This small predator lives in close association with Prairie Dogs and preys upon them. During 1971 and 1972, the Montana Fish and Game Department asked through its bi-monthly magazine for reports of any sightings of Black-footed Ferrets in Montana. Although several reports were sent to the magazine, to our knowledge at this time, there has not been a confirmed Black-footed Ferret sighting in southeastern Montana.

III. VEGETATION

A. Summary

Areas A and B and the Control Area contain very similar plant communities and very similar wildlife species and population densities. The Control Area was selected because it probably will not be disturbed for several years and can serve as a check for those areas which are mined and reclaimed. Portions of the Old Spoils Areas were chosen for study: One was representative of the old untouched spoil banks and the other was on Hodder's reclamation experimentation areas. Due to the extreme vertical and horizontal diversity of plant composition and the wide variance of plant invasion, no transects were established on the old spoils, but species present were investigated and listed.

B. Classifications

The vegetation within the study area was classified into two zones: (1) Ponderosa Pine and (2) Sagebrush-Grassland. The species composition of the vegetative zones and

Exhibit 4

types for which measurements were taken are given in Tables I. through VII. Locations of these vegetative transects are shown on the enclosed map. Plant types which were not quantitatively measured include the Rhus Sagebrush-Grassland type in the Ponderosa Pine Zone and the Agricultural type in both the Ponderosa Pine Zone and the Sagebrush-Grassland Zone. The Ponderosa Pine Zone was divided into seven vegetative types. These are:

1. Ponderosa Pine Type.
2. Ponderosa Pine-Juniper Type.
3. Big Sagebrush-Grassland Type.
4. Silver Sagebrush-Grassland Type.
5. Rhus Sagebrush-Grassland Type.
6. Caprock Gumbo-Knob Type.
7. Agricultural Type.*

The Rhus Sagebrush-Grassland Type was further divided into four sub-types, which are:

1. Rhus-Grassland.
2. Rhus-Big Sagebrush-Grassland.
3. Rhus-Silver Sagebrush-Grassland.
4. Grassland Park.

The Sagebrush-Grassland Zone was divided into five vegetative types. These are:

1. Big Sagebrush-Grassland Type.**
2. Grassland Type.
3. Silver Sagebrush-Grassland Type.
4. Creek Bottom Type.
5. Agricultural Type.

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*Not included in Tables.
**Permission to investigate this type denied by landowner.

Exhibit 4

Few of the vegetative types were clearly defined within the vegetative zone. There is considerable overlap among the various plant types. There are approximately 5 square miles in the Ponderosa Pine Zone and about 6 square miles in the Sagebrush-Grassland Zone within Areas A and B. The Agricultural Type represented about ½ square mile in each area.

IV. WILDLIFE HABITAT COMPARISONS

A. Game Animals

1. Areas A and B mirror each other as wildlife habitat. Five mule deer (2 does, 3 fawns) were observed using the Ponderosa Type on Area A. One doe had a slightly deformed ear and was sighted twice.

Seven mule deer (2 does, 2 fawns and 3 bucks) were observed using the Ponderosa Type on Area B. None of these deer had identifiable individual characteristics.

Checking the vegetational species present with the available literature concerning the overall area reveals an abundance of known deer foods as shown on Table I. The literature indicates that the Ponderosa Type is very important in the mule deer's overall requirements in country such Areas A and B.

Although Areas A and B are important to the deer using them, they represent only 6/10ths of 1 percent of Hunting District #72.

As deer winter range, the importance of any part of Areas A and B is unknown. Winter range is the limiting factor of deer populations. Establishment of observation routes and food habits studies during the fall-winter-spring period would define the importance of the area as winter habitat.

2. The Control Area is so similar to Areas A and B that one could expect similar deer usage and interviews with the landowner (Don Bailey) support this. Establishment of observation routes and food habits studies during the fall-winter-spring period would enable a relationship of deer population presence and usage between the Control Area and Areas A and B to be established.

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3. Areas A and B and the Control Area are only fair antelope habitat in comparison with the overall area. Two aerial and one ground sighting revealed a lone buck and a group of 3 does, 3 fawns, and 1 buck using the western edge of Areas A and B. Vegetation composition of the areas shows an abundance of known antelope foods.

4. The Experimental reclamation plots in the spoils did not reveal any significant deer use.

Tracks, sign and some observable use of known deer food plants showed the Old Spoils to be used by deer at some times of the year although no animals were observed. Our experience suggests the Old Spoils Area is useful to deer for food, cover and possibly winter range because of its configuration and vegetational content.

The usefulness of the Old Spoils to deer in winter would be regulated by snow depths. As long as the gulleys between the banks do not drift in too severely, food plants would be easier for them to reach there. Observation and plant use data during fall-winter-spring would be necessary to establish this fact. Interviews with local residents indicate the spoils are used by deer during the hunting season. Some hunters consider them favored hunting places. It would seem the deer find the juxtaposition of food and cover advantageous when pursued by hunters.

5. Fish

The East Fork of Armell's Creek does not support a sport or commercial fishery because the creek is intermittent in character. A few small ponds are found in northern Area A, but they have no fish in them. The nearest fishery, in the old box-cut at Colstrip, contains a variety of stocked warm-water fish and some stocked rainbow trout, according to local fishermen and the Montana Fish and Game Department.

V. COMMENTS ON WILDLIFE

A. Present Population

Presently there is a healthy wildlife population of both game and non-game species in Areas A and B. This population does not seem to have any unique features

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which make it exceptional in comparison with other areas of southeastern Montana with similar terrain and vegetation.

B. Displacement with Mining

If strip mining progresses at the rate of about 100 acres per year and reclamation follows within a three-year period, during any given year of the estimated 35-year period, 300 acres of Areas A and B (more or less) will not provide any important wildlife habitat. The larger, more mobile species will avoid the immediate mining area, but the rate of mining will be slow enough to prevent significant impact on their overall population. At 100 acres per year mining rate, about half the total acres within Areas A and B would be mined during the 35-year life of the mine.

C. Impact on Small Mammals

Small mammals will be the most susceptible to population disruptions, but normally they are the first classes of wildlife to return to a disturbed area as it re-vegetates. This class is the most numerous in the food chain and has the highest reproductive potential. They also have high annual and cyclic population fluctuations even when man's actions are not a factor.

D. Impact of Increased Local Population

The estimated existing population of Colstrip is 266 with a projected increase to 1,855.* The Montana Fish and Game Department estimates that one person in three buys some form of hunting or fishing license. Applying the 1:3 ratio to the present Colstrip population indicates that about 89 hunting/fishing licenses are sold to residents. When the population increases to 1,855, the number of licenses will grow to 618. This would have a major impact on the immediate Colstrip vicinity including Areas A and B.

If Areas A and B are reclaimed for heavy recreational use, the mere activity of people will make the larger wildlife forms more wary of the area, especially during the daylight hours and in the milder months. Also, if reclamation includes high use

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*Ken R. White Co. data.

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recreational development, hunting is seldom allowed in these areas. The impact of human population on the game species would also be felt outside Areas A and B.

An increase in people brings a corresponding increase of domestic pets and will create an abnormally high "predator" density in a small area. House cats and dogs in uncontrolled or semi-controlled conditions will have some affect on the wildlife in the immediate Colstrip vicinity.

E. Effect of Artificial Lake

A body of water of any size in the A and B Areas, where none presently exists, would draw waterfowl, especially during migration seasons. Depending upon the vegetative complexes established around the lake, some nesting of various waterfowl species could be expected if human intrusion is kept at a minimum during nesting season. Only an occasional pond now exists in northern portions of Area A and no significant natural bodies of water exist in the Colstrip vicinity. The popularity of the artificial mini-lake created by the seepage filling an old box-cut at Colstrip demonstrates that a more amenable body of water would receive high use from people living in the area.

F. Consideration of Small Mammals, Raptors and Predators

Preliminary findings on the Old Spoil Area and the Experimental Area show no signs of burrowing animals establishing themselves there. To some types of burrowing animals, such as pocket gophers, soil types are almost as important as vegetation types. If the habitat conditions of the reclaimed land on Areas A and B do not provide the needs for burrowing animals, the food chains utilized by predators and raptors will be affected. The absence of these burrowing animals on reclaimed areas will reduce the food supply for them and one would not see as many of them utilizing this reclaimed area. However, raptors have great mobility and the size of the area is small enough that they will fly past or over the area.

In a predominantly high-use recreational area, small birds and small mammals are susceptible to destruction due to the thoughtlessness and carelessness of people.

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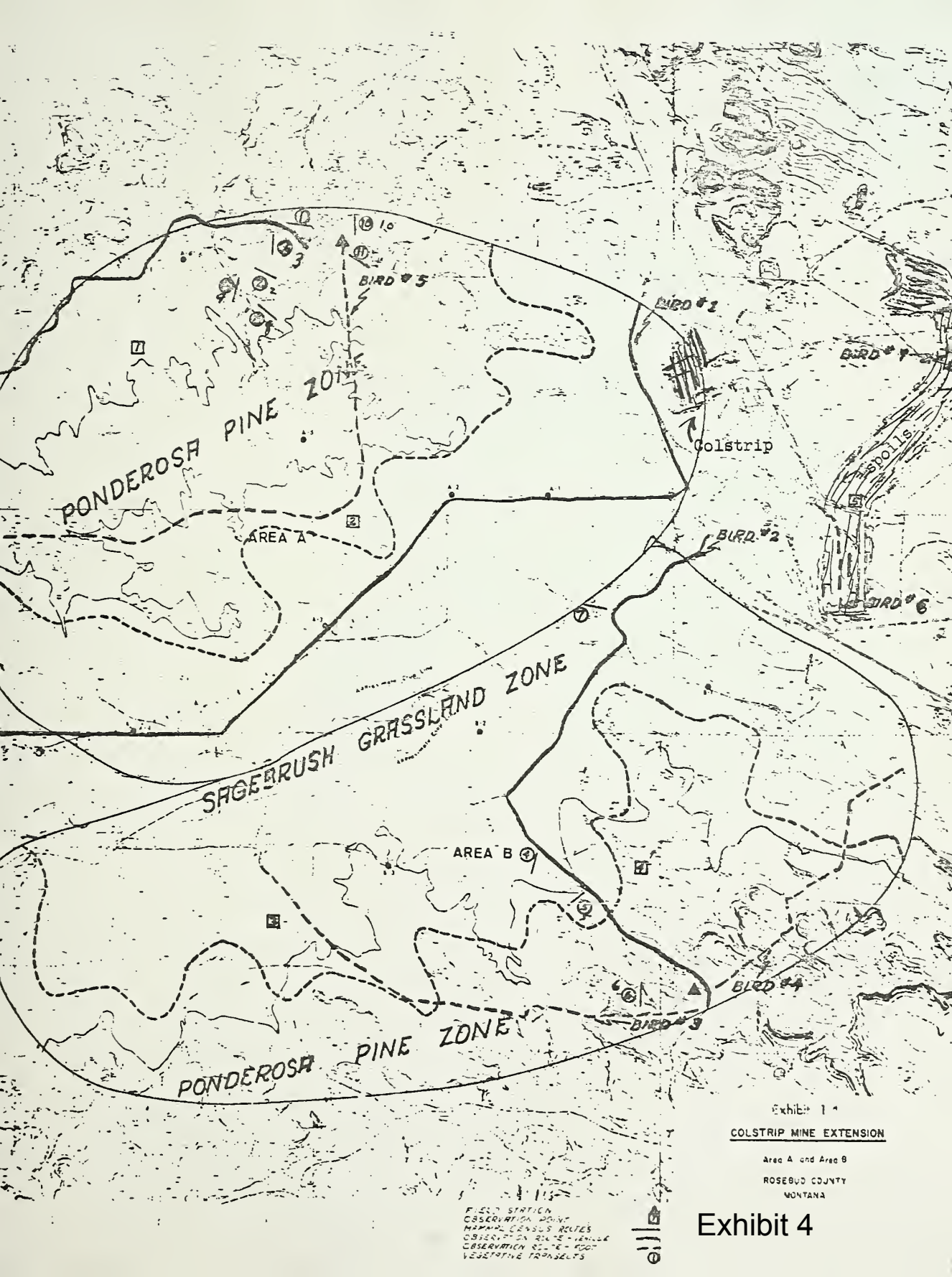
PONDEROSA PINE ZONE
AREA A
SAGEBRUSH GRASSLAND ZONE
AREA B
PONDEROSA PINE ZONE
BIRD #1
BIRD #2
BIRD #3
BIRD #4
BIRD #5
BIRD #6
Colstrip
spoils
Exhibit 1
COLSTRIP MINE EXTENSION
Area A and Area B
ROSEBUD COUNTY
MONTANA
FIELD STATION
OBSERVATION POINT
MAMMAL CENSUS ROUTES
OBSERVATION ROUTE - VEHICLE
OBSERVATION ROUTE - FOOT
VEGETATIVE TRANSECTS

Exhibit 4

Exhibit 4

AGENCY AND PUBLIC COMMENTS

Exhibit 4

Exhibit 4

Because of space requirements, it was necessary to condense some letters commenting on the Draft Statement, as follows:

Name	Main Points Raised
Richard A. Wortman Consulting Geologist Bozeman, Montana	Stated efficiency of scrubbers doubtful. Other plants at Fruitland, New Mexico, Casper, Wyoming, and Kemmerer, Wyoming, have much lower scrubber efficiency than promised by operators.
Montana Chapter American Assoc. of University Women (unsigned)	Too many unknown facts about long term effects. Statement should contain definite information on pipeline size. No permit should be granted until the possibility of using dry towers is assessed. More documentation needed on particulate removal. Impact on schools not assessed. Energy conservation might eliminate need for plant, saving money to use in developing more efficient generating techniques.
Ron Schleyer Billings, Montana	Insufficient cause seen for violating "non-degradation" clause in Air Quality Implementation Plan. Biocides in cooling towers might cause impact on biota. Dry towers could be used.
Margaret Busha Sweet Grass County Treasurer Big Timber, Montana	Stop the plant; save Montana for Montanans.
American Association of University Women Edith Gronhoud Jean M. Evans Billings, Montana	A moratorium should be placed on this and similar developments until legislation is passed to adequately safeguard the environment and guarantee complete land reclamation and until other alternatives to construction of the plant are thoroughly studied.
Vincent Amicucci, M.D. Vice President, Audubon Society Helena, Montana	Industry must take care to safeguard the environment. Construction of additional plants could threaten minimal flows in the Yellowstone River. Site approval by the State should be required.
Mrs. William F. McKinney Birney, Montana	Draft statement contained insufficient data on fluorides and mercury. Dust from strip mining will cause health hazard. Large scale water evaporation could cause weather alterations. EPA or the state should monitor plant emissions, rather than the plant owner. What effect will ash have on groundwater? Future generations will be sorry if plants are built.
Mavis McKelvey Montana League of Conservation Voters Missoula, Montana	Non-degradation clause in the National Environmental Policy Act should be upheld. Burning coal at 30% efficiency not economical. Increased tax base caused by industrial development more than eaten up by needed services. Employment will not continue indefinitely. Ghost towns in Montana demonstrate futility of expecting long term

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	returns from mining. Additive factor of emissions may occur between emissions from Colstrip and Billings. Much power wasted. New York City uses 65% of its power in lighting, including empty office buildings. Montana should call a halt to further despoilation.
American Association of University Women Elizabeth Miller, Chairman Bozeman, Montana	Statement does not provide clear evidence that the known facts outweight the known facts enough to justify issuance of permit. No more than one plant should be permitted until the first one has been evaluated to answer pertinent questions. Plant was under construction two years before respondent was asked to comment. Additive effects between Billings, Colstrip plants will occur. Computer modeling inadequate since it was not based on established fact. Trace element analysis needed. Scrubber efficiency on mercury vapor needs to be known. More information needed on emission of fluoride and radioactive materials. Weather modifications possible from humidity increase from cooling towers. Small changes in the ecosystem resulting from emissions should be carefully monitored, and when damage appears pollution should be abated. The alternatives portion should have listed alternatives and generating developments expected in the next 5, 10, or 20 years. Energy consumption should be moderated through changes in the price structure used by utilities. Coal consumption should be slowed and continued at a low rate over a long period, with boom bust cycle scaled down to a permanent economic asset for the area. Technological advances in coal conversion techniques and solar energy should be encouraged.
Carolyn and Irving Alderson Ranchers Birney, Montana	Federal non-degradation clause should be enforced Total effects of strip mining, water diversion from Yellowstone River, construction of transmission lines, all contribute to environmental degradation. The number of unknown factors cited in the statement are evidence that a permit should not be issued. The vast coal generating complex in the Southwest should have been analyzed for environmental impacts of the sort likely to result from the Colstrip project. Montana Power "arrogant" for beginning construction without a permit. Reclamation of strip mined land not proven for areas such as Colstrip. Strip mining might adversely affect groundwater. Considering the above, granting a permit would be irresponsible.
Montana Federation of Women's Clubs Mrs. William Graham Wyola, Montana	Sulfur dioxide and other emissions would have a serious detrimental effect on wildlife, livestock, and surface water.
Doris Milner Montana Wildlife Federation Hamilton, Montana	Water diversions, structures, aqueducts, pumping stations, transmission lines, and other facilities appurtenant to the generating stations have impacts that were only skimmed over in the draft statement. Cumulative impact

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	of the plant and related facilities should be assessed in the final statement. An independent assessment should be made of the need for the electricity to be generated. The extent of state control over generation facilities not clear in the draft statement. Public should be alerted to the minimal control available to the state over power plant construction.
Michael Williams, Ph.D. Los Alamos, New Mexico	The 90% collection efficiency of fluorides estimated in the draft supplement is too high. Other plants release as much as 97% of fluorides into the air. Predicted fluoride concentrations seem inaccurate. No statement about what conditions they are based on is included in the supplement. Higher values seem to be indicated. TVA experience indicates the maximum 24-hour average is about one-fourth the maximum one-hour average as opposed to one-seventh as stated in the supplement.
Mr. and Mrs. Art Hayes Birney, Montana	Pollution concentrations should be monitored at all times. If standards are violated, the plant should be shut down. Otherwise, the surrounding lands will be rendered unproductive. Instead of building mine-mouth plants, the coal should be shipped to the load centers, with a stiff tax. If the plant is built, dry cooling towers should be required.
Christine S. Jones Birney, Montana	Montana Power Company negligent in not investing in research on other types of generating equipment. Geothermal power is being developed seriously in Japan, Mexico and Russia. Fly ash buried in spoil banks will cause major pollution problems in the future. Temporary construction workers will have drastic social effect on the area. High fluorides in emissions are a serious health hazard to the nearby Northern Cheyenne Indians, who already have a high TB rate, along with other pulmonary and respiratory ailments. Gradual increase of radioactivity over the life of the plant will lead subtle ill effects in the ecosystem. Monitoring of emissions from the plant should be done by the state. Coal should be mined underground.
Robert R. & Joan Tully Ranchers Roundup, Montana	Mercury pollution could result from power plants. Air pollution effects from large generating plants are not known. Large size of the proposed plants indicates fluorides and sulfur dioxide could reach dangerous levels even if within standards. How many dangerous air pollution events will be allowed under the law? How much water can be taken from the Yellowstone River without causing ill effects downstream? Reclamation is impossible in arid regions such as Colstrip. Why was construction allowed before a permit was issued? If there is no check on power plant construction, how can it be assured that future plants will not be under construction before emission effects from the proposed plant are assessed adequately?

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Because of space requirements, it was necessary to condense some comments that were submitted for the record during and after the public hearing in Miles City, January 5, 1973, as follows.

Name	Main Points Raised
Berkeley and Cynthia Dowd Fishtail, Montana	Draft Statement written in a cursory manner, violating the intent of the Montana Environmental Policy Act. Most information in the draft was supplied by the Montana Power Company and not critically reviewed by the state. No permit should be issued until the Montana Power Company has proved no environmental degradation would result from the plant construction and operation.
Frank Dunkle Ecological Consulting Service Helena, Montana	The Montana Power and Western Energy Policy of "determining accurately what the present ecosystem of the Colstrip area really is today, is fundamental to answering accurately what effects mining and power generation may have on Colstrip and Montana. Sound information is the only realistic basis for comparing short and long range values of natural resources."
Byron J. Bennett, Ph.D. Dean of Engineering Montana State University Bozeman, Montana	Energy shortage is developing. No alternative to planning well for the continued use of coal reserves for at least 20 years. Well financed and organized research needed on alternate types of generation. Gas turbine research should be speeded. Research efforts on alternate generating techniques have "been surface efforts compared to what is needed." The finest air pollution equipment is planned for the Colstrip plant. It would be terrible if we were forced to exist with none of the gas or electric services now provided by Montana Power. Electricity indirectly required for auxiliary fans and pumps in most heating systems. Electricity needed to solve environmental problems.
The League of Women Voters of Montana Grace Edwards Billings, Montana	Analysis of coal needed, especially to determine mercury and fluoride content. Acid rain and fog likely to occur from mixing of plumes of stacks and cooling towers. More information needed on meteorology of the area, and of possible weather modification resulting from the plant, before construction is allowed. The discussion in the draft statement concerning the influx of population is inadequate. What plans exist to handle the influx? What will happen to the area population after the plants no longer function? Montana Power Company should live up to its claim of being a good citizen by working openly and cooperatively with state government and smaller political subdivisions.
Steven Jessen, Editor Forsyth Independent Forsyth, Montana	Economic impact of the plant is already felt in a more stable economy, a widened tax base, and increased prosperity in the area and elsewhere in Montana. The taxed collected by Rosebud County will double by 1976. The best interest of the people of Rosebud County and Montana are being served by developing the coal.

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Jerry Landa Broadus, Montana	The population of the sparsely people areas are in no way obligated to sacrifice their health, their property, and their way of life for the big population centers elsewhere, as would be accomplished by the operation of power plants. Coal deposits should be kept for future emergencies. The permit to construct should be denied.
Bill Zumpf, President Miles City Chamber of Commerce Miles City, Montana	The Chamber welcomes new business, new industry and the development of all resources. Total membership of the Chamber not agreed about coal development. The Chamber endorses construction of the plants, within the limits of existing law.
Nick Golder, Rancher Colstrip, Montana	Agriculture is the backbone of Montana's economy, and will remain so if allowed to by the coal developments. Power shortage may be manipulated by big money and big government. Fluoridated water can be dangerous. Fluoride emissions need further study.
Albert Bud White	Coal development provides God-given opportunity for people to work. Jobs are needed. The state can best serve the majority of the people by providing environmental ground rules that will permit the development of natural resources in an orderly manner, without interruptions and the resulting loss of jobs. Should not build a fence around Montana.
Montana Chamber of Commerce	Adequate electrical power is an integral factor in the continued economic growth of any region. The Colstrip plant will meet or exceed existing regulations for ecological protection. The Board should grant the permit. Population in Rosebud County decreasing in numbers, increasing in average age, indicating unattractive total human environment.
R. D. Shipley Beacon Carter Service Miles City, Montana	What we do on our own private deeded land is our own business entirely. Environmentalists should be limited to regulating land they own. Coal is needed to combat the energy shortage. Reclamation is possible if strictly regulated. Grazing will be almost restored and the difference in the kinds of plant life will result in improved game habitat and, therefore, in hunting of a different but highly acceptable kind.
Robert J. Shy Custer County Rancher	Individuals and corporations have the right to do what they want with privately owned land. The Colstrip plant should be permitted, provided reasonable control is used and the surface lands are replaced or reshaped to the best possible use. Coal should be mined the same as any other resource.
Chuck Searl Executive Vice President, Billings Chamber of Commerce Billings, Montana	Plants at Colstrip should be completed, if they can meet existing and future air pollution standards. Power plant operation should not be allowed if it detracts from the life giving forces of the Yellowstone. The Chamber currently favors only the two 350 MW plants now under construction. Montana will need the electricity by the time the plants are completed.

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Harry Swain Swain and Morris Construction Company	Existing businesses need more electricity. Farms need more electricity. Oil fields need more electricity. Living standards should not be lowered by trying to conserve electricity by not using air conditioners, radios, televisions, and other appliances that some call luxury items.
Chris Angle	More local industry, power, and employment needed to give stability to the state economy. 87% of students graduated from state colleges leave the state to get work.
Thomas B. Breen, President Empire Steel Manufacturing	The energy crisis is real, and Empire Steel, along with the rest of modern society, needs a reliable source of electrical energy. The Colstrip plant should be built.
John L. Hansen, President Cop Construction Company Billings, Montana	Construction of the Colstrip plant is necessary; the pollution control equipment will keep emissions within standards; and delays in construction will be detrimental to Montana. The next decade will bring the need for 500 more megawatts than now available. Montana Power Company peak loads exceeded their capacity in December, 1972, requiring import of power. If outside power was not available for purchase, industrial power would have been interrupted, causing economic loss. A power shortage impends, and coal-fired thermal plants are the only apparent remedy.
Roy E. Huffman, Ph.D. Vice-President for Research Montana State University Bozeman, Montana	The University does not conduct secret research. Data collected in research at Colstrip is available to state agencies and others with a need to know. When fully interpreted, research results will be available in published reports. MSU is working on meteorological studies for Montana Power Company. Montana Power Company personnel have displayed a sincere interest in determining the air pollution potential at Colstrip, so as to be able to meet state and federal air pollution standards. MSU has worked on reclamation at Colstrip for Western Energy since 1968. Other studies in progress for Montana Power Company include work on the effects of stack emissions, trace element analysis of coal. The sponsors of the research have made no attempt to influence the results of the studies, and they have been fully cooperative.
Robert A. Ratliff, Manager Billings Refinery, CONOCO Billings, Montana	Coal production should be doubled in the next 15 years to meet the energy crisis. Crude oil imports will have to quadruple. Montana must be concerned about the energy crisis. Billings refinery has experienced 17% compounded annual increase in electrical energy use. More energy yet will be needed, and a reliable source is a must.
James R. Beaty	Should be no urgency in marketing coal, as the energy crisis will cause a continued market. No need to increase Montana pollution to supply energy for out of state. No reclamation effort can be evaluated for at least ten years after all reclamation efforts have ended and the land subjected

Exhibit 4

to the forces of nature. If coal were hauled by rail to plants near the load centers, Montana would benefit from a stronger rail system. High voltage power lines will not move grain, lumber or other goods into or out of Montana. Strip mining should be permitted on a limited scale for ten years, to be followed by evaluation of the effects on land and water. Shipment of coal should be encouraged over mine mouth plants. No major generating plants except hydroelectric should be allowed unless 50% of the output will be used in Montana or adjacent states contributing directly and strongly to the Montana economy.

I. D. Peterson
Midland National Bank
Billings, Montana

Energy crisis is real; generating facilities must be developed to avoid dependence on outside energy sources. Economic and industrial development would stop without required energy. Tax base needed to supply the monetary needs of government. Colstrip plants should be built.

Louise Cross, Delegate
Montana Constitutional Convention
Glendive, Montana

Coal development occurring so fast that Montanans do not realize the environmental effects taking place. Much water will be used, the remainder polluted; productive land will be destroyed, and the air will be contaminated. Land is the only capital in Montana, and sustains Montanans when all else fails. Montana Power Company is building the plant without a permit, and will use the costs as an excuse to allow the operation of the plant. No public official will have the guts to shut down the plant no matter what it does to land, water, and air. Circumvention of the building permit sets a dangerous precedent for other companies. Power companies want to strip the land, ruin the water, take the coal, transport the power, and make the profits.

Exhibit 4

ITEM
#5

STATEMENT

on the

"Draft Environmental Impact Statement on the Proposed Montana Power Company Electrical Generating Plant at Colstrip, Montana"

by

The Montana Power Company

Presented at

Miles City, Montana

January 5, 1973

Exhibit 4

Exhibit 4

STATEMENT OF

THE MONTANA POWER COMPANY

The Montana Power Company and Puget Sound Power & Light Company on the 14th day of August 1972, filed a joint application, pursuant to the provisions of the Clean Air Act of Montana and the Regulations issued under that Act, to the Air Quality Bureau of the Department of Health and Environmental Sciences for a permit to construct and install equipment and machinery which are capable of emitting air contaminants into the atmosphere and for the construction and installation of equipment for eliminating, reducing and controlling the emission of such air contaminants.

The construction and installation of such equipment and machinery is in connection with two 350 megawatt steam electric generating plants to be constructed by the joint applicants at Colstrip, Montana.

Pursuant to the Montana Environmental Policy Act the Department of Health and Environmental Sciences has issued a draft environmental impact statement directed to the application to construct and install such equipment and machinery. This hearing is directed to the consideration of that draft impact statement.

This statement is made in the belief that The Montana Power Company can and should make constructive comments at this hearing. This statement refers only to the first draft of the Air Quality Bureau's Draft Environmental Impact Statement and if we have additional comments on the supplement to that draft, we

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will submit them in writing before the record is closed.

Our comments are intended to supplement the material in the Draft Impact Statement. We ask that they include our remarks in the final environmental impact statement. We feel this would be appropriate since we are the applicant for the Construction Permit.

NEED FOR POWER

The projected electric requirements for consumers in The Montana Power Company's service area show that if the Colstrip Project is not built the Company will fall short of meeting the needs of its consumers by about 20% by 1975. This means that not only will no new customers be connected but that some existing customers will be curtailed or cutoff.

Montana Power Company generation, together with purchased power, served the 1971-1972 winter peak load with 124,000 KW to spare. 144,000 KW of power purchased in 1971-1972 will not be available to Montana Power Company by the winter of 1975-1976 because the electric suppliers now selling us this power will need it for their own customers. An additional 27,000 KW of purchased power will be lost to Montana Power Company by the winter of 1976-1977.

The Montana Power Company load historically grows at approximately 5% per year. We see nothing which will substantially change this. If the Colstrip units are not constructed, Montana Power Company will be 174,000 KW deficient by the winter of 1975-1976. Montana Power Company will be deficient by 246,000 KW by the winter of 1976-1977.

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DESIGN PROCEDURES PRIOR TO CONSTRUCTION PERMIT APPLICATION

There has been some confusion expressed in various public statements regarding the procedure used to design and build a project of this complexity; specifically, questions have been raised as to why we do not have all details of the project designed at the time of application for a construction permit.

In order to design an installation such as this, it is necessary to know all details about every item of equipment to be used, including such things as dimensions, weights, location of connections to other devices, electrical power and control requirements, steam and water flows, nature of materials of construction, etc. No manufacturer, whether he be a supplier of a small water pump or a large steam generator, can afford to provide reliable information of this type until he has actually received an order for his equipment. In order to buy an item of equipment, engineers must first specify the overall operating conditions and the general nature of the devices. With this kind of specification, bids are then invited on a competitive basis and analyzed. Afterward an order can be placed with a supplier and only then can the information necessary to design some other effected feature of the plant be obtained. In this situation, in order to design a power plant, the procedure is to specify and invite bids on the largest and most costly items that have the longest delivery and construction times. This procedure must begin at a point in time sufficiently ahead of the date at which the plant will be required. Steam generators and turbine-generators have lead times of four to five years. After this equipment has been ordered, the manufacturer can provide information that can be used to write specifications, invite bids and place orders for a

Exhibit 4

level of equipment that has somewhat less lengthy delivery and construction periods. After this level of equipment has been ordered, information from its suppliers is again used to specify the next level of equipment and so on. In the meantime, enough time may have elapsed that it is necessary to start building foundations for the first level of equipment and perhaps portions of the equipment itself, even though all components and features of the final plan have not yet been determined.

While this overlapping of construction and engineering activities may cause a small amount of uncertainty in some parts of the plans for some period of time, the procedure has one outstanding advantage. By not specifying and buying items of equipment until the point in time is reached when it is necessary, then any new developments in equipment designs can be incorporated in the bid specifications. In this way the latest available technology can always be incorporated into each system of the plant. If this had not been the case and we had had to specify our air quality equipment at the same time as the steam generator was specified, the newly emerging technology of wet scrubbers could not have been incorporated into the plant design because it had not been adequately demonstrated in early 1970 when the steam generator was ordered. Initial planning for this increment of generation began in 1968, making a total elapsed time from planning to finish of seven years.

Under these circumstances, it should be clear that many details of the design will not be known at the time that a construction permit must be applied for.

If a procedure were followed whereby all engineering, and there-

Exhibit 4

fore all equipment purchasing, was completed prior to the time that an application for a permit is submitted, then major investments would have to be made in engineering time and equipment orders that might not prove to be the most logical. Such a waste of resources is inconsistent with our responsibility to provide power to our customers at the lowest possible rate. Instead, in the case at hand, we followed the normal established procedure after discussing the schedule with State officials, and applied for our construction permit as soon as we had sufficient information about the air quality control equipment.

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ADEQUACY OF EQUIPMENT TO MEET EMISSION STANDARDS

The air quality control equipment we have proposed represents the latest technology in methods of collecting sulfur dioxide from flue gases. In fact, the emission limitation published in the Federal Standards of Performance for New Stationary Sources was predicated on the availability and use of wet scrubbing equipment. The federal government was required by law to publish standards that were consistent with adequately demonstrated technology. When the federal standard of 1.2 lbs of SO_2 per million Btu heat input was proposed on August 17, 1971, the EPA published a report entitled "Background Information for Proposed New Source Performance Standards". We are attaching Pages 8 and 9 of that report which state that flue gas cleaning for sulfur dioxide removal is an adequately demonstrated technology. When challenged in this regard, the EPA has stoutly defended the position that this technology is adequately demonstrated with more public statements, reports and correspondence than we can reasonably list. These federal emission standards are somewhat stricter than comparable State standards.

The ability of this kind of equipment to also meet the particulate removal requirements has been demonstrated on numerous nonutility applications, and more recently at the Dave Johnston power plant at Glen Rock, Wyoming.

Furthermore, our equipment specifications have very strong guarantee requirements that would expose the supplier to substantial financial loss if the proposed requirements are not met. Yet when we invited bids on this equipment, an adequate number of bidders accepted these guarantee requirements expressing the same confidence in their

Exhibit 4

ability to provide equipment to meet the standards as has been expressed by the EPA.

The performance level of this equipment will be maintained continuously because we will install all of the continuous monitoring devices listed in the EPA regulations. With the monitoring equipment in service, the Company can not have excursions of the standards that will go undetected.

Finally, should any element of the control equipment begin to show a mechanical malfunction, there will be no recourse to us other than reducing the load on the plant and repairing the equipment, because there will be no bypass installed by which flue gas can be passed around the control equipment. Maintenance can be performed with the plant in service because the scrubbing system will be modularized into three separate units that can be independently operated. With this arrangement, it will be possible to reduce the plant load and isolate and repair any troublesome portion of the system while continuing in service with the remaining modules performing at their normal level of efficiency.

Considering the foregoing, we are convinced that the equipment can perform initially and in continuous service with the specified efficiencies.

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SUFFICIENCY OF THE STANDARDS

Since the publication of the Draft Impact Statement there have been a number of public protestations that meeting the applicable standards should not be considered sufficient in spite of the statement on the adequacy of the standards on Page 12 of the Draft Statement. We would, therefore, like to adress ourselves to this subject.

First, we point out that for the most part performance will be substantially better than applicable emission or ambient standards.

The federal emission standards, which are slightly stricter than comparable State standards, are based by law on whatever degree of emission reduction can be adequately demonstrated.

Furthermore, both the federal and State agencies that published ambient standards designed them so that they are more than just barely good enough. To quote from the Montana Ambient Air Quality Standards, Regulation No. 90-015, "The air quality standards listed describe a level of air quality designed to protect people from the adverse effects of air pollution; and they are intended further to promote maximum comfort and enjoyment in use of property consistent with economic and social well-being of the community". Further, the federal government in publishing national primary and secondary ambient air quality standards pointed out that their primary air quality standards define levels of air quality which protect the public health with an adequate margin of safety. They defined their more stringent secondary ambient air quality standards as levels of air quality which protect the public welfare from any known or anticipated adverse effects of a pollutant.

The Colstrip Project will meet whatever standards are the strictest

Exhibit 4

Since these standards are the judgment of the responsible federal and Stage agencies, they should be the basis of judging the performance of the plant.

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DISPERSION CALCULATIONS

After equipment was specified to limit emission rates to levels at or below allowable standards, calculations were made to predict the contribution of the proposed plant to ambient air quality levels. The Draft Impact Statement says the State also made such calculations and gives their results. The principal reason for making these calculations is to select a stack height. On the basis of our dispersion calculations, a 500-foot height was selected.

Most of the results reported by the State are well under any applicable standards, and our own calculations are in agreement on this point. However, there are enough differences between the State's results and our own that we are attaching the report of our consultant, W. L. Faith, for your reference. Dr. Faith, a longtime air pollution control officer of the County of Los Angeles, is well qualified in the field of dispersion modeling. His experience and association with similar experts employed by TVA, the AEC and others, help him to employ good mathematical techniques and sound judgment, and we rely greatly on his calculations. Even though both sets of answers appear favorable when compared to the ambient standards, we hope that as soon as we are able to submit the final meteorological report being prepared by researchers at Montana State University, we can review the two sets of dispersion calculations to identify any differences in procedure and preclude any future misunderstandings.

There is a prediction in the Draft Impact Statement with which we strongly disagree. This is the set of values predicted for SO_2 concentrations under fumigation conditions for periods of ten minutes, one hour and three hours. We have already submitted our predictions

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for these conditions which are well under the applicable ambient standard, and we ask that our transmittal dated November 30, 1972, be considered a part of this statement. We understand that we are now in agreement with the State on the method of making calculations for these conditions. We recognize that some other set of meteorological conditions could be postulated that would give a different set of values than our own, but we are confident that any set of conditions that has actually been observed during the meteorological program would lead to a result that compares favorably with the applicable standard.

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TRACE ELEMENTS

While we would not disagree with the sentence in the Draft Statement that only a limited amount of knowledge about the trace element content of Colstrip coal is available, this situation is not abnormal. Coals throughout the country have not been examined extensively for trace element content for good reason, there has been no consensus on the part of the scientific community that trace element emissions from coal burning operations are likely to be harmful. The trace elements in coal are common in many other naturally occurring substances and are an essential ingredient in small quantities for many growing things. They change in nature from a necessity to a problem only when concentrations are unusually large. Consideration of emissions of these materials should not be made without also considering the final concentrations.

Mercury

The Draft Impact Statement states that values of mercury in the coal range from less than .006 ppm to 0.7 ppm for the Rosebud seam. Other analyses indicate an average nearer to 0.3 ppm, but this includes concentrations as high as 6.25 ppm which have been found in the pyrite in the coal. Coal pulverizers reject pyrites. During tests conducted by our Company, 19 samples of coal were taken at the discharge of our pulverizers using Colstrip coal and were analyzed by Truesdail Laboratories. The average content was 0.076 ppm when corrected to the as-received moisture content. Corresponding samples of ash discharged from the boiler at the same time were isokinetically taken and analyzed for mercury. These tests showed 97% of the mercury in the coal appears in the ash and can be removed by ash collection equipment. This would mean that less than .002 lbs/hr of mercury will

Exhibit 4

be emitted from the two units combined. Resulting ground level concentrations would be in the order of .0000003 $\mu g/m^3$.

The EPA has stated concentrations of 0.1 $\mu g/m^3$ is well below the level at which health or welfare effects have been observed. We are attaching the applicable reports, calculations and correspondence to support our conclusions.

Fluoride

The 19 samples referred to in the previous discussion were also analyzed for fluoride content. We have previously submitted the information that the average content was 4.2 ppm referred to the moisture content of the samples taken. We have been advised that subsequent tests on four samples have given higher values and that the values reported by different laboratories are not in agreement. We have no reason to disbelieve the results of the 19 samples we had analyzed. The importance of the information obtained from our tests is that the corresponding isokinetically taken ash samples showed at least 70% of the fluoride appearing in the coal also appeared in the ash and can be removed by ash collecting equipment. Any gaseous fluoride will be highly soluble and can be easily removed by the wet scrubber. These conclusions are consistent with references in the literature such as Pages 540 and 541 of Stern's "Air Pollution", Vol. III, where the use of alkali scrubbing systems is described for uranium ore and phosphate plants where uncontrolled fluoride emissions would be a problem. The importance of this is that when estimating emissions, full consideration should be given to the effects of collection equipment.

Due to the discrepancies in the previously reported fluoride tests,

Exhibit 4

we cooperated with your organization in taking additional samples under carefully controlled and standardized procedures. The samples were taken over the seven-day period from last December 16 to December 22. They were blended and split for analysis by the state and by our Company. Our portions are being analyzed by three different commercial laboratories, including Truesdail Laboratories. The results available to date are generally consistent between the various laboratories and average for the series about 22 ppm when corrected to the moisture content of the coal as received at the plant. We have attached all of the results available to this date and will submit a complete tabulation as soon as possible. We believe when you compare this tabulation with your own tests the results will be consistent.

Even if all the coal to be burned in the proposed plant had a fluoride content equal to the highest reported value, the fluoride emissions after considering the effect of the collection equipment would only be 8.3 lbs/hr based on particulate collection alone. At the average fluoride content, the emission would be 5.1 lbs/hr, and the resulting ground level concentration would only be .01 ppb compared to the ambient standard of 1.0 ppb or 1/100th of the State standard. Calculations showing this have been attached. If gaseous fluorides are also collected as can be expected, these numbers would be even lower.

Radioactivity

We have not tested for radioactive material in our coal and have no reason at this time to disagree with the values given by the State in the Draft Impact Statement.

We do, however, ask that recognition be given to the available

Exhibit 4

literature, such as Stern's "Air Pollution", Vol. I, Section 5, where it is reported that radioactive particles in coal burning operations associate themselves with the particulate matter, and therefore they can be removed by the collection equipment. By taking the values reported on Page 124, Line 3, for typical emissions and correcting those values for the radioactive content reported by the State and the degree of dust collection to be installed on the Colstrip Units, it can be concluded that radioactive emissions will be in the order of .047 grams per year of radium or equivalent. Our calculations showing this have been attached. For the Colstrip Project, the corresponding annual average ground level radioactivity would be in the order of 9 X 10^{-8} REM/yr. The AEC recognized limit of safe exposure is 0.5 REM/yr, or about five million times as much. The predicted amount for Colstrip could not be expected to cause a change in the naturally occurring radiation level of about .18 REM/yr. The exposure from the plants would be 500,000 times less than would be encountered in living in a wood-frame house in Montana.

Exhibit 4

DRY VS WET COOLING TOWERS

All processes which convert heat energy to mechanical energy must reject heat to their surroundings in accordance with the laws of thermodynamics. The use of flow-through cooling is not possible with current water quality regulations so power plants must use some sort of cooling device to discharge waste heat to the atmosphere. The most commonly used device for this purpose is the evaporative cooling tower which has been used on thousands of industrial installations including several in Montana.

Dry type cooling towers, rather than evaporative type, have been considered for use on the Colstrip Project. Dry type towers are being developed in this and in foreign countries for use where water is not available in even the relatively small quantities needed by evaporative towers. The controlling factor in dry tower design is the dry bulb temperature, which is usually considerably higher than the wet bulb temperature that evaporative towers depend on. This means that where dry towers are used, the plant must have a lower efficiency thereby causing more fuel to be used for the same amount of electric generation and more heat to be discharged to the atmosphere.

In addition, dry type towers can not transfer heat as efficiently as evaporative towers so that for the same job a dry tower is much larger than an evaporative tower.

In terms of the Colstrip Project, these differences could cause:

1. About 15% poorer plant efficiency.
2. About a 13% reduction in plant capacity.
3. About five times as much land required for cooling towers.
4. About six times as much cost for cooling towers.

Exhibit 4

In addition, the most significant factor is that there is no accumulated experience anywhere, either in this country or abroad, in the use of dry cooling towers on power plants approaching the size of the Colstrip plants. Extrapolating the limited experience available on small plants to the Colstrip Project would be highly speculative. Based on the above, dry towers should not be considered an available alternative at this time.

Exhibit 4

VISIBILITY EFFECTS

On Page 21, the Draft Impact Statement quotes paragraphs from the Department of Health, Education and Welfare publications discussing particulate and sulfur dioxide concentrations that coincide with certain visibility ranges. We would like to point out that for the lower visibilities to occur, the concentrations reported would have to be pervasive throughout an entire air basin such as the urban areas referred to. The conditions in these areas are caused by emissions from multiple sources. However, in the case of the Colstrip installation, which is a single point source, the estimated ground level concentrations are applicable only for single points in the area and would not at all be representative of the general air character. Therefore, the evidence cited to justify the conclusion that visibility might be reduced is not applicable to the Colstrip situation.

Exhibit 4

INDEX OF PAGES IN THE DRAFT STATEMENT AFFECTED
BY THE FOREGOING MATERIAL

Page	Item	Refer to MPCo. Comment
ii	Summary	All
3	Section 4, Paragraph 2	Introduction, Paragraph 2
10	Table 1	Diffusion Modeling & Trace Elements
11	Table 2 (Fluorides and Mercury)	Trace Elements
12	1st Paragraph, 1st Sentence	Dispersion Calculations
14	1st Paragraph & Table 4	Dispersion Calculations
16	Entire Page	Dispersion Calculations
18-19	Section 5	Trace Elements & Dispersion Calculations
21	Section 7	Visibility Effects
23	Section B	Adequacy of Equipment to Meet Emission Standards
29	2nd Paragraph, 5th Paragraph	Sufficiency of the Standards
34	Section B	Need for Power
37	Section VI	Introduction, Paragraph 2 and Need for Power

Exhibit 4

SUMMARY

To summarize this statement, the following points have been made:

1. The project must be constructed to avoid a shortage of electric power.
2. The design procedure for a complex project is such that many details of the design can not be known at the time that a Construction Permit must be applied for.
3. The proposed air quality control equipment is capable of performing at the specified levels initially and in continuous operation.
4. The information published by public agencies describes the air quality standards as being compatible with the promotion of economic and social well-being and adequate to protect people from known or anticipated adverse effects of pollutants. The Colstrip Project will meet such standards.
5. There are technical but not significant differences between our predictions of ambient air quality contributions and those of the State. The only one in which compliance with an ambient standard is affected is the set of values for SO_2 concentrations under fumigation conditions. Using the agreed upon techniques and current data, calculations show that the standard would be complied with.
6. Mercury, fluoride or radioactive emissions wil not cause any problems particularly after consideration is given to the effect of the air quality control equipment.

Exhibit 4

7. Dry cooling towers are not a logical or feasible alternative for this project.
8. Visibility will not be noticeably affected throughout the area.

Exhibit 4

LIST OF ATTACHMENTS TO THE STATEMENT

1. Background Information for Proposed New Source Performance Standards, Pages 8 and 9, Environmental Protection Agency, August 1971.

2. Letter, W. L. Faith to The Montana Power Company, December 29, 1972.

3. Letter, W. L. Faith to The Montana Power Company, December 6, 1972, with attached report entitled, Air Pollution Effects of Colstrip Unit #1.

4. Letter, The Montana Power Company to the Air Quality Bureau with attachments, November 30, 1972 (previously transmitted).

5. Report, Northern Testing Laboratories to The Montana Power Company, March 17, 1972, Lab. Nos. 22460 through 22478.

6. Report, Truesdail Laboratories to Northern Testing Laboratories, April 18, 1972, Lab. Nos. 22460 through 22481.

7. Letter, Environmental Protection Agency to Senator Clinton P. Anderson, June 25, 1971.

8. Trace Element Calculations by The Montana Power Company, undated.

9. Table, Fluoride ppm, Lab. Nos. 26883 through 26911, revised January 3, 1973.

Exhibit 4

The fact that most low-sulfur fuel oil or crude oil will have to be imported from Alaska or from foreign countries. Substantial quantities of desulfurized fuel oil will be available from Caribbean facilities, several of which will go on-stream in 1971 and 1972.

The fact that naturally occurring low-sulfur coal is restricted for the most part to the Rocky Mountain area, so that shipping costs to eastern and midwestern power stations can be appreciable. Coal-cleaning techniques can be used to remove substantial portions of sulfur and ash from some coals, but the processes are highly dependent on the make-up of the coal.

The fact that stack-gas desulfurization processes have only recently been developed to the point at which they can be applied to steam generators. The first new steam generators to be affected by the standards will be put into operation in 1975 and 1976. In many cases owners and operators can delay decisions on air pollution control equipment for a year or longer after the steam generator has been designed. At that time there should be a greater number of options for sulfur dioxide control schemes from which to choose.

JUSTIFICATION OF PROPOSED STANDARDS

The proposed performance standards are based on inspections and tests of prototype and full-scale control systems, on consultations with state and local officials and operators and designers of steam generators and control systems, on EPA surveys of available combustion fuels, and on review of the literature. Essentially all of the technology applicable to the subject was developed in the United States.

Exhibit 4

The adequately demonstrated techniques include the use of electrostatic precipitators for particulate removal, low-sulfur fuels and flue-gas cleaning for sulfur dioxide removal, and combustion modifications for nitrogen oxides abatement. For the most part, these systems have been developed independently for each pollutant. The best systems for sulfur dioxide and particulate removal have not necessarily been operated on the same coal-fired steam generators. Many of the nitrogen oxides control techniques have been developed on units fired with low-sulfur fuel oil and natural gas, which had no requirements for sulfur dioxide or particulate control.

Particulate Matter

The particulate limits are based primarily on EPA tests of existing electrostatic precipitators that were reported to have high collection efficiencies. Seven precipitator-equipped steam generators were tested during coal burning using the EPA test method. Two of the installations were shown to meet the particulate limit, and two more barely exceeded the limit at 0.21 pound per million Btu. At the most effective precipitators only a trace of the emissions was visible.

Tests of the one scrubber showed particulate emissions of 0.32 pound per million Btu. The marble-bed scrubber, however, was designed principally for SO_2 removal rather than high-efficiency particulate control. Information obtained from various pilot-scale test programs indicates that advanced scrubber designs can achieve the particulate standard of performance. Full-scale scrubbers are now being installed at large steam generators. They have been designed to meet particulate levels that are consistent with the standard.

Exhibit 4

W. L. FAITH
2540 HUNTINGTON DRIVE
SAN MARINO, CALIF. 91108

CONSULTING CHEMICAL ENGINEER

213-287-9383

December 6, 1972

Mr. D.T. Berube
Montana Power Co.
Electric Building
Butte, Montana 59701

Dear Dan:

I am attaching a report showing the maximum ground-level concentrations of various pollutants that may be expected from the 2-360 mw units being constructed at Colstrip. An appendix to the report shows the methodology used in making the calculations. The maximum concentrations shown are well within all applicable Montana and Federal standards.

The actual emissions from the plant represent, in my opinion, best available technology.

Sincerely yours,

W.L. Faith

Exhibit 4

W. L. FAITH
2540 HUNTINGTON DRIVE
SAN MARINO, CALIF. 91108

CONSULTING CHEMICAL ENGINEER

213-287-9303

December 29,1972

Mr. D.T. Berube
Montana Power Co.
Electric Building
Butte, Montana 59701

Dear Dan:

For the record, in my report "Air Pollution Effects of Colstrip Unit 1" dated December 5,1972, the particulate emissions shown in the Appendix (0.1 lb per million Btu/hr heat input) are those allowable under EPA regulations.

I understand that the emissions of particulate matter actually expected are 0.038 lb per million Btu/hr heat input. In that case, the maximum annual mean ground level concentration of particulate matter will be 0.039 ug/m^3.

Sincerely yours,

W.L. Faith

Exhibit 4

APPENDIX

Pertinent plant design and operating data are:

2 - 360MW boilers each with a 500-ft stack
Heat input per hour per boiler - 3410×10^6 Btu/hr
Stack gas temperature - 175°
Stack gas velocity - 90 fps
Stack gas sp.ht - 0.259 Btu/lb/°F
Stack gas flow - 4609×10^3 lb/hr/stack

Emissions data are:

SO_2 - 1.0 lb per million Btu/hr heat input
NO_x - 0.7 lb (calc. as NO_2) per million Btu/hr heat input
Particulates - 0.1 lb per million Btu/hr heat input

Plume rise calculations:

Taken from "Plume Rise" by G.A. Briggs, U.S. Atomic Energy Commission, 1969

Unstable and neutral - Briggs'Eq. 5.1
Stable - Briggs'Eq. 5.7

where $s = 2.22 \times 10^{-4}$ for Category E
$s = 4.71 \times 10^{-4}$ for Category F
$s = 5.99 \times 10^{-4}$ for Cateogry G

Dispersion calculations:

No inversion:
short-term glc - Turner's "Workbook" Eq. 3.3
long-term glc - Turner's "Workbook" Eq. 5.13

With inversion(trapping):
short-term glc - Turner's "Workbook Eq. 3.5

Inversion breakup (fumigation):
TVA inversion breakup model - see Eq. 3 "Principal Plume Rise Dispersion Models: TVA Power Plants", J. Air Poll. Control Assoc. Aug. 1971, pp. 491-495

Correction factors

To change from concentrations derived from use of 10-minute σy and σz values, multiply by 0.74 for one hour and 0.62 for 3-hours.

Exhibit 4

AIR POLLUTION EFFECTS OF COLSTRIP UNIT 1

W.L. Faith
Consulting chemical engineer, San Marino, CA

Colstrip Unit No. 1 consists of 2-360MW coal-fired boilers each served by a 500-ft. stack. Other design and operating data, including emission data, are shown in the Appendix.

Calculated maximum ground-level concentrations (glc) of emitted pollutants are listed below (in comparison with applicable standards, if any)

	Maximum glc	Applicable standard
SO_2 - 1-hour	0.089 ppm	0.25 ppm
- 3-hour	193 ug/m^3	1300 ug/m^3
-24-hour	9.6 ug/m^3	260 ug/m^3
- annual mean	1.08 ug/m^3	60 ug/m^3
Particulates - 24-hour	1.0 ug/m^3	150 ug/m^3
- annual mean	0.1 ug/m^3	60 ug/m^3
Nitrogen oxides - annual mean	0.76 ug/m^3	100 ug/m^3
Mercury 24-hour	3×10^{-6} ug/m^3	None (proposed -0.1 ug/m^3)
Fluoride - 24 hour	<.002 ppb	1 ppb

(See Appendix for methodology of calculations)

San Marino, CA

December 5, 1972

Exhibit 4

... LABORATORIES, INC.

CHEMISTS - MICROBIOLOGISTS - ENGINEERS
RESEARCH - DEVELOPMENT - TESTING

4101 N. FIGUEROA STREET
LOS ANGELES 90065
AREA CODE 213 • 225-1554
CABLE: TRUELABS

CLIENT Northern Testing Laboratories
P.O. Box 411
525 St. John Avenue
SAMPLE Billings, Montana 59103
19 Samples of Coal and
3 Samples of Coal Ash as shown
P.O. NO. 6455-B55
INVESTIGATION Analyses as requested.

DATE April 18, 1972
RECEIVED March 14, 1972
LABORATORY NO. 111340

RESULTS

LAB. NO.	MERCURY, ppm		FLUORIDE, ppm
Coal Samples:			
22460	0.017		2.5
22461	<0.006	Trace	<1
22462	0.028	Trace	<1
22463	<0.006		5.
22464	0.024	Trace	<1
22465	0.058	Trace	<1
22466	<0.006		5.
22467	<0.006		3.
22468	0.109		5.
22469	<0.006	Trace	<1
22470	0.016	Trace	<1
22471	0.041		5.
22472	<0.006		11.
22473	0.104	Trace	< 1
22474	0.017		7.
22475	0.436		11.5
22476	0.023		4.
22477	0.113		9.5
22478	0.700		12.5
	.091		4.2

(Continued)

This report applies only to the sample, or samples, investigated and is not necessarily indicative of the quality or condition of apparently identical or similar products. As a mutual protection to clients, the public and these Laboratories, this report is submitted and accepted for the exclusive use of the client to whom it is addressed and upon the condition that it is not to be used, in whole or in part, in any advertising or publicity matter without prior written authorization from these Laboratories.

Exhibit 4

(from Turner's"Workbook" p.38).

To correct for lower maximum glc brought about by use of 2 stacks and calcualting plume rise from one stack only, multiply glc by 0.9. (See "Recommended Guide for the Prediction of the Dispersion of Airborne Effluents, ASME, 1968).

Data for 24-hour calculation:

Meteorological tower data indicate most persistent wind was 22 hours of Stability D and 2 hours of Stability C in a SE direction. Used Turner equation 5.13 and no corrections.

Data for annual mean calculation:

Meteorological tower data indicate greatest annual concentration will be in sector resulting from a NW wind, which occurs 11.1% of the time. Makeup of wind is essentially 3% Class C at 5.5 m/sec; 8% Class C at 8m/sec; 3% Class C at 10 m/sec; 9% D -5.5; 39% D-8; ;2% D-10; 3% E-5.5; 13% E-8; and 5% E-10. Class G was ignored as it would contribute little. The small amount of Class F was distributed between E and G classes.

Long-term X/Q values for each of the above were averaged on a weighted basis for various distances from stacks.

Highest average X/Q (1.13×10^{-8}) occurred at 10 miles. This value was multiplied by amount of total emissions in micrograms per second and by percentage of NW wind (11.1%) to yeild maximum annual concentration in micrograms per cubic meter.

Other sources of emission data

Mercury emissions - 0.002 lb/hr, based on experimental data showing that 97% of mercury in coal remains in ash.

Flouride emissions - 0.8 lb/hr, assuming 70% retention in ash.

Exhibit 4

ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

COPY
OWS

June 25, 1971

Honorable Clinton P. Anderson
United States Senate
Washington, D. C. 20510

Dear Senator Anderson:

I regret that Mr. McGowan's earlier reply to your letter of June 3, 1971 regarding mercury emissions from the Four Corners power plant at Fruitland, New Mexico, was not fully responsive to your inquiry.

There is a paucity of actual measurements of mercury concentrations in the stack effluents and ambient air in the vicinity of this power plant. Samples of coal taken in May 1971 from the mine supplying all the coal for the Four Corners plant were analyzed by Environmental Protection Agency laboratories and by three outside laboratories. The analyses ranged from 0.3 ppm to 0.6 ppm by weight of mercury. In addition, the State of New Mexico has taken composite coal samples over a three month period. These samples have been sent to Lawrence Radiation Laboratory for analyses to include mercury content. Results will be available early in July.

The State of New Mexico has contracted with Environmental Sciences Associates, Cambridge, Massachusetts, to sample, among other things, the water input and effluent, the stack gases, and the ash for mercury. Results are not yet available but are also expected early next month.

New Mexico will also shortly begin a stack sampling program for mercury emissions from these units. The Environmental Protection Agency has provided sampling equipment for this study. We expect that the results of these analyses will be available in about a month.

Geomet Incorporated of Pomona, California, was retained by the Southwest Research Information Center, Albuquerque, New Mexico, to sample the power plant's stack gases. At the end of May, 1971, Geomet sampled the stack gas after it had passed through the precipitators and reported 80-120 nanograms (billionth of a gram) of mercury per cubic meter of stack gases. These values appear to be low and suggest that some of the mercury is collected with the particulate matter that is removed by the electrostatic precipitator or reacts with the materials in the fire box and boiler flues.

Assuming for purposes of discussion that coal fired at this plant contains an average of 0.5 ppm by weight mercury, that the plant is operating at full capacity, and that none of the mercury is caught by the precipitator or elsewhere in the system, the calculated mercury emissions would be 27 pounds per day. These estimates are as follows:

Unit No.	Operating Capacity Megawatts	Coal Burned tons/day	Mercury Emissions lbs/day
1	175	2,180	2.2
2	175	2,180	2.2
3	225	2,790	2.8
4	795	9,870	9.9
5	795	9,870	9.9
Total	2165	26,890	27.0

Exhibit 4 (Over)

LAB NO.	MERCURY, ppm	FLUORIDE, ppm	Sulfur, %	Combustible Matter, % (Loss on ignition)
COAL ASH:				
22479	0.276	57.5	5.83	0.48
22480	0.163	26.	0.87	0.48
22481	2.201	5.	0.85	0.25
	0.88	29.5		

METHODS OF ANALYSIS:

Mercury
Each sample was digested under reflux with nitric, sulfuric, and perchloric acid with sodium molybdate as catalyst. When digestion was complete, an aliquot of the solution was analyzed for mercury by flameless atomic absorption, using a special 10 centimeter cell. A National Bureau of Standards sample was analyzed by this with an accuracy of ± 0.01 ppm (Theory 0.13 ppm, found 0.125 ppm)

Fluoride
Accurately weighed samples (approx. 5 grams) were treated with saturated lime water in nickel crucibles. After drying at 105°C the crucibles were ignited at 550°C. The ash was transferred to special fluorine stills, sulfuric acid solution added, and steam distillation was conducted until 100 ml of distillate was collected. The distillate was then analyzed by the SPADNS method (colorimetric). The detection limit was 1 ppm.

Sulfate in Ash
Weighed samples were extracted with hydrochloric acid containing bromine. After filtration the sulfate was precipitated as barium sulfate and weighed.

Combustible Matter in Ash
The ash was dried at 105°C. Weighed samples were ashed in platinum dishes. The loss in weight was reported as % combustibles.

Respectfully submitted,

TRUESDAIL LABORATORIES, INC.

Charlie A. Crutchfield

Charlie A. Crutchfield, Ph.D.
Technical Director

Exhibit 4

TRACE ELEMENT CALCULATIONS

I. Emission rate of fluorine and mercury

A. Fluoride

Average content of 19 sample run = 4.2 ppm

Average moisture of partly dried samples = 8.75%

Ash content equivalent to 4.2 ppm = 10.2%

Fluoride content of ash = 29.5 ppm

Coal equivalent =

$$29.5 \times 10^{-6}\# \text{ Fl}/\# \text{ ash} \times .102\# \text{ ash}/\#\text{coal}$$

$$= 2.95 \times 10^{-6}\# \text{ Fl}/\# \text{ coal}$$

% Fl in coal found in ash

$$= \frac{2.95 \times 10^{-6}}{4.2 \times 10^{-6}} \times 10^2 = 70\%$$

Fluoride emission rate =

$2 \times 385{,}500 \times 22.0 \times 10^{-6} \times (1 - .7) = 5.1\#/\text{hr}$ at the fluoride content of the 37 sample average

B. Mercury

Average content of 19 sample run = .091 ppm

Mercury content corrected to 23.9% H_2O

$$= .091 \times \frac{.761}{.913} = .076 \text{ ppm}$$

Mercury content of ash = 0.88 ppm

Coal equivalent =

$$0.88 \times 10^{-6}\# \text{ Hg}/\# \text{ ash} \times .102\# \text{ ash}/\# \text{ coal}$$

$$= 0.088 \times 10^{-6}\# \text{ Hg}/\# \text{ coal}$$

% Hg in coal found in ash

$$= \frac{0.088 \times 10^{-6}}{0.091 \times 10^{-6}} \times 10^2 = 97\%$$

Exhibit 4

Atmospheric diffusion calculations, based upon operational data from the power plant and meteorological conditions typical of the Farmington area, indicate that, under the most adverse meteorological conditions, mercury concentrations would not exceed 0.05 micrograms per cubic meter.

These concentrations may be compared to the threshold limit value of 50 micrograms per cubic meter that has been set by the American Conference of Government and Industrial Hygienists for industrial exposure over an 8-hour day, 40-hour week. Air quality standards for mercury have not been established, but based upon present medical evidence, 0.1 micrograms per cubic meter is well below levels at which health or welfare effects have been observed.

However, any emssions of a toxic substance are of concern to us, especially considering mechanisms by which they might enter the food chain. At the present time, our investigation of such mechanisms is only in the preliminary stages and no conclusions can be provided regarding the present issue.

With respect to the mercury content of fish from Navajo Lake, we can only speculate that some of the mercury emitted from this plant would find its way into the lake, but it is difficult to envision atmospheric emissions as the principal source.

Data in the Report on Mercury in the Environment, Geological Survey Professional Paper 713, 1970, indicate that the mercury content of sedimentary rocks in the Colorado plateau region which surrounds and includes the Four Corners area is extremely high. Such sedimentary rocks compose, or immediately underlie, more than 90 percent of the surface of the region. It may be that water entering the lake contains leached mercury.

As you may know, we have announced our intention to set National Emission Standards for three hazardous air pollutants: asbestos, beryllium, and mercury. The Clean Air Amendments of 1970 mandate that these standards be proposed by September 27, 1971. We are now in the process of assessing the sources and quantities of mercury emissions to the air, as well as available control techniques. Information to date indicates that on a national basis the combustion of fuel accounts for a substantial quantity of mercury emissions. However, as these sources are so widespread through the nation, no one source or area sources are believed to seriously affect the public health or welfare directly.

I hope this additional information is helpful. And I regret that it was not made available in our initial reply.

Sincerely yours,

/s/ William D. Ruckelshaus
Administrator

Exhibit 4

Radioactivity Calculations

From State Impact Statement:
Samples of coal tested contain

Radium	pCi/g
Uranium	0.7 and 0.77 ppm
Thorium	3 and 1.74 ppm

Stern reports on 1000 MW plant without dust collection using coal containing:
1.1 ppm ^{238} U
2.0 ppm ^{232} Th

Plant emitts: 350×10^{-3} curies ^{228} Ra from ^{238} U 0.79 ppm
550×10^{-3} curies ^{226} Ra from ^{232} Th 1.44 ppm

So 2 x 360 MW would give: 252×10^{-3} curies ^{228} Ra corresponding to 0.79 ppm ^{228} U
396×10^{-3} curies ^{226} Th corresponding to 1.44 ppm ^{232} Th

Now averaging State Impact Statement figures:
?U 0.7 and 0.77 — 0.735 ppm
?Th 3.0 and 1.74 — 2.37 ppm
?Ra 2.8 pCi/g — 2.8×10^{-12} curies/gm coal
or 2.8×10^{-12} gm

So using our coal and Stern's Emission figures (99.5% particle collection)
$\frac{0.735 \text{ ppm}}{0.79 \text{ ppm}}$ (1.26×10^{-3} curies/yr ^{228} Ra) = 1.17×10^{-3} curies ^{228} Ra

$\frac{2.37 \text{ ppm}}{1.44 \text{ ppm}}$ (1.98×10^{-3} curies/yr ^{226} Ra) = 3.26×10^{-3} curies ^{226} Ra

Now Radium from our coal
385,500 lb coal/hr-unit 9.23×10^{6} 24 hr
3.37×10^{9} 365 day yr

Mass Radium emission/yr
2.8×10^{-12} curies/GM $\times \frac{454 \text{ gm}}{\text{lb coal}} \times 3.37 \times 10^{9} \frac{\text{lb coal}}{\text{year}} = 4.28$ curies year

Collection 99.5% efficient
0.0214 curies/yr escape
x 2 units
.0428

Three sources and emission rates

^{228} Ra	1.17×10^{-3}	Curies/year
^{226} Ra	3.26×10^{-3}	
? Ra	$\frac{42.8}{47.23} \times 10^{-3}$	

or 0.04723 curies/yr or 0.04723 gm Radium/yr

Exhibit 4

Mercury emission rate =

$$2 \times 385{,}500 \times 0.076 \times 10^{-6} \times (1 - .97) = .00175\#/hr$$

II. Ground level concentrations

A. Fluoride -- The published State standard is 1.0 ppb, 24 hr average.

MPCo. prediction of SO_2 glc = 0.004, 24 hr average.

$$\text{GLC (ppm HF)} = \text{ppm } SO_2 \times \frac{\text{moles/hr fluoride (as HF)}}{\text{moles/hr } SO_2}$$

$$= 0.004 \times \frac{\frac{5.1}{19}}{\frac{6820}{64}} = 11 \times 10^{-6} \text{ ppm}$$

$$= 0.011 \text{ ppb}$$

B. Mercury - No standard published.

EPA states 0.1 $\mu g/m^3$ a safe value.

$$\text{GLC } (\mu g/m^3 \text{ Hg}) = \mu g/m^3 \ SO_2 \times \frac{\#/hr \text{ Hg}}{\#/hr \ SO_2}$$

$$= 11.0 \times \frac{.00175}{6820}$$

$$= 0.28 \times 10^{-5} = 0.0000028 \mu g/m^3$$

Calculations continued on the following page.

Exhibit 4

Source "The Atomic Energy Deskbook" by John F. Hogerton
1963 Consultant to Arthur D. Little Inc. Pg. 59

"Source Book on Atomic Energy" - Samuel Glasstone 1958 Pg. 596

Estimated in most parts of U.S. individual receives about 0.14-0.16 roentgen per year due to natural radiation. NOTE - This figure is before the large weapons tests during 1958-1962 time period.

Maximum permissible dose (X-rays)	0.3 R per week
Exposure to public at rate	0.5 R per year

U.S. Atomic Energy Commission Code of Federal Regulation
Title 10 Part 20 US AEC 1963

Decay Chain

$$^{238}_{92}U \xrightarrow[4.5\times10^{9}\text{yrs}]{\alpha} {}^{234}_{90}Th \xrightarrow[24\text{ days}]{\beta^-} {}^{234}_{91}Pa \xrightarrow[1.1\text{ min}]{\beta^-} {}^{234}_{92}U \xrightarrow[2.67\times10^{5}\text{yrs}]{\alpha} {}^{230}_{90}Th \xrightarrow[8.0\times10^{4}\text{yrs}]{\alpha} {}^{226}_{88}Ra$$

Exhibit 4

$$\frac{0.04723 \text{ gm/yr}}{3.15 \times 10^{7} \text{ sec/yr}} = 1.50 \times 10^{-9} \text{ gm Radium/sec}$$

Annual concentration (GLC)

Annual SO_2 concentration predicted as $7.86 \times 10^{-7} g/m^3$
Produced by 860 GM SO_2 emitted per second (2 units)

$$\frac{7.86 \times 10^{-7} \text{ gm } SO_2/m^3}{860 \text{ gm } SO_2/\text{sec}} \times 1.50 \times 10^{-9} \text{ gm Radium/sec} = 1.37 \times 10^{-14} \text{ gm Radium/m}^3$$

24 Hour concentration

$$\frac{.004}{.0003} (1.37 \times 10^{-14}) = 1,825 \times 10\text{-}13 \text{ gm Radium/m3}$$

Annual exposure

$$(1.37 \times 10^{-14} \text{ gm Radium}) \times 7.5 \times 10^{2} \frac{R}{\text{gm-hr}} \times 24 \text{ hr} \times 365 \frac{\text{day}}{\text{yr}} = 9 \times 10^{-8} \text{ rem/yr}$$

24 Hour exposure

$$(1.825 \times 10^{-13})(7.5 \times 10^{2}) \times 24 \text{ hr} = 3.29 \times 10^{-9} \text{ rem/24 hr}$$

To put these figures into perspective

PG&E licensed to discharge at Humboldt Bay, California
52 MW Nuclear Plant 0.05 curies/second

Commonwealth Edison - Morris, Illinois
185 MW Nuclear Plant 0.7 curies/second

NOTE - In calculating the permissible discharge rate, the physical and biological characteristics of the radioactive gases and meteorological characteristics of the site are taken into consideration (AEC).

Background Radiation

Cosmic Rays (Sea level)	30[1] millirem/yr
Natural Radioactivity	
External[2]	100
Internal[3]	50
	180 x 10^{-3} rem/yr

[1] Compares with 70 millirems at 5000 ft
[2] From Uranium, Thorium, and associated decay products in earth's crust or atmosphere
[3] From Potassium 40, Radium, and its decay products, and Carbon -14 in the body

Exhibit 4

Lab No.	Identification	Date Sampled	FLUORIDE, ppm TRUESDAIL As Rec'd	TRUESDAIL Air Dry	TRUESDAIL Oven Dry	WESTERN APPLIED RESEARCH As Rec'd	WESTERN APPLIED RESEARCH Air Dry	WESTERN APPLIED RESEARCH Oven Dry	RADIAN CORPORATION As Rec'd	RADIAN CORPORATION Air Dry	RADIAN CORPORATION Oven Dry	% MOISTURE As Rec'd Moist.	% MOISTURE Air Dry Loss	% MOISTURE Oven Dry Loss	% ASH As Rec'd	% ASH Air Dry	% ASH Oven Dry
26883	Pulverizer	12/16/72	24.1	25.8	27.7				27.9	29.8	32.0	12.9	6.4	7.0	9.8	10.4	11.2
26884	Belt	12/16/72	11.4	13.5	15.4	26	31	35	35.7	42.4	48.3	26.1	15.8	12.3	8.7	10.3	11.7
26885	Belt	12/16/72	8.3	9.7	11.2	26	30	35	22.4	26.1	30.2	25.7	14.1	13.6	8.2	9.6	11.1
26886	Belt	12/16/72	12.2	14.0	16.4	25	29	34	27.1	31.2	36.8	26.2	13.0	15.1	7.3	8.4	9.9
26887	Belt	12/16/72	10.8	12.3	14.5	25	29	34	21.4	24.3	28.7	25.7	12.1	15.4	8.4	9.6	11.3
26888	Belt	12/16/72	10.4	12.1	14.2	34	40	46	28.7	33.8	38.6	25.8	15.2	12.5	8.2	9.7	11.1
26889	Belt	12/16/72				30	35	41	25.3	29.3	34.4	26.5	13.8	14.8	7.7	8.9	10.5
26890	Pulverizer	12/17/72							25.5	26.8	29.1	12.6	5.0	8.0	10.0	10.5	11.4
26891	Belt	12/17/72	13.2	15.4	17.3				19.2	22.4	25.1	23.8	14.5	10.8	8.0	9.4	10.5
26892	Pulverizer	12/18/72							23.3	24.0	26.7	12.8	3.0	10.1	9.7	10.0	11.1
26893	Belt	12/18/72	4.9	5.8	6.7				28.1	33.0	38.2	26.5	15.0	13.6	8.1	9.6	11.1
26903	Pulverizer	12/19/72	18.8						32.4	33.3	36.3	10.9	2.7	8.4	10.5	10.8	11.8
26904	Belt	12/19/72	~~13.8~~	21.3	25.2				23.2	26.2	30.9	25.2	11.6	15.4	8.6	9.7	11.5
26905	Pulverizer	12/20/72	8.5	8.7	9.4				34.8	35.5	38.2	9.0	2.0	7.2	10.7	10.9	11.8
26906	Belt	12/20/72							23.9	28.7	31.9	25.2	16.7	10.2	9.8	11.8	13.1
26907	Belt	12/20/72	4.8	5.7	6.3				26.4	31.6	35.1	24.7	16.3	10.1	9.9	11.8	13.1
26908	Belt	12/20/72							23.3	27.6	31.2	25.1	15.4	11.5	9.1	10.8	12.2
26909	Belt	12/20/72							27.0	32.2	36.2	25.3	16.0	11.0	8.4	10.0	11.3
26910	Belt	12/20/72							23.5	28.0	31.3	25.0	16.2	10.5	8.9	10.7	11.9
26911	Belt	12/20/72							29.5	35.7	39.6	25.4	17.4	9.8	8.9	10.7	11.9
Avg. of Belt Samples			10.5			27.7			25.6			25.5					
Avg. of Pulverizer Samples			16.3			—			28.8			11.6					
Belt samples referred to field average moisture (23.4%)			10.8			28.4			26.4								
Pulverizer samples refferred to field avg. moisture (23.4%)			14.1			—			25.0								
overall Average 3r tests:				22.1													

Exhibit 4

Revised Jan 3, 1973

Exhibit 4

the plan for
colstrip
montana

WESTERN ENERGY COMPANY
BUTTE, MONTANA

Exhibit 4

KW
A URS Systems Affiliate

RS/THE KEN R. WHITE COMPANY
ailing Address: P.O. Drawer 62[illegible] • Denver, Colorado 80206
155 East Exposition Avenue • Suite 300 • Denver, Colorado

INTRODUCTION

This pamphlet presents a resume of the Plan for Colstrip, Montana, a company town owned and operated by Western Energy Company. Colstrip is located in southeastern Montana 30 miles south of Interstate 94 in Rosebud County. The town planning area is located between Highway 315 on the west and the Burlington Northern Railway lines on the east. Western Energy's property limits determine north and south boundaries of the planning area.

Expansion of mining operations and development of a steam electric generating plant by the Montana Power Company will stimulate growth and the need for additional housing, streets and other urban facilities. The Plan proposes a reasonable, ambitious development program which will benefit Western Energy from the standpoint of economics, public relations and employee relations. In addition, the following benefits can be expected:

(1) Minimal employee turnover can be achieved by compensating for Colstrip's geographical isolation with an attractive and functional community. Good educational and recreational opportunities, comfortable and attractive living quarters and ready access to commercial facilities will go far in fostering satisfaction among employees and their families.

(2) Higher employee morale and job performance should result from pleasant living conditions.

(3) Public relations of Western Energy can be enhanced by developing Colstrip as a model community and avoiding the historic image of the "company town". This concern together with reclamation of mined land are in the best interests of Western Energy Company.

SUMMARY OF THE PLAN

The fast growth rate projected for Colstrip by 1980 required that the Plan for Colstrip be flexible. The construction of homes, streets and other facilities must keep pace with the population influx and must adjust to any unforeseen alterations in the growth rate. Therefore, the concept of the Plan provides for future growth to develop in separate "pockets" surrounded by open space. This concept allows for physical growth to occur in one of several areas at a time, depending on the demand for housing. Three types of housing (single-family, apartments and mobile homes) also provide flexibility to meet the different housing needs of the population.

The following summary reviews population projections for Colstrip and major elements of the Plan: housing, commercial, community facilities, traffic and utilities.

POPULATION

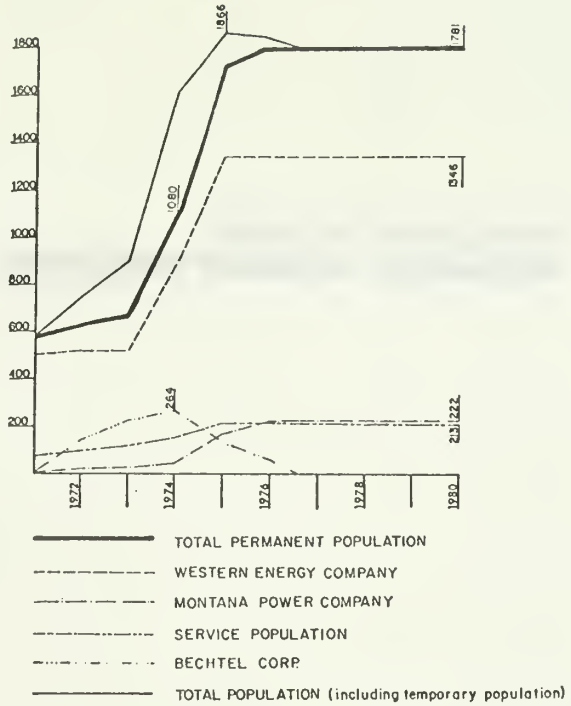
Colstrip's population is projected to grow to 1,780 by 1980, several times the current population. The following table and graph illustrate the yearly incremental increases in population.

POPULATION GROWTH
BY GROUP

Year	WECo.	MPCo.	Services Total	Bechtel	TOTAL
1972	522	17	91	140	770
1973	522	25	118	228	893
1974	885	42	153	264	1608
1975	1346	177	213	130	1866
1976	1346	222	213	63	1844
1978	1346	222	213	0	1781
1980	13[illegible]	222	213		

Exhibit 4

Population Growth



Projections were based on the following factors:

(1) Current census of Colstrip's population;

(2) Estimate of temporary construction employees and their families expected to live in Colstrip during construction of the steam electric generating project;

(3) Projected personnel and their families of Western Energy and Montana Power;

(4) Estimate of professional and commercial personnel required to serve professional, commercial and service businesses in Colstrip; and

(4) Factors establishing the single/married employee ratio and average family size.

Recommendations for relating the population growth to development of the town are as follows:

(1) Establish a system for monitoring population growth to keep abreast of changes in housing and other needs.

(2) Inform the school district of anticipated population changes and other demographic information pertinent to school planning needs.

HOUSING

Colstrip's rapid population growth requires a flexible housing plan. Construction must keep pace with the growth rate and be flexible to changing housing requirements and mix of housing types. To achieve flexibility, each new residential section is separate and surrounded by open space. Therefore, construction can vary from development of one section at a time to simultaneous construction of all sections. If the single/married ratio varies during a growth period from the projections, adjustments in the construction of apartments and single-family homes can also be accommodated. The following table relates projected population and households to anticipated housing requirements.

INCREMENTAL INCREASE OF
HOUSEHOLDS AND DWELLING UNITS
Colstrip, Montana

Year	Households	Dwelling Units by Type M. Fam.	Sing. Fam.	Mo. Home	Total
1972	230	38	64	128	230
1973	274	46	91	128	265
1974	412	61	199	128	388
1975	562	83	273	128	484
1976	551	95	273	128	496
1978	529	95	273	128	496
1980	529	95	273	128	496

Single-family homes are planned for three areas: (1) north of and adjacent to the existing single-family area in the northeastern part of the existing town, (2) in the southern part of the planning area between Highway 315 and the proposed mobile home park, and (3) north of the school to the limit of the planning area. Apartments are planned for the areas southwest and adjacent to the existing town and between the new mobile home park and the new single-family section to the south. The new mobile home park is planned south of the existing mobile home park and adjacent to the rail line.

Single-family homes should be located on lots with sufficient building setbacks to provide sufficient space between homes and to avoid a crowded appearance. Variation of setbacks for groups of houses can avoid a monotonous building setback appearance, particularly on long, straight streets. Variety in the styles of homes between each residential section can do much to provide variety in the visual appearance of neighborhoods. Predominant types of landscaping in each residential section will also enhance the visual appearance of neighborhoods.

Town house and garden apartments are recommended for new multi-family areas. Dwelling unit densities should range from 6 to 14 units per net acre for town houses and 15 to 20 units per net acre for apartments. Major design factors in developing multi-family areas are: (1) low land coverage and abundant open space, (2) privacy and quiet for the individual family, (3) adequate and convenient off-street parking for tenant's cars, and (4) convenient community shopping and recreation facilities.

Exhibit 4

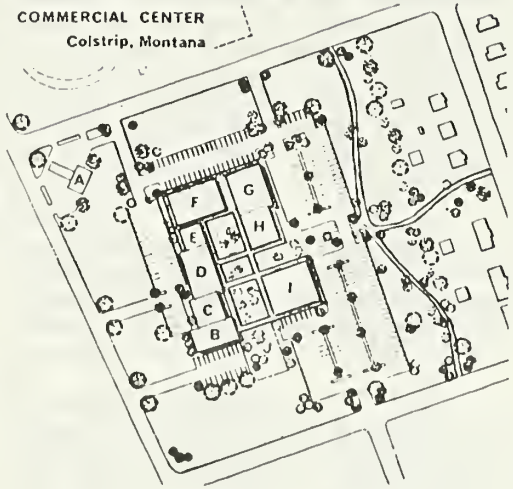
COMMERCIAL

Commercial development is planned for the area south of Main Street across from the school. The site is centrally located to serve both the community and highway traffic.

The proposed complex resembles a small neighborhood shopping center and consists of a grocery store, drug and hardware store, general merchandise store, offices, medical facilities, a post office and space for services such as a laundromat and beauty and barber shops. A service station, small motel and restaurant are located on the site and are oriented toward the highway. A recommended development plan for the commercial center is illustrated below.

Careful consideration should be given to design and aesthetics of the center as it is a major element in the future image of Colstrip. A market study should also precede development of the center to derive spatial requirements and quantity and range of merchandise.

COMMERCIAL CENTER
Colstrip, Montana



A. Service Station (14,000 sq.ft.)
B. 20 Room Motel (3,825 sq.ft.)
C. Restaurant (2,025 sq.ft.)
D. General Office Space (3,375 sq.ft.)
E. Medical-Dental Office (1,089 sq.ft.)
F. Drug-Hardware Store (3,666 sq.ft.)
G. General Merchandise (3,575 sq.ft.)
H. Commercial Services (2,475 sq.ft.)
I. Grocery (4,875 sq.ft.)
J. Future Expansion (optional)

COMMUNITY FACILITIES

Colstrip's community facilities include the school, fire and police protection services, churches, health care, library and parks and recreation services. Fire protection and parks and recreation are the primary responsibility of Western Energy; the other facilities are public or quasi-public facilities.

SCHOOLS — Although provision of additional school facilities is a public function, Western Energy should inform school officials of Colstrip's anticipated impact on school enrollment so appropriate action can be taken for school expansion. The present site can accommodate additional buildings, but additional playground and recreation space may be required. Agreements between Western Energy and the school district can bring about the mutual use of school recreation facilities and the proposed park north of the school site.

FIRE AND POLICE PROTECTION SERVICES — Fire protection will be a responsibility of Western Energy. A fire station is recommended to be constructed along Willow Street where ready access to the community and the Montana Power facility will be available. Police protection will be provided by Rosebud County. If an office is required, it should be located at the fire station or in the commercial center complex.

CHURCHES — Two additional church sites are provided in the Plan. Both sites are in new residential areas. If new churches do not organize, they can be converted to additional residential lots.

HEALTH CARE AND LIBRARY SERVICES – Western Energy's primary responsibility for assisting with health care and library services is to provide sufficient space. A combination doctor and dental office is recommended as part of the commercial complex. Library services will be provided through a bookmobile from Billings, Montana. Therefore, no permanent space will be required for this service.

PARKS AND RECREATION – The plan for parks and recreation consists of the following elements:

- Landscaping of the existing park.
- Development and expansion of the proposed teen and community center.
- Development of new playfields, tot lots and parks within the open space.
- A bicycle path constructed throughout the open space and connecting the parks with major areas of the town.
- Additional facilities (a golf course and community recreation area), which are planned for areas beyond the limit of the planning area.

TRAFFIC

The thorough fare plan incorporates the existing street system and the development of new streets. The plan establishes three categories of thoroughfares which are:

(1) Major Thoroughfares .— which carry through traffic and are designed to move traffic with minimal congestion.

(2) Collector Streets — which connect one area of the community with another.

(3) Local Streets — which provide access to individual land parcels and are designed to encourage slower speeds.

Major thoroughfares are Main Street and Willow Street. Plans call for the termination of Main Street at the rail lines and the extension of Willow Street to the east across the rail tracks and to the west to connect with Highway 315. A grade separation will be required at the rail line crossing.

Collector streets are First, Second and Third Streets, which extend into areas of future development. Another collector extends south from the commercial center through the apartment area and into the single-family area. It will connect with Willow Street and Highway 315. First Street extends to the north and intersects with the extension of Third Street. Second Street serves the existing mobile home area and extends south into the proposed mobile home park. Third Street continues north of its present alignment and connects with Highway 315.

The remaining streets on the Plan are local streets. They are usually shorter than the other streets and are designed to provide access to individual lots. Pavement is narrow and curves are shorter to encourage slower speeds.

It is recommended that Highway 315 remain in its present location and that Western Energy and Montana Power petition the Highway Department to place the highway on a schedule for resurfacing and widening of the pavement. The present road is dilapidated in some areas and presents a safety hazard. An overpass is also recommended for the highway over the proposed road and rail line which will serve new mining areas to the west.

UTILITIES

Storm drainage, sewage and water supply are the major utilities to be provided in Colstrip. Several conditions should be given careful attention to insure smooth operation and functioning of these basic urban facilities. To this end the following recommendations have been made:

DRAINAGE –

(1) Western Energy should conduct a study to define flooding potentials of Armells Creek, particularly in that area within the community.

(2) A water storage basin should be provided in the existing park to handle any excessive drainage loads created by new development to the north. The basin, which normally would be dry, collects water during heavy storms and avoids construction of large drainage structures adjacent to the railroad down to Armells Creek.

(3) Utilize landscaping and the above basin principle in new development areas and in parks and open spaces wherever drainage may become a problem.

(4) Carry excessive surface runoff from the commercial center south to the Armells Creek tributary located in the planned open space within the multi-family area. The drainage should be handled in a subsurface system.

SEWAGE –

(1) The capacity of the existing lift station should be increased if new development south of Willow Street overloads the existing system.

(2) Additional sanitary sewer facilities should use pipe systems with flexible gaskets at joints to avoid infiltration.

(3) The lagoons planned for sewage treatment should be designed for up to 120 days' storage capacity.

(4) Western Energy should keep abreast of changing Federal requirements affecting sewage treatment and treatment discharges.

(5) Land disposal of treated effluent should be considered.

WATER –

(1) Western Energy should plan to provide a yearly water consumption of 400 acre-feet by 1980 — an additional 263 acre-feet of water per year over present supply of 137 acre-feet per year.

(2) Present areas served by four-inch mains should be replaced or at least paralleled with six-inch mains in order to maintain desired pressure and to meet fire department requirements.

Exhibit 4

The MONTANA POWER COMPANY

RECEIVED
1972
ENVIRONMENTAL SCIENCES
DIVISION

GENERAL OFFICES
ELECTRIC BUILDING
BUTTE, MONTANA 59701

October 9, 1972

Mr. Ben Wake
Administrator
Dept. of Health and
Environmental Sciences
State of Montana
Helena, MT 59601

Dear Sir:

In response to your inquiry made by Don Holtz as to specific dates that certain activities were undertaken by The Montana Power Company in the Colstrip area, I submit the following chronology of the activities and developments of our Colstrip project.

1969 - July - Negotiated the Technical Services Agreement with Bechtel Corporation to evaluate turbine generators and boiler additions to The Montana Power Company's system, initially planned for the Billings plant.

- Sept.- Placed an order for the first turbine generator set with General Electric Co.

- Dec. - Placed an order for the first steam generator with Combustion Engineers.

1970 - Mar. - Contracted with Bechtel Corporation for an engineering evaluation of potential coal fired steam electric generating sites throughout The Montana Power Company area. Previously planned addition to the Billings plant had been abandoned because of the local weather patterns, metropolitan development of the area and public attitude. The final Colstrip location was selected over 6 other sites in the Colstrip area, and 15 other locations on The Montana Power Company system, after complete environmental and economic evaluations.

Exhibit 4

- July - Surveys of potential cooling ponds in the general area - three on Stocker creek drainage - one each on Armells, Cow, and Pony creek drainage areas.

- Sept.- Soils and subsurface strata evaluation on four of the above sites by drilling 13 tests holes and digging 15 exploratory trenches.

1971 - Jan. - Colstrip site test hole drilling commenced for soil and subsurface strata evaluation.
- Installed a mechanical weather recording station and a recording hygrothermograph near the proposed site.
- Contracted with Western Scientific Services Incorporated to investigate weather records for the Colstrip area and establish a complete weather station at the location.
- Engaged W. L. Faith, Consulting Chemical Engineer, to evaluate meteorological data, plant design and equipment selection pertaining to air quality control.

- June - Expanded weather investigation and retained Montana State University through their Endowment and Research Foundation to establish long range meteorological program.

- July - Commenced drilling a 9,330 ft. test well to evaluate subsurface aquifers for possible water source for plant water requirements.

- Aug. - Design was finalized for the 350 ft. weather observation tower and erection was completed in November.

- Sept.- Began discussions with Montana State University through their Endowment and Research Foundation for development of a program to evaluate the effects of the Colstrip project on the existing ecosystems of the area.

- Nov. - Excavation for removal of coal underlying plant site commenced.

1972 - Jan. - Installed first air quality monitoring station consisting of an SOx, NOx sampling train, a high volume dust sampler, dustfall jar, Huey sulfation plate and a fluoride plate.

- June - First concrete poured - drilled caisson footings.

Exhibit 4

- Aug. - First surface placement of concrete grade beams on top of caissons.

In addition to above events, construction at the Colstrip site to date has consisted of:

Drilling a water well and installing a water system.

Erection and operation of a concrete batch plant.

Start of construction buildings - structures and placement of utilities for an office, warehouse, worker's change house and a maintenance building.

Building of access roads and subgrade for a railroad site.

Placement of the 840 yard pedestal base for Unit #1 turbine generator.

With the completion of all the caissons, Unit #1 foundations and grade beams, and site fencing expected by the first part of December, construction activity will be suspended until spring.

Yours very truly,

Carl R. Anderson

Carl R. Anderson, Mgr.
Environmental Protection Dept.

CRA:mcs

Exhibit 4

Exhibit 4

The MONTANA POWER COMPANY

Jan 19

GENERAL OFFICES
ELECTRIC BUILDING
BUTTE, MONTANA 59701

January 18, 1973

Air Quality Bureau
State Department of Health and
Environmental Sciences
Helena, MT 59601

ATTENTION: Don Holtz, Chief

RE: Draft Environmental Impact Statement Pertaining to the Colstrip Generating Plant

Gentlemen:

We have received and reviewed your draft Environmental Impact Statement dated October, 1972, relating to our application for a construction permit for the installation of equipment which may cause or contribute to air pollution. We have also reviewed your Draft Supplement, dated December, 1972, to that Statement.

Your statement refers to the ownership as a "joint venture" of The Montana Power Company and Puget Sound Power and Light Company. Actually, the parties are owners as tenants in common and it is technically not a "joint venture."

By letter to you of November 7, 1972, we submitted specific comments on your predictions of ground level concentrations of sulfur dioxide set out in the draft statement. A copy of our letter is attached as Item 1. We have also submitted specific comments on other areas of the draft statement by letter dated November 30, 1972, and December 29, 1972. Copies of those letters are attached as Items 2 and 3. Further, at the public hearing held by the Department in the Custer County High School auditorium in Miles City on January 5, 1973, representatives of both The Montana Power Company and Puget Sound Power and Light Company made oral presentations concerning the statement. A copy of the statement of Puget Sound Power & Light Company is attached hereto as Item 4, and The Montana Power Company's statement is attached as Item 5.

Exhibit 4

Now that we have completed our review of your draft statement and supplement, as well as those comments by others where copies have been furnished to us, we have the following additional comments on the statement and supplement as a whole:

1. Additional Information. In some instances, the draft statement tends to set out conclusions without stating the facts upon which those conslusions are based. For example, the social consequences discussed in the section of the draft statement dealing with the impact on the human environment seem to be predicated on the development of vast number of generating plants and mines and not on the construction and operation of the facilities for which application has been made.

We believe that elaborating on the facts pertaining to our proposed facilities would dispel what appear to us to be a number of erroneous conclusions. To further this end of making the draft statement more factual, we recommend that you consider the following preliminary studies and incorporate them in the statement as you see fit:

A. Meteorological Study

Montana State University is pursuing a long range meteorlogical investigation at Colstrip. A permanent weather station was established in 1971 and a 350 foot tower was erected to monitor wind and temperature up to that height. Higher altitude data has been obtained with balloons and aircraft. A full year of weather information has now been collected, and copies of that data have been submitted to your Department. Correlation between the tower information and the high altitude data is being pursued as well as their relationship with regional meteorlogical data. The Department may wish to supplement this study with data obtained from the National Weather Service at Billings, Miles City, or Sheridan, Wyoming.

B. Environmental Surveillance Study

Montana State University Agricultural Experiment Station has undertaken an evaluation of the existing conditions of the total environment in the area so as to establish a preproject base. The University is investigating the vegetation and soil chemistry, vegetative communities, vegetative growth (including fodder production which is of major concern to the local cattle industry), insect and animal communities and chemistry, surface and ground water chemistry, etc. Copies of the Experiment Station's "proposal" and "Preliminary Study Report" are attached as Items 6 and 7. The Experiment Station has prepared a study entitled "Range Types and Productivity of Two Study Areas in Southeastern Montana". This study was prepared for Western Energy Company, a subsidiary of Montana Power, and relates to certain areas described in that study. We have attached a copy of this study as Item 8.

Exhibit 4

C. Historical Values

An archaeological study was conducted by the University of Montana Anthropology Department under the direction of Dale Fredlund, State Archaeologist, during 1971. This study included all of the lands which will be part of the project during the development and early years of operation of the project. Arrangements are being made to expand the study to include lands that will be affected by mining activity in the later years of the project. A copy of the University of Montana's Archaeological Survey Report is attached as Item 9.

D. Community Planning

Ken R. White Company, Denver, Colorado, Land Use Planners Designers, and Architects has prepared a preliminary report on the development plan and program for Colstrip. This report investigates employment, population forecast, recommends housing plans, commerical facilities, community facilities, recreational facilities and utility requirements, and sets forth a general land use and circulation plant for the community and adjacent area. The final draft of this report has not yet been received, but will be sent to you when received.

E. Wildlife Habitat Utilization

This preliminary report has been developed for a limited area within the project by Ecological Consulting Service. The report essentially deals with a specific control area and is currently being expanded to include the entire project area. The initial summary of this activity is attached as Item 10.

F. Coal Mine Land Reclamation Research

The Montana Agricultural Experiment Station has conducted research in this area since 1968. The study has examined many aspects of reclamation requirements and has lead to the development of a successful reclamation program. A copy of Experiment Station's Research Report #20 is attached as Item 11.

G. Stream Flows and Water Data

The project as applied for will require approximately 8000 acre ft/yr, at rates up to a maximum of 8000 gpm. That maximum rate will be about 0.2% of the average flow rate of the Yellowstone River. Information pertaining to stream flows and other water data could be obtained from the U.S. Geological Survey, such as in their Special Publication 28, "Mineral and Water Resources of Montana", and also from the U.S. Bureau of Reclamation, the Corps of Engineers, and other governmental agencies. The applicants have retained Ecological Consulting Service of Helena, to more fully evaluate the water use and hydrology of the Yellowstone River, and what effects, if any, this minor diversion may have on the downstream characteristics of the river.

Exhibit 4

2. Need for Power. The draft statement makes reference to the need for electric power which necessitates the construction of the proposed project. No where in the draft statement, however, is this need quantified. Therefore, we have attached as Item 12, a summary of the projected loads, resources and deficiencies of the applicants through 1982 which should be included in the statement. This summary is developed on the same basis as data provided by the applicants to the Western Systems Coordinating Council for its annual publication "Summary of Estimated Loads and Resources".

3. Environmental Impact of Realistic Alternatives. In the section of the draft statement dealing with alternatives to the proposed project, nine alternatives are listed. Under the National Evnironmental Policy Act, upon which the Montana Act is modeled, the courts have indicated that "the range of alternatives that must be discussed in an impact statement is generally limited to realistic alternatives that will be reasonably available within the time the 'decision making' official intends to act." NRDC v. Morton, 2 ELR 20029 (D.C. Cir. 1972). Such a standard rules out at least the following alternatives which are discussed in the draft statement: nuclear fusion, magnetohydrodynamics, solar energy, wind, and geothermal energy.

Furthermore, the environmental impact of none of the alternatives set out in the draft statement is discussed. We recommend that the draft statement be supplemented to include such discussions.

4. Other Comments. There are a number of areas in the draft statement which could be made considerably more readable and understandable to the layman and scientist alike by adding the following additional sections to the statement:

a. Bibliography. The draft statement contains some conclusions which appear to be based on surveys or other statistical or research sources. For instance, on page 38, it is stated that "The future needs of the coal may be more urgent than our present needs for electricity." References to the sources for this and similar predictions would be very helpful to persons examining the statement.

b. Glossary. A glossary should be added defining such terms as "primary impact", "secondary impact", "pollution", and other similar words used throughout the draft statement. There are statutory definitions of these terms which appear to be different than the definitions which the drafters of the statement mean to attribute to the terms. For example, see the definition of "pollution" in the Montana Clean Air Act.

c. Appendix. An appendix describing the science of diffusion modeling would prove useful. Although the draft statement on page 12 states that diffusion modeling is "explained

Exhibit 4

more fully in the section dealing with sulfur dioxide", no such full explanation was found in that section. Readers of the statement deserve a full, descriptive explanation of diffusion modeling as it was applied to the analysis of the proposed project.

d. Maps. Illustrations, figures, maps, etc., offering a graphic statement for the laymen of Colstrip and its environs would be useful. The spatial relationship between this project and other features of the surrounding area would be enhanced through these visual aids.

Finally, we wish to point out that the applicants will be conducting continual monitoring studies of the air quality in the area both before and during the operation of the proposed project. These studies will be available to the Department of Health and Environmental sciences if it wishes to use them to supplement its own monitoring studies.

If you wish to review any of these comments with us, we would be pleased to meet with you. We hope that you will give these comments your fullest consideration and revise your environmental impact statement to incorporate them.

Very truly yours,

MONTANA POWER COMPANY

By Carl R. Anderson

PUGET SOUND POWER & LIGHT COMPANY

By W. J. Finnegan

Exhibit 4

Exhibit 4

Montana-Puget Combined

Loads and Resources
Megawatts

	1972-3	1973-4	1974-5	1975-6	1976-7	1977-8	1978-9	1979-80	1980-1	1981-2
PEAK (Energy required at time of heaviest load)										
Firm Load:										
Montana	822	879	926	972	1020	1071	1125	1182	1241	1304
Puget	2022	2175	2341	2514	2719	2937	3177	3423	3716	4018
Total	2844	3054	3267	3486	3739	4008	4302	4605	4957	5322
Net Resources:										
Montana	941	874	940	877	774	774	774	767	811	811
Puget	2086	2151	2184	2430	2438	2465	2605	2542	2387	2373
Total	3027	3025	3124	3307	3212	3239	3379	3309	3198	3184
Net Surplus (Def)	183	(29)	(143)	(179)	(527)	(769)	(923)	(1296)	(1759)	(2138)
Colstrip #1 & #2				330	660	660	660	660	660	660
Less Added Reserve Obligation				-50	-99	-99	-99	-99	-99	-99
Surplus (Deficiency)	183	(29)	(143)	101	34	(208)	(362)	(735)	(1198)	(1577)
ENERGY - (Critical period average)										
Firm Load:										
Montana	567	598	629	661	693	726	760	798	837	878
Puget	1210	1270	1363	1464	1576	1701	1836	1980	2139	2315
Total	1777	1868	1992	2125	2269	2427	2596	2778	2976	3193
Net Resources:										
Montana	613	622	663	616	573	596	597	598	657	665
Puget	1210	1338	1280	1375	1315	1350	1399	1344	1282	1272
Total	1823	1960	1943	1991	1888	1946	1996	1942	1939	1937
Net Surplus (Def)	46	92	(49)	(134)	(381)	(481)	(600)	(836)	(1037)	(1256)
Colstrip #1 & #2				280	561	561	561	561	561	561
Surplus (Deficiency)	46	92	(49)	146	180	80	(39)	(275)	(476)	(695)

The MONTANA POWER COMPANY

GENERAL OFFICES
ELECTRIC BUILDING
BUTTE, MONTANA 59701

February 12, 1973

Daniel Vichorek - Technical Writer
State Department of Health
Helena, Montana 59601

Dear Mr. Vichorek:

The following discussion is offered in reply to your inquiries in your letter of January 12.

January 12 Letter

1 - Why was the Colstrip site most feasible?

Site selection for this project lead to the Colstrip area for environmental and economic reasons.

Environmentally, the Colstrip area is remote and development would affect fewer people directly; i.e., fewer residences, less roads and highways with less use. The weather patterns of eastern Montana are generally less confining than the more mountainous terrain of much of the MPCo.'s service area (detailed investigation has proven the weather patterns at the specific site selected to be acceptable). Existing land use levels would be upgraded by the proposed development; i.e., more people would realize more use from the energy available from this land than the values being received by very few people at its present level of use. Also, the lands disturbed by the mining activity will be reclaimed, and the extensive research over the past 5 years in WECo.'s area, indicates the disturbed land will be back in production in 3 to 5 years. The site adjacent to the town of Colstrip minimizes the travel and time of the operating personnel to and from work, as town facilities, including homes, would be provided by expanding the existing village.

Economically, all locations away from the mine area were subject to uncertain future freight rates for transportation of coal by rail, and also to possible shutdown from transportation labor strife that could interrupt coal deliveries. Also for this project, much of the energy transportation is accomplished

Exhibit 4

Mr. Vichorek

by displacement over existing transmission lines. But even a new transmission line installation has the advantage of known and practically fixed costs associated with it with a one time set investment required. Contrast this known cost with the unknown future freight rates for moving the coal.

2 - What was unfeasible about the other sites and might they be developed in the future?

The other sites considered were not as desirable as the Colstrip site in one or more of the reasons listed in #1, and were not necessarily found to be unfeasible. Each of the fifteen other sites around the state were considered to some degree, but not necessarily in great depth. An obvious unique local condition may have discounted a location promptly without serious consideration.

3 - What was discovered about the soil permeability and the water table at Colstrip?

Drilling throughout the Colstrip area finds the soils to be recent alluvium underlain by interbedded shales and lenticular sandstones overlaying the coal seams. The shales have little or no permeability. The first water zone is found in the coal seal, but potable water supplies throughout the area are taken from below the McKay coal seam; e.g., the Colstrip town shallowest water wells are completed at a depth of 350 ft., whereas the McKay seam at the plant site was at a depth of about 20 ft.

4 - Will any well water be used for any phase of the proposed project?

The only use of well water for this project will be from a 600 ft. Ft. Union well for water at the concrete batch plant. The well was drilled specifically for that purpose. A 9330 ft. Red River well was drilled by the MPCo. to test the availability of water for this project from underground aquifers. Testing of the Red River and Mission Canyon zones indicated deliverability restrictions and chemical composition requiring substantial treatment in order to make it usable.

5 - How much well water is available?

The Red River and Mission Canyon aquifers are practically unlimited in that they are being recharged from outcrops in the Big Horn Mountains and the Black Hills. Productivity on the test well reached 390 gpm from the Mission Canyon and Red River combined.

Exhibit 4

Mr. Vichorek

6 - What possibility is there of materials from the ponds reaching the water table?

None. The settling ponds will be sealed with bentsnite or some other impervious material to eliminate seepage into the ground. Methods and procedures to achieve suitable sealing are currently being investigated.

7 - What precautions will be taken against contamination of ground water?

No seepage into the ground or out of the pond in any direction, except for evaporation will be permitted as stated in #6.

8 - How tall will the cooling towers be?

The height furnished for your draft statement still applies; i.e., 65 ft. high x 48 ft. wide x 252 ft. long.

9 - What precautions were taken to prevent plume mixing between stacks and the cooling tower?

The low level cooling tower water vapor emission is about 600 ft. west of the stacks, which is generally upwind from the stacks.

The low level emissions of water vapor at a height of 65' with little thermal rise, will not mix with the stack emissions being released at 500 ft. with a significant thermal rise effect. In general, air movements will influence both emissions in the same direction which will tend to maintain the elevation difference. Appreciable lateral movement of the plumes will have to occur before mixing takes place, and such movement will dilute the concentrations of each plume. Mixing of plumes with sufficient concentrations of their individual components to have any detrimental effect will not occur.

10 - What is your estimate of monthly payrolls for each month at Colstrip project through the construction period?

See the attached schedule.

11 - Do you have any information on the drift potential from Colstrip on its (cooling water) ?

The cooling water will be fresh water, with some mineral carry over in the vapor, but these minerals will fall out within 200 ft. of the towers. Any fog formation is expected to be dissipated within the project property.

Exhibit 4

Mr. Vichorek

12 - Western Energy declined to cooperate in a study with the Fish and Game Department in 1969. Can you explain this?

WECo. was operating a limited mining activity in 1969 and had entered into a contract with the Endowment and Research Foundation at Montana State University to evaluate the flora and fauna in the area and research the reclamation needed for the mining area. As they had done with other mining companies, the Fish & Game Department approached WECo. suggesting a yearly fee of $1,000 to do some sort of a study of the Colstrip area. MSU was investigating and evaluating everything that the Fish and Game could offer. Government agencies are developed specifically to investigate actions, past, present and future, in unique definite fields of endeavor. I find it difficult to understand that the Fish and Game Department could not investigate the activity just because WECo. did not contribute $1,000/year.

MPCo. had not settled on the Colstrip site for the steam electric generating project in 1969. The choice was made in 1970. MPCo. was aware that a comprehensive study would have to be undertaken during the pre-project development to supply important base line data. Another agreement by MPCo. with the Endowment and Research Foundation at MSU extended their investigation and evaluation to cover a much greater area than just the mining reclamation agreement with WECO. A comprehensive wildlife study is also being pursued by a highly qualified local environmental consulting service. The necessary base line data will be established prior to the operation of these plants.

13- If studies indicate that the plant will be detrimental to the ecosphere, what will the applicant do to offset the effects?

Our extensive studies underway in the Colstrip area will establish what the ecosphere is. Continued observation will monitor changes in the base line conditions established by these studies. Changes identified as resulting from the project operation, will be investigated and evaluated.

Changes required to avoid detrimental effects from the project operation will certainly influence the project's future operation.

This project is being designed and developed to cause as little environmental impact as possible, but it will affect the environment. All actions do, including natural events. We will meet all of the requirements imposed by Federal and State laws and regulations for the operation of the project.

Exhibit 4

Mr. Vichorek

14 - Our booklet on how to conserve power was sent to you last week.

We continue to work on the balance of your questions. As soon as complete answers are developed, they will be sent to you.

Yours very truly,

Carl R. Anderson

Carl R. Anderson
Manager, Environmental
Protection Department

CRA/by

Exhibit 4

ESTIMATED MONTHLY PAYROLL AT COLSTRIP PROJECT
UNITS #1 & #2
(THOUSANDS OF DOLLARS)

	1972	1973	1974	1975	1976
Jan.	-	435	1241	2455	1926
Feb.	-	482	1300	2349	1455
Mar.	-	647	1338	2226	1220
Apr.	-	894	1494	2119	995
May	-	1029	1648	2036	807
June	-	1205	1864	1936	589
July	423	1341	2064	1899	622
Aug.	418	1405	2234	1852	463
Sept.	423	1400	2346	1864	416
Oct.	435	1305	2446	1929	410
Nov.	465	1247	2487	1993	410
Dec.	476	1229	2493	2011	410

based on:

Project 1972 costs - no escalation
Includes payroll estimate for construction, operation, and mining labor.

Exhibit 4

The MONTANA POWER COMPANY

GENERAL OFFICES
ELECTRIC BUILDING
BUTTE, MONTANA 59701

January 31, 1973

Mr. Daniel Vichorek
Technical Writer
State Department of Health
Helena, MT 59601

Dear Mr. Vichorek:

I apologize for the delay in answering your letter of January 3, but your inquiries warranted complete answers and that has taken time. In reply, discussion of each of the questions you asked follows:

1. Has surveying begun on the two additional power lines?

No. Refer to my letter to Don Holtz dated December 29, 1972 included in your supplement to the Draft Environmental Impact Statement.

2. Has right-of-way for above lines been procured?

No.

3. When must survey be completed?

A July, 1973 completion of preliminary survey is necessary to allow sufficient time to evaluate environmental, engineering, right-of-way, and material considerations before construction which must commence in the spring of 1974.

4. About how far from Billings will substations be built?

Not yet located, but probably from 6 to 12 miles north in or adjacent to existing transmission line corridors.

5. How will substations be connected to the existing transmission facilities?

The substation will be the termination point of six lines. Two of those lines, one from Anacona and one from the Billings Steam Plant, are presently in operation. An additional line from the Billings plant will be put on existing double circuit towers. Another of the lines will be the Billings-

Exhibit 4

Great Falls line that will commence construction in 1973. The proposed Colstrip lines will be the last two lines terminating in this substation.

6. How much and what size lines will be required to make the connection?

How much line is unknown until the exact substation location is set. The six lines referenced in No. 5 are all 230 kV size. With some of the lines already installed and operating, environmental considerations suggest location to be so as to require installation of the least amount of new line.

7. When must survey and right-of-way be completed for the pipeline?

By January 1, 1974, assuming everything else is ready, and construction starts that coming spring.

8. Sketch on map of possible pipeline and power line routes.

Attached.

9. Detail flora and fauna along the routes, including how much crop land, range land and waste land?

Without precise routes, such detail would have to be so general and broad, the description would be impossible to ascertain with any precision, and would have little value.

10. How wide a right-of-way required for two parallel 230 kV lines?

Two hundred feet or less.

11. By two parallel 500 kV lines?

That size line is not part of this project, and The Montana Power Company has none of that size line on its system, but industry usage indicates up to 300 feet may be required.

12. What type of poles would be used for 230 kV lines?

Primarily two-pole X-braced wooden structures made with 50 to 60 feet poles. Some three-pole wooden structures required on angles.

Exhibit 4

13. For 500 kV lines?

Again, such lines are not part of the project and The Montana Power Company has none on its system, but industry uses metal structures primarily.

14. What are the specifications, route and projected completion date for the new Billings-Great Falls line?

The line will be a 230 kV routed from Billings via Judith Gap to Great Falls, and is scheduled for completion by November 1974.

15. Is this line related to the Colstrip project?

No.

16. What type and how many pumps will be required for each of the pipeline routes?

The design has not been finalized, and the pumps not selected. There will be a horsepower requirement of about 5000 horsepower and the pumps will probably be staged centrifugal.

17. Provide sketch of the development to illustrate the location of boilers, cooling towers and ponds?

The boiler and cooling tower locations were indicated on the maps submitted with our application for construction of equipment affecting air quality, in August, 1972. The 3-acre surge pond will be located about 1 mile north of the plant site, and the two settling ponds will be located approximately a thousand feet east southeast of the plant site, and will be approximately 30 acres in size. All ponds and equipment will be located on land presently owned by the Applicant.

18. What effort will be made to reclaim the land disturbed by the pipeline?

The normal reclamation procedure as pursued by The Montana Power Company in the past in the installation of its 1500 miles of buried gas transmission line will be applied to this installation. Backfill, compaction and proper re-seeding restores a pipeline right-of-way to its original appearance.

Exhibit 4

Answers to the rest of the questions you've asked in this letter, as well as the two following letters of January 12 and January 24, are being developed and will be sent to you as soon as the necessary information can be gathered and the questions fully answered.

I am enclosing a copy of our power conservation booklet that you requested in your January 12 letter.

A copy of Puget Power's comparable publication is also enclosed.

Yours very truly,

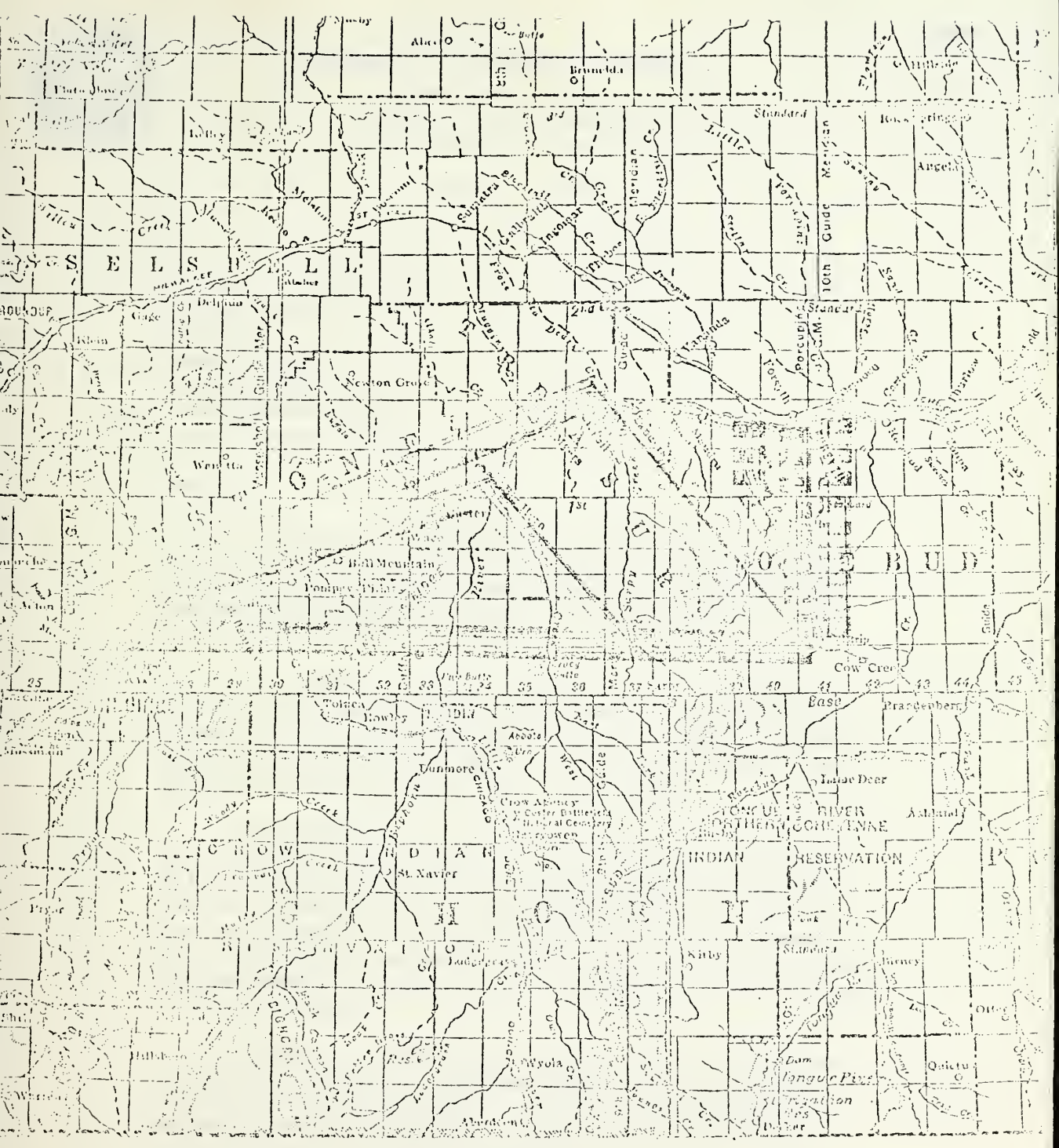
Carl R. Anderson

Carl R. Anderson
Manager, Environmental
Protection Department

CRA/by

bcc: J. A. McElwain
W. H. Coldiron
R. A. Hofacker
J. T. Evans
R. J. Labrie
W. J. Finnegan-PSP&L

Exhibit 4



LEGEND

WATER LINES

230 KV ELECTRIC TRANSMISSION

POSSIBLE CORRIDOR ROUTES

THE MONTANA POWER CO.

DRAWN		SCALE	NTS
CHECKED	T.S.	DATE	17 JAN 73
APPROVED		NO.	

Exhibit 4

Exhibit 4

BOARD OF CRIME CONTROL
1336 HELENA AVENUE
HELENA, MONTANA 59601
TELEPHONE NO. 449-3604

February 16, 1973

IN REPLY REFER TO:

John S. Anderson, M.D.
Director
State of Montana
State Department of Health &
Environmental Science
Helena, Montana 59601

Dear Sir:

In response to a letter from your Technical Writer, Mr. Daniel Vichorek, on the City of Colstrip, we are giving you the information we have in-house related to a subgrant where we funded manpower and equipment for Rosebud County. The City of Colstrip is in that County.

I am enclosing parts of the subgrant, giving you what data we have and information showing the budget page of what we are doing to assist them in trying to take care of any police impact in that area. It will also explain what they believe they can do from added taxes in the years to come after this funding year has ended.

The academic and professional background from the persons contributing information on this is from, what we believe, the expertise in that area, such as the District Judge Al Coate, the County Attorney, the Sheriff and the Juvenile Probation Officer. Since this grant was awarded, the City of Forsyth and the County of Rosebud have consolidated. I believe this will give them even better coverage from the additional manpower that we have funded to cover the impact of this Colstrip area.

Montana Power Company has asked assistance in law enforcement in Colstrip itself. As you know, this is not an incorporated city but a privately owned town. They are having problems with the local sheriff enforcing the law, as their director wants to limit what an officer can do inside the Colstrip area. We have tried to look at the entire county's problems in these matters. The other coal companies have given us what information they have of what they

Exhibit 4

believe their impact will be in the surrounding areas. The information I am sending you is the best that we have been able to come up with at this time. Some of the figures and data is from the State Planning Office here in Helena. Others come from the local law enforcement and criminal justice people.

I hope this will be of some help to you.

Sincerely,

BOARD OF CRIME CONTROL

Laurence L. Lytle

Laurence L. Lytle
Law Enforcement Advisor

LLL:sac

Enclosures

Exhibit 4

COAL INDUSTRY DEVELOPMENT IMPACT AREA

The estimated population increase in Rosebud County due to renewed COAL activity is projected at 700 families or about 2,800 persons. This is a county of 6,032 population; 5,042 square miles; with 281.75 miles of improved roads; 1,391 of unimproved roads and a taxable valuation of $10,559,000.00. It is a fifth class county with the city of Forsyth as county seat and a population of 1,873. Forsyth is a third class city. Within the county boundary is the Northern Cheyenne Indian Reservation, with the towns of Lame Deer, Birney, Ashland, Colstrip, Finch, Rosebud and Angela. These towns are prefected by the Sheriff and five officers. The city of Forsyth has a chief and three officers, three civilian dispatchers and two part-time dispatchers.

The COAL development is solely a private enterprise, and it is felt by local government that they can assume the added costs from a broader tax base provided by the coal industry. If funds are transferred from the ABM area to Rosebud County to assist for one year, local governments can then support the additional man-power to other needs within the Criminal Justice System.

It has been determined by Montana State officials that the COAL development sites will create a primary impact area which should receive planning priorities. A permanent industry will develop with an increasing and permanent population.

In requesting the transfer of funds from the ABM area, we have estimated a one year funding period from September 1, 1972 to August 31, 1973.

Exhibit 4

PROJECT BUDGET

Category:

DESCRIPTION	FROM FEDERAL FUNDS	*FROM LOCAL FUNDS	FROM IN-KIND SERVICES	TOTAL PROJECT COSTS
A. Personnel				
Deputy Probation officer	8,000.00			8,000.00
Deputy Sheriff	5,931.00			5,931.00
Secretary	4,800.00			4,800.00
District Judge (Proj. Dir. 10%)			2,200.00	2,200.00
Chief Probation officer (20%)			2,040.00	2,040.00
Sheriff (20%)			1,400.00	1,400.00
Employee Benefits	2,224.04			2,224.04
TOTAL PERSONNEL	20,955.04		5,640.00	26,595.04
B. Consultant Services				
TOTAL CONSULTANT SERVICES				
C. Travel				
20,000 miles @ 12¢ Probation off.	2,400.00			2,400.00
Expenses-Maintainance Sheriff car		2,400.00		2,400.00
TOTAL TRAVEL	2,400.00	2,400.00		4,800.00
D. Equipment Patrol Car	2,925.00	975.00		3,900.00
2 Mobile radios 4 freq+installation	1,210.00	400.00		1,610.00
Graphic Camera Kit	525.00	175.00		700.00
Typewriter	220.00	75.00		295.00
Psychological Testing kit	276.65	92.00		368.65
2 Monitoring cameras	375.00	125.00		500.00
2 Video Monitors	742.50	247.50		990.00
TOTAL EQUIPMENT	6,274.15	2,089.50		8,763.65
E. Operating Expenses				
Installation of monitoring equip. including wire	600.00	200.00		800.00
Rent-line charge Mountain Bell tel.	15.00	5.00		20.00
TOTAL OPERATING EXPENSE	615.00	205.00		820.00
TOTAL PROJECT COSTS	30,244.19	4694.50	5640.00	40,578.69

*Please indicate if from other than local sources

Exhibit 4

This section constitutes the heart of the grant application. It is the applicant's detailed statement of the project -- its aims, precisely what will be done, who will be involved and what results can be expected. Together with the project budget, it provides primary evidence for LEAA and the Governor's Crime Control Commission of the soundness of the project, the care and planning that has gone into its formulation, and the responsibility and qualifications of the applicant and others who will be involved.

SPECIAL REQUIREMENTS

Request for EQUIPMENT must include the following information:

Full description of present inventory
Is equipment an addition to or a replacement of present resources?
Full description of equipment requested, including make and model.

Request for TRAINING ASSISTANCE must include the following information:

Training background of applicants involved.
Full description of school, including agenda, course out-line, curriculum and instructors. Attach official brochure whenever possible.

THIS NARRATIVE SHOULD FULLY EXPLAIN ANY ITEM NOT COVERED FULLY ON BUDGET PAGE.
Use Continuation pages if necessary

The Following program is designed to alleviate the pressure on law enforcement in the 16h Judicial district caused by the sudden influx of people into Rosebud County.

Personell:
Deputy probation officer to hired from federal funds.
Deputy Sheriff to be hired from federal funds.
Secretary to be funded from federal funds, services to be shared jointly by Probation office and the County Attorney's office.
Judge Alfred Coate will act as the Project Director and will devote 10% of his time supervising the project.
Irvin Zeitner, Chief Probation officer will devote 20% of his time supervising and training the new probation officer.
Sheriff Andy Schulenberg will spend 20% of his time in the supervision and training of the newly hired deputy sheriff.

Travel:
20,000 miles per year to be traveled by the deputy probation officer needed from federal funds. Computed at 12c per mile.
Rosebud county will maintain and support the new or additional patrol car to be purchased. Computed at $200.00 per month.

APPLICATION DISTRIBUTION:

For Units of Local Government

White copy - applicant agency
Green copy - Region Council
Gold copy - Region Council
(to be forwarded to Crime Commission)

For State Agencies

White copy - applicant agency
Green copy - extra
Gold copy - Governor's Crime Control Commission

Exhibit 4

Equipment:
Patrol Car, needed for additional deputy to be hired that will be stationed at Colestrip, Mt.
Two Mobile Radios 4 frequencies, Model MT74TFN 100 Watt including installation. One to be installed in the additional patrol car and one to be installed in the deputy probation officers car.
Graphic Camera Kit, needed equipment by the Sheriff's office.
Psychological Testing kit, usefull instrument needed by the Juvenile Probation office.
Two WV-o33v CCTV/VTR Monitoring cameras.
Two WV-7063P Video Monitors, this equipment to be used to be able to monitor the jail at all times. The jail is used jointly by the Sheriff and the City Police.

Operating expenses:
Installation of monitoring equipment and including the necessary wire.
Line rental charges to Mountain Bell Telephone Co.

Exhibit 4

The MONTANA POWER COMPANY

1973
ENVIRONMENTAL SCIENCES
DIVISION

GENERAL OFFICES
ELECTRIC BUILDING
BUTTE, MONTANA 59701

January 12, 1973

Air Quality Bureau
Montana State Department of Health
and Environmental Sciences
Cogswell Building
Helena, MT 59601

ATTENTION: Mr. Don Holtz

Gentlemen:

We understand you do not have copies of Stearn's "Air Pollution" which we referred to in our statement at the public hearing in Miles City on January 5, 1973.

Enclosed are copies of Pages 535 to 549 from the Second Edition of Volume III of that text. Although this chapter discusses the water quality aspects of air pollution control, the references to the use of wet scrubbing systems for fluoride control, especially Pages 540 and 541, make it clear that this equipment can be expected to minimize residual fluoride emissions from our proposed operation.

Also enclosed is a copy of Part 1 of Chapter 5 from Volumn I of the same text. We referred to this in our discussion of radioactive emissions.

Finally, we are enclosing copies of a chapter entitled "Environmental Radiation From Pressurized Water Reactors" from "The Environment and Nuclear Power" by Dr. James H. Wright, Director, Westinghouse Environmental Systems Department. Pages 14 and 15 give information on naturally occurring radiation which we believe helps to put any expected radiation effects from our Colstrip plants into proper perspective.

Very truly yours,

D. T. Berube
Thermal Generation Engineer

DTB/mje
Enclosures

Exhibit 4

Exhibit 4

STATE OF MONTANA

SUPERINTENDENT OF PUBLIC INSTRUCTION

HELENA 59601

DOLORES COLBURG

RECEIVED
FEB 23 1973
ENVIRONMENTAL SCIENCES
DIVISION

February 22, 1973

Mr. Daniel Vichorek
Technical Writer
State Department of Health
and Environmental Sciences
Helena, Montana 59601

Dear Mr. Vichorek:

I have your letter of February 6 concerning the projected population increase in the Colstrip area, and I am pleased to offer pertinent information.

We have been in touch with the schools in the Colstrip area and our supervisors have discussed with school personnel the building and curricular expansion for their elementary and secondary schools.

We have made our School-Community Assistance Process available to school officials, and we are prepared to offer professional assistance in every way possible. A description of the process is attached for your information. The School-Community Assistance Process is under the direction of Dr. L. E. Scarr, Assistant Superintendent in my office.

If I can be of further assistance, please let me know.

Sincerely,

Dolores Colburg

DOLORES COLBURG
State Superintendent

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ENVIRONMENTAL SCIENCES
DIVISION

The MONTANA POWER COMPANY

GENERAL OFFICES
ELECTRIC BUILDING
BUTTE, MONTANA 59701

February 20, 1973

Daniel Vichorek, Technical Writer
Dept. of Health
Helena, MT 59601

Dear Mr. Vichorek:

Once again I apologize for the delay in answering the rest of your inquiries of January 3rd and 24th. The following discussion is offered in reply to the balance of your questions.

January 3 Letter

19. Why is the power plant needed?

This Colstrip Project is needed to supply the electrical energy required by the customers of M.P. Co. and PSP&L Co., and other citizens of the Pacific Northwest. That customer requirement is based on the projection of past usage adjusted for known changes. The historical peak and energy loads for the M.P. Co. are attached, as well as the projected loads, resources and deficiencies for M.P. Co. and PSP&L through 1982. The projection, which was previously presented to your department with our comments on your Draft EIS, shows the increasing requirements and deficiency and the need for additional electrical energy.

The M.P. Co. generation, together with purchased power, served the 1971-72 winter peak load with 124,000 kW to spare. But 144,000 kW of power purchased in 1971-72 will not be available to M.P. Co. by the winter of 1975-76 because the electric suppliers now selling us this power will need it for their own customers. An additional 27,000 kW of purchased power will be lost to M.P. Co. by the winter of 1976-77.

The M.P. Co. load historically grows at approximately 5% per year. We see nothing which will substantially change this. If the Colstrip units are not constructed, M.P. Co. will be 174,000 kW deficient by the winter of 1975-76. M.P. Co. will be deficient by 246,000 kw by the winter of 1976-77.

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The increasing requirement for electrical energy is the result of our expanding productivity which has made us the greatest industrialized nation in the history of mankind. The use of electrical energy has also increased our life expectancy, decreased our work week, and allowed us to develop the casual pleasures of our life style, such as TV, radio and light to increase our productive hours and expand our horizons. Energy protects us from the elements and adds to our security. Electrical energy is truly a necessity in our modern lives.

There is no alternative to the Colstrip Project. No other technically proven source of electrical energy is possibly achievable in time to supply the electrical needs of the M.P. Co. customers. The only technically proven alternate energy source available in the size of this project is nuclear fission. That source would not only be much more expensive, but could not be constructed by 1975. Eight to ten years are required for such a nuclear project, and there would still be much environmental concern by the public.

Other sources of energy are alluded to by uninformed persons, but such alternatives are not available. Such sources mentioned are wind, solar, organic waste, geothermal and MHD.

Wind power has been used for pumping water wells and charging batteries throughout the world for years. These are sporadic uses and adaptable to the caprice of nature. 700 MW of reliable sustained electrical energy could not be developed with such a system.

Solar energy sites are limited to 35° north and south of the equator. Stronger and more continuous sunshine is available in that area. Even there, with continuous sunshine for reliability (which of course, is not available) a 700 MW output would require about a 70 square kilometer collecting area with a collecting efficiency of 10%. (See Scientific American Vol. 224 No. 3 Sept., 1971, p.67) Montana is not geographically located to even consider such an installation.

Decomposition of organic waste holds interesting, but limited possibilities for future power generation. The city of Missoula is an example of the current technology of such a process. That metropolitan area utilizes the methane generated in their sewage treatment facility, and realize only enough gas to partially power a 187 kW electric generator. Their average electric load in 1972 was about 1800 kW per day, ten times the usable methane realized from their waste processing.

Geothermal is also of limited applications. Such development is confined to unique geological locations where the earth's heat is near the surface, such as the Geysers in California. That prime geothermal project supplies only 302 MW of electric capacity, less than

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one half of the proposed Colstrip Project, and it has been under development since 1956 when the well drilling began in earnest.

The sources listed above are just being investigated or developed, but have hardly progressed beyond the laboratory pilot plant stage. Even MHD (Magnetohydrodynamics) utilizing clean burning natural gas in Russia, which is a rapidly diminishing energy source in most parts of the world, has not been developed beyond 25 MW of capacity.

Coal is the most realistic energy source available for conversion to electrical energy at the present time with known technology. Other fossil fuels are in short supply whereas coal is an abundant resource. Nuclear fissionable material is also limited in supply at the present time, although that will be resolved when the FBR is developed. Developable hydro sites are limited, and such projects have limited public acceptance.

The proposed Colstrip Project is truly the only technically proven and possibly achievable source of electrical power required to supply the increasing demand for electrical energy by the customers of M.P. Co. and PSP&L .

20. Is the demand for power growing faster than the population of Montana?

Yes. For example, the residential customers of The Montana Power Company increased from 131,203 in 1961 to 151,334 in 1971, about a 15% increase. Whereas the individual residential customer average usage increased from 4,177 kilowatt hours per year to 6,032 kilowatt hours per year in the same period of time, about a 44% increase.

21. What accounts for this increase?

One of the classes of customers whose use of electricity has increased the most has been the farmer. Farms now use as much electricity as many small industrial concerns. Television has been one of the larger contributors to the use of electricity. Lights of all kind contribute less to the growth of electric demand than many other appliances, such as ranges and water heaters.

The previously referenced residential increase has been lightening the physical work for the homemaker and increasing leisure time, brightening evenings for more reading and other pleasures, as well as enhancing law enforcement, increasing safety on the streets and highways. But the residential use amounted to only about 20% of the total sales of The Montana Power Company in 1971. The balance of the electrical sales provided jobs, goods, services and conveniences in our commercial and industrial world. Some of that use was for environmental improvement, and more will be required for that use in the future as additional towns install the sewage treatment equipment required by

recent federal law, as proper disposal or recycling of the ever increasing amounts of solid waste is developed and as more emission sources are controlled to improve air quality. With reference to that, about 30,000 to 40,000 kW of the capacity of the Colstrip generation will be consumed at the plant just to operate the air quality control equipment being installed.

22. Use of power by percentage in Montana to industry, home heating, aluminum smelting and all other uses?

The state totals are not readily available, but those figures for The Montana Power Company system in 1971 were:

Industrial - 2,178,169 Mwh
Home Heating - insignificant *
Aluminum Smelting - 0
All other uses - 2,392,116 Mwh

* Only 1,483 dwelling units are equipped with electric heat on The Montana Power Company system, and many of them are seasonal dwellings, such as summer cabins or ski resorts. The overall electric consumption for home heating is very small since natural gas has more than a 95% home heating saturation in the company service area. Other fuels for home heating include oil, coal, propane, wood and hog fuel.

23. Power exported out of state will be delivered where, and will be used for what?

The Montana Power Company system is an integral part of the North west Power Pool and the Western Systems Coordinating Council as described by Mr. John Ellis of Puget Sound Power & Light Company in his presentation to the board at the public hearing in Miles City on Janua 5. We presently have 230 kV ties south to the Bureau of Reclamation and Pacific Power & Light at Yellowtail Dam, southwest near Lima to Utah Power and Light and Idaho Power Company, and west to Bonneville Power Administration and Washington Water Power Company at Anaconda ar Hot Springs.

The power produced at Colstrip Units #1 & #2 largely will be consumed in Montana. Exported power will flow through The Montana Pow Company system to any one or all of the interconnected systems at various times with Montana Power Company and Puget Sound Power and Light Company owning and controlling the output of this project equall for each unit. The power will be used to satisfy the customer require ments of those interconnected utility systems, and will be a necessary part of total supply required to maintain the integrity and reliabilit we all expect and demand of our electric service.

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24. What accounts for the increased demand for electricity in the area where the power will be delivered?

Generally the same things that increase the demand in Montana as described in answers 19, 20, & 21, but compounded by greater population increases in many areas in the Pacific Northwest than the increase experienced in Montana. People migrate to and are productive in the places where the most opportunity and the greatest number of jobs are available. Montana's limited growth indicates a lack in those.

25. What are the economies of hauling coal to the generating plants near the out of state load centers vs power transmission from mine-mouth generating plants?

The economies are unique with individual company situations as shown by the fact that coal continues to be shipped to load centers even for new plants being built in the Midwest by some companies. And others, namely Puget Sound Power & Light Company and Montana Power Company, are investing in mine-mouth generation.

The power produced at Colstrip Units #1 & #2 largely will be consumed in Montana. System Montana flow studies indicate that the only transmission necessary for the project under application would be lines wholly within Montana. The project will not require new transmission westward outside the State.

From a regional reliability standpoint, construction of the generating plant and transmission lines in Montana will significantly improve the load flows within the coordinated network of the Western Systems Coordinating Council, strengthening this traditionally weak portion of the system. With the generating plant at Colstrip, load flows eastward into the State will be reduced and at certain times reversed.

Bonneville Power Administration (BPA), the Washington Water Power Company (Water Power) and Montana Power Company have interconnections in western Montana. Puget Power has interconnections with BPA and Washington Power in western Washington, thus Puget Power's share of the project output will be furnished to Puget by displacement through the company's interconnections with BPA and Washington Water Power. In other words, Puget Power's share will be consumed by customers of BPA and Water Power in the eastern portion of the Northwest Power Pool while an equivalent amount of power will be supplied to Puget Power in western Washington. This procedure eliminates the need for interstate transmission line construction and reduces the line losses of the involved utilities.

With the only transmission required located in Montana, clearly the evidence overwhelmingly favors transmission as the alternative to hauling the coal in this instance. The economics of these

alternatives as applied to other generating plants would, of course, vary with the capacities, plant locations and load locations involved.

Also, definite advantages do exist with an electric transmission line investment, compared to shipping coal. The energy transportation over the electric transmission line would not be exposed to future escalation of freight rates, and the possibility of interruption of energ delivery caused by transportation labor disputes would be eliminated.

January 24 Letter

1. Have you definitely decided on venturis?

Yes.

2. What leads you to believe the venturis will perform up to par over the life of the plant?

The EPA set their recently adopted "stationary new source emission" standards on the fact that scrubber technology was proven, as Dan Berube pointed out in his statement in Miles City.

Also, Bechtel Corporation, the engineering contractor on the Colstrip Project, of world-wide reputation, organized a research team for the investigation of scrubber technology. They concluded venturi scrubbers are feasible and in fact developed, and recommended they be used on this Project. In addition, the M.P. Co. engineering staff investigated this problem in depth and visited numerous scrubber installations throughout the country. Their findings and observations confirmed Bechtel's results and further recommended the use of venturi scrubbers. The expenditure of $20 - $25 million is never done lightly. Every check and evaluation achievable has been pursued prior to committing that amount of money for this equipment.

I would also like to point out that the plant operation is entirely dependent on suitable scrubber performance. The plant cannot be operated without the scrubbers in service, as there will be no by-pass installed. If the scrubbers plug off, the combustion gases cannot be exhausted.

3. Other reports on the operation of venturis on other plants similar to the Colstrip development?

Attached is a review of "the State of the Art" of scrubbing, summarizing the development of scrubbing. We have reviewed many technical reports on other installations, as you no doubt have. We are currently investigating operating performance of this unique venturi application with a pilot installation on the J. E. Corette unit at the Billings Plant for which we have received authorization. Design parameters and performance characteristics developed from the operation of this pilot installation will be the basis for building the Colstrip facilities.

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4. Have you checked into the Krebs-Elbair type scrubbing device?

Yes. It was our decision that if particulate only had to be removed, such equipment could possibly have been used. A limited amount of SO_2 would also be removed, but the capacity and flexibility of this device is much more limited than the more sohpisticated venturi selected. The Krebs could possibly remove up to about 20% of the SO_2 with the Colstrip ash characteristics. The venturi, equipped with delay tanks and utilizing the ash for scrubber liquor, will result in higher SO_2 absorption rates up to 40%. A review of this scrubbing technique is being developed and will be sent to you when done, probably this week.

5. Are the concentrations of sulfur, fluoride and other pollutants uniform throughout the coal seam?

The analysis of various coal samples from the Colstrip seam show minor variations in the sulfur and fluoride content. The coal has also been tested for mercury. Test results have already been submitted to the Department of Health. The majority of the sulfur occurs as pyrite nodules, deposited in fractures in the coal and as fossil replacement. Incidentally, the larger pyrite nodules are rejected by coal pulverizers in the Corette plant, and the Colstrip plants will be equipped with similar pulverizers.

6. Which trace elements will be looked for in the West Associates analysis?

The elements being investigated are arsenic, boron, beryllium, cadmium, chromium, fluoride, germanium, mercury, manganese, nickel, lead, selenium, vanadium, yttrium. The study is not yet completed.

M.P. Co. has now entered into an agreement with the Endowment and Research Foundation at MSU to investigate the same 14 elements in Colstrip coal. This program is just starting. Some core hole coal samples have been collected. Additional sampling will establish a proper pattern for full evaluation of the coal deposit, both laterally and vertically. This information, in conjunction with West's information on disposition during combustion, will lead to positive identification of emissions.

7. When will the results be available?

West Associates have some data that is being evaluated, but is not available until the project is completed, which should be during the last half of 1973.

The MSU investigation is just starting. Assuming no delay in establishing techniques and procedures, data should start becoming available by mid-year.

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8. What other facilities will be built for the construction workers?

A construction camp is being erected by M.P. Co. for construction workers. The camp design has been reviewed and approved by the State Department of Health, Environmental Services Bureau. The camp will be equipped with a kitchen-dining facility that will handle 300 people, and which can be expanded up to a capacity of 500 people. There is also a recreation hall included in this camp.

A 20 unit camper area, including a central washroom with showers, toilets and laundry facilities is also being developed.

Also, M.P. Co. is developing a 200 unit mobile home park for construction workers. The town of Colstrip is also being expanded by Western Energy Company. Additional homes are being built, and the mobile home park is being expanded. The town development is described in detail in the enclosed brochure summarizing the Ken R. White planning group's recommendation. The town sewage facility was recently expanded by a local special improvement district to accommodate all of the present and planned development. An approved landfill solid waste disposal area is also available.

9. What slimicides would be used in the towers at Colstrip?

The precise slimicides have not been selected, as the potential problem has not been evaluated at this time. Any chemical treatment required will certainly be accomplished with acceptable and approved chemicals or slimicides.

10. How will slimicide bearing water be treated?

We do not know at this time. Treatment will depend on the amount and type of slimicide required.

11. How will the water soluble portions of the ash be prevented from reaching the ground water?

Answered previously in question #6 of your January 12 letter.

12. What is the current status of construction at the plant site?

No activity has been underway since last December, when the balance of the concrete footings and foundations was poured for Unit #1. Steel is expected to start arriving early this spring.

13. When will the full year's meteorological report be available?

The total year summary is expected within a month and will be sent to you as soon as it is received.

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Answers in previous letters cover the balance of your questions asked in the last paragraph of your letter of January 24. If additional information is required, please let me know.

I believe this completes the information required in your three letters with the exception of detailed design and operating specifications of the plant requested in your January 24 letter. As discussed with you, this information will be developed directly with Don Holtz by our engineering department.

Yours very truly,

Carl R. Anderson

Carl R. Anderson
Manager, Environmental
Protection Department

CRA/by
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ENVIRONMENTAL POLICY CENTER
324 C Street, S.E., Washington, D.C. 20003
(202) 547-6500

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COMMENTS OF:

THE ENVIRONMENTAL POLICY CENTER

ON

THE DRAFT ENVIRONMENTAL STATEMENT

ON THE PROPOSED MONTANA POWER COMPANY

PLANT AT COLSTRIP, MONTANA

Submitted by:

Bruce C. Driver

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The Environmental Policy Center believes that the Draft Environmental Impact Statement (hereafter known as the Draft) does not adequately measure the environmental impacts stemming from the construction and operation of a 700 mw electrical generating plant at Colstrip, Montana. We recommend that another draft statement be circulated for public comment prior to the preparation of a final statement.

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On page one of the Draft it is said that mine mouth plants are favored, "at least from the owner's standpoint." What about the standpoints of the citizens of Montana whose value preferences, as mirrored in the policy statements of section 3 of the Montana Environmental Policy Act (Montana Statutes 69-6503), are those which the state government is charged with implementing in its actions? In the Northern Plains there is very great risk that decisions made by private enterprise in a climate of indirect governmental subsidy and articulated in dollars and cents figures will be allowed to be determinative of the Region's future. The very real but intangible preferences of the people of the Region may be given short shrift. Nowhere in the Draft is there any example that the State has attempted to measure citizen feelings about the precedent-setting Colstrip Plant and related development. It may be that much useful information is being elicited by the comments to the Draft and attendant public hearings. However, in light of the complexity of the suggestions of the North Central Power Study, Wyoming-Montana Aqueduct Study and the Colstrip Plant's relationship to the concepts of these two studies, it is recommended that the State allow more time to pass before a decision be made on the question of permitting construction of the Plant. During this time citizen preferences ought to be more rigorously examined, the results of such examination appearing in a second draft statement to be oirculated before preparation of a final statement. The extra time will allow citizens to more fully acquaint themselves with the meaning of the decision regarding Colstrip.

Also on page one, the Draft mentions Venturi Scrubbers, stating that, "There is evidenoe that the venturis will also remove most fluorides and trace metal compounds." In conjunction with the material on pp. 18-20 of the Draft pertaining to trace elements in the coal, this halting statement leaves us with no confidence that the State is aware of the problems which

can result from the buildup of trace elements in the environment or, if it is aware, that it is in a position to control these problems. In light of the spotty history of operation of venturis, we recommend that the State complete further research into the effectiveness of venturis in controlling trace elements which could arise from the coal seams to be mined in order to supply the Colstrip Plant with fuel.

The Draft makes only passing reference to the end use of the power to be generated at Colstrip. That much of the electricity will be consumed in load centers outside the boundaries of Montana should be of concern to those citizens of Montana who have a stake in the continuing availability of those aesthetic amenities, the lack of which in centers such as those to which the electricity from Colstrip may be sent, attracted them or their forefathers to Montana. That we live in a federal system in which much commerce is interstate will not mitigate the sting in the minds of many Montanans if most of the benefits from power development in Montana flow to private owners of capital and consumers outside the boundaries of the state, whereas most of the costs are imposed on Montana. At the very least the State ought to provide a more detailed picture of end-use of Montana resources in the "Description of Proposed Action."

We would like to see greatly expanded treatment of the pipeline transporting water to the Plant from the Yellowstone. This most cursory explanation does not let the public know what the size of the pipeline is to be or what the effects on the Yellowstone are of the withdrawal of the given amount of water, to name but two of the deficiencies which must be remedied.

In failing to discuss the strip-mining for coal and attendant problems of land reclamation necessitated by the Colstrip Plant, the State has made a serious mistake. If the Plant is permitted to be constructed, coal will be strip-mined, regardless of the fact that a later environmental impact study

on strip-mining may indicate that satisfactory land reclamation is unlikely. Construction of the Plant is the cruoial event foreclosing honest consideration of future environmental impacts because of the pressure which will be exerted to allow coal to be strip-mined to fuel a plant which has already been certified and constructed. A revised draft must contain information on land reclamation technology and its physical ability to bring about satisfactory reclamation in the Colstrip area. Furthermore, the economics of reclamation and the institutional enforcement mechanisms of the State should be examined.

Section 5, Construction and Location, on page 3 of the Draft demonstrates that the State has little knowledge of or control over populations fluxes associated with construction of the Plant and thereafter. Where will the 800-900 men required for construction and their families live? Who will provide services for them? And what will happen to these services after these men and their families depart? The State must answer these questions before it makes a decision on the Plant. If it cannot answer them or if it allows private actions to determine the answers on an ad hoc basis, Montanans can be sure that they are on the road to seeing their state Appalachianized.

Page 8 of the Draft raises several points which are not effectively treated in the Draft. Under D., "Historical Values", the statements are made that "The archaeology of this area is not well known. This portion of Montana may contain a great wealth of historically significant archaeological material." The logical conclusion of this is to conduct a reconnaissance of the area believed to be affected by the Colstrip Plant and the supplying coal mines before permitting the construction of the Plant.

Regarding E, "Recreation", the importance of the Colstrip area and surrounding country to the national public should be stressed. Although not spectacular country like that found in the national parks and wilderness areas of Western Montana, Southeastern Montana is the epitome of the great rolling plains and, as such, occupies an important niche in American cultural history.

To the urban easterner, the Indian and ranching cultures which have developed on these plains have values of their own, apart from any aesthetic amenities offered by the wilder areas of Western Montana. Further examination should be made of the national demand for the recreational amenities offered by the Colstrip and surrounding areas before even part of the area is committed for power development.

The section on Meteorology leaves something to be desired in our opinion. The major east-west storm track across the United States does not pass through the center of the state. No major storm track crosses any part of Montana or, for that matter, anywhere near the state. Low pressure systems from the Pacific Northwest generally follow a trajectory which takes them southeast from Washington or Oregon across Utah into Colorado, New Mexico and, sometimes, Wyoming before they turn on a more easterly path. Storms not originating in the Northwest may form anywhere along an arc from Colorado through Texas, the Gulf and up the East Coast, but only rarely will a major storm originate in Montana. This is why precipitation levels are low and why no satisfactory, eccnomically feasible technology of land reclamation for arid Northern Plains lands has been developed.

On page 12 of the Draft, it is said that "Emissions are expected to drift to the east." It is probably true that winds in the Colstrip area blow from west to east more than in any other direction. However, strong and prolonged northerly and northeasterly winds associated with arctic air masses may interrupt the west to east pattern for a substantial portion of the fall and winter months. And in the spring and summer, a southerly air flow may predominate for lengthy periods of time. We suggest that the State should have a better grasp of wind conditions and their variability before allowing construction of the Colstrip Plant.

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Regarding "Impacts Other Than Emissions" there is a disturbing reliance on future willingness of Montana Power Company to do what is necessary to avoid damage to the environment. For example, on page 25 of the Draft, "The applicant has indicated that they will selectively landfill the ash if groundwater purity is threatened." Later, "Aeration equipment can be easily added...if an odor problem arises...." Will the state require it? The history of voluntary compliance in the utility industry is not such as to permit us to have confidence that action will be taken when necessary. The State must be able to assure its citizens that it has the power to assure that proper steps will be taken well after the construction of the plant is completed and when power is being produced. Who will monitor the Plant on a continuing basis? What are the sanctions which can be imposed if there are violations of state and federal law and regulations? It may appear that the answers to these questions are not the subject of an environmental impact statement. However, such information is vital and, indirectly, has an impact on the natural environment. Maybe this is why federal NEPA statements now carry extensive information about monitoring, lease forms, stipulations, etc.

On page 26 there is no indication that the State knows what the effect of alternative modes of sewage treatment are. If the state did know, it might have decided that a decision should not be made only on the basis of "simplicity of operation and costs" but also on health and welfare criteria.

We have the feeling when reading the section on "Impact on the Human Environment" that the State does not understand the nature or the magnitude of the problems involved. Planning may offset some of the more grotesque dislocations which mining can produce in a region. But no amount of planning can stop long term deterioration of a region when the capital responsible for

the boom departs, unless there are guarantees that the mining industry or the state pay the costs of relocation and maintenance of public facilities. These costs are likely to be staggering. An eroded tax base in the mining region will not help the State raise the money. Diminished agricultural viability of the land which is as well unable to sustain a tourist trade are but two of the ways in which the wealth of a region is diminished by mining. The source of future revenues to be used to mitigate the deleterious impact on the human environment must be the Montana Power Company and other private investors. Financial guarantees should be exacted before construction of the Colstrip Plant is permitted.

In Alternatives to the Proposed Action, the State is faced with discussing alternative means of supplying power to regions most of which are outside of Montana. The discussion on pp. 34-36 of the Draft talks in very general terms and in extremely cursory fashion about alternative energy sources. We submit that the discussion bears no relevance whatsoever to the question at hand. We realize that it may be irregular for one state to talk about alternatives for load centers outside its boundaries, but due to the nature of Montana Power Company's plans for the Colstrip facility, it is this question which should have been discussed.

In addition to erroneously framing the issue for discussion, the State has come forth with a most superficial analysis of alternatives. What would be the actual effect of not constructing the Colstrip Plant? Exactly who, if anyone, may suffer from the failure of this plant to produce electric power at certain times in the future? How many megawatts would have to be produced at some other power plant? How can we know what the parameters of an alternatives discussion are if we do not have some numbers to go on? A revised draft of the environmental statement must answer these questions.

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Solar energy is more than in the research stage at this time. In fact the equipment necessary to collect and store energy from the sun for heating, air conditioning and ventilation in residences is in the nature of plumbing, not space age technology. Insofar as the electric power generated at Colstrip may be for these residential purposes, solar power would be a feasible substitute for Colstrip power were it not for the fact that much of this power appears to be headed for the cloudy Pacific Northwest, one of the few areas of the United States where solar power for residences may not be viable at this time.

Geothermal resources present much less of an "unknown" at this time than does satisfactory land reclamation technology in the Northern Plains. One study, "Geothermal Energy", prepared by Walter Hickel and staff for the National Science Foundation presents the following table entitled "Geothermal Energy Resources Potential":

	1975	1985	2000
Power (thousands of mws)	0.75	132	395
Electrical Energy* (millions of mwh)	5.913	1041	3114
Oil Equivalent** (millions of Bbls/day)	0.024	4.213	12.60

*90% load factor

**3,412 BTU/KWH and 5,800,000 Bbl of oil used at 40% conversion efficiency

These are estimates made by a Panel on Geothermal Energy Resources, U.S. Dept. of the Interior, August 1972. They represent the amount of electric power possible from geothermal sources at certain times in the future. Data from this report indicate that geothermal power could be considered as an alternative source of power for the Pacific Northwest.

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Missing from the section on Alternatives is consideration of the alternative of conservation of energy. A new draft environmental statement might point out, with reference to the Office of Emergency Preparedness's study, "The Potential for Energy Conservation," October, 1972, that there are substantial savings available in industrial, residential and transportation sectors of our energy-using economy from conservation measures. The OEP study suggests energy conservation measures can reduce nationwide energy demand by as much as the equivalent of 7.3 million barrels per day of oil by 1980. How relevant the potential savings from conservation of energy measures suggested by the OEP Report are to the question of whether or not to permit the construction of a plant at Colstrip cannot be known in the absence of more data regarding end-use of the power. Assuming that most of the power will start to flow to load centers in the Pacific Northwest in the mid-1970's and that the power will be used primarily for residential and industrial purposes, the State might address itself to such measures as more efficient home insulation and the use of taxes to encourage more efficient energy use in industries of the Pacific Northwest. These are but two of the mid and long-term measures suggested in the OEP study as real alternatives to the continuation of the construction of power plants to meet growing demand. Of course the State of Montana has no direct control over whether or not conservation of energy measures are implemented in those load centers to which power generated at Colstrip will flow. Yet the fact that these alternatives exist provides ample justification for the refusal of the State to allow its lands and culture to be disrupted in order to supply areas which have not implemented conservation measures. The State may want to withold permission for the construction of the Plant at Colstrip pending an examination of implementation of conservation and other alternatives measures in the load centers to

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which Colstrip power will flow. In any event, further examination of all alternatives should be made. The results of this examination should be published in another draft of the required environmental impact statement.

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CONCLUSION

While we believe that the State has made an admirable beginning of the arduous task of examining environmental impacts, we must underline the fact that the Draft is only a beginning. The Draft simply is not a satisfactory document on which to base a decision regarding the construction of the Colstrip Plant. We have indicated where we think the Draft is deficient. We think that the procedure to follow is circulation of another draft in which these deficiencies can be remedied.

Perhaps if the Colstrip Plant were but one, isolated plant, we would not be so concerned that the State comply rigorously with the Montana Environmental Policy Act. But, whether or not the North Central Power Study, as such, is defunct, pressures for development on an enormous scale of Northern Plains coal and power facilities are destined to increase to levels which will be hard to resist unless the State is fully aware of the environmental problems involved. State governments in the Northern Plains will get buried in the rush of private and federal governmental interests to develop the riches underlying the Plains regions, unless these States begin early to examine the complex environmental and social problems of development. States must learn to extend their examinations into problem areas heretofore left to the federal government, such as alternatives to conventional power plants supplying multi-state areas. We realize that this Draft does not represent the total effort of the State of Montana regarding electric power production or strip-mining in Montana. Nevertheless, because of the importance of the Colstrip Plant decision, we feel strongly that the State should more fully examine the variables affecting this decision in another draft.

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Student Environmental Research Center
U of Montana, Missoula

Northern Plains Resource Council

TO THE STATE DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES

This statement ~~is being transmitted~~ was sent by air to Miles City. Because of transportation difficulties ~~we will not be able~~ they were not able to attend the hearing. We are asking the Northern Plains Resources Council to read the statement in our absence. This statement was prepared by

Clancy Gordon
Arnold Silverman AS.
Phillip Tourangeau P.T.
William Tomlinson WDT
John McBride JKM

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7) inadequate data throughout upon which to judge the Draft, and hence offer comment.

Comments upon specific portions of the Draft Supplement follow.

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Fluorides

According to the DS, the proposed Venturi scrubbers for the Colstrip generating plant should remove 97-99+ percent of the fluorides from the gaseous and particulate emissions of that "proposed plant" presently under construction. The Department of Health and Environmental Sciences utilizes a report from the Stauffer Chemical Company to demonstrate the efficiency of Venturi Scrubbers in removing fluorides from the Stauffer operation at Ramsey, Montana.

A 1972 study by the personnel of the University of Montana Environmental Studies Laboratory of fluoride accumulation in over 500 samples of flora, fauna and soil collected around the Stauffer Chemical Company's operation at Ramsey demonstrate the effects of fluorides that are not removed by their Venturi scrubbers. Fluoride analysis of 1971 and 1972 forage collected in the area demonstrate that forage on 11,520 acres (not including Stauffer Chemical Company properties) contained from 35 to 55 ppm of fluoride (dry wt. basis). Furthermore the forage on 4,736 acres had accumulated 55 to 100 ppm of fluoride; and forage samples on 450 acres (again outside of Stauffers property) had accumulated from 100 to 500 ppm of fluoride. Maps demonstrating fluoride levels in the Stauffer plant area are presented in the appendix of this statement.

Probably the most important data collected around the Stauffer Chemical plant which have the 97% efficient Venturi scrubbers is that the fluoride levels in forage collected from all 11 study radii (which covers 80 to 100 square miles) around the plant site were above the normal fluoride background level for forage of 7 to 10 ppm. Even more revealing is the

Therefore we cannot accept your conclusion that no fluoride damage will occur because your diffusion model demonstrates to you that the State ambient air fluoride standard will not be exceeded.

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SO_2

Adequate comment on this section is impossible since neither the refined diffusion model nor the new meteorological data are presented. Since the Draft Supplement has revised the maximum SO_2 concentration downward by a factor of 3 the importance of the model and meteorological data are obvious.

The DS states that those conditions necessary for the one hour state standard to be violated are "highly unlikely". There is no data to justify this statement in the DS. We submit that the dismissal of the possibility of the occurrence of conditions favorable for violations of State Air Standards as merely "highly unlikely" without further substantiation is a shirking of responsibility on the part of the Department of Health and Environmental Sciences. This is all the more obvious since the DS admits that the revised predicted SO_2 concentration could be $\frac{1}{2}$ or twice actual levels, and that from the State's experiences violations of state standards do occur.

The SO_2 section is further inadequate and difficient since there is a lack of substantiation for predicting F^-, NO_x and particulate concentrations based upon their relative concentration ratios to SO_2.

Effects on Ecosystems

This section, we submit is again deficient and inadequate. Flourides at concentrations of less than 35 ppm in forage will cause damage to cattle. The Intalco Aluminum Company in Ferndale, Washington recently paid $150,000 in damages to a farmer whose cattle were damaged by consuming

Exhibit 4

vegetation contaminated with F^-. The average flouride concentration in the forage was 26 ppm. The DS expects that "dangerous concentrations" of F^- are not expected to occur in vegetation based upon predicted ambient air fluoride levels, but does not substantiate this expectation with data. Nor does it define "dangerous concentrations." Mention of long term concentration of flouride is made in reference to Ponderosa Pine 17 miles from Colstrip, but range grasses in the immediate vicinity of the plant site with 3 year life cycles, are not considered at all. We submit that the DS does not consider the effects of F^- on the ecosystem since wild indigenous animals are not mentioned at all.

Although the DS indicates that no damage to alfalfa by SO_2 should occur, it is difficient in that it does not enumerate those studies upon which this indication is based. Literature on the effects of SO_2 on vegetation is voluminous and research is continuous. No adequate comment is possible without the bases for the DS's indications of no SO_2 damage to Alfalfa.

The DS is less certain about the synergistic effects of SO_2 and other pollutants. It states that data on synergism is scarce, and that there is no indication from the paucity of data that synergistic process would occur which would damage vegetation. Prudence would seem to dictate that a lack of information and a paucity of data would not be the basis upon which to predict an event.

The section on Effects on Ecosystem is further inadequate in that there is no data supporting the expectation that the physical separation of the cooling towers and the stacks would prevent generation of significant

amounts of H_2SO_4. Although the climate in Colstrip is now dry, the DS ignores any increased humidity as a result of the operation of the cooling towers themselves. Clearly, a substantive statement on sulfuric acid mist is possible only by considering increased humidity. The section is further deficient in that the environmental impact of the amount of acid expected to be formed, although "insignificant" is not considered, nor is a "significant generation of acid mist"defined.

Human Health

The subsection entitled human health is grossly inadequate. One need only refer to the record of the December 15th, 1971 hearing on the Anaconda sulfur dioxide SO_2 petition to note the voluminous literature available on the health effects of air pollution. Such a vital subject as the effects of air pollution on human health deserves more than 5 sentences.

We simply have not had time to comment on the sections entitled, Water Use, Dry Cooling Towers, Powerlines, or Power Use.

Conclusions

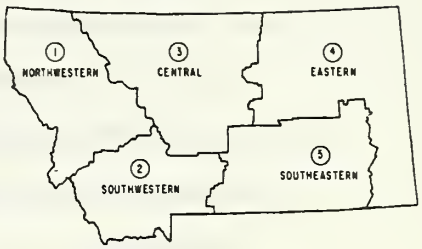
In conclusion we wish to reiterate our objection to the distribution of supplemental materials one day prior to a public hearing which will consider the materials. We believe that the supplemental draft in no way elimates the deficiencies noted in the Draft Statement and in fact is subject to the same shortcomings noted in the draft statement. We therefore urge that the department prepare a revised draft environmental impact statement, as recommended by the Environmental Quality Council, Environmental Defense Fund and Student Environmental Research Center addressing itself to the full impact of this development.

Exhibit 4

EDUCATION -- CONSERVATION

Montana Wildlife Federation

AFFILIATE OF NATIONAL WILDLIFE FEDERATION



STATEMENT PREPARED FOR THE JANUARY 5th PUBLIC HEARING CONCERNING MONTANA POWERS'S APPLICATION FOR CONSTRUCTION OF A COAL FIRED GENERATING PLANT AT COLSTRIP.

My name is Robert Lynam and I reside at 501 Palmer, Miles City, Montana. I am president of the Montana Wildlife Federation and this statement reflects the general policy of that organization.

I have read the draft copy of the Environmental Impact Statement as well as the North Central Power Study and these documents form the basis of my remarks.

The Federations policies reflect concern with the entire environment and while I am concerned with the total environmental consequences of the proposed action, time forces me to narrow my comments to a few. Omission of comment does not imply consent or agreement with the overall plan for the plant or for the energy generation complex in southeastern Montana.

There are two general topics that I will discuss in detail and they are: Air emmissions and water demands.

AIR EMISSIONS:

The impact statement raises the question about the Jim Bridger plant in Wyoming. What will be the effect of emmissions even if the plant complies? Nowhere in the statement do I find this question answered, either about the Bridger plant or the plant at Colstrip. However, the writers summarize in

Exhibit 4

in Item 4 that air quality degradation is a probable adverse effect.

I question also what guarantees that the emission equipment will function as designed? Will the Air Quality Bureau have the ability to stop or scale down operations if the equipment fails? Past experience has taught us that once the investment has been made the regulatory agencies become ineffectual.

The Air Quality Bureau admits in the statement that they expect violations of the 0.25 ppm 1 hour standard for sulphur dioxide. It is difficult to have confidence in these statements when the report states the results are preliminary since input meteorlogical parameters were not founded facts.

TRACE ELEMENTS

The statement contains this quote related to trace elements. "When millions of tons of coal are burned the trace elements become significant potential pollutants." The writers of the statement conclude and I quote, "Very little is known about the trace element content of the coal to be burned at Colstrip. Thorough comprehensive sampling for trace elements has not been done on this coal.

It is important to know how much of these elements will be emitted but it is vital to know the impact of these trace elements upon animals living a normal but stressful life in their natural environment. Will the hunters find eating birds and animals of the area hazardous because of high Mercury levels? The content of mercury and the removal of mercury are admittedly unknowns.

What are the expected deposition levels of fluoride upon the vegetation and ultimately the levels in the animals of the area? What is the fluoride content of the coal and how much will be removed?

Exhibit 4

WATER VAPOR:

The statement contains an estimate of 4 million pounds of water vapor released per hour from the cooling towers and the stacks.

Winter is a very critical time for animals. Will the snowfall increase? Normally available foods and feeding areas may become unavailable to these wintering animals.

WATER DEMANDS.

The water needs for the plant at Colstrip are estimated at 13,000 acre feet per year. Withdrawals in this amount are not expected to have a significant effect on the present flows of the Yellowstone River. However, the Bonneville Power Administration refers to at least two more plants in the Colstrip area in the near future. Other energy companies are planning additional generating plants as well as gasification plants for southeastern Montana.

It is these total water needs which are of great concern to the Federation.

Stabilized flows in the Yellowstone drainage will have adverse effects on the aquatic communities. Paddlefish studies indicate that spawning is triggered by the spring increases in flows. Sauger and walleye depend on clean gravel bars for successful spawning. It is the increase in flows which cleanse the gravel bars of the accumulation of silts.

The water demands can be reduced by incorporating dry cooling towers instead of the evaporative towers. The Federation recommends dry cooling despite the added costs.

The Federation is deeply concerned with the inefficiency of conversion of coal to electrical energy and the high transmission losses. Better methods must be found to convert the non-renewable coal to electrical energy.

The Bonneville Power Administration has requested permission from the Forest Service to run the Colstrip generated power vial high voltage

Exhibit 4

transmission lines through the Magruder Corridor. The Federation opposes this action through this candidate wilderness area.

In summary I find it very difficult and frustrating to make factual comments about the probable impacts of the Montana Power generating plant at Colstrip when the draft statement contains statements such as, efficiency unknown, meteorlogical parameters were not founded facts, no background information, etc. The Montana Wildlife Federation does not oppose the mining of eastern Montana coal, with proper safeguards, but we oppose the granting of this permit until the impacts are more accurately judged and degradation will not occur.

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STATEMENT OF UNITED STATES FOREST SERVICE

Regarding the Draft

ENVIRONMENTAL IMPACT STATEMENT

For

COLSTRIP POWER PLANT

My name is Dan MacIntyre. I am Forest Supervisor of the Custer National Forest, whose headquarters are at Billings, Montana. I am here to make a statement on the behalf of the Regional Forester of the Northern Region of the Forest Service, Steve Yurich, whose headquarters are at Missoula, Montana.

We have previously submitted a written response to the draft Environmental Impact Statement (EIS) to the State Air Quality Bureau and won't go into the details of that document here today. We would, however, like to summarize our views for the hearing record.

The greatest concern which specialists, line, and staff officers of the Forest Service in the Northern Region have expressed, lies not with the Colstrip Power Plant per se, but with the larger areas and issues which will surely follow and hence are associated with the installation of these first two plants. We suggest, therefore, that we cannot put the plant itself in the proper perspective for meaningful comment except as it relates to the total context of these larger areas and issues.

Exhibit 4

Our first and primary concern, therefore, is for the critical need for a more comprehensive study to assure orderly development and the production of needed power from the entire Fort Union Formation Area, in a manner which will prevent, or at least minimize degradation to the environment, traditional uses, and human resources of the area affected.

We believe that an approval for construction and operation of the first two relatively small facilities discussed in the Environmental Impact Statement would act as a precedent for additional plants in the area. An analysis of the cumulative effects of the ultimate amount of mining and the number, size, and location of plants is needed before piecemeal development is undertaken.

Our second area of concern is for the transmission network issuing from the power plant or plants. We are informed that 350 MW of the 700 MW to be produced from the first two proposed plants at Colstrip would be wheeled to the West Coast. This same informational material shows that an additional 1,050 MW would go west from the second two plants being planned by Montana Power and Puget Sound Power and Light. Thus far, we have been unable to determine where the balance of available power will be directed. We are most anxious to find this out since it is not only possible but quite probable that transmission lines will be planned which would have to cross National Forest lands west of Colstrip.

Exhibit 4

Some prominent transmission line corridor possibilities, in light of the above discussion, are:

1. Colstrip, Montana, west to Anaconda, Montana, westerly across the Saphire Range and Bitterroot Mountains via the Magruder Corridor to south of Lewistown, Idaho, then westerly to the load centers.

2. From Anaconda, Montana, to Hot Springs, Montana, to Spokane, Washington, and south and west to load centers.

3. From Anaconda, Montana, to Hot Springs, Montana, following the present Dworshak Hot Springs Transmission Line to west of Dworshak Dam near Ahsahka, Idaho, via the lower Snake River area to the load centers.

The above possible transmission line corridors could involve directly and indirectly National Forest system lands located on eight National Forests.

There is no evaluation as to the possible transmission line corridors, transmission line capacities, and the environmental impacts involved in moving the needed electricity to the Pacific Northwest load centers.

The report of the Senate Committee on Interior and Insular Affairs, concerning problems of Electrical Power Production in the Southwest (released in the fall of 1972) points out in the Findings section on page 29:

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"Although the current controversy over the power development in the Southwest has not greatly highlighted transmission lines, it is probable that the ultimate transmission grid contemplated will pose the most severe problems of aesthetic insults to the region."

In considering potential transmission line corridors where National Forest system lands are involved, there are land and resource management considerations involved which must be solved and alternatives considered before final decisions and authorizations can be made. Comprehensive land and resource evaluations and analysis must be completed to ascertain that the proposed transmission line corridor(s) is consistent with other planned activities and would not create serious adverse consequences for long term management. Determination must be made that the portion of a proposed corridor located on intermingled or adjacent land would not adversely and seriously offset important National Forest system values or preclude the achieving of National Forest objectives. Determination must also be made that the proposed corridor location on National Forest system lands would not adversely or seriously affect the environmental quality of intermingled or adjacent land of other ownerships.

Other factors which must be considered are primitive area studies, social and economic impacts, pending legislative action, environmental statements required by the National Environmental Policy Act, public involvement, coordination between all utilities including public,

private, and Federal agencies involved in the production transmission and marketing of electricity. Until the above is accomplished and all alternatives considered, we consider that options related to the allocation of National Forest lands from a diminishing land base must be kept open. Determination of locations and authorization for transmission line cordidor(s) on National Forest land such as discussed above, would require in-depth analysis and Environmental Analysis and Statements.

Our third area of concern relates to stack emissions from the proposed plants. National Forest lands nearest to the proposed Colstrip plant lie approximately 20 to 25 miles to the east. Due to westerly prevailing winds, the projection for uncontrolled emissions of 3.2 pounds per hour of fluroides and 0.23 pounds per hour of mercury are particularly worrisome. These are cumulative poisons and affect plants and animals at relatively low concentrations. Livestock, for instance, develop fluorosis if grazing is done on vegetation containing more than 35 ppm fluoride.

To summarize then, we have three chief concerns:

1. The need for a more comprehensive study for the total impacts of coal development in the entire Fort Union Coal Formation Area.

2. The need for more information and evaluation of the impacts of the transmission network following power plant development.

Exhibit 4

3. The cumulative effects of stack emissions on National Forest lands lying east of the proposed Colstrip plant.

We would urge that the above factors be more fully considered and evaluated before further land use commitments are made.

Exhibit 4

ORAL TESTIMONY OF MR. JAMES M. BENSON AS TRANSCRIBED FROM TAPE MACHINE

I don't suppose I'm any different than any of the rest of us that are here. I probably have a personal reason for coming up and stating my views and mainly I don't see any objections to this issuance of this permit to Montana Power because we surely will need the power in days to come because I know my wife would be awful unhappy if I told her she couldn't use the vacuum or had to do without a refrigerator, but I have followed the construction work most of my life, I've farmed and ranched before that and this project out here affords a lot of us working people the opportunity for year round employment and this I think is what most of us seek as some source of financial security. We as a family discussed and tried to come to a reasonable conclusion as to why we should or shouldn't move to Colstrip and have the chance for year around employment. We like outdoor activities and we hate to see the air, the water, the earth quality of it impaired in any way, and I don't think this steam plant will do this, so I represent myself, mostly, and I the concensus of opinion that I arrived at from talking to the working man at the mine and around Colstrip who work in the mining operation and on the plant seems to be that they find no objection either. As far as strip mining goes I don't think there is many people in Montana that would like to mine that coal underground. I know I wouldn't and I suppose then we would have to import miners from back East to come out here and mine the coal underground, so I don't think we would be doing the young people of Montana any favor by trying to mine it in this manner, so I think that possibly that this is the most economical and most feasible way to mine the coal and to insure us that we have an adequate supply of electricity in the future. Thank you.

Exhibit 4

Exhibit 4

else. They are just designed for normal stream flow. I happened to be president of the Kinsey Irrigation Association in 1961, and we had Cats right down in the bottom of the river trying to get water enough for our farmers to irrigate. Now if Montana Power, whoever it is, would like, we know 90% of the time there is plenty of water running down this Yellowstone River, but what about that 10% of the time. Now are they willing to come in and construct devices for our irrigation projects to get that water out when it is below normal stream flow? Now this is one question I would like to know. There is quite a little water going down there, but we have to have it. Now if they are willing to come along and construct these devices to get the water out, fine, then I would like to go on record from the Tongue River Yellowstone Beet Association as we are not strictly against the two plants or anything else, but we want to know whether we are going to have water to maintain our crops. Now, for instance a dry land farmer probably averages $30 - $40 - $50 an acre off his crops, an irrigated farmer averages, talking gross, from $100 - $500 an acre off of his crops. My budget would look pretty dim, I'd tell you, if I had 175 acres and I got $35 an acre off of it.

That's all I have to say.

Thank you.

Exhibit 4

Exhibit 4

January 5, 1972

I am Mrs. Leon Hicks. I represent the Billings Chapter of the National Audubon Society with membership of 70 families.

We want to thank the State Board of Health for this opportunity to voice some of our concerns about the plant now under construction and of the plants planned for this area in the future.

Audubon does recognize that a valuable resource is present in great quantities and that there exists a demand for it. Audubon questions the haste with which industry is moving before adequate safeguards over soil, air and water can be established.

As we understand the situation, the only permit needed for operation of this plant is the one concerning the installation of air pollution control equipement. The entire plant abuses several areas of the environment and the delay in filing the impact statement by Montana Power Company violates the intent of the NEPA act and the right of the citizen to know about proposed development in our state.

Montana Power has filed a request at the Rosebud County Courthouse for rights to 59 billion gallons of water a year. They have filed for approximately 112,000 gallons a minute while insisting to the public that they will be using only 8000 gallons a minute in the operation of this plant. Why did they file for such an excessive amount?

Who is the authority for the statement that removing this amount of water from the Yellowstone would not harm the river or the plant and animal life dependent upon its water? Considering other demands already made upstream upon the river, is there any basis for such confidence in the rivers ability to withstand this heavy demand upon it.

Audubon urges that dry cooling towers be used. There is a shortage of fresh water in the United States and it just is not reasonable to use this resource in such an extravagant fashion.

Montana Power claims that they are bringing jobs to Montana so that our youth does not have to go elsewhere for employment. The impact statement says 800 to 900 jobs will be available during the building of this plant, but less than 100 will be needed to operate it and the strip mining operation later. Where will the extra 800 men work after the plant is finished in 1976? Who will use their former housing?

We must presume that city services and schools will be expanded to accomodate the extra people for four years. Is this really a sensible 5 year plan for Montana?

Consider the economic catastrophe when the government pulled out of Glasgow and Conrad. Is it desireable to replace a stable agricultural economy with a boom and bust construction economy? Audubon questions the validity of Montana Power's assertion that they are improving the economy here for anything but a very short period of time. The unemployment problem will be MONTANAS!

The Department of the Interior has conducted a study of the Four Corners steam generation area in the southwestern United States and has drawn the conclusion that it is much cheaper to ship the coal to the population centers for conversion into energy than it is to build mine mouth plants and then ship the energy. In Eastern Montana, the major rail lines already exist for the shipping of the coal to the eastern or western population centers.

This one plant projects three separate power lines to Billings. Since 20 acres of land is condemned for every mile of power line built, this visual and land consuming pollution could be avoided if the coal were shipped to population centers instead of building future

Exhibit 4

mine mouth plants.

Why degrade Montana's air and water and land when it is cheaper to ship the coal to the consumer's area?

What assurance do we have that existing pollution controls will be honored by the Power companies and if not honored, what assurance do we have that violations will be corrected and the law enforced? Past performance of the Power Companies does not engender confidence

Granting a permit to operate means that coal must be mined and with strip mining now permitted under existing laws, it will be strip mined since this is the cheapest and fastest way to utilize the resource. Would it make more sense to deep mine the coal and thereby exercise the subsurface rights while preserving surface rights and maintaining the environment? This method of mining would create many more permanent jobs than strip mining will.

If there really is such an energy shortage and they really do need this coal now, wouldn't they be happy to pay the extra price of deep mining so as not to cause the disruption of people and wildlife and plantlife?

Audubon recognizes other values besides a dollar and how many acres it takes to graze a cow. Several other values can be placed on any given piece of real estate. How long will it take to grow the trees again? The grass? Or rebuild the soil?

If there is any other way to get the coal, why should strip mining even be considered when it is common knowledge that other strip mined areas are useless for generations.

Which is really more important? Preserving the land for the next generations or destroying it during this one to satisfy an artificial urgency for more energy in order to manufacture throw away containers, gadgets that comb your hair, brush your teeth, and open your cans. Energy to produce cars with many times the horsepower needed to get from here to there, light our streets like midday at midnight, illuminate billboards, keep the neon flashing bigger and brighter far into the night.

Audubon is concerned the power companies don't really want us to know the truth about the energy situation. Why do they continue to advertise to increase demands for a product they say is already in short supply?

Audubon is concerned that the state might really believe that 500 foot smokestacks or even taller ones somehow lessen the pollution pouring from them. We have only this one world.. Does it really make a difference how high they shoot the pollutants as long as they remain in our world? From this one plant 266 pounds of dust an hour, 6820 pounds of sulphur dioxide an hour, a maximum of 4774 pounds an hour of nitrogen oxides, with a yearly maximum of 14 tons of water vapor all add to the pollution we already have... Let us not be perpetrate's of another "Legal crime" against the State of Montana.

[redacted]

Exhibit 4

Presented To The State Board
Of Health Concerning The Proposed Steam Generation Plant
At Colstrip.

Miles City, Montana January 5, 1973

By Don Bailey
Forsyth, Montana

I am Don Bailey. My livilihood is sustained from a family ranching operation approximately 10 miles southwest of Colstrip. The threat that accumulative pollution effects may impose upon my future welfare, both physically and economically, have prompted my remarks.

Because others have or will deal in specifics of the impact statement, I have chosen to comment more in generalities.

The statement concludes, in many instances, that there probably is not enough information available to properly determine the long-range effects that the power plant may have on the environment and eco-systems.

The only criteria that must be met are the State and Federal ambient air quality standards. That these standards are considered adequate, is only confirmed in the impact statement, by the Administrator of the Environmental Protection Agency in establishing these standards. The national secondary ambient air quality standards are those which, in the judgment of the administrator, based on air quality criteria, are requisite to protect the public welfare from any known or anticipated adverse effects associated with air pollutants in the ambient air.

Exhibit 4

Admissions are made throughout the impact statement that long range adverse effects will undoubtedly be imposed upon the environment. This appears to me to be an anticipated event, and by definition of the Ambient Air Quality Standards, would mean that it cannot meet these standards. There will be pollution, there will be adverse effects, and they are being anticipated now.

The State Board of Health wrote this impact statement on the basis of information supplied them by the Montana Power Co. Much of the back-ground research was done by firms or agencies that were partially or wholly funded by the Montana Power Co. or other utility oriented industries.

This situation raises the question as to whether every bit of information, both negative and positive to their plans, has in fact, been made available to the State Board of Health.

We in America, have continuously introduced substances into our environment, with good intentions, that were judged to be completely safe. Later, as in the case of DES in livestock feeding, many food additives, and medicinal drugs, it was discovered that they created a definite health hagard. No tolerance was allowed as will be the case of the florides, which have definitely been linked with heart disease and bone deterioration, or the radioactive ones which can cause cancer; these being only two of many dangerous elements resulting from the burning of coal. The reasoning for the variations in this interpretation smells of political overtones.

I fear that one day we will discover our tolerance of these deadly substances, only for the economic benefit of our industries, was also a grave error in human judgment. Is the health and welfare of the people of Montana and the Colstrip area in particular, to pay for this kind of irresponsible actions?

Exhibit 4

I might add that I realize the economic importance that coal mining and its related activities have to the men and their families who work at Colstrip, but because they are on the other end of the philosophical ladder on this matter does not make them immune from the pollutants of this project. The wind does not always blow from the west at Colstrip.

I will briefly list some other problems, as revealed to me by air quality experts with whom I have been in contact, that may result from the 700 Meg. Watt plant.

1. Ponderosa pine within a five mile radius downwind may be severely damaged or completely destroyed by fluoride emissions. The impact statement says that no control equipment or ambient air quality standards will be in effect for fluorids.
2. Acid rains resulting from present annual rain fall and large amounts of evaporated water from the plant, combining with sulphur dioxide emissions, may reduce plant growth in the surrounding eco-system by 1/3 within five years. This is recognizing the advertised 99.5% efficiency in removing particulate and SO_2.
3. Dr. Earnest F Abicht, a research scientist for the Environmental Defense Fund says the loss of 1% efficiency of the control equipment will increase the SO_2 emissions four times. This, of course, can be taken care of by the 24 hour grace period allowed every four days, whereby, any amount of pollutants into the ambient air will be allowed for 24 hours.
4. These same air quality experts have indicated the most dangerous of all effluients may be the trace elements.

Exhibit 4

I quote from the impact statement, "Very little is known about the trace element contents of the coal to be burned at Colstrip. Thorough comprehensive sampling for trace elements has not been done on this coal. Mercury and fluorine have been the trace elements given the most attention, but others may prove to be serious pollutants, especially radio-active ones." (unquote)

I have pointed out only a few of many inconsistancies in the impact statement. There have been and will be some other circumstances evolve from this action which I feel deserve consideration.

1. We will have the creation of a pottntially dangereous pollutant with inadequate regulations to assure that even the tolerable or acceptable degree of pollution will be maintained.
2. We will have a long term accumulation of toxicants in flora and fauna . The effects of this accumulation may not be readily recognized until serious damage has been sustained.
3. There is apparently no legal rexourse for those in the area who may be damaged physically or economically.
4. We have had an apparent after-the-fact atmosphere which has shrouded this project from its inception. By after-the-fact, I refer to the publishing of the impact statement, the construction application, the determination of when the permit is required and finally the ultimate issuance of the permit. I detect a very dangereous precident being se if this is a format for future projects.
5. We have an irreversible commitment of four precious natural resources, land, air, coal, and water at a 12% efficiency. It does not seem that this is commendable

with the needs of a nation that is supposedly on a brink of a major energy and natural resource crisis.

In conclusion, in view of my testimony, I believe it would be very commendable, courageous, and politically inexpediant if the Board of Health were to refuse the permit application at the time when it is determined necessary for construction to begin or continue, until such time as a more educated and responsible decision can be made.

Exhibit 4

Exhibit 4

Mr. Race

WHILE REALIZING THAT A STATEMENT AT A HEARING OF THIS KIND SHOULD BE CONSTRUCTIVE, AND THAT MY COMMENTS WILL PROBABLY BE DISREGARDED BECAUSE THEY ARE NOT DIRECTLY RELATED TO THE CONTENT OF THE DRAFT ENVIRONMENTAL IMPACT STATEMENT, I FEEL THAT IT IS MORE IMPORTANT TO TAKE A BROADER VIEW OF THE IMPLICATIONS OF THE COLSTRIP PLANTS, THAN TO MERELY COMMENT ON WHAT I CONSIDER ARE GROSS INADEQUACIES IN THE IMPACT STATEMENT.

I CONSIDER THIS HEARING, AND ALL OF THE EVENTS LEADING UP TO IT, TO BE A WASTE OF TIME, EFFORT, AND MONEY. I BELIEVE THAT THE SO-CALLED CONSTRUCTION PERMIT HAS BECOME A FRAUD AND A FACADE, AND WHILE THE MONTANA POWER CO. IS PROBABLY WITHIN THE LEGAL LIMITS OF THE LAW, THEY HAVE VIOLATED THE INTENT, AND PURPOSE OF THE LAW, AND HAVE MADE A MOCKERY AND A LAUGHING-STOCK OF THE BOARD OF HEALTH, THAT ADMINISTERS THE LAW, THE LEGISLATURE THAT ENACTED THE LAW, AND THE STATE, AND ITS PEOPLE THAT THE LAW WAS DESIGNED TO PROTECT.

THERE APPEARS TO BE UNINIMITY BETWEEN MONTANA POWER CO.'S HIERARCHY, AND ME ON ONE POINT, AND THAT IS THAT THE PENDING APPLICATION FOR PERMIT WILL BE SUMMARILY APPROVED, AND THAT APPROVAL FOR OTHER PLANTS AT COLSTRIP WILL BE ROUTINELY APPROVED, AS WELL.

THE PROPOSED CONSTRUCTION OF A FIVE-FOOT PIPELINE FOR WATER, WHEN ONLY A TWO-FOOT LINE IS REQUIRED TO COOL THE TWO PLANTS UNDER CONSTRUCTION; COUPLED WITH THE ADMISSION OF A WESTERN ENERGY CO. OFFICIAL TO A GROUP OF PEOPLE AT COLSTRIP THAT SEVEN PLANTS, WITH A TOTAL GENERATION CAPACITY OF 10,000 MEGA-WATTS, WILL EVENTUALLY BE BUILT AT COLSTRIP IS HARDLY A COINCIDENCE.

IS THE ONGOING CONSTRUCTION OF THE POWER PLANTS, THE SURVEYING OF THE PIPELINE ROUTE, THE CONSTRUCTION OF ADDITIONAL TRAILER COURTS AT COLSTRIP, THE CONSTRUCTION OF TRANSMISSION LINES, CONSISTENT WITH ANY DOUBTS AS TO THE FINAL DISPOSITION OF THE APPLICATION FOR CONSTRUCTION? I THINK NOT, AND ONCE AGAIN I BELIEVE THAT MONTANA POWER AGREES WITH ME.

I QUOTE FROM THE IMPACT STATEMENT, UNDER EFFECTS ON THE ECOSYSTEM ON PAGE 22: "WHAT THE LONG RANGE EFFECTS OF SO_2, NO_X, FLORIDES, MERCURY AND

Exhibit 4

OTHER EMISSIONS FROM THE PROPOSED PLANT WILL BE, IS IMPOSSIBLE TO PREDICT AT THIS TIME.....OVER A PERIOD OF YEARS, THE POLLUTANTS MAY BUILD UP TO LEVELS THAT SERIOUSLY DISRUPT THE ECOSYSTEM.....A QUANITATIVE ESTIMATE OF THESE EFFECTS IS IMPOSSIBLE AT THIS POINT IN TIME, GIVEN OUR PRESENT UNDERSTANDING OF THE FATE OF THE POLLUTANTS IN THE ECOSYSTEM." DR. ERNST HABICHT, JR., OF THE ENVIRONMENTAL DEFENSE FUND MADE THE FOLLOWING COMMENT ON THIS PART OF THE IMPACT STATEMENT: "INSTEAD OF DELVING INTO THIS SUBJECT, THE DRAFT ENVIRONMENTAL IMPACT STATEMENT APPEARS TO SUCCUMB TO HELPLESSNESS, AS IF THE FATE OF THE REGION WERE COMPLETELY IN THE HANDS OF THE MONTANA POWER CO."

PRELIMINARY AIR SAMPLING WAS DONE PRIMARILY ALONG DUSTY COUNTY ROADS, AND THE MAIN, RURAL SAMPLING SITE, MENTIONED ON PAGE 13 OF THE IMPACT STATEMENT, WAS IN ONE OF MY NEIGHBOR'S YARDS, DOWNWIND FROM ALL OF THE DAILY TRAFFIC THROUGH THE YARD, AND IN CLOSE PROXIMITY TO A TRASH-BURNING BARREL. I MENTION THIS MORE AS A PROTEST TO THE ACCURACY OF THE STATEMENT, RATHER THAN THE EFFECT IT MIGHT HAVE ON THE APPLICATION'S FINAL DISPOSITION. I GUESS WHAT I AM TRYING TO SAY IS, THAT IN THE VERY LIMITED AREA OF MY PERSONAL EXPERTISE, THE INPUT INTO THE IMPACT STATEMENT IN THE CRITICAL AREA OF PRESENT AIR QUALITY IS ERRONEOUS.

THE ONLY CONSOLATION THAT I CAN FIND IN THE IMPACT STATEMENT IS FOUND IN THE SUMMARY WHICH SAYS: " THE LONG-TERM ADVERSE EFFECTS MAY WELL OUTWEIGH THE SHORT-TERM GAINS."

WHAT I FEAR IS THE PROSPECT THAT BY APPROVING THIS FIRST FACILITY A PRECEDENT WILL BE SET FOR SUBSEQUENT FACILITIES, AND THAT THE BIG SKY COUNTRY WILL ENVIRONMENTALLY SUBSIDIZE THROUGH INEFFICIENT GENERATION, AND INEFFICIENT TRANSMISSION, NON-MONTANA ELECTRICITY CONSUMERS, AND NON-MONTANA FINANCIAL INVESTORS.

A FRENCH PHILOSOPHER NAMED RAYNAL ONCE SAID: "THERE IS AN INFINITY OF POLITICAL ERRORS WHICH, BEING ONCE ADOPTED, BECOME PRINCIPLES." I HOPE AGAINST HOPE, AND PRAY AGAINST MY INTUITION, ADMITTING THAT I AM BIASED, THAT

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AND CYNICAL, THAT YOU WILL REFUSE THE APPLICATION FOR CONSTRUCTION.

Exhibit 4

Exhibit 4

A STATEMENT BEFORE THE DEPARTMENT OF HEALTH & ENVIRONMENTAL SCIENCES COMMITTEE IN PUBLIC HEARING ON THE MATTER OF MONTANA POWER'S APPLICATION FOR A PERMIT TO CONSTRUCT GENERATION FACILITIES AT COLSTRIP

MY NAME IS PETER LOMBARDOZZI, I AM THE PRESIDENT OF THE SOUTHEASTERN MONTANA BUILDING TRADES COUNCIL, AND I AM ALSO THE BUSINESS MANAGER OF THE INTERNATIONAL BORTHERHOOD OF ELECTRICAL WORKERS, LOCAL 532, AND THE FOLLOWING STATEMENT IS PRESENTED ON BEHALF OF BOTH ORGANIZATIONS.

THE SOUTHEASTERN MONTANA BUILDING TRADES COUNCIL IS AN AFFILIATION OF THIRTEEN CONSTRUCTION UNIONS HAVING A COMBINED MEMBERSHIP OF WELL OVER 3,000 MEMBERS. ONE OF OUR FUNDAMENTAL CONCERNS AS A LABOR UNION ORGANIZATION IS A CONTINUING SUPPLY OF WORK FOR WAGE EARNERS AND OF COURSE, THIS IS OUR FIRST INTEREST IN THE DEVELOPMENT OF THE MONTANA POWER COLSTRIP STEAM PLANT PROJECT.

THE DEVELOPMENT OF MONTANA POWER ELECTRICAL ENERGY COMPLEX WILL PROVIDE A NEED FOR A WIDE VARIETY OF PHYSICAL AND TECHNOLOGICAL SKILLS, NOT ONLY FROM THE INITIAL CONSTRUCTION OF THE FACILITIES, BUT FROM THE OPERATION AND PRODUCTION OF THE PLANTS. WE ARE CONVINCED THAT MONTANANS WILL BENEFIT FROM THE JOB IMPACT ON THE ECONOMY FROM NOW ON.

THE RESULTING JOBS EFFECT NOT ONLY THE MEN AND WOMEN DIRECTLY EMPLOYED BUT EVERY MEMBER OF THEIR FAMILIES. WHEN PEOPLE ARE ABLE TO WORK, THEY SPEND THEIR MONEY ON GOODS AND SERVICES PROVIDED BY BUSINESSES WHO IN TURN HAVE TO HIRE MORE PEOPLE TO PROVIDE THE ADDED SERVICES, AND IT GOES ON AND ON.

PEOPLE WHO ARE ABLE TO WORK, ARE ABLE TO PAY TAXES. MOREOVER, THE GENERATING FACILITIES THEMSELVES WOULD PROVIDE AN ADVANTAGEOUS TAX BASE. THE PEOPLE IN MONTANA SHOULD BENEFIT FROM THE ADDITION OF THIS TAX BASE TO THEIR OTHER TAX ROLLS.

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IN ANOTHER SENSE, THE JOBS PROVIDED WILL AFFORD MORE OF OUR YOUNG PEOPLE WHO HAVE COMPLETED THEIR EDUCATION AND ARE LOOKING FOR A CAREER AND A WAY TO REMAIN IN THE STATE A CHANCE TO STAY IN MONTANA AND GROW WITH MONTANA.

WE BELIEVE THAT MONTANA'S NATURAL RESOURCES HAVE TO BE DEVELOPED IF MONTANA IS TO GROW AND PROSPER, AND THE WELL BEING OF ITS PEOPLE DEPENDS HEAVILY ON THIS GROWTH.

ROLLING PLAINS OF SAGE-BRUSH AND GRASS ARE PLEASING TO THE EYE BUT UNFORTUNATELY FOR A MAJORITY OF THE PEOPLE IN THE STATE, IT CANNOT FEED A FAMILY, SEND A BOY TO COLLEGE, BUY A HOME, OR INSURE SOME KIND OF FINANCIAL STABILITY FOR THEM. DEVELOPMENT OF OUR NATURAL RESOURCES CAN DO THIS.

WE WISH IT PLAINLY UNDERSTOOD THAT WE ARE AS CONCERNED ABOUT OUR ECOLOGICAL ENVIRONMENT AS ANYONE ELSE. WE ARE IN ACCORD WITH THE PREMISE THAT ANY DEVELOPMENT WHICH AFFECTS OUR ECOLOGY SHOULD HAVE STRONG ENVIRONMENTAL CONTROLS TO INSURE THE QUALITY OF OUR WATER, AIR, AND LAND. WE ARE NOT INTERESTED IN CREATING JOBS TO DESTROY OUR ENVIRONMENT!

YET WE TAKE THE POSITION THAT MONTANA CAN DEVELOP ITS NATURAL RESOURCES, PROVIDING WORK OPPORTUNITIES AND GROWTH FOR ITS PEOPLE AND AT THE SAME TIME ENJOY A CLEAN ENVIRONMENT AND ECOLOGICAL BALANCE. WE IN LABOR HAVE SEEN GIANT TECHNOLOGICAL STEPS FORWARD TAKEN BY INDUSTRY AND HAVE PARTICIPATED IN PROJECTS TO REDUCE OR ELIMINATE EXISTING POLLUTION PROBLEMS AND CONTROL FUTURE SOURCES OF SUCH DIFFICULTIES. WE HAVE PARTICIPATED IN THE CONSTRUCTION OF COAL-FIRED STEAM PLANT PROJECTS FROM THE VERY FIRST ONE THAT WAS BUILT. WE HAVE BEEN 'ON THE SPOT WITNESSES' TO THE ASTOUNDING ADVANCES MADE BY THE INDUSTRY IN DEVELOPING TECHNIQUES TO ELIMINATE POLLUTION. WE ARE EXTREMELY CONFIDENT AND OPTOMISTIC THAT AMERICAN KNOW-HOW WILL CONTINUE TO DEVELOP BETTER TECHNOLOGY TO ELIMINATE POLLUTION PROBLEMS.

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WE HAVE STUDIED MONTANA POWER'S ENVIRONMENTAL CONTROL TECHNIQUES PROPOSED ON THIS PROJECT AND ARE CONVINCED THEY ARE GOING TO UTILIZE THE BEST METHODS AVAILABLE IN POLLUTION CONTROL AT THE PRESENT TIME. WE ALSO BELIEVE THAT WHEN AMERICAN TECHNOLOGY PROVIDES BETTER METHODS AND SYSTEMS OF CONTROL, THEY WILL UTILIZE THOSE METHODS ALSO, BECAUSE NO ONE, BE THEY GOVERNMENT, INDUSTRY, OR WORKERS, WILL ANY LONGER IGNORE POLLUTION PROBLEMS OF OUR LAND, WATER, AND AIR. ENVIRONMENTALISTS HAVE DONE AN EXTREMELY GOOD JOB OF WAKING UP AMERICA TO THE CONSEQUENCES OF PULLUTION.

OUR UNIONS ALSO KNOW THAT AN ELECTRICAL ENERGY CRISIS IS AT HAND, AND THAT THE LOW-SULPHUR CONTENT COAL SUPPLY THAT IS IN GREAT ABUNDANCE IN MONTANA IS THE MOST ECONOMICAL METHOD OF GENERATING ELECTRICAL ENERGY FOR MONTANA AND OTHER STATES IN NEED OF SUCH POWER.

IT WOULD BE DANGEROUSLY NAIVE FOR MONTANANS TO BELIEVE THAT THEY CAN ISOLATE THIS RESOURCE FROM DEVELOPMENT WHEN THE NEED FOR IT IS SO GREAT IN OUR UNITED STATES. SINCE IT HAS TO BE DEVELOPED, WE BELIEVE THAT IT SHOULD BE DEVELOPED <u>BY MONTANANS, IN MONTANA, FOR THE BENEFIT OF ITS PEOPLE</u>! MOREOVER, IT THIS DEVELOPMENT IS TURNED DOWN OR NEEDLESSLY DELAYED, THE FORCE OF '<u>UNMET DEMAND FOR POWER</u>' IN AREAS AROUND US MIGHT CAUSE THIS TO BE UNDERTAKEN BY OTHERS AT A LATER DATE ON A SPEEDED UP OR CRASH BASIS WITHOUT REGARD TO OUR ENVIRONMENTAL QUALITY. WE SIMPLY CANNOT STAND BY, TAKING NO ACTION, OR ALLOWING ANY ACTION BY MONTANA CONCERNS, TO DEVELOP THIS POWER SOURCE. IF WE DO, WE MIGHT WELL LOSE THE INITIATIVE TO OUTSIDE INTERESTS FOR ITS DEVELOPMENT.

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IN SUMMARY, I WOULD POINT OUT AGAIN:

THAT WE BELIEVE MONTANA POWER'S GENERATION PROJECT AT COLSTRIP WILL CREATE NEEDED JOBS IN MANY CATAGORIES OF WORK NOW AND IN THE FUTURE: JOBS THAT ARE VITAL TO THE CONTINUED HEALTHY GROWTH OF MONTANA'S ECONOMY.

THAT WE BELIEVE THE EXTENDED TAX BASE THIS COMPLEX WOULD BRING CAN ONLY BENEFIT THE TAX PAYERS IN THIS STATE.

THAT WE BELIEVE MONTANA'S NATURAL RESOURCES SHOULD BE DEVELOPED FOR THE GOOD OF MONTANANS WITH ADEQUATE CONTROLS TO PROTECT OUR ENVIRONMENT.

THAT WE BELIEVE A BALANCE MUST BE STRUCK IN THE DEVELOPMENT OF POLLUTION CONTROLS, WHICH WILL FOSTER BOTH ECONOMIC GROWTH AND ENVIRONMENTAL UPGRADING AND THAT WE CAN SUSTAIN INDUSTRIAL DEVELOPMENT AND ENVIRONMENTAL QUALITY TOGETHER BECAUSE OF NEW AND FUTURE TECHNOLOGIES.

IT IS STATISTICAL FACT THAT A POWER SHORTAGE EXISTS IN OUR COUNTRY AND THE MOST FEASIBLE SOLUTION IS TO DEVELOP MONTANA'S ABUNDANCE OF LOW-SULPHUR COAL.

WE ARE CONVINCED MONTANA POWER COMPANY CAN AND WILL MEET TODAY'S REQUIREMENTS FOR ECOLOGICAL BALANCE AND POLLUTION CONTROL AND IN THE FUTURE WILL UPGRADE THESE EFFORTS AS NEW LAWS, STANDARDS, DEVICES AND PRACTICES ARE DEVELOPED.

THEREFORE, THE SOUTHEASTERN MONTANA BUILDING TRADES COUNCIL AND MY OWN LOCAL UNION 532, IBEW, WISHES TO GO ON RECORD AT THIS HEARING OF BEING IN FAVOR OF THE CONSTRUCTION OF THE MONTANA POWER COMPANY COLSTRIP COMPLEX AS BEING IN THE BEST INTERESTS OF THE MAJORITY OF THE PEOPLE IN THIS STATE AND URGE THAT A PERMIT BE GRANTED TO THEM FOR CONSTRUCTION AND INSTALLATION OF THE EQUIPMENT NEEDED FOR THEIR GENERATION FACILITY.

THANK YOU.

Peter Lombardozzi

PETER LOMBARDOZZI
PRESIDENT, SE MONTANA BLDG TRADES

Exhibit 4

ITEM
#4

STATEMENT BEFORE THE DEPARTMENT OF HEALTH
AND
ENVIRONMENTAL SCIENCES IN THE STATE OF MONTANA

Miles City, Montana
January 5, 1973

My name is John W. Ellis, Vice President-Utility Management and Chief Operating Officer of Puget Sound Power & Light Company. As you know, Puget Power and Montana Power Company will jointly own and operate the two-unit coal-fired power plant near Colstrip, which is the subject of this hearing.

My purpose today is not to get into the specific environmental issues, but is more general; to explain to you why Puget is involved in this project -- a project far from our home base in the Puget Sound region, two states away. Intimations have been made that "carpet baggers from Washington" are coming into the state to "exploit and run". The concern of the Montana citizens about their environment and this project is certainly understandable, and a brief explanation of our role is in order.

Although our partnership with Montana for the Colstrip project did not come into being until August of this year, the fact is that Puget and Montana Power Company have been "pooling" resources and facilities for many years. Montana Power Company and five other major investor-owned utilities in Idaho, Washington and Oregon first formed the Northwest Power Pool in 1941 in an effort to coordinate their power generation and transmission facilities. In 1942, a War Production Board order directed all utilities throughout the United States to cooperate with each other to assure carrying the maximum loads during the World War II period. Puget, and all the other major

Exhibit 4

systems in the area, both public and investor-owned, joined the pool at that time. Following the war, the utilities decided that the gains to be realized through coordinated operation were so great that the pool should be continued. For many years, until the 1960's, pool operation was strictly voluntary, but very successful; and, I might add, some years ahead of other regional groups in the United States.

In September 1964, a formal Coordination Agreement was signed by all the major electric utilities in the Northwest, including Montana Power and Puget. One of the purposes of the agreement was to firm up coordination of reservoir storage water releases during the drawdown season and in turn provide for sharing the costs of upstream reservoirs. The Agreement also required each participating system to establish a firm energy-load-carrying capability and to maintain that capability through power interchanges with other systems.

Currently, all the utilities in the pool area participate in setting up an annual operating program. This program serves as a basic guide for the coordinated operation of all plants in the pool during the year. With the Coordination Agreement, scheduled utilization of storage water from reservoirs of those systems covered by the Agreement is on a firm basis. There are also other areas of coordination which have been achieved on a voluntary basis in the pool over the years. One of these is setting up a coordinated maintenance schedule each year where outages for maintenance are scheduled based upon load requirements and the available surplus in the pool. Another is in the hourly interchange accounting. These transactions between utilities are handled on a scheduled basis

and all schedules are balanced out against the actual interchanges each hour.

The pool utilities cooperate with each other in the operation of reactive equipment to maintain satisfactory voltage levels throughout the transmission system. The utilities have also agreed on procedures to be followed by the entire pool during cases of emergency. This includes a comprehensive load-dropping schedule for use during emergencies. Frequency relays have been installed and their pick-up times coordinated to provide for dropping a substantial amount of the total load, if necessary. The new transmission ties constructed in recent years between the Northwest Power Pool and other operating areas to the south and east further strengthen the benefits to be derived from pool operations.

It has been said, "No man is an island", meaning that no one should exist isolated in his own community. This is especially true for electric utilities and has been borne out very emphatically by the Northeast blackout and similar occurrences in other parts of the country where systems with less interconnections and less coordinated operations than exist in the Northwest have suffered accordingly. The benefits and gains which are realized through coordination and the various phases of operation in the Northwest Power Pool have resulted in substantially less investment costs due to the need for less transmission and generation facilities; increased load-carrying capability; reduced reserves; significant improvement in reliability; and improvement in the quality of electric service.

It should also be pointed out that reduction in the need for generation and transmission facilities directly translates to less

use of our valuable natural resources, including land and fuels. Also, less environmental impacts need to be imposed upon the region.

You can see, then, that in an indirect but very real way, Puget has been doing business in Montana for many years, to the benefit of Montana as well as to Washington. The reverse is also true.

What I have been discussing so far are benefits related in general to the Northwest Power Pool operations. Within the pool, utilities can gain other benefits through additional arrangements between themselves. Examples include individual interchanges, sales, and wheeling agreements. Such has been the case between Montana Power Company and Puget Power for the past several years. Short-term agreements have been executed between Montana Power Company and Puget Power in the last few years to interchange capacity and energy. Progress is being made on a long-term interchange agreement between our respective companies. This will mean significant benefits to the owners and customers of Montana Power Company as well as to owners and customers of Puget.

For instance, at this time the construction of generation at Colstrip appears to be the most feasible solution to energy shortages occurring in the mid-1970's. However, as we move into the 1980's, more nuclear plants will be coming on the line. Long-range plans for the pool show that a number of these nuclear plants will be constructed in Washington State. Our company is currently planning such a plant for operation in 1982. The benefits of interchanges between our two companies will then be more apparent to the customers of Montana Power Company. Montana Power may well obtain shares of these nuclear

plants to carry its increased loads during that period. The point is that a power interchange is a two-way street.

One other fact of electric life should be noted. Neither Puget, nor Montana, nor any other system could be wholly independent, even if it wished. The Pacific Northwest, the Pacific Southwest, and the Idaho-Wyoming-Montana and Utah area are all tied together by major transmission lines of varying capacities. This transmission network essentially describes an oval running along the Pacific coast, then east to Arizona, north through Montana and Idaho, and returning back to the coast. Each system in this network is affected electrically by whatever happens elsewhere on the system. A failure of the Hanford nuclear plant in Washington State, for example, may well cause -- and as a matter of fact, has caused -- the lights to go out in Arizona. In order for this network to be properly balanced, generation must be located strategically, both with respect to load and current flow. Presently the portion of this circle -- which we refer to as "the doughnut" -- which runs through the eastern segment is an area of abnormal current flows by reason of the dissimilarity between load and generation. Difficulties have been experienced in this area -- and these will become even greater unless action is taken. In order for this network to operate more successfully, generation on the eastern side of this doughnut is very desirable.

An additional benefit to Montana Power Company and its customers in my Company's participation in the Colstrip project is a substantial reduction in unit costs by immediate consideration of two units for construction, rather than one unit. The engineer-

contractor for the project, the Bechtel Corporation, has estimated that the savings in a two-unit project, as compared to the one-unit project already decided upon by Montana Power Company solely for its own immediate needs, amounts to about 17 million dollars, a unit cost of $234 per kilowatt rather than $289 per kilowatt.

Much has been said -- and will be said -- about the project's impact upon the natural environment. I must say that Puget Power shares the concern of you Montana citizens for environmental values. In the past few years, Puget has developed a regional and even national repurtation for being a responsible steward of our natural resources. We have developed numerous company programs relating to undergrounding of distribution lines, development of public recreation areas and trails, aesthetics of lines and facilities, and fish conservation. Ralph Davis, President of Puget Power, was recently named Chairman of the Committee on Environment for the Edison Electric Institute. Our participation in the Colstrip project is absolutely dependent upon its being environmentally sound, as well as economically feasible.

In summary, participation of Puget Power in the Colstrip project does not represent a "cut and run" philosophy, nor is our involvement here something new to the State. Through the Northwest Power Pool and other coordinated activities, through interchange agreements and other arrangements, Puget and Montana have been doing business together for many years with mutual benefit to each company, its customers, and each region. Our company is environmentally responsible. We will insist that all local,

state and federal regulations be met, or bettered by the project. We believe that this project can provide both protection to environmental values and benefit to the economic well-being of your area.

Thank you for the opportunity to appear at this hearing.

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Exhibit 4

WESTERN SYSTEMS COORDINATING COUNCIL
MAP OF PRINCIPAL TRANSMISSION LINES
1970

Exhibit 4

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ALTERNATIVES IN ENERGY USE

by

Albert G. Melcher, P.E.
Director of Technical Services

Rocky Mountain Center on Environment
4260 East Evans Avenue
Denver, Colorado 80222
303/757-5439

Exhibit 4

ROCKY MOUNTAIN CENTER ON ENVIRONMENT
4260 East Evans Avenue
Denver, Colorado 80222
303/757-5439

May 15, 1972

ALTERNATIVES IN ENERGY USE

I. Alternatives in Energy Conversion

A. Fossil Fuels and Organic Fuels

1. Petroleum.

Uses: electrical generation, water, space and industrial processes, heat, transportation propulsion, lubrication
Feasibility: presently available; 30-50 year world supply remaining.
Efficiency of use: electrical generation = 35%; house heat = 80%; transportation = varies (car = 12%); 53.2% of petroleum consumption is for transportation.

Environmental Factors:
Production: ecological damages; spillage problems; land use; brine disposal
Shipment: spillage; major spill hazard; consumption of energy with pollution.
Refining: thermal pollution; spent caustic and solid wastes; emissions of SO_2, HC, NO_x and odors.
Utilization: emissions of SO_2, NO_x, CO_2, waste heat if burned; emissions of NO_x, CO, unburned hydrocarbons from internal combustion (which also emits gasoline additives including lead.)

2. Oil Shale

Uses: to petroleum; see I.A.1 above
Feasibility: pilot tests have proven feasibility; could have major production in 5-10 years; economics are present barrier.
Efficiency of use: see oil above.

Environmental Factors:
Production: strip mining; land use; disposal of spent shale 50% greater in volume than original shale; leaching of acids and minerals from spent shale; consumption of water (3 bbl water per bbl oil produced), emissions to air of SO_2, NO_x, HC, particulates. Problem of environmental quality is partially in vastness of land areas which could be disturbed.

Utilization: see oil

3. Natural Gas

Uses: electrical generation; water and space heating; cooking and other domestic and industrial heat uses.
Feasibility: presently available; 10-20 year world supply available.
Efficiency of use: electrical generation 35%; house heat 80%; water, residential and industrial process heat = unknown. 32.6% used for household and commercial, 46.6% used for industrial, 17.8% used for electrical generation.

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Environmental Factors;
Production: land use; water consumption if liquid.
Transportation: pipeline land use and hazard by vehicle, rail. NO_x emissions at pipeline compressor stations.

Utilization: thermal pollution, CO_2, NO_x, some CO.
Comments: liquid petroleum gas, gases from refining of petroleum, augment supplies of natural gas, have similar uses and effects.

4. Natural Gas by Nuclear Stimulation

Uses: see Natural Gas
Feasibility: in research stage; production requires solution to technological problems and economics; estimated development is hard to forecast, but appears to be moderately remote potential.
Efficiency of use: unknown, as significant quantities of energy (nuclear) are required for production. Use efficiencies as per natural gas.

Environmental Factors:
Production: Land use disruption and damage in blasts; minute amounts of radioactivity in krypton. Potential radioactive pollution of ground water; potential seismic triggering.
Transmission and use: see Natural Gas.

5. Coal-Electrical Generation

Uses: all uses of electricity
Feasibility: presently feasible; 110-150 year world supply of coal remaining if use trend continues. Four to six year lead time in siting, design and construction.
Efficiency of use: about 35% to busbar; maximum potential with improvements is about 39%. Losses in transmission vary, average about 6%.

Environmental Factors:
Mining: Land use (millions of acres), ecological damage, acid runoff, erosion; mine and waste fires, ground subsidence from underground mining.
Transmission to plant: by road, railway, slurry pipeline, with attendant impacts. Slurry pipeline requires water consumption (as water from slurry is highly polluted).
Production: emission of particulates (especially submicron size), SO_2, NO_x, CO_2, trace elements of toxic minerals and radioactivity. Land use, aesthetics, disposal of ash (can be disposed of in strip mine, but ground water may be affected.) cooling water consumption (15 acre-feet per MW), air and water thermal pollution, water pollution from scrubber bleed-off and cooling tower blowdown. Air pollutants are difficult to control. Land use; about 4 million acres now devoted to electrical generation; by 1990, 7 million more acres for 300 new 3,000 MW plants. (Rhode Island = 1 million acres.)

6. Coal Gasification

Uses: High BTU or low BTU gas can be produced, and can substitute for coal in power plants; low BTU gas can substitute for natural gas in many uses, and can be used in electrical power generation. See "Advanced Power Cycle" below.

Feasibility: A prototype is going to be constructed in New Mexico soon. Gasification by fluidized - bed discussion below). There are a number of various processes under development, and large commercial plants can be available by 1977. Current estimates of high BTU gas costs are 4 to 5 times present costs of coal for western power plants. The "Lurgi"

Exhibit 4

low BTU plant, using a gas turbine for electrical generator drive has been in operation in Europe for 30 years. Low BTU gasification appears competitive with coal if coal-fired plants must spend money on proper environmental controls.

Efficiency of use: not known

Environmental Factors:
Mining of coal
Transmission of coal to plant
Production: Low emissions of SO_2, NO_x, particulates. Emission of CO_2. Ash disposal. Water consumption, land use.

7. Advanced Power Cycle (APC)

Description: Basically, APC is a combination of components to achieve higher efficiencies and means of reducing pollution. EPA is studying one APC system consisting of a coal gasifier, a gas-clean-up element, a gas turbine, a boiler and a steam generator. Sulfur is produced as H_2S, which is much easier to remove than SO_2. Particulate removal is more effective than for conventional plants. Thermal pollution and CO_2 will be about half that of conventional plants per KW output.

Uses: base-load electrical power generation.

Feasibility: 500 MW plants by 1980, major use by mid-1980's.

Efficiency: 50% or higher.

Environmental Factors:
Mining of coal: see IA.5 above.
Transmission of coal: see IA.5 above.
Production: emission of SO_2 (ultimately, about 1/20 of that of conventional plants), NO_x (about 1/10 of that of conventional plants), particulates (significantly lower). Land use, disposal of ash, water consumption.

Costs to consumer of APC electricity may be 20% or more lower than conventional plants.
Transmission lines for electricity.

8. Advanced Combustion - Submerged Bed

Description - One process being studied by EPA is the use of an iron bath as a combustor for crushed coal. This is similar to the process for making steel. Coal and air are fed into a vat of molten iron. Hot gases released by the combustor heat steam in a boiler for driving a turbine and generator. Slag develops on top of the iron, and ash and sulfur are trapped in the slag which is removed.

Uses: electrical generation

Feasibility: A 100 MW demonstration plant could be on line in 3 years if funds were available. This process could be in major use by about 1980.

Efficiencies of use: not known

Environmental Factors:
Mining of coal, limestone
Transmission of coal to plant
Production: air emissions of CO_2, NO_x, unless pure oxygen is used in

combustor instead of air; almost no sulfur or particulate emission. Water for steam production. (Consumes limestone, produces sulfur and some iron.
Transmission lines for electricity.
Cost to consumer probably lower than conventional

9. Advanced Combustion - Fluidized Bed

Description: Air is passed upwards through a bed of granular non-combustible material such as coal ash or lime, causing the granular materials to become suspended. The air serves as combustion air for crushed coal or oil which is air-injected near the base of the bed. Hot gases produce steam in a boiler for turbine and generator drive, to produce electrical power. Advantages are: very high efficiencies of coal energy conversion, potentially high reductions of sulfur, NO_x and particulate emissions, lower capital and power costs, use of lower-grade coals, can use flue gases in APC system.

Uses: combustion-boiler for power generation and other industrial processes.
Feasibility: Great Britain is ready to build a 20MW prototype. EPA's goal is to prove the most efficient variations of this process by 1981.
Efficiency: Not known; probably high.

Environmental Factors:
Mining of coal, or production of oil.
Transmission of coal or oil to plant.
Production: small emissions of SO_2, NO_x, particulates; emission of CO_2. Consumption of water in steam generation. Mining of limestone. Ash disposal.

10. Magnetohydrodynamics (MHD)

Description: A MHD generator converts the kinetic and thermal energy of a moving plasma directly into electrical energy by passing a plasma flow through a strong magnetic field. Gas is superheated (4000° F) until it ionizes and is passed through the magnetic field, causing an electrical flow to occur. There are several concepts for MHD: open cycle plasma, closed cycle plasma and closed cycle liquid metal. In the latter process, plasma is replaced by liquid metal, and electrical currents are generated by its flow in a magnetic field. In the open cycle plasma process, "seeding" with potassium or a similar element is needed to create high conductivity, which is not needed with the closed cycle. The latter could use a nuclear heating source. In the open cycle plasma, MHD generation could "top" a conventional steam-turbine generator, increasing the efficiency. MHD would provide 1/3 of the power; steam would generate 2/3 of the power.

Uses: Electrical power.
Feasibility: R&D needed; estimated development about 1980 to 1985. Feasible production build-up thereafter unless unforeseen technological problems arise. Russians are constructing 75MW plant with MHD providing 25 MW, steam 50 MW. Generator performance and effective life are obstacles. Flue-gas cleaning in open-cycle

Exhibit 4

plasma must be improved to recover "seeding" material. Steam MHD may be feasible, using nuclear heating.
Efficiency of use: The MHD portion alone might be 55-60%; additional efficiency achievable if exhaust thermal energy used.

Environmental Factors:
Mining of coal: see IA.5 above.
Transmission to plant: see IA.5 above.
Power generation: unknown.

11. Fuel Cells

Description: Similar to space program fuel cells, in which hydrogen and oxygen combine to produce water and electricity, but using natural gas and air to produce water and dc electricity. Small "home units" could be used.

Uses: electrical power, in central or dispersed units
Feasibility: requires hydrocarbon gas (natural, coal, petroleum), hence relies on non-renewable resource. Is presently in research stage; demonstration probable in late 1970's.

Environmental Factors:
Requires gas; can be used in water-short regions. Produces CO_2 and waste heat (which may be usable).

12. Miscellaneous minor organic energy sources

Methane: natural, from sewage treatment, animal manure. Feasible and currently being used for small units. For example, some sewage plants produce more energy than they consume.
Wood: the most ancient fuel. Must be considered non-renewable, as it removes materials from natural cycle of decay and material cycling in ecosystem.
Vegetable and animal oils. (Don't count on whales much longer.)
Refuse: a ton of trash, generated at rate of 5.2 lb/day/person, contains about 10,000,000 BTU's (equivalent to 800 to 900 lb of coal).

B. Nuclear Fuels

1. Convential Reactor: water or gas-cooled, Thorium or Uranium 235 fuel, steam generation.

Uses: electrical generation; other uses for "waste" heat.
Feasibility: on line; many water-cooled plants in operation; 1000MW' High Temperature Gas Reactor (HTGR) being designed. England produces 12% of electrical power from nuclear plants. Cost to consumer is equal to or less than coal-fired plants, especially if the latter has proper pollution control devices. Eight to ten year lead time in siting, design, construction. Limited supplies of low-cost ores for U235.
Efficiency of use: 32%, with potential "multiple-use" of heat, including cooling water.

Environmental Factors:
Uranium mining; tailing control problems, including entry into watercourses.

Safety in shipment of uranium.

Production: minute amounts of long-lived radioactive tritium and krypton 85; possible severe disaster or minor incident from radioactivity (perhaps due to seismic activity); cooling water requirements about twice that of coal-fired plants, but Public Service of Colorado has 330 MW HTGR with closed-cycle cooling using towers and smaller amounts of make-up water (3%, or 900,000 gal/day/1000 MW).

Waste: processing and disposal of radioactive wastes with thousand-year half-lives, which must be stored in salt beds and which must not be permitted to contaminate underground waters.

"Waste heat" in cooling water can probably be used for agricultural irrigation or other purposes.

Uranium is non-renewable limited resource, with only about 30 years U.S. supply of low-cost U235 ores, not much longer life of world supplies.

Amount of fuel to be handled = 35 tons uranium dioxide vs. 2 million tons of coal for 1,000MW plant.

2. Breeder reactors.

Description: Breeder reactors, such as Liquid Metal Fast Breeder Reactor (LMFBR) and Gas-Cooled Fast Breeder Reactor (GCFR), uses plutonium and uranium 238, which is 140 times as plentiful as U235. It produces a net gain of half an atom of fissionable plutonium for every 1.5 atoms of uranium used; hence, it "breeds" new fissionable fuel. Liquid sodium, salt or gas transfers heat for steam generation, which drives turbine and generator.

Uses: see IB.1 above.

Feasibility: Three firms have proposals to AEC for 300 KW test plants. Russia, England and France are building demonstration plants. Probably not available for massive use until 1990. The AEC apparently is not interexted in the GCRF, although some scientists favor its development.

Efficiency: not known; not critical except in terms of condensate water.

Environmental effects:
See IB.1 above.
Fuel supply adequate for 20,000 to 60,000 years or more.

3. Fusion

Description: Confinement of heavy isotopes of hydrogen (deuterium and/or tritium) at sufficiently high temperature and density will result in the fusion of these isotopes to produce heavier elements and a large amount of energy, which can be converted to electricity. Fuel is abundant in sea water. Higher efficiencies are possible if "topping cycles" (additional energy conversion cycles) are used, and the chance of a nuclear excursion is eliminated. The heavier elements will be helium and hydrogen.

Uses: Heat to generate electrical power.

Feasibility: It will be about five years before researchers will be able to commit themselves to certainty that fusion process is feasible for significant amounts of energy. Much R&D on engineering and science will remain. Fusion appears to be at least 20 to 30 years away.

Exhibit 4

Environmental Factors:
Less hazard and radioactivity release than conventional fission plant. No mining or waste disposal

C. Natural non-depletable sources.

1. Geothermal

Description: In certain regions, heat from the magma of the earth's mantle, under the cool outside crust, is closer to the earth's surface and in sufficient quantities to heat underground water in porous and permeable rock. This heating is often great enough to produce steam. Hot springs are natural examples of geothermal water flows. By ordinary well drilling, geothermal steam or hot water can be brought to the surface. It can be used to drive turbines for electrical generation or for residential or industrial heat.

Uses: electrical generation, heat for hot water.
Feasibility: Immediate. One plant in California has 82MW of electrical generation on line, 330 MW more under construction, and 2 to 5 thousand MW potential in the geothermal field. Mexico, Japan, Hungary, USSR, Iceland and New Zealand are all producing electricity from geothermal sources, as well as producing hot water. Estimates of available power range from 30,000KW to 100,000MW (present installed generating capacity in U.S. is 300,000MW). Problems exist in exploration, and power must be transmitted to load centers. Potential geothermal fields about 1/3 to 1/2 of the West. Costs of electricity to customer might be 2/3 that of coal-fired plants. Probably 4-5 year lead time from start to on-line of plant.
Efficiencies: vary; moderately low to medium.

Environmental Factors:
Production: wells, land use. Emissions of small amounts of methane, hydrogen sulfide, (which is easily controlled).
Transmission: power lines.
Comment: Nuclear detonations to create subsurface cavities at great depths for geothermal reservoirs is being considered by the AEC. Environmental effects are unknown, but will involve some radioactivity.

2. Hydroelectric Power, including Pumped Storage.

Uses: generation of electrical power, especially good for peak power.
Feasibility: In use. About 35% of world potential, two-thirds of U.S. potential has been developed; accounts for 3.9% of U.S. energy conversion. Lead time in dam planning and construction is usually at least a decade. Pumped storage requires two reservoirs. During off-peak hours, electricity is used (from another source) with reversed turbines to pump water from lower to higher reservoir, where it can be used to generate power during peak periods. Economics limit its use.
Efficiency: high

Environmental Factors:
Damming of rivers and change of flow. Unfortunately, the same physiographic features which make good dam sites also make for scenic beauty and wilderness qualities. Dams cause thermal changes, evaporative losses and salinity concentration increases, [illegible] saturation of nitrogen in water, changed land use, inundation of

Exhibit 4

wildlife habitat, etc., etc. Pumped storage is a fairly good energy storage system.

3. Solar Energy

Description: several different means of capturing and using the sun's heat radiations for energy are in use or are possible. One type uses cells on individual houses or in small units to heat hot water, which can be stored. A proposed massive system would involve a 75 mile square, with solar heat being absorbed, stored in liquid metal, used to generate 1,000,000 MW of electrical power. A third possible method is a synchronous-orbiting satellite with photovoltaic cells of 25 square miles, with microwave energy relay to earth. A fourth method uses photovoltaic cells at the earth's surface. Solar heat radiation induces an electrical flow in photovoltaic cells. This is used in the space program, but presently is extremely expensive. A fifth proposal is a large solar concentrator-converter.
Feasibility: Presently, economics hinder wider use. "Primitive" technology is available. A five-to-ten year lead time for large demonstration plants seems reasonable.
Efficiency: 10%, with 20% as a goal.

Environmental Factors:
Land use: large areas of land will be required for "heat farms."
Transmission: by wires.
Probably the "cleanest" and least depletable energy conversion process possible.

4. Ocean Power.

Description: Tidal flows are presently used to drive turbines and generators in one large estuary in France. Floating wave-power plants are a concept.
Uses: generation of electrical power.
Feasibility: Tidal-flow turbines are in use, but economics of construction is unfavorable.
Efficiencies: not known.

Environmental Factors:
Not known; some effect on estuaries from tidal plants, probably highly disruptive of natural estuarine ecosystem.
Aesthetics.

5. Wind.

Description: remember the windmill? Unfortunately, the wind doesn't blow all of the time. Could be used with (improved) storage batteries, for small scale electrical power.
Uses: Local electrical and mechanical power.
Feasibility: Limited, but available now. Economics not known.

Environmental Factors:
Can windmills be as ugly as transmission lines? (See Holland.)

Exhibit 4

6. Hydrogen

Description: Liquid hydrogen is used as a fuel in rockets, and has tremendous energy potential. Potentials, feasibility, uses and environmental factors have not been adequately studied.

II. Alternatives in Transmission and Storage

Discussion: The mode of moving energy from source to conversion point to point of use, and combinations of modes, give a range of alternatives with varying environmental impacts. Decisions are usually based almost completely on economics, which is affected by the technological state-of-the-art. Better decisions will consider environmental factors to develop a better mix of modes and siting. Also, energy losses in transportation are considered in economic terms; environmental factors of losses should be considered, and to the maximum extent, efficiency (or minimization of energy losses) should be a paramount determinant as well as direct costs of losses.

Environmental factors include spillage, safety hazard, aesthetics, effect on biota, land use, air and water pollutants and thermal changes, effect on recreation and cultural values, potential hazard to service continuity, and other factors.

Storage is a factor in the time-quantity aspects of energy movement. Pumped hydroelectric power has been mentioned as one form of energy storage. Electric batteries are another. Storage is important also in enabling best utilization of "clean" conversion modes, some of which rely on intermittent natural process, or which are not suited to peaking problems without storage.

Following is a brief outline of storage and transmission modes, with limited discussion of certain considerations.

A. Storage

1. Hydro-electric. See pumped storage in Section I.

2. Batteries: The lead-acid storage battery used in automobiles is an example. R&D is being performed to increase storage capabilities. Problems exist in amount of energy stored and release rates, charging rates, cost, and safety, especially for use in cars. Some of the potential battery types operate at fairly high temperatures, such as lithium-chlorine battery at about 600°. Other batteries are nickel-cadmium, nickel-zinc, silver-zinc, organic-electrolyte, zinc-air, and sodium-sulfur. Battery efficiency is 80% or higher, so there are energy losses in storage. World supplies of some of the metals are very limited.

3. Heat storage: hot water, molten metals, and solid materials can be used. At present, low use factors of capital investments in heat storage make them uneconomical. This does not imply that there is no future for heat storage; limited applications should be feasible if the storage is integrated into a production-transmission-storage system. Molten metal takes advantage of the latent heat of liquifaction; to liquify a material requires an input of heat with no change in temperature; this heat is released when the material solidifies.

Exhibit 4

4. Mechanical storage: flywheels can be used to store energy in stationary and mobile situations. R&D is needed, but a good potential exists.

B. Transmission

1. Obviously, energy is transmitted in gas, liquid and solid form by land and water. Ships, barges, trains, trucks, pipelines are all used. The decisions are usually based on economics and on physiography (i.e., oceanic shipment means ships, not trains or pipelines).

2. Electrical energy is transmitted by wire. Current technology limits AC voltages to 345 KV. Future voltages may be as high as 1300 KV. Direct-current transmission is economically competitive in high voltages at distances of 400 miles or more; capital investment in conversion stations is the primary factor in this. There are still problems in reliability of high-voltage DC transmission, and R&D is needed.

Greater energy transmission per corridor is possible. For example, per square foot of corridor space:

345 KV AC permits 47 KW/ft^2
735 KV AC permits 61 KW/ft^2
1300 KV AC permits 94 to 400 KW/ft^2, eventually.

Comparing AC and DC for equal Right-of-Way:

AC		DC	
KV	MW	KV	MW
230	240		
345	580	300	900
500	1,280	500	2,500
765	2,700	700	4,500
1,300	6,500	1,000	8,000

Undergrounding of cables is always of interest to the public for environmental interest. Currently, total capital and M&O costs are 5 to 15 times higher for high-voltage underground transmission. Research is being done in insulation (including gas insulation), cryogenics for very high conductivity, and other factors. There are a number of technical problems.

Grids of transmission systems transfer power, and are especially important in meeting peaking demands. Improved grids can reduce the amount of facilities for production of energy by providing better utilization of facilities. It appears desirable to delay any massive grid development until additional R&D is accomplished, so that the future grid can use advances in technology. Perhaps 6 years of R&D and 5 years of grid development might be reasonable.

"Utilidors" should be developed in urban and non-urban situations. The "utilidor" is a utility corridor, in which transportation, communications, energy, gas, water, wastes and other materials are moved. Space and land use utilization, aesthetics, cost, and potential for waste heat recapture are justifications for utilidors. Europeans are way ahead of this country in developing utilidors.

Exhibit 4

3. General comment: at present, it is just as economical to ship coal as it is to transmit electricity from power plants. Energy efficiency appears greater for bulk coal shipment (97% by train vs. 90% for electricity transmission); i.e., energy losses are higher for mine-mouth generation and wire transmission.

Environmental problems exist in any form of energy shipment or transmission. Perhaps the greatest concern at present is associated with petroleum production and shipment, with oil spillage. Both continuous small amounts (0.1% of shipped oil) and potential supertanker disasters are involved. In the Atlantic, Jacques Cousteau figures that the damage to the ocean is already 30% to 50%.

Proper planning, design, location and controls are imperative to minimize environmental damage.

III. Alternatives in Consumption

Following are a few general comments.

A. Efficiency in Consumption.

1. Transportation. Transportation consumes about 30% of our energy in direct use, and about 10% more in indirect use (refining, asphalt, production of transportation equipment, etc.).

In direct consumption, efficiency in terms of BTU's per passenger miles for various modes is as follows:

Fast train	980
Subway train	1700
Large bus	1000
Car (1.2 people)	7300
747 Jet	5900
SST	9500

In cargo, large pipelines and supertankers deliver 800-1000 ton-miles per gallon, freight trains 100-300, trucks less than 100. In terms of total consumption, automobiles account for the great majority of energy consumption. Efficiency of energy conversion for the car is about 12%; electrical cars could achieve a 20% efficiency from energy source to use.

It is readily apparent that mass transit, smaller and more efficient cars, increased pedestrian and bicycle use, and a number of steps can and must be taken to change transportation efficiencies and reduce consumption. For example, the "Single Urban Fund" proposed by the Secretary of Transportation would permit the use of gasoline taxes for mass transit development. Unfortunately, the proposed $1 billion per year is 1/4 of what is needed, and as constituted, only the very large cities would benefit.

2. Consumption in residential-industrial uses: There are considerable opportunities in better building design to reduce heating loads (by 20% with better insulation), avoid air-conditioning, and improve the use of natural light.

Efficiencies exist in every aspect of consumption, including refrigeration, industrial production, and other uses. The problem must be attacked through R&D, building codes, better engineering, and other means.

Exhibit 4

3. "Waste" heat was discussed in conversion alternatives; opportunities exist in consumption also, but will not be discussed in detail herein.

B. Controls of Consumption

1. Rationing-electricity, gasoline, gas.
2. Education of consumers
3. Pricing: basically, all costs should be internalized. New users bear entire cost of new energy. Surcharges in peak months. Inverse pricing (the rate increases with use). Elimination of all subsidies such as subsidized water, depletion allowances. "luxury" taxes: air conditioning, non-necessary uses. Pollution taxes to producers (to internalize costs).

4. Utility companies change profit and compensation system (from return on on investment). Restrict advertising.

5. Interruptible service to industry to reduce peak loads.

IV. Alternatives in Land Use

A. Generation location.

Past practice has located generation facilities near load centers. Cheaper high voltage transmission and increasing pollution control costs for load center plants have led to the mine-mouth location in the case of coal. There are better alternatives and combinations of components of the system than those proposed in the Southwest and North Central power studies.

Generation of power and heat can be at:

Load Center
Central plant
Individual Units
Energy source
Anywhere in between (limited primarily by cooling water; this limit can be reduced if flow-through water cooling is not used).

New thinking can be utilized. Cooling water could be irrigation water, used and returned to irrigation. Industrial cities should eventually be developed to use every bit of presently wasted heat and material, and should be located at power plant sites. These need not be at energy resource locations, because coal or other energy can be shipped to the plants as cheaply as power can be transmitted by wire.

Transmission systems should be based on land use factors, and should use the utilidor concept.

B. Resource Development.

There are some commercial resources which should never be touched because very high environmental values will be destroyed. Furthermore, there are priorities in developing other resources. Those which conflict with the natural high-value areas should at least be left as options for future generations. Those resources which force the development of other resources, such as water, new roads, new towns, should be low priority. Strippable coal should not automatically

be given high priority, but should be restricted by governmental action and released for use by government, in the general welfare. Complete land reclamation must be practiced.

Comments

1. "Land use" in environmental factors has a number of ramifications. Loss of arable land, vegetation, wildlife habitat, open space are involved. Impacts on watershed and ground and surface water may be involved. Aesthetics is always affected. In some cases, such as land use for oil refineries, economics and technological factors cause especially unpropitious land uses, such as refineries in estuarine areas or near deep-water tanker unloading facilities.

2. Water consumption has attendant ecological damages: reduced stream flows; increased concentration of dissolved minerals; dams and reservoirs in many cases; thermal changes to streams, and others. Pollution can be reduced by evaporation of water from blowdown, scrubbers, etc., but this increases consumption and harms river flows, salinity, etc. Pollution could be reduced by tertiary treatment with less consumption.

3. Alternative uses of resources has not been emphasized in this treatment. For example, petroleum for lubrication is presently essential for industry, transportation and household use. Lubrication presently accounts for 0.8% of net energy input in U.S. Vegetable oils could substitute in the future, but the amount of land required and inputs of water, fertilizers and production facilities could be a significant problem.

   Coal is a potential food source, as an alternate use. Water as many alternate and multiple uses, including cultural and aesthetic uses, but it is a source of energy and is necessary in energy conversion.

4. Other resources and capital involved in energy production/transmission have not been portrayed. A power plant requires cement, steel, copper and other metals which are increasingly scarce or of lower grade ores, etc. All of these materials require natural resources and energy in their production and fabrication, with attendant environmental effects.

5. Pollution control feasibility and cost is a major aspect of alternatives, and this has not been displayed in the itemization above. In general, particulate emissions, SO_2, NO_x and CO are difficult and expensive to control, and synergism is a problem in both control and effects. In coal-fired power plants, for example, electrostatic precipitator removal of particulates is more efficient with high-sulphur coal. Carbon monoxide control in internal combustion engines and NO_x controls are inverse, if control is attempted through compression ratio and combustion control.

   In effects, SO_2, particulates and NO_x all act synergistically on biota and on visibility.

6. Base load and peaking load generation of electricity are separable problems to an extent. Certain technologies are well suited to continuous base load power generation but not as well suited to peak load generation.

7. Research and development funding and time schedules are a major point of contention. It must be recognized that adequate funding ca[illegible] ess

an R&D timetable to a certain point. However, examples in foreign countries indicate that successes are possible and that America lags badly in many respects. This is partially due to U.S. emphasis on military and space research, partially due to reliance on private industrial research. It is obvious that U.S. R&D investment must be greatly accelerated. Electric power companies recommend $10.9 billion on R&D on present methods of generation ("because of heavy industry-wide investment in present day equipment") in the next 29 years, and only $731 million for new non-nuclear technologies (Solar, MHD fuel cell, etc.) in about the same period. Nuclear R&D funds are proposed at $8.4 billion, over 29 years, with major expenditures star ing in 1980. It is highly probable that the public will be better served by R&D which does not perpetuate present generation technologies but which brings new technologies on line as soon as possible. These power companies recommend no Federal investment in geothermal energy, for example. Similarly, power companies recommend major R&D on present methods, minimal funding for new technologies (such as very high voltage AC, DC, undergrounding, etc.).

8. Waste products can be reduced and power costs lowered by efforts to use wastes as by-products. For example, some minerals are recoverable from ash, and ash itself can be used in concrete for and other purposes. Economics presently impedes progress, but more research and positive programming is needed. Siting is important. For example, plant location in remote areas hurts the economics of ash or sulfur use because of shipping costs.

Exhibit 4

United States Department of the Interior
BUREAU OF INDIAN AFFAIRS
NORTHERN CHEYENNE AGENCY
LAME DEER, MONTANA 59043

RECEIVED
FEB 20 1973
ENVIRONMENTAL
DIV.

IN REPLY REFER TO:
Administration

February 13, 1973

Mr. Dan Vichorek
State Department of Health
Coswell Building
Helena, Montana 59601

Dear Mr. Vichorek:

Per our telephone conversation relative to the Colstrip Power Plant, I have discussed this with Mr. Allen Rowland, Tribal President. He is planning to share his thoughts also. I submit the following comments on the subject:

1. The Northern Cheyenne Tribe is definitely concerned over the proposed construction of the power plant at Colstrip. They see this as having a decided negative effect upon the environment of the reservation.

2. There will be a "splash over" effect of influx of people into the Colstrip area. Already, with Peabody Coal and Western Energy mining operations, the influx of people is felt at Lame Deer. A number of employees of these companies do reside on the reservation--these are employees who are not members of the Tribe and who are non-Indian. With the construction of the power plant in full operation, we can anticipate greater numbers desiring to reside here.

3. The power plant will create a pollution problem as it will release fly-ash as well as other emmissions which will be carried to the reservation. The normal wind direction is from Colstrip to the south and the reservation is located in that general area.

4. The Tribe is concerned about the effects of pollution on not only natural resources, i.e. timber, water, etc., but upon humans. Also, the effects on wildlife and other game will be negative. This is of great concern to the Tribe.

5. The Tribe anticipates heavy use of its recreation areas by non-Indians. The Tribe is not prepared to handle this degree of influx. Also, this could create some very real jurisdictional and legal problems.

6. Certainly, with more people moving into the area, traffic by vehicular means will be greatly increased. This will create problems for the reservation and its people.

Exhibit 4

7. Finally, the Tribe is concerned about the loosely and nebulously worded draft impact statement that has been circulated. There are too many unanswered questions contained within that document; insufficient or inadequate responses to questions raised by the writers of that document, etc. It is hoped that a more complete and comprehensive study be made before the permit to construct is issued.

In conclusion, the Tribe is concerned that little or no attention has been given to their views on the proposed plant. The Tribal Council, as the highest governing body of the reservation had not been contacted prior to your telephone call.

Sincerely yours,

Alonzo T. Spang, Sr.

Dr. Alonzo T. Spang, Sr.
Superintendent

Exhibit 4

STATE OF MONTANA

Environmental Quality Council

FLETCHER NEWBY
EXECUTIVE DIRECTOR

CAPITOL STATION, HELENA, MT. 59601

GOV. FORREST ANDERSON
OR DESIGNATED REPRESENTATIVE
MR. GARY WICKS

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APPOINTED MEMBERS
DR. WILLIAM G. WALTER
MRS. DONALD (HARRIET) MARBLE
MR. WARREN A. HOOK
MR. MICHAEL J. MC KEON

January 3, 1973

Dr. John S. Anderson, Director
Department of Health and
Environmental Sciences
Helena, Montana

Attention: Mr. Donald Holtz

Dear Dr. Anderson:

The draft environmental impact statement and draft supplement on the proposed Montana Power Company electrical generating plant at Colstrip has been reviewed by the EQC staff, prompting the ensuing comments.

Page 2--paragraph 2. The pipeline diameter and maximum water diversion figures presented here, in the supplement, and page iv are significantly smaller than those in Montana Power Company's Notice of Appropriation [3] (22"-26" vs. 60" and 8,000 gallons per minute vs. 112,200 gallons per minute). A more definite commitment as to size of pipeline is needed to assess the possible future environmental impact on the Yellowstone River due to water withdrawal. (See comments on water quality impact).

Page 4--paragraph 1. A recent environmental assessment on a proposed mobile home park at Colstrip, prepared by the Environmental Services Bureau of the Department of Health, indicates that at least a portion of the 800-900 man construction work force will live in the Colstrip area. The assessment states that "The immediate population (of the trailer court) is likely to consist of temporary area residents whose interest is construction employment. Too often this transiency precludes care of housing and premises and little aesthetic improvement is undertaken."

The assessment further states that "...the immediate effect (of the total complex) is likely to be a tendency toward a boomtown environment, especially during the construction phase. Unless carefully controlled, spin-off service type business could develop indiscriminately with an eye to operation during the boom phase only. This practice leads to hastily, improperly and cheaply constructed establishments which are abandoned when their profits decline."

Exhibit 4

There was apparently little or no coordination between the Environmental Services Bureau and the Air Quality Bureau in assessing the impact accruing from the influx of construction workers. Furthermore, neither Environmental Services' assessment nor Air Quality's impact statement adequately discussed the full range of ramifications possible, including social and economic, due to the total temporary construction work force.

Page 8--paragraphs 3 and 4. Perhaps more pertinent to local ambient air quality than a description of a modified continental climate would be a discussion of local meteorological conditions, including prevailing wind direction and velocity, inversion strength and frequency, the relationship between seasonal weather patterns and contaminant concentration levels, and the probable behavior of plumes with respect to local topography. It is possible much of this information is now available from the meteorological assessment being conducted for the applicant by Montana State University.

Page 12--paragraph 1. Some discussion should be presented here on the adequacy of the diffusion model and why this model was chosen over others that may be available. Has this model proven accurate in past applications?

Page 19--paragraph 3. The statement that uranium and thorium will be removed from the effluent gases suggests that these elements will be present in the fly ash. If so, in what concentrations are they likely to occur? Also, has uranium and thorium removal from effluent gases been demonstrated in existing installations?

Pages 25,26--parts D,1.b.,c. It is reasonable to assume that the preponderance of the water soluble components of the ash will be extracted and concentrated in the water of the ash ponds before the ash is removed to be buried in the mines. It is therefore conceivable that groundwater contamination could result from percolation of highly charged mineral water into the subsurface reservoir. Is such contamination likely? If so, what provisions have been made for sealing the bottom of the reservoir? If contamination is not likely, mention should be made of this fact.

Page 29--paragraph 4. The changes in water quantity due to diversion from the Yellowstone River can be quantified, and changes in water quality due to this diversion can be predicted, at least intuitively as to the types of changes to be expected. The degree to which these changes would take place is in the realm of speculation.

According to statistics supplied by MPC the proposed plant would consume 8,000 gallons per minute or 17.8 cubic feet per second (cfs). Records from the Rosebud County clerk and recorder's office indicate that the total MPC appropriation from the Yellowstone River is 250 cfs. [3]

These two figures, 17.8 cfs and 250 cfs, can be compared with selected Yellowstone River discharge figures to yield the proportion or percentage of river water diverted from which estimates of impact on water quality may be approximated. The following selected discharge figures were measured by the U.S.G.S. at station 3090 on the Yellowstone River at Miles City. [4]

Exhibit 4

1. 996 cfs (December 14, 1932). Minimum discharge for period of record.
   17.8 cfs = 1.8%
   250 cfs = 25%

2. 1400 cfs (May, 1961). Minimum discharge for water year 1961.
   17.8 cfs = 1.3%
   250 cfs = 18%

3. 2290 cfs (January 7, 1970). Minimum discharge for water year 1970.
   17.8 cfs = 0.8%
   250 cfs - 11%

4. 11140 cfs. Average discharge for 43 years of record.
   17.8 cfs = 0.2%
   250 cfs = 2.2%

From the foregoing it is clear that water diverted for and consumed by the proposed plant (17.8 cfs) would be inconsequential in terms of the total flow of the Yellowstone past Miles City, even at minimum discharge levels. The additive effect of several more plants drawing water from the same source may be considerable, however.

Assuming utilization of the total appropriation of 250 cfs, proportionate use of Yellowstone River water would range from 11% to 25% at minimum discharge levels and 2.2% of the 43-year average discharge. For those who would contend that this is an unrealistic figure because appropriations are usually far above what is actually diverted and used, the Appraisal Report on Montana-Wyoming Aqueducts[2] lists approximately 2,350 cfs (1,700,000 acre-feet per year) of Yellowstone River water subject to development as industrial water supplies and a recent newspaper editorial[1] written by a Bureau of Reclamation official indicates that in normal years the flow of the Yellowstone would be reduced one-third and in a dry year the flow would be reduced about one-half as a result of water diversion for industrial use.

The diversion of water of the magnitude discussed in the paragraph above would have effects on the water quality of the Yellowstone River in the following areas:

1. Temperature. Loss of water volume and buffering capacity would result in more erratic temperature fluctuations, higher temperature maxima and more prolonged periods of freezing, thus affecting:
   a. life histories of fish, invertebrates and aquatic plants.
   b. growth and reproductive rates of preferred and undesirable fish species, possibly giving the latter a competitive advantage and resulting in changes in
   c. relative abundance of preferred and undesirable fish species.
   d. growth rates of aquatic plants, including algae; possibly enhancing seasonal production resulting in nuisance blooms and taste and odor problems.

Exhibit 4

e. diversity of the aquatic community.

2. Concentration of Pollutants. Most water quality management plans are based on the dilution effect afforded by the receiving waters. Once a substantial volume of dilution water is removed polluters may find themselves in a position of noncompliance with existing water quality criteria. Parameters, the concentrations or levels of which may be affected, include:
   a. coliforms.
   b. biochemical oxygen demand (BOD) and dissolved oxygen.
   c. pH
   d. turbidity.
   e. temperature.
   f. residues.
   g. sediment or settleable solids.
   h. toxic substances (pesticides and heavy metals).

   In the extreme case, one or any number of these factors may increase (or decrease) in value or concentration to the point where the tolerance level of fish and bottom organisms is exceeded and community diversity is thereby reduced.

3. Concentration of Nutrients. Nutrients, particularly phosphorus, nitrogen and carbon, are critical to growth of algae and other plants which form the base of the aquatic food chain. Only slight increases in the usable concentrations of these three strategic elements, alone or in combination, are often enough to trigger massive algal growths or blooms which could degrade the water aesthetically by causing taste and odor problems and visual unsightliness. The Yellowstone River, however, is not subject to this type of problem except where it or its confluent the Missouri may be impounded.

These are three areas where water quality would be affected by diversion away from the river. These are merely the types of problems that may arise; statements on their extent would be speculation at this time. The severity of the impact would be determined by the magnitude and timing of the withdrawal. Critical parameters should be monitored over a period of years to detect undesirable changes as development progresses and more water is appropriated, withdrawn and consumed.

Page 37--Section VI. Possibly here or under the description of the proposed action should be presented some information attempting to justify the need for this plant in this location. The applicant should be able to substantiate Montana energy needs by supplying information on the following evaluative criteria: (1) growth in demand and projections of need; (2) socially beneficial uses of the output of this facility, including its uses to protect or enhance environmental quality; and (3) conservation activities which could reduce the need for more power.

Also desirable would be an informative discussion on why the plant is being located here rather than at the load center.

Exhibit 4

Page 45--list of contributors. Although an impressive list of credentials is presented here, the Department of Health has other specialists, such as water pollution and noise specialists, who could have added substantially to the impact analysis. Also, the impact analysis can hardly be considered complete without the input of either a social scientist or a life scientist.

Supplement--Dry Cooling Towers. Additional information on the costs of wet versus dry cooling might be obtained from a recent article based on work conducted out of the EPA Northwest Water Laboratory, Corvallis, Oregon.[5] This article concludes that "...whenever the competitive demands for other water uses put a high enough cost on its use for cooling, the dry system may well become an economically attractive alternative to evaporating cooling systems."

We hope these comments will be helpful in constructing your final impact statement and making your decision on the Colstrip power plant. Thank you for your efforts toward compliance with MEPA and the EQC guidelines.

Sincerely yours,

FLETCHER E. NEWBY
Executive Director

By Loren L. Bahls
Loren L. Bahls, Ph.D.
Staff Ecologist

and Thomas J. Gill
Thomas J. Gill
Research Assistant

cc: Dan Vichorek
enclosure - Fletcher E. Newby testimony

Exhibit 4

Exhibit 4

REFERENCES

1. Aldrich, Harold E. 1972. Guest editorial on power production and energy and water requirements in the Fort Union region. Billings Gazette, December 10.

2. Bureau of Reclamation, U.S.D.I. 1972. Appraisal report on Montana-Wyoming Aqueducts. April.

3. Culver, F.D. 1972. Memorandum to Fletcher Newby on MPC water appropriation from the Yellowstone River for Colstrip area power plants. November 9.

4. Geological Survey, U.S.D.I. 1970. Water resources data for Montana. Part 1. Surface water records.

5. Shirazi, M.A. 1972. Dry cooling towers for steam electric power plants in arid regions. Water Research 6: 1309-1319.

Exhibit 4

Exhibit 4

STATEMENT PRESENTED AT THE PUBLIC HEARING ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT ON THE PROPOSED COAL-FIRED ELECTRICAL GENERATION FACILITY TO BE CONSTRUCTED AT COLSTRIP, MONTANA BY MONTANA POWER COMPANY, JANUARY 5, 1973.

I AM FLETCHER NEWBY, DIRECTOR OF THE ENVIRONMENTAL QUALITY COUNCIL, ESTABLISHED BY THE MONTANA ENVIRONMENTAL POLICY ACT (MEPA) OF 1971.

THE ENVIRONMENTAL QUALITY COUNCIL WAS CREATED BY THE LEGISLATURE TO PROVIDE A POLICY OVERVIEW OF STATE AGENCY ACTIONS WITH ENVIRONMENTAL CONSEQUENCES AND TO ADMINISTER THE ENVIRONMENTAL IMPACT STATEMENT PROCESS. IN ADDITION, THE COUNCIL HAS BEEN INSTRUCTED BY THE ACT "TO REVIEW AND APPRAISE THE VARIOUS PROGRAMS AND ACTIVITIES OF STATE AGENCIES" IN THE LIGHT OF THE ENVIRONMENTAL POLICY TO DETERMINE THE EXTENT TO WHICH SUCH PROGRAMS AND ACTIVITIES ARE CONTRIBUTING TO THE ACHIEVEMENT OF THIS POLICY. IT IS IN THIS CONTEXT THAT THE COUNCIL IS INTENSELY INTERESTED IN THE DECISIONS AND ACTIONS OF THE BOARD AND THE DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES AFFECTING ENVIRONMENTAL QUALITY.

MEPA IMPOSES A LEGAL DUTY ON STATE AGENCIES TO CONSIDER ENVIRONMENTAL VALUES IN THEIR DECISION-MAKING PROCESSES. AGENCIES WHOSE MANDATES PREVIOUSLY DIRECTED THEIR ATTENTION ONLY TO CERTAIN FACETS OF THE ENVIRONMENT NOW HAVE A RESPONSIBILITY AS BROAD AS THE ENVIRONMENTAL POLICY DECLARED IN MEPA. WHERE AN AGENCY PREVIOUSLY LOOKED AT ONLY A LIMITED ASPECT OF PRIVATE ACTIVITIES UNDER ITS REGULATION, MEPA FORCES IT TO BROADEN ITS CONCERNS

Exhibit 4

SUBSTANTIALLY. AN AGENCY MUST CONSIDER, AND AS APPROPRIATE, ACT TO MINIMIZE THE ADVERSE ENVIRONMENTAL EFFECTS THAT CAN BE EXPECTED FROM THE ACTIVITY SUBJECT TO ITS REGULATORY ACTION.

MEPA IS CLOSELY MODELLED UPON ITS FEDERAL PREDECESSOR THE NATIONAL ENVIRONMENTAL POLICY ACT (NEPA). FOR THIS REASON WE REGARD THE PRECEDENTS ESTABLISHED BY FEDERAL CASE LAW AS INSTRUCTIVE GUIDANCE FOR OUR OPERATIONS. IN THIS REGARD OUR TESTIMONY DRAWN FROM THIS BACKGROUND AND PRESENTED TODAY WILL PRIMARILY CONCERN PROCEDURAL MATTERS AS CONTRASTED WITH TECHNICAL COMMENTS, WHICH WE ARE SUBMITTING SEPARATELY, WE ARE AWARE THAT EXTENSIVE TECHNICAL COMMENT ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT HAS BEEN RECEIVED BY THE DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES.

THE TWO PRIMARY PURPOSES OF AN ENVIRONMENTAL IMPACT STATEMENT ARE (1) TO COMPEL THE AGENCY TO CONSIDER THE ENVIRONMENTAL CONSEQUENCES OF ITS PROPOSED ACTION AND (2) THE ACCOMPLISHMENT OF FULL DISCLOSURE. THE ENVIRONMENTAL IMPACT STATEMENT IS NOT ONLY FOR USE BY DECISION MAKERS, IN THIS CASE THE BOARD AND THE DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES, BUT ALSO MUST PROVIDE A BASIS FOR MEANINGFULLY ALLOWING THOSE WHO ARE REMOVED FROM THE DECISION-MAKING PROCESS TO EVALUATE AND BALANCE THE FACTORS ON THEIR OWN. THE STATEMENT MUST, AT A MINIMUM, CONTAIN INFORMATION WHICH WILL ALERT THE PUBLIC TO ALL KNOWN POSSIBLE ENVIRONMENTAL CONSEQUENCES. BECAUSE THE DRAFT SERVES AS A PRIMARY MEANS OF INFORMING OTHERS ABOUT THE ENVIRONMENTAL EFFECTS OF THE PROPOSED ACTION AND OF POSSIBLE ALTERNATIVE ACTIONS, IT SHOULD EMBODY A THOROUGH AIRING OF EACH OF THE POINTS SPECIFIED IN THE STATUTORY LANGUAGE OF MEPA. BY THE TIME IT CIRCULATES A DRAFT THE INITIATING AGENCY SHOULD

Exhibit 4

HAVE FULLY EXPLORED THOSE POINTS WITH HELP FROM OTHER SOURCES WHEN NECESSARY, RATHER THAN LEAVING PARTS OF THE ANALYSIS TO BE FURNISHED BY SOURCES OF COMMENTS.

WE BELIEVE THE DEFICIENCIES TO BE NOTED IN THE DRAFT STATEMENT ARE PRIMARILY THE RESULT OF ALLOWING INSUFFICIENT TIME FOR PREPARATION OF THE DRAFT AND FAILURE TO COMPLY WITH SECTION 69-6504(B)(1) OF MEPA WHICH DIRECTS AGENCIES TO UTILIZE A SYSTEMATIC INTERDISCIPLINARY APPROACH WHICH WILL ENSURE THE INTEGRATED USE OF THE NATURAL AND SOCIAL SCIENCES AND THE ENVIRONMENTAL DESIGN ARTS IN PLANNING AND IN DECISION MAKING WHICH MAY HAVE AN IMPACT ON MAN'S ENVIRONMENT. THE DRAFT STATEMENT WAS THE PRODUCT OF A CRASH EFFORT TO BEAT THE FIRST SCHEDULED DATE OF THE COURT HEARING. FURTHER, A GLANCE AT THE LIST OF PREPARATORS OF THE DRAFT STATEMENT REVEALS THAT ALL ARE PHYSICAL SCIENTISTS. NOTABLY LACKING ARE REPRESENTATIVES FROM ECONOMICS, LIFE SCIENCES, AND SOCIAL SCIENCES. IT ALSO APPEARS THAT THE EFFECT OF FULL DISCLOSURE WAS INHIBITED BY LACK OF COMPLETE INFORMATION FROM THE APPLICANT ON DEVELOPMENTS APPURTENANT TO THE POWER PLANT AND ON THE INTENDED USE OF THE ENERGY GENERATED BY THE PROPOSED PLANT.

THE ENVIRONMENTAL QUALITY COUNCIL, RECOGNIZING THESE DEFICIENCIES, AND AWARE OF SIGNIFICANT NEW INFORMATION, RECOMMENDED TO THE DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES THE ISSUANCE OF A REVISED DRAFT OR SUPPLEMENT TO THE DRAFT. THE COUNCIL DID NOT RECOMMEND ANY CHANGE IN

Exhibit 4

THE PROPOSED TIME FRAME FOR THE HEARING AND RECEIPT OF COMMENTS. OBVIOUSLY THE PROCESS OF CIRCULATION AND COMMENT MUST END AT SOME POINT. THE COUNCIL'S SUGGESTION WAS NOT MADE WITHOUT PRECEDENT NOR WAS IT MADE LIGHTLY. AN EXCERPT FROM THE DECISION OF ONE DISTRICT COURT BEARS DIRECTLY UPON THIS SITUATION -- "IT IS DOUBTFUL THAT ANY AGENCY HOWEVER OBJECTIVE, HOWEVER SINCERE, HOWEVER WELL STAFFED, AND HOWEVER WELL FINANCED, COULD COME UP WITH A PERFECT ENVIRONMENTAL IMPACT STATEMENT IN CONNECTION WITH ANY MAJOR PROJECT. FURTHER STUDIES, EVALUATIONS, AND ANALYSES BY EXPERTS ARE ALMOST CERTAIN TO REVEAL INADEQUACIES OR DEFICIENCIES, BUT EVEN SUCH DEFICIENCIES AND INADEQUACIES DISCOVERED AFTER THE FACT CAN BE BROUGHT TO THE ATTENTION OF THE DECISION MAKERS."

IT SEEMS DESIRABLE TO PROVIDE SOME GUIDANCE AS TO WHAT IS EXPECTED IN THE FINAL ENVIRONMENTAL IMPACT STATEMENT. THE VERY RATIONALE FOR CONSULTATION WITH OTHERS IS THAT A COMMENTING AGENCY OR GROUP MAY UNCOVER ERRORS OR OMISSIONS IN THE DRAFT STATEMENT. THE FINAL STATEMENT, WHEN ISSUED, WILL THUS IDEALLY BE COMPREHENSIVE AND WILL GIVE ADEQUATE GUIDANCE IN THE AGENCY'S DECISION WHETHER TO GRANT THE PERMIT.

AN IMPORTANT CONSIDERATION IN PREPARATION OF THE FINAL STATEMENT IS ADEQUATE RESPONSE TO COMMENTS, INCLUDING

Exhibit 4

RESPONSIBLE OPPOSING VIEWS. WHAT IS INTENDED IS THE INCLUSION OF ALL MEANINGFUL REFERENCES THAT IDENTIFY THE PROBLEM AT HAND FOR THE RESPONSIBLE OFFICIAL. AGENCIES HAVE PUBLIC VALUES TO CONSIDER OTHER THAN THE ENVIRONMENT. BALANCING THEM AGAINST ENVIRONMENTAL VALUES IS IN INHERENT IN THE DUTY IMPOSED BY MEPA. IF THE ENVIRONMENTAL EFFECTS ARE ADVERSE, THE AGENCY MUST CONSIDER WHETHER THEY OUTWEIGH THE BENFITS OF THE PROPOSAL. THE IMPACT STATEMENT PROVIDES A BASIS FOR EVALUATION OF THE BENEFITS OF THE PROPOSED PROJECT IN LIGHT OF ITS ENVIRONMENTAL RISKS AND COMPARISON OF THE NET BALANCE FOR THE PROPOSED PROJECT WITH THE ENVIRONMENTAL RISKS PRESENTED BY ALTERNATIVE COURSES OF ACTION.

IN CLOSING THIS TESTIMONY IT SEEMS OBVIOUS THAT THE DESIRES OF THE PUBLIC AS COMMUNICATED TO THE DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES ARE FOR A BROADER JURISDICTION THAN THAT GIVEN BY THE MONTANA CLEAN AIR ACT TO THE DEPARTMENT. THE GOVERNOR OF MONTANA, THE LEGISLATIVE COUNCIL, AND THE ENVIRONMENTAL QUALITY COUNCIL ALL HAVE RECOMMENDED A POWER PLANT SITING AUTHORITY ACT TO THE 1973 LEGISLATURE. IT MAY BE SMALL CONSOLATION TO THE DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES BUT IF THIS ACT PASSES THE ENVIRONMENTAL IMPACT STATEMENT FOR THE COLSTRIP STEAM-ELECTRIC GENERATION PLANT MAY BE THE ONLY ONE OF THIS NATURE THE DEPARTMENT WILL EVER HAVE TO WRITE.

END.

Exhibit 4

Exhibit 4

United States Department of the Interior
BONNEVILLE POWER ADMINISTRATION
KALISPELL DISTRICT OFFICE
P.O. Box 758, Kalispell, Montana 59901

In reply refer to: OKK

February 1, 1973

RECEIVED
FEB 5 1973
ENVIRONMENTAL SCIENCES
DIVISION

Daniel Vichorek, Technical Writer
State of Montana
State Department of Health and
Environmental Sciences
Helena, Montana 59601

Dear Mr. Vichorek:

This letter contains answers to the questions asked in your January 2, 1973 letter. In addition to the specific information you requested, I am enclosing "20 Questions on Electric Power Loads and Resources in the Pacific Northwest", published by the Pacific Northwest River Basins Commission.

1. What is the rate of line loss in lines of various size, particularly 230-kv and 500-kv lines?

Strictly speaking, for a given line at 230-kv or 525-kv (commonly called 500-kv), and with a given conductor size, the percentage power loss per mile at half and full thermal loading is shown below:

Line Voltage (KV)	Conductor No. per phase	Conductor Designation	Power Loss/Mile Half Load %	Power Loss/Mile Full Load* %
230	1	Drake	.039	0.085
230	1	Pheasant	.033	0.073
525	2	Chukar	.014	0.029
525	3	Bunting	.015	0.033

* 50° rise above 25° c ambient, wind @ 1.4mph. (Max. design loading)

Because of system reliability considerations, BPA lines are normally loaded slightly below half the maximum design thermal rating. These lines would operate near maximum thermal loading only during emergency conditions.

The above information should not lead to hasty conclusions because power transfers through a transmission grid can result in great variations in losses, dependent upon many factors. Generally, the total power flow on a transmission system will result in the least possible losses. The effect of an incremental power transfer on transmission losses may either add or subtract to the existing losses, depending upon the direction of prior flows and the magnitude of the incremental transfer.

Exhibit 4

2. What corridor width is necessary for 230-kv lines? For 500-kv lines?

Each standard BPA right-of-way for both single-circuit and double-circuit, steel structure, 230,000-volt transmission lines is 125 feet wide. The right-of-way width for steel-structure 500,000-volt lines varies between 135 and 165 feet, depending upon the type of structure used. Enclosed for your reference is an information sheet entitled, "BPA's Single and Double-circuit 500 kilovolt Transmission Towers". You will note that tower 4 carries two 500,000-volt circuits which requires a right-of-way width of only 140 feet, whereas, tower 3, also carrying two 500-000-volt circuits, requires a width of 165 feet. The height varies inversly with the right-of-way width depending upon tower type; tower 3 is 143 feet high and tower 4 is 176 feet high. The reverse side of the information sheet shows various configurations of the transmission towers.

3. When two 230-kv or two 500-kv lines are run parallel, how close together may they be?

The minimum separation of two parallel lines is based on the required electrical clearance between the closest conductors. The necessary distance between centerlines is determined by several factors, the main ones being:

a. Line voltage - Higher voltage requires greater electrical clearance.

b. Tower design - This fixes the position of each conductor in relation to the tower center.

c. Span length - Longer spans allow more side swing of the conductor and, therefore, require greater separation.

d. Conductor design and tension - These factors also affect the amount that the conductors will sway horizontally.

The following figures are typical separations between centerlines of two parallel lines currently used by BPA:

230-kv, single-circuit, wood-pole	85 feet
230-kv, single-circuit, steel	115 feet
230-kv, double-circuit, steel	115 feet
500-kv, single-circuit, steel	115 feet
500-kv, double-circuit, steel	160 feet

4. How wide is the necessary right-of-way for parallel lines?

The right-of-way width requirements are based on most of the same factors mentioned above. The criteria for "edge distance" (distance from centerline of each line to the edge of the right-of-way easement) is that it must be great enough to provide for conductor side swing plus safe elec-

Exhibit 4

trical clearance. Typical right-of-way widths for two parallel lines are:

230-kv, wood-pole	185 feet
230-kv, steel	240 feet
500-kv, steel	250 feet

5. How much land would be impacted where a single or double 230-kv or 500-kv line crossed range or crop land? Does this include the service road?

The impact of towers on rangeland is minimal. Livestock graze under and around the structures. The only area permanently removed from use is an approximate five-foot square around each individual tower leg. This amounts to about 500 square feet per mile of line. Cropland is disturbed to a greater extent, both in the area removed from production and in inconvenience to the farmer in his activities. The cropland permanently affected by tower sites is as follows:

	Acres per Tower Site	Acres per Mile
230-kv, single circuit, wood-pole	.001	.007
230-kv, single-circuit, steel	.018	.090
230-kv, double-circuit, steel	.018	.090
500-kv, single-circuit, steel	.020	.10
500-kv, double-circuit, steel	.028	.14

Access roads create additional impacts which vary greatly with terrain. In fairly flat topography (less than 5% side slope), permanent road construction is usually not required on crop- or rangeland. Access can be along the right-of-way on the natural ground surface, with only minor and temporary construction. In steeper terrain the road system will cause more impact than the line itself. A typical access road through rolling farmland will disturb an area 20 feet wide, which amounts to 2.4 acres per mile.

6. What data exists on the use of the power to be exported from Montana?

I presume your question refers to the power to be acquired from the Colstrip development by Puget Sound Power & Light Company. This private company is a member of the Joint Power Planning Council which has formulated and is implementing the Pacific Northwest 10-year Hydro-Thermal Power Program. The Joint Power Planning Council is composed of 4 private utilities, 104 public utilities and BPA. The Hydro-Thermal Power Program is a cooperative regional effort to meet the total load requirements of the Pacific Northwest (which includes the Puget Sound Power & Light Company's loads).

The power that Puget is acquiring from the Colstrip development will not

Exhibit 4

likely to be used in aluminum reduction plants. It is reasonable to assume that the load-growth additions will be similar in nature to that which is presently served, and evaluating data contained in the Company's FPC report for calendar year 1971, energy was sold to the following classes of consumers in the indicated percentage:

Classification of energy delivered to ultimate consumers	Percent of sales
Non-farm residential	56.8
Commercial	21.7
Industrial	18.8
Street & Highway Lighting	0.6
All other	2.1
	100%

7. Since the demand for electricity is growing far faster than the population in the Northwest, what is causing the increased demand?

The enclosed paper on "Power Needs in the Pacific Northwest to 1990" explains in a fair amount of detail the fact that total energy use has been growing much more rapidly than population and electric energy use more rapidly than total energy use and the reasons therefore. The chart following page 6 has been revised and I have entered the revised years and percentage growth figures on the old chart since we have not reproduced a new one as yet.

8. What percentage of the power will go for industrial use, lighting, aluminum processing, home heating, or cooling?

The chart following page 11 in the aforementioned paper shows the relative amount of electric power used for residential space heating. It also indicates, in showing the difference between 1950 and 1970, the population growth accounted for only 4,345 million kwh of the over 22,300 kwh increase in residential use in the West Group Area (the geographic area served by BPA, less loads of Montana and Idaho Power Companies) between 1950 and 1970. The greatest increase, over 18,000 million kwh, came from increased use per customer and the largest single item, almost 8,000 million kwh, was electric space heat.

Also enclosed are two tables. The first shows electric power requirements by major consumer classes 1950 through 1990. The 1950, 1960 and 1970 data are taken from reports to the FPC and the 1980 and 1990 data are our estimates based on the West Group forecasts. The second table breaks down these sales data a little further. It shows industrial energy sales as a percent of total electric energy sales in the West Group Area and sales to the aluminum industry as a percent of total sales and industrial sales. Not only are industrial sales expected to decline as a percent of total sales, but aluminum sales as a percent of either total or industrial sales are expected to decline drastically over the next 20 years.

Exhibit 4

9. What, in laymen's terms, are "design corona losses" in power lines?

Transmission line corona is the electrical breakdown of the air in contact with the high-voltage conductors. It is confined to the conductor surface and is encouraged by rain. In anticipation of this phenomena, transmission lines are designed to minimize corona losses.

Corona loss may be likened to the small leaks in the wooden pipes used in early water systems. Wooden pipes have now been replaced with cast iron and this small water loss no longer exists. Hopefully, technology will advance to where we can also eliminate corona loss. The only methods presently known are uneconomical, so corona loss is minimized but not eliminated.

As in the case of water loss, corona loss reduces the amount of product available for the intended use. However, compared to the amount of product delivered, the loss is extremely small. Corona losses vary between 1-10 kilowatts per mile during fair weather, and 10-100 kilowatts during foul weather.

There are no adverse effects associated with normal line corona activity except for occasional radio and television interference.

10. How much power does BPA now import to Montana? How much is exported from Montana?

Some discussion on terminology may be in order before attempting to answer your question. The term "electric power" is a term used in the industry to mean inclusively "power and energy". Strictly speaking, the term "power" is the time rate of transferring energy, and "energy" is that which is capable of doing work. Power (often called "demand" when associated with loads and "capability" when associated with generation or power-handling facilities) is measured in kilowatts; electric energy is measured in kilowatt-hours. There are also two broad catagories of power -- firm and non-firm power. Firm power is intended to have assured availability and non-firm power does not have assured availability to meet load requirements.

During the 5 calendar years 1967 through 1971, BPA's total firm and non-firm energy sales in Montana have averaged about 4,351,600,000 kilowatt hours each year. The average annual energy actually generated at the Hungry Horse Project (the only Federal Project in Montana which BPA presently markets power from) has been roughly 950,400,000 kilowatt-hours. In terms of percentage, 78% of BPA's energy sales in Montana have been produced by generators located outside of the State.

Another term we often use is "average energy". This is determined by taking the total energy in kilowatt-hours, dividing by the total number

Exhibit 4

of hours in the period, resulting in a power (demand or capability) figure which if maintained throughout the period would transfer the total energy. The foregoing explanation allows me to express BPA's energy imports in a slightly different way. During the Fiscal Year 1972 (July 1, 1971 through June 30, 1972), BPA's average firm energy sales within our marketing area in Montana (West of the Continental Divide) was 418,900 kilowatts. These sales were to Cooperatives, 29,300 kilowatts; private utilities 145,100 kilowatts; Federal Agencies 4700 kilowatts; aluminum industry 302,400 kilowatts; and other industry (Stauffer Chemical Company) 36,400 kilowatts. In addition to these sales of firm energy, BPA sold 186,000 kilowatts average of interruptible power in Montana during Fiscal Year 1972, bringing the total to 604,900 kilowatts average.

The average firm generating capability of Hungry Horse Dam under critical water conditions is 221,000 kilowatts. A corresponding figure for Libby Dam, scheduled to begin generating in 1975, is 204,000 kilowatts. The total average firm generating capability of these two Federal Projects, with the power to be marketed by BPA is 425,000 kilowatts.

It must be recognized that the power flow situation is continually changing. For example, during the summer while Hungry Horse Dam is storing water, little or no power is being generated, resulting in most all of the energy BPA serves in Montana coming from outside the State. One of the uses of the new Dworshak (Idaho) - Hot Springs 500,000-volt transmission line is to carry the heavy power flow during the periods when Hungry Horse is not generating. Conversely during the wintertime when cold weather settles over the Pacific Northwest, the Hungry Horse Project will be generating at or near its rated peak generating capability of 285,000 kilowatts. The approximate peak demand of BPA-served loads in Western Montana during the Fiscal Year 1972 was 800,000 kilowatts.

On a state-wide basis, it appears that the generating sources within the State produce approximately 10 billion kilowatt hours annually, which is about the same amount required by the loads located within Montana. This statement is rough; no exhaustive study has been made. If you wish to pursue this further I suggest you contact the following organizations which operate generation and transmission facilities in Montana:

U. S. Bureau of Reclamation, Billings, Montana
Montana-Dakota Utilities
Montana Power Company
Washington Water Power Company.

I will be happy to provide generation and sales statistics for BPA-marketed power, if you wish to make such an analysis.

11. If Colstrip Unit 4 is built, what is the probable route of the 500,000-volt line out of Montana?

Exhibit 4

I am sure you recognize, assuming the Colstrip Unit 4 is built and that the private power company's desire to make use of the Federal Transmission System within the BPA marketing area, that the route for a 500,000-volt transmission line or lines can only be determined as a result of extensive studies. It is quite reasonable to assume the transmission facilities would connect to either or both Hot Springs Substation or Anaconda Substation. Both of these substations are strong power connection points in the transmission grid. On the west slopes of the Rocky Mountains the lines would probably either connect to existing facilities in the Spokane area or in the Lewiston area. Additional facilities from those areas westward would also be required. By referring to a topographic map, it is obvious that the number of mountain passes in Western Montana and Northern Idaho through which transmission facilities could be constructed are limited. To fulfill the intent of the National Environmental Policy Act of 1969, BPA will consider all available alternative corridors, if such lines are constructed.

12. Would new lines be necessary from Western to Eastern Montana?

I am certain additional lines will be required, both to serve loads in Montana and to provide a path for power to flow to the Northwest. We do not have any specific information available on what will be required, and you may wish to query the Montana Power Company in this regard.

13. What is the comparative cost of hauling the coal from Montana to generating plants near out-of-state load centers, and transmitting the power to the load centers from mine-mouth plants?

I do not have the answer. There would be some important judgment elements involved in such an analysis, such as probability of freight-rate increases. This would be of vital importance to Puget Sound Power and Light Company, and I suggest you make inquiry there.

Please let me know if additional information or clarification is desired.

Sincerely,

Ronald H. Wilkerson

Ronald H. Wilkerson
District Manager

Enclosures:
As noted

Exhibit 4

Exhibit 4

COMMENTS OF THE ENVIRONMENTAL DEFENSE FUND
REGARDING THE DRAFT ENVIRONMENTAL IMPACT
STATEMENT ON THE PROPOSED MONTANA POWER COMPANY
ELECTRICAL GENERATING PLANT AT COLSTRIP, MONTANA

page 1.[1] Description of Proposed Action

The Venturi Scrubber Process was first patented in 1925 and put into commercial practice some 20 years later.[2] It is clear that this type of scrubber has certain advantages and disadvantages when compared with alternative methods of air pollution control. The Draft Environmental Impact Statement (DEIS) must deal with this subject in considerable detail. If there is evidence "that the Venturis will also remove most fluorides and trace metal compounds" such evidence should be cited and discussed. Past operational experience with Venturi Scrubbers and alternative modes of air pollution control is contrary to the optimistic outlook of the Draft Statement.

Pollution control technology, installed at the outset of operation at any given generating station, technically and economically tends to "lock in" the station for its usable life (35 to 50 years). It is imperative that the planned equipment be compatible with envisaged improvements in control technology, so that a retrofit of the generating station is not economically nor technically prohibited. This is particularly true in the case of coal-fired generating stations planned for rural regions with clean air, because it is likely that federal standards for atmospheric emissions of such stations will soon be made more stringent. Such changes in regulations are indicated by recent court interpretations of the Clean Air Amendments of 1970 and will apply to the proposed plant. If, as seems likely, the generating station under consideration is but the first in a series of plants to be operated at or near the same site, it will be critically important to plan for the maximum flexibility of operation, minimal degradation of existing air quality, attainment of economies of scale of pollution abatement, and retrofit of future best available technologies of pollution abatement equipment.

page 2. The DEIS does not discuss the effect of long-term operation of a network of ash ponds on ground water quality. Ash ponds would serve as sumps for both solid and liquid wastes. (An inadequate description of this problem is outlined on page 26 of the DEIS). It is also important to discuss the quantities of waste involved with an appropriate extrapolation for any additional units now planned or envisaged.

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1 Page numbers in the margin refer to the DEIS.

2 Brian W. Lancaster and Werner Strauss. "Condensation Effects in Scrubbers in Air Pollution Control" Part I, edited by Werner Strauss. Wilen-Interscience, New York, 1971.

Exhibit 4

The operation of wet cross flow induced draft cooling towers needs to be discussed in greater detail. Employment of these devices should be compared to alternatives such as natural draft cooling towers. Mechanical or induced draft towers have a substantial potential for ground fog formation as well as sleet and ice formation during cold weather. Considerable attention must be given to the site selection as well as the local climate and flexibility of operation of the particular towers in question.

In addition to the potential for fogging and icing, mechanical draft cooling towers seem more prone to producing drift which may have an adverse environmental impact on the area immediately downwind from their site. The salinity of the drift may pose problems. Salinity is a function of the operational characteristics of the tower, the dissolved solids content of the cooling water, and the rate at which blowdown is bled from the cooling system. Little of the requisite information for calculating the impact of drift is available in the DEIS.

Mechanical draft cooling towers tend to be noisy in operation. Since there is no detailed description of these mechanical draft cooling towers in terms of the number of cells, rated horsepower of motor-driven fans, and plans for noise abatement (if any), it is difficult to calculate the impact of these devices on the adjacent population. We are informed of the environmental costs--in terms of unacceptable noise levels--of installing mechanical draft cooling cells to handle the cooling requirements of Indian Point Unit No. 2, a 873 megawatt generating station on the Hudson River.[3] The cooling requirements of a 700 megawatt coal-fired generating station in Southeast Montana are roughly half those of Indian Point Unit No. 2. Other parameters being equal, a reasonable assumption for cooling requirements for the proposed Colstrip Generating Station would require 19 mechanical draft cooling cells operating in the closed-cycle mode with each cell possessing an electric motor-driven fan rated at 200 hp., giving a total of 3,800 hp. The noise generated by these cooling towers is predicted to produce sound levels of 50 db. (A) at a distance of 3,500 feet. Consequently, an area of approximately 1.4 square miles will be in the unacceptable zone as defined by the Department of Housing and Urban Development.

Of this area, approximately 2 million square feet in the immediate vicinity of the cells will be in the "clearly unacceptable" classification with the remainder of the unacceptable area falling in the "normally unacceptable" classification. These particular acoustic levels are those which are emitted from the louvered face of the cells. The sound level on the cased face of the cell is expected to be from 5 db. to 10 db. lower, so the corresponding areas will experience lower noise levels. Therefore, the above hypothetical noise levels are conservatively high on the case-faced base side of the cooling cells.

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3 The Final Environmental Statement on Indian Point Nuclear Generating Plant Unit No. 2 (Docket No. 50-247) prepared by the staff of the U.S. Atomic Energy Commission (page XI-64).

Exhibit 4

Attention should be given to noise levels from future installations at this site, as well as the one under consideration at the present time. A much more complete site description (with detailed maps of the facilities) is clearly indicated.

Pipeline and Water Supply

The DEIS describes the water supply and cooling system in only the sketchiest of terms despite the fact that this is a crucial feature of the generating station and one that will, in both the construction and operating phases, have a substantial impact on the environment. If the proposed generating station is but the first of a series of generating stations at or near this site, the cooling water supply system for the overall network of generating stations should be described at the outset of the first construction project. Information should be presented in the DEIS regarding the applicant's total water contracts for this region, future power needs, total fuel supply, and the like, since water in the area is a precious commodity and a limiting resource for industrial development.

Repetitive destructive impacts on the environment from the construction of a network of pipelines seems senseless. Yet, in failing to deal adequately with this subject at the outset, the decision-making bodies in the State of Montana may certify a future filled with applications of this sort. If, as discussed below, the initial pipeline is sufficient to serve a much larger generating complex, the DEIS has not candidly analysed the full environmental impact of the proposal. In either eventuality, the pipeline is a precedent-making feature of industrial development in the Colstrip area and needs to be examined with the greatest attention. Indeed, the plausible alternative of dry cooling towers should be probed in depth at this time.[4] No one should fail to recognize that the decision to certify the presently proposed cooling system on this plant may, by establishing a precedent, seal the fate of the Yellowstone River in perpetuity.

Inadequate or non-existent in the DEIS are discussions of studies (related to the impact on aquatic biota, migratory fish, primary producers and consumers, and fisheries) of the consequences of removing large quantities of cooling water from the Yellowstone River. Implicit in any such studies must be the view that, within the foreseeable future, a sizeable portion of that river could be diverted for industrial purposes. Thus, the aggregate impact including such phenomena as the impignment of fish on screens and entrainment of fishes in pumps and in industrial cooling systems should be considered at the outset of industrial development.

In particular, there should be no justification for approval of this diversion of cooling water on the basis that it constitutes a minor or negligible impact on the Yellowstone River Fishery if, in fact, it can be seen that future diversions will constitute a major adverse impact. There is no sound economic justification for permitting the aquatic biota of the river to subsidize the initial industrial development,

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4 A 20 MW(e) air cooled electric generating station is operating in Gillette, Wyoming and a 330 MW(e) facility is planned for the same site--also to operate with dry towers.

Exhibit 4

whilst imposing the bulk of environmental costs on future generations of water consumers in the area, if it is perceived that approval of this initial usage in any way precipitates future industrial and commercial water demands.

There is reason to believe[5] that the proposed pipeline for this power plant will be very much larger than required by a 700 MW(e) coal-fired steam electric generating station. The DEIS itself is suspiciously vague in this regard. For example, page iv of the DEIS refers to the pipeline as "24" diameter (minimum) approximately 30 miles" and on page 2 of the DEIS the pipeline is referred to as " . . . a buried steel pipeline at least 24-inches in diameter." [emphasis supplied]. Such a discussion of one of the most important features of this project is ambiguous and unsatisfactory.

There is no mention in the DEIS of the pumps required to move the water from the Yellowstone River to the generating station at Colstrip. Aside from the impact of these devices on the aquatic biology (by impignment, entrainment and bottom scouring) their size gives a reasonably accurate gauge of the near term plans of the Montana Power Company. Of course, an essential feature in future plans of the utility is the diameter of the pipeline itself.

Though the DEIS may describe the pipe as equal to or greater than 24-inches in diameter, it seems that a permit application describing the intentions of the Montana Company is on file at the Rosebud County Courthouse in Forsyth, Montana. This application calls for a 60-inch pipeline.

A 24-inch pipeline operating at a flow rate of 5.664 feet per second will supply 7,926 gallons per minute, sufficient to handle the total consumptive use of water of the 700 MW(e) generating station described in the DEIS. Table 1 depicts the electric generating capacity of such a complex as a function of pipeline diameter when the water velocity is 5.664 fps.

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5 c.f., the Billings Gazette series of articles on the Project commencing 29 November, 1972; also, repeated private communications from members of the Northern Plains Resource Council in Billings, Montana.

Exhibit 4

Table 1 [6]
(Water Velocity = 5.664 feet per second)

Pipe Diameter inches	Flow Rate cfs.	gpm.	acft/yr	Sustained Generation Capacity [7] MW(e)
24	17.7	7,926	12,800	700
36	39.8	17,830	29,000	1,575
48	70.7	31,700	51,000	2,800
60	110.3	49,540	80,000	4,350
66	133.7	59,940	97,000	5,300

We are further informed that the application for permit describing the intentions of the Montana Power Company describes the 60-inch pipeline as capable of delivering a flow of water of 250 cubic feet per second. Table 2 gives the sustained generation capacity of a power plant complex as a function of pipeline diameter at a flow rate of 12.85 fps., i.e., a rate of 250 cfs through a 60-inch diameter pipe.

Table 2 [6]
(Water Velocity = 12.85 feet per second)

Pipe Diameter inches	Flow Rate cfs.	gpm.	acft/yr	Sustained Generation Capacity [7] MW(e)
24	40.1	18,000	29,000	1,590
36	90.5	40,500	66,000	3,575
48	160	72,000	116,000	6,350
60	250	112,500	181,000	9,875
66	303	136,000	220,000	12,000

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6 1 cubic foot per second (cfs) equals 448.83 gallons per minute (gpm) or approximately 725 acre feet per year (acft/yr).

7 At 100% load factor; these data are based on cooling water requirements of 25.2 cfs per 1,000 MW(e) generated.

Exhibit 4

It is pertinent that the North Central Power Study [8] refers to an aquaduct from the Yellowstone River to Colstrip, Montana. This is dexcribed as a 66-inch pipe with a capacity of 130 cfs. or an annual water delivery of 90,000 acrefeet. This proposed pipeline will be operating at a slightly lower rate of flow than that described in Table 1 above, and would be sufficient to handle the cooling requirements of a 5,150 MW(e) coal-fired steam electric generating complex. It should be noted that the Montana Power Company was an active participant in the preparation of the North Central Power Study.

With the above information in full view, it seems that the discussion on water supply (and indeed the entire DEIS) has been less than forthright. Whether or not this represents a failure of the utilities to disclose their intentions fully to state decision-makers is of little significance. The Environmental Defense Fund believes this failing can only be remedied by the issuance of a revised Draft Environmental Impact Statement which describes the proposed water supply system comprehensively and the attendant environmental consequences of such a supply. Without such a discussion, it is impossible to analyse the full environmental consequences of this proposal objectively.

Transmission Lines

The DEIS fails to examine the full impact of transmission lines, switching facilities, and the like, upon the environment. There is a clear need to supply quantitative information about number of acres impacted, the compromise of aesthetic values in pristine areas, the irreversible committment of private and public lands for industrial purposes, the adverse impacts of transmission facilities on wildlife, and the adverse impacts of transmission facilities on lands of an archaeological or historical value.

It is important to describe the degree to which the choice of any particular transmission corridor will delineate future routings of transmission lines for the utility in question (as well as other corporations which share interties and transmission facilities). If, as is indicated, this is but the first in a series of large coal-fired generating units in the area, there is an obvious need to enter into detailed open planning at the outset of the project. In particular, it is important to determine the activities of other utilities in the region. The past record of cooperation between the investor-owned utilities in the region, the Bureau of Reclamation, the cooperatively operated utilities and municipally owned systems has been a sorry one indeed. [9]

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8 To North Central Power Study, Report of Phase I, Volumes I and II, October, 1971. Bureau of Reclamation, U.S. Department of the Interior, Billings, Montana, (Volume II, page I-34).

9 c.f. for example the Mid-Continent Area Power Pool Agreement before the Federal Power Commission. Docket No. E-7734.

Exhibit 4

For both environmental and economic reasons it is important to plan for and determine interties between the various utilities in the region, the Bureau of Reclamation facilities, and other agency facilities, in order to plan for system stability. This will avoid costly duplicative transmission facilities and generating units. At the very least, these objectives should be spelled out and the ability to comply with them assured before the granting of approval for construction of any further generating units or transmission facilities of the Montana Power Company.

page 4. Since the construction of a mine mouth coal-fired steam electric generating station is determined by these very economies of scale (e.g., transportation of fuel and ash disposal), that arise from proximity of the mining and combustion processes, there is no adequate argument for severing the environmental impact statement on mining from that which deals with the remainder of the operation. Indeed, there is every reason for uniting these impact statements in a revised draft form.

If the Montana State Department of Lands "will make intensive evaluations of the strip mining reclamation necessary for this facility" [emphasis supplied], there is no reason to approve construction or operation of this generating station until such time as the indicated studies are complete. If approval to construct is granted prior to complete stipulation and assurance of ability to comply with mining practices, the State of Montana will forfeit control of the operation and be faced with economic blackmail after the Montana Power Company and its partner have made a sizeable capital investment in the proposed facility.

The success of reclamation depends, of course, on a definition of terms. In areas such as Colstrip with low annual mean precipitation and wide annual variance of precipitation, the prospects for permanent reclamation seem poor (if the term means successful revegetation through the first drought cycle without irrigation or application of fertilizer). Thus "reclamation" in the West German, British, or Appalachian sense of the word has not been proven and does not seem favorably indicated in at least a portion of the Northern Plains States. Other aspects of reclamation (leveling of spoil banks, grading of high walls, and preventive measures to assure good local water quality) can and ought to be stipulated in approving the overall design and mining regimen of the proposed facility. Further, it is important to stipulate that the mining operations are not only in compliance with existing laws, but also with future State and Federal reclamation laws as a prerequisite to operation of the proposed facility.

The proposed 700 megawatt generating station will consume a little over three square miles of land during thirty years of strip mining. Additional envisioned stations will consume correspondingly more land. If this land is lost as a resource in perpetuity, it is important to assess the full environmental costs at the outset of operations. The land must not merely be allowed to be reassessed on the tax rolls at zero dollars per acre after mining has ceased (as has actually happened in Wyoming and elsewhere); indeed, full environmental and economic costs should be established at the outset for any damage that may occur in perpetuity.

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Historical Values

If an area is to be irreversibly committed to the strip mining of coal it is important to assess the impact of the operation on historical and archaeological values. To this end, it is advisable to consult with state and national historical and archaeological societies to determine the nature and extent of any adverse impacts.

Recreation

The impact of this generating plant on tourism is not investigated at all. The impact of the proposed facility on wildlife and fisheries needs to be examined in greater detail. In particular, the migratory and feeding patterns of wildlife will be adversely affected by the physical obstacles imposed by the proposed facility, as well as by noise and increased human activity in the area. Perhaps most importantly, the Yellowstone River Fishery will be adversely affected by this and future operations scheduled for the same site. It is essential to establish liaison with State and Federal departments of fisheries and wildlife, as well as conservation, recreation, and sportsmen's organizations prior to the promulgation of the DEIS.

Meteorology

It is essential that meteorological factors which affect local air quality are determined in the planning stage. These should include local wind conditions, prevailing temperatures, saturation deficits, and the precise nature and extent of inversion conditions. Such knowledge is essential for the choice and design of cooling systems--in this instance the selection of forced-draft wet cooling towers seems to have been made on the basis of incomplete meteorological data.

Regional monitoring appears to have been performed for some, but not all of the expected pollutants. For the one pollutant which is most difficult to control, (oxides of nitrogen) no background monitoring has yet been performed. The draft environmental impact statement suffers from a lack of presentation of wind roses for pollutants. It is impossible to review and comment objectively on the quantative impacts of air pollution in the absence of such data. In the absence of any quantitative information pertaining to emissions, meterology, topography and proven methods of atmospheric modeling, it is a relatively simple matter to "readjust a few parameters" and find the unit in complete compliance. The complete array of data and methodology must be presented in the DEIS.

Exhibit 4

page 9 Probable Impact on the Environment

As referred to above, the data in Table 1 of the DEIS is exceedingly difficult to interpret without the appropriate wind roses. There is a clear need to define the diffusion model employed for calculations of the proposed plant's contribution of pollutants. If, as is intimated, a complex of coal-fired generating stations is to be built, this DEIS is the appropriate vehicle for describing the contribution of all the proposed plants.

page 12 Particulates

The DEIS suffers from being totally dependent on data supplied solely by the applicant. It is important to note that controlling the emission of particulate matter to the level of 266 lbs. per hour depends on operating the scrubbers at maximum collection efficiency, in order to remove 53,200 lbs. per hour of particulate matter from the flue gasses at full load. Even a slight loss in efficiency will lead to a drastic increase in emissions of particulate matter. Table 3 compares the efficiency of operation of these scrubbers and particulate emissions:

Table 3

Efficiency of Particulate Removal	Particulate Emissions (lbs. per hour)	Particulate Emissions (Tons per year)
99.5%	226	1,165
99.0%	532	2,330
98.0%	1,064	4,660
95.0%	2,660	11,650
90.0%	5,320	23,300

Sizeable losses of efficiency in such equipment are not uncommon and occur as a consequence of: (1) inadequate technical experience with the operation of very large electrical generating units; (2) poor operation and maintenance; (3) corrosion or deposit buildup in the scrubbers themselves; and (4), the general fatigue of units operating at the outmost limits of their efficiency.

Other data in the DEIS can be employed to calculate that this generating station may be operated at an 89% load factor, although such calculation is somewhat sketchy as it depends on the statement given on page 41 that "90 million tons [of coal] will be burned in 30 years . . . ." Thus the full load emissions given in Table 3 should be corrected by multiplying by a factor of 0.89 in order to obtain the expected average emissions of the plant. A load factor of 89% is not inconsistent with the mature outage rate of 4 or 5 percent on top of routing maintenance, though it may be slightly optimistic.[10]

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10 See, for example, data supplied by the Edison Electric Institute's Equipment Unavailability Report 26-71.

Exhibit 4

page 13

It is inconsistent to compare the proposed coal-fired generating station with the Corette plant of the Montana Power Company, since the Corrette plant is presently operating under a different array of stipulations and does not comply with EPA regulations for new coal-fired steam electric generating units. The Corrette plant presently emits 426 lbs. per hour under full load, but, if built today would be permitted to emit no more than 175 lbs. per hour at full load. Present particulate emissions from the Corette plant are thus 244% of those permitted for new generating units.

Table 3 of the DEIS presents measurements of particulate matter (taken at what is evidently a single sampling site some nine miles east of Colstrip) for a six month period in mid 1972. As noted above, these and other data are impaired by the lack of discussion of regional meteorology. If, for example, inversion conditions are more frequent in the winter than during the summer, the statement that "(the winter will certainly bring reduced total suspended particulate values)" is questionable.

page 13

The discussion of dust is incomplete without a consideration of particulate matter which will be produced directly by the stripping of coal. Strip mining in a region does produce considerable quantities of dust and this source of particulate matter should be taken into consideration with the other sources described. This is yet another argument for uniting the present draft Environmental Impact Statement with the one proposed to deal with the strip mining aspects of the operation.

page 16

The computer dispersion model and the long-term concentration model should be described in the draft statement. The failure to provide these together with substantive meteorological data for the region is a serious shortcoming of the DEIS. A tremendous range of model results can result dependant upon : (1) the choice of the model; (2) the accuracy of easily calculated parameters--quantities of pollutants, stack gas velocity, and the like; (3) the discretionary choice of measurements and sites; and (4) the accuracy of meteorological phenomonon calculated for or observed at the Colstrip site. One of the most frequent shortcomings in power plant site selection results from the lack of attention that utility companies and regulatory bodies give to the meteorological characteristics of the site. This can occassion enormous expense when remedial action becomes necessary.

With regard to the discussion of particulates, sulphur oxides, and nitrogen oxides, it is important that the DEIS consider additional parameters. For example, it was stated on page 5 of the DEIS that the coal has an average composition of 8.5% ash and 0.77% sulphur. It is important to determine how and by whom this was measured, as well as to know how these parameters will change over the estimated lifetime of the power plant. How much variance is there in the sulphur and ash content of the coal? Will the proposed mining regimen dictate the initial combustion of low sulphur, low ash coal and in later years the combustion of coal containing higher quantities of ash and sulphur, or will the reverse be true? Regarding nitrogen oxides, what are the known operating characteristics of tangentially-fired pulverized coal furnaces of this design? Have nitrogen oxides been measured in the stack gasses in a unit of this design and if so, what are those measurements?

Exhibit 4

page 18 Analysis of mercury indicates that the plant will emit somewhere between a few pounds and an amount in excess of 2 tons of mercury per year. We believe that, if careful systematic analyses are performed, a more accurate estimation of the mercury emissions can be provided. In view of the quantities of such elements as mercury and fluorine found in western coal, it is most important to have objective analytical data concerning these and other constituents. There is reason to believe that there are substantial quantities of fluorine in the coal in question, and that the 12.5 ppm F upper limits determined by Truesdale Laboratories may represent a serious underestimate of actual fluorine concentration.

page 19 Radioactive Substances

The use of Curies per year for describing radium emissions is ambiguous: ^{226}Ra decomposes with a half-life of 1590 years to give ^{222}Rn which then decomposes with a half-life of 3.82 days to give ^{218}Po. ^{218}Po then decomposes with a half-life of 3.05 minutes to yield ^{214}Pb which decomposes with a half-life of 26.8 minutes to yield ^{214}Bi which can decompose through a number of mechanisms and intermediates to yield a single stable end-product, ^{206}Pb.

Just what is meant by "Ci/y" is therefore unclear, since this has the units of disintigrations per (unit time)^2. Total-body doses to an individual (in mrem/year) at the plant boundary might be a suitable substitution, together with a calculation of the man-rem dose to the population within 50 miles of the site as a percentage of the suggested guidelines of the AEC set forth in 10 CFR 20 (with proposed modifications).

From the data provided it can be calculated that 2.1-2.31 tons of uranium and 5.22-9.0 tons of thorium will be emitted per annum. Total body doses ensuing from these materials should be calculated as above for radium.

page 20 The DEIS fails to examine the synergistic effects of pollutants. The operation of any design of wet cooling towers will produce a very moist plume (visible at most times) which can be expected to mix with and greatly increase the humidity of the plume containing the stack gas pollutants. The DEIS should, for example, discuss the increased acidity of the "greater precipitation potential."

page 21 It is important to emphasize that the impairment of visibility by particulate matter is most heavily dependent on the quantity of micron and sub-micron particles injected into the atmosphere. This topic is particularly germane in an area such as Colstrip which presently boasts such pristine air quality that the entire region is collectively known as the "Big Sky" country. Other things being equal, the mass of

Exhibit 4

particles falls off as a function of the cube of the radius (e.g., as 4/3 pi r^3). Removal of 99.5% by weight of the particulate matter could, under the appropriate circumstances, effect the removal of only a tiny fraction of the micron and sub-micron sized particles. It is important to know the efficiency of the Venturi Scrubbers in the removal of such small particles. Thus, considerably more analysis is necessary before one can safely make the statement which appears on page 21 of the DEIS, that: "Particulates are considered the main culprit in visibility reduction and aesthetics, but their effect here will be minimized due to the low emission rates resulting from a 99.5% control efficiency."

The DEIS states that visibility reduction might be expected to " . . . be rare in the Colstrip region because of the relatively low humidity as compared with other areas of the country. It is well established that high humidity combined with sulphur oxide in the atmosphere contributes to visibility reduction."

At full load, the proposed generating station is expected to produce 6,646 gallons per minute (gpm) of water in evaporation and drift from the cooling towers, 500 gpm in evaporation and entrained water originating in the passage of the flue gasses through the scrubbers, and an unspecified amount of water vapor (dependent on the hydrogen and water content of the coal) from the combustion of the fuel. As noted above, the DEIS fails to discuss the mixing of the plumes from the cooling towers and the stack gasses. Hence, such statements as that quoted on page 21 of the DEIS are without substantiation. It should be noted that in other locations the mixing of these plumes is not uncommon.

It is reasonable to expect that a varying portion of the water vapor from the cooling towers will, in fact, continually mix with the stack gasses, while another varying portion may indeed by a "low level source" leading to fogging and ice formation during periods of cold weather. It seems that inadequate or no modeling has been performed to examine these problems. In addition to the missing information noted earlier in these comments, one must know the exit characteristics of the water vapor plume from the cooling towers.

page 22 If " . . . a visible plume will be evident from the stacks that will vary in size depending upon the temperature and humidity," why is no mention made of the visible plume that will be evident from the cooling towers? Why is there no discussion of the possibility of ice formation during cold weather? Why is no mention made of the potential hazards to travel as a consequence of ice and fog formation?

Effects on the Ecosystem

Discussion of effects on the ecosystem seems most inadequate. This is particularly so in view of the evidence that the proposed generating station may be only the first in a series of large steam electric generating stations at or near Colstrip. The effect of industrializing a rural agrarian region with the attraction of large

Exhibit 4

quantities of cheap electric power is of overwhelming importance to the survival of wildlife. It may be that "a quantitative estimate of these effects is impossible at this point in time, given our present understanding of the fate of pollutants in the ecosystem," but there is a growing body of substantive knowledge which allows us to make qualitative predictions. Instead of delving into this subject, the DEIS appears to succumb to helplessness, as if the fate of this region were completely in the hands of the Montana Power Company. The inadequacy of this portion of the Draft Environmental Impact Statement is sufficient in itself to compel the issuance of a Revised Draft Environmental Impact Statement before further action is taken.

page 23 Emission Control Guarantees

The DEIS reads: "The problem of plugging and fan imbalances from flyash and flyash and sulphur oxide combinations is recognized. The few recently-constructed power stations now equipped with scrubbers are experiencing these problems and investigating possible solutions." This portion of the Draft Statement would benefit by a discussion which names these stations and delineates the problems and solutions in detail. It seems that in any certification of these generating units and scrubbers, it should be stipulated that operation would not be permitted unless the efficiency of particulate and sulphur dioxide removal was at or above the guaranteed level on the emission control systems. The DEIS suffers generally from a lack of discussion of sources. A Revised Draft Environmental Impact Statement should incorporate detailed information on the emission control system, together with material germane to this subject (available, for example, from the U.S. Environmental Protection Agency.) Since the Montana Power Company budgets and spends little or no money on research in this area, their confidence " . . . that scrubber systems are inherently workable and that these problems can be met by design or process change" seems at best secondary to the confidence expressed by experienced operators of the equipment.

page 24 A number of these "Special Environmental Studies" need to be performed prior to certification of any aspect of the proposed project. Of paramount importance are: (1) the gathering of meteorological data; (2) the precise determination of the presence of trace elements in coal and their disposition through combustion; (3) additional air quality monitoring; and (4) broad ecological studies.

The most important aspect of the Participant's proposed environmental policy is full and open planning. If the Montana State Department of Health and Environmental Sciences has in any way been limited in the preparation of the DEIS by the failure of applicants to supply full and complete details on its proposed operation, then the proclamation of future behavoir by the applicant on pages 24-25 of the DEIS is of dubious merit. The DEIS sorely requires substantive documentation and detail. Much of this information can be supplied only by the applicant. If, in the future, the full details of operation, maintenance and monitoring are withheld from the public by the utilities responsible for enforcement, we are less than sanguine that these promises will be kept.

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page 25 Again the discussion of dust suffers from a failure to mention particulate emissions (coal dust) from the actual mining of the coal. Potential for groundwater contamination by leaching of the ash should and could be studied prior to the commencement of mining and ash disposal.

page 26 The concentration of dissolved solids as well as slimicides and the like in the blowdown from the cooling water may present a groundwater contamination problem, and not merely "precipitate out into the pond." These materials could and should be easily quantified and described in the DEIS.

The disposal of sewage through dilution flows in Armell's Creek should be reevaluated with attention given to full compliance with the 1972 Federal Water Pollution Control Act.

page 28 We note with interest the statement that: " . . . the proposed Colstrip plant may be only the first of many industrial developments that could conceivably alter the land use of most of the Fort Union Region." This statement deserves elaboration, particularly in view of the indications that a number of additional electric power plants presently are being planned for this region.

page 29 Though it may be impossible to quantify the changes in the flora and fauna discussed in this section, we believe that it is possible to " . . . predict the major changes in such activities as sport fishing." Thus we take exception to the DEIS and further suggest that the Revised Draft Environmental Impact Statement attempt to make some qualitative predictions -- with the help of available sound ecological modeling--as to the major changes in composition of flora and fauna attendant to the various scales of industrial development which can be envisaged for the region.

page 30 Impact on the Human Environment

An increased tax base is one tangible benefit that can result from industrial and commercial development. Any discussion of impacts on the human environment should be accompanied by a detailed description of the expected tax revenues delineating the individuals, municipalities, and governments to whom those benefits will accrue. Will the costs occassioned by the proposed development be equitably defrayed by tax revenues? To what extent are "more and better educational facilities" required in this region? What "transportation systems" and "communication systems" -- besides the private automobile and the existing roads and media--are envisaged for this region?

The discussion of the impact on the human environment, the senses and the community on pp. 29-32 is interesting, although not particularly enlightening. For example on p. 30 of the DEIS we read:

> Traditionally, agrestic life styles have been slow paced and relatively simplistic, whereas existence

Exhibit 4

> in an industrial society is characterized by a hectic, rapid pace complicated by such necessities as the social graces and who gets a key to the washroom.

It is not clear that meaningful sociological expertise has been brought to bear on the problems discussed in these sections. The vitae of those individuals preparing the DEIS indicate training in engineering and the physical sciences--but not sociology. The lack of sound rural sociological analysis of the human environment is a serious shortcoming of the DEIS.[11]

With regard to other areas of the U.S. where one can " . . . perceive the effects of unplanned and poorly planned development in a rural-agrarian area" we believe a compelling example is the Southwest energy complex consisting of the Four Corners, Navajo, Huntington Canyon, Mojave, San Juan and Kaiparowitz Power Plants having a total planned capacity of 36,000 MW(e). If this proposal has even the faintest chance of being the first step in a parallel direction (i.e., Colstrip, Birney, and Gillette), it is obvious that very much more careful planning must be performed.

The entire section dealing with impact on the human environment fails to discuss any impacts on human health. This is a most serious ommission.

age 32 Any discussion of noise levels in the area should be included in a discussion of human health impacts and should include a detailed analysis of the noise produced by the proposed cooling system. It should be recognized at the outset that noise constitutes much more than an aesthetic problem--it is frequently a serious human health insult. Due attention must be given to compliance with The Noise Control Act of 1972, as well as the Occupational Health and Safety Act of 1970.

age 33 The list of adverse environmental impacts which cannot be avoided seems incomplete. It should certainly include the impact on wildlife and fisheries, the impact on groundwater quality, as well as the quality of the Yellowstone River, the impact on regional climate, the local potential for fogging and icing, human health impacts in the region including noise, and a discussion of the various impacts which can be expected in the aftermath of stripmining (only briefly alluded to on page 41 of the Draft Environmental Impact Statement).

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11. A similar comment applies to the lack of economic analysis discussed below.

Exhibit 4

 Alternatives to the Proposed Action

A. Not to Construct

The DEIS contains no discussion of the need for this power within the Montana Power Company's own service territory. The bulk of this new power may be exported to the Montana Power Company's partner in this venture, the Puget Sound Power and Light Company. The lack of any discussion of the advisability of degrading the environment of Montana to satiate the electric demands of the Pacific Northwest is a serious flaw in the DEIS and presents another strong motive for issuing a Revised Draft Environmental Impact Statement prior to the initiation of any further action in regard to this proposal.

B. Other Fossil Fuels: Oil and Gas

In view of the relatively poor apparent heat rate of the proposed plant (the calculated efficiency is 35.2%),[12] the alternative of reserving this particular coal deposit for future exploitation (either combustion with improved technology or coal gasification) should be explored.

C. Nuclear Fission Plants

The argument that " . . . energy required to process this fuel [enrichment in ^{235}U] for power plant use likely contributes, at another location, environmental degradation." is sound. However, the statement that "fission plants require vast quantities of cooling water . . ." is unnecessarily vague and implies that the proposed plant has, in comparison, only a modest requirement for the consumptive use of water. In fact, the proposed plant will consume roughly 70% of the water required by a 700 megawatt nuclear fission plant of recent design operating at 33% efficiency. It should be noted that Philadelphia Electric Company and other utilities have ordered high-temperature gas-cooled nuclear reactors which will operate at roughly 41% efficiency. These latter devices will consume about the same amount of water per kilowatt hour produced as the proposed 700 megawatt coal-fired installation in Colstrip.

D. Solar Energy

Although the direct conversion of solar energy into useable electric power is not yet technically or economically feasible on a wide scale, the conversion of solar energy into heat (e.g., for space or hot water heating) is now a workable and

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12 This figure should be reduced to compensate for pumping requirements, cooling tower fan requirements and pollution abatement equipment requirements--all presently unknown. Transmission losses are not discussed, either.

Exhibit 4

marketable technology in a number of areas in the country. A considerable body of knowledge on this subject now exists and a number of groups (e.g., the Environmental Quality Laboratory at the California Institute of Technology) are seeking the speedy implementation of this technology in residential, commercial and industrial markets. Insofar as the electric power production of the Montana Power Company is converted into heat at the site of demand for purposes of space and water heating, it is germane to investigate the suitability of solar energy as a substitute.

age 37 Utility promotional efforts and discount rates for electric heating should be carefully reviewed and, if necessary, abated. It seems foolish to increase the rate of growth of electrical demand unnecessarily by promotional activities which may not be in the best interests of the residents of the State of Montana. Peak demand charges should be instituted in order to internalize the external environmental costs of both the present demand and the growth of that demand.

There can be no question that a great environmental blessing to the Northern Plains States and especially Montana and Wyoming would be the lessening in the rate of growth of demand for electricity in the nation. In view of the plans of many energy companies and utilities, any reduction in the rate of exploitation of Montana's resources would bring benefits to the people of Montana in terms of human health, aesthetics, a broader brighter outlook for the tourist industry, and a reduced demand upon the state's free flowing rivers and streams.

Insofar as charity begins at home, the State of Montana must address the problem of demand for electricity within its own borders. This should be done with a view towards increasing the efficiency of use of electric power as well as insuring that the large users--those who presently pay the lowest rate per unit energy consumed--pay their full fair share of the environmental costs occasioned by the production and delivery of electric power. If Montana chooses to export its coal resources in the form of electricity, then everything within its power must be done to ensure that the full environmental costs of producing the power in Montana are assessed upon the distant consumer.

If a serious effort is to be made in controlling the demand for electric power in the State of Montana, it must be recognized immediately that a large portion of the financial returns to electric utilities accrue in proportion to their rate of growth. In general, the most rapidly growing electric utilities have the highest rate of return. This is the consequence of the reward system imposed by regulatory bodies. It is no coincidence that the Montana Power Company has enjoyed the highest rate of return of any electric utility in the country for several years during the past decade. It has consistently been one of the top five utilities in rate of return in the nation. If we are to cope with the demand side of the problem, every effort must be made to re-examine the way in which carrots and sticks are apprortioned to the electric utilities industry. It is also germane to note that Montana Power just received a substantial rate

Exhibit 4

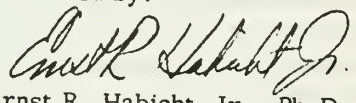
increase from the state Public Utility Commission. We should not be complacent about the environmental consequences of such a rate increase--traditionally, high profitability, a strong position in the capital market, and recent substantial rate increases are intimately coupled with very high rates of utility growth. This, of course, leads directly to constructing the proposed steam electric generating station in Colstrip, Montana.

The failure to discuss any economic data or to examine the demand for power in Montana is one of the most glaring omissions of the DEIS. At the very least, the Montana Environmental Policy Act is an "open planning" statute. In the absence of hard economic ecological and engineering data, vague qualitative statements pertaining to benefits and costs fall into the realm of conjecture, not open planning.

CONCLUSION

In view of the paucity of data provided and the indications that one major aspect of the project--the 30-mile pipeline from the Yellowstone River to Colstrip--may be scaled to handle a very much larger complex of coal-fired steam electric generating stations, the Environmental Defense Fund urges the promulgation of a Revised Draft Environmental Impact Statement which will be both substantive and candid in dealing with the proposed power plant complex.

Submitted by:



Ernst R. Habicht, Jr., Ph.D.
Environmental Defense Fund, Inc.
162 Old Town Road
East Setauket, New York 11733
516-751-5191

Exhibit 4

WALLACE D. McRAE
ROCKER SIX CATTLE CO.
FORSYTH, MONTANA

REGISTERED
QUARTER
HORSES

HEREFORD
CATTLE

November 16, 1972

Air Quality Bureau
State Department of Health and
Environmental Sciences
Cogswell Building
Helena, Montana 59601

Dear Sirs:

Since I live on a ranch in the Colstrip area, I am extremely concerned by the implications of the generation plants that are now under construction at Colstrip.

The following questions and comments are in response to the Environmental Impact Statement on the electrical generating plants at Colstrip.

On page 1, paragraph 1, there is an error stating that the generating station is "proposed" when in reality, the plant(s) have been under construction for some time.

In paragraph 2, I want to stress the importance of this application, since its approval, or disapproval, will have far-reaching effects on future plants. The decision will be much more important as a precident than merely answering the question as to whether or not this facility is to be completed, and operated. There will be a further precident made as to whether the state should accept applications for construction long after the actual construction has been underway when considering future plants of this kind.

On page 2, paragraph 1, I wonder if consideration is being given to the deleterious effect of bottom, and percipitated ash on groundwater.

Concerning "Pipeline and Water Supply, on page 2, the companies are planning, and currently surveyingfor, a 60-inch water pipeline from the Yellowstone River, and are apparently planning their pipeline to supply subsequent plants at Colstrip in addition to the two now under construction. The on-going construction, and the 60-inch line that is planned, appear to be based on the assumption that not only is the present application going to be approved, but that future applications for construction will be summarily approved, as well.

In the section on Transmission Lines there is a further indication that the companies believe that the application will be routinely approved since they have already begun construction of one of the power lines.

Section 4 illustrates the importance of this application relative to subsequent plants.

In section 5 the word "proposed" again bothers me since construction has been underway for some time in what appears to me to be not only a violation of

Exhibit 4

the law, but a direct insult to your department, and the people of Montana.

In section 5, B, I wonder what the consequences, and the nature of the action would be if the emission control system will not perform as "guaranteed". Can, and will your agency shut the plant down if it is constructed, but fails to operate as "guaranteed??

In Chapter II, Section C, Land Use, the minimization of the lumber industry is done by comparison to the western part of Montana. I feel that the lumber industry is very important to Rosebud County. The figure of 11,000,000 bd. ft. sticks in my mind as being the annual county-wide production in recent years. Due to the economic importance of timber on the Northern Cheyenne Reservation, and the Custer National Forest, and the susceptability of ponderosa pine to sulfur dioxide, I believe the economic impact of the lumber industry should be stressed, rather than dismissed as being unimportant.

In Chapter III, Section A, 1, the three questions are essentially unanswered and this is the crux of the emmission problem. The application should not be approved until, and unless the answers to these very important questions are definately resolved, and are completely and unequivocally acceptable to the state, and those of us who live under the shadow of the stacks. There is little comfort for me in the statement, "Diffusion modeling indicates that only in rare cases will either state or federal ambient air standards be approached or exceded. " That "rare case", or the cumulative effect, might be all it takes to kill alfalfa, thereby destroying the hay base on many ranches in this area, precluding their continuation as viable economic units.

Billings is with in 100 air miles of Colstrip, and the additive effects of that city's refineries, and the Corette plant should be considered. The bentonite plant at Vananda, and the tepee burners at Lame Deer, and Ashland, as well as open burning dumps in many towns (including Colstrip) should also be considered as contributing factors to degraded air quality.

There is a serious error on page 13 relative to the sampling site nine miles east of Colstrip, and to a lessor degree other sampling sites as well. The sites are nearly all along dusty county roads, and the site nine miles east of Colstrip is in a ranch yard where many vehicles, and haying equipment passed close by each day during the sampling period. Vehicle exhausts, and the presence of a trash-burning barrel in close proximity to the sampling equipment preclude the assembling of any meaningful data.

No mention of the doubling effect of sulfur dioxide, and particulate matter in combination, and their effect on respiratory tract and eye irritations was made.

Under paragraph 5, surely more tests should be run and the effects of these trace elements should be understood before construction is allowed to continue. There are many more trace elements that should be investigated than the few mentioned. There is evidence that selenium is naturally in such relatively high concentrations that it might already be a limiting factor in livestock production in this area. "Testing for radiation will be conducted if and when the plant is allowed begins operations.", sounds like thinking about closing the barn door after the horse is gone.

Exhibit 4

No mention is made that the microparticulate matter is the size that will escape into the atmosphere. This is the hardest to capture, and is the most damaging size of the particulate matter from a health standpoint.

On page 24, the monitoring of air quality by Montana Power Co. is rather like running a fishing contest by the honor system. The guy who stretches the truth the furtherest gets the prize.

Continuing on page 24, and 25, I take ~~a~~ with a grain of salt all of the high sounding things the MPC says it will do. Number 4 is especially suspect since Company personnel have already told a group of area residents that the Company plans to build 7 plants at Colstrip with a generation capacity of 10,000 megawats. The cavalier attitude exhibited by constructing without a permit is hardly consistant with the pious sounding number 8, unless they are acknowledging that your department has already capitulated to their wishes, and that your approval is assumed to be automatic. Perhaps they meant that all local, state, and federal agencies and groups responsible for the protection of our environment should work harmoniously with the Montana Power Company and Puget Sound Power and Light Company to make the Colstrip project an asset in the companies' ledgers.

On page 31 you state that "...the basic economic pitfalls in an exploitive industry cannot be avoided." This is erroneous. The pitfalls in this instance can be avoided by disapproving the application for permit.

On page 32 Section 6, I would add a ~~sixth~~ fifth area that is already suffering from the impact of the increase in population, and this is the school. Perhaps this was included in the Economic and social parameters, however.

In rereading this letter I find that it smacks of insincerety and facetiousness, but rather than rewriting it to remove the offensive portions , let me say that I sincerely velieve that you should not approve the construction of these plants. Perhaps I feel this way because my ranch, and way of life are threatened. Perhaps I am selfish in wanting the world to pass me by. But I think that if these plants are completed, and they and other plants like them go into operation, all of us in Montana are going to look some day at a scarred landscape under a filthy sky, cut by dry river beds, populated by a callous, socially chaotic population and we will say what fools we were for not stopping this exploitation when we had the chance. I believe you said it all on page iii, in the Foreward, when you said, "The long-term adverse effects may well outweigh the short term gains. I urge you to disapprove the application.

Sincerely yours,

Wallace D. McRae

Wallace D. McRae

Exhibit 4

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NOV 29 1972

November 28, 1972

Director Air Quality Bureau
State Department of Health & Environmental Sciences

Dear Sir

As a full time commercial pilot I have been aware of and indirectly enrolled in the Colstrip and Decker mining projects.

I flew the railroad people over the Area on their initial sight seeing trips. I have flown numerous aerial surveys over the area for Private Citizens, mining and State officials.

In registering my strongest objections to the Colstrip project, I would like to point out the existance of a persistant inversion layer over this entire area during many days of the winter months. In fact one existed for several days only last week. This condition would trap the pollutants close to the surface and the Yellowstone Valley will become one vast Chimney

Respectfully

Harry L. Corbin
1618 Pearl St.
Miles City, Montana
59301

Exhibit 4

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MONTANA CONSTITUTIONAL CONVENTION
STATE CAPITOL • HELENA, MONTANA 59601 • TELEPHONE 406/449-3750

JEAN M BOWMAN
District 8 Delegate
Secretary to Convention
Phone: 449-3764

HOME ADDRESS:
2244 Fairview Place
Billings, Montana 59102

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ENVIRONMENTAL SCIENCES
Division

November 18, 1972

Mr. Benjamin F. Wake, Administrator
Department of Health and Environmental Sciences
Cogswell Building
Helena, Montana 59601

Dear Ben:

I want to register my opposition to the proposed mine-mouth generator at Colstrip. I have read the Environmental Impact Statement prepared by the Department of Health and Environmental Sciences, and this seems to indicate that air quality standards will be met by the proposed plant. However, of an equally serious nature is the un-regulated impact on river water, soil usefulness after being stripped, and the unstable tax base that will result from the proposed plant.

I feel that there is more to consider here than merely the emission data. The long-range effects of this proposal should far outweigh the immediate short-term benefits when considering whether or not to allow this plant to become a reality. The State Department of Health is responsible first to the people of Montana, and the benefits to be gained by Montanans by this proposal are negligible. We will contribute the coal, for which we can expect to receive at this time, only minimum compensation. In return for this we will sacrifice much of our land and the life style of many of our people. We will realize a drastic change in land use which has many unknown ramifications. We will provide the use of an undetermined quanity of water. We will live with the emission of gasses and trace elements into an environment which is relatively pure, with no data to suggest what the effects on the eco-system will be.

If it is determined that this proposal is to proceed, some method must be devised by which the recipients of this power help to bear the burden of its cost. If Montana must, by the unique composition of its coal, contribute so heavily to the nation's energy needs, it should be adequately compensated.

Instead of gearing ourselves to the depletion of our coal for an impending "crisis" which will not be solved by this depletion, we would be wiser to direct our efforts in the area of investigating thoroughly some of the proposed alternatives mentioned in the Impact Study, like

Exhibit 4

ginning the painful process of grinding down our efforts at conspicuous consumption, and by making an effort to conserve what we have--not to deplete it.

I certainly feel that there is little to be gained by Montana by proceeding with the construction of this plant.

Sincerely,

Jean M. Bowman

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November 21, 1972

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Air Quality Bureau
State Department of Health and
Environmental Sciences
Cogswell Building
Helena, Montana

Dear Sirs:

My interest in the proposed Montana Power Company's generating plant at Col trip is one of a personal matter but more important from a professional standpoint. I am a Biologist whose knowledge of the detrimental effects that a company such as Montana Power can have on the environment extends further than the average concerned citizen.

Recently, under the helpful guidance of Lee Denson, Environmental Specialist for the Bureau of Reclamation and former Assistant to the Chief of the Endangered Species Program in Washington, D.C., I have been working on the critical situation that presently faces the Paddlefish status. I am now in the final stages of completing this study and hope to have it ready to send back to the Department of Endangered Species by the end of this week. They have already reviewed the study and had asked me to make a few corrections and send it back to the department.

You may be wondering how Montana Power will have any affect on the Paddlefish. Let me briefly explain. The proposed evaporators will require a certain amount of water from the Yellowstone River. The Paddlefish, of which there are two species, North American and China, are representatives of an ancient and primitive group of which very little is known. Spawning has only been observed once, literature is either outdated or scarce and they are isolated by the various dams on the Missouri River-Mississippi River Systems. Their status is UNKNOWN but yet is classified as a game fish in most states including Montana. Successful spawning has been determined to rely very heavy on rising, warm water levels and is the only initiator of the spawning migration process. Another words low water levels, decreased water flow and cold water inhibit successful spawning.

If more information is needed as to data, literature cited etc., I will be glad to forward as many copies as necessary in order to help in considering this one important species. I have spent more than nine months trying to compile enough information that would warrent placing this fish on the Endangered Species list as Status Unknown.

Sincerely,

Stephen C. Linder

Exhibit 4

Exhibit 4

INTERNAL MEDICINE
ALFRED M. FULTON, M.D.
ALLAN LEE ODULDING, M.D.
GEORGE R. BROBIUS, M.D.
PAUL V. HOYER, M.D.
WARREN D. BOWMAN, JR., M.D.
HEMATOLOGY
DONALD L. HICKS, M.D.
NEPHROLOGY
RONALD N. SMITH, M.D.
INFECTIOUS DISEASES
PHILLIP E. GRIFFIN, JR., M.D.
RHEUMATOLOGY
WALTER C. DEONAN, M.D.
CARDIOLOGY

GENERAL SURGERY
EDWARD W. GIBBS, M.D.

GENERAL VASCULAR AND THORACIC SURGERY
O. ADRIAN JOHNSON, M.D.
HEWES D. AGNEW, M.D.

CARDIAC, VASCULAR AND THORACIC SURGERY
JOHN W. NEIZER, M.D.

NEUROSURGERY
ROBERT C. WOOD, M.D.

ALLERGY
L. BRUCE ANDERSON, JR., M.D.

DERMATOLOGY
THOMAS P. GORMLEY, M.D.
WILLIAM H. SMOOT, M.D.

OBSTETRICS AND GYNECOLOGY
LEONARD A. BARROW, M.D.
EDWARD F. RANOAK, M.D.
H. C. KAYSER III, M.D.
LEE A. RAITZ, M.D.

OPHTHALMOLOGY
JAMES S. GOOD, M.D.

ORTHOPEDICS
WALTER N. NAGEN, M.D.
STERLING R. HAYWARD, M.D.
STANLEY J. YODER, M.D.

OTOLARYNGOLOGY
STEPHEN A. KRAMER, M.D.

PATHOLOGY
EDWIN C. BEOARD, M.D.
GORDON L. COX, M.D.

PEDIATRICS
ALLEN P. HARTMAN, M.D.
W. DEAN WILCOX, M.D.
RICHARD C. REEM, M.D.

UROLOGY
ROBERT S. NAGSTROM, M.D.
JOHN A. SHAW, M.D.
C. DALE VERMILLION, M.D.

RADIOLOGY
JERRY D. WOLF, M.D.
ALAN D. FLYNN, M.D.
V. PAUL JOHNSON, M.D.
WILEY R. BLAND, M.D.
CONSULTANTS

ADMINISTRATION
ROBERT O. TIRRELL
KATHLEEN SULLIVAN
RICHARD W. JOHNSON

THE BILLINGS CLINIC
NINTH AVE. NORTH AT BROADWAY
BILLINGS, MONTANA 59103
406-252-4141

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NOV 2 1972
ENVIRONMENTAL SCIENCES
DIVISION

November 20, 1972

Air Quality Bureau
State Department of Health
Cogswell Building
Helena, Montana 59601

Dear Sirs:

It is with increasing frustration that I view the continuous degradation of the quality of air in Montana particularly in Billings where the addition of the new Montana Power plant has appreciably added to the pall of smog during the past few years. I am an allergist and see many patients with severe asthma all of whom are noticeably worse during inversions. With the advent of yet another monster power plant in Eastern Montana, this can only get worse increasing the already serious problems in asthmatics, chronic bronchitics and patients with emphysema not to mention the increased problems that patients with hay fever, perennial allergic rhinitis and chronic sinusitis face with these pollutants.

I, therefore, protest the further degradation of our air in Montana through callous emissions from the huge power plants contemplated by Montana Power for the mindless increasing consumption of power in this country. In my opinion, if people want power, they should be made to pay for it at the price necessary to assure that its production will cause a minimum of pollution.

Sincerely yours,

L. Bruce Anderson, Jr., M. D.

LBA/ds

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MONTANA CONSTITUTIONAL CONVENTION
STATE CAPITOL HELENA, MONTANA 59601 TELEPHONE 406/449-3750

LOUISE CROSS
Delegate, District 3
Chairman:
Natural Resources and
Agriculture Committee

Box 1388
Glendive, Mont.
Nov. 19, 1972

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NOV 21 1972
ENVIRONMENTAL SCIENCES
DIVISION

Air Quality Board
Dept. of Health and Environmental Sciences
Cogswell Building
Helena, Montana

Members of the Air Quality Board:

Five years ago when the first news stories began to appear about the resurgence of the use of coal in Montana, I began to study strip mining and its impact on land and people. It was at that time that I became aware of a 1965 study on Appalachia by the U. S. Dept. of the Interior, and a corresponding publication on Surface Mining. Everything I read then spelled "bad news", and everything that has transpired since spells more "bad news".

At first I was concerned chiefly about reclamation of land after the mining. One needed only to be aware of what had happened, and is yet happening, in other parts of the U. S., to know that the similar destruction of productive land in Montana was unthinkable.

However, other factors even more unthinkable are the ultimate pollution to our air and water. Montana cannot be anything But the loser under present circumstances.

I hope that hundreds of letters reach your office. However, after investigation, and now knowing what you know about the grim possibilites for our environment, it would be your solemn responsibility as a duly constituted body concerned with the welfare of the citizens of this state, to take action regardless of whether or not you receive one single letter from any citizen.

I am enclosing a copy of a speech I have given recently to various organizations, and am also enclosing copies of statements I made at hearings during the Constitutional Convention, and on the floor of Convention Hall a few months ago in Helena.

If these statements were valid then, they are more so now. In my files are dozens of letters from Montanans who pleaded for a strong environmental plank. I would be glad to forward copies of them if you so wish. It is interesting to note that some of the things I fought very hard for are now being recommended by the Environmental Quality Council.

Since then, many more individuals have become aware of the threat to our environment, more groups have begun to organize to

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LOUISE CROSS
Delegate, District 3
Chairman:
Natural Resources and
Agriculture Committee

protect themselves from the coal companies, the power companies, the railroad, and even some individuals who see only the short term gain.

What individual would have the effrontery to deliberately circumvent the requirements of the Montana Environmental Policy Act and expect to get away with it? Why should the Montana Power Company? ???

Sincerely yours,

Louise Cross

Louise Cross

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COMMENTS ON COALSTRIP POWER PLANT IMPACT STATEMENT

There appear to be a number of serious inadequacies in the draft statement. The meteorological conditions which were used for the calculation of the 3-hour and 24-hour averages were not stated. The 1-hour average appears to be a fumigation condition which would be expected to produce concentrations of about the reported level. The 3-hour and 24-hour averages appear to have been drawn from 1-hour averages through division by factors of 3 and 24 respectively. Such factors would be appropriate for extending the 1-hour averages to the longer periods for fumigation conditions. However, it is likely that the fumigation condition does not produce the highest levels for these longer periods. The experience of the TVA authorities has shown that the maximum longer term concentrations are usually associated with limited mixing conditions and that the maximum 24-hour average may exceed 23% of the maximum 1-hour average.[1] Further, for a plant with this stack height they expect the maximum concentrations (1 hour) for fumigation and limited mixing to be about the same, thus the 24-hour levels would be expected to be about 0.10 ppm under the assumption that the fumigation conditions are representative of actual values.[2]

Second, high terrain is mentioned, but no topographic map is presented. This does not allow the reader to estimate what concentrations may occur when the plume is trapped in a stable layer which interacts with plume-height terrain. The 4400-foot terrain to the south would be at plume height. Under very stable conditions with low wind speeds sulfur dioxide concentrations of 0.7 ppm (1-hour average) would be expected. This illustrates the importance of terrain effects.

Exhibit 4

The levels of flourides reported in the coal are very low. For example, the lowest levels reported are about 40 ppm or ten times the level reported here.[3] Typical levels for coal average 130 ppm.[4] A report of an anomalously low value, such as this one, should be accompanied by some description of the sample preparation and probably an analysis by another laboratory. This is particularly important for flourides, because the data suggest that flourides tend not to be captured in [illegible] and may be easily lost during sample preparation. In this aspect flourides are very similar to mercury and it appears that Truesdale Lab reported low values in that case also. If the flourides actually averaged 130 ppm in the coal, the emissions would be as much as 2300 pounds per day.

Another inadequacy is the lack of data on other trace elements such as selenium, phosphorous and arsenic, all of which are similar to mercury and flourides in that they are more likely to escape particulate collection than other trace elements.[5]

The mercury emissions should also be discussed in terms of their effects on the aquatic environment. It appears that a single ton of mercury can pollute a stream flow of about 4 million acre feet. A level of .17 ppb in water appears to be capable of producing levels in the flesh of fish of .5 ppm.[6] This latter figure is above acceptable levels for human consumption on a regular basis.

Furthermore, emission of 5.5 pounds of mercury per day would be slightly above the emission levels permitted for chlor alkali plants. It is true that scrubbers may be able to collect some of the mercury, although it is clear that other particulate collection devices are

Exhibit 4

rather ineffective and poor collection efficienty (5% or less) should be assumed until higher ones have been demonstrated.

The adequacy of the secondary standards is subject to considerable question. For example, the secondary particulate standard of 60 ug/m^3 would be expected to permit average visible ranges of no more than 12.5 miles. Thus, at least to the extent that people value vistas of objects more than 13 miles distant, the standards do not protect against all adverse effects. It was considerations similar to this one which led New Mexico to ask that the non-degradation decision of the district court be upheld. Furthermore, the criteria documents point to synergistic effects of sulfur oxides and oxides of nitrogen on plants at levels below the secondary standards.[7] These levels could occur near the coalstrip plant.

Another difficulty with the statement is that the test method used to determine the particulate collection efficiency is not stated. I suspect that the ASME method is used, in which case the actual particulate emission may be understated by a factor of three or more.[8]

The last inadequacy relates to the discussion of visibility reductions. The conclusion does not seem to be adequately founded, although the paraseology is sufficiently vague to preclude a precise understanding of the conclusion. Small sources of particulates such as wood waste burners, gypsum plants and perlite mills produce considerable visibility degradation. Compared to these, the plant will be a large source, and, furthermore, the particulates which escape the scrubbers will be of a very small size and consequently will have a much greater impact on visibility per unit mass. These questions

Exhibit 4

need not be left in these vague terms. Plume concentrations of fly ash and particulate sulfate may be estimated so that a picture of the plume's effect on visibility under different meteorologic conditions can be presented. Such calculations should be for plume centerline concentrations rather than ground level values.

One last alternative should be mentioned: that of burning gasified coal. The emissions from the plant and the associated gasification facility would probably be low enough to meet non-degradation requirements.

There is perhaps one problem with the overall construction of the document. The only calculations presented are described as conservative, and in my opinion underestimate the probable impact. Furthermore, the impact is described as impossible to predict quantitatively. While there is an element of truth in this statement, I believe our present knowledge could be used to make "current best estimate" predictions which would be useful. Visibility restrictions associated with the plume would be a natural candidate for such predictions as would be plume impingement on high terrain.

Michael D. Williams, PhD.

1. T. L. Montgomery, "Comments For the CPEAC Panel Discussion -- The Cumulative Effects of the Power Plant Network on or Near the Colorado", Tennessee Valley Authority, Muscle Shoals, Alabama; Sept. 2, 1971.

2. Carpenter, S. B., et al., "Principal Plume Dispersion Models TVA Power Plants", Paper #70-149 presented at the 63rd Annual Meeting of the Air Pollution Control Association; June, 1970.

3. Statement of John Wright (New Mexico Environmental Improvement Agency before the Senate Interior and Insular Affairs Committee during

Exhibit 4

hearings on "Problems of Electrical Power Production in the Southwest", Albuquerque, N.M.; May 24, 1971.

4. Southwest Energy Study -- Coal Resources Work Group; October, 1971.

5. Same as above.

6. Lambou, Victor, "Report on the Problem of Mercury Emissions into the Environment of the United States", presented to the Working Party on Mercury, Sector Group on Unintended Occurrence of Chemicals in the Environment, OECD, Jan. 27, 1972; p. 53.

7. U.S. Dept. of HEW, "Air Quality Criteria for Sulfur Oxides", NAPCA No. AP-50, January, 1969; p. 5-13.

8. "Abatement of Particulate Emissions from Stationary Sources", National Academy of Engineering -- National Research Council, COPAC-5, July, 1972; p. 34.

November 21, 1972

4053-A Sycamore Ave.
Los Alamos, New Mexico 87544

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STATE OF MONTANA

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DIVISION

DEPARTMENT OF FISH AND GAME

Helena, Montana 59601
November 17, 1972

Dr. John Anderson, Director
Department of Health and Environmental Sciences
Helena, Montana 59601

Dear Dr. Anderson:

As requested, we have reviewed your draft statement regarding the environmental impact of the proposed Montana Power Company electrical generating plant at Colstrip, Montana. We will attempt to categorize our comments on the report for easier reference. Before doing so, however, two general comments are in order. First, on practically every page of the statement the lack of information on effects of this development, the mining of coal, the power plant itself, reclamation, power lines and water needs appears obvious. Nevertheless, the development is continuing without regard for these question marks. Secondly, we believe a comparison is in order to clearly identify those individuals and natural systems of Montana that must absorb the adverse effects of this development for comparison with the benefits claimed, along with identification of where and to whom those power production benefits will accrue.

In regard to the "Description of Proposed Action" segment of the report, we have the following questions and comments:

This section discusses mine-mouth plants in Montana and states that in the past, power plants were generally located near load centers and the coal imported over long distances. The reasons for locating the plants in Montana is not specifically discussed. The report does state, "these mine-mouth plants are favored by environmental parameters, at least from the owner's standpoint." This statement definitely needs explanation as to what these environmental parameters specifically are. It is inconceivable that we can afford to sacrifice Montana's quality environment for the benefit of urban areas in the midwest and west coast areas. It would seem appropriate that those areas benefitting from cheap electrical energy should be made aware of the total cost of that energy by enduring the environmental degradation that attends its production.

The discussion on pipe line and water supply in this section fails to adequately discuss the effects of the pipe line on the terrain over which it is to be constructed, on the river where some type of diversion structure must be located, and on the aquatic ecosystem downstream from the diversion, particularly during times of low flows in the Yellowstone. Absolutely no data other than the quantity of the diversion is presented on this topic. Also notable by its absence is the discussion regarding the alternative of dry draft cooling towers.

Exhibit 4

The transmission lines discussion fails to adequately discuss the environmental effects of those structures, and again omits discussion of alternative power transmission techniques. It is also noted that the transmission line discussion terminates north of Billings, even though the purpose of the project is to produce power for consumption in the Puget Sound marketing area.

In regard to the "Probable Impact on the Environment" section, we have the following comments:

In discussing the impact of the various emissions - SO_2, NO_x, trace elements, mercury, fluorides and other radio active elements - the words "not known," "unknown," "very little is known," "no background information" and "results are preliminary" appear quite often, and emphasize the fact that this entire development, like the reclamation attempts, is putting the cart before the horse. A more logical approach would be to determine these effects elsewhere prior to development in Montana. This statement merely discusses the types of contaminants anticipated from the plant and emphasizes our lack of knowledge regarding their impact. Once again the discussion does not place the proposed plant in the perspective of total Fort Union coal region development.

As with the previous section, the effects of water and heat emissions from the power plant and the effects on visibility and aesthetics merely stress the lack of knowledge and emphasize the need to answer these questions prior to development.

Within this section background levels of sulphur dioxides are discussed. It is noted in the report that they appear to be higher than those suggested by the Environmental Protection Agency.

In noting the location of the sampling stations, it appears possible the open fires occurring for some time at the Peabody Mine may be influencing the data. Has this possibility been investigated?

In the discussion within this section of the effects on the ecosystem, we note the word "natural" which is used in reference to "an ecosystem containing species that have adapted to that particular environment and exist there because of that environment, not in spite of it." The terminology "natural ecosystem" needs clarification. Ecosystems that are immune from the impact of man are sometimes thought of as natural ecosystems, and they probably do not exist anywhere on this earth, with the possible and still questionable exception of the north and south poles and some uninhabited regions. Man's activities, in fact his mere presence, institute changes in the ecosystem. The ecosystem at and around Colstrip is obviously not without man's influence.

Exhibit 4

The white man has been there for the past hundred years, and prior to that the Indian affected the system. Plants and animals now present in that area are adapted to that ecosystem, their presence and abundance having evolved with man's activities - in this case, primarily agricultural land use dependent upon cattle and/or sheep grazing. With this in mind one can only marvel at the complexity of the ecosystem at Colstrip. For the present at least, any statements regarding the effects on the system are merely conjecture.

Again the wording of this section includes "impossible to predict," "maybe," etc., and merely emphasizes our lack of knowledge.

Within this section is also contained a discussion of special environmental studies. Once again we are conducting studies after construction decisions and plant sitings have been decided. To adequately study the impact of this kind of development, investigations should be begun many years prior to development. Once again we were forced to travel the same road as we have traveled on so many other environmental problems. Another example of this was our involvement with sagebrush eradication in this state. We lost in excess of 300,000 acres of sagebrush wildlife habitat in Montana before any studies were initiated to determine the effects of such eradication. Once again we are involved in what could simply be monitoring of a bad situation.

On the topic of the listing of special studies, it is impossible to evaluate their worth without reviewing the study outlines and obtaining some indication of the commitment of resources to these studies. Study titles tell us very little, if anything at all. We would appreciate the above information to assist us in our continuing evaluation.

We also noted with interest the participant's environmental policy statement which was printed in this section presently being discussed. Item No. 8 of that policy states, "work harmoniously with all local, state and federal agencies and groups responsible for the protection of our environment." Policy statements mean little unless they are backed by a commitment that is real.

An example of the company's intention, I believe, can be derived from an effort made by this Department in 1969 to initiate a study that would have produced the background information so obvious now by its absence. At that time Western Energy, the wholely owned subsidiary of the Montana Power, declined to enter into a cooperative study with this Department that would have cost them less than $1,000 per year. This fact should be considered when statements of policy are being evaluated. Three years of background data would have eliminated many of the unknowns so evident in this entire statement.

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Again within this section in the discussion of ash and water discharge to the land, we note the words, "appear to be," "maybe," and "may result." On page 28 the statement is made, "without an expression of concern from the persons interested in maintaining some of the present land use in eastern Montana, the proposed Colstrip plant may be only the first of many industrial developments that could conceivably alter the land use of most of the Fort Union region." It appears to us that the "expression of concern" has in fact occurred, and is overwhelming. The question is, will this concern be reflected when the time comes to consider permits authorizing construction of projects causing the concern.

When discussing the impact on flora and fauna within this section, it is stated that the emissions from the generating facility will put a stress on some plants which may kill them or reduce their ability to compete with other species. Once again it is obvious we are proceeding with both facility construction and reclamation research without adequate knowledge regarding the plant species with which we are working. It is conceivable that reclamation is proceeding with plants sensitive to sulphur oxides and doomed to failure for that reason. This is just another example of the paucity of information available for discussing a problem of this magnitude.

In the discussion of the impact on the human environment, there are several items we would like to see discussed in greater detail. One is the value of undegraded natural environments as they affect the wellbeing of people, and the other is the impact an expanding human population, and in turn an expanding hunter population will have on already strained landowner-sportsmen relationships.

In regard to the "Adverse Environmental Effect Which Cannot be Avoided Should the Proposed be Implemented," we have the following comments and suggestions:

Under Item No. 2 of your list, we believe it should be acknowledged that the consumption of 4.2×10^9 gallons of water can be avoided. The installation of dry draft cooling towers would certainly reduce this consumption and would most likely be in the best interest of all other Montana water users, including those persons interested in maintaining healthy aquatic ecosystems. We also believe this list should be expanded to include: No. 9 - Under present reclamation procedures, decreased wildlife habitat and populations. No. 10 - Decrease in recreational opportunities provided by wildlife and undeveloped land. No. 11 - Reduction in what Montana is famous for - notably open space, a modest human population and an excellent fish and wildlife resource.

In regard to the section entitled "Alternatives to the Proposed Action," the report reiterates our lack of knowledge concerning other energy sources and our unwillingness to force serious consideration of alternatives - not only to

Exhibit 4

the development itself, but also to features of the development. An example of this is our unwillingness to discuss dry draft cooling towers versus wet cooling and other specific water-related project features such as offstream storage of water near the plant site to prevent depletion of the Yellowstone River during periods of low flow. Under any circumstance, the 8,000 gallon per minute diversion of water must be considered in the perspective of the ultimate projected development of the Fort Union coal field and not as if it were the only generating plant to be constructed. We all know this is only the first.

In closing, we certainly thank you for the opportunity to comment, and we hope our comments will lead to a more realistic appraisal of the impact of the power plants in question. You can be assured the Montana Fish and Game Department will do everything in its power to assist your Department in making these impact assessments.

Incidentally, at the most recent Fish and Game Commission meeting our Commission instructed us to immediately increase our effort on the coal fields, and as a result we are assigning an additional man to the Decker-Birney-Colstrip region so that our ability to provide information in this area will be improved shortly.

Sincerely,

Don L. Brown

DON L. BROWN
STATE FISH AND GAME DIRECTOR

DLB/sd

cc: Montana Fish and Game Commission
Regional Coordinators

Exhibit 4

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4260 East Evans Avenue · Denver, Colorado 80222 · 303/757-5439

November 27, 1972

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Mr. Don Holtz, Chief
Air Quality Bureau, Environmental
Sciences Division
State Department of Health and
Environmental Sciences
Helena, Montana 59601

Dear Mr. Holtz:

Re: Environmental Impact Statement on the Colstrip, Montana Power Company Plant

Enclosed are our comments on the Draft Environmental Statement. We appreciate the opportunity to review and comment on this. We also compliment the Department for an excellent overall Draft Statement.

I also enclose two documents as relevant to the case at hand. One is on alternatives in energy; I distributed it originally to the League of Women Voters' State Convention, Great Falls, May 1972. The second is entitled "Wanted: A Better Approach to Energy Planning." It is a critique of the North Central Power Study and recommendations for future planning, by ROMCOE. We feel that the Colstrip plant is deficient in the planning methodologies which we advocate.

Sincerely yours,

ROCKY MOUNTAIN CENTER ON ENVIRONMENT

Albert G. Melcher, P.E.
Director of Technical Services

AGM:dbm

cc: Fletcher Newby

Enclosures

Exhibit 4

ROCKY MOUNTAIN CENTER ON ENVIRONMENT
4260 East Evans Avenue
Denver, Colorado 80222
303-757-5439

November 27, 1972

Comments on
Montana Department of Health and Environmental Sciences
Draft Environmental Impact Statement on the
Proposed Montana Power Company
Electrical Generating Plant at Colstrip, Montana.

I. General Comments

The impact statement is unusual in that it seriously addresses the long-term implications of such a development, and in its conclusion that "the long-term adverse effects may well outweigh the short-term gains." (p. iii) This conclusion is perhaps the most important statement in the document.

The Colstrip plant project raises the problem of additive effects: the proposed plant is the first of several (or many) that will probably be built in the area in the near future. There do not seem to be adequate legal or institutional mechanisms either on a state or federal level to consider the additive effects until we are several steps further down the road. Ideally, the presently proposed plant should be evaluated not only as a separate phenomenon, but also as part of the overall picture. Clearly, the environmental impact of one plant may be "acceptable"; and the entire complex probably will not be acceptable. But, since one plant is a part of the whole, the decision to build, modify, or not to build one plant should not be made in a vacuum. The impact statement cannot justifiably be faulted on this point. We mention this problem to indicate that our evaluative procedures are not yet adequate to handle it. We face the danger of considering each increment of development separately and never evaluating the eventual aggregation of increments.

The preparation of this statement should have involved experts from more disciplines. Certain portions of the analysis are weak; biota, aesthetics and noise are several such sections. The statement concludes that stack emissions will cause the most significant impact (p.11) of the various parameters. This is probably true in this case, but it must be pointed out that a more comprehensive and rigorous study would justify this assumption beyond question or argument. It would also lead to more precise definition of the impacts from emissions. Studies now underway will be of considerable help (p. 24).

However, the absence of a complete range of disciplines probably results in a conservative estimate of the impacts in this case. In other words. it is probable that some adverse effects are undiscovered and hence total impacts could be worse than those portrayed.

There is an unevenness in the treatment of the various components of the entire facility. The power plant receives most attention; less attention is devoted to the mine and to urbanization, and even less is given to the transmission line and water consumption. Even if there are differences in legal jurisdiction

Exhibit 4

over the various components of the project, the obvious interdependencies of mine, plant, water and transmission lines would seem enough reason for the Statement to consider the impacts of all of these.

The Statement seems to confuse the importance of quantities of emissions with that of *environmental impact*. The former is really only a means for determining the latter. The latter is the real subject matter for a statement such as this. Unfortunately, this statement stresses quantities of emissions. What we really need to know is, what is the *effect* of the emissions? In some cases, the impact is not entirely known (for example, "The potential for damage to the ecosystem by flourides from the proposed Colstrip plant is not known at this time. At 77 lbs./day, more than 800,000 lbs. may be emitted over the 30-year life of the plant. . . ." (p.19)), but the responsibility of the authors is to define *impact* insofar as possible. "Effects on Ecosystem" (of air emissions) occupies only ½ a page, and contains little information. It does, however, caution that "over a period of years, the pollutants may build up to levels that seriously disrupt the ecosystem." (p.22) Clearly the subject matter under this heading should have occupied a major part of the statement. Although the authors are correct that exact impacts cannot be defined at this time, there is a good deal of information available as to the nature of expected impacts. In a later section, *some* of this information is discussed. (p. 29)

We feel that the final Environmental Impact Statement, and subsequent ones, should seek to define environmental impacts more precisely, and to focus on them.

The Statement would be improved with graphics showing physiography and ecosystems of the area, and other environmental parameters.

The current court interpretations that the 1970 Clean Air Act is to be construed by EPA to require non-degradation of existing air quality have not been discussed or dealt with in this Draft Environmental Impact Statement. This policy could have a significant effect on all proposed plants in the area, and should be considered seriously.

The impact statement should make clear the status of the project at the present time. From reading only this document, one would assume that the decision to build had not yet been made. However, we understand that the project is under construction.

It would also be useful to answer some procedural questions: what role will and should the impact statement and the Montana Environmental Quality Council play in the project? Is there any further decision-making procedure to be completed which might change the course of action now under way? In other words, is the project to be re-evaluated?

This Draft Statement is one of the more forthright which we have encountered. It is better than most which are prepared by the Federal government. The Montana Department of Health and Environmental Sciences is to be commended for this Statement.

Exhibit 4

II. Specific Comments

A. P. ii, Cutting Plant Load to Meet Standards. It is stated that "Reduction of plant load when these meteorological conditions arise could prevent the high one-hour levels" (of ambient sulfur oxides). Will such reduction be possible, or mandatory, so that "could" can be replaced by "will"? Furthermore is it possible to anticipate the meteorological conditions far enough in advance so that standards will not be violated?

B. P. 5, Particulate Size. It should be noted that the particulate emissions will be primarily in the range of 2 microns and smaller. These are most damaging to animal health, and remain in the air for prolonged periods. They act synergistically with SO_2 in the atmosphere, in effects on visibility, and in lungs, although precise effects are not known. This should also have been discussed in pages 12-19.

C. P. 12, Standards. It is stated that only in rare cases will either state or federal ambient air standards be violated. This bears further explanation -- how "rare," and is it legal to violate standards ever?

The impact statement refers to a statement by the Administrator of EPA to document the assertion that ambient air standards "are considered adequate." The Statement, to be complete, should mention that biologists (and others) consider the standards to be inadequate -- see, for example, the EPA and the BSFW Work Group reports to the Southwest Energy Study. The seriousness of this concern is emphasized by the fact that EPA is considering more rigid standards. It has been shown that emissions within the limitations of federal standards do significant damage to vegetation, hence to the entire food chain. See also our comment on non-degradation policy, in "General Comments."

D. P. 17, Potential Inaccuracies in Diffusion Modeling. It is stated that "wind channeling, impingement and other real-life phenomena" might cause higher SO_2 concentrations than predicted in the diffusion models. It is indicated that the same thing might prove true for other emission parameters. In view of the fact that the estimate that standards would be violated only in "rare" cases (p. 12) was obtained by diffusion modeling, and that charts in the Statement (pp. 9, 10) show that some expected emissions fall barely within standards, inaccuracies due to "real-life phenomena" could prove to be extremely significant. The Statement should emphasize this problem. The implication is that violations of standards are expected.

E. P. 21-22, Visibility. This section does not indicate if there is any physiographic "pocket" and inversion potential which could cause an accumulation of emissions over a period of time without dispersion. The implication of the comments on modeling is that this would not occur. The Statement should be more specific. The effects of any reduction in visibility should be related to a landscape analysis, including scenic vistas, visual corridors, etc.

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F. P. 22, "Effects on Ecosystem." The "triggering" effects of certain actions could be significant. If vegetative species are reduced in any way, wind and water erosion could be triggered, especially in any extreme weather cycle such as drought.

G. P. 24, Studies Underway. It is noted that the Company intends to do a number of studies to assess the impact of their operation, and to save any endangered species or archeological materials on their sites. It would seem that the appropriate time to conduct these studies -- before construction -- is past. At least they should be conducted before operation of the plant. The Statement should review the status and findings of any studies underway.

H. P. 27, "Land Use." The impacted acreages of land use greatly exceed the direct acreage in many ways. For example, in aesthetics, the acreage affected is a "line-of-sight" area from which the mine, plant and transmission line can be seen. This is subject to rational analysis; the Forest Service has a computer program to determine "seen areas." If migratory patterns of some species of wildlife are involved, the effect on habitat of a road, mine or plant may involve many times the direct acreage of the plant.

The long-range possibility of changing the region from an agricultural to an industrial society also represents a land use effect far larger than the acreage directly affected.

The last paragraph on this page includes the sentence "Whether this is good or bad depends upon whether you are a golfer or a hunter." This misses the essence of environmental analysis very badly. Regardless of whether one is a golfer, a hunter or neither, a golf course which significantly disrupts ecological processes is not good; if it could have been located elsewhere with less environmental impact, it is less than good.

I. P. 29, Aquatic Ecosystems. Paragraph 4: Information on flows of the Yellowstone River should be furnished. An attempt should be made to define more thoroughly the impact of the project on aquatic ecosystems and on water resources.

J. P. 32, Noise. We disagree that quantitative values are meaningless. EPA and HUD have developed planning guidelines for noise using quantitative values. The workers'environment (plant and mine) includes probable exposure to certain decibel levels for certain periods of time. Will this lead to any loss of hearing? Other questions about noise can be quantified.

K. Pp. 34-36, Alternatives. The "alternatives" section does not really address the fact that the power from the Colstrip plant is headed for distant load centers, and that many potential alternatives could be taken at these distant points. For example, coal-fired plants could be built at the load centers instead of in Colstrip. The alternative "Not to Construct" should be expanded to include the alternative "Not to Construct in Colstrip." In addition, the alternative of energy conservation -- in its many forms -- has not been mentioned.

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Alternatives of Advanced Power Cycles (or "combined power cycles," using gas and steam turbines) are not discussed, despite advantages in efficiencies and emission controls.

We note with interest that wind was formerly used in Montana to provide DC power. This source should be re-examined for modern use.

J. Pp. 37-40, Long-term vs. Short-term. The section on short-term uses provides excellent perspective. It presents the important long-term questions which so frequently are ignored in favor of the crisis of the moment. These four pages are worthy of separate publication and wide distribution -- the Colstrip plant is only a small part of the issues it addresses. Unless society -- the public, the decision-makers, the utility companies -- faces these far-reaching questions, it will have no basis for evaluating incremental short-term decisions such as the proposed plant at Colstrip.

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student environmental research center

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In the matter of the Draft Environmental Impact Statement on the proposed Montana Power Company Electrical Generating Plant at Colstrip, Montana

Before: Air Quality Bureau, Montana State Department of Health and Environmental Sciences

Submitted by the Student Environmental Research Center

John McBride

William Tomlinson

Phillip Tourangeau

Exhibit 4

On review of the draft environmental impact statement, prepared for the two (2), 350 MW coal fired units of the steam electric generating plant presently being constructed at Colstrip, we find the statement generally inadequate, being insufficient, both in scope and depth to enable definition and quantification of impact. After detailed study of the draft statement we believe that the following questions should be considered in the final impact statement, and further that consideration of these questions is required under Section 69-6504 of the Montana Environmental Policy Act.

Administrative

What was the date declared for commencement of construction by applicant Montana Power on their application for a construction and operating permit?

What was the date of department receipt of application for construction permit as required under section 2 of Regulation 90-001 entitled Air Pollution Control Construction and Operating Permits?

Section I (A) (1)

It is stated that "this complex...will provide electricity for Montana users and for shipment to the load centers of the Pacific Northwest." Of this power supply what percent will be utilized in state? What percent will be consumed in the Pacific Northwest load centers? (please itemize)

Is this plant required under projected levels of growth for Montana?

Exhibit 4

It is stated in the impact statement that, "Mine-mouth" plants, which are located near enough to the coal for conveyor or short-distance rail transfer of coal, are presently favored by economic, technical, and environmental parameters, at least from the owners' standpoint." How and to what degree are "mine-mouth" plants favored over load center development employing either fossil fuel based generation, nuclear or other alternative energy conversion technology?

How will the venturi scrubbers remove gaseous fluorides and heavy metals? (Cite evidence)

Section I(A) 2

What is the applicant Montana Power Company's water appropriation claim at Nichols?

What percent of the minimum flow and average flow of the Yellowstone at the point of withdrawl is Montana Power's appropriation?

What percent of the appropriation is represented by the stated withdrawal of 8000 gallons per minute?

What percent of the minimum flow and average flow of the Yellowstone at the point of withdrawal is this?

What is the maximum capacity of the proposed water supply system? (Both the 24 inch pipe and larger pipes up to 60 inches)

What will be the impact on down stream water quality by the withdrawal of the 8,000 gallons per minute as proposed herein?

What will be the impact on the down stream water quality by the withdrawal of the entire Montana Power appropriation?

Exhibit 4

An 8,000 gallon per minute flow will deliver 13,058 acre feet of water per year. According to the flow diagram appended to section I, the water consumption of the two (2) units will be 13,068 acre feet per year. Assuming a 26-inch per year evaporation rate approximately 65 acre feet per year will be evaporated from the surge pond. Thus the water supply to the Colstrip generating facility as described is inadequate. Please comment. (Give a detailed water balance from intake through generation, cooling tower and settling ponds.)

What are the operating characteristics of the water supply system? (Size of pump, exact diameter of pipe, number of pumping stations, etc.)

What will be the environmental impacts associated with the construction and continued maintenance of this pipeline?

How will the area disturbed by the construction of the pipeline and pumping stations be reclaimed?

Has right of way acquisition begun for the pipeline?

Will the pipeline cross any sections of state or federal land?

If the answer to the preceeding question is affirmative have the easements for these parcels of land been obtained?

Does the applicant expect to exercise the powers of condemnation in securing pipeline right of way?

Section I (A) (3)

What are the environmental impacts of the powerlines associated with the generation complex?

Exhibit 4

Section I (A) (4)

What precautions will be undertaken to control particulate air pollution from the crushed coal stockpiles?

What percent of the mined land will be reclaimed each year?

Will additional lands, not presently held by the Western Energy Co. be required for their expanded mining operation required under this proposal?

Section I (A) (5)

What is the physiographic setting of the power plant and requisite facilities? (On suitable topographic maps or air photos locate the two (2) thermal electric generators, cooling towers, aquaduct, pumping stations, transmission lines, settling or ash ponds, surge ponds, coal storage areas, strip mines, haul roads, and housing developments.)

What are the qualifications of Ron R. White and Company?

Of the total cost of the Colstrip facility what will be the cost of the abatement equipment? (Include cost description of all abatement equipment.)

Section II (A)

The sandstone caprocks are considered by many to be one of the most outstanding topographic features of the Colstrip area. What are the unique landscape features of the Colstrip area?

Section II (B)

Please clarify what is meant by the Tongue River Indian Reservation?

Section II (D)

Have archeology surveys been conducted on the steam generator site, mine site and the site of all requisite facilities?

Exhibit 4

What percent of power generated will be lost in transmission to the Billings substation and to west coast load centers?

Will the ozone generated by the powerlines react synergistically with sulfur dioxide from the power plant to create an air pollution problem?

What route is to be selected for the two additional 230 KV powerlines that will be constructed?

Will the two (2) additional transmission lines cross any state or federal land?

Has right of way acquisition begun for the two additional powerlines?

Does the applicant expect to exercise the powers of condemnation in securing transmission line right of way?

On what date did construction commence on the transmission line currently under construction?

Has all the right of way been secured for the transmission line currently under construction?

Does the transmission line currently under construction cross any state or federal land?

If the answer to the preceeding question is affirmative have the easements for these parcels of land been obtained?

Has the applicant exercised the powers of condemnation in securing any portion of right of way for the transmission line under construction?

Exhibit 4

What effect will the increased travel on unpaved streets, mining and construction have on particulate levels in the town of Colstrip?

What is the basis for the statement, "It is anticipated then that an annual geometric mean for the area may approach 50-60 ug/m^3?

Section III (A) (3)

What is the accuracy of the sulfation plate method for determining SO_2?

How can the predicted Annual Average SO_2 concentration after the power plant is built be less than present background levels?

Please detail and document the computer diffusion model used to predict pollution levels by the State and EPA. (Perhaps this could best be done by including the entire model and input data)

Can particulate and NO_x values be determined from the SO_2 model?

Have baseline studies been conducted to determine the particle size and number density in the ambient air? What are the results?

What will the particle size and number density be in the stack gases?

What influence will these particles have on the base line conditions?

Section III (A) (5)

How can the environmental impacts of trace elements be assessed without a comprehensive statistically significant elemental analysis of the coal?

We are particularly concerned with the fluoride concentration reported by Truesdale Labs. Analyses from the Southwest Energy Study

Exhibit 4

If the answer to the above question is affirmative please describe the location and contents of all finds?

Section II (F)

The statement made on page 8, titled Meteorology can only be considered a climatic description of the area. The following Meteorologic parameters are necessary to evaluate air pollution potential and to provide baseline data for climatic modification, resulting from the development.

- Mean annual and monthly temperature and precepitation
- Wind speed and wind direction both at ground level and for the upper atmosphere
- Standard deviation for both wind speed and wind direction for both ground level and upper atmosphere
- Annual and monthly average relative humidity at standard observation times
- Inversion frequency and duration as evidenced by temperature differential at varying elevations and barometric pressures
- Solar radiation
- Visibility and cloud ceiling

Section III (A) (1)

The aquaduct, transmission lines and surge ponds also have primary impacts on the environment.

Section III (A) (2)

How was the estimate of 15 ug/m^3 total suspended particulate derived?

What are the present particulate levels in the town of Colstrip?

Exhibit 4

indicate levels much higher as do preliminary analysis on Montana coal at the University of Montana. As vegetation is particularly sensitive to fluoride levels, an accurate analysis must be made.

What are the qualifications of Truesdale Labs?

How are uranium and thorium removed from the effluent gases?

Section III (A) (6)

Explain paragraph one (1).

What effect will water vapor and heat emissions have on relative humidity, fog incidence, cloud ceiling and incoming solar radiation?

What effect will the localized heat island associated with the power plant have on the surrounding ecosystem?

Section III (A) (7)

We cannot agree with the first sentence following the quotation from the First Annual Report of the Council On Environmental Quality. Relative humidity near the power plant will be high and will probably be near 100 percent during the winter months. Under these conditions visibility reduction will definitely take place. The initial contention is also contradicted by the last sentence of the paragraph, "It is possible that under meteorological conditions such as high humidity a marked increase in fog occurrence will be observed due to the water emission."

Section III (A) (8)

There are numerous studies on the effects of SO_2, NO_x, particulates, etc. on ecosystems. It is certainly possible to predict some of

Exhibit 4

the effects of these pollutants. We can only stress that this section should be greatly expanded and should include a review of the pertinent literature on the effects of these pollutants.

Section III (B)

What is the past record of the designated contractors in meeting their guarantees on boiler and emission control facilities?

Section III (C)

What facilities are employed by West Associates in performing trace metal coal analysis? (What specific chemical and physical determinations are employed?)

Does the public have access to the special Environmental Studies performed by the applicant and subcontractors?

Does the public have access to all monitoring data collected by the company?

How will endangered species and archaeological materials be saved for posterity?

Section III (D) (1) (a)

What methods of dust supression will be employed in the handling and storage of flyash?

Section III (D) (1) (b)

Has the effect of boron in the flyash been appraised?

What solubility studies have been preformed on the flyash?

Exhibit 4

Section III (D) (1) (c)

What studies have been undertaken to determine ground water contamination from flyash and settling pond leaching?

Section III (D) (1) (d)

The discussion of sewage treatment seems to be quite sketchy and numerous questions arise. (Please give a detailed description of proposed sewage facilities and particularly what sewage treatment facilities will be available for the construction work force.)

Please include in the discussion on the Colstrip sewage system the "Water Quality Management Interim Plan for Colstrip, Montana" as prepared by the department and the grant application and granting stipulation for the funding of that system under EPA.

Section III (D) (4)

Explain pages 29 - 31.

Section IV

The following are also adverse environmental effects which cannot be avoided should the proposed facility be implemented:

1. New road construction and the upgrading of existing roads.
2. If the proposed facility just meets ambient air standards further industrial development will be precluded.

Section V

The discussion of alternatives is inadequate. The impact of non development must be considered and additionally the alternative choices for the proposed facility should be considered. (i.e. wet versus dry

Exhibit 4

cooling towers, de-ashing coal, desulfurization of coal, advanced SO_2 emission controls, etc.)

The discussion of alternative technologies should be greatly expanded particularly in reference to why each choice was eliminated.

Exhibit 4

Comment Recipients

Fletcher E. Newby
Environmental Quality Council

Frank Culver
Governor's Task Force on Coal Development

Ellen Withers, Chairman
Northern Plains Resources Council

Board Members
Montana Board of Health

John A. Green
Environmental Protection Agency

Thomas Judge
Governor Elect

Ernst R. Habicht, Jr.
Environmental Defense Fund

Glenn Paulson
Natural Resources Defense Council

Carl Anderson
Montana Power Company

Exhibit 4

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UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
P. O. Box 970, Bozeman, Montana 59715

November 30, 1972

Don Holtz, Chief
Air Quality Bureau
Environmental Services Division
State Department of Health and
Environmental Sciences
Helena, Montana 59601

1972
ENVIRONMENTAL SCIENCES
DIVISION

Dear Mr. Holtz:

The draft environmental statement for the proposed Colstrip Power Plant in Rosebud County was reviewed by the Soil Conservation Service.

Our staff offers no comments on the draft statement.

Sincerely,

A. B. Linford
State Conservationist

Exhibit 4

Exhibit 4

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE

Post Office Box 1296
Billings, Montana 59103

December 4, 1972

Mr. Don Holtz, Chief
Air Quality Bureau
Environmental Sciences Division
State Department of Health and Environmental Sciences
Helena, Montana 59601

Dear Mr. Holtz:

Thank you for the opportunity to review the draft "Environmental Impact Statement on the Proposed Montana Power Company Electrical Generating Plant at Colstrip, Montana", dated October 1972.

We offer the following comment for possible inclusion in your report:

Page IV. Pipeline. The size of the pipeline (diameter) should be shown since it is a critical factor in estimating the many unknowns associated with possible effects of the development. If it is only 24 inches diameter as shown as the minimum, it can be assumed that this environmental impact statement reflects the needs of this 700 mw plant. If, however, the diameter is to be 60 inches as reported likely (Billings Gazette, 12/1/72), we are compelled to conclude that the ultimate development associated with the construction and development in this vicinity will be many times greater, perhaps nine times greater.

The effects upon the river fishery of a diversion of the magnitudes herein considered is not likely to be significantly detrimental. However, intake structures should be screened or so designed as to preclude entrance of fish now in the Yellowstone River.

Water Consumption. It is much more meaningful to people (in the West, at least) to show water volumes or rates of flow in terms of acre feet (af) or cubic feet per second (cfs). Thus, we suggest that the 8,000 gallons per minute be shown as 17.8 cfs, and 12,816 af per year.

Page 2. Pipeline and Water Supply. Comments immediately above are applicable here and this paragraph should be revised accordingly. It would be appropriate to suggest that the surge pond be constructed so that 30 percent or more is over 15 feet deep. This would then have potential

Exhibit 4

value for fish and fishing. Its value for this purpose may hinge on other factors ie., rate of water change, problems associated with screening intakes and outlets, and fish management (fish planting, rough fish control, and regulation of fishing).

Page 2. Transmission Lines. All power lines should be so designed and constructed that they will not present an electrocution hazard to raptors or other birds.

River crossings are particularly dangerous to waterfowl that move up and down stream, particularly during migration periods.

Page 8. E. Recreation. This paragraph ought to be headed Recreation, Fish and Wildlife. We suggest that it be written as follows - "Southeastern Montana offers limited opportunities for outdoor recreation. Campgrounds have been established in the Custer National Forest and on the Indian Reservations, but opportunities for boating, sailing and swimming are few, and winter sports and other organized activities such as golf, hiking, nature study, and summer group camp activities are scarce. However, all of these are available in some measure within 200 miles west.

The pronghorn antelope and mule deer provide excellent big game hunting of national importance to residents and non-residents. Whitetailed deer are common along major watercourses and are hunted in proportion to their limited numbers. Some of the State's best ring-necked pheasant populations are found along the Yellowstone River, and particularly in the nearby side drainages. Hungarian partridge, sage grouse, and sharptailed grouse are common and where habitat is suitable provide a moderate amount of hunting, however, almost none of it by non-residents. A fair fishery for walleye pike and sanger is provided by the Yellowstone River and major tributaries. Trout are seldom caught below Billings on the Yellowstone River or Hardin on the Bighorn River. A few trout are to be found in farm ponds having adequate depth and other conditions favoring cooler water temperatures. There is an important paddlefish population in the Yellowstone River below Forsyth and fishing for this species has increased greatly in the past ten years."

Page 14. 2. Particulate. The second paragraph top page 14, should be strengthened. We are concerned that dust from the mining operations, including the trucking of the coal to the plant site, along with the particulate matter from the plant, will be deposited on vegetation over a wide area. Prevailing winds will be instrumental in carrying this dust. Vegetation coated by dust and particulates will either die or at least be unpalatable to both livestock and wildlife.

Page 14. 3. Sulfur Oxides. Sulfur oxide emissions of 6,820 per hour from furnace stacks of the proposed project is a serious threat to the

Exhibit 4

existing environment and additional efforts should be made to improve emission control more than the 39 percent proposed.

Page 20. 6. Effects of Water and Heat Emission from the Power Plant. The bottom paragraph would be much more meaningful if the water volume and rate were conventionally expressed. We suggest the "3,300,000 pounds per hour" be revised to say "395,000 gallons per hour (14.7 cfs) or 10,600 acre feet per year". The above comments apply to the top paragraph on page 26 as well. (Note our related comment for pages IV and 2.)

We feel very confident that discharges to the atmosphere in this magnitude at relatively low levels will result in very significant climatic changes in the direction of prevailing air currents. The individual impact of this primary unit (of 700 mw) may not be significant, but cumulatively with prospective full development precipitation may be very substantial. Erosion problems in nearby drainage ways may be accelerated and the effects upon both fish and wildlife habitats could be significant. Some of the effects might be expected to be beneficial, others could be detrimental unless measures are taken to offset them.

Page 29. 3. Impact on Flora and Fauna. We do not agree that " . . . hunters, dogs and so on will have a damaging effect . . ." Although there may be some increase in hunting pressure, the take of deer and antelope, the primary species of concern, is carefully managed by hunting areas and excessive use can and probably will be avoided. We suggest deletion of all of the first sentence of the second full paragraph on page 29.

This section should discuss plans to offset damage to the flora and fauna, in particular, the details concerning land reclamation. Among other things, land reclamation should include consideration for the construction of fish ponds, or reservoirs suitable for future management for public fishing by the Montana Fish and Game Department.

We believe that steam electric power generation stations based on the coal deposits in Eastern Montana should not be constructed until a better total evaluation of their potential impact on the environment can be made.

Sincerely,

Wilfred D. Crabb
Acting Area Manager

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

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ENVIRONMENTAL SCIENCES
DIVISION

1940

DEC 26 1972

Mr. Don Holtz
Chief, Air Quality Bureau
State of Montana Department of Health and
Environmental Sciences
Helena, MT 59601

Dear Mr. Holtz:

Your draft Environmental Impact Statement for the proposed Colstrip Power Plant has been reviewed by this office.

The following is a consortium of views expressed by individuals having expertise in a wide variety of disciplines. The greatest concern expressed by these people does not relate specifically to your Environmental Impact Statement, but is one which identifies the need for a more comprehensive study to assure orderly development and the production of needed power from the entire Fort Union Formation Area in a manner which will prevent or minimize degradation to the environment, traditional uses and human resources of the area affected.

We believe that an approval for construction and operation of the first two relatively small facilities discussed in your Environmental Impact Statement would act as a precedent setting action for additional plants in the area. An analysis of the cumulative effects of the ultimate amount of mining, number and size of plants is needed before piecemeal development is undertaken.

Although the first two plants proposed for the Colstrip area are large when compared with existing electrical generation facilities in Montana, they represent a very minor portion of the possible number and size of plants now being considered for the utilization of coal in the Fort Union Formation. The North Central Power Study, as an example, proposes development up to 53,000 MW in the area. The 53,000 MW capacity is 75 times as great as the first two plants proposed by Montana Power.

The first two plants at Colstrip propose the construction of a 30-mile aqueduct from the Yellowstone River and two additional powerlines to the Billings area. If there are to be additional plants in the area, a more comprehensive analysis should be made to determine if larger

Exhibit 4

capacity aqueducts and power transmission lines would be more economical and create less total adverse environmental and social effect and impact. The preferred location of these lines needs to be identified along with alternates in order to adequately evaluate their impacts.

Your Environmental Impact Statement points out that Montana Power is presently considering additional units at the Colstrip location. It is our understanding that two more plants are being planned for completion by September 1978 and 1979, respectively. Each of these plants would equal the total generation capacity of the two plants discussed in your Environmental Impact Study. Information made available to us indicates that 350 MW of the 700 MW to be produced from the first two proposed plants at Colstrip would be wheeled to the West Coast. This same material shows that an additional 1,050 MW would go west from the second two plants being planned by Montana Power and Puget Sound Power and Light. Thus far, we have been unable to determine where the balance of available power will be directed. We are anxious to find this out since it is possible that transmission lines might be planned which would cross National Forest lands east of Colstrip.

The environmental statement indicates "the rapid growth of electrical energy consumption in the United States at this time is an indication of our dependence on this comodity." "This demand is presently growing in such manner that consumption doubles every ten years."

Estimates of future electrical power loads in the Pacific Northwest is estimated to double about every 12 years. The Pacific Northwest region in order to meet its future power needs will in all probability have to shift its reliance on hydroelectric generation to a system made up of hydroelectric and thermal generation. Major load centers of the Pacific Northwest are located along the Pacific slope with hydro-generation plants located east of the Cascade Mountains. Much of the needed thermal generation may also come from east of the Cascades and also east of the Continental Divide.

The electricity from the Colstrip project as discussed in your Environmental Impact Statement would be transfered by three 230 K.V. transmission lines originating in the plant switch yard and extending westerly to the Billings area. These lines will terminate as a new substation to be added to the Montana Power Company integrated system north of Billings, Montana. There is no evaluation as to the possible transmission line corridors, transmission line capacities, and the environmental impacts involved in moving the needed electricity produced to the Pacific Northwest load centers. In the Pacific Northwest where present peak loads are approaching 20,000 MW, the right-of-way problem can be somewhat reduced by the replacement of existing lines with higher capacity lines. As transmission voltage increases the land use per kilowatt for transmission right-of-way decreases. A 230 K.V. alternating current line carries about 300 MW,

while a 500 K.V. alternating current line carries on the order of 1,250 to 1,500 MW, about five times as much power, yet the 500 K.V. lines require only 125'-150' of right-of-way--slightly more than the 125' for a 230 K.V. line.

It would appear that, should the development of Montana coal become as significant as is presently committed by the environmental statement for the Colstrip project, power transmission corridors will be needed across the Continental Divide to reach the Pacific Northwest load centers and especially the coastal area of the region. Western transmission of generation from Colstrip to the load centers involved could involve several existing and potential transmission corridor possibilities. These possibilities are directly related to major existing and proposed transmission grid systems and known power marketing responsibilities. Some prominent transmission line corridor considerations are:

1. Colstrip, Montana, west to Anaconda, Montana, westerly across the Saphire Range and Bitterroot Mountains via the Magruder Corridor to south of Lewiston, Idaho, westerly to the load centers.

2. From Anaconda, Montana, to Hot Springs, Montana, to Spokane, Washington; Grand Coulee, Washington, south and west to load centers.

3. From Anaconda, Montana, to Hot Springs, Montana, following the present Dworshak Hot Springs Transmission Line to west of Dworshak Dam near Ahsahka, Idaho, via the lower Snake River area to the load centers.

The above possible transmission line corridors could involve directly and indirectly National Forest system lands located on eight National Forests.

In considering the above or other possible existing or potential transmission line corridors where National Forest system lands are involved, there are land and resource management considerations involved which must be solved and alternatives considered before final decisions and authorizations can be made. Comprehensive land and resource evaluations and analysis processes must be completed to ascertain that the proposed transmission line corridor(s) is consistent with other planned activities and would not create any foreseeable serious adverse consequences concerning long term management. Determination must be made that the portion of the considered corridor located on intermingled or adjacent land would not adversely and seriously offset important National Forest system values or preclude the achieving of National Forest objectives. Also, determination must be made that the proposed corridor location on National Forest system lands would not adversely or seriously affect the environmental quality of other intermingled or adjacent land. Also included are primitive area studies, social and economic impacts, pending legislative action, environmental statements required by the National Environmental Policy Act, public involvement, coordination between all

utilities including public, private, and Federal agencies involved in the production transmission and marketing of electricity. Until the above is accomplished and all alternatives considered, all land options related to the allocation National Forest lands from a diminishing land base must be kept open. Determination of locations and authorization for transmission line corridor(s) on National Forest land such as discussed above would require approximately 5 years.

National Forest lands nearest to the proposed Colstrip plants lie approximately 20 to 25 miles to the east. The prevailing westerly winds passing through the Colstrip area also pass over the Ashland Division of the Custer National Forest. We are, therefore, concerned about stack emissions from the proposed plants.

The projection for uncontrolled emissions of 3.2 pounds per hour of fluorides and 0.23 pounds per hour of mercury are particularly worrisome since they are cumulative poisons and affect plants and animals at relatively low concentrations. Livestock develop fluorosis if grazing is done on vegetation containing more than 35 ppm fluoride.

If the second two plants being planned by Montana Power are constructed an should they produce fluoride emissions at an equal rate, a total of approximately 42 tons per year could be created. The effect of this volume of fluorides on the downwind livestock industry is not known, but would no doubt be significant.

The projected emission of 82 tons per day of sulfur dioxide by the first two small plants would degrade air quality seriously. There is need to identify the amount of sulfurous and sulfuric acids that would be deposited downwind from the plants before construction is permitted. The effects of this large amount of emissions is the important thing to identify. It matters little if the proposed plants individually comply with State and Federal air quality standards based on pounds per million BTU of input.

In summary, I would like to reemphasize the need for comprehensive area-wide study to assure the orderly management of the coal resources within the entire Fort Union Formation to help meet the energy needs of this country in a manner which is in harmony with a quality environment.

Sincerely,

Warren G. Davis

for STEVE YURICH
Regional Forester

Exhibit 4

STATE OF MONTANA

DEPARTMENT OF STATE LANDS

STATE CAPITOL HELENA 59601 (406) 449-2

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ENVIRONMENTAL SCIENCES
DIVISION

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FRANK MURRAY
SECRETARY OF STATE
ROBERT L. WOODAHL
ATTORNEY GENERAL

TED SCHWINDEN
COMMISSIONER

November 22, 1972

Mr. Don Holtz, Chief
Air Quality Bureau
Environmental Sciences Division
State Department of Health and Environmental Sciences
Board of Health Building

Dear Mr. Holtz:

We have reviewed the Draft Environmental Statement for the proposed Montana Power Company Electrical Generating Plant at Colstrip, Montana, and wish to comment thereon.

We are concerned over the proposal to bury flyash, bottom ash, and economizer ash in "worked out" strip mines and feel that the discussion of the impact of the proposal (on page 25) is inadequate for the following reasons:

1. A complete analysis of the material and of its trace metal content should be requested before a decision is made concerning burial. Otherwise, any adverse impacts such as ground water contamination might be irreversible before they were discovered.

2. There is no discussion of the affect of fly ash burial on future mining for lower seams and the subsequent reclamation of ash contaminated spoils.

3. There is no discussion of other alternatives. We understand that some generating facilities presently sell this material to cement manufactors for industrial use in cement processing, cinder blocks, etc. This alternative would eliminate any possible adverse effects and would prevent the "wasting" of a portion of Montana's coal resource.

Sincerely,

John Henson

John Henson
Staff Counsel

SCHOOL LANDS

A RESOURCE FOR THE PRESENT
AN OPPORTUNITY FOR THE FUTURE

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MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

FORREST H. ANDERSON, GOVERNOR
GARY WICKS, DIRECTOR

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JOSEPH W. SABOL, CHAIRMAN
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449-3647
SAM W. MITCHELL BUILDING
HELENA, MONTANA 59601

December 18, 1972

Mr. Don Holtz, Chief
Air Quality Bureau
Environmental Sciences Division
Department of Health and
Environmental Sciences
Helena, Montana 59601

RECEIVED
DEC 19 19[illegible]
ENVIRO[illegible]
DIVISION

Dear Mr. Holtz:

We have reviewed the draft environmental impact statement for the proposed Colstrip Power Plant and would like to offer the following comments:

1. With regard to possible alternatives nothing was mentioned about alternative plant designs - e.g. different size or type of plant with different water requirements.

In particular we would like to see the final impact statement discuss the advantages and disadvantages of utilizing dry-cooling towers as an alternative to the proposed wet-type cooling towers as a means of disposing of waste heat from the generating plant. Dry-type cooling systems eject waste heat directly to the atmosphere without an evaporative loss of water.

Studies indicate that dry-cooling towers require only one percent of the water that wet-cooling requires; therefore, it may be possible to reduce the consumptive water use of the Colstrip plant if dry-cooling towers are used. ("North Central Power Study", Phase I, Vol. II, pg. XI-13, 1971.)

In addition direct savings to the utility may be possible with dry-cooling. Examples are: (1) reduced fuel cost due to greater flexibility of plant location with the dry-cooling system, (2) possible transmission cost savings as a result of greater flexibility of plant location, and (3) possible savings in cooling-water costs. ("Dry-Type Cooling Towers for Steam Electric Generating Plants," a paper by John P. Rossie, R. W. Beck and Associates, 1971.)

Advantages to the public sector are also apparent and, although presently unquantifiable, are obviously important. Two advantages are: the possible reduction in future water use conflicts between agriculture and the energy industry and the reduction of pressure to build storage reservoirs to provide water for the energy industry.

Exhibit 4

2. The size of the pipeline is not well defined. The statement mentions only a minimum size of 24 inches. The size could be an important factor on total impact.

3. The impact statement indicates that approximately 8,000 gallons per minute from the Yellowstone river will be needed for operation of the plant with no water being returned. Since Montana Power Company filed a notice of appropriation on December 22, 1970 for 250 cu. ft. sec. or 112,200 gal. per minute to be transported to the vicinity of Colstrip by a 60" diameter pipe to be constructed by 1974, does this mean that other plants are being contemplated in addition to the one being built? What does 8,000 gal. per minute or 112,200 gal. per minute from the Yellowstone mean in terms of percent of minimum flow and average flow of the Yellowstone at the point of diversion? What impact would the withdrawal of such quantities of water have on water quality or on the quantity available for downstream users?

4. Other than the statement on page 2 with regard to "common corridors where feasible" for two transmission lines to be built in 1975 and 1976, what considerations have been given to routing of pipelines and transmission lines? Have alternative routes been thoroughly investigated and has a common routing corridor been considered? Has there been consultation with other companies having future plans in the area concerning the possibility of a common aqueduct for water supply? What are the impacts of contemplated pipelines and transmission lines?

5. It appears to us that ash from the plant may have some deleterious soluble compounds. We would be interested in receiving the results of the investigations to be conducted by the Department of Health and the Montana Power Company concerning this potential problem.

6. What class of agricultural land by Soil Conservation Service standards will this plant occupy? Does the 1365 acres proposed for the plant occupy prime agricultural land? Does the proposed plant site location plus supporting facilities and activities represent a planned land use consistent with the needs and desires of the county, southeastern Montana or Montana?

Thank you for the opportunity to comment.

Sincerely,

Gary J. Wicks

GARY J. WICKS, DIRECTOR
DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION

GJW/nw
cc: Fletcher Newby

Exhibit 4

United States Department of the Interior

BUREAU OF LAND MANAGEMENT

STATE OFFICE
316 NORTH 26TH STREET
BILLINGS, MONTANA 59101

IN REPLY REFER TO

911: 1792

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ENVIRONMENTAL SCIENCES
DIVISION

Air Quality Bureau
Montana State Department of Health
and Environmental Sciences
Cogswell Building
Helena, Montana 59601

Gentlemen:

Our agency has reviewed the draft Environmental Impact Statement prepared by your Department concerning the proposed Montana Power Company electrical generating plant at Colstrip, Montana, and has compiled the following comments:

1. Description of the Proposed Action and Assessment

Considerable detail was developed pertaining to the activities surrounding the plant site and mine location. However, information concerning the three proposed 230 KV transmission lines that will originate at the plant site and cross the state towards the Billings area was very limited. Also, little discussion was focused on the proposed 31 mile aqueduct which will divert 8,000 gallons of water per minute from the Yellowstone River. The impact of the three power lines and the aqueduct should have been fully evaluated in conjunction with the entire project operation to enable an in-depth assessment of the total magnitude of the project as proposed. With this information on hand, a more realistic approach to possible alternatives and the various tradeoffs involved in each alternative could have been developed and assessed.

An incremental assessment and/or licensing approach may preclude full assessment of the entire project and viable alternatives because such an assessment could lack comprehensive information needed at the crucial decision-making stages.

2. Impacts on the Environment

a. Ecological Impacts from Emissions:

It appears that further study of the items listed below are needed to determine both their short term and cumulative effects on the living and non-living components of the environment:

Exhibit 4

Pollutants - Air
Particulates
Sulfur Oxide
Nitrogen Oxide
Fluorides
Mercury
Other trace and/or radioactive substances

Studies and data would also appear to be needed on the wind flow and climatological patterns in the Colstrip area. Some questions meriting consideration are noted as follows: What areas will be affected by the plant emissions? Will the emissions drift towards Broadus and the Black Hills? Will they drift into the Yellowstone Valley? What effect, if any, will inversion layers have on the stack emissions and the steam which is emanating from the cooling towers?

b. Impacts Other than Emissions

From the draft statement, it was summarized that the project proposal would physically affect the following acreages of land:

Mine	2,000 acres	
Plant Site	1,365 acres	(maximum)
Rights-of-Way	2,900 acres	

The text covered the plant site in considerable detail while the proposed mine field, water pipe line and transmission lines were treated in a more limited fashion.

The design, construction method, and routes of pipe line and transmission line rights-of-way would have been helpful. This discussion should have included such items as right-of-way widths, the type of topography and vegetative cover disturbed, and the measures considered for each affected resource along the primary and alternative routes selected.

One critical factor meriting considerable discussion and not covered in the mine field operation was the potential effect, if any, of strip mining on the area's water bearing aquifers. If adverse effects are possible, or anticipated, what corrective measures, if any, could be taken to safeguard or alleviate the situation? This potential environmental impact could have substantive local and regional effects concerning current and future ground water quality and utilization practices.

Exhibit 4

3. People Influence or Impact

The text discussed this topic but several questions still persist and should be addressed in this type of environmental assessment. In the short run, during the construction phase, 800-900 workers and their families, if any, will be involved in the proposed project. However, during the operational phase, this number will drop to approximately 100 full time employees.and their families. How will the local amenities and natural resources be affected by such an influx of population and its inherent characteristics? How will the project affect area housing, public services such as education and law enforcement, professional services such as medical needs, transportation services, and facilities, public administration goals, financing services and planning and overall outdoor oriented public recreation? The short and long term implications and cumulative effects concerning this proposed project and its people influence and impacts are, therefore, of critical importance.

4. Impacts on Flora and Fauna

Plant and animal life should have been considered along the various proposed right-of-way routes to supplement the discussion of these factors at the plant and mine site locations. Also, more information concerning the specific vegetative types and wildlife species affected by the proposed project would have been desirable to enable an assessment of the short term and long range effects of the overall development proposal in this relatively remote area of the state.

5. Alternatives

Within the alternatives section, an alternative not considered and meriting consideration would have been the locating of the plant site closer to the power demand centers. Although this action would not mitigate the total impacts of the project, it would provide an expanded forum for discussing and weighing the local and regional tradeoffs involved concerning the proposal under consideration.

Thank you for the opportunity to review the draft.

Sincerely,

Edwin Zaidlicz

Edwin Zaidlicz
State Director

Exhibit 4

Exhibit 4

STATE OF MONTANA
DEPARTMENT OF INTERGOVERNMENTAL RELATIONS

PLANNING & ECONOMIC DEVELOPMENT DIVISION
1424 NINTH AVENUE — HELENA, MONTANA 59601
406-449-2400

FORREST H. ANDERSON
GOVERNOR

December 8, 1972

Air Quality Bureau
Montana State Department of Health
and Environmental Sciences
Cogswell Building
Helena, MT 59601

Gentlemen:

Reference is made to the draft Environmental Impact Statement on a proposed Montana Power Company electrical generating plant at Colstrip, Montana. Comments were collected from several members of our staff and have been consolidated and can be summarized as follows:

It is difficult to provide an objective evaluation of the statement without benefit of data furnished by the Montana Power Company in its permit application. However, we concur generally with the statement in its overall evaluation of the probably impact on the environment. As we read Part III of the Statement, the proposed 700 M.W. plant is expected to operate within federal and state standards for emissions and ambient air levels (except for ambient sulphur oxides which may, infrequently, exceed established levels).

We would suggest that an additional alternative to the proposed action concerns building the plant in another area of Montana or in an adjacent state or closer to load centers. It would be useful to evaluate this alternative for the purpose of validating data provided by the sponsor and to determine what the impact of this size plant might be if located in an area where industrialization has already taken place, in terms of the environment and social and economic impacts, etc., or where there are marked differences in climate and meteorological phenomena from that of southeastern Montana. Also, in the final EIS on this proposal, a dichotomy might be developed which would expand the alternative of not building the plant at all - i.e. a moratorium vs. the opportunity to closely monitor the construction and operation of the project under consideration, and use it as a "test bed" to determine if future expansions are feasible at all. This discussion might consider the extend of risk involved in permitting the 700 M.W. plant as setting a precedent for unlimited expansion. Would it be reasonable to support a moratorium now rather than look upon the 700 M.W. plant as a situation which would tell us whether larger and more numerous plants of this type could be tolerated?

In future draft statements of this type, the Department of Planning and Economic Development and other state agencies should be called upon to contribute to the portions dealing with strengths and weaknesses of the political, social, and economic institutions of the area and the capabilities of those institutions to

Exhibit 4

absorb impacts expected from the proposed development. We do not see wholly "adverse environmental effects which cannot be avoided" (see Part IV) in population increases of the magnitude (around 2,000) facing Colstrip, for example. Such a facility as this might well provide job opportunities and living standards adequate to retain some of the large numbers of our young people who now leave Montana because there is no future for them in remaining here. Also, if the penalty on the environment is not excessive, we question whether it would be an adverse effect for an increased flow of capital and goods to occur in the vicinity of the plant. Permit these examples to serve to illustrate why we suggest that more inputs perhaps might have been considered.

There are good reasons to raise the larger issue of strip mining in eastern Montana from a long-term view of what extensive coal development portends. But that is a task calling for a different kind of review and a much more comprehensive study and analysis. It requires that the entire spectrum of electrical energy production using strippable coal be examined in the context of the potential and the threat to eastern Montana, the State, and the Nation. Over the long term and under conditions of expansion, there will unquestionably loom grave threats and considerable promise. We would suggest that these disparate conditions cannot be related and compared with finality based merely upon this proposal for a first "mine-mouth" plant. The kind of broad review which addresses the total issue is a main function of the Coal Task Force. It is vital that the Task Force enjoy the positive cooperation by all agencies and that it arrives at well-reasoned conclusions as quickly as possible.

Thank you for the opportunity to review and comment.

Sincerely,

Lloyd F. Meyer
A-95/EIS Coordinator

LFM/rm

cc: Bill Spilker; Bureau of Economic Development
Department of Natural Resources
Environmental Quality Council

Exhibit 4

Aubrey D. Larson
- PUBLISHER -

Box 1298
MILES CITY, MONTANA

Nov. 25, 1972

State Dept. of Health
Air Quality Bureau
Helena, Mont.

Dear Sirs:

I support the construction of a power generating plant at Colstrip by the Montana Power Co. I also support construction of other generating plants as proposed by the company and others.

Montana desperately needs investment money. The Montana Power plant is one example of this type of money. Montana must encourage a climate which encourages development in order for Montana to realize its fair share of plant investment money related to coal mining. Further, Montana must espouse a strong, unequivocal statement supporting coal development and processing. This is an absolute first step if Montana is to realize benefits of her resources and if her people are to realize the benefits of the many jobs that go with it.

The need for more electricity is obvious. The "energy crisis" is a fact. According to a noted economist-writer, Donald Rogers, writing in Economy Report, "there will be a fuel crisis in the Northeast this winter. Natural gas will be in short supply. And electricity will be in short supply." Don't forget, he reminds us, that every major city in the nation's upper latitudes has for four years suffered "brownouts" during the hottest and coldest days. And the shortage is expected to get worse.

We may, as we are inclined to do in Montana, say, what the hell do we care about the northeast part of our country. (One wonders how we might react to a similar statement directed to US by THEM!) We care because we live in the United States. And if our area happens to have the resources available to help out, by all means we are obligated to so do. But "doing something about an energy crisis" is not easy. It requires vast investment money. It requires new technology. It requires transmission of large quantities of power...and the right kind of power...large quantities of base load power to augment the user requirements of other power companies in different parts of the country. Montana can help fill the bill on all counts by development of her coal resources. Private industry has the capability and the desire to go ahead and fill the need, so why do we tarry and seek a stoppage? In the name of the environment? Bosh!

Pollution efforts will be overcome by the technology of industry. Not by some autocrat sitting in some agency office in Helena or Washington D.C. As Peter Drucker tells us: "...the sewage treatment plants(as an example) that are urgently needed all over the world will be designed, built and kept running not by purity of heart, ballads, or Earth Days but by crews of crew-cut engineers working in very large organizations, whether businesses, research labs or government agencies." We must remember that any pollution is controllable - but at a price. Practically every environmental task demands huge amounts of electrical energy, way beyond anything now available. And

THE CIRCLE BANNER Circle, Montana | THE POWDER RIVER EXAMINER Broadus, Montana | THE HYSHAM ECHO Hysham, Montana | THE JORDAN TRIBUNE Jordan, Montana

Exhibit 4

Aubrey D. Larson
- PUBLISHER -

Box 1298
MILES CITY, MONTANA

cont.

why do we indulge in the grossest hypocrisy in this matter. On the one hand we say we are serious about pollution control programs - whether waste, emissions, sewage or pesticides - WHILE WE REFUSE TO BUILD THE POWER PLANTS WE NEED TO RESOLVE THE PROBLEMS. We need to put first things first and generation of electricity is that "first."

In the same newspaper that tells me of the peril of coal development for Eastern Montana is another article, tucked on the bottom of page 20 in small headline package: "Montana's jobless rate continues to climb...by February more than 10% of the state's civilian work force will be unemployed." This is another bit of hypocrisy we can do without. It's time we got serious about the problem of job opportunity in Montana.

The environmental doomsayers have reigned long enough. Now it's time to go to work and solve the problems facing Montana and the nation.

Sincerely,

Aubrey D. Larson

Aubrey D. Larson, publisher
Miles City, Montana

THE CIRCLE BANNER
Circle, Montana

THE POWDER RIVER EXAMINER
Broadus, Montana

THE HYSHAM ECHO
Hysham, Montana

THE JORDAN TRIBUNE
Jordan, Montana

Exhibit 4

218 Glenwood
Glendive MT 59330

November 20, 1972

Air Quality Bureau
State Dept. of Health and Environmental Sciences
Cogswell Building
Helena MT 59601

Dear Sir:

I am becoming increasingly disturbed by the campaigns being waged by some environmentalist groups and the Billings Gazette over strip mining and power production.

Those of us who keep up with the energy situation in this country know that we are headed for a period of energy shortage if positive steps are not taken very soon. I have enclosed a copy of the conclusions drawn in a study conducted by the Chase Manhatten Bank entitled "Outlook for Energy in the United States to 1985." I believe these conclusions sum up our situation very well.

As a result of this energy pinch, Montana is faced with what I believe to be a golden opportunity. We have here an opportunity not only to help alleviate the energy crisis but to bolster our own economy at the same time. I believe that with proper control, by that I mean reasonable polution limits and realistic strip mining laws, we can all benefit from the orderly harvesting of the coal resources that we have here in Montana.

In the past few years it seems that any time some new idea or situation arises, there are many boistrous shouts against change. Most of these are negative scare tactics and have little basis in fact. I only hope that we are not overcome by such propaganda.

In the case of the Montana Power plant at Coalstrip, I hope that you will grant them a license to operate their proposed plant if they meet the polution standards now on the books. I feel it is a step in the right direction and should be encouraged by all.

Respectfully yours,

Wes Eyer

WE/kls
encl./

Exhibit 4

Exhibit 4

[illegible]
Missoula, Mt. 59801
January 22, 1973

RECEIVED
ENVIRONMENTAL SCIENCES
DIVISION

State Board of Health
Cogswell Building
Helena, Mont 59601

Gentlemen:

I am a native Montanan - born in Ronan in 1915.

I think we cannot run our state with only college professors and retired Californians. With increasing demands from all divisions of government our taxes are getting unbearable. The only way we can alleviate these taxes is to broaden our tax base and to do this we need industry.

I am for a clean environment but I think we have to clean it up with reason. We cannot put the country back in the shape it was in before the white man came unless we give the country back to the indians and move out.

If we take the stand that we will not export any goods or services from Montana that will cause some impact on our environment we are open to real reprisals. Minnesota could say no iron produced in Minnesota can go to Montana. Michigan could say, no cars produced in our state could go to Montana. Washington could say, no goods coming through our ports can go to Montana and no produce from Montana can go through our ports. Kind of foolish? What is the difference? Why should we refuse to export goods and services and expect other states to export to us?

Please leave politics and hysteria out of your decisions and work for a better Montana.

Yours sincerely,
R. J. Sterling

Exhibit 4

Exhibit 4

Mrs. Norene Sellers
709½ North 26th St.
Billings, Montana 59101

Air Quality Bureau
State Department of Health
and Environmental Sciences
Cogswell Building
Helena, Montana 59601

Gentlemen:

With reference to the Editorial on the front page of the Billings Gazette, I for one, am getting just a little tired of reading about how much damage the Montana Power Co., Decker Coal Co., and all others are doing by strip mining in our state. And how much pollution there will be if we let the Montana Power Co. build this big plant.

The people in the State of Montana want our people to stay and work in Montana, yet they don't want to create any jobs for them. Just how do you expect to create jobs if you try to stop every kind of industry from coming into our state.

And another thing, where do you think you are going to get money from income taxes, if every one leaves our state to find employment. And they are doing it every day. There are not enough jobs for the people now. I have two children that have been trying to find work, with no luck.

I have visited the Colstrip area, and I can not see where the strip mining is doing as much damage as some of these stupid, and I do mean stupid environmentalists claim.

If I were the Montana Power Co., I would shut off the power for the whole state for about three days, and then we would see how fast people would be complaining about not having heat, electric lights, and able to use their electric appliances. I for one, like my electric appliances, and especially my electric automatic washing machine. I do not want to go back to washing my clothes on the board, of which I have done quite a few times in the past. I don't want to cook with wood or coal. You think there is pollution now, just what would it be, if all of us had to go back to cooking with the old coal range and coal heating.

Sincerely,

Norene Sellers

Exhibit 4

Exhibit 4

2811 Poly Drive
Billings, Montana 59102
November 27, 1972

Air Quality Bureau
State Department of Health and
Environmental Sciences
Cogswell Building
Helena, Montana 59601

Re: Construction of coal-burning electrical generating plants-Colstrip area

Gentlemen:

I am writing this letter because I am extremely concerned about the unbelievably adverse criticism towards the plans by Montana Power Company and Puget Sound Electric to build certain electric generating plants in the Colstrip area.

First of all, I would certainly suggest that you disregard to a great extent the paranoid approach of the Billings Gazette to this problem. The Gazette, in its desire to make news, has consistently refused to present both sides of the picture; and consequently many of us in Billings feel that they are completely abdicating their responsibility as a news reporting service.

However, I, like all interested Montanans, am concerned with the plans of the two power companies to build a steam generating plant. Let me say that I am not in favor of total degredation of the Colstrip area. However, I must further add that I do believe that the plants can be built within the parameters as set forth by the State Department of Health, by the Environmental Protection Agency, and by all other associated state and federal bureaus who have jurisdiction over this type of operation.

There is, without a doubt, a vital need for the energy which can be produced from the low-sulfur coal currently found in the Colstrip area. Regardless of what politicians may say, there is now an immediate energy crisis, as witnessed by the fact that commencing as early as last winter, certain industrial plants in the Middle West and East were placed on an "interruptable" schedule and some were even shut down because of insufficient fuel, generally in this instance being natural gas.

Exhibit 4

All forms of energy are needed to make our country grow to maintain a viable economy. The American people have become accustomed to a relatively easy standard of living and are using increasing amounts of energy at a very rapid pace. It is going to be necessary that some type of plants be built in this area to generate needed electrical power throughout the United States. The coal in Eastern Montana does not necessarily belong just to us Montanans. The current study being carried on in the Decker-Birney area of approximately 900,000 acres discloses that approximately 80 to 85 per cent of the coal rights in this area are owned by the United States Government. Certainly the State of Montana does not have the power to prohibit the federal government from mining its own coal; and I think that the State should be extremely careful in any laws and regulations which it passes regarding the prohibition of strip mining and its associated activities.

However, I would like to add my voice to the few which I am sure you have received relating to the problem of the construction of the plants as discussed above. I am in favor of the project, but only so long as the plants are built within the regulations and restrictions as set down by the pertinent governmental agencies.

Very truly yours,

David Schaenen

David Schaenen

DS:hg

Exhibit 4

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

1973
ENVIRONMENTAL SCIENCES
DIVISION

ER-72/1344

FEB 26 1973

Dear Mr. Holtz:

This is in further response to your letter of October 20, 1972, asking for our comments on the Montana State Department of Health and Environmental Sciences' draft environmental impact statement, dated October 1972, on environmental consideration for Colstrip Power Plant, Rosebud County, Montana.

We regret that we were unable to respond to your request for comments within your timeframe due partially to the limited number of copies received with your letter of October 20. To facilitate more comprehensive reviews in the future, we should receive 20 copies of the documents at least 45 days in advance of the review deadline.

General

We find that the statement provides a good overall view of the environmental impacts of the construction and operation of the proposed project. The section on the Relationship Between Local Short-Term Uses of Man's Environment and Long-Term Effects is a typical example of the sound philosophical discussion woven throughout the statement. However, the statement is grossly lacking in quantification of the impacts.

We suggest that the construction permit include environmental protection provisions. We have enclosed a conformed copy of the Bureau of Reclamation's Huntington Canyon Water Service Contract and the Bureau of Land Management's transmission line right-of-way permit for the Jim Bridger Plant as examples of provisions which could be used with this project.

Figure 1 is referred to on page 4. The flow diagram following page 5 should be labeled "Figure 1." Likewise, the maps of sampling stations in the appendix should be designated Figures 2 and 3, as mentioned on page 19.

Exhibit 4

A portion of the statement is based on material prepared by the applicant. The appendix should include references to such material by title and date as well as references to other sources of data. Our other detailed comments are presented in the following paragraphs according to the format of the statement or according to specific subjects.

Department of the Interior's Jurisdictional Areas

It appears that the transmission line rights-of-way will cross the Crow Indian Reservation and possibly Northern Cheyenne Reservation. Three 230KV transmission lines are proposed, each in a corridor from near Hardin to Billings, Montana. If any element of the total project, including the water pipeline from the Yellowstone River, the transmission lines, or the strip mines, affects public lands or Indian reservations, the statement should clearly point this out on a map and in the text. It should also discuss any permits that are required for these facilities.

Northern Great Plains Resource Program

The proposed powerplant lies within the Northern Great Plains area. This area consists of large segments of Montana, Wyoming, North Dakota, and South Dakota which have vast amounts of relatively low sulfur coal and lignite. Extensive interest has developed in the Northern Great Plains' coal resources as the result of national energy needs and increased emphasis on improved air quality. The possibility of substantial development of these coal reserves has resulted in national, regional, and local concern for effective land use and resource utilization, including environmental resources such as mined area reclamation, optimum use of water resources, effects on plant and animal life, and economics.

Private, local, State, and Federal agencies are presently involved in the Northern Great Plains Resource Program. The State of Montana is an active participant. The program objective is to provide an analytical and informative framework for policy and planning decisions and alternatives. We suggest that this study be described in the final environmental statement along with a discussion of the proposed project's conformity to any present or future guidelines.

Exhibit 4

Maps

The statement should contain a map showing the general layout of the plant facilities, including the ash slurry ponds and the coal fields. This map should also indicate present and future use of land areas within the project boundary, including the transmission lines. A second map should also be included to indicate the existing and expected land uses of the region expected to be impacted upon by the project. These maps would be valuable assets to the final statement in the identification and quantification of expected environmental impacts.

Ash Disposal

A large amount of ash will be produced by plant operations in the 30-year projected life of the project. There is an inadequate description of the impact which the ash that is subject to erosive forces will have on the environment in the downstream and downwind area. It is stated on page 2 of the statement that periodically the ash in the ponds will be removed and used as fill in worked-out strip mines. It may be necessary to bury the ash in the stripped mines areas to prevent it from being moved by wind and water rather than simply using it as fill.

Programs to monitor the quality of surface and subsurface discharge from ash disposal areas and settling ponds should be considered in the section on Emission Control and Guarantees.

Pipeline and Water Supply

This section should provide a better description of the facilities in order that the environmental impacts can be adequately evaluated. Data on type of diversion facilities, pumping requirements, duration of construction period, and right-of-way should be given.

Transmission Lines

There is little discussion of the transmission line plan except for one paragraph describing three 230 kilovolt lines that will extend from the plant to the Billings area. In recent power system studies, the Montana Power Company has shown additional 230 kilovolt lines from Billings to Great Falls and Anaconda, Montana.

Exhibit 4

A high voltage transmission line map showing routing of all existing lines and the proposed and alternative transmission lines associated with the Colstrip Plant would be desirable and helpful in evaluating environmental impact. It should indicate the number of miles of new high voltage transmission lines that are involved.

Geology and Hydrology

This project includes a long-term strip mining operation resulting in considerable disturbance of the bedrock, soils, and topography. The geology and soils of the area and the impact of geologic conditions on all facilities and operations should be discussed in considerable detail in the statement. Much of this data could be provided in illustrative materials and maps. Since the geology and hydrology associated with the project are not adequately described, the impacts of the facilities and operations on the water resources cannot be evaluated.

Strip Mines

Reclamation of the strip mine area should be discussed. The mining operations will result in considerable changes in the soil. This significant change in addition to being located in a semi-arid climate may present problems in reestablishing a suitable vegetation cover to stabilize soil and slopes. The intent and plans of the utility in regard to the mined areas, standards that apply to strip mining, and monitoring programs should be covered in the statement even though, as indicated on page 3, a separate environmental impact statement will be written on strip mining and necessary reclamation.

Detailed Description of Process

The third sentence on page 5 is incorrect. The reaction of calcium carbonate and SO_2 will not result in a solid sodium salt.

We have serious reservations at this time concerning the implication of the last sentence, first paragraph, page 5. Although great strides have been made in the development of SO_2 removal processes, our latest review of the situation indicated that none of the many different systems being studied have as yet been commercially demonstrated (continuously operated for more than 1 year on a scale of 100MW or larger)

Exhibit 4

in the United States. Operation of the 22 full-size desulfurization control processes for powerplants, which are in the design, construction, or startup phase in this Country has been intermittant and serious plugging, scaling, and corrosion problems have been reported. Under such circumstances, it is doubtful that any SO_2 control process is yet available whose operability can be guaranteed at any level.

Population

The population of Lame Deer consist of 1,341 Northern Cheyenne tribal members and about 2,000 non-Indians. The second paragraph on page 7 should be corrected to indicate this data.

The "Tongue River Indian Reservation" should be changed to "Northern Cheyenne Indian Reservation."

Meteorology

We suggest that the amount and distribution of precipitation be added to this section on page 8.

Recreation

The excellent recreational opportunities in Southeastern Montana is recognized on page 8; however, neither this section nor the following impact section discusses the cumulative impact of the construction and operation of this plant and future coal-fired plants in the area. A plant-by-plant analysis will not reveal the impact that all of the plants will have on the nearly pristine environment of eastern Montana. Therefore, it is necessary to consider the present proposal in relationship to future developments in order to obtain an accurate assessment of these impacts.

Sulfur Oxides

The comments given for the foregoing section on Description of Process also apply to this section beginning on page 14.

Trace Elements

The purpose of the last sentence, paragraph 4, page 18, is not clear. This paragraph should relate the concentrations of mercury indicated to acceptable or safe emission levels. If

Exhibit 4

the venturi scrubber will be used to remove mercury vapor, it should be indicated.

Emission Control and Guarantees

Although the procedures to eliminate problems with scrubbers described on page 23 are reasonable from a technical standpoint, the draft statement does not indicate its economic implications. Costs for currently tested SO_2 control systems are $40-$70 per kilowatt plus rather high operating costs. The procedure of reducing the boiler load everytime one of the scrubbers is shutdown for cleaning purposes would significantly increase the operating cost and could interfere with the noninterruptible nature of the power by lowering the reliability of the power generation.

Plans by Applicant to Maintain Air Quality and Lessen Overall Impacts

According to the list of studies underway and the company's environmental policy given on pages 24 and 25, a significant effort is being made to evaluate and control the impacts of the construction and operation of the plant. It appears that if the information gained from these studies would be incorporated into the final environmental statement that many of our concerns for adequate quantification and description of impacts would be satisfied.

A typical example involves historical values. An indication of the historical value is given on page 8; however, it is also stated that the archeology of the area is not well known. It is stated on page 24 that the University of Montana has an archeological survey underway for the plant site. The available information from this study should be reflected in the section on page 8.

Land Use

The general description of the changes in land use is not adequate. According to page 27, the plant will occupy 1,365 acres, the mine will disturb an area of approximately 2,000 acres, and the aqueduct and transmission line will alter approximately 2,900 acres. This significant change in land use should be quantified. The statement should indicate the amount of land transferred to or from crops, forest, recreation, and wildlife. It should indicate the intensity of use and probable use if the project were not built.

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Water Use

The impact of withdrawing up to 8,000gpm of water from the Yellowstone River is not discussed except to indicate on page 29 that aquatic ecosystems will be altered in a number of ways. It appears that these effects will be negligible; however, data should be included to indicate to the reviewer a basis for judging the magnitude of the diversion in relation to historic flows. Also, since there is a possibility that the proposed diversion will interfere with prior water rights, we think that a discussion of augmenting natural flows during dry periods from Mystic Lake Reservoir should be included.

We suggest that the final statement consider the need for irrigation and the possibility of using sewage plant output in revegetation programs.

Impact on the Community During Construction

It is mentioned on page 32 that haphazard trailer parks and temporary unplanned residential and commercial development could negatively affect air and water quality, aesthetics, and economic and social parameters. This statement is so general that it could be used in any report; however, its value is negligible. This section should indicate the impacts which are expected to occur as a result of the project. General statements are of little value in impact assessment.

Another example of such a general statement is item 6 on page iii. This sentence says that the long-term adverse effects may well outweigh the short-term gains. The writer could just as appropriately have said that the short-term gains may well outweigh the long-term adverse effects. This type of assessment is of little value to the reviewer or the decisionmaker.

Adverse Environmental Effects Which Cannot be Avoided Should the Proposal be Implemented

Several of the items listed in this section appear to be beneficial environmental effects. The environmental statement can be equally misleading by being too conservative as it can by being too liberal in its assessment of adverse impacts.

Exhibit 4

Alternatives to the Proposed Action

Many general statements are made in the document that need to be expanded and supported with factural information. For example, it is stated on page 35 in paragraph E that feasibility studies indicate that hydroelectric power could not supply the needed electricity. If such studies are a matter of public record or available for review, the statement should indicate this.

A factural discussion is also needed on the environmental problem and negative aspects mentioned in the first paragraph on page 35.

This section should evaluate the environmental impacts of the proposed action in addition to evaluating the economics. It is not necessary to describe these impacts to the same depth that is done for the proposal; however, there should be a general assessment which could be in the form of a comparison of impacts between the proposal and the alternatives.

Irreversible and Irretrievable Commitments of Natural and Economic Resources

A general statement is made in the second paragraph on page 41 that if adequate reclamation is not practiced, the 2,000 acres of land will be permanently degraded. This statement does not indicate whether adequate reclamation will be practiced. At a minimum, the paragraph should indicate the degradation which will remain after programs are completed.

We hope these comments will be useful in the preparation of the final environmental statement.

Sincerely yours,

Assistant Secretary of the Interior

Mr. Don Holtz, Chief
Air Quality Bureau
Environmental Sciences Division
State Department of Health and
Environmental Sciences
Helena, Montana 59601

Enclosures

Exhibit 4

Testimony
Miles City Hearing
January 5, 1973
Department of Health and Environmental Sciences
Subject: Draft: Environmental Impact Statement on the Proposed Montana Power Company Electrical Generating Plant at Colstrip, Montana October 1972

This impact statement, which is the subject of this hearing, was prepared as a result of the directives contained in the Montana Environmental Policy Act. The Clean Air Act of Montana which regulates air pollutant emissions in this state was passed in 1967; by the later passed Montana Environmental Policy Act, some of the purposes and considerations, as well as the procedures, of the Clean Air Act of Montana were in effect amended and broadened. See Section 69-6507 R. C. M., 1947. The Montana Environmental Policy Act, hereinafter referred to as "MEPA", in its "Declaration of Policy for the Environment" lays down some goals for the administration of the laws of the State of Montana, two of which I particularly wish to call to your attention. They are as follow:

> to . . . fulfill the responsibilities of each generation as trustee of the environment for succeeding generations;
>
> and
>
> to . . . attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences;

I wish to emphasize the concept of use without degradation and use without other undesirable and unintended consequences. I find throughout the statement areas where there is such a lack of information that the consequences of the action could certainly be undesirable and unintended.

MEPA directs that an impact statement shall be prepared using an interdisciplinary approach utilizing the natural sciences, social sciences, and environmental design arts, and that prior to making the

Exhibit 4

statement, the responsible state official, i. e. someone in the Department of Health and Environmental Sciences, shall consult with and obtain the comments of any state agency which has legal jurisdiction or expertise in any environmental impacts involved in the action being considered for the statement. Looking over the list of authors of the draft statement and their qualifications, it would seem that the weight of the expertise involved is heavy in the area of air pollution control, but rather light in other areas of the natural sciences, thin in the area of the "environmental design arts", and non-existant in the areas of the social sciences. There is no indication in the statement that consultation took place with other state agencies as directed by MEPA.

The atmosphere of the statement reflects a rather passive attitude on behalf of the department, a waiting by the department for the permit applicant to furnish hard information upon which the department can base its opinions. My reading of MEPA does not indicate that the role of the department preparing an impact statement is to sit back and wait until the permit applicant furnishes information from which the department can prepare a statement. The impact statement should be an independently prepared document and should indicate some initiative on the part of the agency preparing the document. The statement gives off an aura of insufficient preparation, as though the authors were greatly hurried and may not have had time to sufficiently investigate the situation and obtain source material and documentation. One outside source is cited twice as a reference in the entire document. The statement would be more persuasive and a stronger document, if the sources supporting the authors' opinions were cited with footnotes and bibliography.

Exhibit 4

The plans and specifications for the air pollution control equipment are very general in the statement, so general in fact, that it is difficult for an expert to make a real assessment of its effectiveness, let alone a struggling member of the public like myself. The regulations of the State Board of Health relating to air pollution control equipment, Regulation No. 90-001, III allow the director to dispense with the requirement that plans and specifications be submitted with the application upon prior written agreement. The technical information on the venturi-type scrubbers to be employed is so general that I wonder if a prior written agreement exists as allowed in the regulations. The name of the contract-bidder does not appear in the statement, which might raise still another question, and that is whether or not the permit applicant has let the bid for the construction of the scrubbers.

It would have been enlightening to have included in the statement the experiences of the Arizona Public Service Company with the wet scrubbers on Units 1-3 of the Four Corners plant and to have also set forth the experience of Kansas Power and Light with using wet scrubbers to control both particulate matter and SO_2, with the SO_2 control up to a factor of 70% efficient (The Price of Power: Electric Utilities and the Environment, by Komanoff, Miller, and Noyes, published by The Council on Economic Priorities, pp. 17 and 22). It would be useful to have a history of the reliability of venturi-type scrubbers showing in which areas scrubbers of that type are prone to mechanical troubles impairing their efficiency together with a setting forth of the means by which the design specifications of these particular scrubbers will overcome such problems, and if it is the opinion of the department engineers,

Exhibit 4

both chemical and mechanical, that such problems can be overcome. The efficiencies of the scrubbers depend on the factors of the speed of the flue gases taken together with the size of the solution droplets from the atomizer. In 1968 these matters were somewhat a matter for mathematical calculation rather than practical experience. (Air Pollution, Vol. III, Stern(Editor), Chp. 46, Source Control by Liquid Scrubbing by Seymour Calvert, Academe Press, New York (1968)). Evidence should be advanced in the statement indicating that theory has advanced into effective reality. On page 5 of the statement we are told that there are guarantees on the emission control system. Who is the guarantor, and does the department adjudge the material which forms the basis of the guarantee to be effectively convincing.

Various places in the statement ponds for the disposal of fly ash and the effluent for blow-down and from the scrubbers are mentioned. If the applicant uses soda ash in the scrubber, because sodium is a component, the solutions which will form as a result of its reaction with the flue gases will have a sodium component, and therefore tend to be soluble in water. If there is deposit of this material in fly ash ponds, which will be kept wet to keep down the dust problem, a question arises in my mind as to how much of these sodium compounds would leach out of an unsealed pond and find their way into the ground-water table, increasing its salt content. Calcium compounds are relatively insoluble in water, and would probably have no effect.

Another point in relation to the fly ash ponds is their location. The statement does not set forth an analysis of the chemical composition of the flyash from the Rosebud seam, therefore, it is an unknown factor

other than reference in the statement that it will have an overall alkaline character. It is not stated if the ponds in which the fly ash will be deposited will be sealed to keep the mineral content from leaching out into the underground water supply. It would seem that the Korette plant in Billings would have an adequate ash supply from which to obtain an analysis. An alternative plan to sealing the pond with a commercially prepared sealer such as concrete, might be to level and excavate in the old Burlington Northern spoils in the Colstrip area in the spoils areas which are largely composed of gray and blue shale material. These shales have a low permeability to moistureand would probably be nearly as effective as concrete in preventing unwanted mineral leaching.

A certain lack of candour must be imputed to the applicant when one compares the information submitted by the applicant to the Department and information filed elsewhere by the applicant. The statement says that a 24 inch stainless steel pipeline will be used to transport water from the Yellowstone River to the plant, which will be sufficient to serve a 700 MW plant, but in the Rosebud County Court House, the applicant filed a water appropriation for a 60 inch diversion pipe. A 60 inch pipe takes a much bigger hole and results in much more disturbance of the land than a 24 inch pipe. Just the land reclamation problems would be much more severe, because in areas of thin soil, it would take a great deal more blasting of subsurface rock to bury a 60 inch pipe than it would a 24 inch pipe. The question arises as to what are the applicant's intentions with the excess water.

Exhibit 4

The applicant's intentions are important, because this statement does not consider the additive effects of additional plants. One wonders if the applicant does indeed have plans for additional plants, when the applicant is so long-headed as to appropriate a great deal more water than is required to operate a plant of this size.

An additional area indicating lack of candour is the incomplete information supplied regarding all the new construction of transmission lines in connection with this plant. The statement gives the impression that all new construction will cease at Billings. The applicant did not supply the information that it was involved with Bonneville Power Administration seeking power line routings over the Continental Divide to the Lewiston, Idaho area through Federal lands. This is an additional environmental impact which the applicant apparently chose to withhold from the Department.

There may be some question whether the applicant can clearly appropriate the river water at this time. In 1969 the Montana Water Resources Board filed numerous documents in the Rosebud County Court House appropriating all the water in the Yellowstone River which was unappropriated by any other appropriator at that time. The applicant filed its notice of appropriation in December 1970. The applicant may be unable to begin appropriation steps until the claim of an agency of the State of Montana to the water has expired.

If the applicant proposes to use wooden poles for its high voltage transmission lines, it should be specified that they be proof against the effects of grass and timber fires in the areas through which they pass.

The statement is silent on the nature and chemical analysis of the water from the Yellowstone River which the applicant proposes to use in its plant. If the water from the River is "hard" water, then the applicant will have to soften the water to prevent excessive scale accumulation and increased maintenance costs. If the water must be softened, there are different methods, some of which have undesirable side by-products. Some processes of softening water increase the salt content of the water. This water, if discharged into unsealed ash pond, may in some cases increase the sodium content of soils already sodic. This area should also be examined in the statement.

On page 3 of the statement it is noted that the plant will have a coal storage area, but it is not stated in the statement what proposals have been made to control the dust from the coal storage area and its attendant activities. It should be noted that a strip mine in the Rock Springs, Wyoming area was forced to close because it could not economically control the dust from its operation and storage area in a manner which could meet the National Environmental Policy Act Standards.

It will be interesting to see what effect the large amounts of steam condensation the wet cooling towers will release will have on the area surrounding the plant. It has been found in the Appalachian region that small fogs and icing may be created 1/4 mile away from the plant. (The Price of Power, op. cit. p. 57) It should be noted that the excavation and cement work for the generators of the plant at Colstrip are situate quite close to the paved state highway. It might be possible that wet cooling towers on the plant could increase the accident rate on this road during the winter months. There is nothing in the impact statement indicating the location of the cooling towers in relation to the

Exhibit 4

state highway. Another question arises in my mind. The new Montana Constitution allows suit against the State. If an accident happened upon the state highway as a result of icing conditions directly attributable to the wet cooling towers excessive production of atmospheric moisture, under the provisions of the New Constitution, would the state be liable for having issued a permit which allowed the construction of such a device in an area where its emissions could constitute a hazard to highway traffic?

There are presently suits pending dealing with the interpretation of the clause in the National Environmental Policy Act relating to the anti-degradation phase of that act. MEPA was modeled after the national act according to MEPA's author, George Darrow. Air sampling has been done in the general Colstrip area. Maps are included in the statement indicating approximately where the samples were taken. I find the information relating to the sample locations quite incomplete. Judging from the map, they were all quite close to a road of some kind. There is no information given concerning elevation, approximate distance from the road, general topography (whether on top of a hill or down in a draw), frequency of traffic on the road, whether the sampler was in someone's yard, by a windmill, or in the middle of the prairie. If the intention was to measure the air quality in areas close to human activity only, it should have been clearly stated in the statement. In addition to traffic on unpaved roads, the wind will some times go down the road stirring up as much dust as a car, but no, or very little dust, will be blowing across the prairie at the same time. I do not think as the samples were taken, judging from the statement, that the Department has informed itself of the quality of the Colstrip area ambient air prior to the operation of the

proposed plant.

It is difficult to believe the statement of page 18, "Thorough, comprehensive sampling for trace elements has not been done on this coal." It seems that surely with all that has been burned at the Korette plant and all that is being shipped East to be burned in Illinois, that someone has not gotten curious about what is in this coal beside carbon and a low rate of sulphur.

Dr. Clarence C. Gordon on December 14, 1972, in sworn testimony stated that he received four samples of coal from the State Department of Health and Environmental Sciences, which that department alleged to be from Colstrip, and that he tested the four samples for flourine content, and found that the F content ranged from 40 ppm to 80 ppm. Dr. Gordon forwarded the samples on to an unnamed laboratory in Seattle, and their analysis concurred with his and not with the information presented in the statement. Assuming 40 ppm (see p. 18, statement) in relation to the 4.2 ppm used as average in the statement to arrive at the 77 lbs. F projected to be released per day, then there is a possibility that rather than releasing 77 lbs. per day, a more nearly correct figure is 770 pounds of F released per day from the plant operations. If the flouride factor is greater than 40 ppm, then it is possible that this plant will be approaching or exceed the 864 pound per day hopeful emission standard set for the Columbia Falls aluminum plant.

On page 19, the following statement appears: "However, it is expected that a large but unknown percentage of the flourides will be removed by the venturi scrubber." This X factor becomes extremely frightening if the amount of flouride to be released is 10 times the

Exhibit 4

amount anticipated in the statement. Dr. Gordon also stated that flouride pollution had been detected as far as 6 miles away from the Korette plant in Billings. The reason he stopped with six miles was that his study had tested no further away, which did not mean that the pollution did not exist beyond that point. Pines are exceptionally sensitive to elevated flouride levels. For more information on this point, see Dr. Gordon's study of the affects of flouride emissions in the Columbia Falls area.

In Barry Commoner's book, The Closing Circle (Bantam Books), p. 69, reference to a study is made which studied the relation of NO_2 and tomato plant growth. A dosage of 1ppm reduced plant growth 30%. It brings to mind the question, if prolonged periods of NO_2 emissions, although at prescribed dosages, would significantly reduce the amount of grass cover produced on surrounding lands.

The statement is entirely silent on the possibility of the production of photochemical oxidants as a result of hot weather in the Colstrip area and the plant emissions.

There is a reference in the statement to the "Colstrip airshed". It seems to be in reference to how far the wind will carry the plant emissions before the emissions will become so dispersed that no one will notice them. I think it would be very informative for the public to know how many miles in each direction the Colstrip airshed extends. This would serve to define the area which could expect to have its air somewhat degraded and would give a clearer idea of the impact of the plant.

The statement indicates that most of the SO_2 will drop out of the "clean" stack gases within 1/4 mile from the stacks. Will this SO_2 affect any reclamation experiments currently being carried on by MSU?

Exhibit 4

There is no information in the statement which would tend to predict the number of days which would have winds over 20 miles per hour, thus causing a different pattern of dispersion of plant emissions and varying from the dispersion pattern of days which would be only moderately windy or still. It might be possible that given the prevailing winds in the area to have a long narrow path of relatively intense effects from the emissions if the prevailing winds are strong enough often enough. (See Whatever Happened to Fresh Air, by Michael Treshou, University of Utah Press, Salt Lake City, 1971, p. 46 et seq.)

Mr. Treshou also has some interesting comments on fine particulate matter or aerosols. His opinion is that tall stacks, wind and diffusion do not remove the polluting emissions, but only disperse, and that particles smaller than 10μ remain suspended almost indefinitely and that those smaller than 0.1μ remain suspended until they find an agent with which they can chemically react. SO_2 and F form solutions in rain and snow and fall as precipitation. On page 51, he states, "In regions where precipitation is sparse, the pollutants may be longer lived." (Treshou, op. cit.) The statement does not effectively discuss the life of the pollutants or give any idea as to where they may ultimately accumulate. The build up of pollutants is obvious in the Billings area over the period of the last 20 years. They are now visible on any clear day hanging over the Yellowstone valley. I think the statement is defective in that no real effort is made to determine the ultimate natural barrier which will intercept the pollutants' natural drift on air currents.

In order to determine the effect which plant emissions will have on parties other than the applicant, whether the effect be on health, society, or economics, it would be worth while to set forth

how much land applicant owns and controls in the area, and how far the radius of applicant's land does extend from the proposed plant site. This would also give an indication of whether the effect from the plant emissions will be borne primarily by the applicant and its employees and subsidiaries, or by other persons who would stand to receive no financial gain from the plant.

Actions by the applicant raise doubts in my mind as to the future plans of the applicant in construction of additional power plants. At present the applicant in the last year has mined 5 million plus tons of coal with an electric shovel having a 24 cubic yard bucket. It is proposed to feed this proposed plant 3 millions tons of coal yearly; therefore, it would seem reasonable that this plant would need a shovel no larger than the current shovel to supply its needs, if an additional shovel is needed. I wonder why then has the applicant sought bids for two electric shovels each having a bucket of 60 cubic yards in capacity, as stated in applicant's July 1972 shareholders' report.

Considering the amount of water sought by the applicant in December 1970, the ordering of two huge shovels presupposing a drastic increase in strip mining activity, it is reasonable to assume that the applicant has other big plans which may well cause additive effects in the Colstrip area and that applicant is probably well along in its progress in their execution.

The applicant has not entered into a tenancy in common agreement with Puget Sound Power and Light (See "Abstract of Agreement", dated October 27, 1972, executed by and between Montana Power Company and Puget Sound Power and Light Company, filed October 31, 1972 at 3:20

P. M. in Book 21, Page 168, in the office of the Clerk and Recorder of Rosebud County at Forsyth, Montana) for the purpose of receiving free financing from Puget Sound Power and Light Company. Apparently the applicant would have use believe that the people of the State of Montana will receive all the power produced from this proposed plant, but I hardly find it creditable that Puget Sound Power and Light would be so generous as to put up money for plant construction, receiving nothing in return. The applicant should have divulged exactly how much benefit the citizens of Montana will actually receive from the plant. Several areas come to mind. How many Montanans will be employed in construction and operation of the plant? How many Montana firms will have contracts to supply the needs of the plant and participate in its construction? How much of the power produced from this plant will be used in Montana for the next 5 to 10 years after the plant begins operation? In light of the ecological areas about which so little appears to be known, factors such as the foregoing would have to be disclosed in order to give any balance at all in favor of the construction of the plant.

There are so many factors on which the statement fails to shed any light. Some of the information may be known only to the applicant and has not been disclosed to the Department. Some of the research information the Department was probably hindered in obtaining through lack of time and funds. With the information set forth in the statement at this point, I think that the opinion that the long-term detriment resulting from the construction of the plant would out weigh its short-term benefits is correct.

Exhibit 4

I, therefore, commend to the Board and to the Department for their mutual consideration, the following language from the Board's publication entitled "Implementation Plan for Control of Air Pollution in Montana", Section III. Control Strategy, Sub-section C. Non-degradation Clause.:

> The following non-degradation clause is to be made a part of this plan under the authority and requirements of the Federal Register, dated April 30, 1971, Section 410.2. c as follows: "The promulgation of national primary and secondary ambient air quality standards shall not be considered in any manner to allow significant deterioration of existing air quality in any portion of the state." In compliance with this directive and as a policy of the State Board of Health of Montana it is hereby declared to be the policy that ambient air whose existing quality is better than the established standards, will be maintained at that high quality unless it has been affirmatively demonstrated to the Department of Health and Environmental Sciences of the State of Montana that a change is justifiable as a result of necessary economic and social development vital to the state. Any industrial, public or private projects or development which would constitute a new source of pollution or increased source of pollution to high quality air will be required to supply the necessary degree of treatment to maintain that high quality of air.

The statement which sets forth the standards and operating performance for the emission control equipment is so indefinite that considered in relation to the foregoing requirement, I do not think anyone can be sure that the applicant can meet the required standard to maintain the Colstrip ambient air quality. I would remind the Board and the Department that such control of emission must be <u>affirmatively demonstrated</u>. I do not think this has been accomplished, and that therefore, the permit should be denied at this time.

Submitted by:

E. P. Withers
Chairman, Northern Plains Resource Council

Exhibit 4

ORAL TESTIMONY PRESENTED BY PATRICK SWEENEY AS TRANSCRIBED FROM TAPE RECORDING MACHINE

Ladies and Gentlemen. My name is Patrick Sweeney. I am a native of Montana, from Billings, and a member of the Northern Plains Resource Council. I am a graduate of the University of Montana, Missoula, and am not part of that some percent of young people who wish to leave Montana for employment elsewhere. Instead, I wish to stay in Montana. I plan to stay in the Montana I grew up in. I am not an emotional environmentalist just to mumify Montana and let her die in stagnating economy. I do not wish to turn back the hands of the clock. I'm concerned about people, however, and that's what has led me to Miles City today. I would like to address my comments to one aspect of the draft environmental impact statement--the standards for granting of the Montana Power application.

As stated in the Implementation Plan for Control of Air Pollution in Montana, prepared by the Montana State Department of Health and Environmental Sciences, Division of Environmental Sciences, Bureau of Air Quality, the section entitled 'Standards for Granting Applications, Section A. "The Director shall deny a permit to construct if the applicant does not show that it may be expected to operate without emitting air contaminants in violation of standards and regulations formulated under authority of the Clean Air Act of Montana or will interfere with the attainment or maintenance of any application, applicable national standards, or violate any regulations promulgated by the Administrator, U. S. Environmental Protection Agency, pursuant to the Federal Clean Air Act as amended." Given these standards for granting or denial of the application, there is a non-degradation clause in the Implementation Plan for control of air pollution in Montana. I wish to quote that clause if I may. "The following non-degradation clause is to be made part of this plan under the authority and requirements of the Federal Register, dated April 30, 1971, Section 410 (2)(c) as follows: The promulgation of national primary

Exhibit 4

and secondary ambient air quality standards shall not be considered in any manner to allow significant deterioration of existing air quality in any portion of the state. In compliance with this directive and as a policy of the State Board of Health of Montana, it is hereby declared to be the policy that ambient air, whose existing quality is better than the established standard, will be maintained at that high quality unless it has been affirmatively demonstrated to the Department of Health and Environmental Sciences and the State of Montana that a change is justifiable as a result of necessary economic and social development vital to the State. Any industrial, public or private projects or development which would constitute a source of pollution or increase a source of pollution to high quality air would be required to comply to necessary degree of treatment to maintain that high quality of air."

Unfortunately, the Department of Health and Environmental Sciences has not addressed itself in any manner in the draft environmental impact statement to the non-degradation clause. I believe that it is important to the Colstrip development because the high quality air in the Colstrip area will be significantly degraded by 700 megawatt coal-fired electrical generating facilities and that the presently proposed pollution abatement equipment for these plants will not "supply the necessary degree of treatment to maintain that high quality of air;" instead, it will significantly deteriorate the air quality. The significant deterioration of existing high quality air by industrial development is now being litigated in federal court. A federal appeals court has already affirmed a lower court decision that EPA was wrong in interpreting the Clean Air Law in such a way as to permit deterioration of existing air quality. Air quality standards or non-degradation standards would apply to relatively clean air with pollution levels below secondary limits established by the federal government. This would most certainly include the Colstrip area. The court decision, in fact, is aimed at areas where any of the six air pollutants,

Exhibit 4

including sulfur dioxide and particulate matter, currently are below the secondary limits. Thus, a coal-fired power plant planned for the Colstrip area, where the air is relatively pristine at present, must be barred altogether because the best available controls cannot adequately control its pollutants. It has been asserted that prohibitions against air quality deteriorations would be tantamount to barring all industrial and population growth in rural areas. However, in specifying significant deterioration of existing air quality, the courts have left EPA and the state's administrative latitude. That is to say, if there are several proposals that the federal agency might allow levels of five major pollutants, particulates, sulfur dioxide, nitrogen oxide, hydrocarbons, and photochemical oxidants to rise by 10 percent or 5 micrograms per cubic meter, whatever is greater, from existing levels, thus giving some latitude for development of rural areas with high air quality. This would allow for some development, but the level of air quality deterioration would not be such that the high quality air in areas such as Colstrip would be deteriorated to the level of the air quality of Los Angeles or New York City. In a June opinion by the U. S. District Court, Judge John H. Pratt concluded that "Permitting the states to submit plans which allow pollution levels of clean air to rise to the secondary standard levels of pollution is contrary to the legislative policy" of the Clean Air Act. In addition, "the public interest in this case strongly supports legislative policy of clean air and non-degradation of areas in which the clean air exists." Thus, it can be concluded that given the implementation plan for control of air pollution in Montana, the Department of Health and Environmental Sciences has the authority to deny the Montana Power Company's permit to construct the 700 megawatt coal-fired electrical generating facility at Colstrip, Montana, due to violations of the non-degradation clause; that is, the air pollution abatement equipment to be installed at the Colstrip plant will significantly degrade existing ambient air quality whose standards are higher than secondary ambient air

Exhibit 4

quality standards of the federal government. On these grounds, the permit for construction must be denied.

I would submit for the record of this hearing the following petition to the Department of Health and Environmental Sciences and its some 1,000 odd signatures. The petition reads as follows:

"WHEREAS, the State of Montana has adopted as part of its air pollution control regulations, the following statement, the promulgation of national primary and secondary ambient air quality standards shall not be considered in any manner to allow significant deterioration of existing air quality in any portion of the state. In compliance with that Federal directive, the State Board of Health has adopted a directive and policy that ambient air whose quality is better than the standards will be maintained at that high quality unless it has been affirmatively demonstrated that a change is justifiable as a result of "...necessary economic and social development vital to the State." WHEREAS, it is the opinion of the undersigned that the environmental impact of the proposed Colstrip generating plant does not meet the foregoing requirements, and that it would substantially degrade the quality of the ambient air in the Colstrip area, and that it has not been demonstrated that the construction of the plant would provide economic and social development vital to the State of Montana, and that it is probable that such a plant, being the first of a series would create more social and economic problems than it would solve: THEREFORE, it is the opinion of the undersigned that the State Board of Health would deny the permit to construct to Montana Power Company for the construction of a coal-fired electrical generating plant at Colstrip, Montana.

Thank you.

Exhibit 4

United States Department of the Interior

BONNEVILLE POWER ADMINISTRATION
KALISPELL DISTRICT OFFICE
P.O. Box 758, Kalispell, Montana 59901

In reply refer to: OKK

RECEIVED

MAR 2 1973

ENVIRONMENTAL SCIENCES
DIVISION

March 1, 1973

Mr. Daniel Vichorek
Technical Writer
State Department of Health
& Environmental Sciences
State of Montana
Helena, Montana 59601

Dear Mr. Vichorek:

Responding to the question in your February 20 letter, the power output of Libby Dam is included in forecasts of resources available to meet projected power requirements in the Pacific Northwest, which will help alleviate power shortages in Montana.

The electrical loads which the regional cooperative Hydro-Thermal Power Program is attempting to supply includes essentially all loads in Idaho, Washington, Oregon, and Western Montana with the exception of those served by Idaho Power Company, Montana Power Company, and Utah Power and Light Company. Even though the planning is done on a regional basis, the addition of Libby will not change the fact that BPA will be bringing energy into Montana to meet its obligations. Item 10 of my February 1 letter discusses this in some detail.

Obviously, it is not prudent for the entire output of a federal resource project such as Libby to be dedicated to a particular State. More efficient utilization is possible if the Project output is integrated with other projects to meet the needs of a larger coordinated system.

The average firm generating capability of Libby Dam under critical water conditions is 186,000 kilowatts (note the change from incorrect figure of 204,000 in my February 1 letter). January firm peaking capability associated with the first 420,000 kilowatts of installed capacity is 216,000 kilowatts.

Enclosed for your information is our recently-published "Power Outlook". Please let me know if you have additional questions.

Sincerely,

Ronald H. Wilkerson

Ronald H. Wilkerson
District Manager

Exhibit 4

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JOHN L. MC CLELLAN, ARK., CHAIRMAN
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JAMES R. CALLOWAY
CHIEF COUNSEL AND STAFF DIRECTOR

United States Senate
COMMITTEE ON
GOVERNMENT OPERATIONS
WASHINGTON, D.C. 20510

RECEIVED
ENVIRONMENTAL SCIENCES
DIVISION

18 January 1973

Mr. Daniel Vichorek
Technical Writer
Dept. of Health & Environmental Sciences
State of Montana
Helena, Montana 59601

Dear Mr. Vichorek:

I am pleased to respond to your 12 January letter in which you properly challenge the statement that "in general, the most rapidly growing utilities have the highest rate of return".

High rate of return is a result of indulgent regulation or non-regulation. The most convenient documentation of the non-correlation between growth and return is the attached table from the 1 January 1973 issue of Forbes.

You can there see that unregulated Texas utilities rank highest in profitability, followed by those in Ohio (the state with the ultra-lenient "reproduction cost new" rate base), Illinois (fair value rate base) and Minnesota (no regulation). By checking the growth column for these same utilities you will see that most of them are below average by that measurement.

By carbon of this letter, I am asking Professor John B. Dicks of the University of Tennessee to send you some of his materials on MHD development in other countries.

The Senate hearings you requested are being sent under separate cover. They are scarce documents, so I may refer others to you, or perhaps you could put them in a Helena library.

Very truly yours,

Lee Metcalf

Enclosure

cc: Professor John B. Dicks

Exhibit 4

Exhibit 4

THE UNIVERSITY OF TENNESSEE SPACE INSTITUTE
TULLAHOMA, TENNESSEE 37388
Graduate Education, Research, Postdoctoral Study
and Continuing Education in the Aerospace Sciences

January 29, 1973

RECEIVED
JAN 1973
ENVIRONMENTAL SCIENCES
DIVISION

Mr. Daniel Vichorek
Technical Writer
Department of Health and
Environmental Sciences
State of Montana
Helena, Montana 59601

Dear Mr. Vichorek:

I received a copy of a letter from Senator Metcalf to you dated the 18th of January 1973, along with a copy of your letter to him. Enclosed is an article of mine on the status of MHD power generation in the world that appeared in MECHANICAL ENGINEERING this past spring. Since this article was written, we have heard that the U-25 plant in Moscow has been operating with 5MW of MHD power. This indicates that they are on or ahead of schedule in bringing this technology into use in the Soviet Union. We have been trying to negotiate a program of technical cooperation in MHD with the Soviet Union and were having great success until the recent bombing of North Viet Nam brought a diplomatic coolness on their part in relations with the United States. Hopefully, with the cessation of hostilities in Viet Nam, we can resume negotiations again.

I have the responsibility of coordinating all of the energy programs in the University of Tennessee System and so have obtained some overview of the current energy situation. It appears that coal is the only resource that we have to rely on to fill the gap between the failure of the oil supply and the time near the end of the century when appreciable nuclear fuels can be produced in the breeder reactors.

Exhibit 4

Those of us in the energy field have long been grateful to Senator Metcalf for his intelligent efforts to lead the electrical utilities towards policies that are more nearly in the public interest than they are now. If we can send you further information on power generation, please let us know.

Sincerely,

John B. Dicks
Professor of Physics

JBD:eb

Enclosure: (1)

cc: Senator Metcalf

Exhibit 4

The MONTANA POWER COMPANY

GENERAL OFFICES
ELECTRIC BUILDING
BUTTE, MONTANA 59701

December 29, 1972

Mr. Don Holtz
Chief, Air Quality Bureau
Department of Health and
Environmental Sciences
State of Montana
Helena, Montana 59601

Dear Mr. Holtz:

With reference to our past conversations, I would like to summarize the present status of The Montana Power Company's planned electric transmission and water system portions of the Colstrip project. That project as described in our application to your Department for a Construction Permit to install equipment which may contribute to air pollution and to install air pollution control equipment is two 350 MW generating units. With that generating capacity, the following facilities will be required:

Electric Transmission Lines

The partially completed Billings-Hardin-Colstrip 230 kV line will be completed. That line is presently completed from Billings to Hardin, and most of the right of way from Hardin to Colstrip has been secured. This line will be completed in 1973 and will be used to supply power to the Colstrip area until the Colstrip generation is on-line.

In addition to that line, two 230 kV lines from Colstrip to Billings will be required to bring the Colstrip generation into the existing MPCo system. Those lines will be required, one in 1975 and one in 1976. Their route has not yet been detailed, but presently it is assumed that generally they will be north of the Yellowstone River valley and will connect to MPCo's existing system at a new switchyard to be located north of Billings.

The existing MPCo electric transmission system is continually expanding to meet the increasing energy requirements of its customers. Generating capacity introduced into the system at Billings will change the system flow patterns and may change the timing of system additions. Such additions may be influenced by the Colstrip project, but are not an integral part of that project.

Exhibit 4

Water System

The proposed two 350 MW units will require approximately 8,000 acre-feet/year of water, at rates up to a maximum of 8,000 gpm. The water will come from the Yellowstone River at either Nichols or Forsyth, depending on the pipeline route selected. Two potential routes currently being evaluated are from Nichols up Armells Creek valley, and from Forsyth over the benchland between Armells and Rosebud valleys. The pipeline size will be in the range of 22" - 26" OD, depending on the length of the route selected.

The design of those particular facilities is still flexible, and of course, the best planning maintains the maximum flexibility for as long as possible. The greater the flexibility, the more options remain open so that the final plan will have been adjusted to accommodate the latest technology, including all environmental considerations.

Additional generating capacity at the Colstrip site is a potential change that would affect these facilities. There has been discussion and interest shown by utilities in the northwest for this additional generation. No commitments have been made but the discussions continue. If a commitment is made soon enough, significant economies could be realized by enlarging the initial water pipeline rather than having to install a second line which would also have great environmental advantages. The same would apply to the transmission lines.

Be assured that if changes materialize before a permit is granted, the Department of Health and Environmental Sciences will be notified immediately and a new application submitted for permission to construct any new equipment capable of emitting any contaminants to the atmosphere.

Sincerely,

Carl R. Anderson

Carl R. Anderson, Manager
Environmental Protection Department

CRA:ror

Exhibit 4

The Montana Power Company

GENERAL OFFICES
ELECTRIC BUILDING
BUTTE, MONTANA 59701

March 1, 1973

Air Quality Bureau
Montana State Department of Health
and Environmental Sciences
Cogswell Building
Helena, MT 59601

ATTENTION: Mr. Don Holtz

Re: Colstrip Units #1 and #2
Application for a
Construction Permit

Gentlemen:

The purpose of this letter is to transmit information supplementing our other replies to the several inquiries written by your Mr. Vichorek in the last several weeks and to transmit information we have previously promised.

Attached to this letter are discussions on the following topics that fall into the above categories:

1. Additional Information on the Pollution Control System

   All the information on this system developed since our permit application was submitted is presented. The vendor's preliminary design drawings are under review by our consulting engineers but no final dimensions have been developed as yet. When these drawings are finalized, they can be provided if desired.

   We have also revised our plant Flow Diagram, Item VII of the permit application, to reflect a design change from bypass air for reheating to a steam supplied plate-coil heater.

Exhibit 4

2. Pilot Plant Results as of February 28, 1973

The results of the pilot plant program available to date are submitted.

3. Particle Size Distribution

In answer to your request for information, we submit graphs summarizing the available test results. These apply to the Corette Plant precipitator inlet.

4. Fluoride Content of Colstrip Coal

Our statistical analysis of the most recent tests is submitted in support of our conclusion that an average value of 33 ppm, oven dry basis, is appropriate (25 ppm as received).

5. Fluoride Emission Prediction

Using all of the recently developed data, we have revised our estimate of fluoride emissions to a number that is smaller than the one we projected in our formal statement on the draft report.

6. Scrubber Technology

We submit additional discussions of the status of scrubber technology in answer to your requests.

7. Nitrogen Oxide Production

We submit references discussing the available data on nitrogen oxide production in tangentially-fired boilers in answer to your request.

8. Cooling Tower Information

We submit the design information on the cooling towers and information on the considerations that were given on minerals carryover and ice and fog formation in answer to your request.

Exhibit 4

You should also receive from Professor Super a separate transmittal of the final one-year data summary from the meteorological program. As soon as he has completed them, we will also forward the summary and final reports.

We would welcome the opportunity to discuss these materials with you at your convenience.

Very truly yours,

David T. Berube

D. T. Berube
Supt. of Thermal Generation Engineering

DTB/mje
Attachments

Exhibit 4

Exhibit 4

SCRUBBER TECHNOLOGY

Sulfur Dioxide Removal

To supplement our previous statements on the capability of sulfur dioxide removal technology to meet the required performance levels, we attach a copy of the Federal Register of March 21, 1972. In this publication, the Environmental Protection Agency reviews the status of this technology. Nine of the twenty installations listed by EPA have or will use venturi type scrubbers. Rather than rewriting this information, we are enclosing the EPA statement as our statement (Paragraph II.2).

Particulate Removal

In the area of particulate removal, venturi scrubbers have long been used for high efficiency collection of particulates finer in nature than fly ash. (Refer to various manufacturers' information, such as Research-Cottrell Bulletin RC-975 and Peabody/Lurgi Bulletin 35000.) Numerous applications of scrubbers for particulate control are discussed in the Los Angeles Air Pollution Engineering Manual. A summary is on Page 231. A recent paper (Mathematical Models for Pressure Drop, Particulate Removal, and SO_2 Removal in Venturi, TCA, and Hydro-Filter Scrubbers, M. Epstein, et al, Second International Lime/Limestone Wet Scrubbing Symposium, New Orleans, LA, November 1971) shows that theoretical equations indicate that 99.5% particulate removal can be achieved at gas velocities and liquid to gas ratios that are compatible with the system sulfur dioxide removal requirements. The same paper reports a good correlation between results predicted by the equations and tests run in a venturi type pilot plant.

In addition to the basic venturi stage, the Colstrip design will utilize a stage of counter-current sprays. Although these are intended to insure adequate SO_2 removal, they will provide additional particulate removal. The previous discussion on the pilot plant operations to date showed that particulate outlet loadings below the maximum guaranteed for Colstrip have been demonstrated.

Fluoride Removal

Numerous articles in the technical literature discuss fluoride removal by venturi scrubbers. A specific article appearing in the March 1958 issue of Industrial and Engineering Chemistry written by K. E. Lunde of the Stanford Research Institute describes the removal of gaseous and particulate fluorides. The concept of the number of transfer units, N_T, is used to compare various types of control equipment.

Exhibit 4

When there is a lean gas mixture at a total pressure of about one atmosphere, the number of transfer units is defined as:

$$N_T = \int_{y_1}^{y_2} \frac{dy}{y-y^*}$$

In many installations, there is no vapor pressure or at least an insignificant vapor pressure for the fluoride compound above the liquid, so $y^* = 0$. The equation reduces to:

$$N_T = \int_{y_1}^{y_2} dy/y = \ln (y_1/y_2)$$

Where:

y = concentration in gas, mol fraction

y_1 = inlet, y_2 = outlet

y^* = vapor pressure above solution, mol fraction

Then:

N_T = Number of Transfer Units = $\ln \left(\frac{1}{(1 - E/100)} \right)$

A table of N_T versus E follows:

N_T Transfer Units	E Efficiency %
1.61	80
1.90	85
2.078	87.5
2.302	90
2.59	92.5
3.0	95
3.68	97.5
3.9	98
4.61	99
5.3	99.5

The article also states water or a basic solution is used as an absorbent for hydrogen fluoride and silica tetrafluoride. Table 1 on Page 296 of I&EC gives two examples each for counter-current sprays and venturi that use water as the absorbing liquor. The two counter-current sprays give 2.5 to 5.85 transfer units while the venturi exhibits 2.0 to 2.9 transfer units.

Exhibit 4

The scrubber at Colstrip contains the venturi stages and counter-current flow stage. If the transfer units for both are added where the 2.0 transfer unit value for the venturi is used and 2.58 for the counter-current sprays, then the efficiency is projected to be between 98% and 99% for gaseous fluoride removal.

Stern in Air Pollution, Vol. III, Page 541 states that a jet-venturi scrubber in a super phosphate plant removes 98% of the fluorine in the exhaust gas. This compares favorably with the projection for Colstrip.

Attached is the article by Lunde in I&EC, and the page from Stern - Air Pollution, Vol. III.

Exhibit 4

Exhibit 4

NORTHERN CHEYENNE TRIBE
INCORPORATED

P. O. Box 128

LAME DEER, MONTANA 59043

RECEIVED
1973
ENVIRONMENTAL
DIVISION

LITTLE WOLF AND MORNING STAR - Out of defeat and exile they led us back to Montana and won our Cheyenne homeland that we will keep forever.

- WOHEHIV - The Morning Star

OFFICERS

Allen Rowland
President

Wendell Shoulderblade
Vice President

Jacqueline Bemet
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Matthew Two Moons
Busby

Eugene Russell
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Kenneth Beartusk
Lame Deer

Daniel Foote
Lame Deer

Dennis Limberhand
Lame Deer

James McLane
Lame Deer

James Shoulderblade
Lame Deer

Raymond Harris, Sr.
Muddy

March 13, 1973

Mr. Daniel Vichorek
Technical Writer
State Department of Health
and Environmental Sciences
Helena, Montana 59601

Dear Mr. Vichorek:

This will acknowledge receipt of your letter of February 22, 1973 concerning the feelings of the Northern Cheyenne people on the coal development now in progress at Colstrip, Montana.

Actually we did not pay too much attention as to what was happening in other areas of Eastern Montana as far as coal development was concerned. We were confronted with our own very serious problems during this period.

We have been quite concerned about the generating plant being constructed by Montana Power Company at Colstrip and I understand that three (3) more such plants will be constructed there at some future date.

We feel that these generating plants will eventually be creating a very serious pollution problem for us and we wonder what effects this pollution is going to have on our other natural resources such as our grass, water and timber.

We are also concerned about the very large number of people who have already moved or will be moving into Colstrip and the surrounding area and the effect they will have on our people. We envision large numbers of the people swarming over our reservation roads and recreation areas.

We are not prepared to handle this type of problem at this time, however, we are making an attempt to be ready for any eventually.

Exhibit 4

We also are very disturbed about the environmental impact statement as far as Montana Power Company's generating plant is concerned. We do not think it was adequately put together and a more meaningful impact statement should be made before the construction permit is issued to Montana Power Company.

I wish to thank you for this opportunity to state our views on Montana Power Company's proposed generating plant. If you need anything further from us please feel free to call or write. I am,

Sincerely yours,

Allen Rowland

Allen Rowland, President
Northern Cheyenne Tribal Council

Exhibit 4

PUGET SOUND POWER & LIGHT COMPANY

Puget Power Building - (206) GLencourt 4-6363
BELLEVUE, WASHINGTON
98009

March 7, 1973

RECEIVED
1973
ENVIRONMENTAL SCIENCES
DIVISION

Mr. Daniel Vichorek
Technical Writer
State of Montana
State Department of Health and
Environmental Sciences
Helena, Montana 59601

Dear Mr. Vichorek:

This is in response to your letters of February 5 and 20, 1973 in which you requested information to be incorporated into the final environmental statement that your agency is compiling for the Colstrip generating plant proposed by Montana Power Company and Puget Power.

1. Why is it necessary to build the plant in Montana, and how will Montana Power achieve any savings?

First of all, it appears from your letters that some clarification of Puget Power's status in the project is appropriate. Montana Power and Puget Power are owners as tenants-in-common of the Colstrip plant. Each is the owner of an undivided one-half interest in the entire project including each of the two 350-megawatt generating units. Each company will receive one-half of the output of the project according to its schedules. Montana Power is not building a plant to sell power to Puget Power. However, we do intend to establish a procedure whereby each utility can use a portion of the other owner's capacity in order to obtain the advantage of diversity in meeting peak loads. In fact, we have already entered into a contract pursuant to which Montana Power will receive a substantial portion of Puget Power's capacity at Colstrip during certain months in 1975 and 1976.

With Puget's interest in the plant at Colstrip being constructed at the same time as Montana Power's, significant construction economies can be realized. The engineer contractor for the project, the Bechtel Corporation, estimated the cost differential between the one-unit project and the two-unit project to be in excess of $50 per kilowatt.

Exhibit 4

These construction cost savings represent a significant savings for Montana Power Company and its customers who must ultimately pay these capital costs. It should be noted that Montana Power Company's 350-megawatt plant would have been necessary for its system, and the Company had already begun its plans for Colstrip before Puget decided to join with it in a larger plant.

Since there is currently a net import of electric power to the northeast sector of WSCC, it is essential for system reliability and for system efficiency purposes to construct generation facilities in Montana. Properly balancing the network with added generation at the traditionally weak link of the system, the northeast sector, will improve the reliability of the systems serving that area. In addition, Montana Power will have greater generating reliability because it will own one-half of two units, rather than the whole of one unit, thus facilitating scheduling of maintenance, mitigating the effect of forced outages, and substantially reducing the amount of forced outage reserves that Montana Power must carry. This last item alone represents a substantial savings to Montana Power as its forced outage reserve obligation will be substantially reduced, thus increasing the firm capability of Montana Power's share of the plant.

Since the Colstrip plant will not require new transmission outside the State of Montana, existing transmission systems will be utilized more efficiently. With the only transmission required to be located in Montana, the evidence clearly favors transmission as the alternative to hauling coal to a plant in Western Washington, which was the question posed in your earlier letter. This point is also discussed more fully on Page 5 of Montana Power Company's letter to you dated February 20, 1973.

I trust the above fully answers why the plant is necessary in Montana.

2. Next you ask, "Why is the plant needed at all?" and further request information on Puget Power's load growth.

I am enclosing a copy of Puget Power's 1971 Annual Report, the latest available, which on Pages 18 and 19 presents the financial and statistical record of the Company during a ten-year period, 1961-1971. During this period the annual increase in kilowatt-hour sales has averaged 9.75 per cent, a load increase of over two and one-half times. We are projecting annual increases to average about eight per cent in the next ten-year period as shown on the Table of Loads and Resources furnished to you in Montana Power Company's letters dated January 18 and February 20, copies of which are attached. Puget Power's peak load is projected to increase from an actual system peak load of 2115.2 megawatts in 1972-73 to 4,018 megawatts in 1981-82; and its energy load from 1,210 megawatts in 1972-73 to 2,315 megawatts in 1981-82.

The reasons for this growth are several: growth in number of customers, the primary factor, as well as increased use by each customer. These

Exhibit 4

facts are borne out by the statistics in the Annual Report. Obviously, people find the Puget Sound area a desirable place to live and we do not foresee a significant decline in the rate of population increase in Puget's service area. In fact, new family formations from the existing school age children of Puget's service area alone assures the Company of the reasonableness of the load growth trends noted in the table.

3. Has the Company spent any money on research?

Through the Edison Electric Institute and individually, Puget Power has contributed to research of various alternative power generation methods, including development of the High Temperature Gas Cooled Reactor (HTGR).

Puget and other electric utilities, both public and investor-owned throughout the nation, and government agencies are planning to participate in a research and development program to be carried on by a newly formed research and development organization called Electric Power Research Institute (EPRI). This corporation was formed under the guidance of the Edison Electric Institute with broad support of both public and private organizations. The purpose of this corporation is to provide a technical staff and administration with facilities to embark upon a massive research and development program to invent, design, plan and test with pilot projects new or improved forms of producing, transmitting and distributing electric power and energy that will be feasible to meet environmental standards. The project will include research and development of improved technology and equipment in order to reduce the environmental impact of the generation of electricity by thermal power plants and to develop more efficient utilization of electric energy. The project also includes the construction of the first large-scale LMFBR demonstration plant. Funding of this organization and its research and development program will be by annual payments by all participating electric utilities and other organizations. Puget's total contribution to the LMFBR program is $1,835,000, payable in ten equal annual installments commencing in 1972. Commencing in 1973, the contributions to the LMFBR program will be part of the total commitment to EPRI. It is anticipated that Puget's contribution to EPRI will be $470,000 in 1973 and $761,000 in 1974.

4. Programs for reduction of peak load.

Several years ago, Puget Power initiated a new program for voluntary peak reduction during certain hours on peak consumption days, generally in December and January. This program involves a number of industrial and commercial customers, as well as some schools. The response has been very encouraging. The peak reductions resulting from the program, combined with the curtailment of interruptible industrial and school loads, account for noticeable reduction in the peak hour demands.

Exhibit 4

In addition, Puget has embarked on an extensive energy conservation program directed at the consuming public. This program is currently the principal objective of the Company's advertising program, with all of the communications media being used. As part of this program we have made available a booklet on energy conservation, a copy of which is enclosed. Puget has not implemented any load promotional type of advertising for a number of years. Puget Power application engineers assist customers in choosing facilities and rates to reduce their energy requirements.

5. Is the use of electricity "socially beneficial"?

It is difficult to imagine any use of electricity that is not "socially beneficial." Electric power lights our houses, streets, offices and factories; allows man to be more productive in his work and more relaxed and comfortable at home and at leisure. Electric power serves increasingly more medical and hospital purposes, powers pollution control equipment, and enhances the quality of life for all.

We hope the above will be sufficient to complete the environmental statement in acceptable form. If further information is desired, please let me know.

Very truly yours,

John W. Ellis
Vice President
Utility Management

Enclosures

Exhibit 4

The Montana Power Company

GENERAL OFFICES
ELECTRIC BUILDING
BUTTE, MONTANA 59701

March 5, 1973

Mr. Daniel Vichorek
Technical Writer
Department of Health
Helena, MT 59601

RE: Your letters of February 16, 1973, and February 23, 1973 with questions concerning the environmental impact of The Montana Power Company's Colstrip development.

Dear Mr. Vichorek:

The following is in reply to the above subject.

1. Does The Montana Power Company intend to follow "The Plan for Colstrip" developed by Ken R. White Company?

Western Energy Company, a subsidiary of The Montana Power Company, intends to closely follow the "Plan for Colstrip" prepared by Ken R. White, Denver, Colorado, December 1972. (See attached copy of said plan, marked Exhibit No. 1, and Map 1A)

The plan will be reviewed and updated periodically to reflect alterations in existing development and new, presently unforeseen developments. The plan will be implemented by architect-engineers selected by Western Energy Company. The architect-engineers selected are: Drake-Gustafson, Architects; Christian, Spring, Sielbach and Associates, Engineers; and Wirth Associates, Landscape Architects. The three firms are located in Billings.

2. What does the Western Energy Company expect to do to accommodate the social, recreational, educational and other needs of the expanded population?

The social, recreational, educational and other needs are recognized and accommodated in the "Plan for Colstrip", which

Exhibit 4

will be implemented by Western Energy Company. Colstrip's community facilities include a school, fire and police protection services, churches, health care, library services, parks and recreational services. Some facilities and services, such as water, fire protection and parks are the primary responsibility of Western Energy Company; other facilities and services such as health care and library services are considered quasi-public in that Western Energy Company would be involved to the extent of providing sufficient space. Other needs of Colstrip can be adequately accommodated by existing public facilities, such as existing schools.

It is the intent of Western Energy Company to work closely with local, county and state groups to ensure an orderly, attractive development of the community of Colstrip.

There follows a more specific discussion of the services and facilities contemplated to accommodate the social, recreational, educational and other needs of Colstrip.

(a) Social Needs

Library services will be provided through a bookmobile from Miles City, Montana. (Page 28 - Ken R. White, Supra.) Two additional church sites are provided in the Plan. If new churches do not organize, the property can be converted into additional residential lots. (Page 27, Ken R. White, Supra.)

Western Energy Company intends to promote civic organizations which will contribute to a good social community environment.

(b) Educational

In relation to schools, Western Energy Company has reviewed with local school authorities the impact Colstrip development is expected to have on enrollment. School authorities then can take appropriate action for school expansion (Page 25, White, Supra.) Western Energy Company will contribute significantly to the tax base for the operation of schools.

(c) Recreational

The plan for parks and recreation includes further landscaping of existing parks, development and expansion of the proposed teen and community center and development of new play fields, tot lots and parks. (Pages 28-33, White, Supra.)

Several other recreational developments are recommended or planned outside the town, such as a golf

Exhibit 4

course, lake and picnic areas, rifle and pistol ranges, snowmobile and motor trails, wildlife and nature areas. (Pages 33, White, Supra.)

(d) Other Needs
Western Energy Company owns and maintains a number of single-family homes, apartments and a mobile home park. Detailed plans have been developed for expected growth and even growth beyond present growth expectations. (Pages 14-16, White, Supra.)

The architect-engineers hired by Western Energy Company will study the drainage and sewage needs of the area. Western Energy Company plans to provide for an increased water consumption. Western Energy Company has built a new 500,000 gallon water tank and will put in some new transmission pipes. Other existing utilities are deemed to be adequate for future requirements. (Pages 39-44, White, Supra.)

Commercial development is planned for the area. Provisions are made for a grocery store, drug and hardware store, general store, offices, medical facilities, a post office and space for such services as a laundromat, beauty shop, barber shop, service station, motel and restuarant are planned. (Pages 21-24, White, Supra.) Private enterprise should participate in the development of said facilities.

3. What are present and future costs of locating the plant at Colstrip compared with a site nearer load centers?

Comparative studies done by Montana Power Company based on total revenue required and levelized annual cost of expenditure indicate that it is slightly more economical to locate the plant at Colstrip than in other potential areas such as Springdale or Cushman.

There follows a partial summary of this study.

Exhibit 4

Two Units 1974-1985

	Total Revenue Required	Percent Difference	Levelized An. Cost	Percent Difference
Colstrip	$ 279,189,000	Base	$ 21,427,000	Base
Springdale	281,142,000	+ .52%	21,494,000	+ .32%
Cushman	281,989,000	+ .82%	21,626,000	+ .93%

Two Units 1974-2013

Colstrip	$ 1,089,103,000	.10%	$ 24,328,000	Base
Springdale	1,152,497,000	+6.05%	24,983,000	+3.20%
Cushman	1,129,406,000	+3.81%	24,849,000	+2.37%

Although the study showed the Colstrip site to be more economical the difference is less than 1%. Envirnomental and other considerations such as uncertainties in freight rates and freight performance for transportation of coal were the more persuasive reasons in the selection of Colstrip. (See our letter of February 12, 1973.)

4. Will the minerals in the drift precipitate out within 200 feet of the towers?

All minerals should precipitate out within 2,000 feet from the place of emission, and 60% of all minerals should precipitate out within 1,000 feet of the place of emission according to diffusion specialists of Bechtel Corporation.

Fog and ice formations should not develop beyond 200 feet from the cooling towers, according to cooling tower specialists of Bechtel Corporation. In reliance on Bechtel authorities, The Montana Power Company plans to construct its plant 200 feet in the direction of the prevailing winds from the cooling towers. The state highway is approximately 3,500 feet in the direction opposite the prevailing winds.

The Montana Power Company considers Bechtel Corporation to be a reliable authority on matters relating to cooling towers and mineral drift because Bechtel is one of the most experienced authorities in these areas. Bechtel Corporation is a worldwide Contractor which has constructed many different types of power plants.[1] (See also data submitted by Mr. Dan Berube at meeting in Helena on March 2, 1973)

Exhibit 4

5. How may cells will there be in the cooling towers, and what is the rated horsepower of the fans?

There are seven cells in the cooling towers and each of the seven fans has a rated horsepower of 185.2 according to the manufacturer.[2] (See also data submitted by Mr. Dan Berube at meeting in Helena on March 2, 1973)

6. Is any noise pollution from the Colstrip plant anticipated?

NO. There follows noise level specifications as set forth in the manufacturer's data sheet.[3] (See also data submitted by Mr. Dan Berube at meeting in Helena on March 2, 1973)

Noise Level (SPL - DB re 0.0002 Microbar at Ground Level 100 feet from Louvers at Center of Tower):

Octave Band		1	2	3	4	5	6	7	8	Weighted Freq. Band			
CPS:	From	20	75	150	300	600	1200	2400	4800				
	To	75	150	300	600	1200	2400	4800	9600	A	B	C	Flat
DB		84	83	82	78	74	72	68	64	81	NA	NA	NA

7. What are the known operating characteristics of tangentially fired furnaces of the types hereinvolved and what is the measurement of nitrogen oxides in the stack gases of a unit hereinvolved?

The tangentially fired furnaces hereinvolved have the lowest nitrogen oxide production of any furnace.

It is also important to note that the performance of the type of furnace hereinvolved was adopted by the Federal Environmental Protection Agency as the standard under the Federal Clean Air Act. (See also data submitted by Mr. Dan Berube at meeting in Helena on March 2, 1973)

8. Has Montana Power Company done any research on the development of any other type of generating facility?

The Montana Power Company individually has not done any extensive research regarding other forms of generating facilities. However, The Montana Power Company is a member of, and supports the Edison Electric Institute,[4] which has done research on all forms of power generation.

Exhibit 4

9. Is there reason to think Montana's annual 5% increase in energy demand will not continue?

Montana's energy demand is expected to continue to increase at least at its present rate. This projection is based on and consistent with national projections, historical experience in Montana and particular known factors about Montana's future supply and demand.

Forecasters of the Federal Government and the electric industry expect the demand for electricity to continue to grow at an average rate of 7% a year with a doubling every 10 years.[5] Attached is a chart, marked Exhibit No. 2, from the 1970 National Power Survey of the Federal Power Commission showing past and future energy requirements in the west region of the United States. The peak demands by load centers from the same National Power Survey shows the demand on certain Montana supply areas to increase from 1,460 megawatts in 1970 to 2,590 megawatts in 1980.

Power supply area	Load Center	Peak demand--megawatts 1970	1980	1990
30	Butte-Anaconda	700	1,240	2,260
	Billings	175	312	563
	Helena-Great Falls	330	587	1,060
	Kalispell-Missoula	220	390	707
	Unassigned	35	61	110
	TOTAL	1,460	2,590	4,700

Studies by The Montana Power Company, based on historical data, also indicate a significant increase in future demand for electric power in Montana. (See Attached Exhibit No. 3, "The Montana Power Company Annual Average Electric Energy Loads", Exhibit No. 4, "The Montana Power Company Annual Peak Loads", Exhibit No. 5, "The Montana Power Company Electric Load Peaks and Average" and Exhibit No. 6, "The Montana Power Company Electric Load Peaks and Average (Future)".

Furthermore, it is important to note that The Montana Power Company has had a deficiency in self-generated electric power in past years. Presently this deficiency is accommodated by purchases and exchanges with other utility sources.

For example in January 1973, The Montana Power Company's self-generated resources of electric power total 768 megawatts. The Montana Power Company received an additional 263 megawatts from other utility sources.[6]

Exhibit 4

By 1975 many of these other sources of power will no longer be available. By 1975 the peak load demand in Montana is projected to be 1098 (See Exhibit No. 4, Supra). Obviously Montana Power's present self-generated total of 768 megawatts would not be sufficient to meet the projected 75-76 peak load requirement of 1098 megawatts. This is why "brownouts" are anticipated by 1975. Although these projections of future energy loads of The Montana Power Company set forth in Exhibits No. 3 through No. 6 are based primarily on historical experience, and although power projections are subject to a number of variables, other known factors must be anticipated and taken into consideration. For example, U. S. Plywood and Champion paper of Missoula will need a significant increase in power for expanded activities in about 1974, and the Anaconda Company will need about 25 additional megawatts for its new Great Falls smelter by 1975.

10. If an increased number of television sets, water heaters and electric ranges have caused the energy demand to grow faster than the population since 1961, what indication is there that this growth rate will continue?

First, it is important to note that residential usage in which water heaters, televisions, etc. are included as a rather small part thereof, is itself only a smaller portion of electric power usage in Montana. For example in 1972 residential usage amounted to 20% of the total electric power usage from Montana Power Company.

Commercial and industrial usage accounts for 2/3 of Montana Power Company's electric usage.

Several signs of growth, such as population growth, rise in the living standard, rise in recreation and tourism and employment for Montana in the decade 1970-1980, are evidence of the continued growing need for electrical energy in Montana for both residential and industrial usage.

Secondly, in addition to the projection or more people and industry in Montana which will require more energy, the present market of electric energy is not exhausted. For example, only 75% of Montana's potential residential customers have electric ranges, only 60% have electric dryers, only 14% have outdoor lights and only 9% have air conditioning. The percentage of customer growth has been the highest in history in the past two years for Montana Power Company and is expected to continue.

11. Is there any specific information on how much power is now used and will be used by farmers, sewage plants and other environmental facilities?

The Montana Power Company's marketing personnel think farm and environmental usage has and will continue to expand. For example, the following is the annual added usage for irrigation purposes.

Year	Horsepower Added
1961	1380
1962	1333
1963	1622
1964	2163
1965	2042
1966	1643
1967	2767
1968	2582
1969	2081
1970	2743
1971	4643
1972	4292

It is projected that the amount of energy used for environmental improvement on a national basis will increase from about 2% of total energy consumption in 1970 to 4 or 5% in the period 1970-1985.[8] In Montana, sewage and water treatment facilities in Billings and Great Falls will each alone use enough electricity to serve an average Montana town with a population of 10,000.

Montana industry is also using an increasing amount of energy to improve air and water quality.

The Humble Oil Company in Billings has a water treatment system that returns their water effluent to the Yellowstone River in better condition than the water that comes into the plant. They use four 50 HP electric motors on large aerators in the ameliorating process. Great Western Sugar Company in Billings is constructing a new sewage treatment facility that will require 600 to 700 HP in electrical load. Furthermore, the air pollution equipment to be installed in the Colstrip plant will use approximately 25 megawatts of power, which is approximately 1/30 of the total electricity now generated by The Montana Power Company.

12. If so few Montana homes are electrically heated, why do the annual peak loads occur in the winter?

Montana Power Company's peak load occurs in winter because the temperature is colder and the days are shorter which results in greater uses of electricity. For example, with shorter days more lighting is required. With shorter days and colder weather there is a tendency for people to be indoors and use more electricity for lighting, clothes drying, hot water and heating. In addition, to electric heat, forced air and natural gas heating systems use electric thermostats, fans and blowers. Of course, residential

use of electricity is only part of the power drain experienced during winter in Montana. Montana industrial and commercial customers also consume added energy loads in winter, because of colder temperatures and shorter days.

13. What workers are included in the Montana Power Company's projected payroll figures, and are theses figures consistent with population projection of Ken R. White?

The Montana Power Company's payroll figures are based on payroll estimates for construction, operation and mining employees for particular months and years. (See Exhibit No. 7) Population projections by Ken R. White are also based on an estimate of the number of construction, operations and mining employees but additionally White's estimates are also based on professional and support personnel. (See White's "Population Projections", Supra, Exhibit No. 1, Page 10.)

Secondly Montana Power Company's payroll estimates and Ken R. White's population projection are in fact consistent. For example, The Montana Power Company's payroll estimates peak in early 1975. Similarily Ken R. White's population figures peak in 1975. (See Population Growth Table 2, White, Supra, Exhibit No. 1, Page 12, 13.)

I believe this completes the information requested in your letters of February 16, 1973, and February 23, 1973. If I can be of further assistance, please let me know.

Sincerely,

John W. Ross, Esq.
The Montana Power Company

JWR:mcs
Enclosures

Exhibit 4

Exhibit 4

FOOTNOTES

1. Bechtel Corporation, P. O. Box 3965, San Francisco, California.
   Mr. Tom Hamilton, Bechtel Cooling Tower Specialist
   Mr. E. L. Currier, Bechtel Diffusion Specialist.

2. Ibid.

3. Ibid.

4. Edison Electric Institute, 90 Park Avenue, New York, NY.

5. "The Economy, Energy, and The Environment", A Background Study. Joint Economic Committee, Congress of the United States, 1970, P. 9.

6. "Winter 1972-73 Loads and Resources", Montana Power Company.

7. "The Montana Economic Study of 1970", Bureau of Business and Economic Research.

8. "Environmental Reporter - Current Developments", Bureau of National Affairs, Inc., December 15, 1972, P. 941.

Exhibit 4

Exhibit 4

AIR SAMPLING NETWORK AND RESULTS

Exhibit 4

Exhibit 4

STATE DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES SOUTHEASTERN MONTANA AIR SAMPLING NETWORK

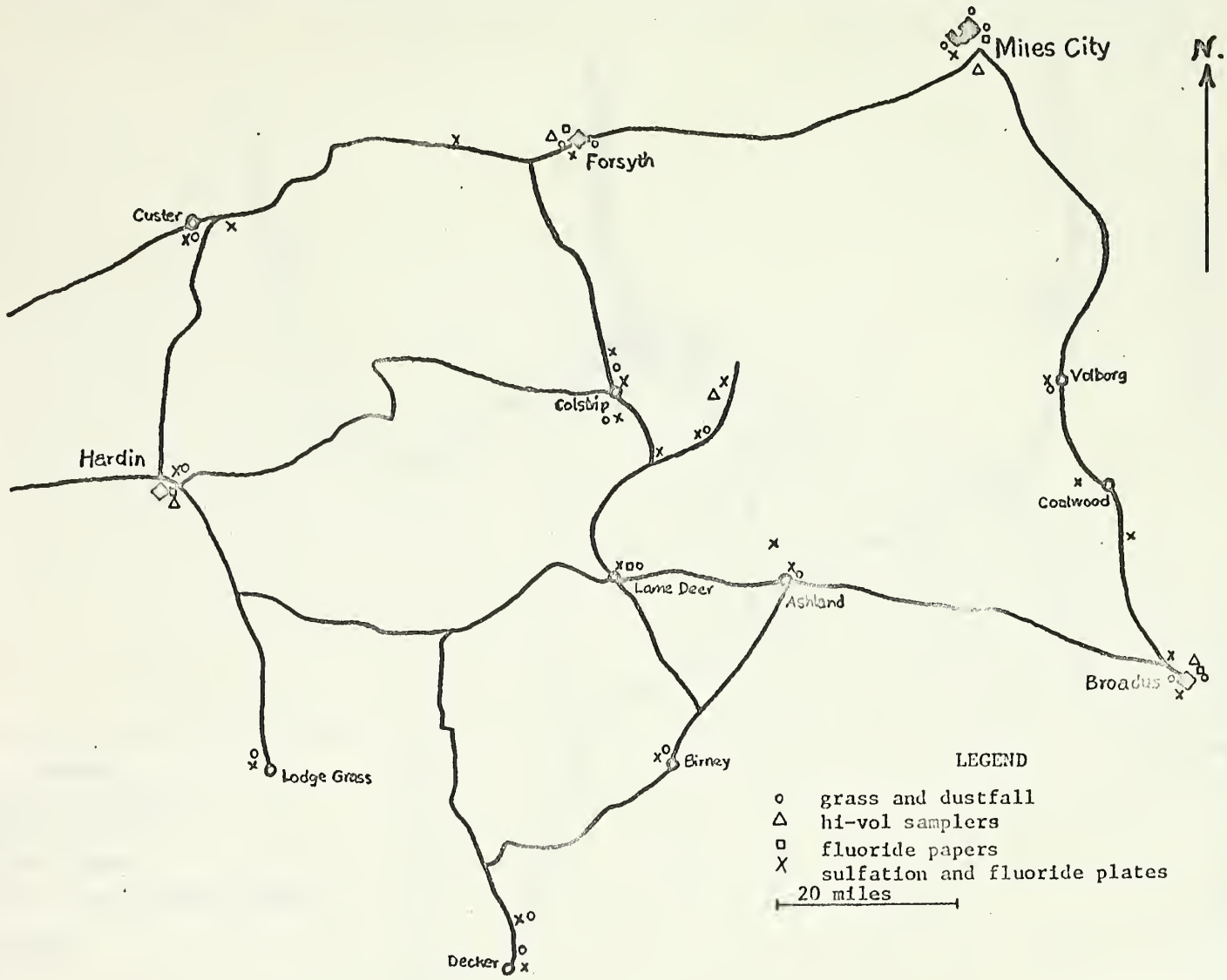

Exhibit 4

Exhibit 4

STATE DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES COLSTRIP AIR SAMPLING NETWORK

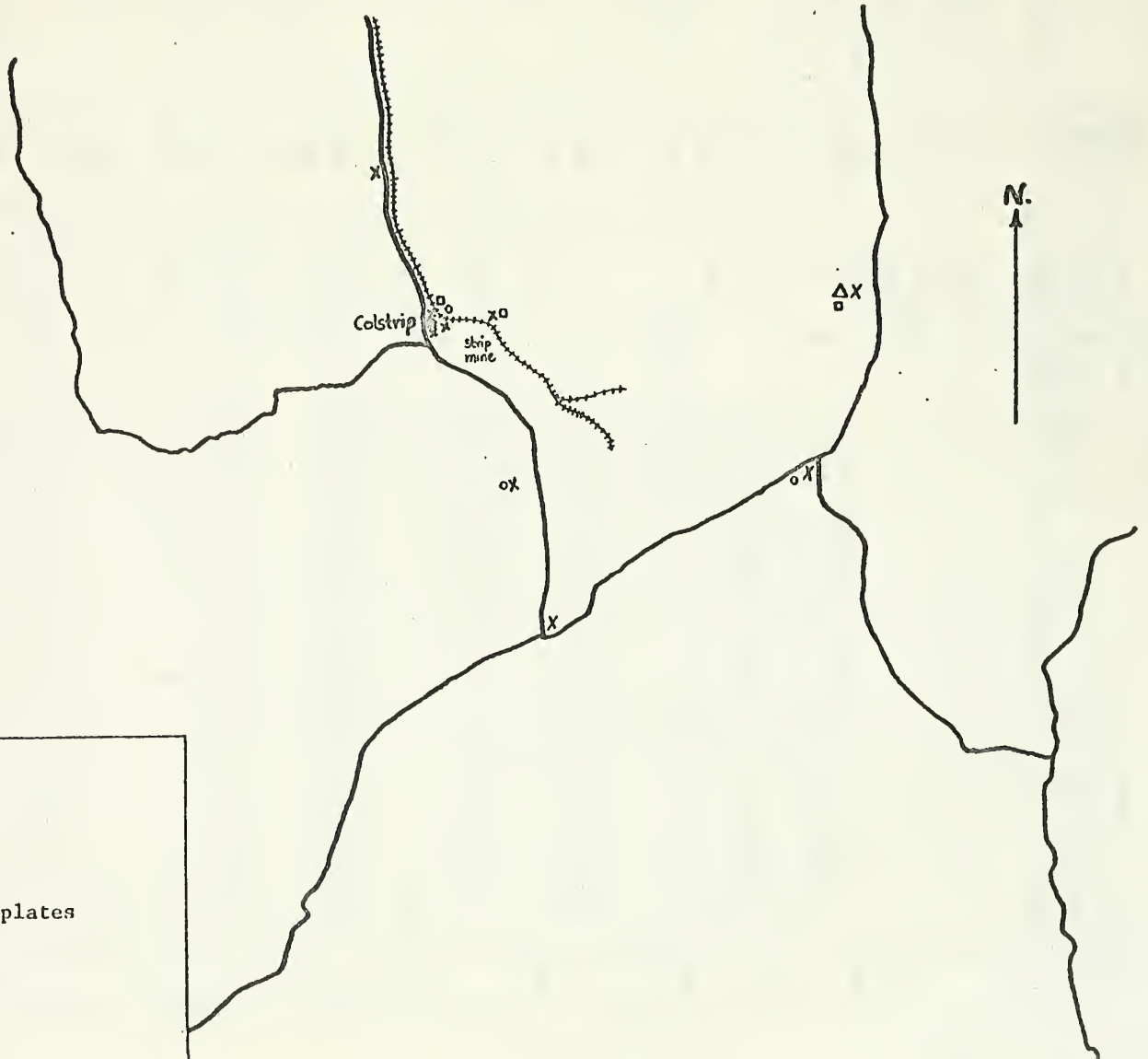

Exhibit 4

Exhibit 4

SAMPLING RESULTS

	SULPATION PLATES		F⁻ PLATES		F⁻ PAPERS		GRASS								DUSTFALLS						HI-VOLS	
										Conc. PPM								Pounds per square miles/mo.				
*($mgSO_3/100cm^2/day$) .035 = ppm	# Samples	Conc. PPM* $\bar{X}$	# Samples	Conc. $\bar{X}$ ug/cm^2/ 30 days	# Samples	Conc. $\bar{X}$ ug/cm^2/ 30 days	# Samples	Conc. PPM $\bar{X}$	# Samples	As	Pb	Cd	Zn	# Samples	Conc. T/mi²/mo. $\bar{X}$	# Samples	Cd	Zn	Pb	# Samples	Conc. $\bar{X}$ ug/m³
COLSTRIP																						
Approx. 5 miles N.	6	.0021	2	0.00																		
Water Tower Pumphouse	7	.0045	3	0.05	5	.060	3	3.2	1	0.0	11.0	0.2	33.0	4	8.6	1	0	12.0	3.6			
Western E. Office	8	.0049	4	0.00																		
Werehouse	7	.0021	4	0.00																		
Approx. 1½ miles E.	5	.0014			5	.044																
Approx. 9 miles S.	8	.0014	4	0.00																		
Kluver Ranch (9 miles E.)	5	.0024	3	0.00	5	.011														23	22.0	
Peabody E.	4	.0017	4	0.00			3	5.9	1	0.2	8.0	0.4	25.0	4	9.6	1	.22	16.0	5.2			
Approx. 8 miles SE	4	.0024	4	0.00			3	2.7	1	1.1	6.0	0.3	19.0	3	28.6	1	.22	16.0	4.4			
NO. OF COLSTRIP																						
Forsyth																						
West	5	.0045	4	0.00			3	2.2	1	1.9	20.0	0.6	58.0	4	17.0	1	.08	24.0	15.8			
East	5	.0028	4	0.00			3	11.0	1	2.2	67.0	1.2	55.0	4	19.6	1	.26	24.0	13.2			
Deport	4	.0028	2	0.00																		
Greson Res.	5	.0028			5	.045														23	68.6	
Interstate Marker 507	1	.0031																				
N.E. OF COLSTRIP																						
Miles City																						
Fish & Game	5	.0028	4	0.03			3	7.0	1	1.6	15.0	1.0	43.0	4	22.1	1	.22	58.0	12.2			
East	5	.0031			4	.016	3	3.3	1	1.1	15.0	0.7	25.0	4	25.9	1	.36	48.0	20.0			
Asay Res.	5	.0031	4	0.00			1	4.0						2	28.8					70	71.5	
Gravel Pit N.	4	.0024	3	0.00																		
EAST OF COLSTRIP																						
Volburg	5	.0021	4	0.00			3	2.9	1	0.6	11.0	0.5	26.0	4	7.2	1	.08	10.0	6.6			
Coalwood	5	.0024	4	0.00																		
Ash Creek	5	.0021																				
S.E. OF COLSTRIP																						
Broadus																						
East	4	.0035	4	0.06			3	7.9	1	1.4	9.0	0.3	27.0	4	43.1	1	.32	142.0	24.0			
West	4	.0042	3	0.00			3	9.2	1	1.9	15.0	1.0	34.0	4	47.2	1	.22	26.0	9.6			
LaPlamme Res.	4	.0028			3	.023														12	39.7	
Sewage Lagoon	4	.0059	2	0.00																		
U. S. Junction 312 & 212	5	.0024																				
Ashland																						
Power Substs.	4	.0024	4	0.03			3	5.2	1	0.3	7.0	0.7	17.0	3	12.0	1	.04	48.0	2.2			
East	5	.0024	4	0.00																		
St. Labria Mission	4	.0024																				
North	5	.0028	4	0.03																		
S. OF COLSTRIP																						
Lame Deer																						
L.D.S. Church	4	.0017																				
North	5	.0028	3	0.03																		
West	5	.0017	3	0.00																		
East	3	.0017	2	0.00	5	.033	2	6.4	1	0.0	10.0	0.2	30.0	4	10.7	1	.22	22.0	7.8			
Birney																						
Southwest	3	.0028	4	0.00																		
Northeast	4	.0024	4	0.00			3	2.6	1	0.0	5.0	0.2	19.0	3	9.5	1	.02	10.0	4.2			
Decker																						
Decker to Birney Rd.	3	.0014	3	0.05																		
Coal Co.	4	.0024	4	0.00			3	3.5	1	0.3	7.0	0.3	25.0	3	24.4							
Post Office	4	.0035	3	0.00			3	3.2	1	0.0	5.0	0.5	28.0	2	19.6							
S.W. OF COLSTRIP																						
Lodge Grass																						
West	4	.0017	4	0.10																		
East	4	.0017	4	0.00			3	10.7	1	0.0	13.0	0.7	35	2	26.1							
W. OF COLSTRIP																						
Hardin																						
West	4	.0038	4	0.08																		
MDU Sta.	4	.0045			4	.038														18	58.4	
East	4	.0038																				
Radio Tower	4	.0038	4	0.04			3	4.2	1	0.0	4.0	1.8	32	2	9.8							
N.W. OF COLSTRIP																						
Custer																						
West	4	.0056	4	0.04			3	3.5	1	0.0	16.0	0.7	34.0	4	8.6	1	.22	22.0	10.6			
Prairie Bar & Cafe	5	.0045	4	0.03																		

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Western Energy Company's Rosebud Mine
Area C, Block 1

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MONTANA DEPARTMENT OF STATE LANDS
U.S. OFFICE OF SURFACE MINING

FINAL
ENVIRONMENTAL IMPACT STATEMENT

WESTERN ENERGY COMPANY'S ROSEBUD MINE AREA C, BLOCK 1

DSL / OSM EIS-8

Prepared by
Montana Department of State Lands
U.S. Office of Surface Mining

James Harris, Director
U.S. Office of Surface Mining

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Montana Department of State Lands

JULY, 1982

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SUMMARY

(x) Draft ( ) Final Environmental Impact Statement

Montana Department of State Lands
U.S. Office of Surface Mining

Type of Action: (x) Administrative ( ) Legislative

Western Energy Company proposes to begin mining in Sections 1, 2, 3, and 11 in T1N, R40E, and has submitted a mine permit application for this proposed action. The Commissioner of State Lands and the Secretary of Interior must decide whether to 1) approve the permit as proposed; 2) approve the permit with stipulations; or 3) deny the permit or portions of the permit.

Brief Description of the Company's Proposal:

Western Energy proposes to remove an estimated 24 million tons of coal from an area of 709 acres over a period of five years. An additional 1,145 acres would be used for shop facilities, haul roads, topsoil stockpiles, boxcut and highwall reduction areas, a crusher facility, and the coal conveyor. The mine plan permit area would total 3,104 acres, 1,227 of which would not be disturbed. Coal would be transported to Colstrip Units 3 and 4 for power generation via a coal conveyor.

Mining is anticipated to begin in 1983 and proceed until 1988, and active reclamation of the area in question will continue until at least 1991.

Western Energy has not submitted to OSM or DSL a complete life of mine proposal for Area C, although the company would probably implement a 34-year mine plan during Block I mining. Over the entire Area C life of mine, approximately 5,040 acres would be mined and an additional 2,862 acres disturbed by related activities.

Summary of Impacts by Discipline:

- Geology - geologic impacts would be minor, including disruption of the stratigraphy by removal of the Rosebud coal and replacement with spoil material, general smoothing and a slight lowering of the topography, possibe creation of gullying and slumping along the highwall/backfill interface and to a lesser extent in other areas in the reclaimed spoils, a slight decrease in electrical conductivity in the near-surface material, and potential localized increases in molybdenum, nickel, or cadmium in near-surface layers.

- Hydrology - groundwater aquifers would be distrupted by mining and replaced with spoils that would have similar flow characteristics to the original aquifers. Groundwater flow would be intercepted by the pit during mining. The majority of groundwater discharge

to the pit would occur immediately after the pit is opened and would diminish with time. The water levels in the spoils would eventually reach pre-mining levels.

The concentration of total dissolved solids in the spoils aquifer would be approximately twice that of the present Rosebud coal and overburden aquifers. Spoils water would follow the regional southeast flow direction and would eventually reach Cow Creek. The quality of water in aquifers underlying the Rosebud coal would generally not be affected by the placement of spoils. Water discharging at the boundaries of the mined area to streams would have no appreciable effect upon surface water quality. However, water discharging from the spoils to the valley fill of East Fork Armells Creek would displace water in the valley fill and would increase concentrations of total dissolved solids.

In general it is anticipated that few surface water changes would occur during the first five years of the Area C permit period. The probable impacts to the surface water hydrology over time would include a decrease in the total volume of runoff from the mined areas, a reduction of peak flow magnitudes, and the near-total removal of sediment introduced to the streams from the mined areas, all due to the placement of sediment ponds. Sediment ponds may also cause an episode of high erosion upon removal. Seepage from the proposed fly ash pond associated with additional power generating facilities in Colstrip would constitute an indirect impact of mining. Possible increases in salinity attributed to pond seepage could have detrimental impacts on Cow Creek.

- Climate - mining in Area C would have no impact on the climatic regime in the area.

- Air quality - a slight increase in fugitive dust would occur in the locality of the mine. Projected levels would be far below federal and state air quality standards and would represent a minor impact. Impacts to the townsite of Colstrip and to the Class I area (the Northern Cheyenne Indian Reservation) would be below detection limits.

- Noise - increased noise levels due to construction, operation of mining equipment, or blasting would be audible only near the site and would not influence the noise levels presently occurring in Colstrip.

- Soils - soils of the area would experience mixing and some alteration of chemical and physical properties. These changes would influence the post-mining potential for crop production and might limit the successful establishment of conifers or warm-season grasses. Organic matter of the soils would decrease, bulk densities might increase, and nutrient cycling in the soil would take a number of years to reach equilibrium.

- Vegetation - impacts to vegetation would include a temporary disruption of vegetative cover and reestablishment of vegetation dominated by productive cool-season grasses and legumes. Most crop and pasture areas would be replaced with native grasses and legumes. Forage production would increase with an accordant increase in the grazing capacity over pre-mine levels, but may not equal the potential forage productivity that could be achieved on the existing range sites. There would be a likely decrease in warm-season grasses when compared to pre-mine conditions and a significant decrease in the potential for warm-season grasses on the post-mined soils. Shrub cover would decrease and there would be fewer areas of ponderosa pine in the post-mined areas.

- Wildlife - several wildlife habitats would be temporarily destroyed by the project, and a long-term reduction in ponderosa pine stands and shrub habitats and their associated wildlife would result in the mined area. Sharp-tailed grouse dancing grounds may be substantially disturbed. An inactive golden eagle nest may experience some secondary impacts due to nearby mining activities. Continuation of mining through the remainder of Area C would destroy an eagle's nest and two sharp-tailed grouse dancing grounds.

- Sociology and economics - population increases contributed by the project would be greatest in the second quarter of 1983, and would postpone but not prevent the decline in population due to completion of Colstrip power generating Units 3 and 4. Social impacts would be small due to the similarity of existing and incoming work forces and is not expected to significantly affect the level of services required. An 11 percent increase in revenues or expenditures could be expected for any given year.

- Land use - the mine and associated disturbances would displace 606 acres of cropland, of which all but 60 acres would be reclaimed to rangeland following mining. Temporary displacement of grazing would occur over much of the area to be mined, to be restored in some reclaimed areas prior to bond release and in the entire area after mining is completed.

- Transportation - four miles of East Fork Castle Rock Road would be permanently relocated. Current daily traffic volumes would increase by less than five percent during both construction and operation phases of the mine.

- Recreation - recreation resources in Colstrip and Rosebud County are presently insufficient to serve the existing population. The project would serve to prolong the period of high population, thus extending these use pressures; however, the anticipated decline in Colstrip's population by 1985 or 1986 due to completion of Units 3 and 4 and winding down of Area C construction would reduce all of the project-related population increases.

- Cultural resources - Nine cultural resource sites are located within Area C, Block 1, and 25 are located within a one-mile buffer zone around Area C, Block 1. Seven of the nine cultural resources within Area C, Block I woould be partially or totally destroyed. Of these seven sites, four appear to be eligible for the National Register of Historic Places, four do not appear eligible, and one needs additional work before an eligibility determination can be made.

  Eleven of the 25 cultural resources sites within the one-mile buffer zone contain rock art or standing structures and coule be affected by blasting. Another site, not containing rock art or standing structures, will be directly impacted by road relocation. Of these 12 sites that may be impacted, two have been determined and one appears to be eligible for the National Register.

- Aesthetics - the landscape would experience an alteration in color, contrast, and texture due to the reduction or loss of ponderosa pine, shrub areas, and sandstone outcrops, none of which are intrinsically unusual for the region.

Relationship between short-term uses of the environment and long-term productivity:

The 166 million tons of coal mined from Area C would serve as the sole source of fuel to be burned in Colstrip generating Units 3 and 4. This short-term use of the Block I mine site would last through 1988, when mining in Area C, Block I would end, and through 2017 for all of Area C when the economically recoverable coal would be exhausted. If the mine area were not disturbed, it would continue to produce winter wheat, livestock forage, wildlife habitat, and limited scenery. Crop production, wildlife habitat, and scenic value will be reduced after reclamation. Compared to the pre-mining (1978) conditions, productivity for livestock grazing would increase, however the potential productivity of the post-mined area would be lower than the pre-mining potential, primarily due to the loss of discrete sandy soil areas.

Irreversible and irretrievable commitments of resources:

Under the Block I proposed mine plan, the mine would produce 23.7 million tons of coal from the Rosebud seam and leave 9.6 million tons of the lower quality McKay coal seam, for which no current market exists. Future mining would be unlikely if a market became available, due to very high overburden thickness. For the entire Area C life of mine, about 166 million tons of coal would be recoverdd from the Rosebud seam. About 66 million tons of coal would be left in the McKay seam. The McKay seam would probably not be mined in the future.

If federal leases become available adjacent to the Block I area, overburden averaging might allow recovery of additional coal that is considered unminable under the proposed Block I mine plan. If this

Exhibit 3

option becomes available after the mining of Block I, a significant amount of coal in these areas would be unavailable for future mining.

The existing stratigraphy would be permanently altered, however, the stratigraphy is not unusual or intrinsically valuable. The existing topography would be altered, and mixing of stratigraphy and overburden would alter the character and land use potential of the reclaimed surface. The likelihood of establishing a vigorous productive vegetative cover is excellent, however vegetative diversity and successful establishment of conifers or certain shrubs may be limited after mining.

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CHAPTER I

DESCRIPTION OF THE PROPOSAL UNDER CONSIDERATION

A. SCOPE OF THE ANALYSIS

Western Energy Company (Western Energy) has applied to the Montana Department of State Lands (DSL) and the Office of Surface Mining (OSM) for a surface mine permit for Area C, Block I of its Rosebud Mine near Colstrip, Montana (Figure I-1). The company proposes to permit a five-year mine area encompassing 2,693 acres referred to as Block I, as shown in Figure I-2. The sequence of mining proposed for Block I is depicted in Figure I-3.

Under the provisions of the Montana Strip and Underground Mine Reclamation Act, DSL must approve the mining and reclamation plan (hereafter called the "mine plan") for the proposed Block I mine area before mining or related facility construction can begin. Federal approval to begin mining must be obtained from the U.S. Department of the Interior, Office of Surface Mining (OSM). In addition, the federal coal lease in Section 2 T1N, R40E will have to be renewed in August of 1986.

The Block I mine plan was submitted by Western Energy as a complete life of mine plan, scheduled to be terminated with complete reclamation of the proposed five-year mining area. This mining plan was developed and submitted because the company did not have federal coal leases in Sections 4 and 10, T1N, R40E or Section 12, T1N, R41E. Without these key leases, continuous mining directly from Block I through the remaining 5,300 acreas of Area C would not be economically feasible.

On April 28, 1982 the Bureau of Land Management held a coal lease sale at which Western Energy submitted the apparent high bid for these and other parcels. The issuance of leases usually follows a sale by several months. This sale has been challenged and may delay or prevent issuing the leases. Nevertheless, it appears reasonable to assume that the company may eventually obtain these leases and implement the 34-year life of mine plan for Area C, known as Block II.

The Block II mine plan would begin in the proposed Block I permit area during the second year if the company obtains the leases prior to completing the third mining cut. A comparison of Figures I-3 and IV-1 will illustrate the reorientation of the mining pits required to initiate the Block II plan.

The pit realignment and its environmental effects within the proposed Block I mine area are discussed in Chapter IV, Section B.

This EIS is designed to serve as an informational and environmental document for the OSM, DSL, and the general public, in compliance with the National Environmental Policy Act (NEPA) and the Montana Environmental Policy Act (MEPA). Technical Support Documents for this EIS are available for public review at several locations (listed in Chapter V) throughout the state. Prior to approval of the surface mining permit

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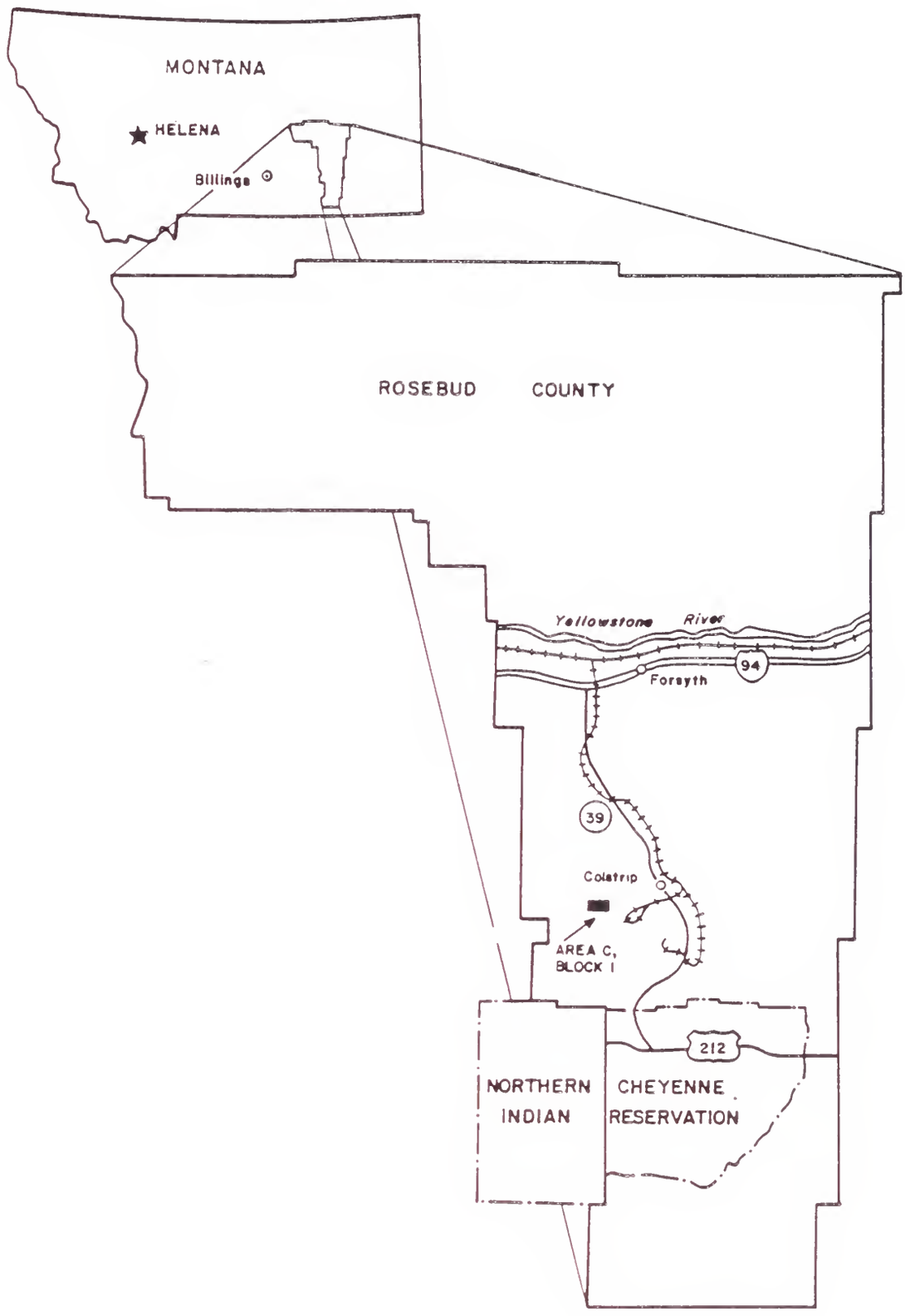

FIGURE I-1 LOCATION OF AREA C, BLOCK I

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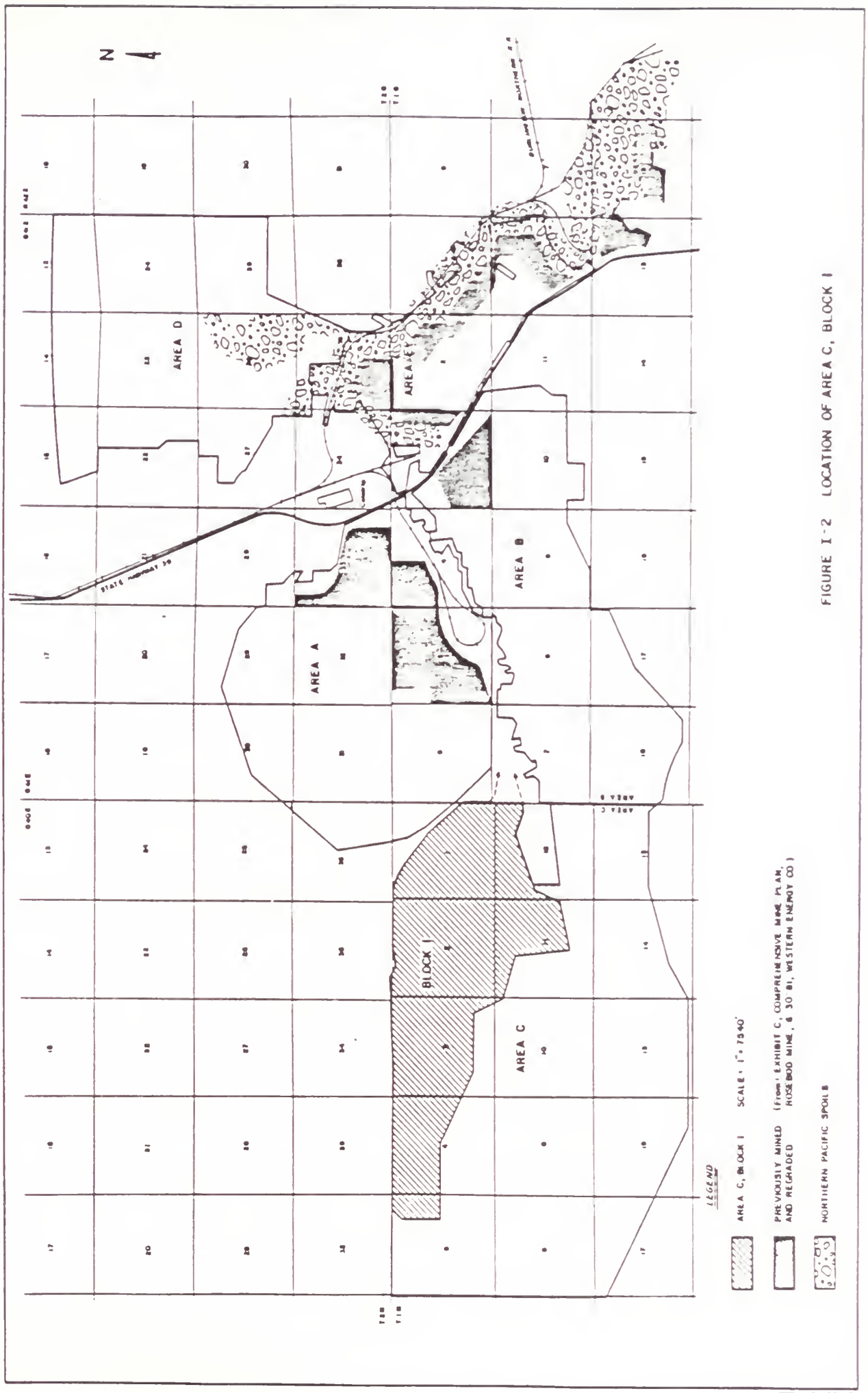

FIGURE I-2 LOCATION OF AREA C, BLOCK I

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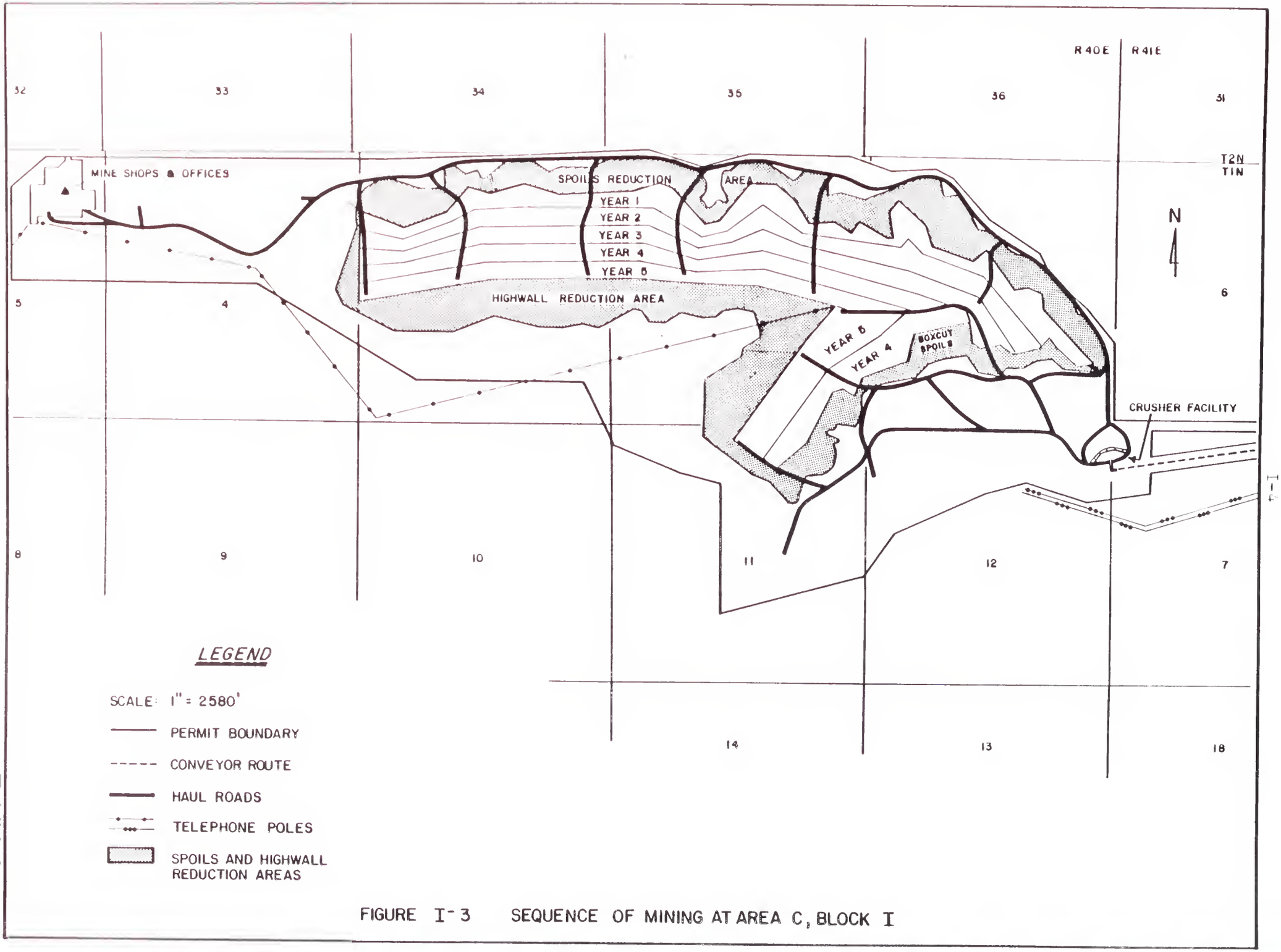

FIGURE I-3 SEQUENCE OF MINING AT AREA C, BLOCK I

Exhibit 3

application, a findings of compliance with the federal and state surface mining statutes must be made by the regulatory agencies (OSM and DSL). Approval of the permit is a process separate from the EIS.

Only two other permits are required to conduct the proposed surface mining operations, aside from the surface mining permit: an air quality permit and a water pollutant discharge permit, both of which are issued by the Montana Department of Health and Environmental Sciences (DHES). The DSL has entered into a Memorandum of Understanding with the Department of Health and Environmental Sciences stating that the Area C, Block I EIS will satisfy the Air Quality Bureau's MEPA needs regarding the issuance of an Air Quality Permit.

Western Energy has applied to the DHES to amend the existing air quality permit for the Rosebud Mine (Permit #1483) to include the proposed activities at Area C, Block I. Western Energy will also be applying for a water pollutant discharge permit from DHES. Although DSL does not issue air and water quality permits, the agency can require measures to control fugitive dust and water pollution from mined lands and reclaimed areas.

Previous EISs have been prepared for mining and mining-related projects in and adjacent to the Rosebud Mine, and have been used in the preparation of this document. Among these are the Northern Powder River Basin EIS (U.S. Department of Interior, 1979), the Colstrip Project EIS (U.S. Department of Interior, 1979), the Rosebud Mine Area B Extension EIS (MDSL, 1980), and the Rosebud Mine Area E Extension EIS (MDSL, 1981). The Colstrip Project EIS (1979) specifically addresses the potential impacts of mining in Areas C and D of the Rosebud Mine.

Presently, in addition to this site-specific EIS, a comprehensive EIS is being prepared to evaluate the impact of mining at the Rosebud Mine for the life of the mine, through the year 2017. The comprehensive EIS will address the cumulative impact of all proposed mining activities at the Rosebud Mine in relationship to all other mining and industrial activities in the area around the Rosebud Mine (Figure I-4). Several EISs for other projects in the Rosebud County area are currently in progress or proposed, including Western Energy's Area B and MONTCO's EIS. The impact from these proposed mine areas, the Big Sky Mine, and other projects for which no EISs are available were considered during the preparation of this EIS. The locations of other active mines close to the Rosebud Mine are depicted in Figure I-4.

B. MINE HISTORY

Surface strip mining of the coal resource was begun in the Colstrip area by Northern Pacific Railroad. During the period from 1924 to 1958, Northern Pacific extracted approximately 44 million tons of coal from the Rosebud seam to be used for steam locomotives and domestic purposes, resulting in approximately 1,800 acres of surface disturbance.

When the Northern Pacific Railroad changed from steam locomotives to diesel locomotives, mining ceased. In 1959, the mining leases and the townsite of Colstrip were purchased by Montana Power Company (MPC). In

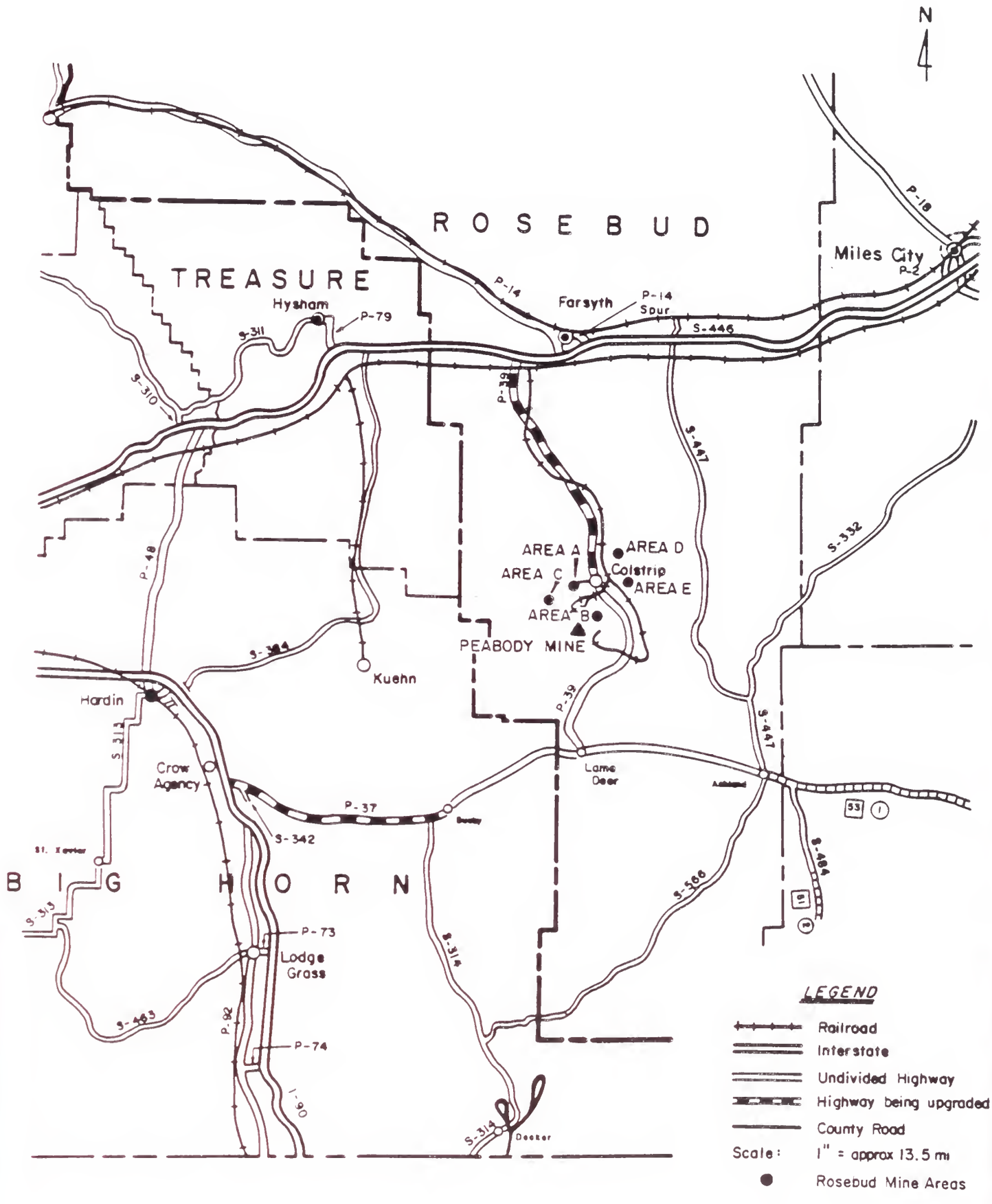

FIGURE I-4 LOCATION OF PEABODY MINE IN RELATION TO THE ROSEBUD MINE AREA

Exhibit 3

1966, Western Energy, a wholly owned subsidiary of MPC, was formed to manage and develop the properties. In 1968, Western Energy began mining the coal of the Rosebud seam adjacent to Northern Pacific's old workings in an area called Pit 6. Western Energy has subsequently completed mining in Pit 6, and has expanded mining of the Rosebud seam in Areas A, B, and E. Numerous permits have been granted and numerous EISs written related to mining in these areas. Copies of each permit application and EIS are on file with DSL in Helena, Montana.

Table I-1 shows the approximate projected annual coal production by year from Area C, Block I during the period from 1983 through 1988 and the approximate annual production in five year increments for the remainder of Area C.

C. WESTERN ENERGY COMPANY'S PROPOSAL

1. Summary

Western Energy's proposed Area C, Block I mine is in southwestern Rosebud County, Montana, about five miles west of the town of Colstrip (Figure I-4). Coal would be transported by conveyor from the mine to MPC's Colstrip power generating facility, Units 3 and 4, a distance of about four miles, and would become the sole source of fuel for these units.

Coal production from Area C, Block I would average 4.7 million tons of coal per year over the five-year mining period, ranging from 3.8 million tons for the first year to 5.6 million tons for the fifth year. These reserves would be mined through the year 1988 at an average annual rate of 4.7 million tons per year. The probable life of mining activities in Area C is expected to be at least 34 years, with the anticipation that successive five-year mine blocks would be permitted sequentially after Block I.

Of the six coal seams underlying the proposed mining area, only the uppermost two, the Rosebud and the underlying McKay, are of economic importance. Western Energy mines only the Rosebud seam, because a market has not been found for the McKay coal, which has a higher sulfur content than the Rosebud coal and has a tendency to form slag in some steam boilers.

The land surface in Area C, Block I is owned by Burlington Northern, Inc. and Farley's, Inc. The coal to be mined is leased by Western Energy from Burlington Northern and the federal government. Surface ownership and coal leases for Area C are shown in Figures I-5 and I-6, respectively.

The increased labor force required for early construction phases would be approximately 300 to 400 people, with a net increase of approximately 200 people to operate the mine and support facilities.

TABLE I-1

APPROXIMATE ANNUAL PRODUCTION BY YEAR

Year		Five Year Plan Production (Million Tons)
1	9/83-8/84	3.8
2	9/84-8/85	4.0
3	9/85-8/86	4.8
4	9/86-8/87	5.5
5	9/87-8/88	5.6
		23.7

Years	Life of Mine-Area C Tons (Million)
1 - 5	24
6 - 10	28
11 - 15	25
16 - 20	23
21 - 25	23
26 - 30	23
31 - 34	20
	166

Exhibit 3

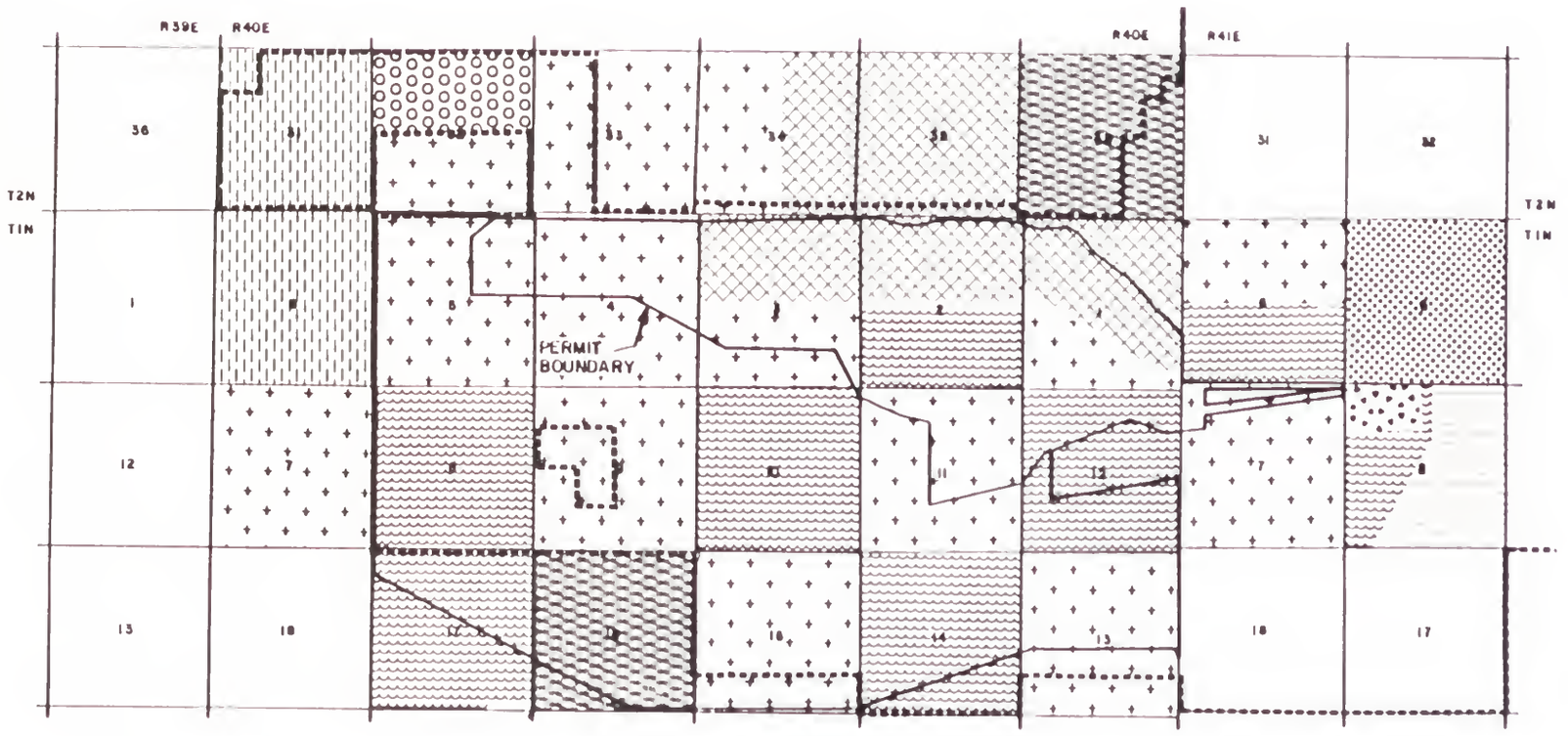

FIGURE I-5 -- SURFACE OWNERSHIP AT AREA C, BLOCK I

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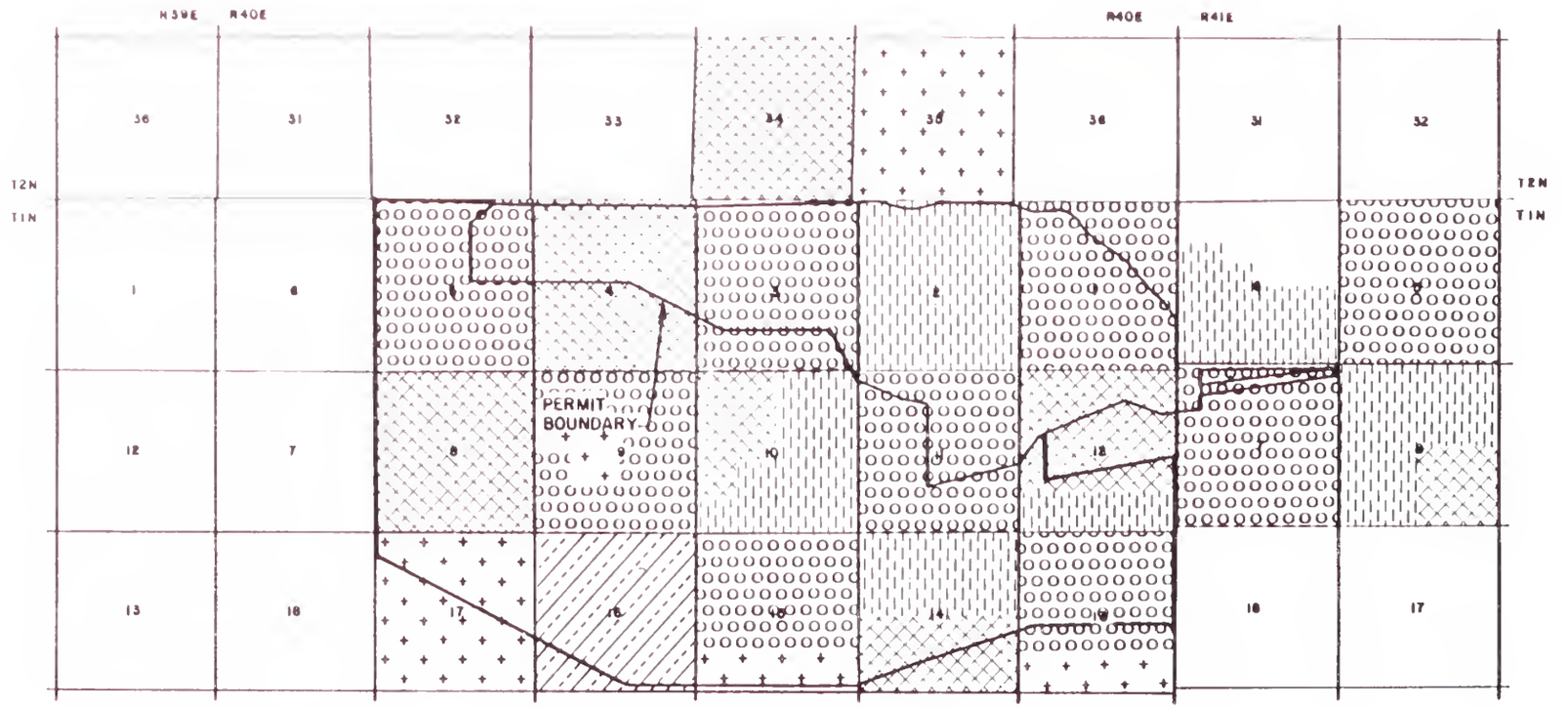


FIGURE I-6 -- COAL LEASES AT AREA C, BLOCK I

Exhibit 3

2. Facilities

Western Energy plans to construct two separate facility complexes to support the Area C, Block I mine operation: (1) a shop and office facility; and (2) a coal crusher and conveyor facility, with an associated overland conveyor corridor beginning at the crusher facility and extending a distance of four miles to MPC's electric generation Units 3 and 4 (Figure I-7). All but one mile of the conveyor system will pass through areas presently permitted to Western Energy in Areas A and E. Facility construction is scheduled to begin in August of 1982 and will be completed by July of 1983.

The new shop and office facilities will include:

- An office building
- A parts warehouse, with adjoining storage yard
- A lubricant storage building, with adjoining fuel storage tanks
- An equipment repair building
- A machining and welding building
- A crew change building, with adjoining parking lot
- A sewage treatment facility
- Adjacent parking facilities

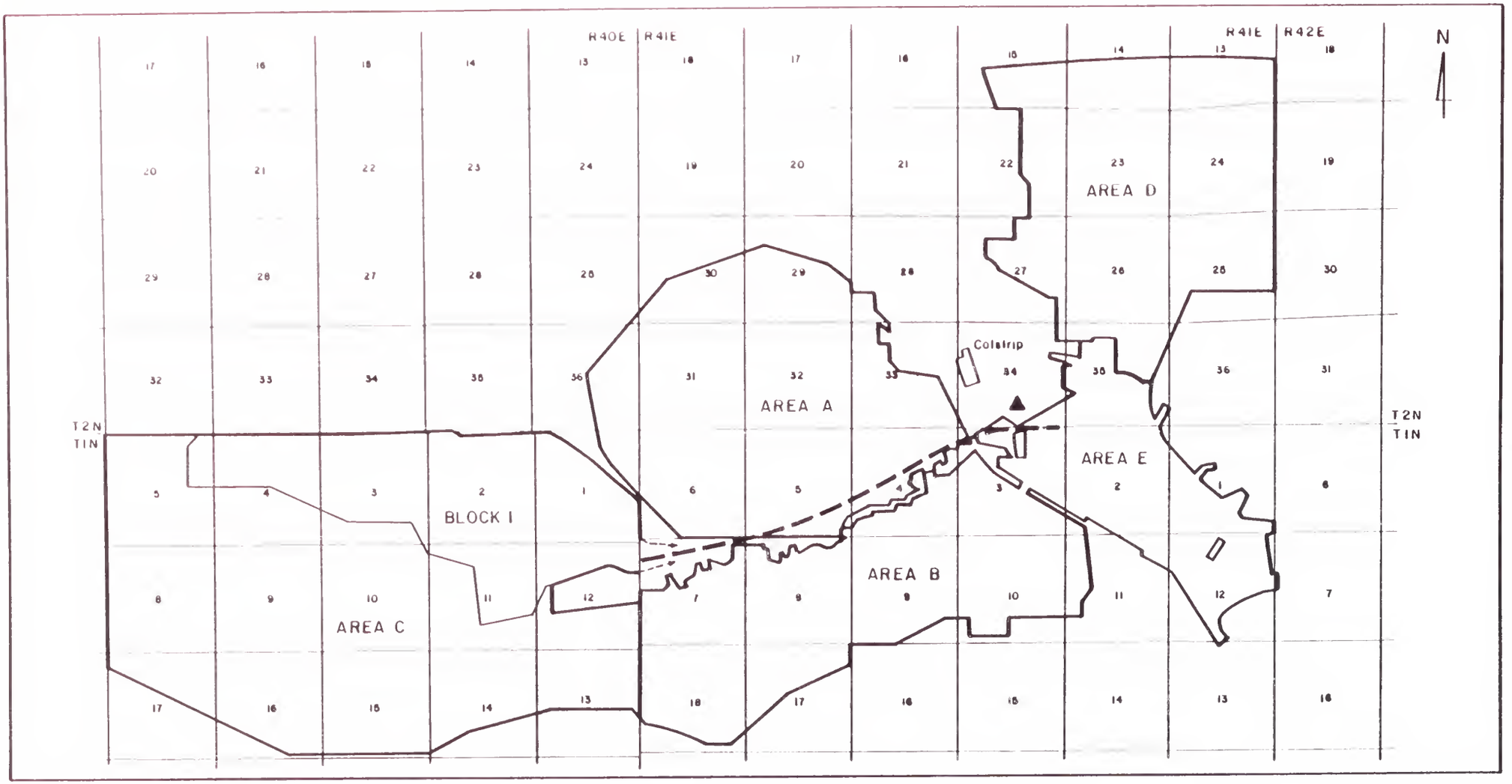
Facilities to be included in the new crusher complex are:

- Fuel storage tanks
- Negative air pressure truck dump
- Primary crusher
- Secondary crusher
- Beginning of an overland conveyor

3. Mining Plan

Western Energy's mine plan is a five-year plan to conduct surface mining operations in Area C, Block I of the Rosebud Mine. Block I is located in Sections 1, 2, 3, 4, 5, 11, and 12 of T1N, R40E and Section 7 of T1N, R41E. The permit area addressed in the mine permit application encompasses 2,693 acres, of which 709 acres are proposed to be mined, and an additional 918 acres are planned to be disturbed as a result of mining-related activities, including a shop complex, crusher complex, haul roads, topsoil storage areas, boxcut, and highwall reduction areas. Approximately 1,066 acres within the permit area will remain undisturbed under this mine plan. Additionally, the conveyor corridor would occupy about 226 acres, running 4.5 miles from the Area C, Block I mining area to Colstrip power generating Units 3 and 4.

It is planned that a total of 23.7 million tons of coal from the Rosebud seam will be mined from Area C, Block I as a dedicated fuel source for Colstrip Units 3 and 4. Western Energy has proposed a typical single pass dragline operation as the optimum method for coal recovery. Extraction of the reserves lying within this mine plan area will be



LEGEND

CONVEYOR ROUTE

▲ LOCATION OF MPC GENERATING UNITS

SCALE: 1"= 7540'

FIGURE I-7 CONVEYOR ROUTE, ROSEBUD MINE, MONTANA

Exhibit 3

accomplished by the area strip mining method, which is used in all of Western Energy's operations at Rosebud Mine. The maximum production rate will be approximately 5.6 million tons of Rosebud coal per year, which will be attained during the fourth and fifth years of production.

The mine plan calls for developing a boxcut with a dragline along the coal outcrop line (see Year 1 in Figure I-3). The overburden from the boxcut (or first cut) would be placed on an area outside the coal outcrop line directly adjacent to the boxcut. Successive pits would parallel the boxcut, progressing into deeper overburden to the south and northwest through Year 5 as shown in Figure I-3. Overburden from each successive dragline cut would be placed in the previous pit after removal of the coal. As new federal leases become available to Western Energy in Area C, it is intended that an amended mine permit application would be submitted, showing an adjustment to the orientation of the pits, whereby more coal would become available for mining.

Topsoil and subsoil would be stripped in advance of each pass in two separate lifts. The average depth of topsoil stripped will be six to eight inches. Topsoil stripping will be accomplished by scrapers that will strip, transport, and deposit the topsoil on regraded areas or in topsoil storage areas. Crawler tractors will be used as needed to assist the scrapers in loading.

After topsoil has been removed from a sufficient area, subsoil will be removed to an average depth of 2.5 feet. Overburden will be drilled and blasted in preparation for stripping. The rubblized material will then be stripped using a dragline, assisted at times with mobile diesel equipment. This overburden will be cast into the empty pit remaining from the preceding cut after the coal has been removed. Overburden will be regraded to approximate original contour to comply with Montana's Strip and Underground Mine Reclamation Rules and Regulations as soon as adequate working room is available. Regrading will lag behind the mining operation by two spoil ridges during normal operations.

As the Rosebud coal seam is exposed in each pass, the coal will be drilled and blasted, and will then be excavated by loading shovels or mobile diesel equipment. These machines will load the coal into coal haulers, which will transport the coal to the new crusher facility for sizing to three-inch minus. The final product will be loaded onto the new overland conveyors for shipment to Colstrip Units 3 and 4.

The final cut will be backfilled and regraded using crawler tractors and scrapers. Final slopes no greater than 5:1 (20 percent slopes) will be achieved using material from the highwall reduction zone and final spoil ridge. Western Energy uses a 22 percent swell factor in calculating the post-mine topography.

4. Reclamation Plan

To comply with the Montana Strip and Underground Mine Reclamation Act, Western Energy must reclaim and restore all lands disturbed by

mining. Western Energy's proposed reclamation program includes topsoil and subsoil salvaging, backfilling, regrading, highwall reduction, drainage reconstruction, subsoil and topsoil redistribution, revegetation, and monitoring.

Western Energy is committed to a soil sampling program just prior to soil salvaging, in which a majority of the soils will be sampled using a Giddings soil sampler for electrical conductivity and texture. The results will be used to determine topsoil and subsoil salvage depths. As an erosion abatement technique, soils with excessively high sand content will be salvaged separately and placed on slopes of less than ten percent, away from drainage channels.

Prior to mining, soil will be salvaged using scraper haulers to the depths identified and staked during the pre-salvage sampling program. Spoil will be leveled using crawler tractors, and the final spoil surface scarified using bulldozer-mounted ripper bars. Salvaged soil will be hauled to a prepared regraded spoil surface or to a designated stockpile location. After subsoil and topsoil have been placed, the soil will be prepared by chisel plowing and discing using a farm tractor.

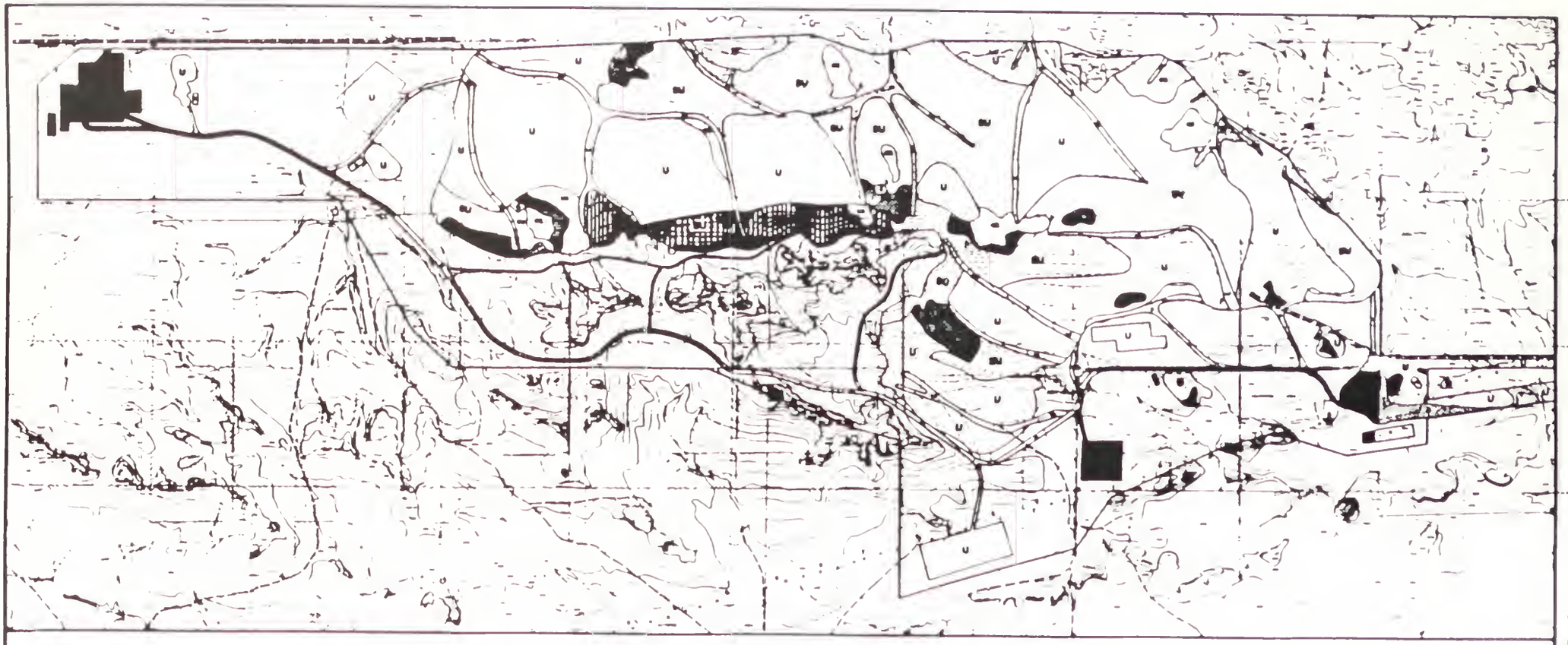
Revegetation of disturbed areas will be designed to return the land to livestock grazing and wildlife habitat uses. In a first phase of seeding, forbs, shrubs, and less competitive grasses will be planted using a Brillion seeder. Mulch will be applied on those areas with slopes exceeding ten percent using a modified stakprocessor. After an establishment period of one to three years, competitive cool-season grasses will be interseeded with a rangeland drill into the established first-phase seeding. In addition, patches of sandy soil materials of one acre or less will be seeded to a mixture of warm-season grasses adapted to sandy soils. Where feasible, existing shrubs and trees from areas to be disturbed will be transplanted to bottomlands and scattered upland areas using a tree spade. In addition, nursery-grown shrubs and tree tubelings will be used to reestablish shrub and woodland vegetation types. The areas to receive seedlings and the seed mixes included in Appendix G are shown on Figure I-8.

D. AREA C LIFE OF MINE PLAN

Western Energy has not formally submitted a life of mine plan for Area C beyond Block I to OSM or DSL. Figure I-9 shows the generally anticipated mining sequence and location for all mining in Area C, tentatively identified by Western Energy for comprehensive planning purposes.

Mining under the 34-year life of mine plan would recover approximately 166 million tons of coal (Table I-1). All coal from Area C would be transported to Colstrip generating Units 3 and 4 by the conveyor belt proposed in the Block I plan.

During the Area C life of mine under the Block II plan, coal production would proceed at an average annual rate of 4.9 million tons per



LD

U

SU

CZ

SHRUB LIST & NUMBERS

211 WYOMING BIG SAGE

212 SILVER SAGE

213 SKUNKBUSH SUMAC

214 RUBBER RABBITBRUSH

830 SMALL GRAIN FIELD

WILDLIFE ENHANCEMENT

S

FIGURE I-8 POST-MINE WILDLIFE ENHANCEMENT AND REVEGETATION, AREA C, BLOCK I
ROSEBUD MINE, MONTANA

Exhibit 3

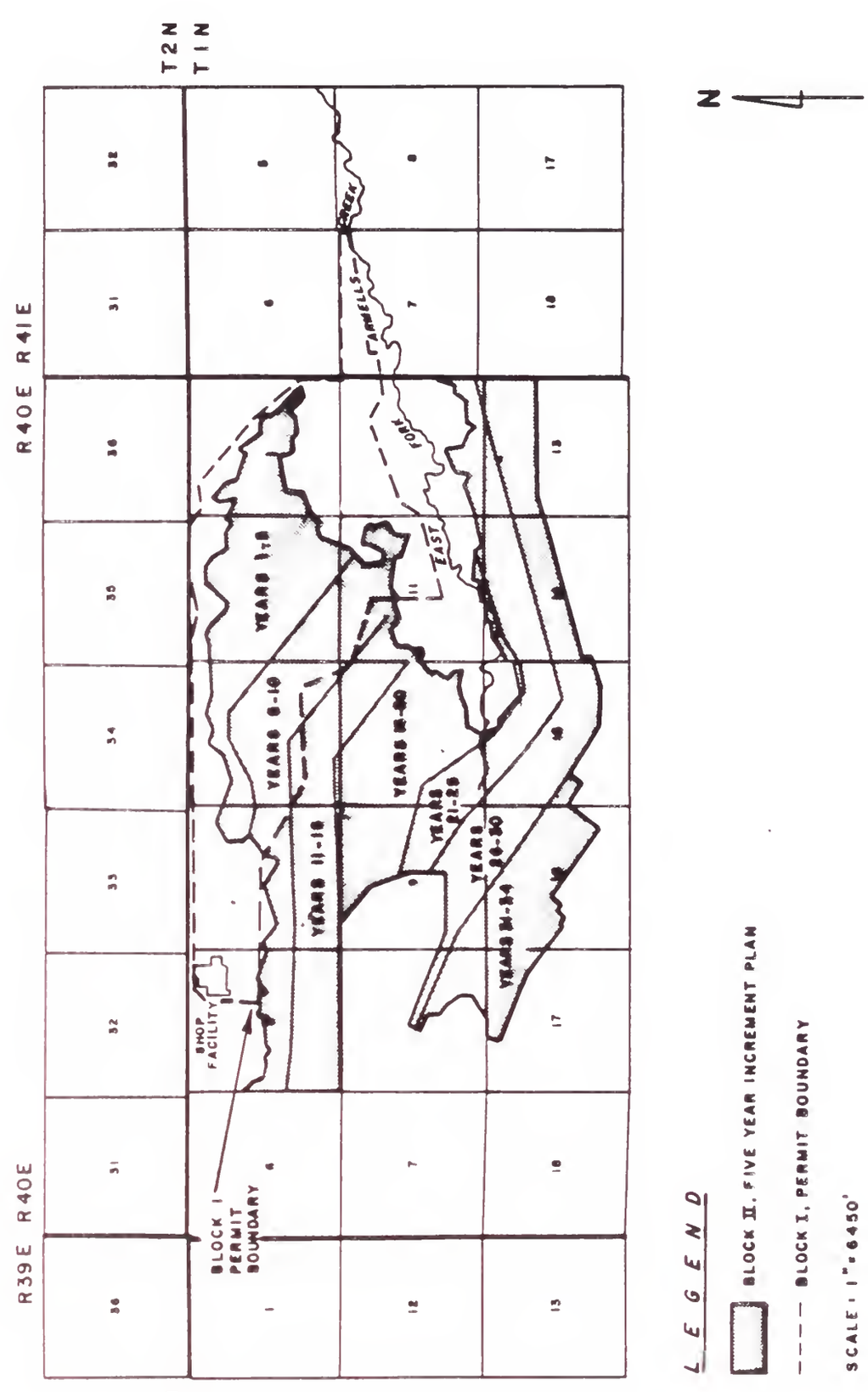


FIGURE I-9 -- BLOCK II, AREA C. LIFE OF MINE PLAN

Exhibit 3

year, resulting in an annual disturbance of approximately 148 acres. A total of approximately 5,040 acres would be mined in 34 years. In addition, about 2,862 acres would be disturbed by facilities, roads, the conveyor system, boxcut spoils, and highwall reduction activities. In Area C, a total of some 7,900 acres would be disturbed. No major facilities in addition to those proposed under the Block I plan would be required.

At any one time, mining and related disturbances would result in as much as one-eighth of the total 7,900 acres having no vegetative cover. This would include the period between initial topsoil salvage and seeding of the replaced soil on the regraded surfaces. Seeding failures caused by drought or other factors could increase the total areas not protected by vegetation.

Exhibit 3

CHAPTER II
DESCRIPTION OF THE EXISTING ENVIRONMENT

A. GEOLOGY

The proposed mine site is located on the gently-dipping northwest flank of the Powder River Basin. Geologic formations that are exposed in the lease area are limited to the Tongue River Member of the Paleocence Fort Union Formation, and Quaternary Alluvium. Other formations in the region and subsurface mine area are described briefly in the columnar section depicted in Figure II-1.

1. Topography/Geomorphology

The Rosebud Mine lies within the unglaciated Missouri Plateau, a division of the Northern Great Plains Physiographic Province (Fenneman, 1931). The topography of this region is described by Keefer (1974) as being characterized by open high hills, with low to moderate relief.

Area C, Block I lies within the drainage basins of East Fork Armells Creek and Stocker Creek, both of which are intermittent streams draining away from the permit area in a northeasterly direction. Stocker Creek empties into East Fork Armells Creek north of the permit area and East Fork Armells Creek runs generally north from there to the Yellowstone River. No other drainages would be affected by the proposed mining activities. The drainage divides of East Fork Armells Creek and Stocker Creek drainage basins are formed by either prominent ridges of sandstone or resistant clinker caprock, or more rounded hills developed on siltstone units. Small ephemeral drainages start from close to these upland crests and drain toward the main channels. Elevations within the Area C, Block I permit area range from 3,440 feet to 3,680 feet.

The landforms in Area C have developed on the essentially flat-lying Tertiary sediments of the Fort Union Formation, and can be divided into five major map units. The characteristics of these units are summarized in Table II-1. Each landscape unit reflects modern processes acting on surficial materials with different geologic and geomorphic histories.

The most stable unit in the permit area is the Sandy Valley Bottom Unit (B_1), which covers 18.9 percent of Area C. The low sediment yields from this unit are a consequence of the high infiltration rates, low drainage densities, and gentle gradients characteristic of this landscape component. The silty residual upland unit (U_2), comprising 49.1 percent of Area C, is the most unstable unit. A moderate volume of runoff and sediment is derived from this unit. The relative unstability of this landscape component is partly a consequence of its geologic history. Incision due to base level lowering has removed any protective surficial deposits, exposing the underlying bedrock. On these residual slopes blanketed by soils with low infiltration capacities, hill slope erosion processes dominate, resulting in increased sediment yields. A dense vegetation cover (40 percent) appears to play an important role in moderating erosion within this unit.

Exhibit 3

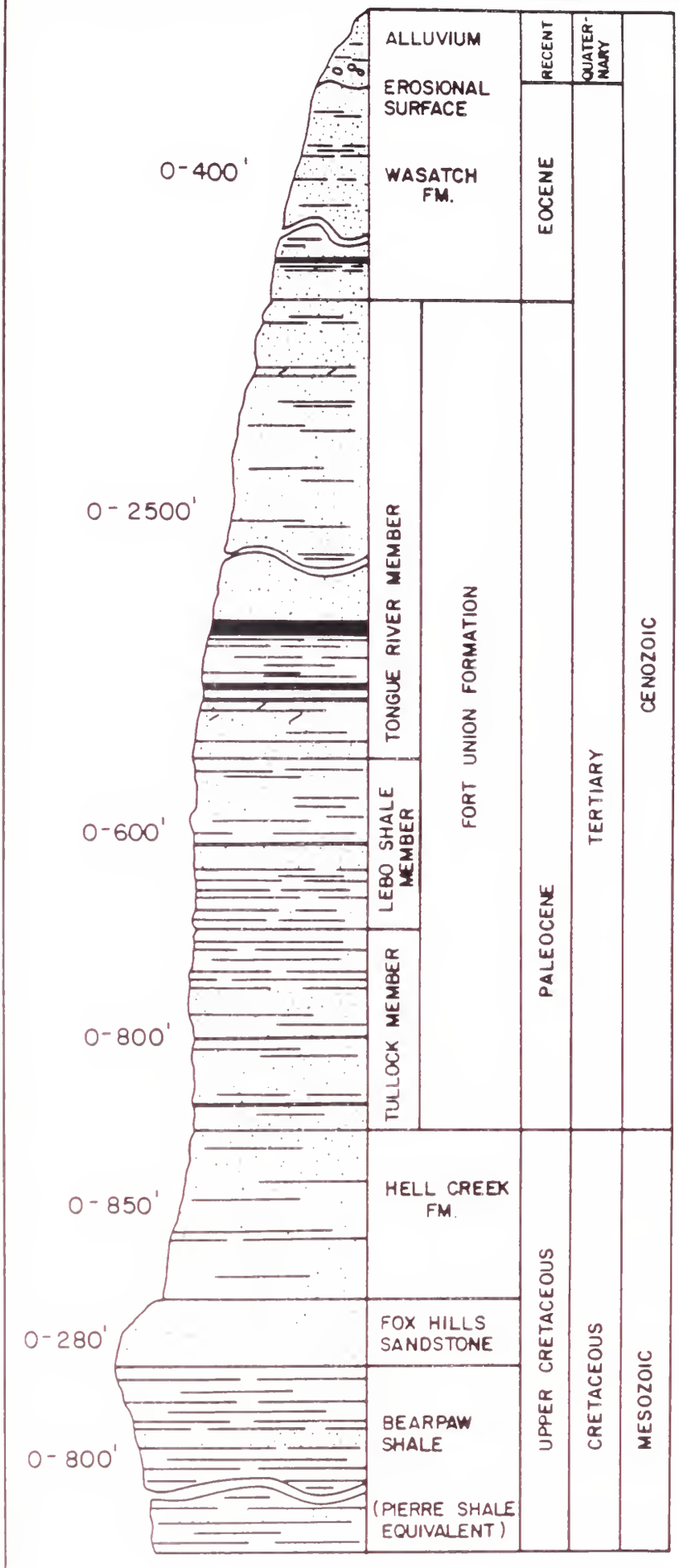


FIGURE II-1

GENERAL COLUMNAR SECTION OF UPPER CRETACEOUS AND CENOZOIC ROCKS IN THE COLSTRIP AREA, NORTHWESTERN POWDER RIVER BASIN, MONTANA
(After Lewis and Roberts, 1978)

ALLUVIUM - Sand, silt, clay, and local gravel lenses and benches.

WASATCH - Brownish-gray to light-gray, fine- to coarse-grained lenticular beds of sandstone and interbedded gray shale and coal. Base of unit is mapped as the top of the thick and persistent Roland coal bed, as defined by Baker (1929). Locally eroded off in the Rosebud Mine permit area.

TONGUE RIVER - Light-yellow to light-gray, fine- to medium-grained thick-bedded to massive locally crossbedded and lenticular sandstone and siltstone; weathers to a buff color. Commonly contains light-buff to light-gray shaly siltstone and shale, and brown to black carbonaceous shale. Contains numerous coal beds. Burning of the coal along outcrops has formed thick red and lavender clinker and baked shale beds. Base of unit is mapped as the change from predominantly siltstone and sandstone to predominantly shale of underlying unit.

LEBO SHALE - Predominantly dark shale containing interbeds of light-gray and brown to black carbonaceous shale, siltstone, and locally thin coal beds. Shales contain altered and devitrified volcanic ash and brown ferruginous concretions. Base of unit mapped as the change from predominantly shale to predominantly fine-grained sandstone and shale of underlying unit. Conformable contact with underlying unit; however the Lebo exists locally as deposits in channels eroded deeply into the underlying Tullock member.

TULLOCK - Lower part of member is interbedded medium-gray to light-gray shale, fine-grained light-gray sandstone and siltstone, and thin but persistent coal beds; grades upward to light-gray carbonaceous shale. Locally at the top is a resistant sandstone that forms a well-developed rimrock. Base of unit is mapped as the change from fine-grain, thin-bedded sandstone, siltstone, shale, and coal beds to predominantly massive channel sandstone and dark-gray shale of underlying unit. (Brown, 1952 and Dunlap, 1958)

HELL CREEK - Shale and siltstone, gray to yellowish-gray, silty, clayey, sandy, carbonaceous, and bentonitic; locally, a yellowish-gray to tan, fine- to medium-grained silty sandstone containing thin coal beds predominates. Lower contact is gradational. Contact probably unconformable with underlying Fox Hills Sandstone or Bearpaw Shale.

FOX HILLS SANDSTONE - Near-shore sand facies that is the uppermost marine deposit in the area. Two members are recognized: Colgate Member -- very light-gray, fine- to medium-grained massive sandstone. Unnamed lower member -- gray to brownish-gray, fine-grained thin-bedded sandstone, interbedded with gray sandy shale and siltstone. Lower contact is gradational, considered to be the base of transition zone between sandstone above and shale of underlying unit. Conformable contact with underlying unit.

BEARPAW SHALE - Gray to black marine shaly claystone and shale. Contains some thin-bedded siltstone and silty sandstone, and locally thin beds of bentonite.

Exhibit 3

TABLE II-1
CHARACTERISTICS OF LANDSCAPE UNITS IN THE COLSTRIP AREA

LANDSCAPE UNITS	% AREA C	% AREA C BLOCK 1	TYPES OF SURFICIAL MATERIALS	RANGE OF SLOPE GRADIENT	VEGETATIVE COVER (%)	DRAINAGE DENSITY (Mi/Mi^2)	INFILTRATION RATE In/Hr.	ESTIMATED SEDIMENT YIELD (AF/Mi^2)
B_1 SANDY VALLEY BOTTOM	18.9	16.8	Sandy alluvial dept. & weathered residual sandstone	8%	60-70	3.5	2-6	0.15
B_2 SILTY VALLEY BOTTOM	8.7	15.9	Deep alluvium silts	<8%	50	4.1	0.2-0.6	0.26
U_1 UPLAND SANDSTONE	23.3	32.7	Weathered -poorly lithified sandstone no rock fragments	8-15%	70	5.5	2-6	0.20
U_2 UPLAND SILTSTONE	49.1	34.6	Lacustrine units-silts & mudstone sandy facies	8-18%	40	7.3	0.2-0.6	0.73
U_3 CLINKER UPLAND	--	--	Clinker fractured resistant	15-20%	70-80	6.3	2-4	0.17
U_4 STEEP UPLAND UNIT	--	--	Fractured hard sand-stone & siltstone w/ some massive formations	30%		4.7	4-6	0.22

Exhibit 3

The silty valley bottom unit is characterized by a low density of drainage lines (despite low surficial infiltration rates), apparently due to the destruction of channels by cultivation. As a consequence, the existing channel network may be inadequate to conduct runoff from this unit. To adjust, the network will tend to expand by entrenchment, resulting in increased sediment yields. This unit may, therefore, be potentially unstable. Sediment yields from the other landscape units in the permit area are estimated to be low, reflecting high infiltration capacities, resistant surficial materials, and a dense vegetative cover on these components.

East Fork Armells Creek and Stocker Creek both reflect strong bedrock and structural control (by faulting) on drainage basin and stream network development. This influence is strongest in the headwaters of these creeks and decreases downstream. Sediment yield from subbasins of these drainages in Area C is generally low, reflecting the high infiltration rate and the relative inefficiency of the vegetated ephemeral streams in transporting sediment. A discussion of the sedimentation rates and the method of calculation is presented in the Technical Support Document. The main channels within the basins are generally stable, while the smaller, ephemeral channels are less stable.

2. Stratigraphy

Quaternary deposits consist of weathered bedrock, colluvium, and unconsolidated clay, silt, and sand alluvium. In the five-year mine plan area, clinker deposits (locally known as scoria) have formed at and above the burned coal outcrop. Alluvial gravels are present in the East Fork Armells Creek Valley, which lies outside of Area C, Block I. Alluvium, colluvium, and clinker all constitute porous, near-surface aquifers of limited potential volume.

The Wasatch Formation has been removed by erosion in the Rosebud Mine area, and the only rock unit outcropping is the Tongue River Member of the Fort Union Formation. This member is predominantly a fine- to medium-grained silty sandstone with interbedded siltstone, silty shale, carbonaceous shale, localized clinker deposits, and coal beds. Pederson (Western Energy, 1981) states that the total thickness of the Fort Union Formation at Colstrip is 445 feet, with at least the top 360 feet being the Tongue River Member. Three coal seams in this member, in descending stratigraphic order, are the Rosebud, McKay, and Stocker. The coals dip generally one to two degrees southerly, with many local variations in the mine area as a result of small-scale folding, faulting, and localized thinning and thickening of coal seams and interburden.

3. Overburden

The overburden in Area C, Block 1 is composed of interbedded sandstone, siltstone, shale, and clinker, with various degrees of gradation between the units. Geochemical analyses of samples collected from drill holes in the overburden are presented in table form in Western Energy Company's Mining Permit Application for Area C, Block I, and in computer

printout form in the Technical Support Document for this EIS. The location of overburden test holes in Area C, Block I is shown in Figure II-2.

The overburden material was tested for 18 parameters (Western Energy Company, Mine Permit Application Area C, Block I, 1981); however, only seven of the 18 parameters tested showed significant values exceeding DSL suspect levels: electrical conductivity, molybdenum, cadmium, lead, nickel, zinc, and sand (See Appendix A, Table 1, for description of DSL suspect levels).

Because of the widespread contamination of samples by zinc- and lead-based drilling pipe joint grease, the anamalous lead and zinc values in the overburden have not been considered valid in this study. The remaining five parameters are shown graphically in Table II-2 by percentage of samples in each overburden hole that exceed state suspect level.

As Dollhopf et al. (1977, 1978, 1979) reported in their studies on the eastern part of Area B, the trace metals have a generally greater affinity for shale in the overburden than for other lithologies. In Area C this is particularly true of the shale immediately overlying the Rosebud coal seam.

4. Aquifers

Aquifers in the mine area include alluvial and colluvial deposits, Tongue River Member sandstones and coals, Lower Fort Union sandstones, and the lower Hell Creek-Fox Hills Sandstone (considered a single aquifer). In the mine area, only those aquifers above the McKay coal seam would be physically disturbed. A baseline description of these aquifers is presented in Section B, Hydrology.

5. Structure

The proposed mine area lies entirely within the northwestern portion of the Powder River Basin, a large depositional basin extending east into South Dakota, southward into Wyoming, and over thirty miles west and north from Colstrip. Superimposed upon this northwest flank of the Powder River Basin are numerous smaller scale structures, including the Ashland Syncline, a west-northwest trending shallow structural trough that cuts the southwest quarter of T1N, R40E. The axis of this syncline roughly coincides with the southwestern limit of proposed mining as shown in Western Energy Company's Comprehensive Mine Plan, Exhibit C (1981) (see Surficial Geology Map in the Technical Support Document).

Local doming, rolls, and minor folds are indicated in the Area C, Block I structural contour maps (Western Energy, Mine Permit Application, Area C, Block I, Volume 7, Exhibits T and U). No faults have previously been mapped in Area C, Block I, but in other sectors of the Rosebud Mine several faults have been mapped and/or inferred from aerial photos.

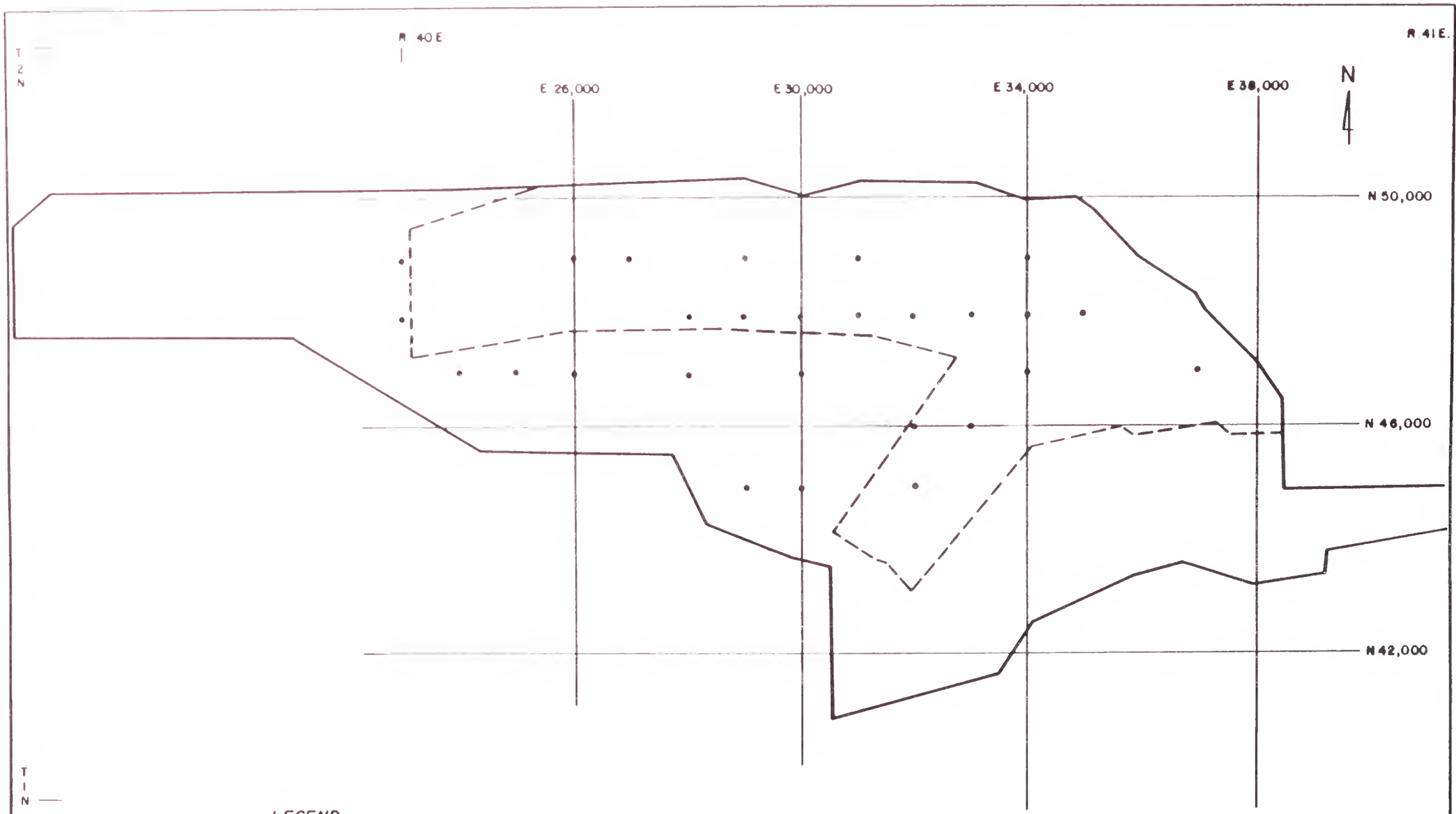


FIGURE II-2 OVERBURDEN GEOCHEMISTRY HOLE LOCATIONS
ROSEBUD MINE, MONTANA

Exhibit 3

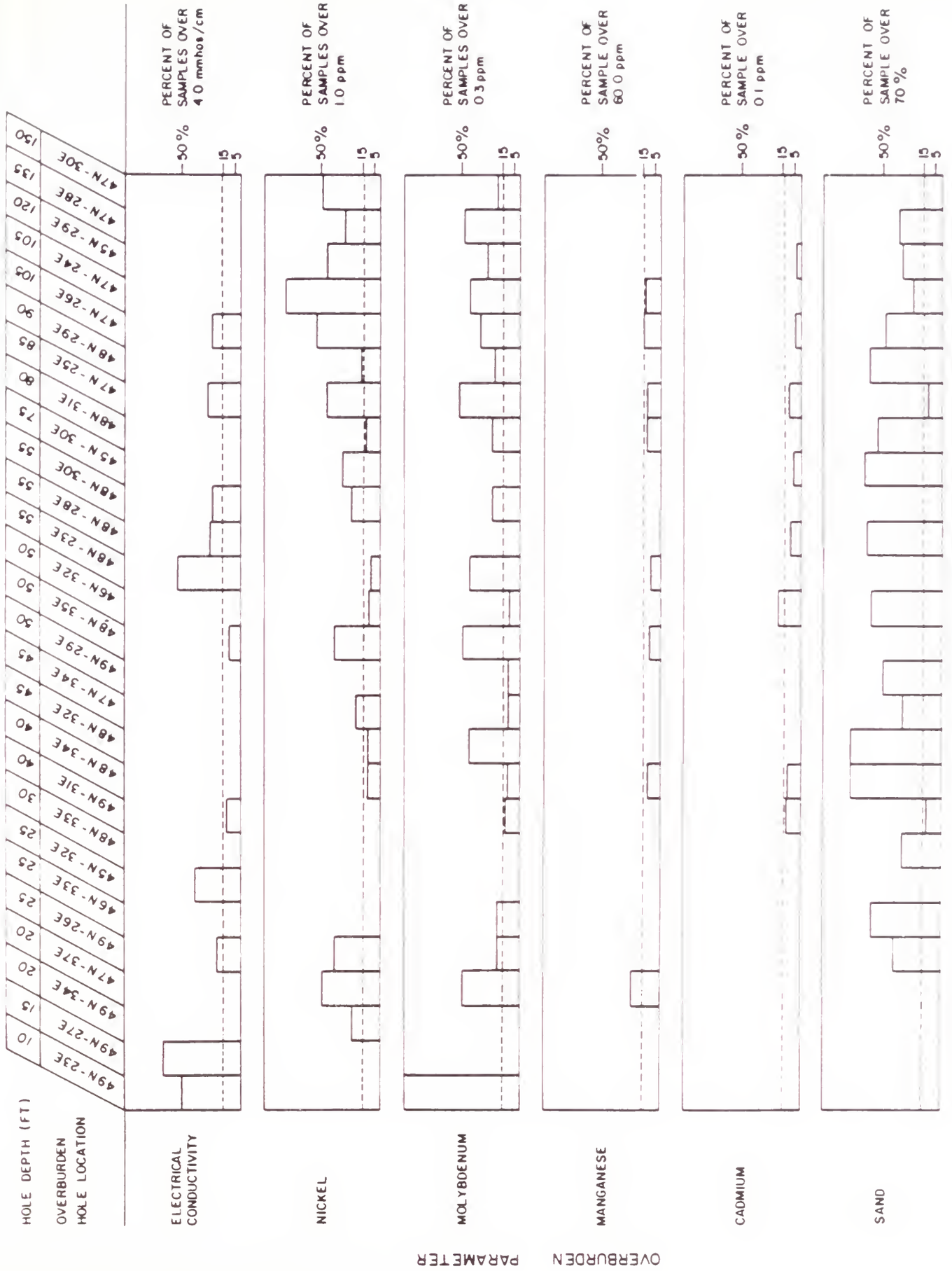


TABLE II-2 PERCENTAGE OF SAMPLES EXCEEDING STATE SUSPECT LEVELS IN OVERBURDEN TEST HOLES, AREA C, BLOCK I
ROSEBUD MINE, MONTANA

Exhibit 3

These faults have a strong west-northwest trend paralleling the Ashland Syncline axis.

Based on geologic cross sections from Western Energy's Area C, Block I Permit Application (Volume 7, Exhibit W) and topographic and air photo interpretation, a fault zone with at least two apparent faults is inferred in Area C, Block I. This zone trends northwest-southeast approximately through the northwest corner of Section 11 and halfway across Section 3, T1N, R40E. On cross section 46,000 N (Exhibit W) the northeastern-most inferred fault has a maximum displacement of greater than 70 feet down to the southwest. On cross section 29,000 E (Exhibit W) the southwestern-most inferred fault has a maximum displacement of 60 feet up to the southwest. It appears likely, from the evidence in the Exhibit W cross sections and topographic coincidence of linear features with anomalous dip changes in the sections, that some additional faulting along northwest-trending structures would be encountered in mining Block I. The same evidence suggests that such faults, if present, would likely have a displacement of less than 30 feet.

6. Geologic Hazards

There are no known significant geologic hazards in the proposed mine area. No active faulting is evident and the entire northern portion of the Powder River Basin is a tectonically stable area.

7. Paleontology

Fossil leaves and invertebrates of the Paleocene Period occur fairly abundantly throughout the Fort Union Formation and are likely to be encountered at the proposed mine. However, these are all common fossils and have limited scientific significance. No significant vertebrate fossils are known to occur in the Fort Union Formation (Taylor, 1975; U.S.D.I., 1978). There are no known fossil collecting sites in the mine permit area.

8. Resources

Natural resources occurring in the Northern Powder River Basin include coal, oil, gas, uranium, sand, gravel, and some clay. Of these, the coal resources are by far the most important.

Oil and gas exploration is currently active in Rosebud County, but no discoveries of oil or gas have been found in the area of the Rosebud Mine. No oil or gas wells have been drilled in Area C. The nearest oil and gas production to the mine area is in the Hardin field approximately 36 miles to the west, where gas is produced from the Mid-Cretaceous Frontier Formation. The nearest oil production to Colstrip is 48 miles north on the Porcupine Dome.

There are no known or indicated reserves of uranium in the Rosebud Mine area. Sand, gravel, and some clay are present in minor amounts.

Clinker deposits along the burned coal outcrop have been used for road gravel in the past.

Coal resources in Area C, Block I consist of the Rosebud, McKay, and Stocker seams, in descending stratigraphic order. The Rosebud seam is the primary coal seam of interest at the Rosebud Mine, and would be the only seam mined at Area C, Block I. Total in-place reserves in the Rosebud seam (Block 1) are approximately 27 million tons, of which Western Energy estimates 23.7 million tons recoverable in the Area C, Block I first five-year mine plan (see Table I-1). The Rosebud coal in Area C averages 8,348 Btu per pound and 0.86 percent sulfur (as received, proximate analyses).

The McKay coal seam lies below the Rosebud seam at an average interburden depth of 23 feet in Area C, Block I. The McKay averages eight feet thick, yielding approximately 9.6 million tons in place (calculated at 1,700 tons per acre-foot). Western Energy does not plan to mine the McKay coal for several reasons, which are discussed in depth in Chapters I and IV of this EIS. McKay coal in Area C averages 8,348 Btu per pound and 1.31 percent sulfur (as received, proximate analyses).

The Stocker seam lies between eight and nine feet below the McKay seam over most of Area C, Block I. This coal is of lower Btu value and higher sulfur content than the McKay seam. Average, as-received proximate values for 15 samples of the Stocker coal in Area C (Western Energy, analyses reports) yielded an average of 7,469 Btu per pound and 1.76 percent sulfur and exhibited an average thickness of 4.44 feet.

B. HYDROLOGY

The following section discusses groundwater and surface water systems, on both a regional scale and on a more localized scale (Area C, Block I). The regional data considered within this section is specific to the area of influence surrounding the existing Rosebud Mine, near the townsite of Colstrip. The general hydrologic setting within the study area is depicted on Figure II-3. The figure also illustrates the surface water drainage networks and coal seam outcrops*/subcrops* that have been examined during the preparation of this EIS.

The purposes of this section are to identify flow characteristics, describe the existing quality and usage for both surface and groundwater systems, and also to identify the relationship between surface and groundwater throughout the hydrologic study area. Regional and site-specific characteristics of Area C, Block I will be discussed under each of the major topical headings, particularly when site-specific characteristics deviate from the regional characteristics.

Primary information on the hydrology of the Rosebud Mine area was obtained from site-specific reports completed in the past ten years. Western Energy's data base includes information on groundwater, surface water, and water quality. Data was also obtained from published reports and ongoing studies on the general hydrology of the area prepared by The Montana Bureau of Mines and Geology, United States Geological Survey (USGS), and the U.S. Environmental Protection Agency (EPA). In addition, existing regional and site-specific Environmental Impact Statements (EIS), Montana Power Company special reports, state documents, Peabody Coal Company's data base, and Montana State University Agricultural Experiment Station research documents were also used.

1. Groundwater

The discussion on groundwater includes:

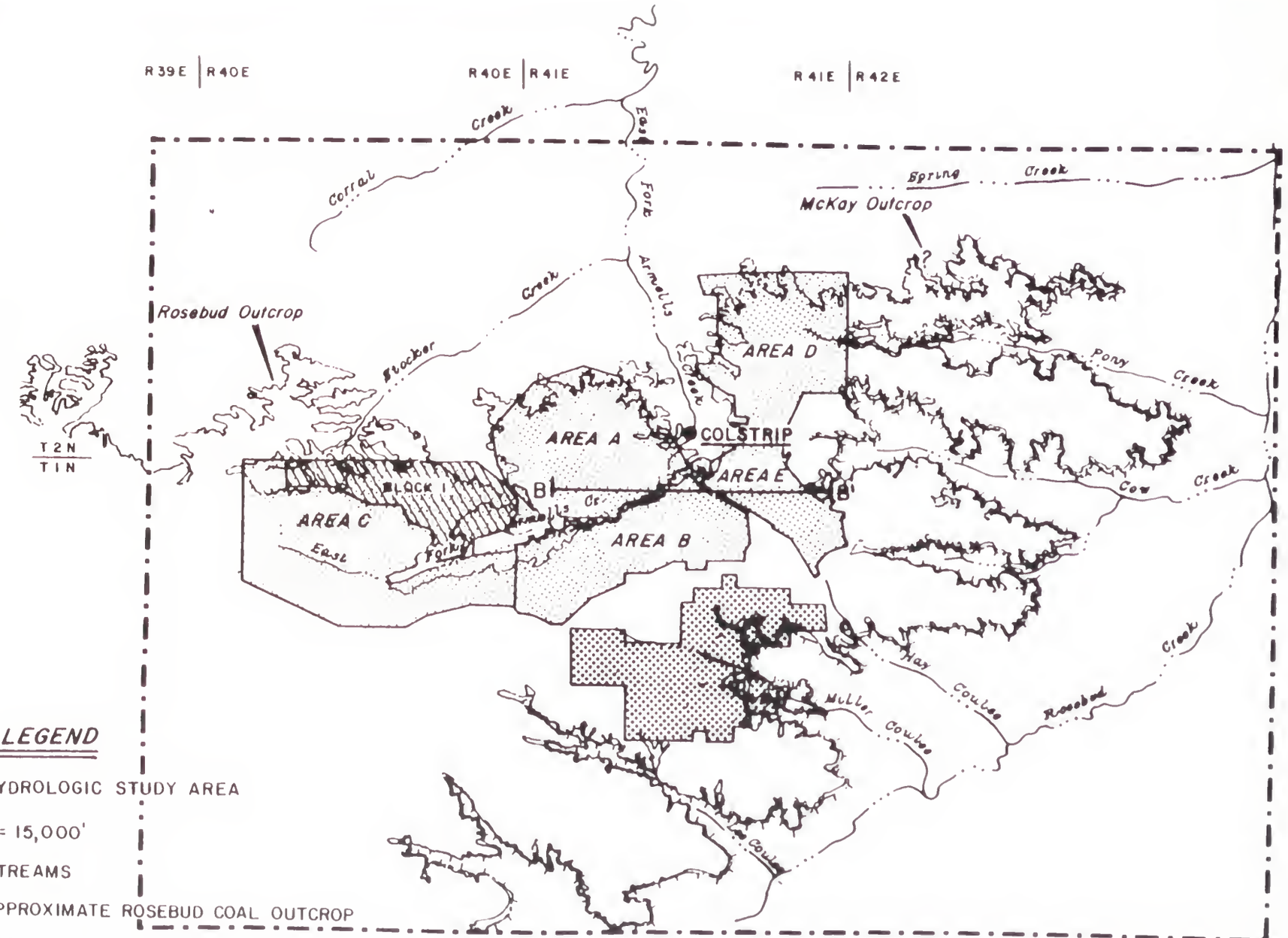
- The physical and hydraulic properties of each water-bearing unit
- The characteristics of groundwater flow in each unit aquifer
- Groundwater quality
- Groundwater use

In some instances, the characteristics of Area C, Block I are different from the hydrologic study area as a whole. Appropriate comparisons are made in these instances.

a. Water-bearing Strata

Groundwater and geologic studies (Section A.2) have identified seven near-surface geologic units within the Rosebud Mine area that can store and transmit water (Figure II-4). The water-bearing strata are (from youngest to oldest):

* Indicates the first appearance of a term defined in the Hydrology Glossary

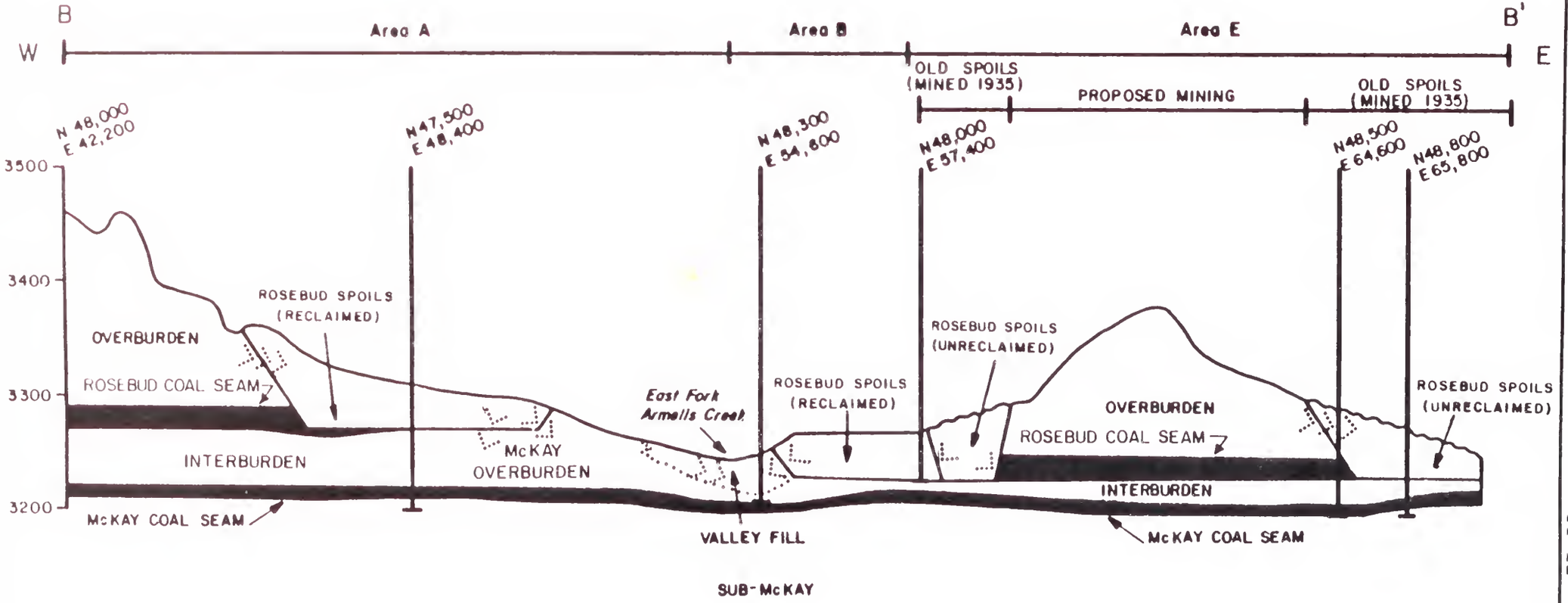


LEGEND

- HYDROLOGIC STUDY AREA
- SCALE 1" = 15,000'
- STREAMS
- APPROXIMATE ROSEBUD COAL OUTCROP
- APPROXIMATE McKAY COAL SUBCROP/OUTCROP
- B — B' LOCATION OF FIGURE II-4, CROSS SECTION OF SPOILS AND SURROUNDING MATERIAL
- ROSEBUD MINE AREAS
- BIG SKY MINE - AREA A-2/4/82
- BLOCK I SITE-SPECIFIC STUDY AREA

FIGURE II-3 HYDROLOGIC STUDY AREA SHOWING DRAINAGES WITH APPROXIMATE COAL SEAM OUTCROPS/SUBCROPS

Exhibit 3



LEGEND

HORIZONTAL SCALE: 1"= 2790'

VERTICAL SCALE: 1"= 143'

VERTICAL EXAGGERATION: 20X

DIRECTION OF GROUNDWATER MOVEMENT

SEE FIGURE II-2 FOR LOCATION OF CROSS SECTION B-B'

FIGURE II-4 SCHEMATIC CROSS SECTION OF GROUNDWATER MOVEMENT THROUGH SPOILS AND SURROUNDING MATERIAL, ROSEBUD MINE AREA, MONTANA

Exhibit 3

- Rosebud spoils*
- Valley fill material*
- Rosebud coal overburden*
- Rosebud coal
- Rosebud/McKay interburden*
- McKay coal
- Sub-McKay

In terms of importance (defined as the number of wells completed), the aquifers listed in order of diminishing importance are:

Sub-McKay
Rosebud Overburden
Rosebud Coal
Valley-Fill-McKay Coal

The following is a description of the physical and hydraulic properties for each of these water-bearing units. The discussion relates to the hydrologic study area in general (Figure II-3), except as qualified by site-specific references in the text. Sub-section 8, entitled "Area C Characteristics" describes properties that are specific to Area C. In general, however, the properties identified for each water-bearing unit are considered to beconsistent throughout the hydrologic study area.

1) Rosebud Spoils

The Rosebud spoils consist of reworked Rosebud coal overburden material, which has been replaced where the Rosebud coal has been mined out.

Since the dragline operation deposits spoils parallel to the stripping operation, spoils exhibit higher permeability* coincident with the direction of the dragline movement. Due to the linear nature of the spoils, permeability* values also vary directionally. Data from aquifer* tests in the spoils indicate that the mean transmissivity* of the spoils is 2,000 gallons/day/ft, the median transmissivity value of 61 gpd/ft, and a range of transmissivity values from <1 to 23,400 gpd/ft (see Table II-3).

Rosebud spoils in previously mined areas vary in thickness from less than one foot near the coal outcrop to over 120 feet in Rosebud Mine Areas A and B. A more permeable rubble zone has been noted (Van Voast et al., 1978) at the base of the spoils. This zone consists of waste coal and larger rock fragments that roll to the bottom of the spoils during stripping. According to Van Voast et al. (1978), the rubble of boulders and wasted coal at the base of the spoils is probably responsible for the large range of transmissivity values. Generally, however, Van Voast found that hydraulic conductivity* values for the spoils were similar to the hydraulic conductivity values of the aquifers they replaced.

2) Valley Fill Material

The materials comprising the valley fill system consist of alluvial* and colluvial* deposits. These deposits consist of interbedded silts,

sands, gravels, and clays and are generally less than 40 feet thick. In the Rosebud Mine area valley fill material is found in stream bottoms and on terraces*, which are situated approximately 10 to 20 feet above the stream bottoms. Colluvial and alluvial material intermingle where the hillsides merge with the alluvial terraces, and are often difficult to differentiate.

The large range of particle sizes, from boulder-sized colluvial fragments to clay-sized particles in the alluvial deposits, along with the lenticular nature of the valley fill deposits has an effect on the direction of groundwater flow in this system. These lenses of alluvial material in the valley fill system result in zones of variable hydraulic conductivity. Table II-3 lists the available transmissivity and hydraulic conductivity values for the wells tested in the study area. Most of the valley fill aquifer tests were performed along East Fork Armells and Stocker Creek drainages.

Botz (1979) and Van Voast (1977) state that storage coefficients ranging from 0.1 to 0.3 are typical for the valley fill material. Transmissivities for the East Fork Armells Creek valley fill range from 6 to 74,800 gpd/ft for 29 tests. The mean and median transmissivity values are both approximately 10,000 gpd/ft.

The Valley fill material in Stocker Creek appears to consist of the same material present in East Fork Armells Creek, but exhibits a narrower range of transmissivity values (2,200 to 50,000 gpd/ft). Only six aquifer tests have been conducted in the Stocker Creek drainage. It should be noted that the mean and median values for transmissivity and hydraulic conductivity (Table II-3) are highest for the valley fill aquifer, as compared to the other water-bearing strata underlying the area. This is due to the coarse-grained nature of some of the valley fill materials.

3) Rosebud Coal Overburden

Rosebud overburden is found throughout the area overlying the Rosebud coal, and is composed of brown to gray, very fine- to medium-grained sand, shale, claystone, and clinker*. Overburden thickness varies from zero at the Rosebud coal outcrop/subcrop to over 240 feet beneath the sandstone ridges in Area C. The sandstone, shale, and claystone are interbedded and discontinuous, so that the ability of the aquifer to transmit water is variable from well to well.

The overburden is generally considered to be an unconfined* aquifer, although in some areas it does show confined* characteristics. Twenty-two aquifer tests conducted in the Rosebud overburden indicated a range of transmissivity values from 1 to 79,000 gpd/ft. The mean (8,950 gpd/ft) and median (57 gpd/ft) values vary by approximately 8,900 gpd/ft. This wide variation in transmissivity may be due to the discontinuity of the lithologic units in the overburden (Geology, Section A.3). Faults

TABLE II-3

SUMMARY OF TRANSMISSIVITY AND HYDRAULIC CONDUCTIVITY VALUES
FOR AQUIFER TESTS IN THE ROSEBUD MINE AREA

	TRANSMISSIVITY				HYDRAULIC CONDUCTIVITY			
Aquifer	Number of Aquifer Tests	Range of Values (gpd/ft)[1]	Mean Value (gpd/ft)	Median Value (gpd/ft)	Number of Values Used in Analysis[2]	Range of Values (ft/day)[3]	Mean Value (ft/day)	Median Value (ft/day)
E. Fork Armells Valley Fill	25	6-74,800	12,600	9,900	23	6.400-501.3	119.50	102.50
Stocker Cr. Valley Fill	6	2,200-50,000	18,900	5,300	--	--	--	--
Spoils	17	0.24-23,400	2,000	61	17	0.001-65.3	6.02	0.30
Rosebud Overburden	23	1-79,000	8,950	57	12	0.006-3.8	0.47	0.02
McKay(a) Overburden	9	230-2,600	1,500	570	--	--	--	--
Rosebud Coal	35	3-12,700	526	30	35	0.005-68	5.17	0.12
Interburden(b)	8	1-210	43	7	8	0.002-0.9	0.15	0.01
McKay Coal	24	1-560	147	104	18	0.002-3.6	0.72	0.15
Sub-McKay	6	90-3,200	860	470	--	--	--	--

-- no data available

1. gallons per day per foot
2. conductivity values were not calculated for all aquifer tests because of lack of information
3. feet per day

(a) McKay overburden - Rosebud coal does not exist above the McKay coal unit

(b) Interburden - Rosebud coal overlies the McKay coal unit.

Exhibit 3

and fracturing in the overburden in Area B (Plate B-1, Technical Support Document) could be responsible for the high transmissivity values (79,000 gpd/ft) in that area.

An overburden aquifer pumping test was performed at well WX-101, 2-1/2 miles southwest of Colstrip along East Fork Armells Creek (Figure II-5), where data from four observation wells were analyzed. Storage coefficients ranging from 0.006 to 0.03 were calculated from this test and indicate that in this area the overburden shows confined to semi-confined* conditions. The mean (0.468 ft/day) and median (0.015 ft/day) hydraulic conductivity values indicate a very low rate of flow through the aquifer. Recovery data on both the pumped well and observation wells indicate that there is a lower permeability boundary* or an absence of recharge in the vicinity of the well, since the transmissivity values decrease from 45,000 gpd/ft to 8,000 gpd/ft between 10 and 30 hours after pumping has ended.

In some areas, the overburden includes clinker, which is usually brittle and highly fractured. According to Dollhopf (1978), fractures in the clinker create potential areas of groundwater recharge or discharge.

4) Rosebud Coal

The Rosebud coal varies in thickness from zero at the outcrop to approximately 24 feet, and has an average thickness of 22 feet. The coal is locally fractured and folded, resulting in an increase in porosity* and permeability.

The Rosebud coal aquifer is confined over most of the mine area, except where it crops out or subcrops, along parts of East Fork Armells Creek and the eastern drainages. A broad range of transmissivity values has been calculated for the Rosebud coal. The results of 37 tests range from 3 to 12,700 gpd/ft. The mean transmissivity is 526 gpd/ft, and the median value is 30 gpd/ft. The wide range is probably the result of the inconsistent fracture pattern that is characteristic of the coal bed. The ability of the aquifer to transmit water is directly proportional to the degree of fracturing in the coal.

A constant discharge test of the Rosebud coal aquifer was conducted at well 34-R, one mile south of Colstrip (Figure II-5), where two observation wells were monitored. The storage coefficient was calculated to be about 0.000015, which is within the typical range of 0.00001 to 0.001 for confined aquifers. One observation well, completed in overburden material, was not affected by the drawdown test at the pumped well, indicating that the two aquifers are not connected in that area.

5) Rosebud/McKay Interburden

The Rosebud and McKay coal seams are separated by 10 to 100 feet of interburden. The average interburden thickness varies from 40 to 60 feet in the Rosebud Mine area and consists of clays and shales that act as confining layers. The interburden contains more clay than the overburden and is considered to be a less productive water-bearing stratum.

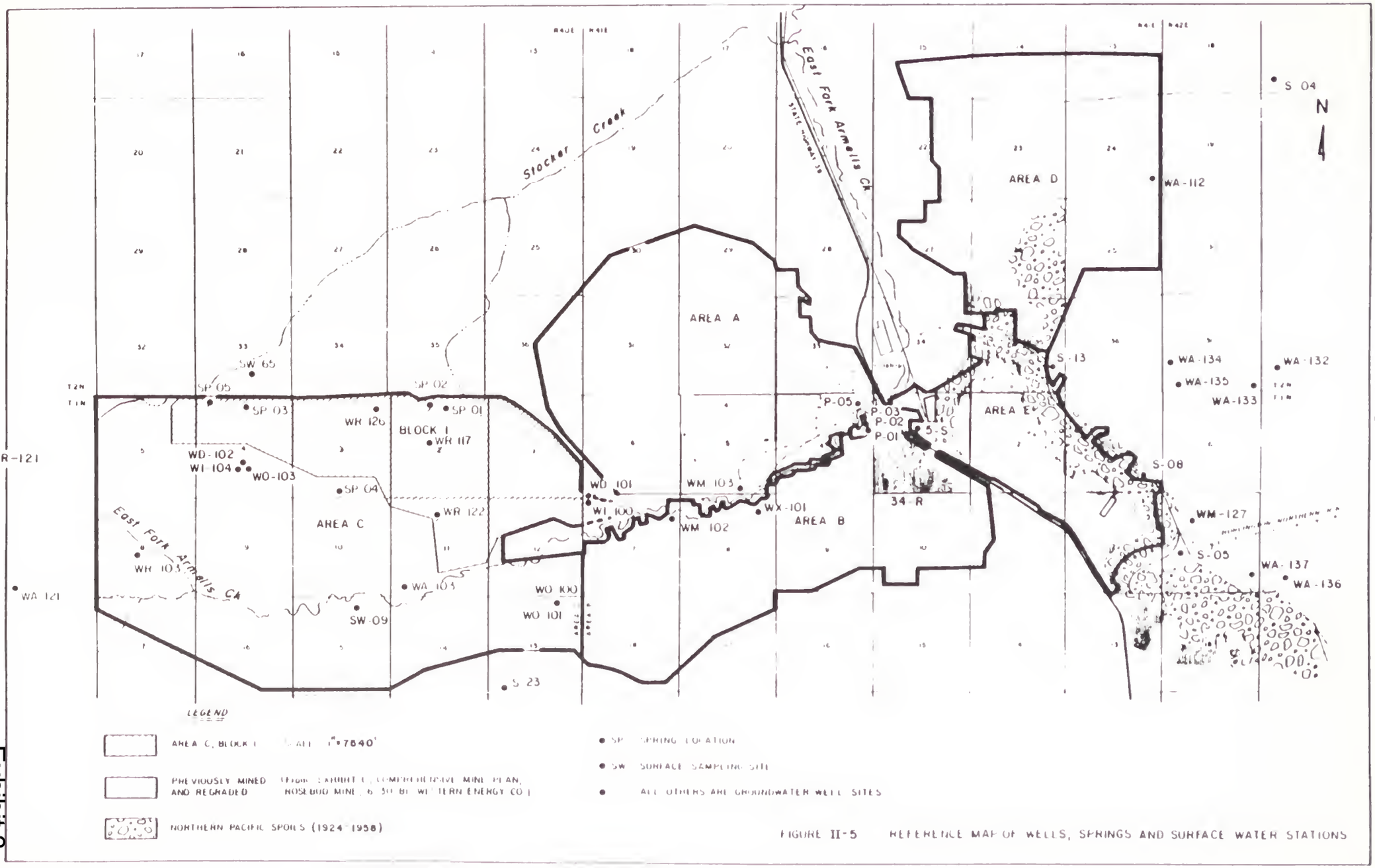


FIGURE II-5 REFERENCE MAP OF WELLS, SPRINGS AND SURFACE WATER STATIONS

Exhibit 3

However, fractures and lithologic changes in the interburden may allow some exchange of groundwater between the Rosebud and McKay aquifers in some areas.

The interburden between Rosebud and McKay coal seams exhibits a mean transmissivity of 43 gpd/ft, and a median transmissivity value of 7 gpd/ft. The range of transmissivity values (1 to 210 gpd/ft) is the lowest for any of the aquifers. Some fractures and faulting have caused anomalously high transmissivity values, but as a unit it appears that the clays and shales characteristic of the interburden are responsible for inhibiting the groundwater flow through this aquifer.

Lithologically, the McKay overburden and the interburden are similar, but, in areas where the Rosebud coal has been eroded (refer to Figure II-4), the material above the McKay coal exhibits the characteristics of an unconfined aquifer*. Transmissivity values for the McKay overburden range from 230 to 2,600 gpd/ft, with a mean of 570 gpd/ft and median of 1,500 gpd/ft. These values are higher than those for the interburden, indicating a difference in hydrologic characteristics between these two units.

6) McKay Coal

The McKay coal is approximately 8 to 12 feet thick in the Colstrip area and exists over most of the area shown on Figure II-3.

The McKay coal is a confined aquifer in the Rosebud Mine area and its porosity and permeability are related to fracturing in the coal seam. According to Van Voast (1977), storage coefficients for both the Rosebud and McKay aquifers are within the same range (0.00001 - 0.0001). However, the transmissivity of the McKay coal aquifer ranges from 1 to 560 gpd/ft (24 tests), which is considerably lower than the range of values for the Rosebud coal aquifer. This is due to the fact that the McKay coal is thinner than the Rosebud coal (transmissivity is a function of thickness). Assuming that the Rosebud and McKay aquifers have equivalent hydraulic conductivities, the thicker Rosebud coal aquifer can transmit more water per unit width than the McKay coal.

7) Sub-McKay

The regional sub-McKay aquifer consists of sandstone and sandy clays in the Tongue River Member of the Fort Union Formation. The sub-McKay unit underlies the McKay coal and ranges from 20 to 250 feet beneath the surface in the Rosebud Mine area. The Lebo Shale Member of the Fort Union Formation forms an areally extensive impermeable base to the sub-McKay unit.

Available information indicates that the sub-McKay is a confined aquifer system; however, very little hydraulic data exists for the aquifer. Transmissivity values from six aquifer tests in the sub-McKay range from 90 to 3,200 gpd/ft and have a mean and median of 860 and 470 gpd/ft, respectively.

8) Area C Characteristics

The physical properties of the water-bearing strata are generally the same throughout the hydrologic study area, including Area C. However, the average Rosebud/McKay interburden thickness is approximately 20 feet greater in Area C than the average for the whole area. Also, because of the existence of sandstone ridges the overburden is up to 240 feet thick in Area C, which is about 90 feet thicker than anywhere else in the Rosebud Mine.

Specifically, ten aquifer tests were performed in the valley fill material, three in the overburden, eight in the Rosebud coal, one in the interburden, one in the McKay coal, and no tests were performed in the sub-McKay coal (see Plate B-1, Technical Support Document, for locations of tests).

The mean calculated hydraulic conductivity for Area C valley fill is 104 ft/day. This compares favorably with the calculated mean hydraulic conductivity of 119 ft/day for East Fork Armells valley fill in the hydrologic study area.

The mean hydraulic conductivity for the Area C overburden is 0.4 ft/day; however, not enough data exists to statistically compare test results with the hydraulic characteristics of the hydrologic study area.

The average transmissivity of the Rosebud coal in Area C is 190 gpd/ft. This is lower than the average transmissivity for the hydrologic study area. There is no apparent reason for this difference; it may be due to natural lithologic variations within the coal.

The McKay coal and Rosebud/McKay interburden Area C hydraulic characteristics cannot be compared to the hydrologic study area test results because only one aquifer test was performed in each aquifer in Area C.

b. Groundwater Flow

The following section will discuss the nature of groundwater flow in the hydrologic study area and, more specifically, Area C. Flow will be defined by: 1) focusing upon the direction of flow within each water-bearing stratum; 2) identifying the way in which significant quantities of water move between aquifers; 3) discussing where and how groundwater recharge and discharge occur; and 4) discussing which aspects of flow in Area C are most significant, as compared with the hydrologic study area in general.

First, before proceding with the discussions outlined above, there are some important overall trends in groundwater flow that should be summarized briefly to provide the reader with a general introduction to groundwater flow systems in the Rosebud Mine area.

- The most significant bedrock groundwater flow exists in the Rosebud and McKay coal seams. Flow velocities are not large,

but they have a higher relative conductivity than the Rosebud overburden or Rosebud/McKay interburden units.

- Bedrock flow generally follows the south-southeast structural gradient of about one-half percent. Deviations in regional flow patterns occur in the vicinity of mine pits, in areas of structural highs and lows, and where coal seams crop out and subcrop.

- A local recharge area appears to be located in Area C. This conclusion is based not so much on the equipotential map, which is inconclusive, but more on geologic and structural evidence.
- Some bedrock discharge occurs along upper East Fork Armells Creek although just above Colstrip the situation reverses and the valley fill along East Fork Armells Creek recharges bedrock.

- Flow in spoil and valley fill originates either by direct infiltration of precipitation or by inflow from bedrock.

- Flow directions in spoils are highly dependent upon the placement of spoil and can't be easily generalized.

- Flow direction in valley fill is generally parallel to the direction of the stream channel.

- Minor deviations in flow direction in valley fill material result from the recharge-discharge relationship with bedrock aquifers; the seasonally controlled amount of net infiltration (from precipitation); and an influx of water to the valley fill from a leaking surge pond downstream of Colstrip.

1) Nature of Flow Within Water-Bearing Strata

The seven water-bearing strata have varying types of flow (i.e., confined and unconfined) and also have varying flow directions. Generally, aquifers of regional extent, such as the Rosebud coal aquifer, show regional flow directions from the northwest to southeast. However, less extensive strata (such as spoils, valley fill, and to some extent the Rosebud coal overburden) tend to have a less uniform flow direction.

The following discussion summarizes flow characteristics in each of the seven water-bearing strata.

a) Rosebud Spoils

The inflow and outflow of spoils groundwater is illustrated schematically in Figure II-4. The groundwater in the spoils is generally unconfined; however, it should also be noted that there is evidence to suggest that water may be confined in the lower portion of the spoils unit.

Figure II-6 is a potentiometric map of the Rosebud Spoils aquifer which clearly shows the lack of uniformity of flow within the spoils.

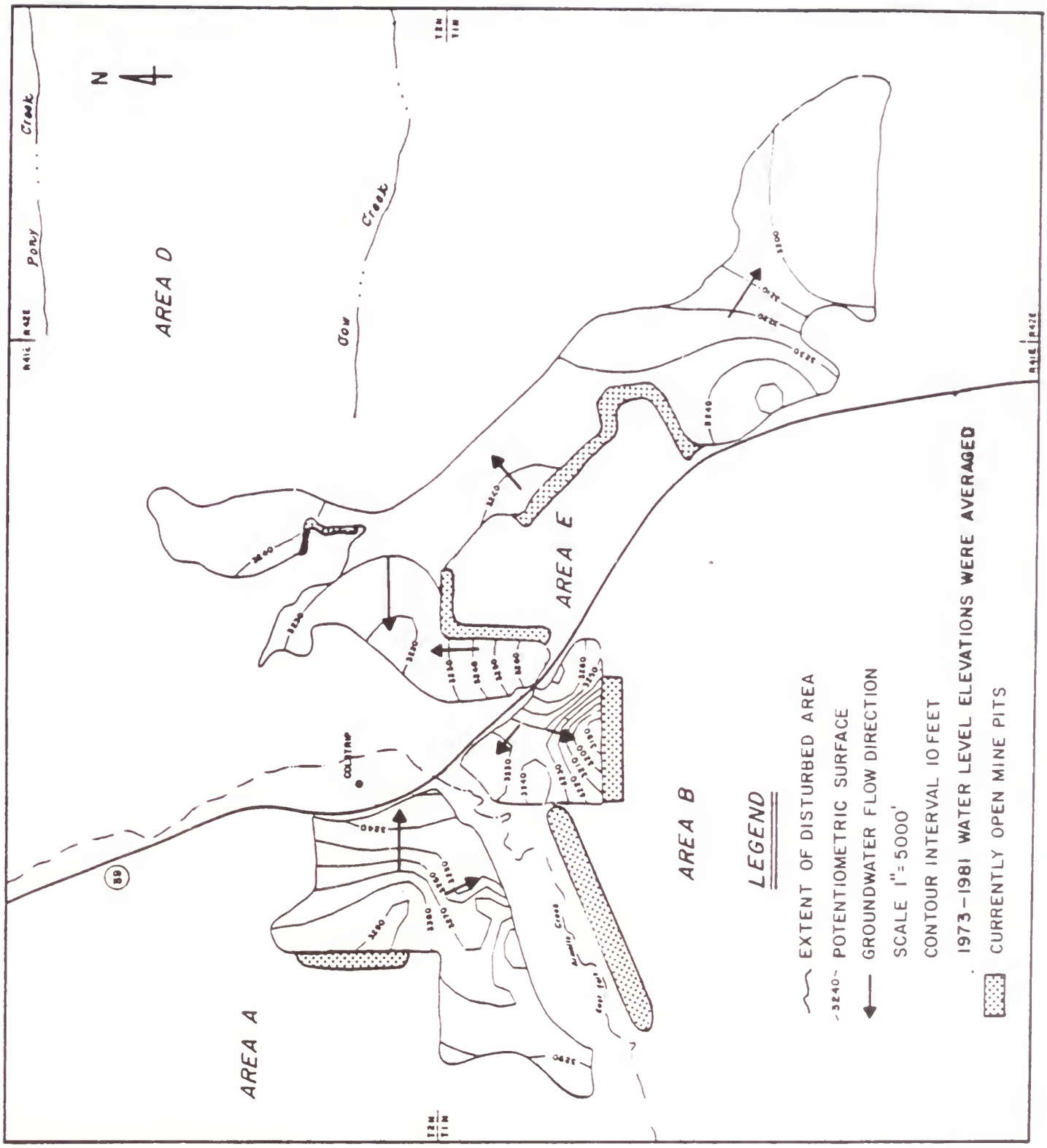


FIGURE II-6 POTENTIOMETRIC SURFACE OF SPOILS AQUIFER, ROSEBUD MINE, MONTANA

Exhibit 3

The following variations in flow direction occur within the Rosebud spoils:

- Where the Rosebud spoils abut a bedrock face left from mining, and overlie the McKay overburden, groundwater flows laterally from the Rosebud overburden and Rosebud coal into the spoils and perhaps vertically into the McKay overburden.

- Where Rosebud spoils are located adjacent to other valley fill material, they are along portions of East Fork Armells Creek, spoils water may originate from bedrock discharge to the spoils or from direct infiltration.

- Where Rosebud spoils become part of the valley fill groundwater flow system, spoils water migrates laterally into valley fill.

b) Valley Fill Material

Groundwater flow in the valley fill system generally parallels the stream channel, as indicated on Figure II-7. This general relationship seems to hold true not only along East Fork Armells Creek and Stocker Creek but also for smaller valley fill systems that are tributary to East Fork Armells Creek. Review of the static water levels demonstrate that water levels and, to an extent, the direction of flow in the valley fill, depend upon net infiltration of precipitation. This relationship, discussed in more detail in Section 3 (Hydrology), shows that water levels decline in summer when evapotranspiration is high and precipitation is low. During winter months, when evapotranspiration is minimal, water levels tend to rise. When water levels rise in winter, equipotentials are deflected toward the stream because the channel has a more significant dewatering effect on valley fill when groundwater levels are higher.

The direction of flow within valley fill is also affected somewhat by whether valley fill is receiving bedrock discharge (as in the upper reaches) or is recharging the bedrock (as in the lower reaches, see Section 1.b.2). Because the valley fill permeabilities are so much higher than those of bedrock strata this discharge-recharge relationship doesn't greatly affect valley fill groundwater equipotentials.

c) Rosebud Coal Overburden

The large variability in overburden lithology makes it difficult to construct an accurate potentiometric map for the overburden. It appears that the general gradient of water in the overburden follows the structural gradient of 0.5 to 1 percent to the southeast. Groundwater is not laterally continuous throughout the overburden, but where there is a saturated condition, the groundwater may be either confined or unconfined. The source of water in the overburden is probably direct infiltration of precipitation, but may also be due to upward leakage from the Rosebud coal. Limited seepage may occur at locations where the overburden has been truncated by mining or where it crops out.

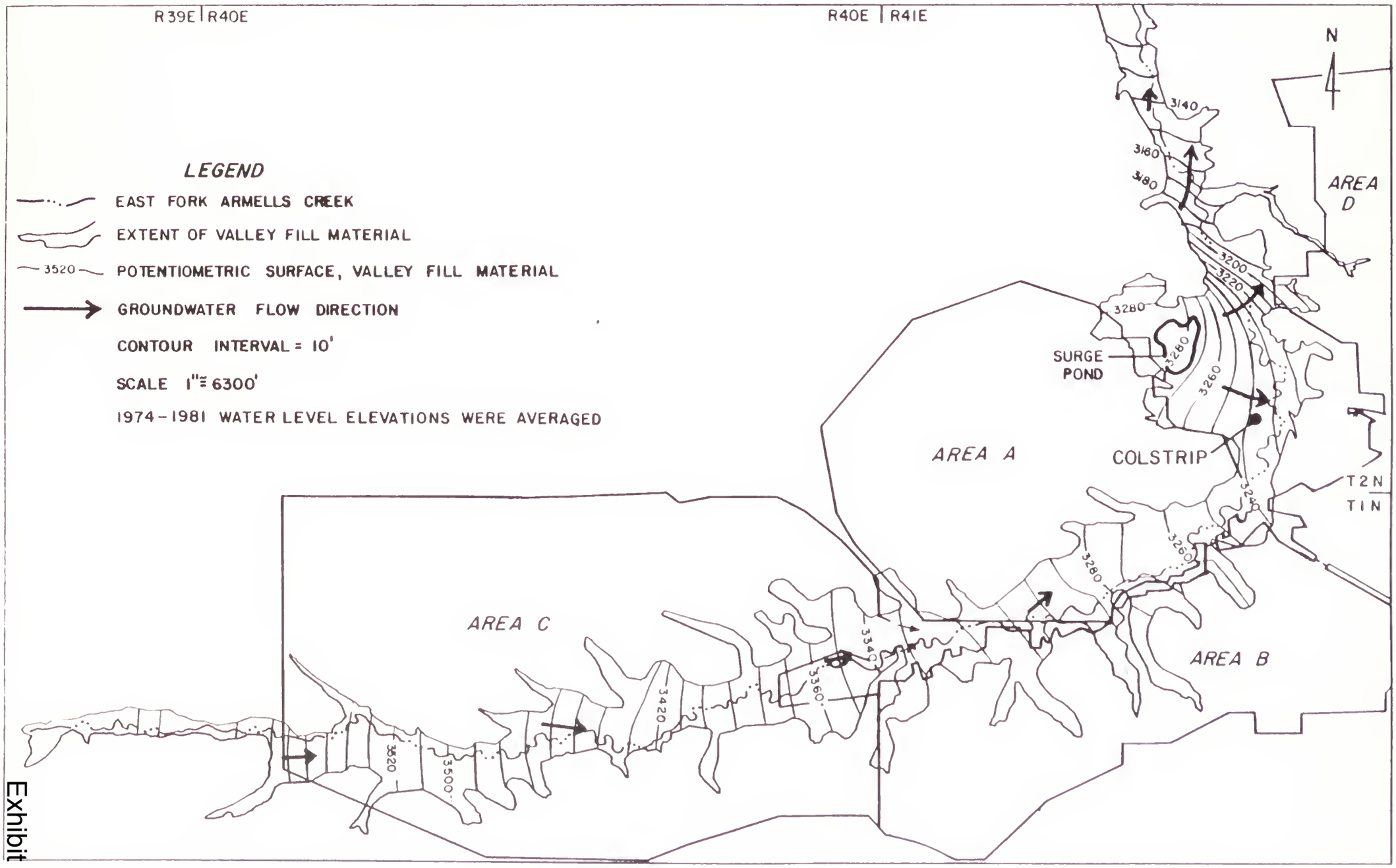


FIGURE II-7 POTENTIOMETRIC SURFACE MAP OF VALLEY FILL AQUIFER
ROSEBUD MINE, MONTANA

Exhibit 3

d) Rosebud Coal

The direction of groundwater flow within the Rosebud coal aquifer is illustrated in Figure II-8. Regional flow originates in the vicinity of Area C and moves from that groundwater high to the south, southeast and east. The hydraulic gradient in the Rosebud coal aquifer follows the structural dip of the unit.

Conditions in the Rosebud coal aquifer vary from confined to unconfined, as shown in Figure II-9, where the bedrock is apparently faulted and fractured. It is not clear whether the faulting has caused groundwater conditions to become unconfined, or if it is because the Rosebud coal seam is almost entirely exposed between the faults. The faults do not appear to cause significant changes in the regional lateral direction of flow in the Rosebud. The fact that the coal has been offset, but the flow remains unaffected, seems to indicate that vertical hydraulic communication may also be occurring across the fault zone. It is possible that the faulted area provides an excellent conduit for vertical groundwater flow.

e) Rosebud/McKay Interburden

The nature of flow in the Rosebud/ McKay interburden has not been well defined. The interburden is probably largely unconfined, with discontinuous lateral saturation. The regional direction of flow is probably structurally controlled (i.e., northwest to southeast). Water occurring in the interburden probably comes from minimal leakage downward from the Rosebud coal and upward from the McKay coal, depending on the portion of the study area examined.

f) McKay Coal

Figure II-10 is an illustration of the regional flow in the McKay coal aquifer. Flow directions are very similar to those observed for the Rosebud coal aquifer, and are, once again, similar to the structural dip of the rock unit.

g) Sub-McKay

Although a large percentage of domestic wells are completed in the sub-McKay unit there is little specific data on the groundwater flow. The aquifer is confined by a 30-foot thick layer of clay situated at the top of the sub-McKay unit. This clay layer effectively separates flows in the sub-McKay from the McKay coal aquifer. It is probable that the southeast structural dip of the sub-McKay aquifers is a controlling factor in the direction of flow, as is the case with the Rosebud and McKay coal aquifers.

2) Aquifer Communication

There are four major modes of communication between water-bearing strata:

- Vertical leakage from the McKay coal seam
- Movement along faults

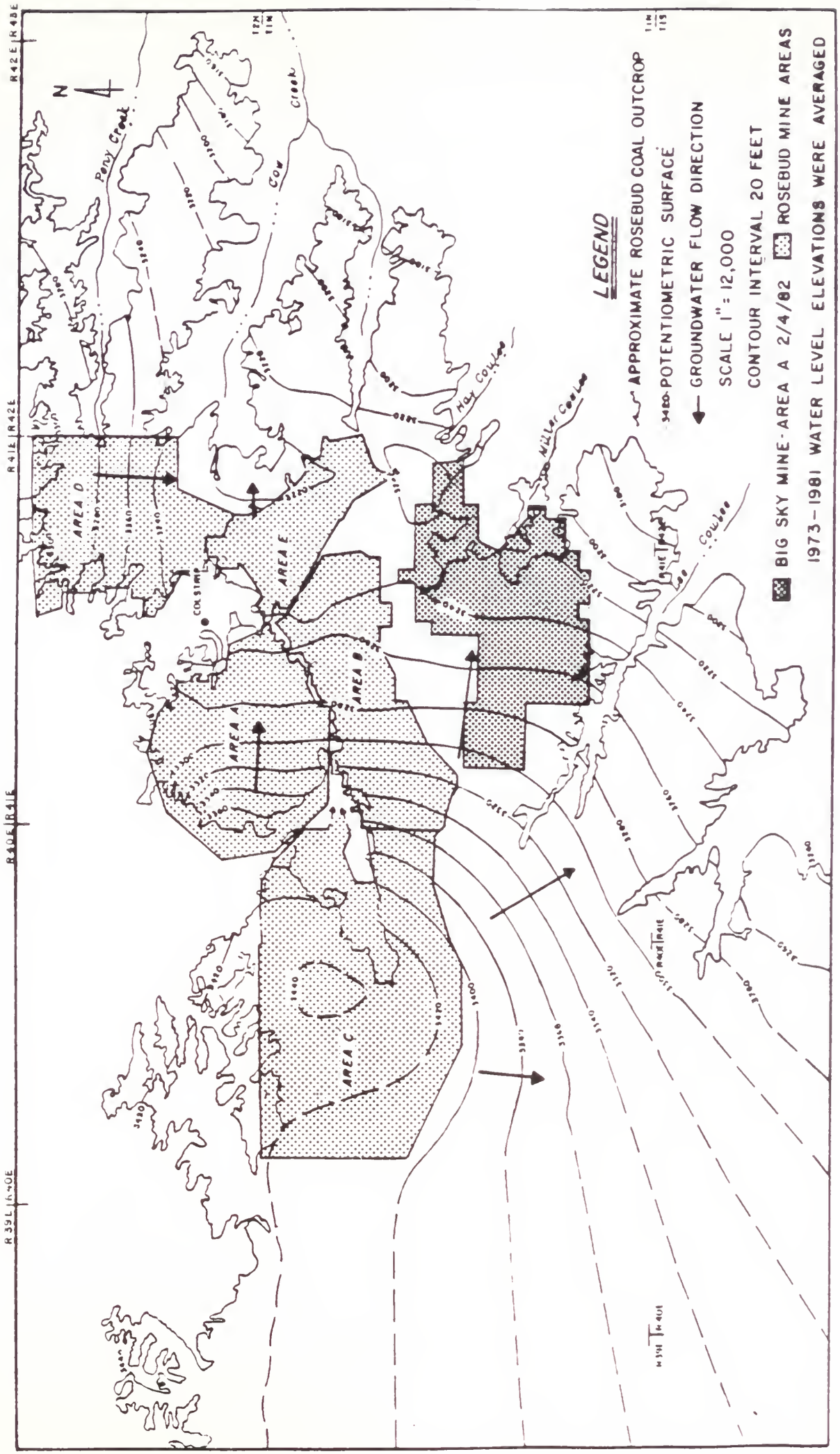


FIGURE II-8 REGIONAL POTENTIOMETRIC SURFACE OF ROSEBUD COAL AQUIFER, ROSEBUD & BIG SKY MINES, MONTANA

Exhibit 3

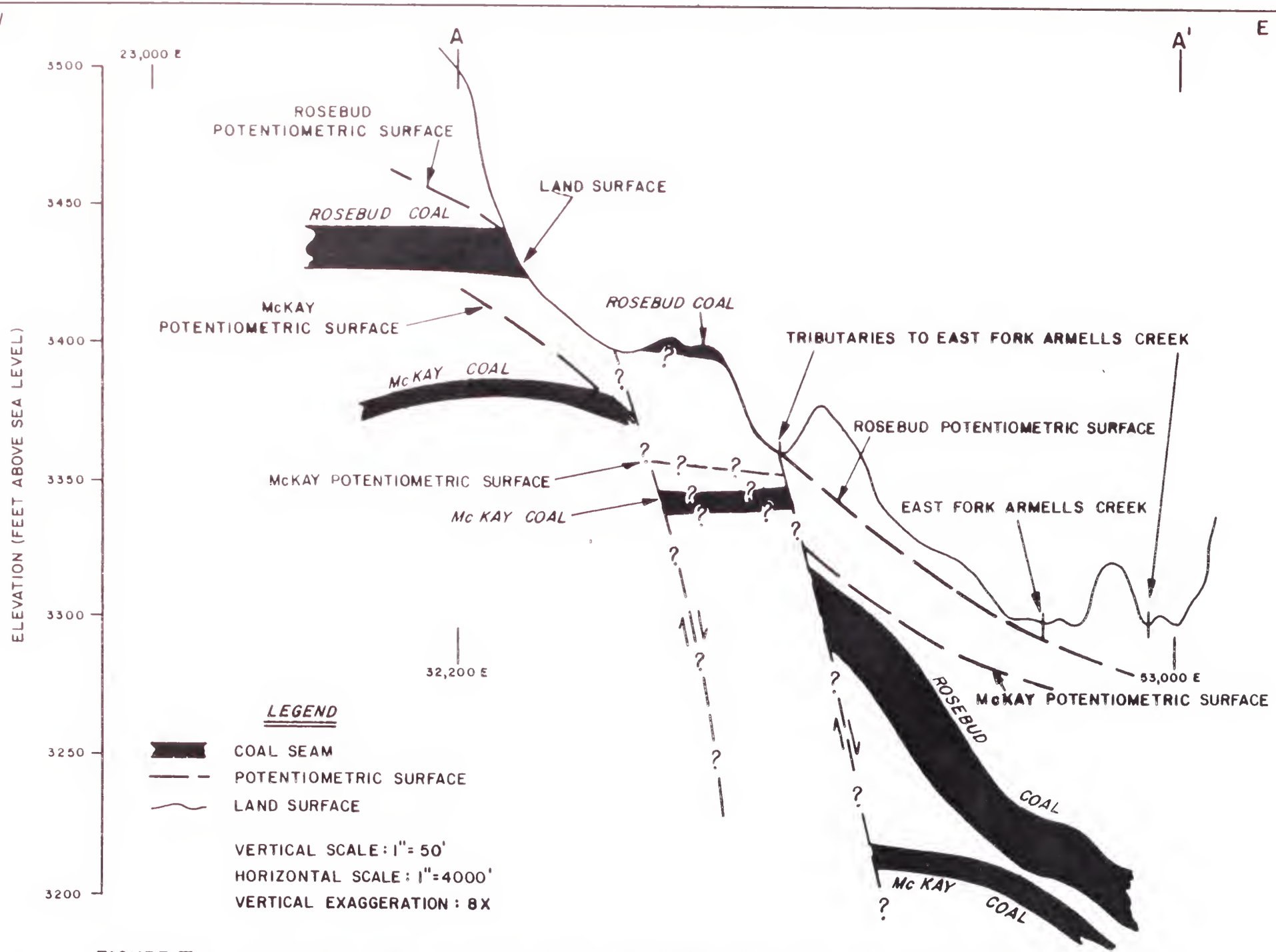


FIGURE II-9 POTENTIOMETRIC SURFACE AND STRUCTURAL CROSS SECTION ACROSS TWO FAULTS ROSEBUD MINE, MONTANA

SEE FIGURE II-13 FOR LOCATION OF CROSS SECTION

Exhibit 3

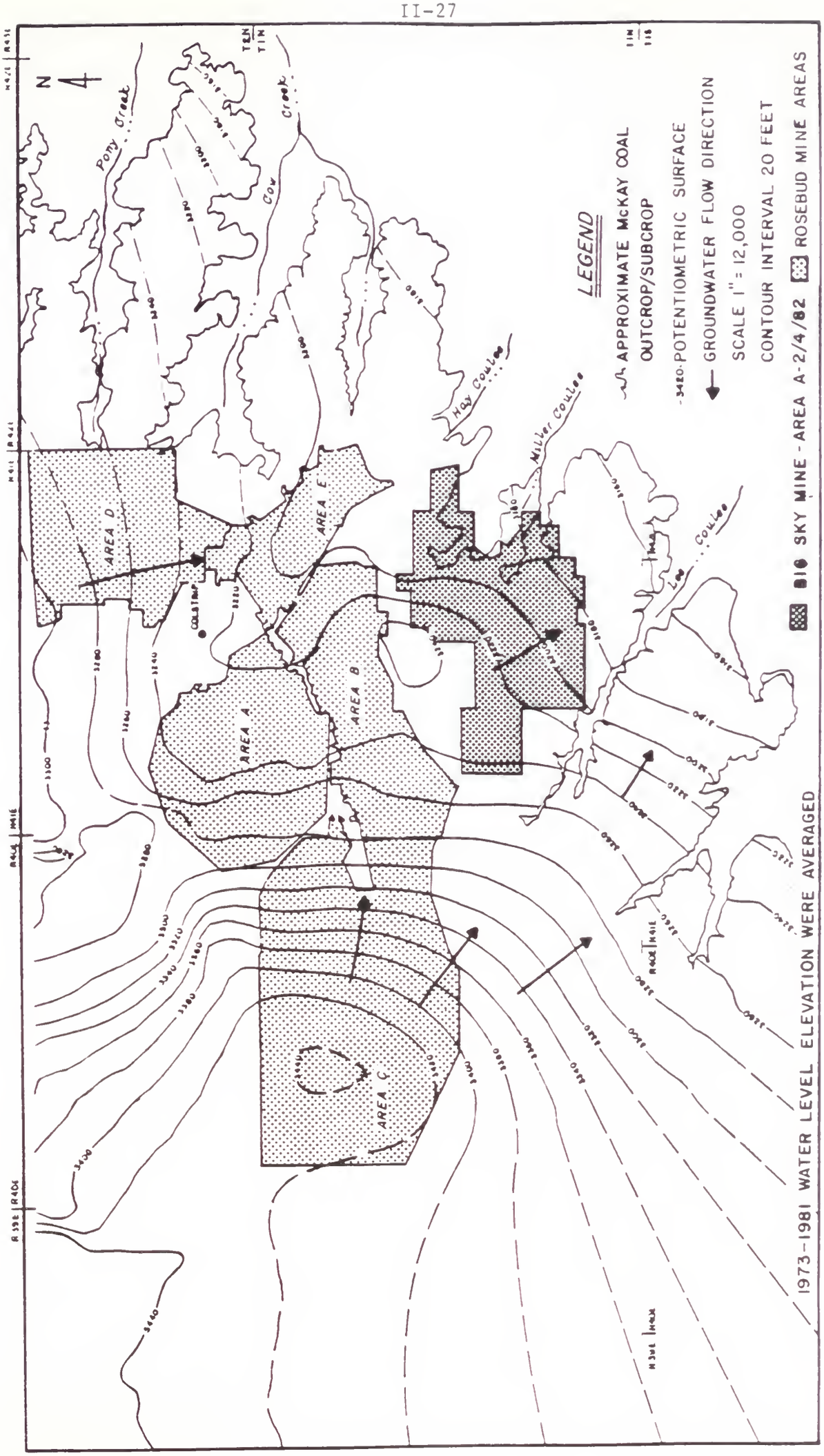


FIGURE II-10 REGIONAL POTENTIOMETRIC SURFACE OF McKAY COAL AQUIFER, ROSEBUD & BIG SKY MINES, MONTANA

Exhibit 3

- o Exchange between consolidated* and unconsolidated* materials
- o Exchange betwen two unconsolidated, water-bearing strata

Water levels in Area B wells WM-102 and WM-103 (refer to Figure II-5) completed in the McKay coal have been observed to decline. This indirectly suggests that mining of the Rosebud coal in Area B has allowed for an increase in upward vertical leakage from the McKay coal seam.

As previously mentioned, faulting occurs in both the McKay coal and the Rosebud coal west of Colstrip. The fact that the groundwater becomes unconfined in the vicinity of the faulting and that there are some anomolously high transmissivities in bedrock aquifers close to the fault suggest the possibility that the faults and related fractures allow for intermingling of water between the McKay and the Rosebud coal seams, depending on the vertical hydraulic gradient.

Clearly, wherever the spoils or valley fill material are in direct contact with bedrock strata the potential exists for either the bedrock to discharge to unconsolidated strata, which is most common, or for the spoil or valley fill to recharge the bedrock.

In some areas along East Fork Armells Creek, Rosebud coal spoils have been placed in direct contact with valley fill. There is no clear subsurface evidence to indicate that spoils are in direct contact with valley fill in any other drainages. Where the spoils in contact with East Fork Armells Creek valley fill receive significant infiltration or inflow from bedrock, groundwater may flow laterally through the spoils into the valley fill. However, this contribution to the valley fill is probably not significant, as compared with the normal flow through valley fill.

3) Groundwater Recharge-Discharge

Groundwater recharge and discharge is usually inferred from groundwater flow data. In an area where there is a high point on a potentiometric surface (or groundwater contour) map water must flow away from that area. Also, water must be contributed to the aquifer as recharge in that area in order for the groundwater high point to be maintained. However, a goundwater high cannot by itself be interpreted as a significant area of groundwater recharge since spatial and topographic configurations can cause a groundwater high even if recharge is uniform through a regional area.

Discharge may be inferred by places where groundwater contours come to the surface and the strata transmitting the water either crops out or comes close enough to surface for discharge to occur. The relationship is, of course, not always simple and many gray areas exist.

Rosebud spoils receive net infiltration (or recharge) from precipitation during the autumn to early summer period. It is probable that this net infiltration is higher in unreclaimed spoils than reclaimed spoils. This difference is probably due to the fact that reclaimed spoils are revegetated, which caused higher evapotranspiration values than in unreclaimed spoils, where natural revegetation may occur slowly.

It is also due to the hummocky* nature of unreclaimed spoils where precipitation is trapped in depressions, causing it to infiltrate rather than run off.

Figure II-11 depicts recharge and discharge areas in valley fill material along East Fork Armells Creek. For most of its course above Colstrip townsite, the valley fill is receiving discharge from underlying and adjacent bedrock and from adjacent spoils. For a short section, the valley fill becomes a losing* system as it recharges bedrock just above the townsite of Colstrip. Immediately above and below Colstrip insufficient data exist to establish a relationship; however, it is logical to assume that the valley fill continues to receive recharge from the bedrock in this area.

The MPC power plant surge pond is located along the western flank of the valley downstream from Colstrip. As shown schematically in Figure II-12 the surge pond is in direct contact with valley fill materials in a minor tributary to East Fork Armells Creek. Valley fill groundwater contours of East Fork Armells Creek show the influence of seepage from the surge pond on the valley fill. This influence is visible as a groundwater mound, causing flow to move perpendicular to the direction of the creek, rather than subparallel to it. It is probable that surge pond leakage contributes to bedrock recharge, because groundwater flow in the valley fill is recharging bedrock throughout this reach of East Fork Armells Creek.

Figure II-13 illustrates the groundwater flow patterns for the Rosebud and McKay aquifers (which are essentially similar) within the hydrologic study area. Recharge is definitely occurring within proposed mine Area C, but may also be occurring in adjacent areas as well. It is possible, due to the higher sand content in overburden, the closeness of coal beds to the surface in the northern portion of Area C, and the relatively high degree of fracturing, that a proportion of recharge occurs in Area C.

As the groundwater moves south, southeast, and east away from the bedrock recharge areas, a small percentage is discharged to the spoils or valley fill adjacent to East Fork Armells Creek. However, the major portion of the goundwater is carried by the two coal aquifers and moves southeastward to discharge points along the outcrops of both aquifers, as illustrated in Figure II-13. The figure shows that significant discharge occurs along a series of coulees that are tributary to Rosebud Creek. Although the Rosebud overburden and Rosebud/McKay interburden follow the same structural trend, they do not transmit much water, and, thus, have not been considered with respect to recharge-discharge. Modeling results quantify existing discharge rates along surface drainages throughout the study area (Table III-3).

Recharge has been quantified during the process of calibrating the computer model with respect to existing groundwater conditions. It was found that an overburden recharge rate of 2.5×10^{-5} ft/day allowed for a close approximation between equilibrium modeling results and observed groundwater levels.

Exhibit 3

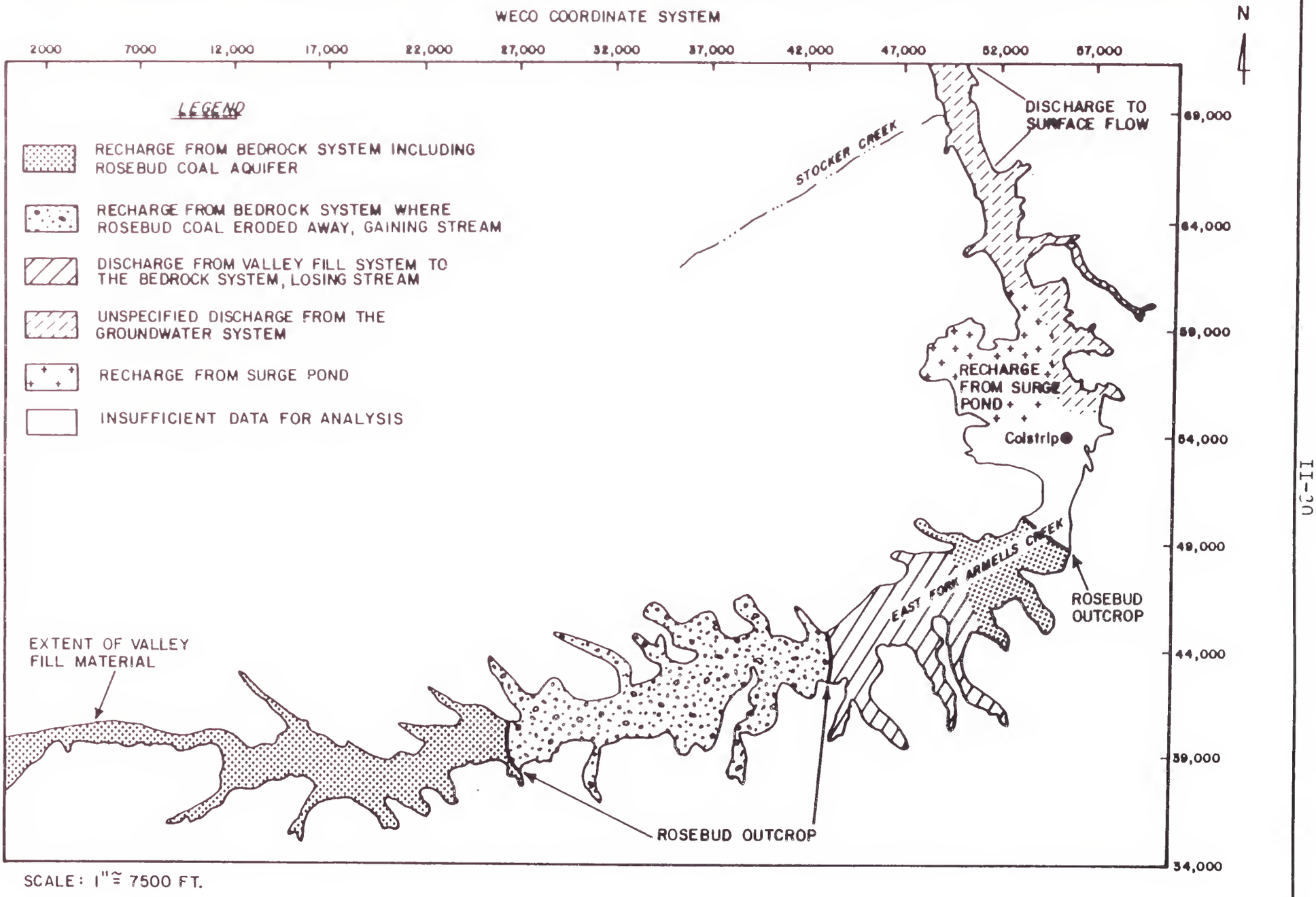


FIGURE II-11 RECHARGE / DISCHARGE AREAS OF THE VALLEY FILL MATERIAL FOR EAST FORK ARMELLS CREEK, ROSEBUD MINE AREA, COLSTRIP, MONTANA

Exhibit 3

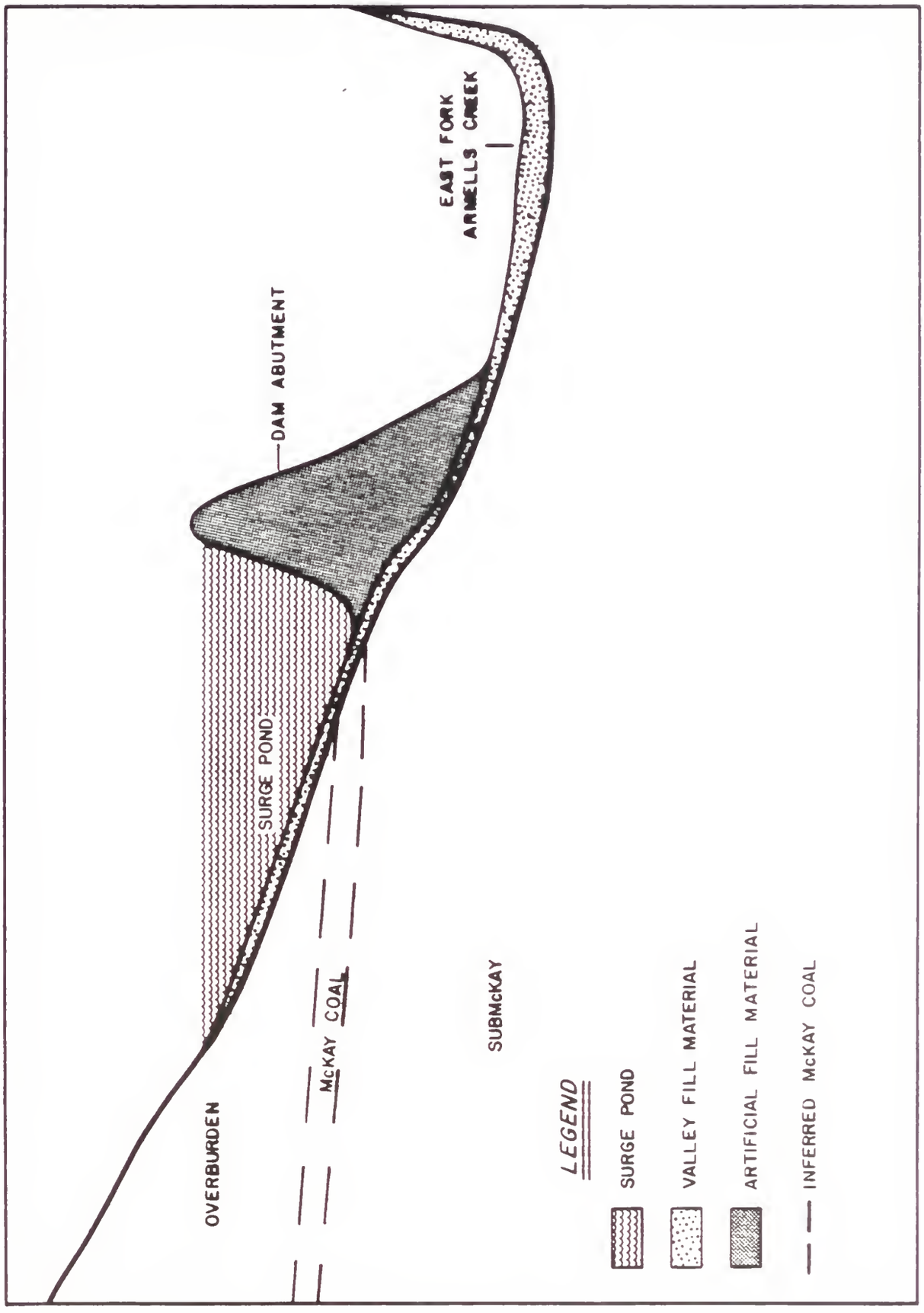


FIGURE II-12 SCHEMATIC WEST-EAST CROSS SECTION ACROSS SURGE POND, COLSTRIP, MONTANA

Exhibit 3

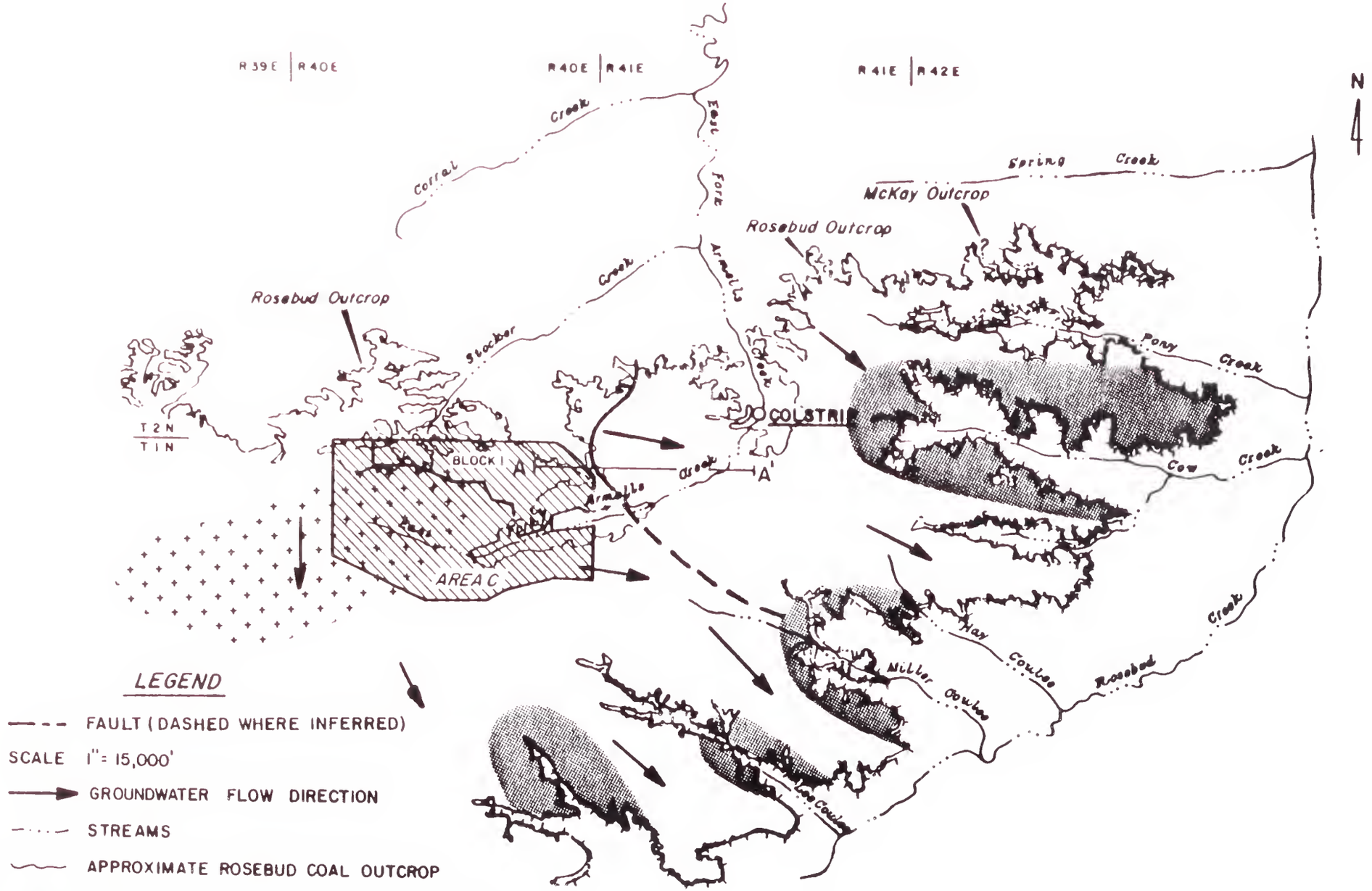


FIGURE II-13 ROSEBUD COAL AND McKAY COAL RECHARGE/DISCHARGE AREAS, ROSEBUD MINE, MONTANA

Exhibit 3

There is a relationship between the surface hydrologic structures such as the surge pond, the fly ash and evaporation ponds, the power plant ponds, the sewage lagoon, and the recharge-discharge of area groundwater. The majority of the ponds are known to leak and the amount of this leakage has been established for most of the ponds. Table II-4 presents information concerning the location and construction of these structures and the estimated amounts of seepage from each.

The seepage from these structures is a source of recharge to the valley fill system and also probable recharge sources to the bedrock system.

The effects of this recharge are two-fold. The most apparent effect is in increased water levels in the valley fill system. This, along with the potential increased stream flow from groundwater discharge, present irrigation practices, and the current trend of increased yearly precipitation, may result in the increased severity of the water logging problems presently taking place downstream of Colstrip. Recent studies have concluded that while the water logging problem is a result of the increase in water in the valley fill system, seepage from surface water impoundments may not be the sole reason for this occurrence (Hydrometrics, 1981, 1982). Estimated seepage from surface impoundments may constitute approximately 30% of through flow of East Fork Armells Creek alluvium (see Table II-4, Estimated Pond Seepage Amounts).

The amount of net infiltration to the valley fill depends upon the season. During the summer, the valley fill groundwater is being diminished by baseflow and plant uptake, while during autumn, winter and early spring there is net positive infiltration to the valley fill.

4) Groundwater-Surface Water Relationship

The relationship between surface water and groundwater in the hydrologic study area has been addressed, to a great extent, in the discussion of recharge and discharge of groundwater. Within the hydrologic study area, groundwater from the bedrock aquifers is generally discharging to valley fill and hence to surface water along minor reaches of East Fork Armells Creek above Colstrip. For a segment of East Fork Armells Creek above (and probably below) Colstrip, the stream and the valley fill is recharging the bedrock aquifer.

Farther to the southeast, a major groundwater discharge zone occurs along a series of coulees tributary to Rosebud Creek (refer to Figure II-13). The Rosebud and McKay coal seams both outcrop along these coulees, and consequently both aquifers must discharge along these outcrops, contributing to valley fill groundwater flow in each tributary.

There is also an anomalous situation that contributes to stream flow downstream from the Colstrip townsite. Leakage from the surge pond to valley fill aquifers and then to East Fork Armells Creek occurs below Colstrip.

TABLE II-4

ESTIMATED POND SEEPAGE AMOUNTS

Source	Location	Estimated Seepage (acre-feet/year)	Lining
Fly Ash Evaporation Pond[1]	N1/2, Sec 29 T2N R E	21	Partially blanketed
Surge Pond	S1/2, SW1/4, Sec 27 T2N, R E	175	Partially blanketed
Sewage Lagoon	SW1/4, SW1/4, Sec 27 T2N, R E	Unknown (surface discharge of effluent = 130 gpm/ag)	Unlined
Fly Ash Clearwater Pond[1]	NW1/4, NW1/4, SE1/4, Sec 34, T2N, R E	A	3 ft. clay blanket
Wash Tray Pond[1]	NW1/4, NW1/4, SE1/4, Sec 34, T2N, R E	A	3 ft. clay
Fly Ash Disposal[1]	W1/2,W1//2, SE1/4, Sec 34, T2N, R E		Compacted silty clay liners
Pond A		A	
Pond B		A	
Bottom Ash Pond[1]	SW1/4, SE1/4, Sec 34 T2N, R E	13	3 ft. clay blanket
Brine Waste Ponds[1]	SE1/4, SE1/4, Sec 34 T2N, R E	0	Hypalon membrane
Cooling Tower Blowdown Pond[1]	NW1/4, NE1/4, Sec 3 T1N, R E	24	Compacted silty clay liner
TOTAL		257	

[1] Hydrometrics, July 1981.

A Combined aggregate seepage estimate for all ponds - 21 acre-feet/year

Exhibit 3

During periods of high streamflow, there is the potential for surface water to recharge valley fill where water may be stored temporarily in valley fill materials. This water would either drain back into the channel or remain as part of the valley fill groundwater, depending upon the groundwater level.

The extent of subirrigation in the valley fill material depends on depth to groundwater, texture of the valley fill material, the type of vegetation, and relationships between ground and surface water. Subirrigation occurs where a combination of groundwater depth and capillary fringe brings water to within 14.5 feet of the ground surface where agricultural plants such as alfalfa can use it. The 14.5-foot depth is considered the maximum depth at which alfalfa can efficiently obtain water for plant maintenance and growth (Dollhopf, 1981). Along East Fork Armells Creek, a capillary fringe of 2.5 feet was estimated, based on averaged textural analyses and discussions with Dr. Doug Dollhopf of Montana State Univeristy. Thus, a depth to groundwater of 17 feet is considered the maximum for subirrigation to occur along East Fork Armells Creek. Figure II-14 illustrates the areas in which, according to the above criteria, subirrigation is known or expected to occur.

5) Summary of Relationships Between Area C, Block I and the Hydrologic Study Area

Throughout the section on groundwater flow, groundwater movement within the hydrologic study area has been discussed. It is of particular interest to focus on Area C of the hydrologic study area to delineate aspects of groundwater flow that are considered to be unique with respect to flow in the larger hydrologic study area.

The groundwater flow system in Area C, Block I is simpler than the larger area. The major characteristics of flow in this area are: 1) Area C serves as a recharge area for the Rosebud and McKay coal seams; 2) groundwater flow is in a south, southeast and easterly direction; and 3) some of the groundwater is discharged to the valley fill along East Fork Armells Creek. Exactly which bedrock unit is contributing flow to valley fill depends upon the reach of the stream (refer to Figure II-11). The course of East Fork Armells Creek through Area C is nearly on strike (normal to the dip of beds), so that as the stream valley floor drops in elevation it contacts deeper strata.

As an area of groundwater recharge, Area C ultimately contributes to flow in tributaries to Rosebud Creek.

c. Groundwater Quality

Groundwater quality in the Rosebud Mine area is influenced and controlled by geology, climate, and human activities. Geologic materials controlling near-surface water quality are Rosebud spoils, valley fill material, Rosebud coal overburden, Rosebud coal, Rosebud/McKay interburden, and McKay coal. The physical and hydraulic characteristics of

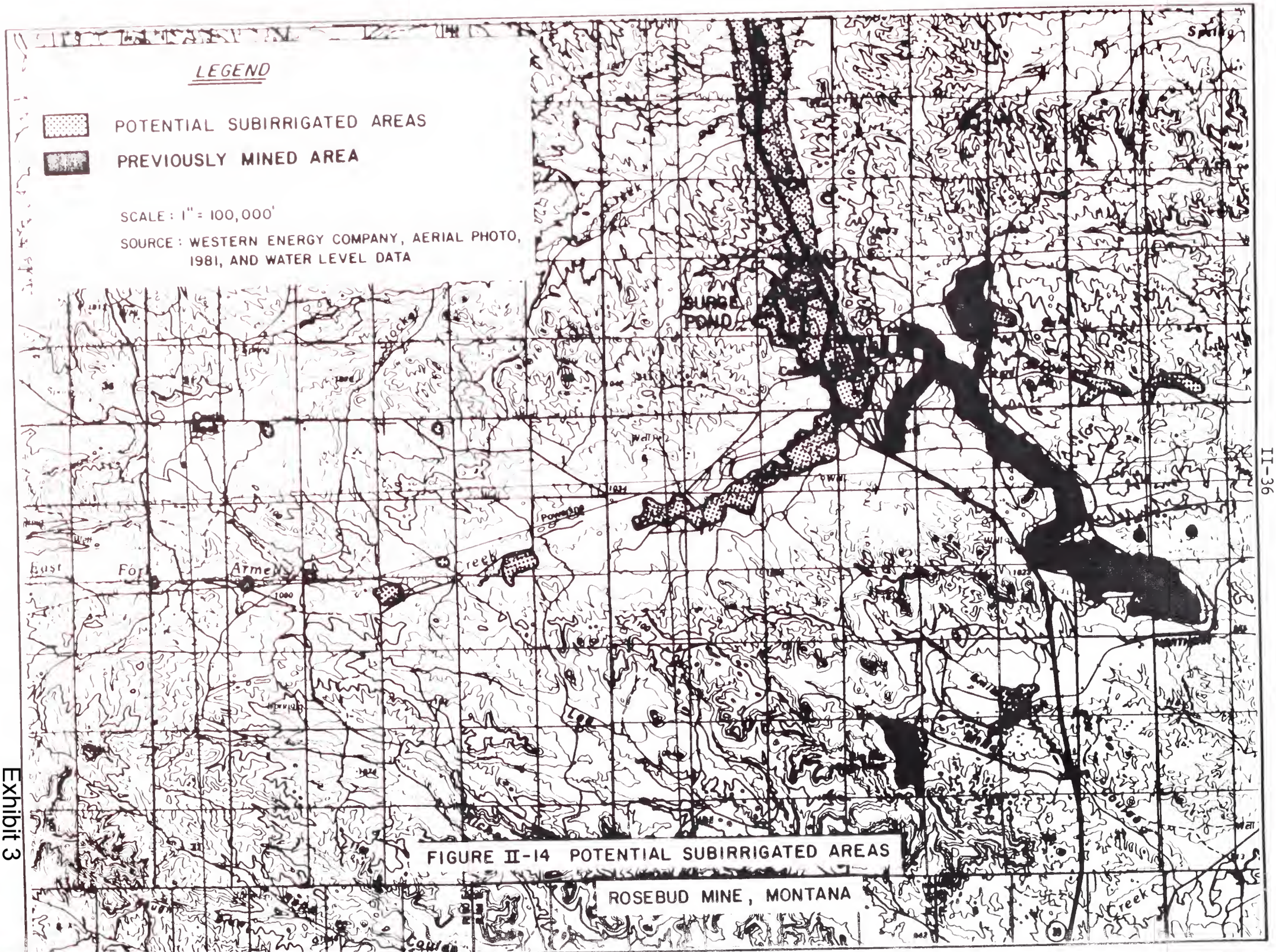


FIGURE II-14 POTENTIAL SUBIRRIGATED AREAS

ROSEBUD MINE, MONTANA

Exhibit 3

each of these water-bearing strata were discussed earlier in Section B.1.a of this chapter.

The influence of climate on water quality in the Rosebud Mine area is generally related to the number, duration, and frequency of precipitation events. Climatic factors are discussed in Section C of Chapter II.

Human activities influencing groundwater quality in the Rosebud Mine area are mining, the MPC electric generating facility, and community activities at Colstrip townsite. The areal extent to which groundwater in the vicinity of the Rosebud Mine has been potentially affected by human activities is depicted in Figure II-15.

The present-day quality of groundwater in Area C has not been affected by human activity.

In the following sections, the existing quality of water in each water-bearing unit is discussed, preceded by a discussion of water quality suitability criteria.

1) Water Quality Suitability

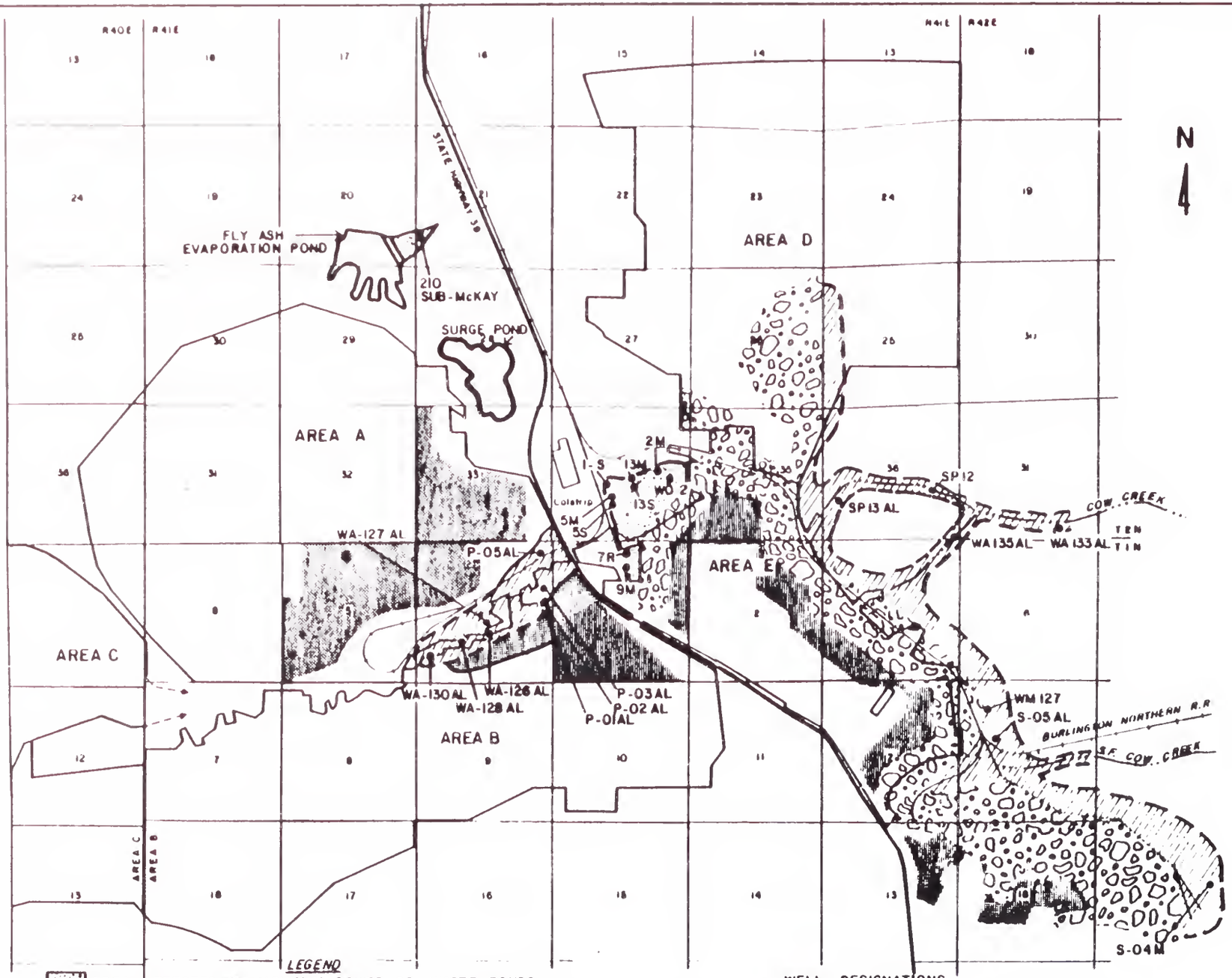
Suitability of waters for irrigation depends to a large extent on factors such as soil type, drainage conditions, management practices, crop type, and on the salinity* hazard* of the water. The classification shown in the following table, as modified from the U.S. Salinity Laboratory Staff (1954), is often used with respect to irrigation water:

Salinity hazard	Range of dissolved solids
Low	Less than 170 mg/l
Medium	170-500 mg/l
High	500-1,500 mg/l
Very High	More than 1,500 mg/l

Raising livestock is an important industry throughout the Rosebud Mine area and stock watering is an important water use. Livestock tolerance to high levels of dissolved solids depends upon the type and age of stock and the period of adjustment to higher levels. Stock water standards for Montana waters (McKee and Wolf, 1971) are shown below:

Category	Range of dissolved solids
Good	Less than 2,500 mg/l
Fair	2,500-3,500 mg/l
Poor	3,500-4,500 mg/l
Unfit	More than 4,500 mg/l

Poultry, pigs, horses, cattle, and sheep (in respective order) have increasing degrees of tolerance to salinity. McKee and Wolf (1971) list the suggested upper limits of dissolved solids concentration for various types of stock as follows:



NOTE: EFFECT OF SPOILS BOUNDARY DASHED WHERE INFERRED
WELLS SHOWN HAVE RECORDS WHERE EFFECTS ARE EVIDENT OR SUSPECT
OTHER WELL LOCATIONS SHOWN ON FIGURE II-5

FIGURE II-15 WATER QUALITY MAP SHOWING AREAS AFFECTED AND POTENTIALLY AFFECTED BY HUMAN ACTIVITIES, ROSEBUD MINE AREA

Exhibit 3

Livestock	Concentration, in milligrams per liter
Poultry	2,860
Pigs	4,290
Horses	6,430
Cattle (dairy)	7,150
Cattle (beef)	10,100
Sheep (adult)	12,900

Some investigators suggest that these values are much too high for optimal growth and development of livestock. It has also been determined that certain major ions may be more limiting than the sum of all constituents. For example, stock can tolerate higher dissolved solids when the water is a sodium-chloride type (McKee and Wolf, 1971).

Most groundwaters in the Rosebud Mine area and Area C have average TDS concentrations ranging from 1,500 to 2,500 mg/l. The range of concentrations normally varies from 500 to 3,500 mg/l. For livestock use, this range would fit the categories of "fair" to "good," however, as applied to irrigation, the salinity hazard classification indicates that a "very high" hazard exists. The fact that an agricultural economy has been viable in the Rosebud Mine area for many decades demonstrates the adequacy of water quality in this part of Montana.

2) Quality of Water-Bearing Strata

A summary of water quality constituent concentrations for the Rosebud spoils and the other water-bearing strata in the Rosebud Mine area and for Area C is provided in Table 1 of Appendix B, and is detailed in the following sections.

a) Rosebud Spoils

The groundwater that occurs in the spoils generally has higher TDS concentrations than the Rosebud overburden or the Rosebud coal aquifers. Average TDS level in the Rosebud Mine area for 35 spoils wells is 3,300 mg/l, as compared to 1,250 mg/l for 22 wells in the Rosebud overburden aquifer and 1,890 mg/l for 55 wells in the Rosebud aquifer. TDS levels of spoils wells at the Big Sky Mine average 3,400 mg/l.

An increase in calcium, magnesium, sodium, bicarbonate, sulfate, and chloride was recorded for spoils wells, which is generally in proportion to the increases in TDS found in Rosebud overburden and Rosebud coal wells. Concentrations and ranges of individual constituents are presented in Table 1 of Appendix B. The pH* of spoils waters is slightly lower than that of overburden waters, ranging from about 6.8 to 7.8; whereas, the pH for overburden water ranges from 7.2 to 8.4. Iron concentrations are slightly lower; whereas, manganese is slightly higher in spoils waters than in overburden waters. Other trace elements are comparable in overburden and spoils. Spoils waters fall into a fair-to-poor category for livestock watering.

Exhibit 3

b) Valley Fill Aquifer

Water quality in the valley fill of the Rosebud Mine area is quite variable, with TDS ranging from about 1,300 to 6,000 mg/l. The average concentration for all wells is about 2,800 mg/l. Highest concentrations, in the range of 3,500 to 6,000 mg/l, are found at random locations and result from natural causes and the impact of mining. An effect of mining operations on valley fill water quality in the headwaters of Cow Creek and on East Fork Armells Creek is suspected. However, some of these elevations may result from natural causes. Because there has been no detailed water quality investigation prepared for Cow Creek prior to milling disturbance (pre-1950 mining) a comparison between pre-mining and post-mining TDS levels cannot be made . Wells showing evidence of water quality changes are as follows:

Well Number[1]	Maximum TDS Concentration (mg/l)	Area-Location
S-05	6,000	Cow Creek
S-13	4,530	Cow Creek
WA 133	3,930	Cow Creek
WA 135	4,340	Cow Creek
PO-5	5,110	A,B, E. Frk. Armells Crk.

[1] Refer to Figure II-5 for well locations

Table 2 of Appendix B shows data documenting changes in TDS concentrations with time for wells P-01, P-02, P-03, and P-05. Table 3 of Appendix B compares TDS concentrations of some alluvial wells showing elevated TDS values with alluvial wells in other drainages indicating unaffected TDS levels.

Water quality in the Armells Creek Valley Fill adjacent to Area C has not been impacted by mining and is more variable than that of other undisturbed areas. TDS concentrations range from 1,390 mg/l in well WA-103 (Figure II-5) to 4,680 mg/l in well WA-121 (Figure II-5). Higher concentrations are found toward the western end of the area and in Stocker Creek headwaters, where concentrations are predominantly in the range of 2,000 to 4,000 mg/l. In the eastern portion of Area C and in the mid-reach of Stocker Creek, concentrations range from about 1,500 to 2,000 mg/l. The water is a magnesium sulfate type with hardness*, ranging from 837 to 2,430 mg/l.

Trace element and nutrient levels are at or near detection levels, which are well below drinking water standards, and should present no problems. All waters should be suitable for stock watering, the primary use in this area.

c) Rosebud Coal Overburden

Analyses of water from three wells, WO-101, WO-103, and S-23 (located on Figure II-5) drilled in the overburden in Area C show that TDS

levels range from 400 to 2,500 mg/l. The overburden well nearest to Area C, Block I is located at the western extremity of Block I and has a TDS level of 2,410 mg/l. The amont of chemical information collected from overburden wells in Area C is not sufficient for statistical comparison; however, the data are similar to data collected in Area B, which are sufficient for statistical analysis. TDS concentrations in Area B range from 600 to 2,500 mg/l, and average 1,850 mg/l. These concentrations have been used as reasonable estimates of water quality in the overburden in Area C.

d) Rosebud Coal

Some of the best quality groundwater in the Rosebud Mine area is found in the Rosebud coal aquifer (Table 1, Appendix B). TDS concentrations range from 400 to 6,500 mg/l; however, the majority of water samples had TDS concentrations in the range of 400 to 1,500 mg/l. Only three wells have concentrations greater than 3,000 mg/l in the Rosebud Mine area, two of which are located in the headwater area of East Fork Armells Creek and Stocker Creek in Area C (wells WR-103 and WR-121 on Figure II-5). The high concentrations in the western portion of Area C may be due to a higher clay and shale content in the overburden and to numerous faults, which have produced solution zones allowing deeper-seated, more mineralized waters to migrate upward into the Rosebud coal aquifer.

The three wells drilled in Area C, Block I have the following TDS concentrations: WR-122 - 534 mg/l; WR-117 - 459 mg/l; and WR-126 - 2,260 mg/l (Figure II-5). Well WR-126 is located along the outcrop of the Rosebud coal, where mineralization from the overlying shale and surface weathering are considered responsible for the higher concentration. Much of the water underlying Block I is probably similar in quality to that of wells WR-117, WR-122, and WR-126.

e) Interburden Aquifer

The predominant range of TDS for all interburden wells in the Rosebud Mine area is 1,500 to 3,000 mg/l. TDS concentration for the Rosebud Mine area ranges from 684 to 3,500 mg/l. There are no wells in the Rosebud Mine area to indicate that waters from spoils have contaminated or penetrated the interburden aquifer; however, power plant wastes appear to have caused an increase in TDS in the interburden aquifer near the townsite of Colstrip and at fly ash pond 210, located about two miles northwest of Colstrip (see discussion in next subsection on McKay coal). In 1980, water in some wells located below or near industrial ponds had TDS concentrations as high as 8,000 to 9,000 mg/l. Pre-mining levels were probably in the range of 500 to 3,500 mg/l (Botz, 1978).

Two wells, WI-100 and WI-104 (Figure II-5), located in the vicinity of Area C, Block I, have TDS concentrations of 1,655 and 2,700 mg/l, respectively. Concentrations of TDS for two interburden wells (WI-100 and WI-104) are probably typical of the range of concentrations for interburden aquifer water in Area C. The water can be characterized as calcium sulfate or magnesium sulfate water, depending on well location. Calcium and magnesium concentrations are generally in the range of 100 to 200 mg/l. Sodium concentrations typically range from 100 to 300

mg/l; however, because of faulting in the area and the suspected upward migration of deeper waters, it is probable that sodium sulfate waters are present in the interburden of Area C. In that case, sodium concentrations in these areas could be similar to that found in the sub-McKay, which has a sodium concentration as high as 700 mg/l.

f) McKay Coal

Two types of water are found in the McKay aquifer: a magnesium-sulfate and a sodium-sulfate type. Magnesium-sulfate water is found in most of Areas B and E, in the eastern and western portion of Area C, and in parts of Area D. Sodium sulfate waters are present in the central portion of Area C, in the northern portion of Area A, in Area D, and in one well at the Big Sky Mine. It is postulated that the sodium-type water is fault or coal flexure* controlled and results from upward migration of water along fracture zones from the sub-McKay aquifer or below, where such waters predominate.

The sodium-sulfate type water has calcium, magnesium, and sodium concentrations in the range of 15 to 100 mg/l, 6 to 75 mg/l, and 200 to 800 mg/l, respectively. Magnesium-sulfate type water has calcium, magnesium, and sodium concentrations in the range of 150 to 250 mg/l, 100 to 150 mg/l, and 100 to 200 mg/l, respectively. Bicarbonate and sulfate concentrations are similar to those found in all waters of the area: sulfate predominates, with a range of 200 to 1,500 mg/l, and bicarbonate varies from about 400 to 600 mg/l. Trace element concentrations are at or near detection levels.

Except where affected by spoils water, TDS concentrations range from about 500 to 2,500 mg/l. The description and concentration range cited above generally fits the situation in the Rosebud Mine area except for Area E, where wells S-04, S-08, and WM-127 (Figure II-5) indicate elevated TDS values with average concentrations of 5,725, 3,192, and 7,455 mg/l respectively (see Table 4 of Appendix B). The data for well SO-4 also appear to indicate an increase in TDS with time. The increase in TDS concentration over time indicates an external source of the salinity. The cyclic variation evident in well S-04 demonstrates the influence of precipitation on the recharge to wells and on the dissolved solids content. That is, wet years produce more recharge and usually lower salt concentrations than dry years. The time when these changes occur is dependent upon the amount of recharge from precipitation, the transmissivity of the aquifer, and the distance from the recharge area. This cyclic effect on TDS can be noted in data from other wells with sufficiently long periods of record.

g) Sub-McKay Aquifer

The majority of waters in the sub-McKay are of the sodium-sulfate type in the Rosebud Mine area. Water quality data is available for two wells in Area C, WD-101 and WD-102 (Figure II-5). Well WD-101 has water of a sodium-sulfate type and WD-102 yields magnesium-sulfate type water. Based on inspection of water quality in the McKay aquifer of Area C and the prevalence of faulting, one would expect the predominant water type in the sub-McKay to be of the sodium-sulfate type. TDS concentrations

in the sub-McKay waters of the Rosebud Mine area generally occur within the range of 1,000 to 3,000 mg/l. The only sub-McKay well in the Rosebud Mine area where some contamination is indicated is well 5-S (see Figure II-5), located adjacent to pond 951 at the Montana Power Company generating station in Colstrip, where TDS in December 1980 was 8,500 mg/l.

d. Groundwater Use

Groundwater withdrawn from the water-bearing strata in the Rosebud Mine area is primarily used for livestock. A few wells are also used for domestic water supply. Based on data presented by Van Voast (1977), approximately 36 percent of the domestic and stock wells are completed in the sub-McKay aquifer. The sub-McKay aquifer appears to be the most dependable water source because most of the wells in the study area are completed in this formation. Of the remaining stock water and domestic wells in the area, thirty percent are completed in the Rosebud overburden, ten percent are completed in the Rosebud coal, and less than ten percent are completed in the valley fill and McKay coal. Sixteen percent of the recorded wells in the study are either completed in other aquifers or well records cannot be located.

The McKay coal aquifer is rarely used as a water source because of its low productivity.

Ephemeral* springs are also used for livestock watering. Table B1-3 in the Technical Support Document lists the springs located in the hydrologic study area, while Plate B-2 illustrates their locations. Specific information on private wells and groundwater rights can also be found in the Technical Support Document (Tables B1-1 and B1-2, and Plate B-2).

2. Surface Water

The proposed Area C, Block I permit area is 4.5 square miles ($mi.^2$) (or 2,877 acres), and straddles the watershed divide between East Fork Armells Creek and Stocker Creek. Stocker Creek, with a drainage area of 26.1 $mi.^2$, flows into East Fork Armells Creek about three miles north of the Colstrip townsite. At the confluence of these two streams, the total drainage area is approximately 73.8 $mi.^2$. A total of 1,646 acres (2.6 $mi.^2$) of the permit area lies within the Stocker Creek drainage, and 1,231 acres (1.9 $mi.^2$) lay within the East Fork Armells Creek drainage (Figure II-16).

a. Drainage Basin Characteristics

East Fork Armells and Stocker Creeks both reflect the influence of bedrock and structural control. This influence is strongest in the headwaters of these creeks and decreases downstream, although some bedrock control of East Fork Armells Creek may continue throughout Area C. The areal extent of valley fill in both basins generally increases downstream, so that the main streams of East Fork Armells Creek and Stocker

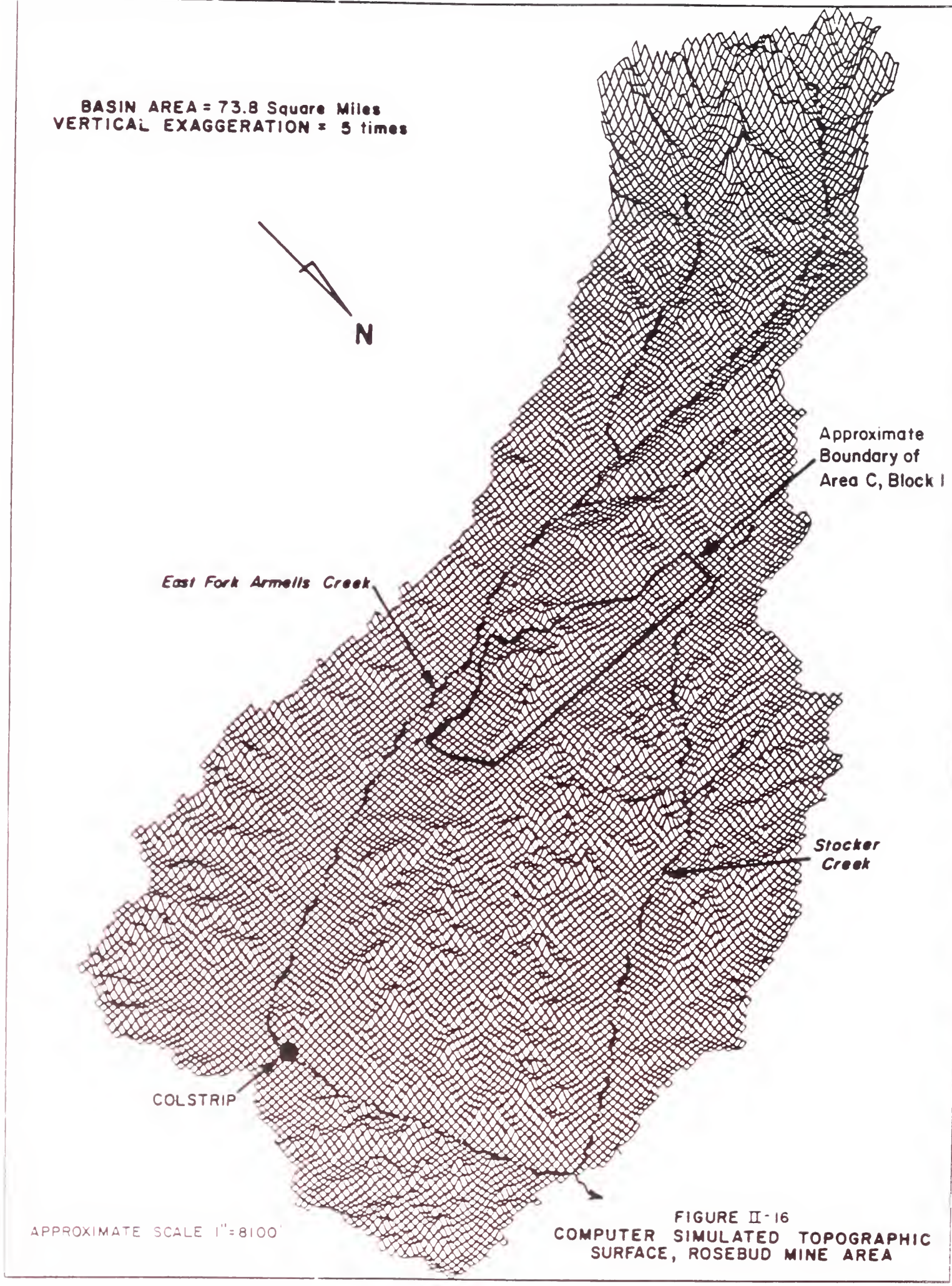


FIGURE II-16
COMPUTER SIMULATED TOPOGRAPHIC SURFACE, ROSEBUD MINE AREA

Exhibit 3

Creek flow within alluvial channels. The small, ephemeral* tributaries, however, are developed primarily on bedrock throughout the permit area.

Analysis of the drainage networks suggests that they are in equilibrium, where a relative balance between stream energy and transport exists. Both the main channels and tributaries of East Fork Armells Creek and Stocker Creek are entrenched, vegetated, and appear to be stable. Major entrenchment of the main streams of the basins is related to climatic change and base level* lowering since the Pleistocene Epoch. The stream network characteristics indicate that the tributary channels have generally adjusted to such long-term changes.

b. Stream Channel Characteristics

Through Area C, the main stem of East Fork Armells Creek is an alluvial channel, with sinuosities* ranging from 1.56 to 2.37, which increase progressively downstream. The longitudinal profile of the creek channel is concave and shows no clear evidence of current instability, neither as major slope changes nor as knickpoints*. In contrast, the ephemeral channels developed on the hill slopes of the upland areas have much straighter longitudinal profiles. Detailed surveys of 12 ephemeral channels in Area C (Appendix O, Western Energy Company Area C, Block I, Application for Surface Mining Permit) indicate that channel oversteepening due to deposition, followed by channel entrenchment, is common in these channels. Deposition and incision are also occurring in response to a change in base level from dam construction.

c. Drainage Basin Sediment Yields* and Landscape Stability

Calculations (see Section B.4 of the Technical Support Document) estimate that sediment yields within Area C are relatively low, ranging from 0.11 to 0.29 acre-feet per square mile per year, and are significantly below average basin yields, which range from 0.3 to 1.0 acre-feet per square mile per year that have been measured under similar geologic conditions in the High Plains region (e.g. Schumm and Lichty, 1965; Ringen et al., 1970). This reflects the predominance of landscape units (sediment source areas) with low or moderate sediment yields and the inefficiency of the vegetated ephemeral stream channels in transporting sediment.

The results of the geomorphic studies summarized above indicate that over relatively large areas (the scale of the East Fork Armells and Stocker Creeks drainage basins) and a long time frame of several hundred years, the landforms and drainage networks within Area C appear to be stable under existing environmental conditions. There is no evidence of widespread accelerated erosion. The major stream channels, although commonly entrenched, are vegetated and do not appear to be undergoing active gullying. However, at the scale of the small ephemeral drainages within Area C, there is some evidence (Technical Support Document, Section B.4) to suggest that these channels are inherently unstable.

d. Surface Water Flows

East Fork Armells Creek and Stocker Creek are intermittent* streams in Area C that flow in response to local and regional groundwater inflow over short reaches, as well as for short time periods in response to snowmelt and high-intensity precipitation events. The proposed permit area is drained by 14 ephemeral drainages tributary to East Fork Armells Creek and Stocker Creek. These tributaries also flow in response to late winter and early spring snowmelt and to late spring and early summer high-intensity precipitation events. Estimates of average annual discharges of 0.08 inches per year have been made by Van Voast (1977). This is equivalent to 315 acre-feet per year at the confluence of Stocker Creek and East Fork Armells Creek. Low flow in both drainages is zero. Although surface water gaging stations exist in the area (Appendix B, Table 5), flow records for Stocker Creek and East Fork Armells Creek are insufficient to accurately describe the magnitude and frequency of floods. However, techniques described by Parrett and Omang (1981) can be applied for estimating flood flows for the 2-, 5-, 10-, 25-, 50-, and 100-year floods. Estimates of flood peaks for Stocker Creek and East Fork Armells Creek are shown in Tables II-5 and II-6, respectively.

USGS continuous flow records for nearby areas were investigated for flow duration statistics. A relationship of the probability of flow occurrence per square mile of drainage area (Appendix B, Figure 1) was computed using these flow duration statistics. The computations demonstrated a close relationship between each stream, indicating a similarity of flow characteristics in the basins (Table II-7). This relationship was used to estimate flow statistics and to synthesize a probability of flow occurrence curve for East Fork Armells Creek below the confluence with Stocker Creek. The synthesized curve (Appendix B, Figure 2) indicates that for 90 percent of the days investigated, flow would be less than 2.5 cfs; for 80 percent of the days flow would be less than 1.0 cfs; and for 40 percent of the days, flow would be less than 0.01 cfs (essentially no flow). This curve illustrates that East Fork Armells Creek below the confluence with Stocker Creek has little or no natural base flow*.

e. Surface Water Quality

1) Streams

The proposed mining in Area C, Block I will occur in Sections 1, 2, 3, 4, 11, and 12 of T1N, R40E. The study area crosses the drainage divide between the north side tributaries of East Fork Armells Creek and the headwater areas of several tributaries on the south side of Stocker Creek. All tributaries in the area are ephemeral and dry for much of the year, flowing only in response to snowmelt and storm runoff (Surface Water Section 2.d). Data from surrounding areas on East Fork Armells and Stocker Creeks have been collected by Western Energy for a sufficient period of time and in a range of conditions to permit an adequate assessment of surface water quality. These data are used to supplement longer term data collected by the USGS on several streams in the area. Records

TABLE II-5

FLOOD MAGNITUDE CALCULATIONS
FOR STOCKER CREEK AT MOUTH

Drainage Area (sq. miles): 26.11

Area Code: 4; Southeast Plains Region

Percent Forest Cover: 10.8

Geographic Factor: 0.8

Recurrence Interval	Flood Magnitude[1] (Cubic Feet per Second)
2	101
5	266
10	415
25	667
50	933
100	1,240

[1]Parrett and Omang, 1981

TABLE II-6

FLOOD MAGNITUDE CALCULATIONS
FOR EAST FORK ARMELLS CREEK
AT CONFLUENCE WITH STOCKER CREEK

Drainage Area (sq. miles): 47.7

Area Code: 4; Southeast Plains Region

Percent Forest Cover: 10.7

Geographic Factor: 0.8

Recurrence Interval	Flood Magnitude[1] (Cubic Feet per Second)
2	145
5	379
10	584
25	928
50	1,300
100	1,720

[1]Parrett and Omang, 1981

Exhibit 3

TABLE II-7

FLOW STATISTICS FOR SELECTED STREAMS
ROSEBUD MINE AREA

USGS Gage Number	Stream	Period of Record (Water Year)	Flow (cfs) Mean	Median	Mode	Range
062941940	Sarpy Creek near Hysham ($453\ mi^2$)	1974 through 1980 (7 years)	8.3	1.3	5.0	0-390
06294690	Tullock Creek near Bighorn ($446\ mi^2$)	1975 through 1980 (6 years)	12.3	1.1	5.0	0-1110
06294995	Armells Creek near Forsyth ($370\ mi^2$)	1975 through 1980 (6 years)	8.1	0.46	5.0	0-750
---[1]	East Fork Armells Creek ($73.8\ mi^2$)	---	1.5	0.13	---	---

[1]These flows were derived from the other recorded flows in this table.

Exhibit 3

of complete chemical data collected on almost a monthly basis by the USGS are as follows:

Location	Period of Record
East Fork Armells Creek near Colstrip	January 1975 to May 1981
East Fork Armells Creek near Forsyth	October 1974 to October 1981
West Fork Armells Creek near Forsyth	November 1974 to June 1977
Rosebud Creek Near Colstrip	October 1974 to October 1981
Rosebud Creek above Pony Creek near Colstrip	October 1974 to November 1977
Cow Creek near Colstrip	October 1979 to May 1981

Concentrations of dissolved constituents are highly variable with respect to time in the East Fork Armells Creek and Stocker Creek basins in response to surface runoff events that dissolve minerals from the land surface. Discharge of subsurface water from valley fill, overburden, and possibly the Rosebud aquifer also influence stream quality. TDS concentrations range from about 200 mg/l at highest flows to about 6,500 mg/l at low base flow. TDS concentrations generally are in the range of 3,000 to 4,500 mg/l since low flows prevail for most of the year. Table 6, Appendix B lists TDS for samples collected by USGS for several sites in the Colstrip area. Stream discharge of the East Fork Armells Creek at Colstrip is also provided to show the relationship between conditions in the area at the time of sampling. Highest TDS concentrations in the range of 4,500 to 5,000 mg/l frequently occur during extreme low flow as a result of concentration from evaporation, transpiration, and biological activity as water passes slowly through pools along several reaches of the stream. These concentrations usually exceed those found in groundwaters of the valley fill and Rosebud aquifers along stream channels by 200 to 300 percent. Valley fill is the predominant source of recharge to streams at low flow, with water also contributed from the Rosebud aquifer in some areas (Groundwater Flow Section, Section 1.C).

Several areas in the East Fork Armells Creek drainage basin appear to have slightly higher TDS concentrations than those found in other stream segments in the Rosebud Mine area, and are presumed to be due to geologic differences. These areas are located approximately as follows: (a) the western half of Area C; and (b) the upper half of Stocker Creek basin (refer to Figure II-3). The evidence for these higher concentrations comes through an inspection of the data collected at surface water site SW-09 in the headwaters of East Fork Armells Creek, about one mile southwest of Area C, Block I; and from site SW-65 on Stocker Creek, about one mile northwest of the northwest of Area C, Block I. Data for West Fork Armells (SW-09 and SW-65, see Figure II-5) are provided in Table 7 of Appendix B. The soils in these areas contain higher proportionate amounts of clays and shales, which contain more soluble minerals than the sandy materials found in the remaining area (see discussions on Geology and Soils, Sections A and F). The surface waters of upper East Fork Armells Creek and Stocker Creek are very hard and have a very high salinity hazard most of the time, with TDS concentrations usually above 2,500 mg/l.

The surface waters in the Rosebud Mine area are a magnesium-sulfate type, with magnesium concentrations usually in the range of 200 to 500 mg/l and sulfate ranging from 1,500 to 3,000 mg/l. Calcium ranges from 200 to 300 mg/l, and sodium from 200 to 400 mg/l; bicarbonate concentrations are usually 400 to 550 mg/l. The relationships between TDS and specific conductance and between specific conductance and calcium, magnesium, sodium, and bicarbonate and sulfate for East Fork Armells Creek near Colstrip are shown in Figure 3, Appendix B.

The quality of water in the reach of East Fork Armells Creek upstream of Colstrip is quite similar to that shown on Figure 3 in Appendix B. Concentrations occurred at the high end of the range about 80 percent of the time. Sodium, magnesium, and sulfate constituents have a linear relationship with TDS at all levels; whereas, calcium and bicarbonate at these high levels reach a plateau, indicating saturation. The water is alkaline with pH in the range of 7.5 to 8.3. Nitrogen and phosphorus are usually low, with concentrations of a few tenths to a few hundredths milligram per liter, respectively. Fluoride concentration is generally 0.1 to 0.2 mg/l.

Trace metal concentrations are at or near the detection level of analytical methodology and constitute no problem, except for mercury concentrations found at several sampling points. For example, samples collected at SW-09, located about one mile southwest of Area C, Block 1, had mercury concentrations of 0.030 and 0.040 mg/l on several occasions. These values exceed the primary drinking water standard, and are believed to be inaccurate; probably resulting from sampling and/or laboratory error.

2) Ponds

The quality of water in ponds in the Rosebud Mine area that receive runoff from disturbed and reclaimed areas of strip mined lands is similar to that contained in the streams of the area. During spring runoff, concentrations will range from about 300 mg/l upward to about 2,000 mg/l. During summer and fall months, concentrations from about 2,000 to 4,000 mg/l will occur as a result of concentration from evaporation and possibly inflow from subsurface drainage. However, the latter is not considered to be a major factor. These concentrations are in a range suitable for stock watering purposes.

Several farm ponds in the area have water quality similar to that found in mining areas, except during late summer and fall they become slightly more concentrated, possibly due to farm activities or increased evapotranspiration rates.

3) Springs

Five springs are located in the Stocker Creek drainage of Area C. Two springs, SP-05 and SP-03 (Figure II-5), are located in Stocker Creek valley fill. The water is highly mineralized, with TDS concentrations of 5,160 and 4,930 mg/l. The remaining three springs (SP-01, SP-02, and SP-04 in Figure II-5) are located along the northern boundary of the Rosebud outcrop in the eastern portion of Area C. SP-01 is similar to

the valley fill springs in concentration with TDS of 5,310 mg/l. Spring SP-04 has a TDS of 3,240 mg/l and spring SP-02 is of relatively good quality, with TDS of 470 mg/l. Chemical data on quality of springs is contained in Table 8 of Appendix B.

The nitrate (NO_3) concentration of spring SP-02 far exceeds the normal for waters in the area, and probably results from organic material such as livestock wastes. Trace metal concentrations were at or below analytical detection levels, except for mercury in springs SP-01 and SP-04, which were 0.230 and 0.010 mg/l, respectively.

f. Surface Water Use

Surface water in East Fork Armells Creek is used for stock water and for flood irrigation downstream of Colstrip. There is no municipal, commercial, or irrigation use of surface water in the East Fork Armells Creek in the immediate vicinity of Colstrip townsite or the Rosebud Mine area. Stocker Creek surface flows are used for stock watering only.

Water is imported via a 29-mile pipeline from the Yellowstone River at a potential maximum rate of 10,000 gallons per minute, for municipal and commercial use by the town of Colstrip, mining activities, and the Montana Power Company power plant. A 112-acre surge pond with a capacity of 2,250 acre-feet stores this imported water. Seepage rates from the surge pond are estimated to range from 175 acre-feet per year (Technical Support Document, Section B.1), to 180 acre-feet per year (Hydrometrics, 1981).

The MPC power plant complex uses approximately 90 to 95 percent (or 7,700 acre-feet) of surge pond water per year. Approximately 85 percent of the water used at the power plant is lost to the atmosphere through evaporation from cooling processes and pond surfaces, some water is lost from pond seepage, and the balance is used mostly for road watering for dust suppression. During the months of March through October, current mine water use for dust suppression amounts to approximately 400 acre-feet of water. Most of this water is lost to the atmosphere through evaporation.

Municipal water use at Colstrip townsite is approximately 630 acre-feet of surge pond water per year, given the present (1980) population. Large amounts of this water are used during the summer months for household and community irrigation. Wastewaters from aproximately 1,150 housing units in Colstrip are treated and released into East Fork Armells Creek (Hydrometrics, 1981). The treated discharge ranges from 17 acre-feet per month to 23 acre-feet per month. This discharge is an additional potential contributing factor to a rise in the local water table, and may also have downstream effects.

The combined estimated seepage from the surge pond, the fly ash pond and the power plant ponds to the valley fill system has been determined to be 256 acre-feet per year (Hydrometrics, 1981). This along with an additional 210 acre-feet per year of effluent discharge from the sewage treatment plant represents a potentially significant addition to the

valley fill hydrologic system (combined surface and alluvial groundwater). Another addition is the seepage occurring from the unlined sewage lagoon; however, detailed monitoring of seepage has not been performed by the town of Colstrip to quantify the seepage volume.

The effects that the addition of more than 467 acre-feet per year of water to the valley fill system can vary. The most immediate and apparent effects would be the increase in downgradient water table elevations and the possible increase in stream flow in the valley fill system. Presently, flow in the valley fill system is approximately 1,180 acre-feet per year, 1,080 acre-feet per year is comprised of surface flow (Table II-7) and 80 acre-feet per year is groundwater flow (Hydrometrics, 1981). The 467 acre-feet per year being added represents 40% of the total flow in the system. However, evapotranspiration reduces this amount to 325 acre-feet per year, as determined by the two-dimensional model, or 28% of total flow in the valley fill system.

Another effect is the potential increase in groundwater discharge in other surface water drainage systems. Along this reach of the valley fill system, the adjacent bedrock units are being recharged by waters from the valley fill. This recharge will be manifested as an increase in the potential discharge to downgradient drainage systems. Those systems that are most likely to be affected are the Cow Creek and Hay Coulee systems. The effects that this increase in discharge has on the surface water use in these drainages cannot be quantified because background monitoring was not performed prior to the start of operations of the various ponds and the sewage treatment plant.

3. Hydrologic Budget

The hydrologic budget quantitatively defines inflow and outflow water and changes in storage within a specific hydrologic system.

The major components that will be discussed are:

- Precipitation (rain and snow)
- The role of vegetation in the hydrologic budget
- Evaporation from surface water sources
- Infiltration rates into the soil
- Soil-water budget
- Groundwater recharge
- Groundwater discharge

Other elements in the hydrologic budget, including surface runoff and groundwater flow, are discussed in Sections 1 and 2, respectively, of this EIS. In each component, both existing conditions and post-mining impacts will be addressed as presented by Western Energy in:

- Area C Permit Application (26.4.314)
- Comprehensive Mine Plan

a. Precipitation

The Colstrip area is influenced by a Continental-type climate, characterized by a wide range of average seasonal temperatures. The average annual precipitation at the Colstrip National Weather Service (NWS) station is 15.8 inches (Bison Engineering, 1981). Annual precipitation may deviate substantially from this long-term average, and the standard deviation of precipitation totals for the period 1928 to 1977 is 3.5. The extremes in total annual precipitation for the period 1970 to 1980 were 22.12 inches in 1978 and 7.66 inches in 1980.

Approximately 12 inches of this precipitation falls during the April to September growing season, with April, May, and June the wettest months. Summer precipitation occurs as showers and high-intensity thunderstorms.

From November to April, precipitation occurs predominantly in the form of snow. Due to the prevailing westerly winds, snow typically accumulates on the leeward (east) slopes of north-south oriented drainages and shallow depressions. These areas are potential sites of groundwater recharge when snowmelt occurs.

Little information is available on variations in precipitation that occur with topography. However, due to the prevailing westerly winds, it is anticipated that more precipitation will occur on the westerly slopes of the upland areas, particularly in the areas of more extreme relief to the west of the Colstrip study area.

b. The Role of Vegetation in the Hydrologic Budget

The analysis of the hydrologic budget includes an assessment of the influence of vegetation (through its control over the rate at which evapotranspiration occurs). Since actual measurements have not been made, results of pan evaporation studies and of calculations using a modified Blaney-Criddle formula (Soil Conservation Service, 1970) have been used as independent methods to calculate potential evaporation and evapotranspiration losses (see Technical Support Document, Section B.3).

This rate is normally expressed by the potential evapotranspiration, but with a plant cover, this value can be modified with a factor that varies with the type of plant, the stage of plant growth, the development of leaves, and the density of the plant cover. The factors were applied to the measured pan evaporation of 53 inches per year (Technical Support Document, Section B.3), suggesting that potential evapotranspiration from grassland in the Colstrip area is in the range of 36 to 45 inches per year (Dollhopf, 1980; Gray, 1970). Monthly values for these estimates are presented in Table II-8.

The results of the Blaney-Criddle analysis and the balance of monthly precipitation and evapotranspiration are presented in Table II-9. Both this method and the pan evaporation study illustrate that evapotranspiration is highly significant in the water balance of the area.

An additional, although less significant, role of vegetation is the interception of precipitation by vegetation and its subsequent loss by evaporation. No actual measurements of this mechanism exist; however, as part of the water budget analysis made by Western Energy in the Area C Permit Application (26.4.314), the interception of rainfall by grasses in the Colstrip area has been estimated using a relationship developed by Horton (1919). Unfortunately, this empirical relationship is appropriate only for individual storm events and is therefore difficult to apply on an average basis. Results of Western Energy's average monthly interception calculations are discussed in the Area C Permit Application (pages 349 through 351). The total yearly value for the interception of rainfall was estimated to be approximately 0.5 inch per year.

c. Evaporation from Surface Water Sources

Evaporation from surface water sources, such as ponds and reservoirs, can be estimated from Class A pan evaporation data. The results of various studies of pan evaporation data are discussed in the Technical Support Document, Section B.3. These studies indicate that surface water evaporation can range from 33 to 53 inches per year.

d. Infiltration

Infiltration rates for soils in Area C have been estimated from soil surveys conducted by Western Energy as part of the mine permit application (26.4.314, p. 356-358). Most soils in the proposed mining area have a fine loam texture. Infiltration rates for this group range from slow (0.06 inch per hour) to moderately rapid (6 inches per hour).

e. Soil Moisture Budget and Deep Percolation

A major consideration in the water budget of the Colstrip area is whether any of the surface moisture received from precipitation will reach the groundwater table.

An analysis of properties of the major soil groups in Area C indicates that little, if any, water is contributed to the groundwater from these soils (see Technical Document, Section B.3). The soils with the greatest potential for recharge under realistic field conditions appear to be the clinker residual soils (Technical Support Document, Section B.4). Also, in areas where water can accumulate (such as small depressions, ponds, and channel bottoms) sufficient moisture may be available to allow significant infiltration into the subsurface.

f. Groundwater Recharge

Water flow in ephemeral stream channels in the Colstrip area is characterized by the passage of well-defined peak flows, often of only a few hours duration in the summer season, separated by long periods without flow. As a consequence, groundwater recharge is relatively low, both in the channels and on the hillslopes. Infiltration (or transmission loss*) into the groundwater reservoir formed by the valley fill material is controlled by hydraulic gradient*, hydraulic conductivity of the aquifer, and hydraulic conductivity of the stream bed.

No direct observations of infiltration or transmission losses of streamflow are available in the Colstrip area. However, measurements in other semiarid areas indicate that the volumes lost to valley fill aquifers may be large. Keepel and Renard (1962), for example, observed that 50 percent of the maximum stream discharge was lost and total flow volume was reduced by 35 percent over a 10-mile stream reach. Turner et al. (1943) stated that infiltration losses of 75 percent in 15 to 25 miles were common. In perennial channels, a study of 57 flood events on 18 rivers in the Great Plains revealed an average loss of 40 percent on channel lengths of 50 miles, with as much as 75 percent of the flood volume being lost.

The relative importance of transmission losses is obviously related to the inflow volume, at least up to some level of discharge because of the characteristics of the channel cross section. Where the width/depth ratio of a channel is large (that is, where a small increase in flow depth will yield large increases in stream width), the consequent increase in surface area covered by water will also increase transmission loss. Many of the streams of the Colstrip area are similar to this, with an incised, active channel bordered by a shallow high-flow channel and floodplain. In these cases, there may be a sharp jump in the increased losses as flow spreads out onto the floodplain during high flows.

Ertec's estimate of recharge to the valley fill aquifer at a point approximately three miles north of Colstrip was made using a two-dimensional model of the system at steady state (Technical Support Document, Section B.1). Input considerations included rainfall, evapotranspiration, transmission losses, and tributary inflow. This analysis indicates that the amount of recharge to the valley fill aquifer is approximately 195 acre-feet per year.

g. Groundwater Discharge

Groundwater discharge to the East Fork Armells Creek drainage system (and specifically to its valley fill aquifer) takes the form of springs, seeps, and upward leakage from the Rosebud aquifer. A value was estimated by Ertec using a two-dimensional steady state computer model of the valley fill system (Technical Support Document, Section B.1). This model indicates that the total amount of groundwater discharge to the system is approximately 130 acre-feet per year.

h. Hydrologic Budget Analysis

The hydrologic budget of the water transmitted in the valley fill aquifer of East Fork Armells Creek is based on Ertec's two-dimensional steady state computer model (Technical Support Document, Section B.1). The inflow to the system consists of discharge from the Rosebud aquifer, seepage from the Montana Power Company's surge pond, recharge and tributary inflow. Outflow from the system includes downward leakage, evapotranspiration losses, and the amount of underflow through the valley fill material out of the system.

Considering these parameters, the hydrologic budget for a location on East Fork Armells Creek approximately three miles north of the Colstrip townsite is as follows:

Inflow	
Discharge from the Rosebud Aquifer:	130 acre-feet/year
Surge Pond Seepage:	175 acre-feet/year
Fly Ash Pond:	24 acre-feet/year
Recharge and Tributary Inflow:	195 acre-feet/year
	524 acre-feet/year

Outflow	
Downward Leakage and Evapotranspiration:	375 acre-feet/year
East Fork Armells Creek Underflow:	149 acre-feet/year
	524 acre-feet/year

Total inflow = Total outflow

No other data, whether measured or estimated as available for leakage (inflow) or outflow in the system (Hydrometrics, 1981). A similar water balance was conducted for Stocker Creek which indicated no impacts would occur (see Table III-3).

It is difficult to accurately quantify gains and losses from the Cow Creek Drainage. However on a sustained basis one can assume that most inflow occurs from groundwater discharge while most losses occur via evapotranspiration in those areas of Cow Creek alluvium which are assumed to be subirrigated.

The potential evapotranspration calculated for grassland in the study area was used to calculate the estimated losses in subirrigated areas. It is assumed that troughout the growing season a subirrigated area plant community has all of the available water it needs. That total loss (annually) would be 25.2 inches/year (see Table B3-27 TSD). The total present groundwater discharge to both North and South Fork Cow Creek is 15,681 cubic feet per day, or 5,723,565 cubic feet per year (131.4 acre-feet/yr). Potential losses due to subirrigation (all occurring along the North Fork of Cow Creek) total 319 acre-feet/year, or 13,895,640 cubic feet per year. Since this value obviously exceeds the amount of water contributed by groundwater discharge one or more of a number of factors are involved:

1. There are contributions such as infiltration from precipitation on alluvium which make a significant and unaccounted for contribution to alluvial groundwater.
2. The area identified as being subirrigated is, in fact, smaller than as mapped.
3. The actual uptake by plants is less than that calculated.

There is a constant difficulty with the use of synthetic water balances, particularly for the semi-arid west. Generally any water balance arrived at without direct meausrement is only a gross approximation of real conditions. In the semi-arid west a standard water balance usually results in zero net infiltration values. A water balance does not include the anomolous conditions which may allow for rapid infiltration, for example, without evapotranspiration losses.

HYDROLOGY GLOSSARY

Aggradation: The building up of the grade or slope of a stream by the deposition of sediment.

Alluvium (alluvial): A general term for clay, silt, sand, gravel or similar unconsolidated material deposited during comparatively recent geologic time by a stream or other body of running water.

Aquifer: Stratum or zone that contains sufficient saturated permeable material to produce water to a well or spring.

Base flow: The sustained runoff of a stream system, primarily composed of effluent groundwater; the natural flow of a stream unaffected by peaks due to storms, snowmelt, or the works of man.

Base Level: The lowest level to which erosion of the earth's surface constantly progresses; the level below which a stream cannot erode its bed; the level at which stream equilibrium exists.

Boundary: (As it refers to hydrology) Indicates or fixes a limit of lower permeability that affects the hydraulic characteristics of a system, i.e., faults, springs, creeks.

Clinker (Porcelanite) - Fused shales and clay that occur as a result of burned coal seams.

Colluvium (colluvial): A general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff and moved chiefly by the force of gravity.

Confined: Refers to a groundwater aquifer under sufficient hydrostatic pressure to rise above the surface of the aquifer when penetrated by a well and bounded by an impervious stratum directly above or below the zone bearing water.

Crop out: To appear exposed and visible at the surface of the earth.

Dip: The angle that a bedding plane makes with the horizontal.

Discharge area: An area in which subsurface water, including both groundwater and vadose* water is discharged to the land surface, to bodies of surface water, or to the atmosphere.

Dissolved Solids: The quantity of dissolved material in a sample of water; the residue on evaporation or the sum of determined constituents; results are usually reported in milligrams per liter.

Electrical conductivity: A measure of the ability of a solution to conduct an electrical current, measured in millimhos. It is used on soil extracts as a measure of the soluble salts in soils.

Energy grade line: A line joining the elevations of the energy heads of a stream when referred to the stream bed.

Exhibit 3

Ephemeral stream: A stream or portion of a stream that flows only in response to precipitation. Its channel is at all times above the water table.

Erosion rates: The amount of soil loss per unit land area for a given time frame.

Evapotranspiration: Loss of water from a land area through the transpiration of plants and evaporation from the soil.

Flexure: A fold; a monocline formed by warping or other gentle deformation rather than by compression.

Gaining stream: A stream or reach of a stream that receives water from a zone of saturation and provides base flow; its channel lies below the water table.

Hardness of water: A physical-chemical characteristic that is commonly recognized by the increased quantity of soap required to produce a lather. It is mainly attributable to the presence of calcium and magnesium and is expressed as equivalent calcium carbonate ($CaCO_3$) in milligrams per liter.

Hummocky: Abounding in rounded or conical knolls, mounds, hillocks generally of equidimensional shape and not ridge-like.

Hydraulic conductivity: The rate of flow of water through a one square foot cross section under a unit hydraulic gradient, measured in feet per day (ft/day).

Hydraulic gradient: In a aquifer, the rate of change of pressure head per unit distance of flow; in a stream, the slope of the "energy grade line.*"

Hydrogen-ion concentration (pH): Indicates the degree of acidity or alkalinity of water and is expressed in terms of pH units. The pH value of a solution is the negative logarithm of the concentration of hydrogen ions, in moles per liter.

Interburden: At the Rosebud and Big Sky Mines, Montana, the consolidated material that separates the Rosebud and McKay coal beds.

Intermittent stream: A stream that does not flow continuously. Flow occurs in response to precipitation, snowmelt, and groundwater inflow.

Knickpoint: Points of abrupt change in the longitudinal profile* of stream valleys.

Longitudinal profile: The surface of a valley bottom or stream, drawn along its length from the source to the mouth of the stream.

Losing Stream: A stream or reach of a stream that contributes water to the zone of saturation; its channel lies above the water table.

Milligrams per liter (mg/l): A unit expressing the concentration of chemical constituents in solution. Milligrams per liter represents the weight of solute per unit volume of water.

Normal fault: A fault in which the hanging wall (or overlying side) appears to have moved downward relative to the footwall (or underlying side).

Outcrop: The exposure of bedrock or strata at the surface of the earth.

Overburden: Consolidated or unconsolidated material that overlies a coal bed.

Permeability: The capacity of porous rock, sediment, or soil for transmitting a fluid.

pH: See hydrogen-ion concentration.

Porosity: The percentage of bulk volume of rock or soil occupied by pores.

Potentiometric: Refers to an imaginary surface representing the static head of groundwater, defined by the level to which water will rise in a well.

Recharge area: An area in which water is absorbed that eventually reaches the zone of saturation in one or more aquifers.

Reverse fault: A fault in which the hanging wall (or overlying side) appears to have moved upward relative to the footwall (or underlying side).

Salinity: Qualitative term expressing the soluble salt content of a solution or material.

Salinity hazard: The impact of salt content in irrigation waters on crop growth. It depends on the dissolved solids in the irrigation water, soil condition, drainage, and management practice.

Sediment yield: The actual amount of eroded material delivered by a stream system to a given point in a drainage basin or subbasin.

Semi-confined: Refers to a regional groundwater aquifer that exhibits both confined and unconfined characteristics.

Sinuosity: ratio of the length of the channel to the down-valley air distance; streams with sinuosities of greater than 1.5 are called "meandering."

Specific conductance: A measure of the ability of water to conduct an electrical current, expressed in micromhos per centimeter at 25°C. Because the specific conductance is related to the number and type of ions in solution, it can be used for approximating the dissolved solids content in the water.

Spoils: At the Rosebud and Big Sky Mines, Montana, the reworked Rosebud coal overburden material, which has been replaced where the Rosebud coal has been mined out.

Storage coefficient: The volume of water an aquifer releases from or takes into storage, per unit surface area of the aquifer per unit change in head.

Subcrop: A buried outcrop.

Subirrigation: Supplying water to plants from underneath or from a semi-saturated or saturated zone where water is available for use by vegetation.

Terrace: Horizontal or gently inclined, relatively flat surfaces which are bounded by a steeper ascending slope on one side and by a steeper descending slope on the opposite side.

Transmission loss: The loss of stream flow to the alluvium (Syn: losing stream)

Transmissivity: Measure of the ability of an aquifer to transmit water through a unit width under a unit hydraulic gradient measured in gallons per day per foot (gpd/ft).

Unconfined: Refers to a groundwater aquifer that has a free water table, i.e., water not confined under pressure beneath relatively impermeable rocks.

Vadose water: Water in the zone of aeration.

Valley fill material: The unconsolidated colluvium and alluvium deposited by any agent so as to fill or partly fill a valley.

C. CLIMATE

Southeastern Montana, including the Colstrip area, has a continental climate. The majority of large-scale weather systems move from west to east, and being on the lee side of the Rocky Mountains, the Colstrip area is influenced by descending air masses characterized by the dissolution of clouds, and thus, clear-sky conditions and temperature extremes. In winter, inversions predominate; in summer radiation increases atmospheric turbulence (USGS, No date).

1. Temperature

Summers are characterized by warm days, but most nights, even during midsummer, cool down to 60 degrees F or less, so oppressive hot spells are not very common. Temperatures of 90 degrees F or more occur about 40 days each year and can occur in any month from May through October. The average temperature during the warmest month at Colstrip (July) is 71.5 degrees F. During July the average maximum temperature is 89.2 degrees F and the average minimum is 53.8 degrees F.

During winter, nights generally cool to less than 15 degrees F at night, but warm to 30 degrees F or better during the day. An occasional cold spell will generate sub-zero temperatures, but these spells seldom last more than two or three days. The average temperature during the coldest month (January) is 21.0 degrees F. During January the average maximum temperature is 34.4 degrees F and the average minimum is 7.7 degrees F.

The annual average temperature at Colstrip for the period 1941 to 1970 was 45.9 degrees F.

2. Humidity

The annual average relative humidity for the townsite of Colstrip was 55 percent in 1976 and 68 percent in 1977. The relative humidity has a wide diurnal variation related to similar variation in air temperature and a relatively constant amount of ambient moisture.

3. Precipitation

The annual average precipitation at the Colstrip National Weather Service station is 15.8 inches. Three-fourths falls during the April through September growing season. Winter precipitation is generally light with just over half an inch a month during the period November through February. Most of the precipitation during this time is in the form of snow. The average snowfall at Colstrip is 34.6 inches.

4. Severe Weather

Hailstorms are typically the most common and damaging form of severe weather in Montana and occur mainly in July and August. Floods may occur in spring and early summer as a result of the melting snowpack, but are more likely due to locally heavy thundershowers in late spring and summer.

5. Evaporation

The nearest National Weather Service station measuring evaporation rate is at Terry, Montana, about 90 miles northeast of Colstrip. Over a five- to ten-year period, the average total evaporation for May through September was 40 inches. Evaporation data are not obtainable from October through April because periods of below freezing weather frequently occur.

Evaporation rate is also measured at the Absaloka Mine by Westmoreland Resources, about 25 miles west of Colstrip. During 1979 (May 7 through September 17), total evaporation measured was 35.7 inches, or about 0.42 inches per day.

6. Dispersion Meteorology

Since the primary air pollutant emissions related to the proposed mining operations at Area C, Block I are particulates released from ground level or near-ground level sources, the meteorological parameters that affect air pollution potential the most are precipitation and/or soil moisture content, surface wind, and mixing height. Surface wind speed determines how fast the air pollutants are removed from the area, and in the case of fugitive emissions, the amount of air pollutants that are entrained into the atmosphere. The wind direction simply dictates where the air pollutants are transported. Therefore, atmospheric stability is important to the air pollution potential because if repeated or extended stable conditions occur, air pollutants will tend to accumulate in an area. Finally, mixing height is the height above the ground to which the air pollutants are carried or mixed. If mixing heights are low, air pollutants are contained in smaller volumes and concentrations are greater.

Surface wind speed and direction are monitored by Western Energy at the meteorological station located on a ten-meter tower inside the train loop in Area A (see Figure I-2). Figure II-17 summarizes the surface winds for 1980. Because of the predominance of southerly wind directions during several of the seasons, the annual windrose also shows a predominance of southerly winds. Strongest wind speeds were from the west-southwest, while slowest wind speeds were from the east. Calm conditions occurred 15 percent of the hours. Wind speeds in excess of 13 miles per hour occurred about ten percent of the hours, but wind speeds in excess of 25 miles per hour occurred less than one percent of the hours.

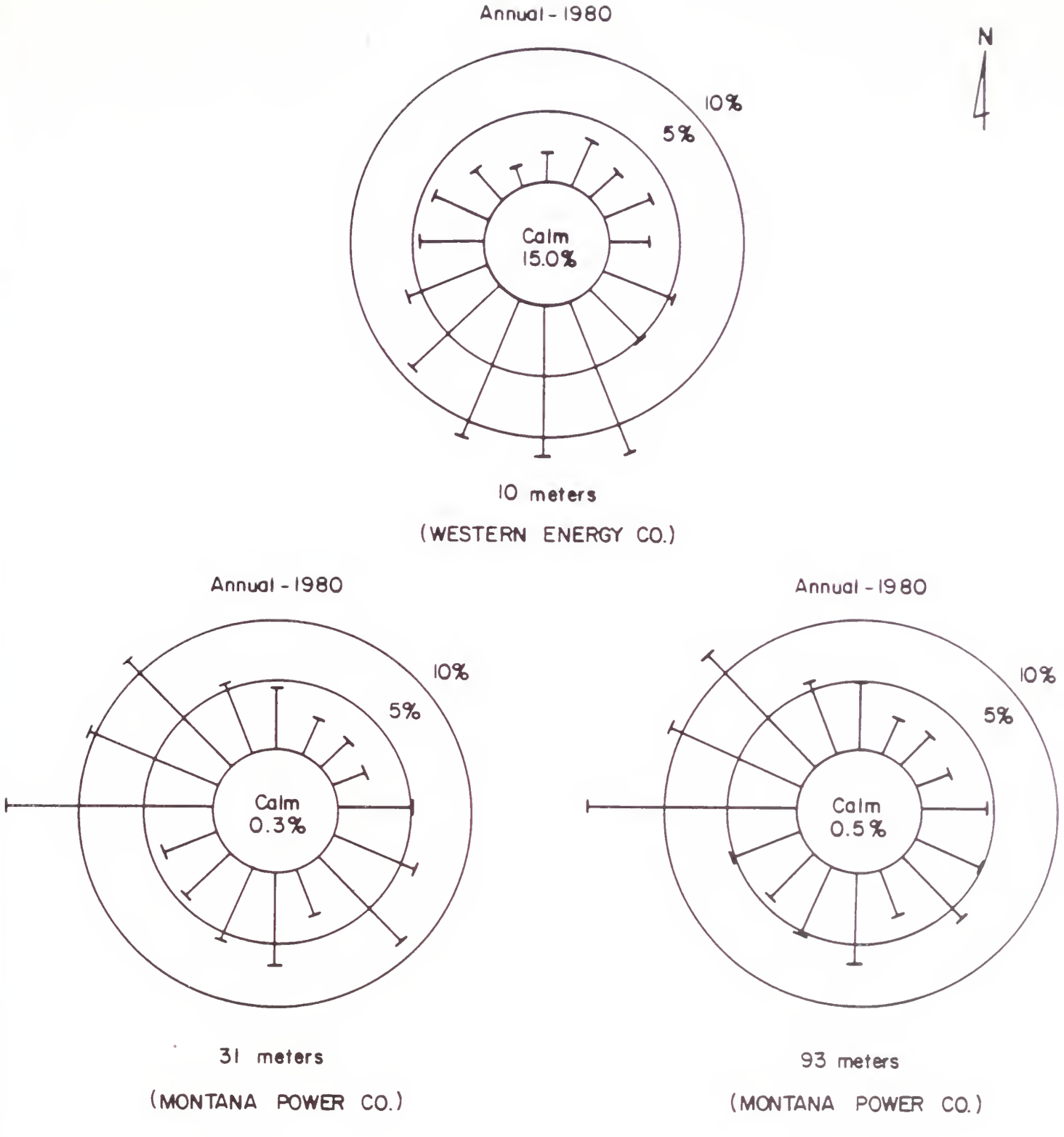


FIGURE II-17 COLSTRIP AREA ANNUAL WIND FREQUENCY DISTRIBUTIONS

Exhibit 3

Although a wind direction shift to a more westerly direction with increased elevation is predictable, the shift of some 90 degrees from the Western Energy ten-meter site to the MPC 31-meter level is more than expected. The MPC tower is located on top of a 30-meter hill, which can account for some difference. However, it appears likely that either local terrain influences or instrument problems account for the wind direction changes.

Mixing heights (or vertical temperature above 100 meters) have not been routinely measured in the Colstrip area. Montana State University (MSU) measured vertical temperature using aircraft in the Colstrip area during 1971-1972 (MSU, 1973). Results from the MSU measurements indicated Glasgow mixing heights were quite similar to Colstrip heights except during spring. Annually Colstrip and Glasgow mixing heights were very similar. Holzworth (1972) reported Glasgow mixing heights as shown below.

GLASGOW, MONTANA MIXING HEIGHTS*
(Values in meters)

	Annual	Winter	Spring	Summer	Autumn
Morning	310	283	391	304	262
Afternoon	1564	524	1971	2454	1307

* Holzworth (1972)

Exhibit 3

D. AIR QUALITY

The following discussion is limited to particulate matter since the source of concern is a surface coal mine. Other, gaseous pollutants have been monitored in connection with MPC's generating Units 1 through 4, but the discussion only addresses those issues that are associated with the proposed mine operation.

1. Ambient Air Quality Standards

Air quality standards applicable to pollutant sources in the Colstrip area are those resulting from the Federal Clean Air Act and the Montana Clean Air Act. The Montana Ambient Air Quality Standards (MAAQS) and the National Ambient Air Quality Standards (NAAQS) are outlined in Table II-10. The NAAQS are expressed as both primary and secondary standards. Primary standards are those required, with an adequate margin of safety, to protect public health. Secondary standards are those necessary to protect the public welfare from any known or anticipated adverse effects associated with air pollutants.

Because of the high particulate matter levels, an area of 120 square miles centered on Colstrip has been designated as a non-attainment area for TSP. Part of the Area C, Block I mining operation is within this designation.

2. Total Suspended Particulates

Western Energy presently monitors TSP at ten sites around Colstrip; additionally, MPC monitors TSP at four locations. The location of these monitors is shown in Figure II-18.

Examination of the data from the existing Western Energy mining areas (Western Energy 3, 4, 6) reveals that current levels exceed both the NAAQS and the MAAQS. Short-term concentrations as high at 6,585 ug/m^3 have been recorded. The three samplers near or in Colstrip (Western Energy 1 just southwest of Colstrip, Western Energy 2 south of Colstrip; MPC 3 in the center of town) generally are near or exceed the 24-hour standards. The Montana annual arithmetic standard of 75 ug/m^3 has been exceeded at all three sites, although only MPC 3 exceeds the federal primary annual geometric standards of 75 ug/m^3. Western Energy has recently moved its monitoring station 2 to a new location where lower concentrations are being observed. According to a letter to the Montana Air Quality Bureau (MAQB) from Western Energy (August, 1980), Western Energy Company #2 was moved due to realignment of the county road. The sampler was moved to Area B (from Area A) in anticipation of monitoring emissions from Area B moving toward Colstrip. The relocation was approved by the MAQB.

The samplers located further from Colstrip and not in the mining areas generally reveal particulate concentrations below the NAAQS and MAAQS. Only the MPC samplers have measured short-term particulate concentrations near or above the standards. Annual particulate concentrations at these more distant sites are well below the ambient standards. It should be noted that NAAQS and MAAQS are considered to be violated if

TABLE II-10

MONTANA AND NATIONAL AIR QUALITY STANDARDS

POLLUTANT	MONTANA STANDARD	FEDERAL PRIMARY STANDARD	FEDERAL SECONDARY STANDARD
Total Suspended Particulates	75 ug/m^3 annual arithmetic average 200 ug/m^3 24-hr average*	75 ug/m^3 annual geometric mean 260 ug/m^3 24-hr average*	60 ug/m^3 annual geometric mean 150 ug/m^3 24-hr average*
Sulfur Dioxide	0.02 ppm annual average 0.10 ppm 24-hr average* 0.50 ppm 1-hr average**	0.03 ppm annual average 0.14 ppm 24-hr average*	0.5 ppm 3-hr average*
Carbon Monoxide	9 ppm 8-hr average* 23 ppm hourly average*	9 ppm 8-hr average* 35 ppm 1-hr average*	9 ppm 8-hr average*
Nitrogen Dioxide	0.05 ppm annual average 0.30 ppm 1-hr average	0.05 ppm annual average	0.05 ppm annual average
Photochemical Oxidants (ozone)	0.10 hourly average*	0.12 ppm 1-hr average*	0.12 ppm 1-hr average*
Lead	1.5 ug/m^3 90-day average	1.5 ug/m^3 calendar quarter average	None
Foliar Fluoride	35 ug/g grazing season 50 ug/g monthly average	None None	None None
Hydrogen Sulfide	0.05 ppm hourly average*	None	None
Settled Particulate (Dustfall)	10 gm/m^2 30-day average	None	None
Visibility	Particle scattering coefficient of 3 x 10^{-5} per meter annual average***	None	None

* Not to be exceeded more than once per year

ug/m^3 micrograms pollutant per cubic meter of sampled air

ppm parts pollutant per million parts of sampled air

** Not to be exceeded more than 18 times per year

*** Applies to PSD Class I areas

Exhibit 3

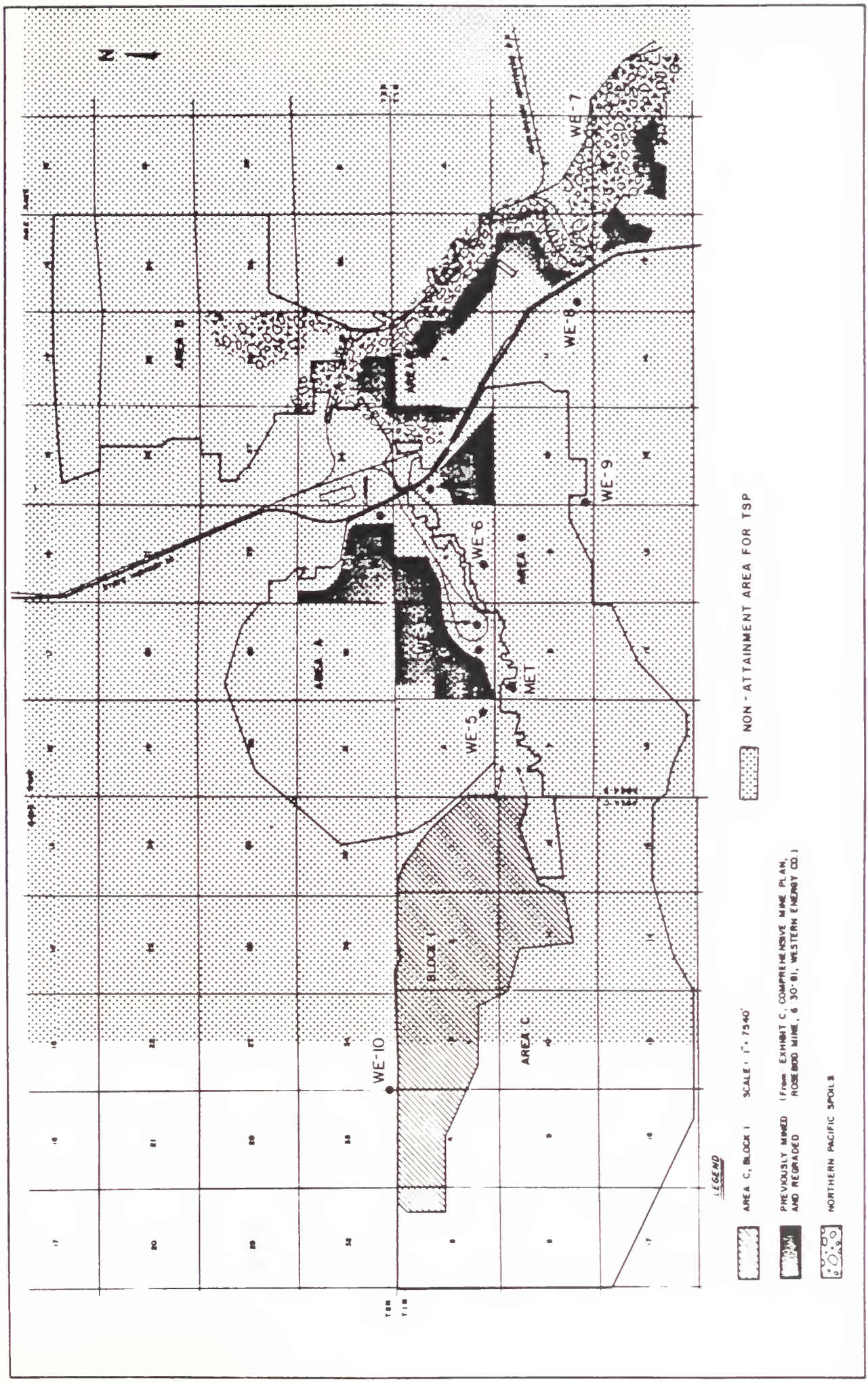


FIGURE II-18 HIGH VOL. & MET. STATIONS

Exhibit 3

values are obtained from samplers located in areas where the public would have access. Values greater than the standards at monitors located on company property are not considered violations of the standards.

Because of the high particulate matter levels, an area of 120 square miles centered on Colstrip has been designated as a non-attainment area for TSP. The U.S. Environmental Protection Agency (EPA) designated the attainment status of this area and various other areas in Montana on March 3, 1978 (43 FR 9009-9010). The state of Montana submitted a revision to the State Implementation Plan (SIP) on April 23, 1979 in which the state committed to bring the Colstrip area into compliance with both the annual and 24-hour NAAQS TSP standards by December 31, 1982. The Montana Department of Health and Environmental Sciences (MDHES) proposes to attain these standards through the enforcement of a revised airborne particulate rule by requiring existing mining operations to meet conditions of required operating permits. In the meantime, for any mine to expand in the non-attainment area, the mining company must demonstrate that it is decreasing nonfugitive particulate emissions in the area to a degree greater than will be generated by its proposed expansion. This is known as "offset" under the state and federal air regulations. The requirements hold true for any other major plant that might be sited in the non-attainment area.

The particulate situation in the Colstrip area is characteristic of fugitive dust impacts. Because the emission sources causing the problem (e.g., mining dust, construction dust, vehicular travel on paved and unpaved surfaces, and the coal handling around the power plant) produce particulates of a relatively large size (PEDCO, 1981; TRC, 1981), the dust settles out quickly and the impacts are very localized. Areas not close to any significant source generally experience low concentrations. Area C, Block I currently experiences very low particulate concentrations on the order of 25 ug/m^3 annual arithmetic mean based on Western Energy monitor numbers 10 and 11.

Fugitive dust problems of this type are relatively difficult to solve. Western Energy has in recent years undertaken a number of new dust control measures at their existing operations. A detailed discussion of these actions is provided in the EIS prepared for Area B (Montana DSL, 1980). The results have not significantly reduced TSP concentrations in Colstrip, partly because local sources in town, including construction sites, the coal handling facilities for Units 1 and 2, and unpaved roadways may be responsible for a sizable percentage of the impact, and because the amount of emissions reduction was small when compared to total emissions.

3. Settled Particulates

Settled particulate samplers or dustfall buckets are presently located at five of the Western Energy TSP sites. No federal ambient standard addresses dustfall. The Montana 30-day average standard of ten grams per square meter has been exceeded at Western Energy 3, 4, and 6, all in the train loop area. At Western Energy 7 (located in reclaimed portions of Area E) and 11 (located in Area C) dustfall amounts exceeded

the Montana standard during 1981. Dustfall levels exceeded the Montana standard in the past; however, sampling at Western Energy 5 (about one-quarter mile southwest of Area A) and 8 (two and one-half miles southeast of Colstrip) was discontinued in 1980. The settled particulate values follow the pattern of fugitive dust areas. The large-sized particles produced by fugitive dust sources settle readily and generally occur in large quantities.

4. Visibility

Ambient visibility has not been measured in the immediate Area C, Block 1 vicinity. However, an estimate of visual range (a measure of visibility) can be made using TSP measurements. In this way a value of 35 miles is derived for the existing visual range in the area. The Technical Support Document provides the details of this computation.

E. NOISE

Existing sound levels have not been measured in Area C, Block 1, but are believed to be very low. Summer sound levels are generally slightly higher than winter due to bird and insect noise. Noise related to man's activities is presently limited to occasional blasting from other nearby mining operations.

The 1979 Colstrip Project EIS (U.S.D.I, 1979) reported measurements taken some distance from the town. It was found that the tone radiating from the generating plant stack was distinctly audible, with a sound level of 37 dBA at a distance of 2.6 miles from the plant. At 3.8 miles from the plant, the tone was marginally audible at 32 dBA. It was assumed from these measurements that the background ambient sound level in the Colstrip area would be approximately 29 dBA if no noise source existed in the area. Thus the ambient sound levels in Area C, Block I are probably about 29 dBA.

Sound levels in the townsite of Colstrip have been documented more thoroughly. The 1979 Colstrip Project EIS discussed measurements at a variety of locations in and around the townsite. Due to the presence of generating Units 1 and 2, the sound levels observed (53 to 68 dBA) were more typical of an urban area than a small town. The measurements reported in the Colstrip EIS indicate that the L_{eq} (24) at two community locations was less than the 70 dBA level that might cause hearing loss, but greater than the 55 dBA that causes interference with outdoor speech and activities.

Neither Montana nor the townsite of Colstrip has specific ambient noise regulations. The Environmental Protection Agency, however, has published noise level guidelines in "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety" (EPA, 1974). Since the identified sound levels consider neither cost nor technical feasibility, EPA states that its guidelines are not to be interpreted as federal ambient noise standards, but rather as information for state and local government use in establishing their regulations. These levels are summarized in Table II-11.

TABLE II-11

SUMMARY OF NOISE LEVELS IDENTIFIED
AS REQUISITE TO PROTECT PUBLIC HEALTH
AND WELFARE WITH AN ADEQUATE MARGIN OF SAFETY

Effect	Level	Area
Hearing loss	$L_{eq} \leq 70$ dBA	All areas.
Outdoor activity	$L_{dn} \leq 55$ dBA	Outdoors in residential areas, farms, and other areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	$L_{eq} \leq 55$ dBA	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity intereference and annoyance	$L_{dn} \leq 45$ dBA	Indoor residential areas.
	$L_{eq} \leq 45$ dBA	Other indoor areas with human activities, such as schools, etc.

* In this table, L_{eq} refers to a 24-hour equivalent sound level; this is the constant sound level that has the same sound energy as a time-varying sound would over a 24-hour period. L_{dn} is a 24-hour equivalent sound level in which the nighttime (10:00 p.m. to 7:00 a.m.) sound levels are increased by 10 decibels to account for the added annoyance due to sleep interference.

Exhibit 3

F. SOILS

The soils of the Area C, Block I permit area are predominantly light-colored soils with weakly developed subsoils and thin, dark-colored surface layers (Aridisols). Other, less common soils in the area include poorly developed soils (Entisols) in which very little alteration from the underlying material has occurred (Soil Survey Staff, 1975).

Eighteen soil series have been recognized within the permit area in detailed mapping and sampling (Western Energy Permit Application, Area C, Block I). These can be grouped into four major soil types by similarities in parent material, texture, and landscape position. The four soil groups include:

- Sandy Residual Soils
- Alluvial Loamy and Clayey Soils
- Clinker Soils
- Unbaked Shale and Siltstone Soils

Each group represents several soil mapping units recognized in detailed soil mapping as occupying similar landscape positions and having similar physical characteristics. Table II-12 shows the characteristics of these groups, and detailed supporting summaries are included in Appendix F. Figure II-18 shows the general distribution of these soil types within Block I. Detailed large-scale maps of the Block I permit area and descriptions of each soil series and mapping unit can be found in the Area C, Block I permit application prepared by Western Energy.

The proposed disturbed area includes the crusher facility, the mine shops, the haul roads, clinker (locally known as scoria) pits, topsoil stockpile, and highwall reduction zones and boxcut spoil zones, in addition to the mine pit itself. These disturbances are anticipated to total 1,627 acres of the 2,693-acre permit area.

1. Sandy Residual Soils

These soils are formed in material weathered from sandstones of the Tongue River member of the Fort Union Formation, which are weakly consolidated calcareous sandstones capping many of the many rolling hills in the Colstrip area. This group represents 44 percent of the 1,627-acre disturbed area. The Busby, Reidel, Yetull, and some areas of the Cooers soil series are included in this group (refer to Table 1, Appendix F).

Two landforms and vegetation types can be recognized within this group. Hilltops and ridges containing small knobs and weathering outcrops of sandstone commonly have sandstone within 40 inches of the surface. Scattered ponderosa pine (*Pinus ponderosa*) and skunkbush sumac (*Rhus trilobata*) occur in these areas, with an understory of tall and midgrasses.

In the gently rolling portions of this unit, sandy material commonly extends to a depth of more than 40 inches before sandstone is encountered.

TABLE II-12

CHARACTERISTICS OF GENERAL SOIL GROUPS
AREA C, BLOCK I

Soil Group	Acreage	Percent of Disturbed Area	Limitations	Proposed Salvage Depth (feet) Topsoil	Subsoil	Approximate Reclaimed Area Reclaimed Acreage*	Percent
Alluvial Loamy and Clayey Soils	710	44%	High salts in subsoil, occasional high clay	1.0	0.5-3.5	947	58%
Sandy Residual Soils	710	44%	Excess sand, depth to rock	0.5	1.0-2.5	580	36%
Clinker Soils	138	8%	Depth to fractured rock, slope	0.5	1.0-1.5	80	5%
Unbaked Shale and Siltstone Soils	69	4%	High salts, depth to rock, high clay	0.5	0-2.5	20	1%

* Assumes an average replaced topsoil thickness of 8" and replaced subsoil thicknesses ranging from 26-28".

Exhibit 3

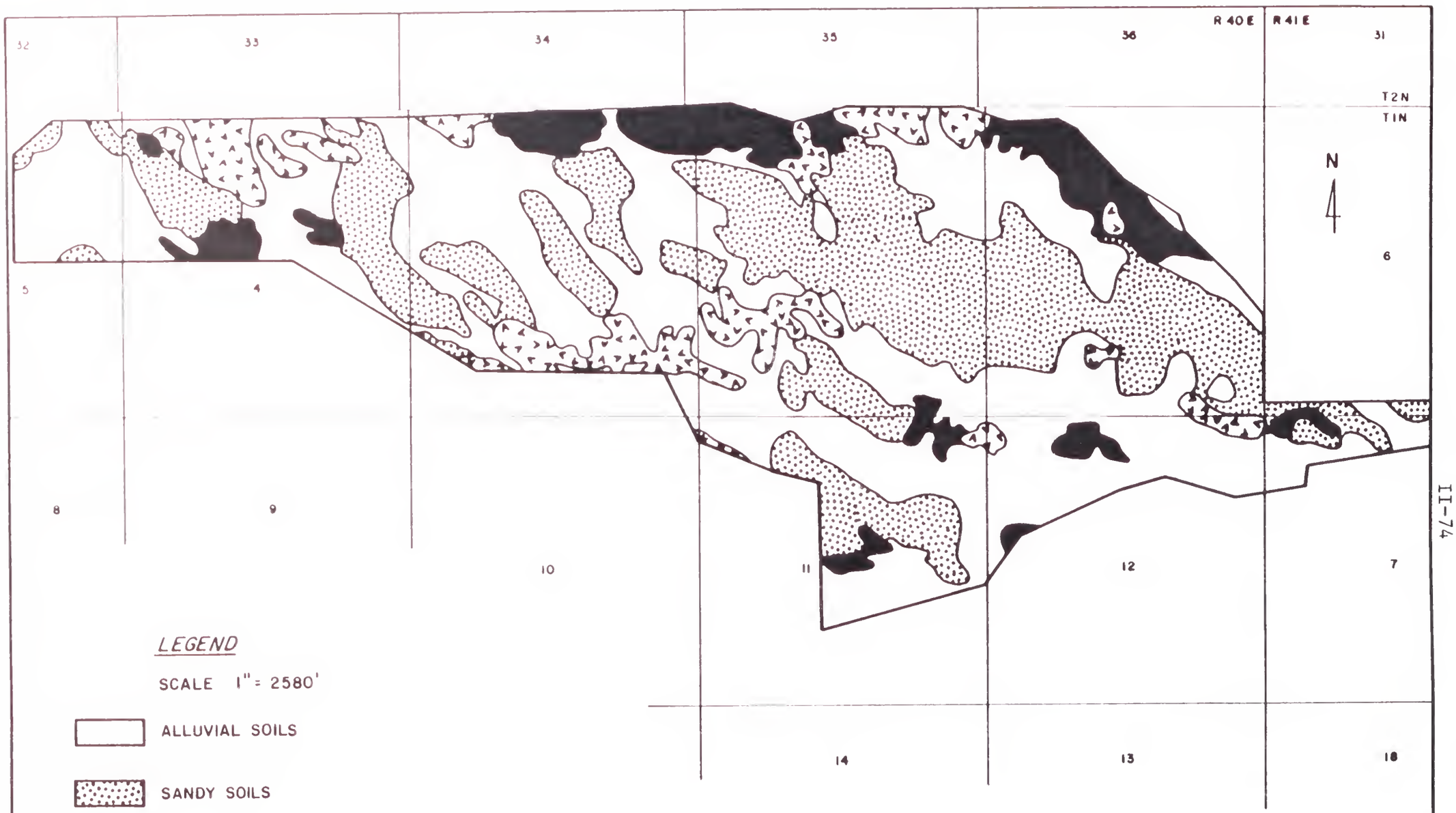


FIGURE II-19 GENERAL SOIL GROUPS, AREA C, BLOCK I

Exhibit 3

Ponderosa pine and skunkbush sumac stands are rare in these rolling areas; instead, cool-season grasses dominate the vegetation. The adapted climax community for this soil type includes a large component of productive deep rooted warm-season grasses (USDA-SCS, 1981).

Sandy residual soils are best suited to grazing use. Crop production is limited by low available water in the surface soil layers where most annual crops have their roots. This results in low crop yields and increased wind and water erosion, especially during drought years. Of the few areas where cropping has been attempted in Area C, Block I, most have been replanted to grass for grazing.

The soils of this group are limited for topsoil use by excess sand content. DSL guidelines suggest that soils containing an excess of 70 percent sand are a poor source of topsoil or subsoil. All of the soils in this group occasionally exceed the recommended limits of sand (see Technical Support Document).

2. Alluvial Loamy and Clayey Soils

Deposition of mixed loamy and clayey material has occurred at the bases of hills and on benches and terraces along the drainages of Area C, Block I. The soils occurring at these locations represent 44 percent of the soils to be disturbed in Block I, and include the Yamac, Kremlin, Lonna, Vanstel, Kobar, and Havre soil series and the undifferentiated unit referred to as Ustic Torriorthents. The major limitations for salvaging these soils include moderate to high electrical conductivities in some of the subsoil layers and occasionally excess clay.

The soils in this group commonly extend to 60 inches or more before bedrock is encountered, and have moderate water availability in the surface soil layers, which is critical to the successful establishment of crops. A majority of the land presently under cultivation in Block I occurs in the gently sloping portions of this soil group. This indicates that the soils of this group are well-suited to small grain production, limited only by regional characteristics of low rainfall and the short growing season. In soil areas containing natural vegetation, shallow-rooted cool-season midgrasses dominate the existing plant communities in association with big sagebrush (Artemisia tridentata) and silver sagebrush (Artemisia cana). The adapted climax plant community for this site is also made up of shallow-rooted, cool-season midgrasses, in association with a smaller component of shrubs.

Excess clay content may be encountered in the Kobar and Vanstel soils, and all of the soils of this group may contain layers with high salts (Technical Support Document). Generally, these soils are good sources of topsoil and subsoil.

3. Clinker Soils

On scattered hilltops within the Block I area, reddish- or purplish-colored baked sandstones and shales occur, known as clinker or locally

as scoria. This material commonly occurs along ridge tops and on the crests of hills. Much of the clinker that occurs within the Area C, Block I permit area will be mined as a source of road base construction material, or disturbed by placement of the boxcut spoils. This soil group represents eight percent of the total 1,627 acres to be disturbed. It includes shallow rocky soils formed directly in the clinker (Birney and Kirby series), and soils formed in close association with the clinker hills, including portions of the Cabbart and Cooers series.

Clinker soils consistently support stands of ponderosa pine and Rocky Mountain juniper (Juniperus scopulorum), and of all the soils found in the vicinity of the Rosebud Mine, clinker soils support the most vigorous stands of these vegetation types (Richardson, 1981). This is apparently due to the competitive advantage to trees due to the apparent availability of free water at depth where bedrock is encountered (McQueen, 1982; Stark, 1980). Grass and shrub understories are also well established on these soils, although they are less dense than in other communities because of shading by trees and the mulching effect of the surficial rock fragments (Richardson, 1981).

4. Unbaked Shale and Siltstone Soils

This soil group includes residual soils forming in material weathered from shales and siltstones. They are often found in association with the clinker soils, except that the bedrock has not been baked by burning coal. The soils are widely variant, and occur in complex terrain (i.e., with steeply rolling hills and ridges and limited small swales or valleys between the hills).

This group includes the Cabbart, Delpoint, Yawdim, and Rentsac soils and occupies four percent of the proposed disturbance area. A majority of these soils are Entisols, weakly developed soils that vary only slightly from the bedrock from which they were derived. Most of the soils have bedrock at depths between 15 and 30 inches and scattered rock fragments on the surface. The primary limiting factors of the soils in this group are depth to rock, high clay content, and high salt content. These soils support a sparse cover of shrubs and scattered junipers.

5. Soil/Plant Relationships

From the above descriptions, it is apparent that a wide range of vegetative types occur in Area C. For some, especially the warm-season grasses characteristic of the tall grass prairie and ponderosa pine, the Colstrip area is near the edge of their extent (Howard, 1982). Compared to other plant communities in the area, the ponderosa pines and skunkbush sumac probably occur in microsites with lower moisture stress conditions (F.A. Branson, unpublished data, see Technical Support Document), indicating that one of the major reasons for their presence in portions of the Colstrip area may be the availability of additional soil moisture.

Work by the Water Resources Division of the U.S. Geological Survey in the Hanging Woman Creek area not far from Colstrip (USGS, 1981) has shown that a wide variability of soil moisture availability and plant stress can occur in a small area, due primarily to the physical characteristics of the soil.

In general, crops and shallow-rooted, cool-season grasses such as the wheat grasses are most competitive in soils such as the alluvial soils in Area C in which infiltration is relatively moderate or slow, allowing the near-surface root system to use much of the precipitation received in these areas. Where infiltration is relatively rapid and precipitation results in deeper soil wetting, such as in the deep sandy residual soils, deep-rooted grasses and shrubs have the competitive edge. If, in addition, a bedrock layer allows water accumulation at deeper layers, trees can take advantage of this more readily available water. Trees and shrubs are also found where readily available deep soil water occurs along drainages.

In steep areas, rapid infiltration rates (such as in the clinker soils) will prevent excess runoff, whereas moderate or slow infiltration rates will result in increased runoff such as on the unburned shale and siltstone soils. Increased runoff effectively reduces the amount of moisture available to plants. The "gumbo knob" vegetation type (Appendix G) occurs on the unbaked shale and siltstone soils, and reflects the low productivity and dominance of drought-resistant shrubs and grasses common to such a situation. Table II-13 illustrates the general characteristics of moisture availability to which the present or potential vegetative communities would be responding.

There are many other variables that complicate the simplification presented in Table II-13, including seasonal fluctuations, annual variability resulting from low or high precipitation periods, the introduction of other stresses on vegetation such as insect infestations, grazing, or rodent activity.

TABLE II-13

GENERALIZED SOIL/PLANT WATER RELATIONS

Soil Group	Runoff	Infiltration	Generalized Water Availability* Near Surface	At Depth	Adapted Vegetation*
Alluvial Soils					
Uplands	moderate	moderate/slow	moderate	moderate	Shallow-rooted grasses, big sagebrush
Drainage ways	low	moderate	moderate	high	Silver sagebrush, chokecherries
Sandy Residual Soils					
Deep sands (rolling uplands)	low	rapid	low	moderate	Deep-rooted grasses
Sands over bedrock (hills and ridges)	low	rapid	low	high	Ponderosa pines, skunkbush
Clinker Soils	low	rapid	low	high	Ponderosa pines, skunkbush sumac
Unburned Shale and Siltstone	high	slow/moderate	low	moderate	Rabbitbrush sumac

* Highly competitive increaser species such as needle-and-thread grass and prairie junegrass are found in a majority of the area.

Exhibit 3

G. VEGETATION

The vegetation of the proposed permit area consists of a variety of grasses, forbs, shrubs, and trees. Cool-season perennial grasses are the dominant plants in terms of canopy cover and vegetative production. Several different native plant communities occupy various sites within the area. Ponderosa pine (Pinus ponderosa) is a highly visible species found growing in colonies on ridges and adjacent upper slopes. The native vegetation sites are used primarily for livestock grazing under present management systems. Existing vegetation also supplies important wildlife habitat and watershed protection.

Several sites within the permit area support introduced forage plants that are used for hay or pasture. A considerable acreage is presently cultivated for production of small grains, primarily winter wheat. Roads, ranch facilities, and localized mining of clinker (locally known as scoria) has resulted in the removal of vegetation from a small portion of the area. For the small areas involved, clinker mining has had only a minor impact or vegetation, the most obvious being the removal of ponderosa pine and the creation of small depressions in these areas. Coal mining on adjacent areas at the Rosebud Mine has not had a noticeable effect on the vegetation in Area C.

Of the total 2,693 acres within Area C, Block I, 71 percent (1,904 acres) is rangeland and ponderosa pine stands; 13 percent (334 acres) is hayland and pasture; 16 percent (436 acres) is cultivated for wheat; and one percent (19 acres) is disturbed land generally devoid of vegetation. No rare or endangered plant species have been identified in the area. The vegetative cover on the soils in these land use categories is further described in the following paragraphs.

1. Rangeland Vegetation

Western Energy has identified six rangeland plant communities in the proposed permit area. They have been identified and named according to the two or three plant species dominating the different sites at the time of examination. This approach identifies only the vegetation dominant when examined, a highly variable characteristic evidenced by the fact that the dominant and co-dominant plant species have changed for some communities even since measurements were begun in 1978. Therefore, in order to provide more basic ecological data for reclamation and management, the existing plant communities are compared with the potential communities of equivalent range sites, as described by the Soil Conservation Service in the Montana Technical Guide, Section II-8 (USDA-SCS, 1981). The key element of a range site is its ability to produce a characteristic plant community (USDA-SCS, 1976). A map designating range sites in Area C, Block I is provided in the Technical Support Document. This map correlates closely with Figure II-19.

Three basic vegetative types can be delineated from the six rangeland plant communities identified for detailed investigation. These are differentiated by major growth form and landscape position, and include: grassland, shrub-grassland, and conifer-shrubland as shown in Figure II-20.

Exhibit 3

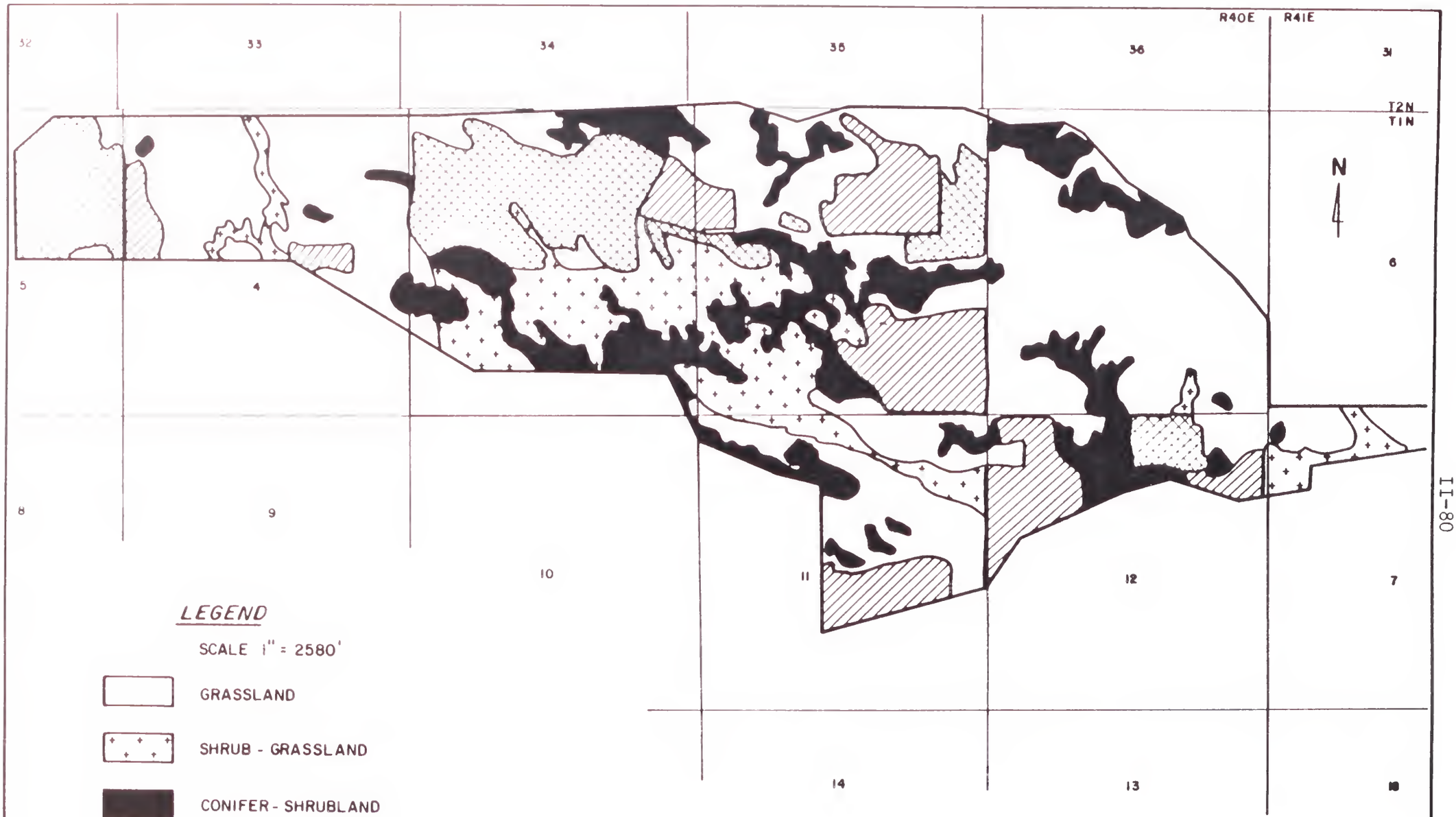


FIGURE II-20 GENERAL VEGETATION TYPES, AREA C, BLOCK 1

Exhibit 3

- Grassland. This is the largest plant community in Area C, Block I. It comprises 60 percent (1,147 acres) of the rangeland in the proposed permit area. At present, needle-and-thread (Stipa comata), western wheatgrass (Agropyron smithii), and prairie junegrass (Koeleria cristata) dominate the community. The grassland community occupies two range sites, silty and sandy, as described by SCS. The climax dominants on the silty site are western and thickspike wheat grasses (Agropyron smithii and A. dasystachyum), bluebunch wheatgrass (Agropyron spicatum), and needle-and-thread, all cool-season grasses. The climax dominants on the sandy site are prairie sandreed (Calamovilfa rongifolia) and little bluestem (Schizachyrium scoparium), two warm-season grasses. Needle-and-thread, thickspike wheatgrass, and big bluestem (Andropogon gerardii) are of secondary importance on the sandy site. Apparently past grazing patterns have favored the cool-season grasses at the expense of the warm-season grasses.

  Forbs and shrubs are relatively minor components of both the existing and potential vegetative communities.

- Shrub-Grassland. This vegetative type occurs primarily on deep loamy to silty soils. It includes three communities dominated by three different shrubs: big sagebrush (Artemisia tridentata), silver sagebrush (Artemisia cana), and rubber rabbitbrush (Chrysothamnus nauseosus). The shrub-grassland vegetative type occupies about 23 percent (435 acres) of the rangeland in the proposed permit area. Big sagebrush (Artemisia tridentata) is the dominant species in upland positions. Bluebunch wheatgrass (Agropyron spicatum), green needlegrass, and other native cool-season grasses occur in association with the big sagebrush and make up nearly 30 percent of the vegetative production. Forb coverage is high.

  In swale and bench positions, silver sagebrush (Artemisia cana) is the dominant shrub, with skunkbush sumac (Rhus trilobata), western snowberry (Symphoricarpos occidentalis), and big sagebrush also occurring in association with the silver sage. Numerous forb species are present. Western wheatgrass (Agropyron smithii) and Kentucky bluegrass (Poa pratensis) are abundant. Cool season grasses account for nearly two-thirds of the vegetative canopy. Minor areas dominated by rubber rabbitbrush (Chrysothamnus nauseosus) occupy steeper portions of this general vegetation type.

  The two sagebrush communities correlate with the silty range site. The principal difference between the present and climax plant communities is the dominance of shrubs in the existing communities. In the climax community shrubs account for less than ten percent of the annual vegetative production.

  The rubber rabbitbrush community occupies a shallow clay range site. The existing community is similar in species composition to the climax.

- Conifer-Shrubland. Ponderosa pine in scattered to moderately dense stands with adjacent areas of skunkbush sumac are characteristic of this site. Stand density ranges from 32 to 360 trees per acre (Western Energy Company, 1980). Rocky Mountain juniper (Juniperus scopulorum) is a minor component of the community. This community occupies 17 percent (330 acres) of the rangeland in Area C, Block I.

  The stands of pine have an average age of 50 years and an average height of 28 feet. The predicted height at 100 years of age is 48.7 feet. This community is generally found on the rocky, shallow, and moderately deep soils often associated with weakly consolidated sandstone or clinker outcrops. The presence of pine appears to be favored by soils having rapid infiltration and percolation rates, which cause precipitation to become readily available to tree roots. At the same time, a less favorable moisture regime is created for competing herbaceous plants, primarily grasses.

  Canopy cover of the understory and open areas consists of grasses, forbs, and shrubs, including silver sagebrush, prairie rose (Rosa arkansana), yucca (Yucca glauca), and shrubby evening primrose (Oenothera serrulata). Dominant grasses and grasslike plants include needle-and-thread, threadleaf sedge (Carex filifolia), and prairie sandreed.

  Because of the slow growth rate of ponderosa pine in the area, the stands have low potential for timber production. The site is considered to be rangeland rather than woodland. Its present value and function are primarily for wildlife habitat, aesthetics, grazing, and watershed protection. Range sites are usually thin sandy where this community occurs.

2. Range Condition and Production

Range condition is the present state of vegetation of a range site in relation to the climax (natural potential) for that site, and may be expressed as excellent, good, fair, or poor depending upon the degree that the present plant community reflects that of the climax. Forage production is usually related directly to range condition. Rangeland in fair condition can be expected to produce less than 50 percent of the site potential, while rangeland in good condition should produce 50 to 75 percent of the site potential. It should be noted that sites in lower range condition classes may produce greater total biomass than the preceding statement would indicate. This could occur when invader or secondary climax species dominate a site and growing conditions are favorable for their vegetative expression.

Overall range condition in Area C, Block I is fair. The suggested initial stocking rate is about five acres per animal unit month. At this stocking rate, the 1,904 acres of range will carry 63 cow-calf units for a six-month grazing period. Information on range condition and

production of the vegetative communities in Area C, Block I is summarized in Table 1 in Appendix G.

3. Cropland

The 436 acres of cropland in Area C, Block I are used primarily for production of winter wheat in a wheat-fallow cropping system. Average yields are reported to range from 20 to 30 bushels per acre (Hydrometrics, 1981). A majority of these areas occur in loamy and clayey soils. Vegetative cover is provided by the growing wheat crop, the standing stubble after harvest, and crop residues remaining after summer-fallow tillage. Aside from the grain produced, vegetative production on an air-dry basis ranges between 2000 and 3000 pounds per acre (Greb, 1977).

4. Pasture and Hayland

Vegetation on haylands and pasture consists primarily of introduced cool-season grasses and legumes. Various fields support a stand of either crested wheatgrass (Agropyron cristatum), alfalfa (Medicago sativa), or a mixture of the two species. Forage yields for hay are reported to range from one-half to two tons per acre annually, with the average yield being 1.2 tons per acre (see Land Use, Section J). These areas are not irrigated on a regular basis.

H. WILDLIFE

An extensive wildlife data base exists relevant to the Rosebud Mine. Western Energy has sponsored wildlife investigation programs that have been under way since before 1973. Under this program data has been collected on big game, upland game birds, raptorial birds, songbirds, waterfowl, mammalian predators, small mammals, and reptiles and amphibians. No specific studies were conducted on reptiles, amphibians, and fish. The study area is shown in Figure 1, Appendix H.

Although surface mining of coal in the Colstrip area has been active for many years, no mining has occurred in Area C. Mining in Colstrip areas prior to 1973 was not subject to reclamation requirements, consequently, most of the reclamation activity there has been recent. Areas A, B, and E have active reclamation plans designed to rehabilitate disturbed lands to productive condition. It is unknown what effect, if any, past and ongoing mining activities outside of Area C may have had on the wildlife populations of the area. The destruction of habitat by mining and related surface developments may have decreased the maximum potential wildlife carrying capacity of the area and increased exposure of wildlife to human activities may have adversely affected survivorship and production of wildlife, but the actual impact of such changes is unknown.

1. Big Game

Most big game data is from aerial surveys conducted throughout the year. Although aerial surveys can yield indications of abundance and distribution of big game and herd composition by sex and age class, absolute quantification of these parameters is seldom feasible. There are several potential sources of bias in this methodology, including:

- Flight speed, altitude, and spacing - flying faster, higher or more widely spaced transects reduces total data capture (observation or sampling efficiency).
- Topography and vegetation - topographic relief can shield animals from view; vegetation, particularly trees and shrubs, can hide or camouflage animals.
- Observation conditions - adverse weather, including precipitations, fog, or haze, and "bumpy" air can reduce observation efficiency; snow cover generally provides much improved observability.
- Number of observers - use of the aircraft pilot as observer for one side of the transect is less effective than two dedicated observers.
- Double-counting - movement of animals between sample flights or flight lines; contrast this bias with flightline spacing bias.

- Daily and seasonal activity patterns - animal behavior patterns may affect observation efficiency, for example diurnal use of wooded and shrubby habitats where animals are camouflaged or completely hidden from view; or seasonal herding behavior wherein groups are easier to detect than individuals.

In addition to the aerial surveys, big game habitat preference data were collected opportunistically on the ground. The biggest difficulties with this type of data are the lack of control over uniformity of coverage of the area, inability to define the relative level of sampling effort expended by habitat type, and the observability biases related to diurnal and seasonal activity patterns of the animals and accentuated difficulties with topographic and vegetation visibility barriers.

Therefore, the following big game descriptions emphasize indices of abundance and herd composition available from Western Enery's aerial survey data base and rely more heavily on published literature for general information on big game habitat requirements.

a. Antelope

Over the eight years that intensive big game investigations have been conducted in the Colstrip vicinity, the pronghorn antelope (Antilocapra americana) has been consistently the most numerous big game species (Ecological Consulting Service, 1973, 1974, 1975; ECON, 1976, 1977, 1978, 1979; Western Energy, 1980). The Wildlife Study Area does not have large tracts of preferred pronghorn habitat, big sagebrush-grassland. Shrub-grassland habitat is particularly important to pronghorns during the winter months when sagebrush may represent over three-quarters of total forage intake, and the relative scarcity of this habitat in the Wildlife Study Area accounts for the substantially reduced pronghorn population in the area during winter. Since grassland is the predominant habitat, the area is favorable for antelope use in spring, summer, and fall.

Productivity of the pronghorn herd in the study area as reflected in fawn/doe ratios has been similar to estimates for production in game management units in the region. Observations per hour (Table 1, Appendix H) indicate severe winter die-off for the 1978-79 winter. The fawn/doe ratios indicate increased survival subsequent to this decline. Suitable habitat is available in Area C for pronghorn fawning.

Pronghorn observations for Area C follow the same general pattern as the Wildlife Study Area as a whole. Pronghorn observations are generally common in spring, summer, and fall when use of grasslands and agricultural areas predominates, but infrequent during the winter months, although an occasional small herd may remain in the vicinity of Area C during mild winters. These wintering pronghorn range over suitable habitats in the upper East Fork Armells Creek, Upper Lee Coulee, and Stocker Creek drainages (Western Energy, 1980).

b. Mule Deer

Mule deer (Odocoileus hemionus) are widely distributed over the Wildlife Study Area. Although deer forage in open grassland and agricultural fields, particularly in spring, they show a marked preference for timber-grassland and shrub-grassland habitat types during all seasons. These types are particularly important for forage and shelter during the harsh winter months, especially when snow cover restricts availability of low-growing forage. Although there is fairly consistent mule deer winter use of the eastern end of the Greenleaf Ridge, there generally are no large winter concentrations of deer observed in the Wildlife Study Area (Western Energy, 1980). Moister creek/coulee bottom habitats are often favored by foraging deer in summer and fall. Timber and shrub habitats are more common in the rougher terrain of the northwest and north-central portions of the Wildlife Study Area, including the high land to the north of Area C and drainages leading northward into Stocker Creek (ECON, 1981).

The deer population in the area has undergone a substantial reduction since the early studies were conducted in 1974 as reflected in the number of observations per hour of aerial survey time (Table 2, Appendix H). The reason for the reduction in deer in the area is not entirely clear, although severe winters in 1977-78 and 1978-79 may have contributed (ECON, 1977, 1978; Bureau of Land Management, 1981). The impediment of snow combined with a prolonged and sometimes drastic reduction in quantity and quality of available forage frequently accounts for large-scale winter die-offs (Wallmo and Regelin, 1981). It is not known to what extent legal and illegal hunting and other human activities may have contributed to the overall decline in deer numbers; some increase in both types of hunting is an inevitable consequence of population growth in the area over the past decade.

c. Other Big Game Animals

The only other big game animals reported in the study area have been white-tailed deer (Odocoileus virginianus) and elk (Cervus elaphus). Such observations are infrequent since the area does not support a sizable number of white-tailed deer and no permanent elk population.

2. Other Mammals

Small mammals in the Colstrip area include bats, shrews, rabbits and hares, and numerous rodent species (see Table 3, Appendix H). Small mammals provide an important prey base for mammalian predators and for raptors. The black-tailed prairie dog is a species of concern in Montana (Flath, 1981). Additionally, prairie dog towns provide habitat for an endangered species, the black-footed ferret. Other mammals that have been observed in the area include porcupines and chipmunks, which inhabit conifer/shrub habitat, cottontails and marmots in rocky areas, and muskrats, which are found in stock ponds and Castle Rock Reservoir. No population estimates have been made for these species in the area.

3. Mammalian Predators

The most common large mammalian predator in the Colstrip area is the coyote (Canis latrans), with badger (Taxidea taxus), red fox (Vulpes vulpes), and bobcat (Felis rufus) seen infrequently (Western Energy, 1980). Habitats found in Area C could be used by all these large predators. Coyotes and red foxes range widely across open brushland, woodlands, and farmland; badgers prefer grassland, brushy areas, and disturbed sites; and bobcats prefer forested and shrubby areas like those found in the north-central part of Area C (Whitaker, 1980). Weasel and skunk have also been observed in the area. Mammalian predators known in the area are shown in Table 3, Appendix H.

4. Upland Game Birds

Sharp-tailed grouse (Pedioecetes phasianellus) are the most numerous native upland game bird in the Colstrip vicinity. Sharp-tail dancing grounds are fairly evenly distributed across the Wildlife Study Area; twenty dancing grounds were active in the area in 1980 (Western Energy, 1980). Eight years of sharp-tail investigations in the Colstrip vicinity have shown fairly consistent numbers of grouse in the area, with variable attendance at individul dancing grounds. During the years of study, some grounds were abandoned, while other, new grounds were apparently established (ECON, 1975, 1976). The Area C vicinity has three dancing grounds (numbers 8, 25 and 35; Western Energy, 1980) with dancing ground 8 being the only ground within Area C, Block I boundary (T1N, R40E, S1, SE1/4, SW1/4). Dancing grounds tend to be open, sparsely grassed areas, often on knolls or ridges, and nesting habitat is generally shrub-grassland and ungrazed or lightly grazed grassland with good ground cover typically within about one-half mile of the dancing ground (Hillman and Jackson, 1973). Upland habitat types are preferred by sharp-tailed grouse. Moderately dense grass or grass-shrub cover provides shade and protection from detection by predators. Small grain fields in Area C are an important supplementary food source.

Ring-necked pheasant (Phasianus colchicus) crowing counts have been conducted since 1975 in the Wildlife Study Area. The main concentration area for pheasants is in the East Fork Armells Creek drainage primarily in the rail loop track-Colstrip area; overall, the study area is marginal pheasant habitat as reflected by fairly low call count results. Barley and wheat plantings and a winter feeding program enhance pheasant survival and production in the vicinity of the rail loop track (Western Energy, 1980).

Lesser numbers of Hungarian (Gray) partridge (Perdix perdix) and Merriam's turkey (Meleagris gallapavo) are found in the Wildlife Study Area. The Hungarian partridge is most often observed in reclaimed areas with good grass cover whereas turkeys are most often observed in grassland, shrub-grassland, and timber-grassland areas typically in the portions of the study area with rougher topography. Few partridge or turkey observations have been made in the vicinity of Area C.

Sage grouse (Centrocercus urophasianus) are not numerous in the Wildlife Study Area and have not been observed in Area C.

5. Waterfowl

Waterfowl recorded in southeastern Montana, including the Wildlife Study Area, are included in Table 4, Appendix H. Several of these waterfowl are considered of high federal interest (Spear, 1980). Of these species, only the canvasback has been reported in the study area (ECON, 1979). Most waterfowl observations are associated with Castle Rock Reservoir, Area A sediment pond, East Fork Armells Creek, and several small stock impoundments. Area C does not presently have adequate available surface water to attract concentrations of waterfowl, however limited nesting habitat is available in Area C.

6. Songbirds

The Migratory Bird Act of 1973 (16 USC 703-711) placed most songbirds in the United States under federal protection. Table 4, Appendix H shows songbirds expected in the Colstrip area on the basis of published reports, and notes those observed as part of the Wildlife Study Area investigations (Ecological Consulting Service, 1973, 1974, 1975; ECON, 1976, 1977, 1978, 1979; Western Energy, 1980). Most of the observed songbirds have been species commonly associated with grasslands or with open pine forests, both found in Area C. No songbird species observed in the study area is listed as threatened or endangered (Federal Register, 1980). No songbird species of federal interest (Spear, 1980) have been recorded in the Wildlife Study Area, although it is within the range of and suitable habitat for several. State species of special concern that have been observed in the area include eastern bluebird (Sialia sialis) and western bluebird (Sialia mexicana).

7. Raptors

The most common raptors in the Colstrip area are the red-tailed hawk (Buteo jamaicensis), American kestrel (Falco sparverius), and harrier (Circus cyaneus) (Bricco, 1981; ECON, 1979). Other common raptors are the great horned owl (Bubo virginianus), prairie falcon (Falco mexicanus), and golden eagle (Aquila chrysaetos) (Martin, 1981; ECON, 1979; Western Energy, 1980). Table 4, Appendix H includes raptors expected to occur or actually observed in the study area.

Although all raptor species are federally protected, there are several known from the Wildlife Study Area that have been given special status by Montana (Flath, 1981) or the federal government (Spear, 1980; Federal Register, 1980). These species are discussed briefly in the following paragraphs.

Golden eagles and bald eagles are protected by the Bald Eagle Protection Act of 1940, as amended in 1962 (16 USC 668a). Golden eagles are observed fairly often in the Colstrip area, and have nested on a

sandstone cliff in Area C as recently as 1978 (ECON, 1978, 1979). In all, three golden eagle nest sites, two on sandstone cliffs and one in a ponderosa pine, have been identified in the study area. Rabbits and rodents are usually the primary food of golden eagles (Peterson, 1961).

Ferruginous hawk (Buteo regalis) was observed in the northern part of Area C during a 1978 bird survey (ECON, 1978), and is listed as a species of high federal interest (Spear, 1980). Ferruginous hawks may nest in trees, on cliffs, or on the ground in open rangeland, and have been known to feed on prairie dogs and ground squirrels (Udvardy, 1977).

Prairie falcons (Falco mexicanus), considered of high federal interest (Spear, 1980), are fairly common in the Colstrip area; four active prairie falcon nests were recorded in the study area in 1980 (Western Energy, 1980). These birds nest on cliff ledges and eat ground squirrels, other rodents, and songbirds in open country (Udvardy, 1977). A prairie falcon nest is located on the same sandstone outcrop in Area C as the golden eagle nest. These falcons are of special interest in the Colstrip area because of the number of known nests and occupied territories.

The burrowing owl (Speotyto cunicularia) was observed in the southwest corner of Area C in 1979 (ECON, 1979), is of high federal interest (Spear, 1980), and is thought to be declining in Montana (Bricco, 1981). This owl lives in burrows deserted by species such as prairie dogs or badgers, and hunts rodents, mostly by day. Considerable grasslands and scrublands in Area C provide suitable habitat for burrowing owls.

Several species of raptors observed during Rosebud Mine Wildlife Resource Studies are listed as species of special concern in Montana (Flath, 1981). These species are Cooper's hawk (Accipiter cooperii), ferruginous hawk, golden eagle, bald eagle, prairie falcon, merlin, burrowing owl, and long-eared owl (Asio otus).

8. Reptiles and Amphibians

No specific surveys have been made for reptiles or amphibians, but incidental sightings have been noted in the annual wildlife surveys at the Rosebud Mine (Western Energy, 1980). Prairie rattlesnake (Crotalus viridis) sightings were mentioned every year from 1976 through 1980. Bull snake (Pituophis melanoleucus) sightings were mentioned each year from 1977 through 1980. Other reptiles and amphibians mentioned in the annual wildlife survey reports included snapping turtles (Chelydra serpentina), painted turtle (Chrysemys picta), sagebrush lizard (Sceloporus graciosus), hognose snake (Heterodon sp.), racers (Coluber constrictor), salamanders (Ambystoma sp.), and frogs.

Table 5, Appendix H lists reptiles and amphibians expected to occur in southeastern Montana (Stebbins, 1966), and notes observations in the Rosebud Wildlife Study Area between 1976 and 1980 (ECON, 1976a, 1977a, 1978, 1979; Western Energy, 1980). Turtles, salamanders, and frogs are not likely to be common in Area C since they require a wet habitat, and

such habitat is limited in Area C. Hognose snakes, of special concern in Montana (Flath, 1981), may be present, especially in farmland in Area C. Prairie rattlesnakes inhabit virtually all of the habitat types present in Area C (Stebbins, 1966; ECON, 1981).

9. Threatened and Endangered Species

Bald eagles (Haliaeetus leucocephalus) (ECON, 1979) and a peregrine falcon (Falco peregrinus) (Martin, 1981) have been observed in the Wildlife Study Area during migration. These two birds are listed as endangered species (Federal Register, 1980); however, no critical habitat for either bird is known to be present in the Colstrip area. No specific studies for these species were conducted.

Because the endangered black-footed ferret (Mustela nigripes) is largely dependent on prairie dogs for food, the possibility of black-footed ferrets being present must be considered. There are not records of black-footed ferrets in Rosebud County. The only known prairie dog colony, approximately 100 acres in size, is north of Area C in the Stocker Creek drainage. In 1978 and 1979 the colony was inspected for black-footed ferret signs. Additionally, a black-footed ferret spotlight survey was conducted in 1979. None of these surveys revealed evidence of black-footed ferrets (ECON, 1978, 1979).

I. SOCIOLOGY AND ECONOMICS

1. Economic Conditions

Traditionally, agriculture has been the primary economic activity in Rosebud County, but during the past decade, agriculture has been declining in relative importance. The county is undergoing a transition from an agrarian economy to an economy primarily dependent on energy development. This fact is supported by substantial increases in personal income and employment for energy-related activities and a corresponding decrease in agricultural income and employment. All statistical data presented in the following subsections were derived from the Bureau of Economic Analysis, U.S. Department of Commerce.

a. Personal Income

Over the past decade, labor income has been the most significant contribution to total personal income in Rosebud County, more so than in the state of Montana as a whole. Labor and proprietors' income (sometimes called participation income) accounted for about 84 percent of total personal income during 1979 in Rosebud County and approximately 73 percent in Montana. In 1970, the corresponding figure was about 79 percent for Rosebud County and 78 percent statewide.

Table 1, Appendix I presents personal income by major source for Rosebud County and Montana during 1970 and 1979. Annual data for Rosebud County are shown in Table 2, Appendix I. These figures were converted to constant 1980 dollars.

In 1979, agriculture accounted for only 2.7 percent of total personal income, compared to 18.7 percent in 1970, however, mining and construction have shown sizable gains. In particular, mining increased from 3.9 percent of total personal income in 1970 to 20.9 percent in 1979. Despite the downward trend, the relative importance of agriculture in Rosebud County continues to be slightly greater than the figure for Montana. However, the relative importance of mining employment in Rosebud County is more than four times the figure for Montana.

Per capita income figures for Rosebud County and Montana from 1970 to 1979 are presented in Table 3, Appendix I. Per capita income is equal to total personal income divided by population; in other words, it is average income per person. In order to correct for inflation, per capita income was converted to constant 1980 dollars.

Per capita income in 1979 for Rosebud County was $6,948 (1980 dollars), or about 19 percent below the Montana average of $8,601 (1980 dollars). During the 1970s, real per capita income in Rosebud County grew at about the same rate as in Montana; between 1971 and 1979 it rose 26.5 percent in Rosebud County and 26.4 percent statewide. The stability of real wages in the county from 1970 to 1979 indicates that Colstrip Units 1 and 2 did not cause significant increases in labor costs to local businesses (Polzin, 1981). Per capita income in Rosebud County was much

more variable than in Montana during the 1970s, reflecting the wages paid during the construction of Colstrip Units 1 and 2, and the fact that agricultural income is highly cyclical.

b. Employment

As shown in Table 4, Appendix I, total employment in Rosebud County rose from 2,465 in 1970 to 4,472 in 1979, an increase of about 81.4 percent. Annual data for Rosebud County are presented in Table 5, Appendix I. In Montana, total employment increased from 279,091 to 373,409, or 33.8 percent during the same period.

The decline of agriculture and manufacturing, and the rise of mining, services, construction, government, transportation, and public utilities employment is evident, as shown in Table 4, Appendix I. In 1970, agriculture was the largest employer, but by 1979, both services and government employed more people.

Labor market trends may also be analyzed in terms of employment in basic and derivative industries. Basic industries depend on nonlocal markets or are otherwise influenced by factors originating outside the area. Derivative industries, on the other hand, serve the local population. Economists believe that changes in basic industries lead to further changes in derivative industries. Employment data for Rosebud County have been organized into basic and derivative categories, presented in Table 6, Appendix I. The decreasing relative importance of agriculture and the increasing importance of mining, construction, transportation, and public utilities to the economic base of Rosebud County is reemphasized by this data.

2. Demographics

The 1970 and 1980 populations of Colstrip, Rosebud County, and Montana are presented in Table 7, Appendix I. Estimates of the populations of Colstrip and Rosebud County have been used rather than census figures to more accurately present actual growth in the area. The timing of the census and the boundaries of some census enumeration districts distorted the count of actual area residents. Population estimates were developed by Western Analysis, Inc. (1982), based upon actual area employment and population employment multipliers. The populations of Colstrip and Rosebud County increased dramatically during the 1970s; Colstrip's 1980 population was more than 13 times as large as its 1970 population. The Rosebud County population nearly doubled during the same period. By comparison, the population of Montana increased 13 percent between 1970 and 1980 (U.S. Bureau of the Census, 1981).

A comparison of age and sex compositions of the 1970 and 1980 Colstrip and Rosebud County populations is shown in Table 8, Appendix I. A comparison of age cohorts expressed as a percentage of total populations is presented in Table 9, Appendix I for Colstrip and Rosebud County populations. The age composition of both populations has shifted toward the younger adult age groups (23 to 44), with corresponding decreases in

the proportions of older adults. This phenomenon is more pronounced in the Colstrip population, where the age 25 to 34 cohort proportion of the population has doubled during the decade. Slight increases in the proportion of younger children (ages up to nine) also occurred in the Colstrip population. The sex ratios of Colstrip and Rosebud County populations show a slight surplus of males in 1970. In 1980, the surplus of males in the Colstrip population had increased ten percent; a much smaller proportionate increase in males occurred in the Rosebud County population.

3. Baseline Economic/Demographic Forecast

Table 10, Appendix I contains the annual employment, population, and per capita income forecast for Rosebud County. Similar quarterly information is presented in Table 11, Appendix I. Table A, Appendix I presents the personal income projections for Rosebud County.

As displayed in Table 12, Appendix I, per capita income in Rosebud County is projected to increase during the construction of Colstrip Units 3 and 4 and then return to normal levels by 1985. Per capita income is projected to increase from $7,986 (1980 dollars) in 1980 to $9,090 in 1983, then to decrease to $8,250 by 1985. Beyond 1985, real per capita income is projected to grow throughout the forecast period.

Total employment and population for Rosebud County and Colstrip are expected to peak the fourth quarter of 1982, then decrease until 1990, then increase through 2010 and then decrease thereafter as illustrated in Tables 10 and 11, Appendix I. Peak basic employment, total employment, and population for Rosebud County are 6,001; 8,414; and 16,913 persons, respectively. Colstrip population is expected to peak at 7,665 persons in the baseline forecast. Nonbasic employment is forecast to increase through 2010 and then decrease thereafter.

Between 1980 and 1985, basic employment, total employment, and population follow the construction cycle of Colstrip Units 3 and 4. Turbine roll is expected the fall of 1983 for Unit 3 and the fall of 1984 for Unit 4 (Kelley, 1982). Between 1990 and 2010, basic employment, total employment, and population in Rosebud County and Colstrip are forecast to increase due to basic growth in the trade, services, and nonfarm proprietors industries. The service industry in particular experienced significant growth after the completion of Colstrip Units 1 and 2 and is expected to continue to expand throughout the forecast period. It was assumed in the report that coal mining in Rosebud County would cease after 2018.

Despite a projected decrease in agricultural employment, agriculture will continue to have an important role in Rosebud County as a large employment category and source of personal income. Agricultural experts are optimistic about the outlook for both grain and cattle during the coming decades. The trend toward larger and more capital-intensive farms and ranches should continue. The Rosebud economy will, however, become less dependent on agriculture and more dependent on energy development during the baseline forecast period.

4. Social Life

a. Social History

The earliest nonmilitary white settlers in the Rosebud County area were range livestock operators, who began to arrive in 1876. Population growth in the area was gradual until the siting of the Northern Pacific Railroad in 1882, when access and immigration to the area increased. Economic activity in the area was agricultural or tied to the railroad (Western Historical Publishing, 1907). Agriculture and derivative service employment remain the primary economic activity in Rosebud County, except for the Colstrip area.

The presence of a company town and industrialization in the Colstrip area are not new phonomena. Colstrip was developed as a company town after coal strip mining was initiated in 1924 by the Foley Brothers, on contract to Northern Pacific. During this initial mining period, Colstrip evolved into a community center serving agriculture and industry. The Colstrip School became a focal point of community and social activities for area residents. The maximum area population during this mining period appears to have been about 550 residents in 1950 (Douglas, 1982). Mining ceased in the area in 1958 when diesel engines replaced steam locomotives. After mine closure, the residual population comprised a maintenance crew for the mine properties, school personnel, and ranchers (Rosebud County Bicentennial Committee, 1977). The town has continued to serve as a primary social focal point for the surrounding area, until large-scale coal and energy development resumed.

Mining operations were resumed in 1968 by Western Energy, a subsidiary of Montana Power Company, followed closely by construction of power plants and additional mines in the area. The population of Colstrip jumped from 250 in 1970 to about 1,500 in 1972. The population peaked during the 1970s at an estimated 2,800 people in 1975, during construction of Colstrip Units 1 and 2 (Rice, 1982). The present population is estimated to be approximately 5,800 (Western Analysis, Inc., 1982).

The scale of recent energy development in the Colstrip area was a phenomenon to the area's residents and intensified conflicts between agricultural and industrial interests. Sources of conflict have included resource development and land management issues, economic impacts of industrialization upon agriculture, loss of political influence and community identity among long-time area residents, and differing value systems (Gold, 1974, 1975).

A recent survey was conducted by Western Analysis, Inc. (1982) to characterize social life in the Colstrip area. The information presented in the following sections addressing the social life of Colstrip was drawn from three sources. Those sources were:

- Lengthy personal interviews of 31 Colstrip and Rosebud County residents who were selected on the basis of their reported knowledge of the study area

- o A quality of life survey of 243 Colstrip households conducted by Western Analysis (1982)

- o Various statistical reports published by federal and state agencies

The items discussed below are distinct definable characteristics of most human groups, whether communities or aggregations. These characteristics can be and are used to describe the social life of human groups. They also can be and are used to indicate change and the effects of change in the social life of human groups.

b. Community

Colstrip remains a company town. Decisions regarding development of Colstrip are made by the Montana Power Company. A recent voter initiative to incorporate Colstrip as a self-governing municipality was defeated. Reportedly, only a small proportion of the present town residents identify themselves with Colstrip or consider Colstrip "home." Those Colstrip residents who predate the recent development boom and comprised the Colstrip community are fewer in number and are submerged within the larger, "new" Colstrip. The ranching community, traditionally the dominant group in the Colstrip area, reportedly has severed most ties with Colstrip and exists as a parallel (and diminishing) community outside its bounds. According to area informants, relatively few residents of Colstrip know any member of, or have much in common with the ranching community. Further, few Colstrip residents reportedly possess ties to, or interest in the remainder of Rosebud County. Most present residents of Colstrip are said to identify themselves most strongly with their occupations or employers.

Several characteristics of Colstrip appear to have inhibited its development as a social community: its status as a company town, its rapid growth, and the large number of temporary jobs available. Community is defined as a human population living within a limited geographic area and possessing an interdependent life under common cultural and institutional regulations. Virtually all decisions concerning community development rest in the hands of persons not elected by the residents. The costs of improvements to city properties are borne in large measure by Montana Power Company. The physical structure of new parts of the city developed in response to company plans, rather than to pressures from the residents. In the early stages of city development, housing shortages resulted in segregation of residents by employer (Western Energy, Montana Power Company, Bechtel, and Long Construction) and by type of employment (blue collar or white collar). The rate and degree of growth overwhelmed the older, existing community. Many newcomers reportedly were from urban, industrial areas and had little in common with the existing, particularly rural, residents. Finally, the short-term nature of many jobs discouraged the development of community identification.

The consensus of informant opinion suggests that Colstrip has not yet regained a true community identity as defined above. Further, these

residents suggest that a community identity cannot be formed until the transient construction and management crews depart upon completion of Colstrip Units 3 and 4. Despite this, the basis of a Colstrip community exists and is comprised of those residents who have remained in Colstrip for several years, are employed in permanent jobs, and intend to remain in Colstrip.

c. Social Structure in Colstrip

City residents consistently divided the Colstrip population into three major groups:

- Transient workers, usually craftsmen, but also including some supervisory personnel.
- Technicians/operators, usually employed in permanent jobs, who have been in Colstrip more than two years and intend to stay.
- Management/high level supervisory personnel, usually employed in permanent positions, but including some long-term temporary personnel (e.g., Bechtel personnel).

Area informants stated that school personnel formerly had constituted a fourth group, but now are being assimilated within the management and technical/operators groups.

Twenty-two formal social organizations in Colstrip list their meeting dates in the local newspaper. City informants state that these groups constitute the primary social organizations in the area, although other, smaller, and very informal organizations also meet from time to time. Of the organizations listed, nine exist for recreational purposes. Four youth organizations (scouting) are listed. Three organizations have community service functions: the PTA, the Women's Club, and Parents Against Drug Abuse. A fourth group of a similar type, addressing the problem of spouse abuse, reportedly is being organized. Only two organizations appear to serve purely social or fraternal purposes. The remaining groups are concerned with alcoholism, obesity, commercial matters, and governance of the local library. Religious groups also exist in Colstrip, in connection with approximately ten church congregations.

Area informants state that membership in the formal social organizations is a matter of personal interest. Reportedly, none of the organizations is exclusive except the commercial and fraternal ones. Despite the nonexclusive policies of these organizations, temporary residents reportedly are far less likely to join than the permanent residents. Most organization members are said to be from the technician/operators social group, which is the larger of the two groups comprising the more permanent residents of Colstrip.

d. Social Interaction in Colstrip

Social interaction between individuals and groups in Colstrip reportedly is now less dependent upon occupation or employer than in previous years. As mentioned in Section b. (Community), during the initial population boom period engendered by construction of Colstrip Units 1 and 2, a housing shortage forced segregation of residents by company and reportedly by occupation (white collar and blue collar). As a consequence, most social interaction in Colstrip is between employees of the same companies and within like occupational groups. This segregated social interaction is further strengthened by company practices that provide social and recreational activities for company employees only. More recently, in some instances Western Energy has allowed residents to purchase company-built houses as they have become vacant. This situation has broken the earlier, segregated housing pattern and has made social interaction across company and occupational lines more possible among homeowners.

A substantial majority (more than 70 percent) of Colstrip survey respondents indicated that Colstrip residents are friendly, helpful, and sociable. Over 50 percent of respondents indicated that it is easy to get to know people in Colstrip, that length of residence and income have little effect upon community acceptance or influence, that the more long-term residents are friendly. However, one's occupation does affect his influence within Colstrip, according to more than 50 percent of the residents. The perceived occupational distinction is drawn between white collar and blue collar workers. Some blue collar workers are as well paid as white collar workers, but have less influence within Colstrip. A plurality of respondents (45.1 percent) indicated that there is "some" or "a great deal of" status consciousness in Colstrip.

Colstrip informants agreed that residents in Colstrip townsite are friendly and added that social interaction across occupational and company lines is increasing. Nevertheless, social interaction reportedly remains somewhat bound by occupation, and to a lesser degree, by employer. Length of residence in Colstrip and the permanence of one's job often were identified as influences that govern the likelihood of social interaction. Those who hold permanent or long-term jobs are more apt to socialize and to do so across company lines. Those employed in temporary positions are less apt to socialize. Further, craftsmen employed in temporary positions reportedly are apt to socialize almost exclusively with other members of their own craft, rather than with all crafts at a given site.

The apparent selectivity of social interaction in Colstrip among the more permanent residents reportedly is determined more by opportunity than by intent. Conversely, patterns of interaction among craftsmen reportedly are by choice. Nonetheless, many informants stated that there are many lonely people in Colstrip and added that loneliness in Colstrip can be particularly intense, given the town's isolation and limited recreational facilities. Some Colstrip residents reportedly do not interact with others.

e. Colstrip Lifestyle

Colstrip informants were unable to describe a uniform "Colstrip lifestyle," but did identify several common characteristics of life in Colstrip. Informants agreed that life in Colstrip has little in common with the remainder of Rosebud County or with Colstrip before coal development resumed. Due to a high degree of turnover in crafts employment, the job market in Colstrip reportedly is quite good and the population of the town is in a state of flux. The proportion of workers earning relatively high wages is greater in Colstrip than in the surrounding area. The minimum salary for non-clerical personnel at the MPC and Western Energy operations in Colstrip is roughly $400 to $450 per week. There are very few low income or unemployed people in Colstrip. There are very few organized recreational opportunities and facilities in Colstrip, relative to the size of the population. Although many informants insist there is plenty to do in Colstrip, they also indicated that many residents are bored, in part because they are not accustomed to entertaining themselves. Boredom reportedly accounts for the heavy consumption of alcohol that is said to be characteristic of Colstrip residents and for the exodus from Colstrip each weekend. Unemployed wives are said to be especially bored with life in Colstrip.

Distinctions are drawn between the lifestyles of transient (primarily crafts) residents and the more permanent technicians/operators. The latter are said to be more home- and family-oriented and to lead more routine, predictable, and community-oriented lives. The transient residents are said to lead less stable, less home-oriented lives, and to display less interest in the community. Temporary crafts employees very often were characterized as leading "work hard, play hard" lives. Temporary employees also were described as less apt to have families in Colstrip and to be less family-oriented.

Most informants agreed that life in Colstrip can be inconvenient and stressful to those accustomed to more urban environments. Colstrip is isolated, has very few commercial resources for its size, and very few outlets for those not employed. Although a community recreation center does exist (and is well used), and a small women's welcoming club serves newcomers, Colstrip's infrastructure provides very few opportunities for casual social interaction. Further, there is very little public land in the immediate area for recreational purposes.

f. Values

Colstrip informants who predate the resumption of coal development (about 30 percent of those interviewed) distinguish between the values of the newer residents of Colstrip and those who were in residence before redevelopment. Pre-redevelopment residents were said to value family, community, neighbors, hard work, frugality, and an independent, self-reliant approach to life. Post-redevelopment residents are described as placing less emphasis upon community, neighbors, frugality, and work for work's sake; and more emphasis upon money, materialism, and more immediate gratification of wants. Colstrip informants also draw distinctions between the values of temporary and more permanent residents. The more

permanent residents are said to place a higher value on home and family life and upon what the informants labeled as a stable, responsible, and predictable lifestyle than do the more temporary residents. The temporary residents were described as valuing community life and stability the least of all Colstrip groups and as placing higher value upon material goods and immediate gratification of wants.

Education reportedly is no longer a value among Colstrip's children. This circumstance is said to be strikingly different from pre- and early redevelopment periods in Colstrip's history. Reportedly, a large number of students regard an education as less important, particularly in light of their assumptions that quite lucrative jobs will be available to them in the construction industry at Colstrip and elsewhere without an education. Colstrip informants were in general agreement that although most residents appear to value education primarily as an economic tool, the attitude of children toward education distresses most parents. The informants were not able to state with any consistency whether the children's perceptions of education were influenced by their parents' lifestyles or occupations.

g. Conflict

There is little overt, formalized conflict between social groups in Colstrip, according to informants. Conflict between the rural agricultural community and the Colstrip coal community no longer is as visible as in the early and mid-1970s. Specific objections to specific aspects of coal development are still made by members of the agricultural community, but the opposition reportedly lacks the scope and intensity of that in previous years. Conflicts concerning trespass largely have been resolved through formal, legal channels; in addition, a deputy is now assigned to patrol the rural areas adjacent to Colstrip.

Conflicts within and between temporary and permanent groups apparently exist on an individual, informal basis. Several informants suggested that the Colstrip population is so diffuse and fluid that there has been no opportunity for conflicting groups to develop. Individual conflicts within the transient population reportedly are resolved through mutual avoidance, or in a few cases, through overt conflict; whereas avoidance of overt conflict reportedly is the mode of choice of the city's residents. Some conflict over construction of new schools and the busing of children to the schools has arisen recently. In this instance, no coherent, formal, group-based positions have developed as yet.

Area informants uniformly state that Colstrip residents are remarkably apolitical. Many stated that the residents are too passive politically. County elected officials have stated that development in Colstrip has not resulted in identifiable or attributable shifts in the political balance of the county.

h. Religion

There are ten active churches in Colstrip, some of which reportedly have very small congregations. The congregations are described as being evenly divided between mainline and fundamentalist orientations. There reportedly is little ecumenical spirit among the various congregations; the ministerial association is said to have collapsed from lack of interest. A plurality (45 percent) of Colstrip survey respondents indicated that some or few residents attend church regularly; 21 percent of respondents did not know whether residents attend church or not. One minister suggested that perhaps 15 percent of town residents attend church regularly. Informants suggested that permanent residents were more apt to attend church than transient residents. Over 70 percent of survey respondents considered religious activities to exert an average or minor influence on community affairs. Nearly 22 percent had no idea of religion's influence on community life.

i. Family Life

Family life reportedly is very important to most residents who have families. Sixty-seven percent of surveyed residents have children living at home; an average of two children reside in those households with children living at home. Colstrip informants suggested that life in Colstrip exerts a very strong influence on families. Whether this influence is positive or negative depends upon the nature of the family. If a family is close and "healthy," life in Colstrip can exert a positive influence. Conversely, if the family is "unhealthy" or unstable, life in Colstrip reportedly can exert a very negative influence. Family problems reportedly include spouse abuse, child neglect and, less often, child abuse, excessive drinking, marital infidelity, and divorce. No reliable data were available to substantiate these perceptions. Several informants and social service professionals described Colstrip as a testing ground for family life. The limited availability of recreational and other alternatives to family life forces family members to spend more time together and thereby intesifies the strengths and weaknesses of family relationships.

j. Social Problems

Divorce, family instability, and drug and alcohol abuse were mentioned consistently as the major social problems in Colstrip. However, law enforcement officials indicated that the incidence of major crimes in the area was surprisingly low and added that the majority of crimes with which they deal are petty crimes (Ash, 1982). Various statistics support some of these perceptions, although such statistics may be compromised in part by the presence of the Northern Cheyenne Indian Reservation within the county. Indian reservations often have high rates of alcoholism, divorce, crime, illegitimacy, teenage pregnancy, family instability, suicide, death, and morbidity. The presence of the Northern Cheyenne Reservation in Rosebud County <u>may</u> raise the level of some of these indicators at the county level.

Alcoholism rates (as measured by admissions to institutional treatment programs) are nearly three times higher in Rosebud County than in Montana. The rate of out of wedlock births in Rosebud County is nearly twice the state rate. Comparative rates of admissions to the state mental hospital were much higher in Rosebud County than in Montana (over twice as high) in the years 1970 through 1974, but were lower than the state rate after those years. This statistic may be compromised by the greater availability of community mental health programs (which divert patients from institutional treatment) in the rest of Montana and the much more stringent statutory criteria for admission to statewide institutional treatment facilities. Contrary to community perceptions, the divorce rate in Rosebud County has been consistently below the corresponding state rate since 1970. No data are available to refute or support the perceptions of informants and service professionals that spouse abuse and child neglect are problems in Colstrip.

5. Social and Community Services

a. Law Enforcement

Law enforcement in Colstrip is provided by the Rosebud County Sheriff. The sheriff's jurisdiction in Colstrip includes all areas except the generating station and construction sites. Six deputies, five dispatchers, and one dogcatcher are assigned to the Colstrip office. An additional deputy patrols the rural area south of Colstrip to Ashland. All deputies are graduates of the Montana Law Enforcement Academy. Law enforcement personnel and equipment are located in the Colstrip Community Service Center. Detention facilities, located in the same building, comprise four cells, each with two bunks. The cells are arranged to provide segregation of prisoners by sex and by age. The Colstrip detention facility is used only as a holding facility, pending adjudication of prisoners. Persons sentenced to jail terms are transferred to Forsyth. The Colstrip office is provided with three patrol cars and one pickup truck. Communications are provided by a low frequency band radio system, with transceivers in each motor unit. The sheriff's office provides communications and dispatching services for the local emergency medical service and fire protection organizations.

All vehicles within the sheriff's fleet are replaced on a planned and budgeted biennial schedule. The detention and office facilities were constructed in 1976, and are in excellent condition. The office's radio equipment is also in good condition and will require replacement in the near future only if Montana law enforcement agencies change to high-frequency equipment. The sheriff considers his manpower and equipment to be adequate to serve the present population (Ash, 1982). Over 60 percent of surveyed residents considered law enforcement services to be good to average.

b. Fire Protection

Fire protection services in Colstrip are provided by a 22-member volunteer fire department. Only the chief is certified at present. All

volunteers are in training and are expected to be certified within six months. Fire flows in Colstrip are considered adequate for present and future needs and are expected to improve with scheduled modifications of the city water distribution system. The fire department is equipped with the following:

- One 1957 International Harvester 1,000-gallon pumper
- One 1980 Superior 1,000-gallon pumper
- One 1972 International Harvester 1,500-gallon tanker with a 300-gallon-per-minute pump

An additional 1,000-gallon pumper will be purchased and should be delivered by the fall of 1982. Equipment storage is provided at the Colstrip Community Services Center and is considered adequate. A two-stall garage is to be constructed in the vicinity of the Pine Butte School in the northern end of Colstrip in the fall of 1982. The new fire truck will be stationed at that facility.

The fire station is located on the west side of railroad tracks that bisect Colstrip. An overpass on the northern end of town allows access to all areas of Colstrip in the event that the railroad crossings are blocked by a train.

The Colstrip fire chief considers his department adequate to meet the fire protection needs of Colstrip for the present and the foreseeable future. No plans have been made to replace any equipment in the immediate future (Durham, 1982). Fifty-five percent of surveyed residents considered fire protection services to be good to average.

c. Sanitary Sewer

Wastewater treatment in Colstrip is accomplished with an oxidation ditch facility. That system is to be supplemented by an aerated lagoon, which is to be installed at the site of an older, now unused three-cell lagoon system. The town's wastewater will be retained in the aerated lagoon for a ten-day treatment period, after which it will be discharged to the oxidation ditch. The remaining two cells of the old lagoon system are to be used as sludge drying beds (Mountain West Research, 1981). Although construction of the aerated lagoon was completed in January 1982, the lagoon has not been filled for fear that it will freeze. As a result, the oxidation ditch facility is operating at levels above its hydraulic capacity. The new lagoon will be filled as soon as the weather permits, at which time the combined system is expected to function properly. The new treatment system is considered adequate to meet the needs of the present and projected peak construction population of Colstrip (Miller, 1982). Over 73 percednt of surveyed residents considered sewer services good to excellent.

d. Water Supply

The Colstrip public water supply is drawn from Castle Rock Lake, a surge pond built to supply make-up water to the Colstrip electrical generating units. The water right to the water is held by the Montana Power Company. The lake is filled with water piped from the Yellowstone River. Two water treatment and distribution systems, with a combined capacity of 2,200 gallons per minute (gpm), serve Colstrip. One system, an upflow clarifier and filtration system, supplies 1,000 gpm. The other, a diatomaceous earth filtration unit, operates at 1,200 gpm. Three high-volume service pumps transfer treated water from a 30,000-gallon clearwell to the distribution system. Storage for treated water is provided by three reservoirs with a combined capacity of three million gallons. The present system is inadequate to meet projected peak demands. Western Energy is constructing an expanded water treatment plant that will include a 4,000 gpm direct filtration unit, a 390,000-gallon clearwell, a new high-volume pumping station, and an additional 680,000-gallon storage facility (Mountain West Research, 1981). The new system should be operating by April 1982, and will replace the two older systems. The 1,000-gpm upflow clarifier/filtration unit will be maintained as a peak demand backup unit. The new treatment system is considered adequate to meet the needs of the present and projected peak construction populations of Colstrip (Miller, 1982). Over 76 percent of surveyed residents considered the water supply to be good to excellent.

e. Solid Waste

Solid waste collection and disposal services now are the responsibility of Rosebud County, and are met by a rural refuse disposal district. The district is served by a three-man crew and is equipped with one truck with a 25-cubic yard compactor. Solid wastes are buried in old strip mine cuts that have been sealed with clay; old mine spoils are graded over the solid wastes. The present dump site serves Rosebud and Treasure Counties; the Northern Cheyenne Reservation reportedly also will use that disposal site in the near future. No capacity or groundwater contamination problems are foreseen at the current dump site for either the present or projected peak populations of the service area. Four groundwater quality monitoring wells have been installed near the dump site, and are checked at six-month intervals. Solid waste collection capacity is adequate at present, with one pickup-day per week. The cost of an additional collection unit has been estimated at about $55,000 (Tusler, 1982). Over 67 percent of surveyed residents considered local waste disposal service to be good to average.

f. Social Welfare

The social welfare programs provided by the Rosebud County Department of Public Welfare are identical to those available in all county offices in Montana. These programs include:

- Aid to Families with Dependent Children (AFDC)
- Medical Assistance (Medicaid and County Medical Assistance)

- o Foster Care
- o Food Stamps
- o Social Services (e.g., Homemaker Services, Meals on Wheels, etc.)
- o General Assistance
- o Transient Assistance

All of these services are available to Colstrip residents; however, some of the services must be obtained directly from the Forsyth office. The income status of most Colstrip residents precludes their eligibility for many programs; therefore, most services rendered in Colstrip are child protection services.

The Colstrip Community Welfare Office is staffed by one social worker, whose workload primarily consists of investigating referrals of child abuse or neglect, placing children in foster homes, supervising foster homes, and following up on AFDC cases (Polley, 1982). In 1981 (fourth quarter), there were 61 child protection cases in Colstrip (Gabel, 1982).

Colstrip reportedly is adequately staffed at this time. During the peak construction of Units 3 and 4, however, an additional social worker or paraprofessional will be required to meet Colstrip's expanded needs (Kennedy, 1982). Most survey respondents (75 percent) had no opinion of the adequacy of local welfare services.

g. Medical Services

The outpatient medical needs of Colstrip are served by the Colstrip Medical Clinic, a Southeastern Montana Rural Health Initiative (SEMRHI) clinic. Counties that are served by SEMRHI, namely Rosebud County, are considered medically underserved and are funded by a grant from the Department of Health and Human Services. The clinic's professional staff includes two general practitioners (one National Health Service physician and one contracted physician), two part-time registered nurses, and one x-ray technician (Catapano, 1982). There are three examining rooms, an x-ray unit, a laboratory, and a fully-equipped emergency room (Palm, 1982). The medical staff and facilities are adequate to serve the Colstrip community (Viall, 1982). Fifty percent of survey respondents considered local medical services to be good to average; 32 percent considered them fair to poor.

The Colstrip Dental Clinic and Optometrist are located in the same building (Colstrip Mall) as the Medical Clinic. There are two dentists, two dental assistants, and one dental hygienist (May, 1982). The optometric office staffs one part-time optometrist (two days a week) and an optometric assistant (Porter, 1982).

The Eastern Montana Community Mental Health Center of Miles City administers the Colstrip mental health services. The Colstrip Mental Health Center, which is staffed by one psychologist, handled approximately 50 cases in 1981 (Mountain West Research, Inc., 1981). The Mental

Health Center is at its maximum capacity now (Peterson, 1982). Over 60 percent of respondents had no opinion of the adequacy of these services.

There are four ambulances in Colstrip; two are owned by Bechtel Energy Company and two by the Colstrip Emergency Medical Service (EMS). Helicopter and fixed-wing air ambulance service is available through Saint Vincent Hospital in Billings. EMS is staffed by 11 volunteers, all of whom are either Emergency Medical Technicians (EMTs) or in EMT training (Kampf, 1982). This emergency service is adequate for current needs (Mountain West Research, Inc., 1981). Over 64 percent of surveyed residents considered emergency medical services to be good to excellent.

Rosebud Community Hospital in Forsyth is the closest hospital to Colstrip (approximately 33 miles). It staffs 36 personnel: five registered nurses, three licensed practical nurses or licensed vocational nurses, and 28 other personnel (Montana Department of Health and Environmental Sciences, 1980). The hospital has 18 licensed beds, maternity care, emergency facilities, x-ray department, and a part-time pharmacy (Montana Department of Health and Environmental Sciences, 1980). During 1980, the hospital had a 20.9 percent occupancy rate (patient days/ licensed beds x 365 days x 100%). Over 60 percent of respondents considered hospital service to be of poor to fair quality.

Forsyth is also the closest city offering nursing home facilities to Colstrip residents. The Rosebud Community Nursing Home has 39 skilled-care beds and eight intermediate-care beds, and experienced an 82.9 percent occupancy rate in 1980 (patient days/(skilled beds + intermediate beds)/days reporting x 100%) (Montana Department of Health and Environmental Sciences, 1980). Most respondents (75 percent) had no opinion of nursing home care or stated that it was not available.

h. Housing

Total housing units in Rosebud County increased from 2,055 in 1970 to 4,363 in 1980, or 112.3 percent. Of the 1980 count, it is estimated that 3,764 were occupied households (see Table 13, Appendix I). This is based on the assumption that the 576 housing units counted in Colstrip that were in addition to the 1980 census count were occupied. Mobile homes accounted for almost 60 percent of all new housing units in Rosebud County between 1970 and 1980, due to the reliance of energy growth areas on this type of housing (U.S. Bureau of the Census, 1981). About 42 percent of the county's housing unit increase occurred in Colstrip (Mountain West Research, Inc., 1981). The rapid growth in mobile homes in the county is reflected in the differences between Rosebud County and the state in 1980 housing mix. Whereas the share of total housing units that are multi-family is similar, mobile homes comprise 36 percent of the county's housing stock, and only 12 percent of the state housing stock.

Baseline projections of housing demand (households) in Rosebud County through 2020 are presented in Table 13, Appenddix I. These estimates of average household size for permanent and temporary population applied to the population projections given above yield a peak projected

baseline housing demand of 5,624 units in 1982, 1,860 more than the 1980 figure. Households are then projected to decline by 1,672 by 1985, remain stable through 1990, and increase by 820 from 1990 to 2010 (Western Analysis, 1982).

Prior to 1968, the townsite of Colstrip was owned by the Northern Pacific Railroad, and consisted of about 63 houses. In 1968, the Montana Power Company (MPC) bought the community, and has controlled the pace and scope of commercial and residential development since. Through its subsidiary, the Sunlight Development Company, MPC has (since 1970) financed and/or constructed single-family dwellings, multi-unit apartments, mobile home spaces and recreational vehicle (RV) pads, and temporary housing for the construction work force associated with Colstrip Units 1 through 4, and Western Energy mining operations (Colstrip High School Bond Prospectus, 1981).

Between 1970 and 1980, Western Energy and MPC developed about 960 housing unit in Colstrip. It has been estimated that in 1980, 1,050 units were avilable in Colstrip (Mountain West Research, Inc., 1981). Of the total, 250 were single-family homes, 292 were multi-unit dwellings, and 508 were mobile homes (Reardon, 1982).

In January 1982, the Sunlight Development Company reported that 1,403 permanent housing units and 906 temporary units are available, and 405 more units are under construction. In addition, 124 additional single-family units are proposed, and 224 additional lots are available for development (Reardon, 1982).

Costs of housing are higher in Colstrip than Forsyth. Homes that cost $80,000 to $85,000 in Colstrip are priced at $50,000 to $60,000 in Forsyth. Apartment rentals in Colstrip are $155 per month for a one bedroom, $205 to $350 per month for a two bedroom, and $255 to $450 per month for a three-bedroom unit. Houses rent for over $500 per month. Installed mobile homes rent for $280 to $370 per month (Mountain West Research, Inc. 1981; Reardon, 1982).

There are few vacancies in Colstrip today. Roughly twelve unsold homes are being held for permanent operator personnel at Colstrip Units 3 and 4. Few, if any, houses are available for rent. Some trailer and RV spaces are available. The bachelor camp is at 96 percent of capacity (Reardon, 1982).

Current plans are to convert the Big Timber, Sweet Grass, and Stillwater mobile home pads to single-family lots after the construction phase for Colstrip Units 3 and 4. This would make available 550 more lots, in addition to the 224 potential lots mentioned above. The temporary construction work force housing will be maintained after the construction phase to house the yearly maintenance crews (Reardon, 1982).

Baseline projections of housing demand in Colstrip are contained in Table 13, Appendix I. Housing demand is expected to peak in the fourth quarter of 1982 at 2,731 units, decline 62 percent to 1,042 units in

1985, and gradually increase to 1,171 units in 2010. The projected baseline peak housing demand is 152 units fewer than the existing units, plus those under construction and proposed (Western Analysis, 1982).

i. Education

Colstrip School District #19 currently operates two elementary schools and a junior-senior high school complex. The Isabelle Bills Elementary School is a masonry structure completed in 1978. It includes a large library and gymnasium, in addition to classroom and office space. In mid-January, 1982, the enrollment was 370 students. Instruction is offered from kindergarten to sixth grade. Class sizes range from 17 to 28 pupils and the average class size is 20.6. Children attending the Isabelle Bills School live predominantly in the original section of the Colstrip townsite and Castle Rock neighborhoods (Tokerud, 1982).

The Big Timber, Sweet Grass, and Stillwater mobile home neighborhoods, located north of the original Colstrip townsite, are served by the Pine Butte Elementary School, a modular, wood-frame building. It is intended to be a temporary facility until a new Pine Butte School (under construction) is ready for student occupancy in the fall of 1982. The mid-January, 1982 enrollment at Pine Butte School was 340 students, in kindergarten through sixth grades. Class sizes range from 14 to 21 students, with an average class size of 17. (Tokerud, 1982).

Both elementary schools have large physical plants and have space for many more students. Accreditation standards for class size established by the State Board of Education are the principal limitation to increased school enrollments. Current minimum accreditation standards limit elementary classes to a maximum of 24 students in kindergarten, 26 students in the first and second grades, 28 students in the third and fourth grades, and 30 students in grades five through eight (Montana Board of Public Education, 1976). At present, two kindergarten sessions in the Isabelle Bills School, each with 28 students, exceed accreditation standards. All other classes are well below the accreditation standards. Using the minimum accreditation standard as a guide, the existing elementary school classroom configuration could accommodate up to 321 students. There are 119 available vacant student spaces in the Isabelle Bills facility and 202 available spaces in the Pine Butte School. In mid-January, 1982, the Colstrip elementary school district was being operated at approximately 69 percent of capacity (Hofeldt, 1982).

Colstrip Junior High School is located behind the high school in a modular, wood-frame structure that was erected in the early 1970s to accommodate increased school enrollments associated with the construction of Colstrip Units 1 and 2. The building will need to be replaced in the near future. The seventh- and eighth-grade enrollment is 158 children and the average class size is 21.1 students, well below the accreditation maximum class size of 30 students (Tokerud, 1982).

Colstrip High School is a masonry structure. It was erected in 1944 and remodeled in 1966 and 1978. A modular wood-frame structure was recently added to the north side of the high school for temporary use

until the proposed new high school is completed. The new high school building will occupy 136,000 square feet of space and accommodate 500 students. It will include space for the basic educational program, vocational education, a 600-seat auditorium, 2,000-seat gymnasium, indoor swimming pool, and central food facility for the entire school district. The new high school will cost $13,074,250, of which $3,367,833 is being paid for by a grant from the Montana Coal Board. When the new high school is completed in the fall of 1983, the current high school structure will be converted to a middle school for grades six through eight (Schye, 1982).

Secondary school accreditation standards limit class sizes to 30 students except in instrumental and choral music, physical education, and typing, where classes can be larger. In addition, individual teacher/student loads are limited to a maximum of 160 students except in the areas noted above (Montana Board of Education, 1976). In mid-January, 1982, the Colstrip High School enrollment was 323 students. Class sizes ranged from one to 23 pupils, with an average class size of 9.1 students (excluding study hall). The largest individual teaching load for an instructor was 77 students. Given the size of its current physical plant and student/teacher ratio, the Colstrip High School enrollment could practically double before significant expenditures for instructional staff or facilitites would be necessary (Hofeldt, 1982).

Colstrip School District #19 currently employs 170 persons, including 12 administrators, 106 professional staff, and 52 support personnel (e.g., secretaries, custodians, cooks, etc.) (Montana Board of Education, 1976).

6. Public Finance

The following analysis of public finances in Rosebud County includes the three taxing jurisdictions of Rosebud County, High School District #19 (Colstrip), and Elementary School District #19 (Colstrip). It also includes the townsite of Colstrip, which is owned by Montana Power Company and managed by the Sunlight Development Company. The historical analysis includes an examination of historical revenues, expenditures, taxable valuation, and mill rates. The historical analysis was used in conjunction with information provided by informed officials familiar with the study area in making the baseline projections to the year 2018. The projections were developed using PUFMOD, a local government public finance simulation model developed by Western Analysis, Inc. (see Technical Support Document).

For the purpose of analysis and projections, all dollar figures have been converted to constant 1980 dollars using the GNP implicit price deflator.

a. Historical Conditions

During the period 1970 to 1980, real per capita taxable valuation increased 8.31 percent annually in Rosebud County due to industrial and

coal development in the area around Colstrip. Similar increases were experienced by the two school districts in Colstrip. In comparison, real per capita taxable valuation declined or increased at a much lower rate in comparable jurisdictions. Since 1975, the addition of generating Units 1 and 2 has increased Rosebud County taxable valuation about 30 percent. The additions of Units 3 and 4 are projected to increase the county's taxable value another 15 percent by 1986. Units 3 and 4 will thereafter decline in terms of relative importance as the property depreciates.

For Rosebud County and both Colstrip school districts, total operating expenditures and total expenditures increased significantly between 1970 and 1980 (Table 14, Appendix I). On a real per capita basis, the average annual rate of increase was 8.19 percent for total expenditures and 5.61 percent for total operating expenditures. Because of the sizable enrollment increases in the Colstrip schools, ranging from 150 percent to 444 percent during the period from 1970 to 1980, real total school expenditures per average number belonging (ANB) increased at most by 0.15 percent annually. Despite the real increases in virtually all major expenditure categories, mill levies in these three taxing jurisdictions decreased at an annual rate of between 5.43 percent and 6.72 percent. These declining mill rates reflect the increase in taxable valuation during this time period due to coal and industrial development.

Revenues experienced similar increases during this same time period. At the county level, total revenues increased 8.19 percent annually in real per capita terms. However, local revenues increased only 4.42 percent annually. The lower rate of increase in local revenues occurred in large part due to the change in the proportion of intergovernmental transfers as a revenue source. In 1970, intergovernmental revenues represented five percent of total revenues for the county; by 1980 they represented 34 percent of total revenues. This change in the revenue mix was consistent with comparable jurisdictions. A similar change was experienced by all governing units in the county due to the influx of Coal Board Grants received to mitigate the impacts of coal development. Of the $32 million of Coal Board Grants issued since 1977, approximately 51 percent of this money has gone to governing units in Rosebud County.

The historical public finance analysis for the Colstrip townsite covered the period from 1977 to 1980. Changes in accounting procedures precluded the inclusion of prior years in the analysis. However, the 1977 to 1980 period included much of the permanent population settlement and infrastructural development associated with the industrial and coal mining development in the area. The townsite has experienced a sizable increase of 30.30 percent annually in total real operating expenditures per capita, while locally generated revenues per capita have increased 22.57 percent annually, in real terms. The relatively higher rate of increase in per capita expenditures vis a vis revenues can be explained by the residential, infrastructural, and community service development that has occurred in order to establish and serve the growing permanent population in the townsite. Despite the differences in rates of increase between revenues and expenditures, the townsite operation has remained economically viable for Sunlight Development Company, based on available information (Reardon, 1982).

Exhibit 3

b. Baseline Fiscal Projections

Baseline fiscal projections for Rosebud County, the two Colstrip school districts, and the Colstrip townsite were estimated to the year 2018. Balanced budget scenarios were developed using PUFMOD for the three taxing jurisdictions. The Colstrip townsite projections were developed using per capita rates of change for each of the revenue and expenditure categories in the simulation model.

The balanced budget approach used in these projections provides an indication of what property taxes must be in order to balance the budget, given a predetermined level of expenditures and nontax sources of revenues. Using estimates of the expected taxable valuation and given the corresponding year's property taxes, the mill levies needed to generate that level of property taxes can be determined. Tables 15 through 17, Appendix I, contain the projections for Rosebud County, Colstrip High School District #19, and Colstrip Elementary School District #19.

The initial annual increases in real operating expenses per capita in Rosebud County result from the continuance of historical annual increases in general government and public safety expenses of 4.46 percent and 16 percent, respectively, through fiscal year 1983, when the population peaks. Thereafter, public safety expenditures increase at a declining rate until 1987 when the population stabilizes. Public services and transportation expenditures are assumed to continue their historic real per capita annual rates of increase of 1.17 percent and five percent, respectively, through 1986. These forecast percentage increases permit the continued development of these county services during this period of population growth. Thereafter, all operating expenditures are held constant in real per capita terms.

Infrastructural development is assumed to be near completion with regard to the county government, therefore capital outlays are assumed to be cut in fiscal year 1982 to their historic per capita level. Since Coal Board Grant funds for impact mitigation are expected to fall off dramatically, as are federal transfer payments, intergovernmental revenues are reduced by over 50 percent, bringing them back to prior years' per capita levels.

Based on these assumptions for Rosebud County, the estimates contained in Table 15, Appendix I show an increase of 25 percent to 47 percent in the major expenditure and revenue categories through fiscal year 1983. Thereafter, throughout the forecast period, there are moderate fluctuations in real terms reflecting changes in population. Between 1982 and 1990, mill levies decrease approximately 48 percent and thereafter rise by 2.17 percent annually. The later mill levy increase is due to projected declines in taxable value caused by decreasing coal production and the declining real values of industrial plant and equipment.

Operating expenditures per capita are held constant at 1981 levels in both the high school district and the elementary district, with one

exception. Elementary instruction expenditures are assumed to increase 6.50 percent through 1984, bringing per capita instructional expenditures back up to the 1980 peak of $2,171 per ANB. Since the additional teachers are expected to be only temporary, after 1984 instruction expenditures are assumed to return to historic levels.

The baseline projections for the high school district include the sale of $9.7 million in bonds, with debt service payments beginning in 1983 and extending through 2002.

Nonproperty tax school revenues are held constant in real per capita terms, with two exceptions: 1) county funds to the elementary district continue their historic 3.66 percent annual increase to supplement the funding for the additional temporary teachers; 2) per ANB federal funds to the high school decline 11.50 percent due to recent federal funding policies.

Tables 16 and 17, (Appendix I), contain details of the baseline forecasts based on these assumptions. As expected, revenues and expenditures are forecast to peak in 1983 and will thereafter exhibit moderate, generally downward-trending fluctuations.

Mill levies in these two balanced budget scenarios are more erratic than those forecast for the county due to the relatively greater influence of coal production and prices on the taxable valuation of the school districts.

Colstrip townsite baseline projections presented in Table II-18, Appendix I, include three major capital outlays as part of the baseline assumptions. All three projects are expected to be funded solely by Coal Board Grants. They include: 1) $1.1 million water treatment plant in 1981; 2) $150,000 for a new fire truck and storage facility in 1982; and 3) $300,000 for a snow blower and street cleaner in 1983 (Workman, 1982). No additional capital outlays are included in the baseline projections.

Operating expenditures are assumed to remain constant in real per capita terms with the exception of general expenditures, public services, public utilities, and housing expenditures. These four expenditures are assumed to increase in real per capita terms at their historic annual rates through 1984 (i.e., general expenditures, 3.05 percent; public services, 8.01 percent; public utilities, 14.29 percent; and housing, 16.19 percent). This will enable the continued development of townsite infrastructure and services for as long as the population continues to grow. The growth in residential and community services is assumed to be necessary to attract and maintain a permanent work force.

Real per capita revenues from housing rents and trailer park rents are forecast to decline after 1984, when the population peaks. Housing unit sales are projected to increase at a declining rate until 1987, when the population stabilizes (McIntosh, 1982).

Given the above assumptions, the Colstrip townsite managers can expect a 40 percent increase in real operating expenditures per capita by 1984, with no change thereafter. Real annual total expenditures and operating expenditures are forecast to peak in 1983 when the annual population peaks. Thereafter, expenditures, like revenues, fluctuate moderately with a downward trend through the remainder of the forecast period.

Exhibit 3

J. LAND USE

1. Present Land Use

The land use pattern and productivity of the 2,693 acres in Area C, Block I are similar to the rest of the Western Energy leasehold at the Rosebud Mine. Approximately 1,904 acres (71 percent) of Area C, Block I is rangeland, with 436 acres (16 percent) cultivated for wheat and 334 acres (12 percent) in hayfield production. The remaining acreage (1 percent) includes sandstone outcrops, clinker (locally known as scoria) pits, and a ranch yard. By comparison, rangeland uses make up about 67 percent of the Western Energy leasehold, 78 percent of Rosebud County, and 74 percent of the 45 million-acre Yellowstone River subbasin (Rosebud County Planning Board, 1979).

Coal development in Rosebud County has temporarily displaced about 3,350 acres of rangeland and 200 acres of cropland (Montana Department of State Lands, 1981). About 77 percent of the disturbance is due to the Rosebud Mine (Table II-14). Additionally, about 550 acres of land at Colstrip and Forsyth have been permanently converted to urban and industrial uses (Montana Department of State Lands, 1981). The cumulative impact of coal mining to date represents about 0.1 percent of rangeland in Rosebud County and about 0.2 percent of Rosebud County's cropland.

The cropland in Area C, Block I represents less than 0.6 percent of the 130,000 acres of cropland in Rosebud County. Principal crops are dryland winter wheat and alfalfa. Average production in Area C, Block I is about 30 bushels per acre for wheat and about 1.2 tons per acre for hay, while average production for Rosebud County is 29 bushels per acre for winter wheat and 1.5 to 2.0 tons per acre for dryland alfalfa (Prinkki, 1982). Production comparisons are presented in Table II-15 and field locations are shown on Figure II-21. Relic irrigation structures occur along Stocker Creek and operational irrigation structures occur along East Fork Armells Creek, but cropland within Area C, Block I is presently farmed on a dryland basis. This cropland is designated as class three and four lands under the Soil Conservation Service Land Use Classification System. Although this classification is considered marginal for crop production as compared to the United States as a whole, it is the best classification of croplands possible, given the regional constraints of low rainfall and a short growing season.

The rangeland in Block I represents less than 0.07 percent of the 2.5 million acres of rangeland in Rosebud County. Presently, rangeland productivity in Area C, Block I is about 0.15 AUMs per acre for grassland and shrubland, based on the Montana Soil Conservation Service Technical Guide (1979) for rangeland in "fair" condition, and about 0.2 AUMs per acre for ponderosa pine areas. Under optimum management, this could be increased to about 0.45 AUMs per acre for grassland and shrubland, and to about 0.23 for ponderosa pine (Appendix G, Table I). The average production level for southeastern Montana ranges from 0.25 to 0.30 AUMs per acre (Montana Department of State Lands, 1981).

TABLE II-14

SUMMARY OF LAND USE IMPACTS OF THE ROSEBUD MINE

Land Use Category	Pre-mining Use	Present Use[a]
Rangeland		
Grassland and Shrubland	16,500	14,683
Ponderosa Pine	7,440	7,290
Cropland	1,420	1,220
Mining Disturbance	640[b]	315
Mine Facilities and Associated Disturbance	0	424
Reclamation	0	2,011
Bond Release	0	57[c]
	26,000 acres	26,000 acres

[a] Estimated as of 1981 (Montana Department of State Lands, 1981).

[b] Unreclaimed spoils remaining from the original Northern Pacific Mine, and Burlington Northern railroad right-of-way spoils.

[c] County road

Exhibit 3

TABLE II-15

FIELD PRODUCTION IN AREA C, BLOCK I

Field[a]	Crop	Acres	Production[b]	Acres to be Disturbed
1	wheat/speltz	122	27 bu/ac	90
2	winter wheat	185	33 bu/ac	185
3	winter wheat	34	33 bu/ac	34
4	winter wheat	19	33 bu/ac	19
5	winter wheat	3	33 bu/ac	3
6	winter wheat	28	33 bu/ac	28
7	winter wheat	17	33 bu/ac	17
8	winter wheat	28	35 bu/ac	--
9	crested wheatgrass/alfalfa	13	1.0 t/ac	--
10	crested wheatgrass/alfalfa	50	1.0 t/ac	12
11	crested wheatgrass/alfalfa	43	1.0 t/ac	20
12	crested wheatgrass/alfalfa	91	0.6 t/ac	91
13	crested wheatgrass/alfalfa	70	1.5 t/ac	70
14	crested wheatgrass/alfalfa	36	1.5 t/ac	36
15	crested wheatgrass/alfalfa	11	0.6 t/ac	--
16	crested wheatgrass/alfalfa	20	0.6 t/ac	1
		770		606

a Field locations are depicted in Figure II-21

b Based on land owner interviews conducted in September, 1980 and 1981 as reported in Western Energy Company's Application for a Surface Mining Permit Area C, Block I. Production figures reported by Burlington Northern (Western Energy Company, 1981) are somewhat lower.

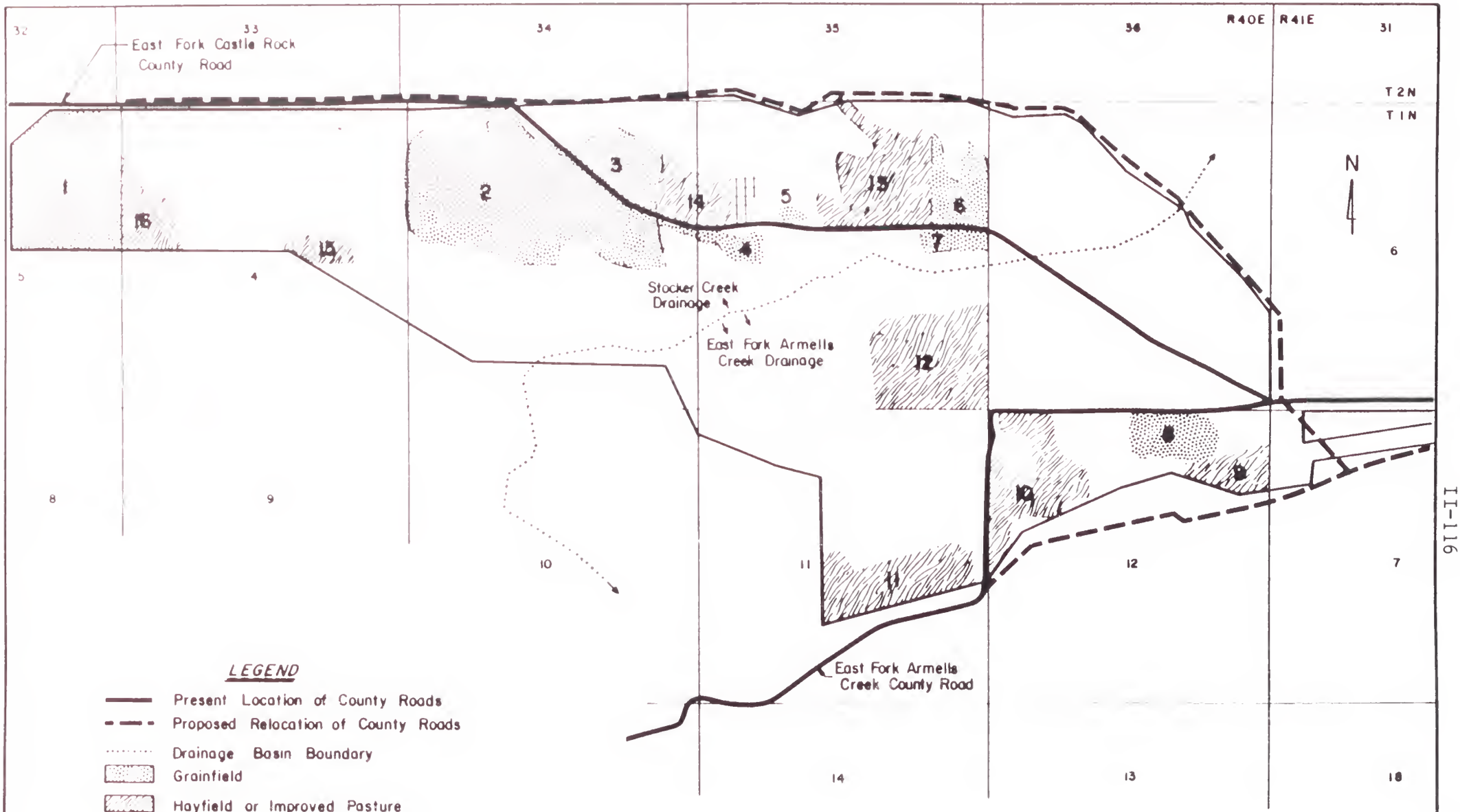


FIGURE II-21 AGRICULTURAL USE IN AREA C, BLOCK I

Exhibit 3

2. Federal Planning

Portions of the coal in the Rosebud Mine are federally owned and administered by the Bureau of Land Management. The BLM has developed a land use plan called the Management Framework Plan for the South Rosebud Planning Unit. The mining plan described in the mine permit application for Area C, Block I is compatible with the recommendations made in the Management Framework Plan.

3. Local Land Use Planning

The future land use plan for Colstrip is contained in the Rosebud County Planning Data Book and Comprehensive Plan (1979). Since Colstrip is a privately owned company town, it is not subject to city council-adopted regulations or zoning plans. The future land use plan for Colstrip as designed for Montana Power Company has been approved by the Rosebud County Planning Board.

K. TRANSPORTATION

Rosebud County's transportation network consists of a series of roadways, two railroads, five commercial truck lines, a bus line, and a county-owned and operated airport located in Forsyth. Road travel is the most common mode of transportation in Rosebud County. Graveled county roads and two-lane state highways service the Colstrip area (Figure II-22). Federal Aid Primary (FAP) 39 connects Colstrip with Interstate 94, the major east-west highway to the north, and with FAP 37 (US 212), a heavily used east-west highway to the south. Access to Area C, Block I is along FAP 39, located about three miles east of the area, and by Castle Rock County Road running adjacent to the area.

The Montana Department of Highways is in the process of reconstructing 31 miles of FAP 39 in order to meet the increased traffic demand resulting from coal development in the area. A seven-mile section south of the intersection with I-94, and a 5.8-mile section at Colstrip have already been completed, with the entire project scheduled to be completed in spring, 1983 (Randall, 1982). The reconstruction consists of widening the roadway, resurfacing, realignment where needed, and providing grade separations at the four places where FAP 39 and the Colstrip railroad spur intersect. The theoretical capacity of the reconstructed highway is estimated to be 200 vehicles per hour (Colbert, 1982). These reconstruction projects are financed in part by coal severance tax augmented with Federal Aid Primary Funds.

FAP 37, which intersects FAP 39 at Lame Deer, leads west to Busby, Crow Agency, and Hardin, and east to Broadus in Powder River County. This road is heavily used by trucks and the Department of Highways is currently planning to reconstruct 27 miles of FAP 37 between Crow Agency and Busby, although there is no scheduled completion date at this time.

Traffic on the major highways leading to Colstrip has increased considerably since coal development at Colstrip (Table II-16). Traffic on FAP 37 increased about 77 percent from 1968 to 1980. Traffic on FAP 39 from Colstrip to I-94 increased about 562 percent from 1968 to 1981. The majority of the increase in traffic levels is due to power plant construction with about 20 percent of the increase contributed by mining activity. This increased traffic and the deteriorating road conditions made FAP 39 extremely unsafe (rated 1 on a scale of 20 by the Montana Department of Highways), but the scheduled reconstruction projects should alleviate many of the dangers involved in driving this highway.

A railroad spur connects Colstrip and the Burlington Northern mainline about 25 miles to the north of Colstrip (Figure II-22). This spur serves both Western Energy's Rosebud Mine and Peabody's Big Sky Mine, 7.5 miles south of Colstrip. Coal from the Rosebud Mine is shipped to such places as Billings, Montana; St. Paul, Minnesota; and Bayfront, Wisconsin. On certain occasions, the Colstrip spur is also used to haul heavy machinery for construction projects. An average of three loaded unit trains per day used the Colstrip spur in September, 1981 for a total of six trips per day, counting returning empty trains (Coefield, 1982).

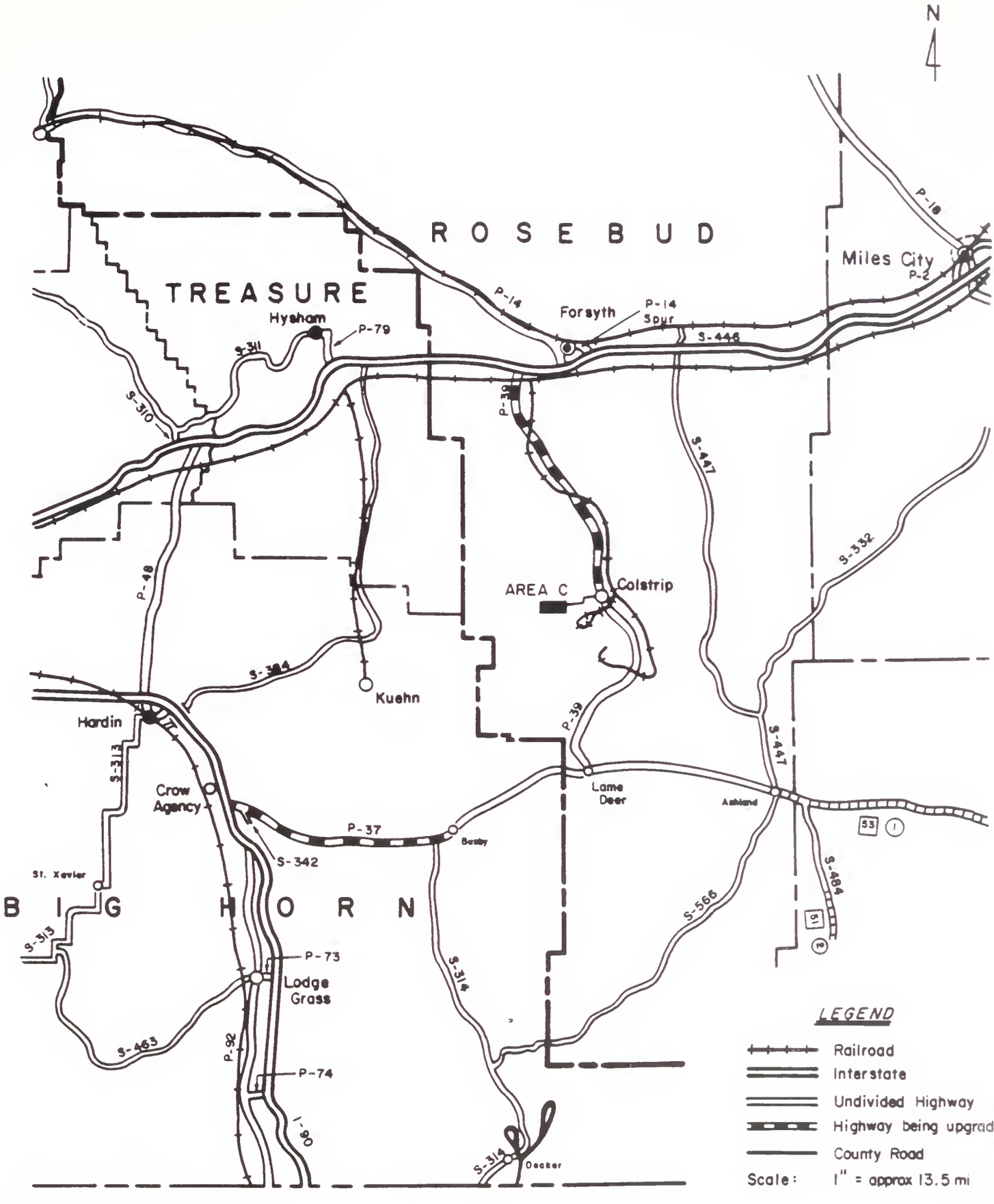


FIGURE II-22 TRANSPORTATION ROUTES NEAR COLSTRIP

Exhibit 3

TABLE II-16

AVERAGE DAILY TRAFFIC COUNTS FOR HIGHWAYS NEAR COLSTRIP, 1968-1981

Highway Segment	Year													
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
FAP 37														
Jct. 342 to Busby.....	673	603	657	701	766	860	778	791	1,052	1,443	1,159	1,130	1,250	---[1]
Busby to Rosebud County line.....	782	773	802	766	854	924	914	1,072	1,223	1,585	1,153	1,130	1,250	---[1]
Rosebud County line to Lame Deer.....	858	850	863	820	962	1,033	1,011	1,263	1,243	1,800	1,370	1,130	1,590	---[1]
FAP 39														
Lame Deer to Reservation boundary.....	238	274	320	363	395	---	---	---	359	511	585	640	1,180	---[1]
Reservation boundary to Colstrip.....	159	170	195	203	269	508	451	498	388	344	364	340	610	---[1]
Colstrip to I-94 interchange.....	210	190	236	253	370	1,193	1,047	1,425	1,087	783	678	570	1,270	1,390[2]

1 Data for 1981 not yet compiled

2 ADT from permanent counter located 6 miles south of the Colstrip Interchange

[Source: Montana Department of State Lands, 1981; Bill Colbert, Montana Department of Highways, 1982]

L. RECREATION

1. Urban Recreation Resources

Most formal recreational activities in Colstrip are provided by the Colstrip Area Recreation and Parks Association (CARPA), a citizen organization concerned with recreation in Colstrip. The organization is supported by contributions from the energy corporations located in Colstrip (about 90 percent of the total capital and operation budget) and fees from association memberships. At present, CARPA numbers 287 family, adult, and youth memberships (Noyd, 1982). Resources available under the aegis of CARPA include a 51-acre park system, a swimming pool, a wading pool, three tennis courts, three basketball courts, and five playgrounds for young children. Indoor facilities are provided at the Colstrip Community Center and comprise 16,000 square feet of space allocated to two handball/racquetball courts, a weight/exercise room, a basketball court, and a meeting room (Colstrip High School Bond Prospectus, 1981). Other indoor facilitites include a library and a former construction dining hall, which has been converted and is currently used for meetings and other social gatherings (CARPA Recreation Guide, 1980). Colstrip is in the process of creating a new outdoor recreation complex, to be named Stillwater Park, which will comprise two softball and one baseball fields, a soccer field, an outdoor basketball court, and a playground area (Mountain West Research, Inc., 1980).

Nearly 60 percent of surveyed residents considered the adequacy of organized recreation in Colstrip to be good to excellent. Over 51 percent considered Colstrip area recreational opportunities to be adequate to great; about 45 percent considered them to be limited or insufficient. Popular organized recreational activities of surveyed residents include baseball/softball (40 percent), movies/dining (83 percent), dancing (55 percent), and bowling (46 percent). Facilities for these activities are limited in Colstrip except for baseball/softball fields.

2. Nonurban Recreation Resources

Developed, public recreation resources in the area are limited. Four federal, four state, and one private nonurban recreation site have been developed within the county. Table II-17 summarizes facilities and activities available at the sites.

The U.S. Forest Service manages 95,827 acres of forest land for recreational purposes within the county and maintains 217 road miles of access within that area (Montana Department of Fish and Game, 1978). In addition, some 230,000 acres of public land managed by the Bureau of Land Management are available to public use. A motocross course, rodeo grounds, and the Rosebud Park are available in the Forsyth vicinity (Montana Department of State Lands, 1981).

The Tongue River Reservoir, located in Bighorn County, about 55 miles south of Colstrip, is the only major water impoundment in Rosebud

TABLE II-17

NONURBAN DEVELOPED RECREATION SITE INVENTORY - ROSEBUD COUNTY

DESCRIPTION	FACILITIES/ACTIVITIES			
Name	Picnic Units	Camp Units	Other*	Fee
FEDERAL OWNERSHIP				
1. Poker Jim Butte	3	0		$0
2. Crazy Head Springs	3	5	S, F	0
3. Green Leaf	0	0	F	0
4. Lost Leg	0	0	F	0
STATE OWNERSHIP				
1. East Rosebud	5	0	F, FT	0
2. Far West	0	0	F, FT	0
3. West Rosebud	0	10	F, FT, BA	0
4. Forsyth Rest Area	5	0	I, W	0
PRIVATE AND NONPROFIT				
1. Wagon Wheel	0	20	TC, W, F	3

*KEY: Facilities/Activities - Other

F - Fishing
I - Information or interpretive exhibits
S - Swimming area
TC - Trailer/camper hookups
W - Waste disposal station
BA - Boat access
FT - Float trips

Abstracted from 1978 Montana Statewide Comprehensive Outdoor Recreation Plan (SCORP), Volume 2, Outdoor Recreation Inventory

Exhibit 3

County. The reservoir is largely undeveloped for recreation, although three primitive camping areas exist nearby. The reservoir fishery offers a number of warm-water game species. The Tongue River below the reservoir also offers recreational resources and opportunities and sustains a trout fishery in its upper reaches and a warm-water fishery in the area downstream of Birney. Access to the river upstream of Ashland, however, is limited by private owners and the Northern Cheyenne Indian Reservation. The Yellowstone River also is available for boating, fishing, and other recreational activities; two fishing access sites and two recreation areas are located on the river near Forsyth (Mountain West Research, 1980). Montana Power Company allows access to Castle Rock Lake, the 152-acre surge pond that provides make-up water for the Colstrip generating units and the Colstrip public water supply (Williams, 1982).

The results of recreation surveys conducted in 1976 and 1977 by state authorities indicated that area residents prefer recreation in undeveloped, natural areas. A survey conducted by Western Analysis (1982) confirms these findings. Over 75 percent of surveyed adults camp, picnic, hunt, or fish. Sixty-seven percent enjoy swimming. Outdoor recreation in the Colstrip area reportedly is not now approaching the capacity of the area's recreational resources (Montana Department of State Lands, 1981). Still, federal authorities anticipate increased demands for recreation, particularly motorized recreation, picknicking, overnight camping, and fishing. Federal land resources are to be managed to satisfy such demands (Mountain West Research, 1980).

M. CULTURAL RESOURCES

Several cultural resources surveys have been conducted since 1971 that include some or all of the lands within Area C, Block 1 (the direct impact area) and surrounding one-mile buffer zone (the indirect impact area). DSL requires a buffer zone to preserve, to the extent possible, important cultural resources from the effects of blasting. The seismic effects of blasting can affect rock art, rock shelters, and historic sites with standing structures. Table 1, Appendix M summarizes this survey information. A summary of cultural resources found and their National Register eligibility follows.

1. Area C, Block 1

Nine cultural resources sites were recorded during surveys within Area C, Block 1. Five of these are prehistoric, one is historic, and three are of unknown affiliation. These sites are summarized below and in Table 2, Appendix M.

a. Prehistoric Sites

- The Cooley Site (24 RB 1059). This site was first recorded in 1973 (Fredlund and Fredlund, 1974) and re-evaluated in 1980 (Fredlund, 1980) and 1981 (Steere, 1982). The applicant's archaeological consultant (Mineral Research Center) reports the site to be a prehistoric temporary campsite. It consists of a lithic scatter located next to a spring and evidences subsurface cultural deposits (Steere, 1982). The 1981 reevaluation and testing indicate the site is much larger than initially thought (Steere, 1982).

- The Medicine Root Site (24 RB 879). This site was recorded in 1981 as a prehistoric occupation site. It consists of a large lithic scatter, and initial testing revealed the presence of subsurface cultural deposits (Mineral Research Center, 1982).

- The Fadhl Kill Site (24 RB 299). This site was first recorded in 1973 (Fredlund and Fredlund, 1974) and was reevaluated in 1981 (Steere, 1982). The site is recorded as a prehistoric bison impoundment, kill, and processing site. The consultant feels it may also represent an occupation site. All test pits revealed subsurface cultural deposits (Mineral Research Center, 1982).

- The Tripoint Site (24 RB 873). This site was first recorded in 1981 as a prehistoric hunting lookout, lithic workshop, and temporary occupation site. Testing revealed no subsurface cultural deposits (Mineral Research Center, 1982).

- The Farley Lookout Site (24 RB 1058). This site was first recorded in 1973 (Fredlund and Fredlund, 1974), reevaluated in 1980 (Fredlund, 1980), and tested in 1981 (Steere, 1982). The site was recorded as a hunting lookout and temporary campsite. Testing in 1981 revealed subsurface cultural deposits (Steere, 1982; Mineral Research Center, 1982).

b. Historic Sites

- Fadhl Homestead (24 RB 884). This historic homestead complex, still in use today, was first recorded in 1981 (Mineral Research Center, 1982) and is thought to be underlain by portions of the prehistoric Fadhl Kill Site (Steere, 1982). The complex includes thirteen standing wood frame buildings that date back to the 1920s when the site was first homesteaded. Numerous historic documents on the homestead allow compilation of a detailed ownership history (Mineral Research Center, 1982; Steere, 1982).

c. Sites of Unknown Affiliation

- The Three Ring Site (24 RB 1060). This site was first recorded in 1973 (Fredlund and Fredlund, 1974) and reevaluated in 1980 (Fredlund, 1980). The site consists of three stone circles of unknown cultural or temporal affiliation. The rings may be prehistoric tent rings or may be associated with the nearby Cooley Place Homestead. No artifacts were found in association with the stone rings (Fredlund and Fredlund, 1974; Fredlund, 1980).

- The Lynn's Square Site (24 RB 1071). This site was first recorded in 1973 (Fredlund and Fredlund, 1974) and reevaluated in 1980 (Fredlund, 1980). The site consists of a rectangular sandstone rock structure. No cultural material was found associated with the feature or in the test pit. The feature's function and origin are unknown (Fredlund and Fredlund, 1974; Fredlund, 1980).

- Gene's Vision Quest Site (24 RB 1072). This site was first recorded in 1973 (Fredlund and Fredlund, 1974) and reevaluated in 1980 (Fredlund, 1980). The site consists of two rock structures located on the crests of two knolls adjacent to the historic Doc Taylor's Homestead site. The origin and function of these features are unknown. The consultant suggests it could be a prehistoric vision quest site or could be associated with the historic homestead and may possibly be children's forts (Fredlund, 1980).

Based on the information currently available on the nine sites, the Three Ring, Lynn's Square, Tripoint, and Gene's Vision Quest sites appear to be ineligible for nomination to the National Register based on the lack of potential for yielding additional information on the prehistory or history of the area. Although the Medicine Root site has been tested, its extent indicates the need for additional testing in order to evaluate its potential eligibility. The Cooley, Fadhl Kill, Fadhl Homestead, and Farley Lookout sites may be eligible for nomination because of their potential to yield additional information on the history and prehistory of the area.

DSL, the State Historic Preservation Office (SHPO), and the Office of Surface Mining (OSM) had not yet received the final report on the Archaeological Survey of Area C, Block I and buffer zone when this EIS was finalized. These agencies will review the report and assess the potential of the sites for National Register eligibility at the earliest possible date. Determinations of eligibility will be sought from the keeper of the National Register prior to any disturbance.

2. One-Mile Buffer Zone

Twenty-four cultural resources sites and one "Minimal Activity Locus" (MAL) were recorded during surveys within the one-mile buffer zone around Area C, Block 1. A "Minimal Activity Locus" is defined as a location that has a small amount of cultural debris and has the potential to yield limited information to the interpretation of prehistoric or historic cultural activity (Fredlund, 1980). Sixteen of these are prehistoric, six are historic, and three are multi-component sites consisting of both historic and prehistoric components. A brief synopsis of these sites is presented in Table 3, Appendix M.

Of the 24 sites recorded within the buffer zone, only one (How Dry I Am Site) has been determined ineligible for nomination to the National Register (Montana State Historic Preservation Office, 1981). This determination was made as a part of the review of an adjacent area of the Rosebud Mine (Area B). Fifteen other sides (McDonald Quarry, Lovelace Memorial, Petro City, Rabbit Ridge, Rocky Top, Dusty Shelter, Caskey 320, Castle Rock Post Office and Homestead, P.E. Davis Rock Art, Wheatfield Vista, Connie's Gallery, Pottery, Sunburn Out, Pigeon, and Normand Estates sites) appear to Western Energy to be ineligible for the National Register based on their lack of potential to yield useful information and/or their lack of integrity as a site (due to natural deterioration, destruction, alteration, etc.). The Forsite, East Fork, and Albino Deer sites need testing before National Register recommendations can be made. This however, would be necessary only if mining were to expand into these portions of the buffer zone at some future point. It is recommended that testing be done on the minimal activity locus (MAL 1401) to determine whether it warrants a site designation prior to considering a National Register recommendation. The Sly Bison, Insite, Cooley Place, Doc Taylor's Place, and the Muskrat Homestead sites are potentially eligible for the National Register and official determinations of eligibility will be sought.

No Native American concerns as defined under the American Indian Religious Freedom Act of 1978 were identified for Area C, Block I or the buffer zone. However, much of the work conducted in the area was done prior to the law's enactment and no consultations with Native American groups have been made.

Exhibit 3

N. AESTHETICS

Determination of the aesthetic values of any given place is a subjective process determined by each individual's perceptions, tastes, and values.

Texture, color, relief, and contrast make up most of what we see in a landscape. At the Rosebud Mine, Area C, Block I, the texture varies from the even range grasses on gentle slopes to smooth, linear sandstone outcrops, to the jagged profile of ponderosa pines on the skyline. Colors are mostly neutral: pale yellow, tans, browns, and greys, with dark greens in the timber and scattered orange, rust, and purple clinker outcrops. Relief is low to moderate and slopes are generally broken only by the scattered sandstone or clinker ledges on the upper slopes and ridges. The most striking contrast is between the light range grass covering open slopes and the dark ponderosa pine stands along the higher ridges and divides. In cropland areas, a distinctive contrast exists between the long, straight plow rows (and subsequent linear crop lines) and the free-flowing, gradational contacts between natural vegetative types.

The sounds that currently dominate Area C, Block I, are typically natural and rural, associated with ranching, rangeland farming, and light traffic on the county road. Block I is sufficiently removed from the present mining activity around Colstrip that the sounds of that activity cannot readily be heard.

CHAPTER III

ANALYSIS OF IMPACTS

A. GEOLOGY

1. Topography/Geomorphology

The post-reclamation topography would approximate the existing landscape in Area C. A general smoothing of the topography and a slight reduction in elevation would be the obvious changes, with drainages and divides restored to their approximate pre-mine location. The current Block I plan does leave an undisturbed sandstone ridge in part of the southern permit area. This would be the only undisturbed bedrock in the permit area. A proposed post-mine topographic contour map for Area C, Block I is included in the mine permit application and in the Technical Support Document.

While the topography of Area C would be modified, the landforms would largely be constructed and continue to develop on reclaimed spoils materials. Due to the proposed reclamation techniques (see Section F, Soils), these surficial materials would be highly variable over space and with depth. Consequently, broad landscape units would not develop, but rather a range of land forms would develop on a single anisotropic medium.

The characteristics of the surficial materials anticipated under post-reclamation conditions are summarized in Table III-1. The characteristics of these materials, which determine their erodibility, are in themselves strongly influenced by the techniques employed during reclamation.

Studies of currently reclaimed spoils in the Colstrip area and estimations of source area sediment yields under post-mining conditions (see Technical Support Document for detailed studies), suggest that yields would be moderate in comparison with undisturbed conditions. The highest yields can be anticipated on topsoiled spoils on which only a limited vegetation cover has developed. As vegetation cover (including root density and soil organic content) increases during reclamation, source area sediment yields will decrease.

Other large scale sources of instability in the reclaimed landscape could include accelerated erosion at the highwall interface and subsidence due to settling of the spoils. The long-term significance of these problems are difficult to assess.

There is a potential for increased infiltration along the highwall zone, which could result in piping and the formation of gullies. Differential erosion rates between the competent bedrock and the spoils materials may also occur at the interface, which could result in modification of drainage profiles and base levels, accelerated erosion, and local diversions of drainages. Subsidence and differential settlement may also result in a range of problems.

TABLE III-1

GENERALIZED CHARACTERISTICS OF RECLAIMED LANDSCAPE

Nature of Surficial Materials	Range of Slope Gradient (%)	Vegetative Cover (%)	Drainage Density (Mi/Ml^2)	Infiltration Rate (In/hr.)	Estimated Source Area Sediment Yield ($Acre/Ft/Mi^2$)
Unconsolidated spoils material with sandy loam or loam texture. Bulk densities of 1.3 to 1.8.	Smooth rolling topography <20%. Only limited areas over 10%.	First 3 years after disturbance: 25%. 3-10 yrs. following revegetation: 70% of weeds + grass.	5-8 mi/mi^2	Highly dependent on treatment. 2-4 in/hr.	0.04
Overlain by topsoil. Low organic content (1-2%) and very little armoring.		After 10 years: 75% vegetative cover			

Note: method of calculation discussed in detail in Technical Support Document.

Exhibit 3

2. Stratigraphy

The portion of the Tongue River Member that constitutes the Rosebud coal overburden would necessarily be disrupted in mining the Rosebud coal seam, and the backfilled material would not have the same stratigraphic characteristics as the undisturbed unit. Inasmuch as the overburden has no unique or intrinsic value, the disruption to this stratigraphic section would not produce a significant impact.

3. Overburden

Mining of the Rosebud coal using conventional dragline overburden removal techniques would nonselectively strip and mix the overburden materials. Studies by Dollhopf et al., (1978, 1979) indicate that "normal spoiling" of overburden results in as good a mixing of the spoiled material as can be reasonably achieved with a large dragline. While large-scale mixing would be achieved, the degree of such mixing is limited by the size of equipment to be employed. Pockets of essentially unmixed and undiluted overburden would be preserved in the reclaimed spoils. Dollhopf et al. (1981) state that materials (exceeding state suspect levels) found in the overburden that make up less than five percent of the overburden in a single test hole are almost never detected in the post-mine spoils. They further found that materials (exceeding state suspect levels) constituting 5 to 15 percent of a hole were generally found in pockets in the spoils, though often diluted. Overburden materials exceeding state suspect levels and constituting greater than 15 percent of the overburden tested were always found exceeding state suspect levels in some sample(s) from the spoils. Table II-2 shows the overburden holes in which suspect materials in the overburden exceed the state suspect levels and what percentage of the samples are in exceedance for each suspect parameter.

Table II-2 suggests that manganese and cadium do not exceed suspect levels in significant volume in Area C, Block 1. The remaining parameters (electrical conductivity, nickel, molybdenum, and sand) all exceed state suspect levels in enough samples to be potentially significant.

An uncertainty exists regarding the drawing of inferences about spoils geochemistry based on the available overburden data. This uncertainty is related to the findings of Dollhopf et al. (1981) in their Western Energy Company Area B study that overburden sampling on a grid pattern with hole density similar to that of Area C (1500- to 2000-foot centers) is only about 50 percent reliable in predicting the occurrence of unsuitable overburden material. (Note: The DSL is currently reviewing its guidelines regarding overburden sampling procedures and sampling density requirements.)

Nevertheless, review of the existing overburden data relative to Western Energy's mining plan suggests that, while stripping and replacing the overburden would result in a material having the same overall bulk chemistry characteristics as the undisturbed materials, several other impacts would likely occur, as follows:

Near-surface electrical conductivity across the mined area would be generally reduced.

- o Localized areas of molybdenum, nickel, and sand concentrations above DSL suspect levels may be created in the near-surface spoils.
- o Very localized areas where cadmium concentrations may exceed DSL suspect levels in the near-surface spoils may be created.
- o Present near-surface materials with high soluble salt contents (electrical conductivity) would be buried in the spoils, thus making the soluble salts available for solution in groundwater.

A discussion of the significance of trace element concentrations, electrical conductivity, and sand content in reclaimed spoils is presented in Chapter III, Sections B and F, and in more detail in the Technical Support Document.

4. Structure and Paleontology

There would be no foreseeable impact on the geologic structure or paleontology of the area as a result of strip mining. However, the structure, particularly the inferred faults in Area C, may have an impact on the recovery of coal in the proposed mine. Mining through a fault having a displacement of 70 feet paralleling the highwall would necessitate a discontinuous pit development in the fault area to get the pit floor down to the coal level. Such a mining procedure would probably leave one or more cuts of coal unmined and irretrievable.

5. Geologic Hazards

No major geologic hazards would result from strip mining, though some instability due to settling in the spoils would occur for a number of years after reclamation. Minor settlement problems have been noted by DSL personnel in spoil areas at the existing mine. settlement cracks ranging up to three feet deep in a small area of newly-graded but untopsoiled spoil in Area B, an area of small "sinkhole" features at the toe of a slope in a topsoiled and seeded portion of Area B, and a recent subsidence feature where spoil is settling away from the crest of a backfilled endwall. These problems have occurred within the first three years after regrading. The instability of the backfilled spoils may preclude construction of large structures on the reclaimed spoils until they are stabilized. Normal agricultural use of the reclaimed spoils would probably not be affected.

The proposed limitations on blasting, in terms of weight of explosive per delay charge and associated ground motion in the vicinity of structures, meets the requirements of 10 CFR 715.19. There is some evidence that the proposed limit of one in/sec. peak particle velocity

may allow minor damage in structures, consisting of small plaster cracks or loosening of paint. The limitation on explosive weight would likely generate ground motions that are much lower than the suggested limit, based on analyses of numerous blasts at other surface coal mines. There is no evidence that this shallow blasting would cause earthquakes.

Generally, the effects of blasting on groundwater supplies adjacent to Western Energy's or Peabody Coal Company operations is believed to be insignificant. According to a seismic study conducted in Montana by Ernest Bond, neither groundwater flow nor quality were adversely affected. Another study conducted by Berger Associates states that aquifers show little or no affect to coal mine blasting activities. The report states the maximum effects extend out from the blast hole a distance ranging from 140-160 feet. Water quality samples obtained after the blast indicated no change in water quality characteristics.

6. Resources

Coal resources would be diminished by the 23.7 million tons of Rosebud coal to be mined in Area C, Block I. In addition, approximately 9.6 million tons of McKay coal in Area C, Block I would probably become an irretrievable resource if not mined when the Rosebud is removed. Any reserves that may be calculated in the Stocker seam would also be irretrievably lost, since it is highly unlikely that either the Stocker or the McKay would ever become more economic to produce than at the time of mining the overlying Rosebud seam.

B. HYDROLOGY

The hydrologic impacts section addresses the influence of both existing and proposed mining on the groundwater and surface water flow, quality, and use within the hydrologic study area (Figure II-3). This section examines the anticipated impacts for the five-year mine plan period in Area C, Block I and considers Rosebud Mine Areas A, B, C, D, and E and Peabody's Big Sky Mine, with respect to cumulative impacts on groundwater use and surface water flow and quality over the entire mine life and 100 years beyond.

1. Groundwater

The purpose of the groundwater section is to specifically address the influence that existing and proposed mining activities would have on the quantity and quality of groundwater, either originating in or flowing through the hydrologic study area. The potential for impacts by disturbing the groundwater flow system are straightforward. It must be determined: 1) whether or not mining would deplete or contaminate aquifers to the extent that it would affect existing or future users of groundwater; or 2) if groundwater discharge to surface water would be depleted or contaminated to the extent where the potential for surface water use is affected.

a. Impacts Through Five-Year Permit Period

1) Groundwater Flow

a) Aquifer Properties

The spoiling of Rosebud overburden and removal of the Rosebud coal would modify hydraulic properties in the Rosebud Mine area. As a result of rubblizing the Rosebud overburden, the porosity of the backfilled material would be double that of the original material. The post-mining increase in effective porosity would allow for increased groundwater storage. However, this increase in effective porosity would also result in the slight retardation of the recovery of groundwater levels. Horizontal hydraulic conductivities of spoiled materials would be equivalent to pre-existing horizontal hydraulic conductivities. However, vertical hydraulic conductivity values would increase significantly from pre-mining values, and would be equivalent to horizontal hydraulic conductivities. The high vertical hydraulic conductivities would increase the potential for post-mining groundwater recharge. However, vertical hydraulic conductivity of spoils is only one of several factors affecting actual recharge rates.

b) Groundwater Movement in Water-Bearing Strata

A regional, three-dimensional computer modeling effort was undertaken for this study because of the complex nature of the hydrologic study area. The geology consists of multiple thicknesses of geologic strata with variable hydraulic properties, cut by surface water drainages. Superimposed on this system are the five mine areas at the Rosebud Mine (A, B, C, D, and E) and the Big Sky Mine. Mining is in various

stages of progress in four of these areas: Rosebud A, B, and E, and Big Sky. The model has been used to depict the changes in the groundwater flow system as a consequence of mining.

The flow modeling performed at the Rosebud Mine has several limitations.

- o The model is regional in nature and includes assumptions on regional aquifer properties.

- o The model was calibrated with quantifiable known stresses included. If data did not exist such as for the proposed fly ash ponds, or if the stress was insignificant compared to the regional flow system such as the existing fly ash pond leakage it was not included in the model.

The modeling effort is considered to be a tool to determine the regional impacts on the flow system caused by mining. It represents a best estimate of how that system will react based on input parameters. The aquifers may respond differently when the stress of mining is imposed on the flow system because of stress induced aquifer property variation. It is impossible to quantify these variations until after they occur. If significant regional variation is the flow system is observed after mining has been taking plan for a time then it is advisable to reexamine and remodel the study area.

The model has allowed for a computation of changes in the groundwater system as existing pits are backfilled (slowly resaturating), while new pits opened (causing localized lowering of water levels).

Inflow to the Area C, Block I - initial boxcut pit has been estimated to be less than 125 gallons per minute (gpm) for each 14,000-foot pit using the method described by McWhorter (1980). The result of modeling for maximum boxcut pit inflow produced a "worst-case" inflow rate estimate of 110 to 120 gpm for a 14,000 linear foot pit.

After the boxcut has been developed and groundwater is removed from storage the average pit inflow for a 14,000 linear foot pit is estimated to range from 35-40 gpm. Based on the modeling results future pit inflows can be estimated to equal approximately 2.5 3.0 gpm per 1,000 foot of highwall.

Table III-2 shows the ranges of "worst case" results obtained by computer modeling for each mine area. The table presents the amount of drawdown at various distances from pit centers for each mine area for the five-year Area C mine plan. It can be seen that drawdown is usually small at a distance of 2,000 feet for any given year, except where the 2,000-foot radius includes previously mined and spoiled acreage (e.g., mine Area E). Actually, this manifestation is not drawdown, but rather, a slow recovery of water levels in spoils after mining.

The only water-bearing unit of significance that would be affected by mining is the Rosebud coal. The Rosebud overburden and interburden would

TABLE III-2

DRAWDOWN EFFECTS OF MINING ROSEBUD OVERBURDEN
AND ROSEBUD COAL SEAM,
(in vertical feet)
ROSEBUD MINE AREA, MONTANA

Rosebud Mine Area	Year	0[2]	2,000	4,000	6,000
A	1983	M	NP	NP	NP
	1984	30	2-3	0.0-1.0	0
	1985	26	4-6	0.5-1.0	0
	1986	23	5-10	1.0-2.0	0
	1987	22	5-10	2-3	5-10
	2017	12	5-10	5-10	5-10
	2118	1	0-1	0-1.5	-2-2
B	1983	M	NP	NP	NP
	1984*	80	10-15	1.5-2.0	0.0-1.0
	1985	64	2-4	0.0-1.0	0
	1986	56	4-6	1-2	0.0-1.0
	1987	50	45-50	10-15	2-4
	2017	42	40-46	36-46	17-46
	2118	24	23-25	21-26	19-26
C	1983	50	4-6	0.5-1.0	0
	1984	72	2-5	0.5-1.0	0
	1986	72	5-10	1-3	0.0-1.0
	1987	72	5-10	3-4	0
	2017	82	15-70	8-60	3-45
	2118	30	27-32	23-35	NP
D	1983	M	NP	NP	NP
	1984	46	20-25	0-0.2	0
	1985	34	15-20	1.0-2.0	0
	1986	28	15-20	2-3	0.0-1.0
	1987	24	15-20	3.0-4.0	0.0-1.0
	2017	4	2-6	2-6	4-10
	2118	-4[1]	-1-5	-0.5-7.0	0-8
E	1983	M	NP	NP	NP
	1984	55	50-55	5-7	0.5-0.9
	1985	45	40-45	5-10	1.0-2.0
	1986	40	35-40	10-15	2.0-3.0
	1987	35	30-35	10-15	3.0-5.0
	2017	15	12-18	10-23	6-27
	2118	0	-1-2	5-4.5	8-6
Big Sky Mine	1983	25	4-6	0.0-1.0	0
	1984*	24	4-6	0.0-2.0	0.0-1.0
	1985	23	5-10	1.0-3.0	0.0-1.0
	1986	22	5-10	2.0-3.0	0.0-2.0
	1987	20	5-10	2.0-4.0	1-3
	2017	15	12-18	10-23	6-27
	2118	0	-1-2	5-4.5	8-6

M - Mined (aquifer has been affected by mining)
NP - Not Predicted
* Combined effect from Western Energy and Peabody Coal Compoany operations
[1] Negative values indicate levels exceeding pre-mining conditions
[2] Radial distance from approximate mine area center

Exhibit 3

be impacted by mining, but neither stratum is consistently saturated; thus, the impact on these strata is not significant.

c) Recharge/Discharge Relationships

The impacts to be addressed within a discussion of recharge/discharge are: 1) whether or not recharge to the aquifer would be significantly impaired during the five-year mine permit period, and 2) whether or not there would be a significant change in the rates of discharge to surface water that would diminish surface water flow.

As stated in the description of the existing hydrologic environment (Chapter II, Section B), Rosebud Mine Area C is a probable recharge zone. A majority of East Fork Armells Creek above Colstrip receives groundwater (bedrock) discharge as do the coulees tributary to Rosebud Creek farther to the south.

The potential for impacts on recharge, particularly in Area C, can be gauged indirectly by examining the influence of mining on the potentiometric surface in the recharge zone. A computer program was used to determine that where Area C would be mined, there would be a maximum drawdown of 82 feet with a maximum radius of significant influence of 6,000 feet (Table III-2). This suggests that at some future time recharge loss would be reflected in the groundwater flow system.

A reasonable measure of changes in recharge, may be changes in discharge. Table III-3 shows a comparison, based upon results of computer modeling, of changes in groundwater discharge rates for each drainage area between 1983 (pre-mining effects) and 1987. The results show that no influences are seen within the mine plan period. A decline in water levels within a recharge area may cause some noticeable changes in discharge at some time. Despite increased evapotranspiration accompanying revegetation, the potential recharge capacity of the spoils would be higher than that of pre-mining conditions in Area C. In the long-term, mining Area C may increase recharge, resulting in increase flow in the Rosebud aquifer.

d) Groundwater/Surface Water Relationships

The potential for impact to surface and groundwater communication has been discussed in the previous section. Table III-3 shows the of influence of mining on discharge. By subtracting discharges between 1983 and 1987 shown in Table III-3, the maximum change in flow for East Fork Armells Creek and Stocker Creek has been estimated. The results of flow modeling show an average increase of 0.6 acre-foot per year in East Fork Armells and a net loss of one acre-foot per year in Stocker Creek.

The discharges to area drainages from the groundwater system are generally greater after mining (Table III-3). The larger discharges to surface waters are caused by a lowering of the water levels by mining. The changes in discharge are relatively small except for Miller and Coal Bank Coulees.

TABLE III-3

GROUNDWATER DISCHARGE*
MINING IMPACTS TO SURFACE DRAINAGES
(acre-feet per year)

Drainage Area	1983	1987	%*	2017	%*	2118	%*
Pony Creek	71	71	0	71	0	71.5	+0
Cow Creek	121	116	-3	121	+0.2	122.9	+1.
South Fork Cow Creek	10	10	0	10	0	10.7	+2.
Unnamed Coulee	31	31	0	31	0	31.6	+1.
Hay Coulee	38	38	0.1	39	+2.1	41.1	+7.
Coal Bank Coulee	12	12	0.8	16	+29.1	21.2	+66.
Miller Coulee	83	83	+0.3	40	+4.7	43.7	+14.
Lee Coulee	63	63	+0.2	65	+3.3	68.4	+8.
Richard Coulee	88	88	0	88	-0.3	87.3	-1.
Rosebud Creek	278	278	0	278	0	270.8	-2.
East Fork Armells Creek**	141	138	-1.8	131	-7.8	146.0	+3.
Stocker Creek	181	180	-0.7	169	-7.0	169.0	-7.
East Fork Armells Creek/ Stocker Creek Drainage	322	319	-2.5	300	-14.8	315.0	-4.
Rosebud Drainage	753	749	-0.5	761	+1.1	769.2	+2

* Figures on this table were corrected from what they appeared in DEIS and Errata sheet. Refer to letter Nos. 17,Responses to Comments at end of text.

** % change from 1983 discharge amount

Exhibit 3

The discharge to these two drainages is controlled by mining at the Big Sky Mine. There are no studies completed for either coulee so it is not clear whether there is a real increase in groundwater discharge or whether the discharge is returning to pre-mining levels.

The changes in discharge are fairly small. In areas where discharge increases, water levels would increase. Because of these small changes it is anticipated that downgradient water levels would rise only slightly. This slight rise would be insignificant because of increased evapotranspiration. Decreases in discharge along Stocker and Rosebud Creeks and Richard Coulee would have the opposite effect.

2) Groundwater Quality

a) Valley Fill

Mining in the Rosebud Mine area would, over time, lower the water quality of valley fill material adjacent to spoils materials (refer to Figure II-15). However, in the first five years water quality in valley fill aquifers is not expected to change as a result of mining Area C, Block I. Waters discharging from existing spoils aquifers would continue to recharge the adjacent valley fill of East Fork Armells Creek and Stocker Creek. The TDS concentration in the valley fill of East Fork Armells Creek presently ranges from 1,600 to 2,300 mg/l. Recharge from the spoils would increase the TDS concentration in the valley fill material to approximately 2,500 to 3,500 mg/l, as is presently seen in the valley fill adjacent to the spoils in Areas A and B. These increases are due to existing mine activity and activity occurring over the first five years of the permit period.

There would be very little impact from spoils water discharge to Stocker Creek valley fill because the existing TDS values for Stocker Creek valley fill groundwater are equivalent to predicted spoils water TDS values. TDS values farther downstream in the valley fill of Stocker Creek presently range from 1,600 to 1,800 mg/l due to dilution by bedrock groundwater inflow from the west. Since this dilution effect should continue, the overall valley fill water quality should not change as a consequence of mining in Area C during and beyond the five year period.

Current valley fill in the study area TDS ranges from 1340 - 6000 mg/l with a mean of 2590 mg/l. Currently the water is being used for livestock watering, subirrigated hay fields and by WECO to water roads for the control of fugitive dust. Since water in excess of 4300 mg/l TDS is currently being used for these purposes in Cow and Pony Creeks, it is believed an increase of groundwater valley fill water quality from 2500 to 3500 mg/l will have little or no effect on future land uses. Those increases are caused and would be caused only by on-going mining during the first five years of the permit period.

*Indicates the first appearance of a term defined in the Hydrology Glossary.

b) Rosebud Overburden

In order to estimate the quality of Rosebud spoils water, a relationship was established between electrical conductivity* of extracts from the Rosebud overburden and actual TDS values for spoils groundwater located in mine Areas A, B, and E.

TDS values were calculated for 26 bore hole extract composite electrical conductivity (EC) values in Area C. TDS values obtained ranged from 1,600 to 8,800 mg/l. The highest TDS values occurred where the ratio of shale and clay to sand in Rosebud overburden material is highest. The average calculated TDS values for spoils water in Sections 1, 2, and 3 (from east to west) in Area C, Block I are 2,400, 2,500, and 5,200 mg/l, respectively, and compare favorably to measured TDS values from spoils wells in Areas A, B, and E, which range from 1,700 to 5,000 mg/l.

c) Rosebud Coal

This water-bearing unit would be essentially removed in Area C, Block I, except for the areas underlying the sandstone ridge. This pocket of coal would be isolated from the original recharge areas, and would receive recharge from the surrounding spoils in the future. With time, the better quality water in this pocket of Rosebud coal would be replaced by spoils water and would eventually become indistinguishable from spoils water.

d) Rosebud/McKay Interburden

The spoils aquifer in Area C would be in direct contact with the interburden and mixing may take place in localized areas because of potentiometric head differences. Areas of increased TDS in the interburden caused by spoils water would disperse through the unit with time.

e) Deeper Aquifers

Because of differences in potentiometric head, sub-McKay aquifers should not be impacted by mining in Area C.

3) Water Use

a) Water Quantity

Mining within the hydrologic study area has the potential for impacting present and future users of the groundwater resource. Mining would actually remove most existing wells and springs and would have drawdown effects on several others in the Rosebud Mine area. The dewatering effects of mining can cause a drawdown of the potentiometric surface. Wells would still penetrate the water-bearing unit, but the dewatering results in a greater depth to water.

Table III-4 lists the affected wells and springs that lie within the hydraulic area of influence, as calculated the computer model. The

TABLE III-4

WELLS AND SPRINGS AFFECTED BY MINING
(LIFE OF MINE)
ROSEBUD AND BIG SKY MINES
ROSEBUD COUNTY, MONTANA

Area	Well or Spring Designation	Distance from Pit[4] (in feet)	Maximum Estimated Drawdown (in feet)
A	PW-25[1]	0-2000	8-13
	W.R. #42KJ-W-039569-00[2]	0-200	12-17
	(none)	2000-4000	
	(none)	4000-6000	
B	PW-4111	0-2000	28-33
	W.R. #42KJ-W-039568-00[2]	0-2000	28-33
	W.R. #42KJ-W-039570-00[2]	0-2000	28-33
	PW-40[1]	2000-4000	20-25
	PW-42[3]	2000-4000	10-15
	W.R. #42KJ-C-015835-00[3]	2000-4000	24-29
	PW-39[1]	4000-6000	9-14
	W.R. #42KJ-C-000589-00[3]	4000-6000	3-8
	W.R. #42KJ-C-000872-00[3]	4000-6000	10-15
	SP-06[3]	4000-6000	5-10
C	PW-03[1]	0-2000	20-25
	PW-04[1]	0-2000	5-10
	PW-31[1]	0-2000	20-25
	SP-02[1]	0-2000	15-20
	SP-19[1]	0-2000	25-30
	SP-20[3]	0-2000	25-30
	PW-32[2]	2000-4000	0-5
	SP-01[1]	2000-4000	5-10
	PW-19[3]	4000-6000	0-5
D	(none)	0-2000	
	(none)	2000-4000	
	W.R. #42A-W-034885-00[3]	4000-6000	0-5
	W.R. #42A-C-000871-00[3]	4000-6000	0-5
	SP-16[3]	4000-6000	0-5
E	(none)	0-2000	--
	(none)	2000-4000	--
	SP-13[3]	4000-6000	7-12

Exhibit 3

TABLE III-4 (Continued)

Area	Well or Spring Designation	Distance from Pit (in feet)	Maximum Estimated Drawdown (in feet)
Big Sky Mine	(none)	0-2000	--
	PW-45[3]	2000-4000	0-5
	W.R. #42A-C-005968-00[3]	2000-4000	0-5
	W.R. #42A-C-005969-00[3]	2000-4000	2-7
	W.R. #42A-C-008398-00[3]	2000-4000	0-5
	W.R. #42A-W-027336-00[3]	4000-6000	0-5

[1]Will be mined out prior to 1987 and replaced

[2]Will be mined out post-1987 and replaced

[3]Indicates a well or spring that will not be removed by mining

[4]Three radii (2,000, 4,000, and 6,000 feet) were drawn from a point within each pit that would be mined for the year of the greatest effect due to mining (greatest drawdown)

(Refer to Plate B-2 in Technical Support Document for locations of wells and springs.)

Private wells without water rights designations are numbered as PW; those wells with water rights designations are WR, and developed springs are designated as SP.

table also shows the maximum possible drawdown throughout the life of the mine for affected wells and springs. It should be noted that the existence of some of these wells and springs is suspect.

Most of the wells and springs would eventually be mined and replaced. Each water well and developed spring lost directly because of mining would be replaced by a well completed in the sub-McKay aquifer.

The results of computer modeling show that twelve water wells and four springs (Table III-4) would not be destroyed by mining, but would experience declines in water levels. Although it is difficult to tell the exact influence this water level decline will have on spring flow without a site-specific study, it is possible that the effect of drawdown would be either to diminish flow or dry up these springs.

In the case of the twelve wells, the increased depth to the water level would not dry up the wells, but pumping costs would increase as a result of the pump having to lift water from a greater depth. The following summarizes, in a general way, the magnitude of pumping cost increases that may occur in the situation where a well has an original static water level of 150 feet, where the wire-to-water efficiency is maintained at 0.5 and desired discharge is fixed (Anderson, 1979).

Decline in Water Level (in feet)	Kilowatt Hours per 1,000 gallons	Electrical Pumping Costs (in cents per 1,000 gallons)
0	0.942	7.0654
10	1.005	7.54
20	1.07	8.03
30	1.13	8.48

If a value for electrical power of 7.5 cents/kwh is assumed (personal communication, Intermountain Rural Electrical Association), it can be seen that an increase in pumping costs of about 1.5 cents per 1,000 gallons would occur if water levels were drawn down by 30 feet.

For the average water user the change would not be significant because the difference in cost per month would be a matter of a few pennies.

If a spring is disturbed or affected by mining and if a future water supply is required to sustain the existing or future land uses, the company would be required to install a well and maintenance costs would be borne by the land owner. The estimated cost to complete a well, assuming that electricity is available at the site, and that the groundwater quality would not require treatment, is approximately $4300 to $4550.

WELL CONSTRUCTION AND COMPLETION COSTS

Well Construction	
Drilling[1] $75 - $90 an hour 10 hours	$750 - $900.00
Pipe[2] 6" - PCV - Schedule 80 150' @ $5.00 a foot	750.00
Gravel Pack/Mud/Cement/Stabilizers	250.00
Screen - PCV - 6" Schedule 80 Slotted 20' @ $7.50 a foot	150.00
Subtotal	$1900 - $2150.00

[1] Assumes mobilization will require one hour transportation

Well Completion	
Pump - 4" Sumbersible 1/2 hp 230 volt - single phase 5 gpm pumping rate	$450.00
Water Supply Control Switches	100.00
Electical Wiring - 400' @ $0.75 a foot	300.00
Pipe - PCV Schedule 80 150' @ $1.00 a foot	150.00
Surface Pipe - 100' @ $4.00 a foot	100.00
Adapter, Miscellaneous Material	200.00
Subtotal	$1300.00
Surface Pipe and Storage Installation	
Backhoe - 10 hrs @ $50.00 an hour	500.00
Storage Tank	600.00
Subtotal	$1100.00
TOTAL	$4300-4550

b) Water Quality

(1) Valley Fill

During the first five years of the permit period no changes in valley fill water quality or water use would be experienced due to mining in Area C, Block I. On-going mining activity will result in an increase in TDS concentrations in valley fill water adjacent to mined areas, and would lower water quality in valley fill material in East Fork Armells Creek and Stocker Creek making it slightly less suitable for stock watering than at present. However, the water would still be within the limits of the water quality standards presented in Chapter II.

Exhibit 3

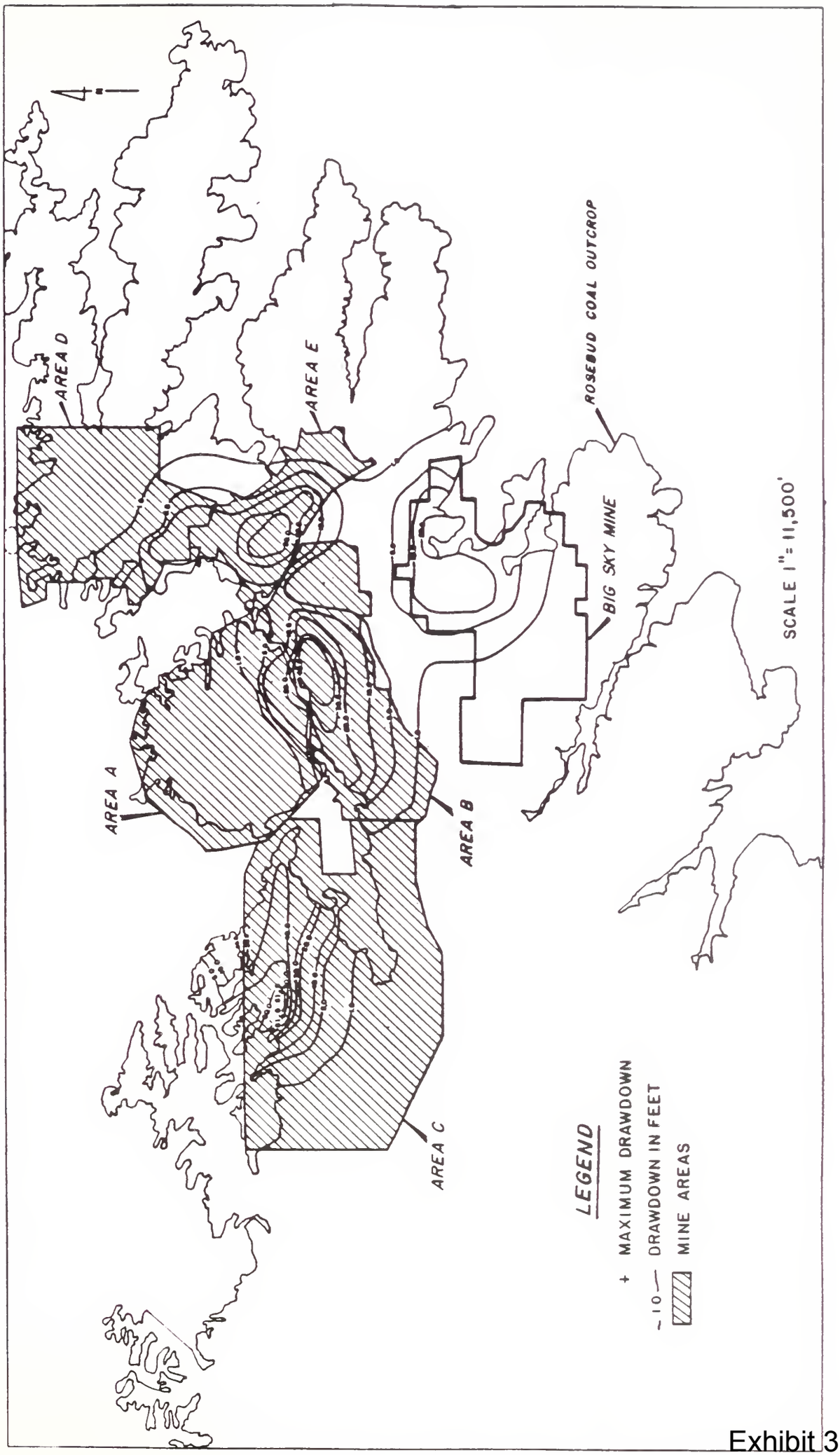


FIGURE III-1 PREDICTED DRAWDOWN, ROSEBUD COAL AQUIFER YEAR 1988, ROSEBUD MINE AREA, MONTANA

Exhibit 3

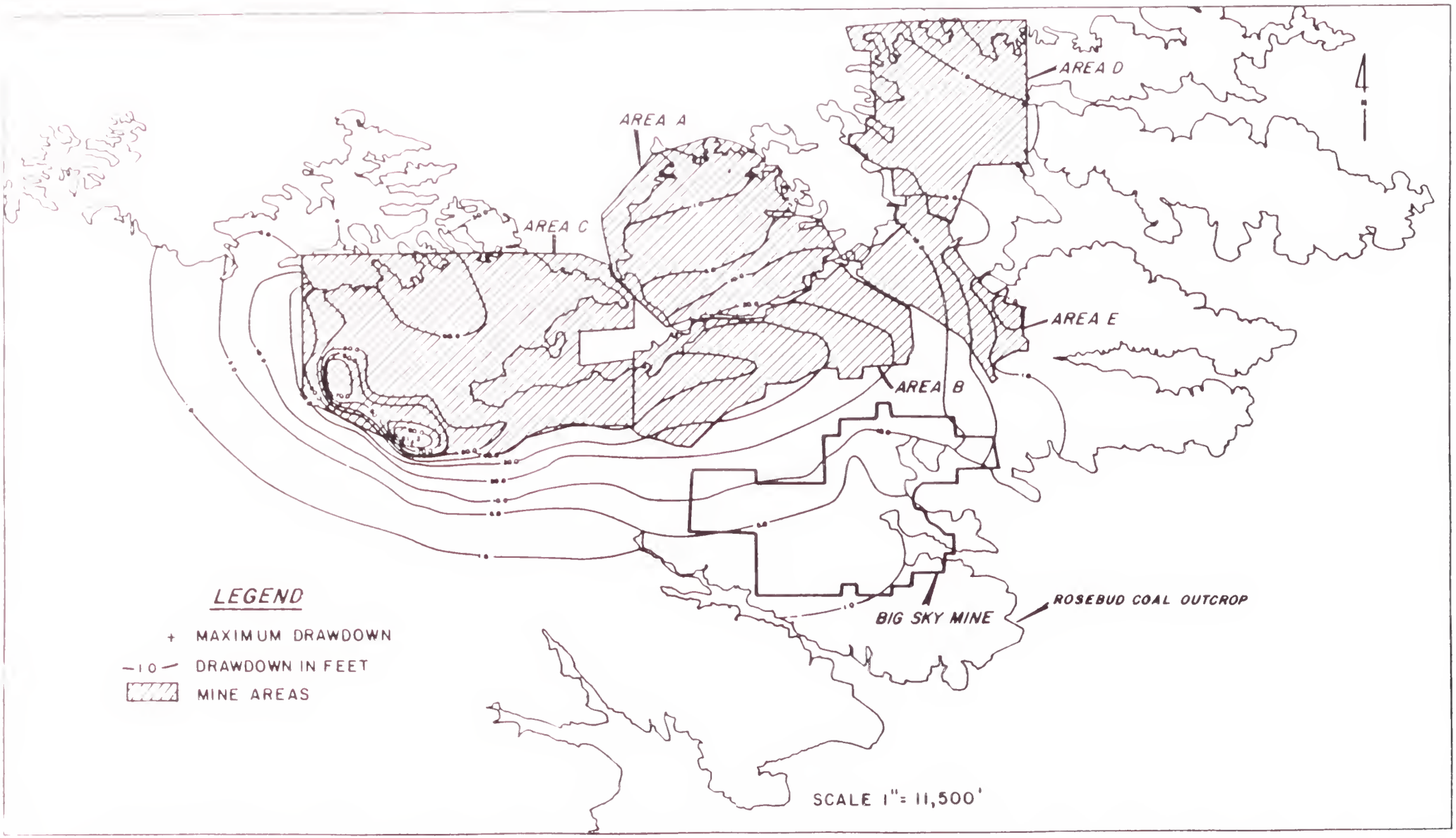


FIGURE III-2 PREDICTED DRAWDOWN, ROSEBUD COAL AQUIFER YEAR 2018, ROSEBUD MINE AREA, MONTANA

Exhibit 3

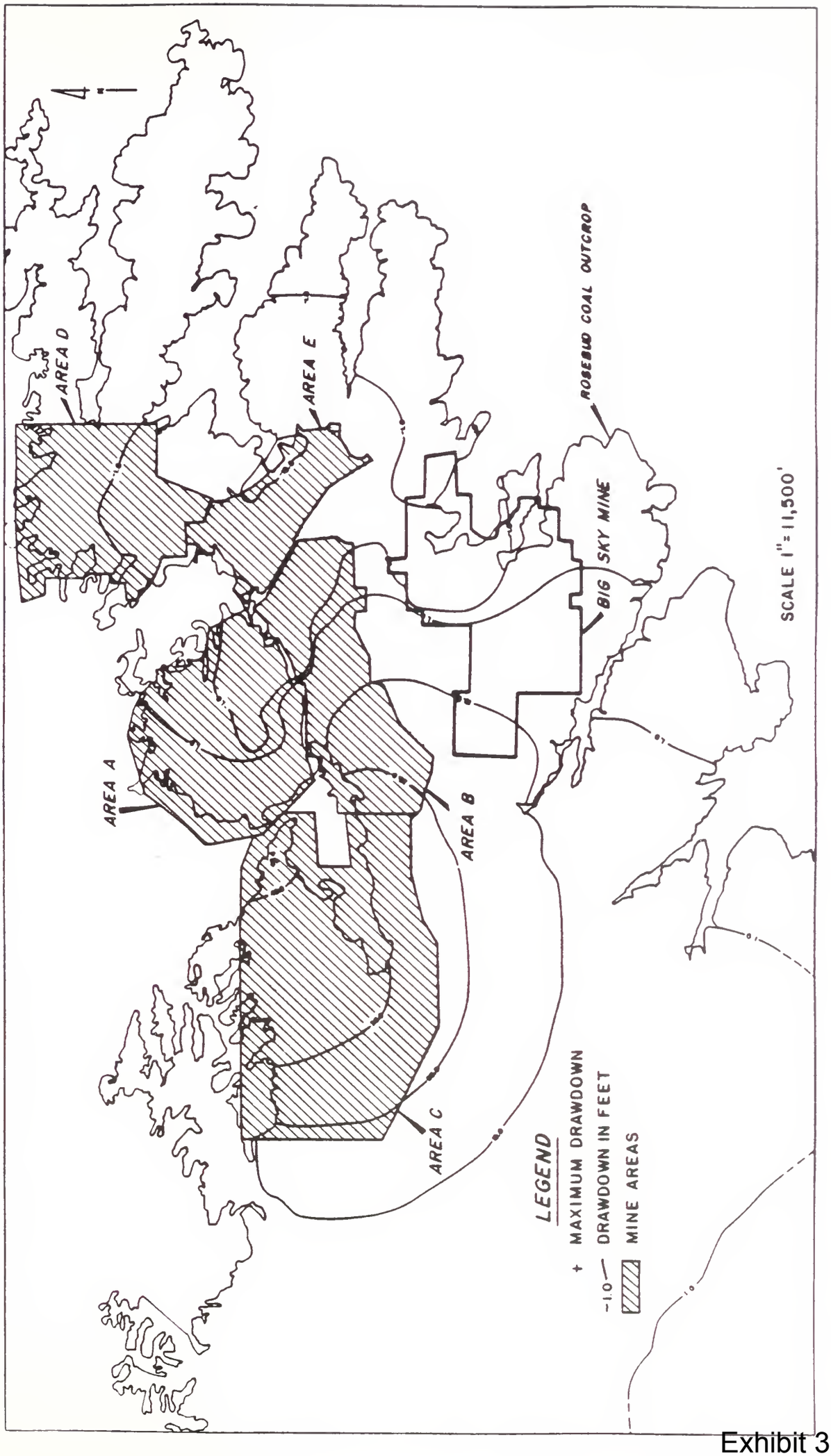


FIGURE III-3 PREDICTED DRAWDOWN, ROSEBUD COAL AQUIFER YEAR 2118, ROSEBUD MINE AREA, MONTANA

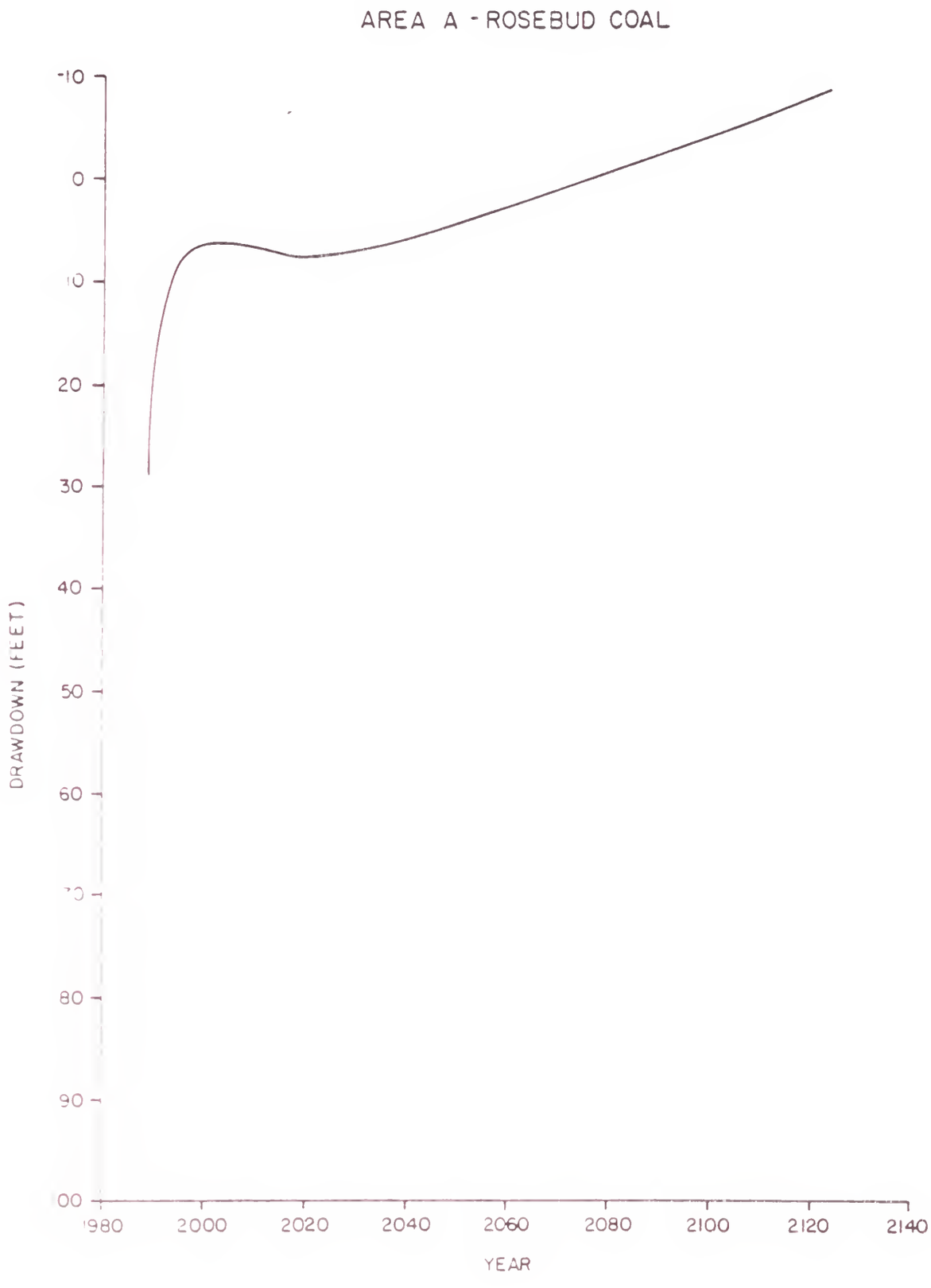


FIGURE III - 4 TIME - DRAWDOWN PLOT, AREA A

Exhibit 3

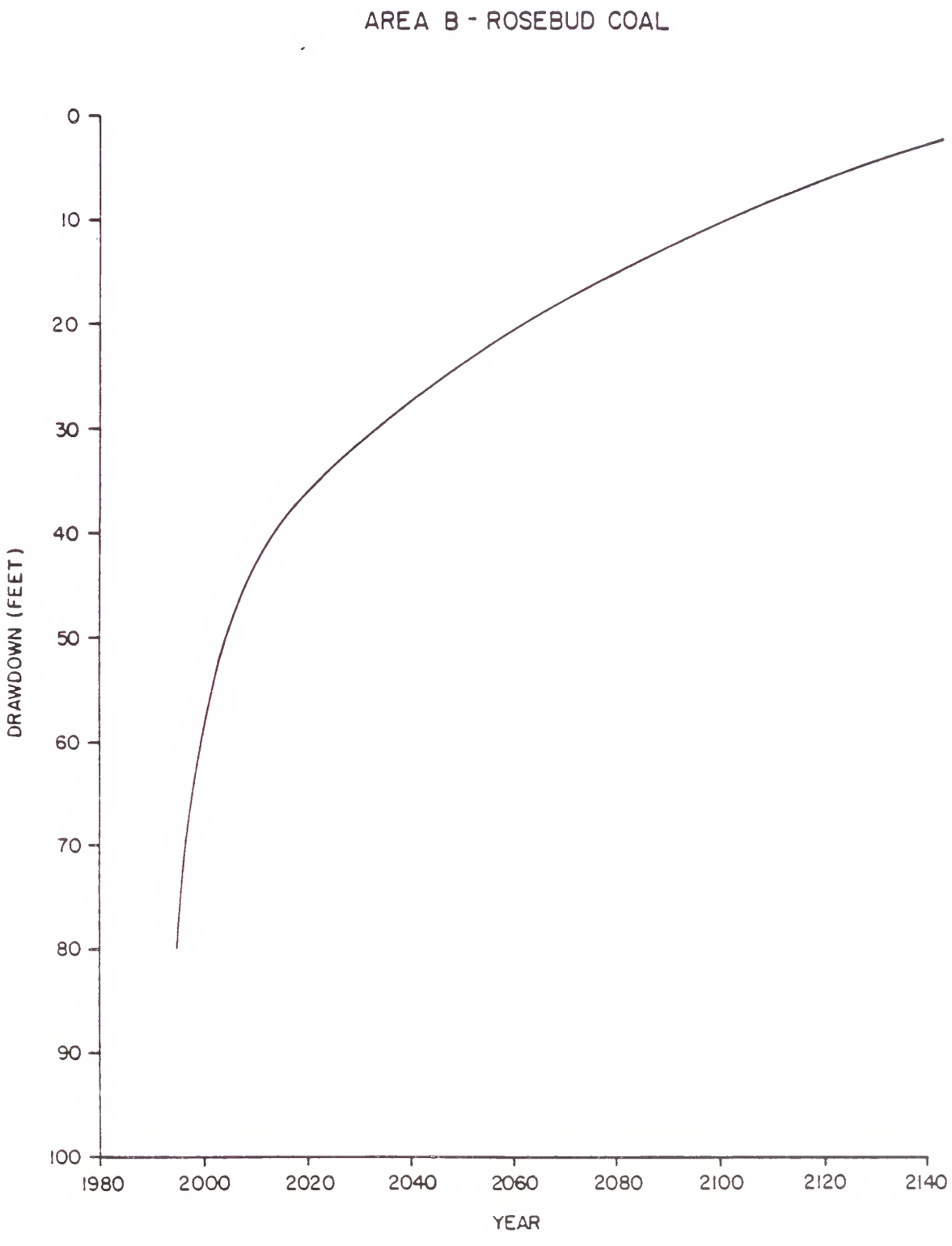


FIGURE III-5 TIME - DRAWDOWN PLOT, AREA B

Exhibit 3

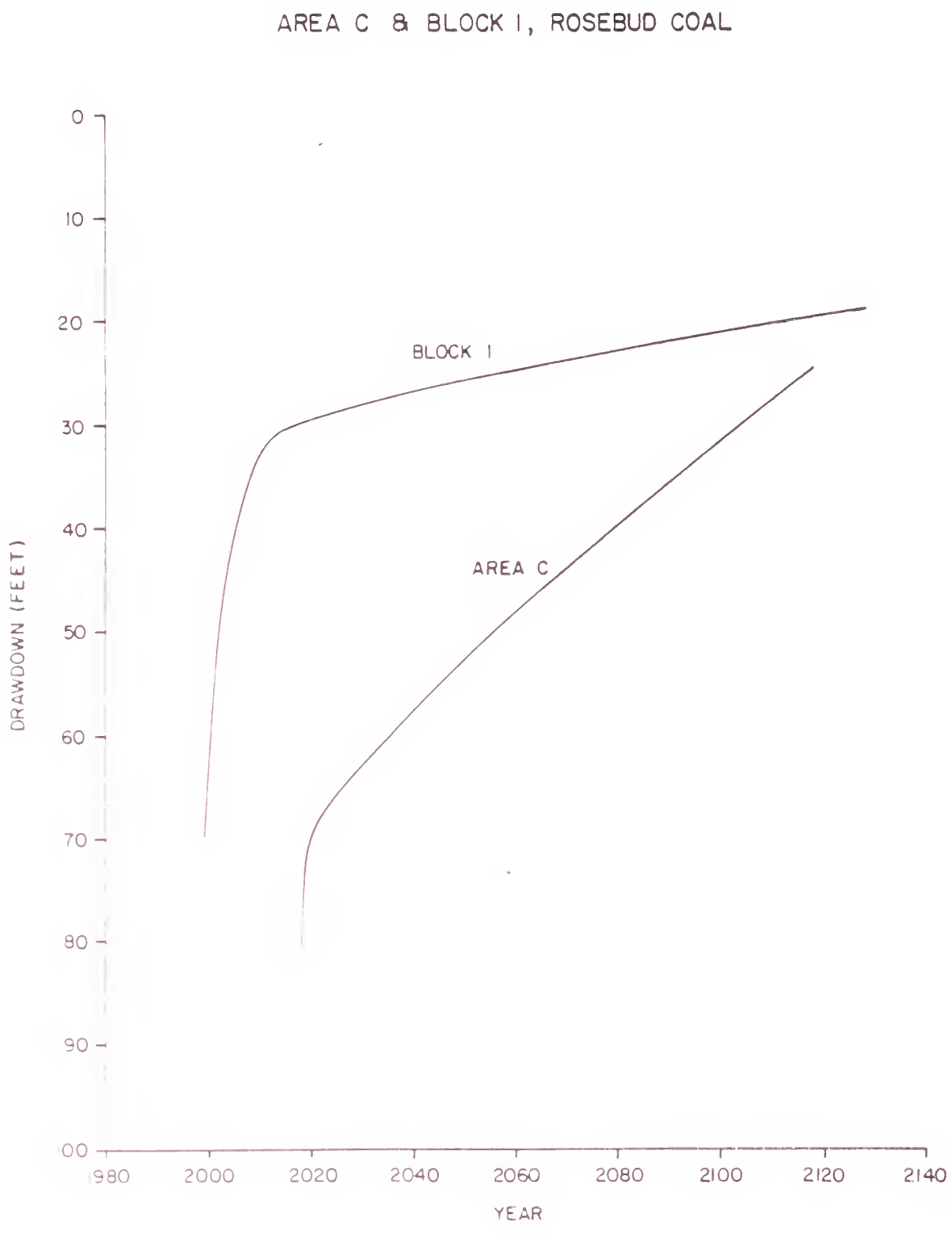


FIGURE III-6 TIME - DRAWDOWN PLOT, AREA C and BLOCK I

Exhibit 3

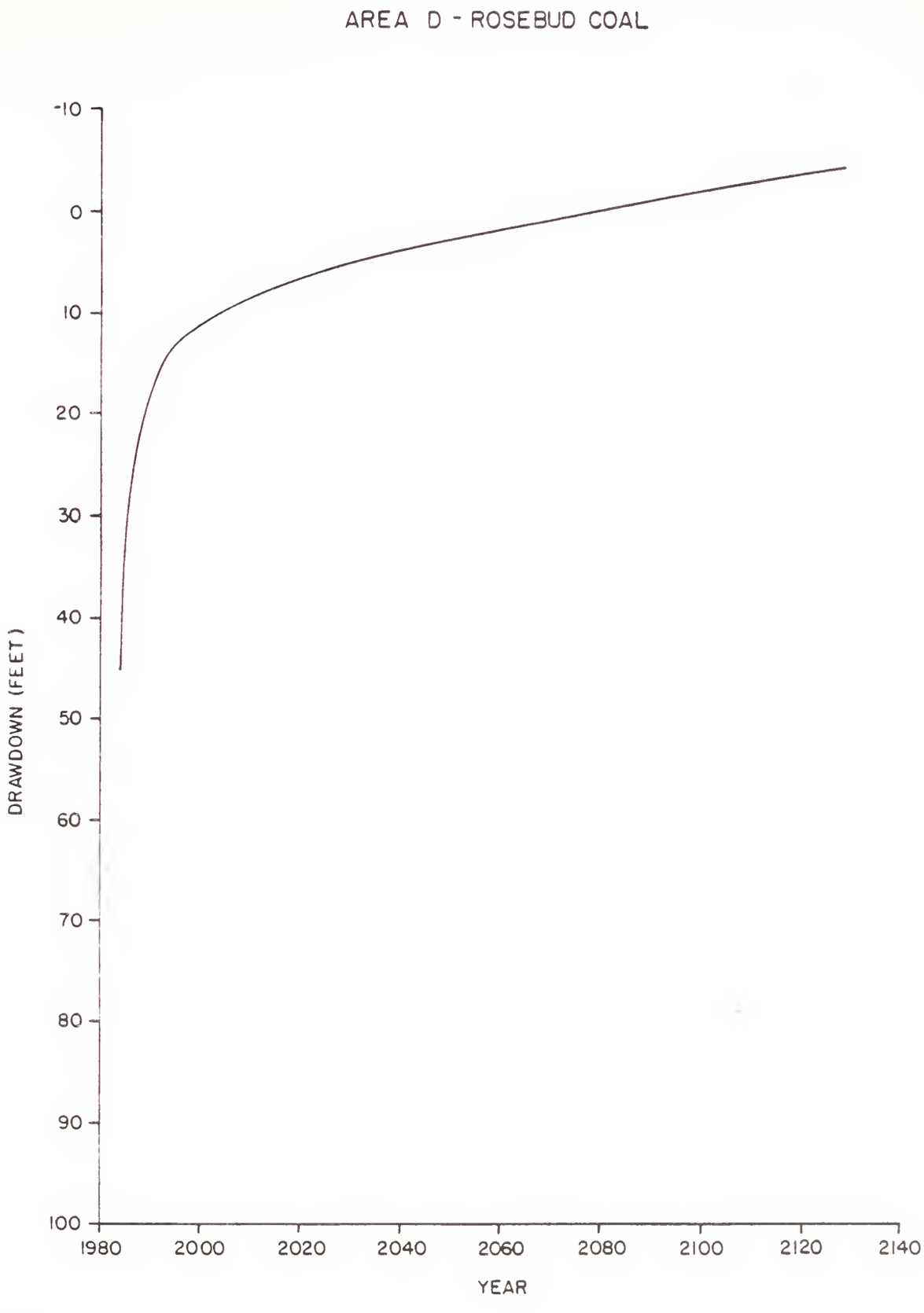


FIGURE III-7 TIME-DRAWDOWN PLOT, AREA D

Exhibit 3

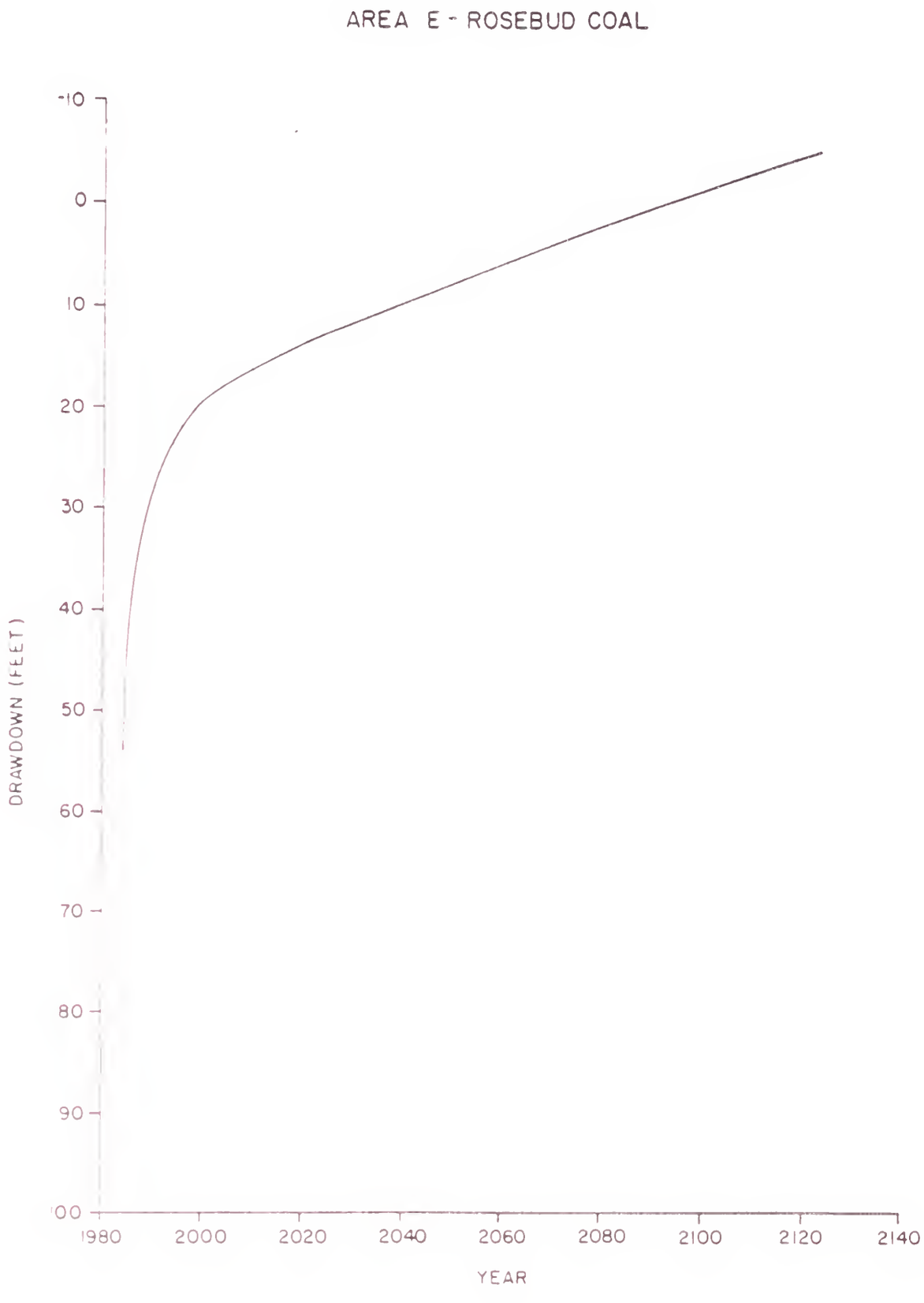


FIGURE III -8 TIME -DRAWDOWN PLOT, AREA E

Exhibit 3

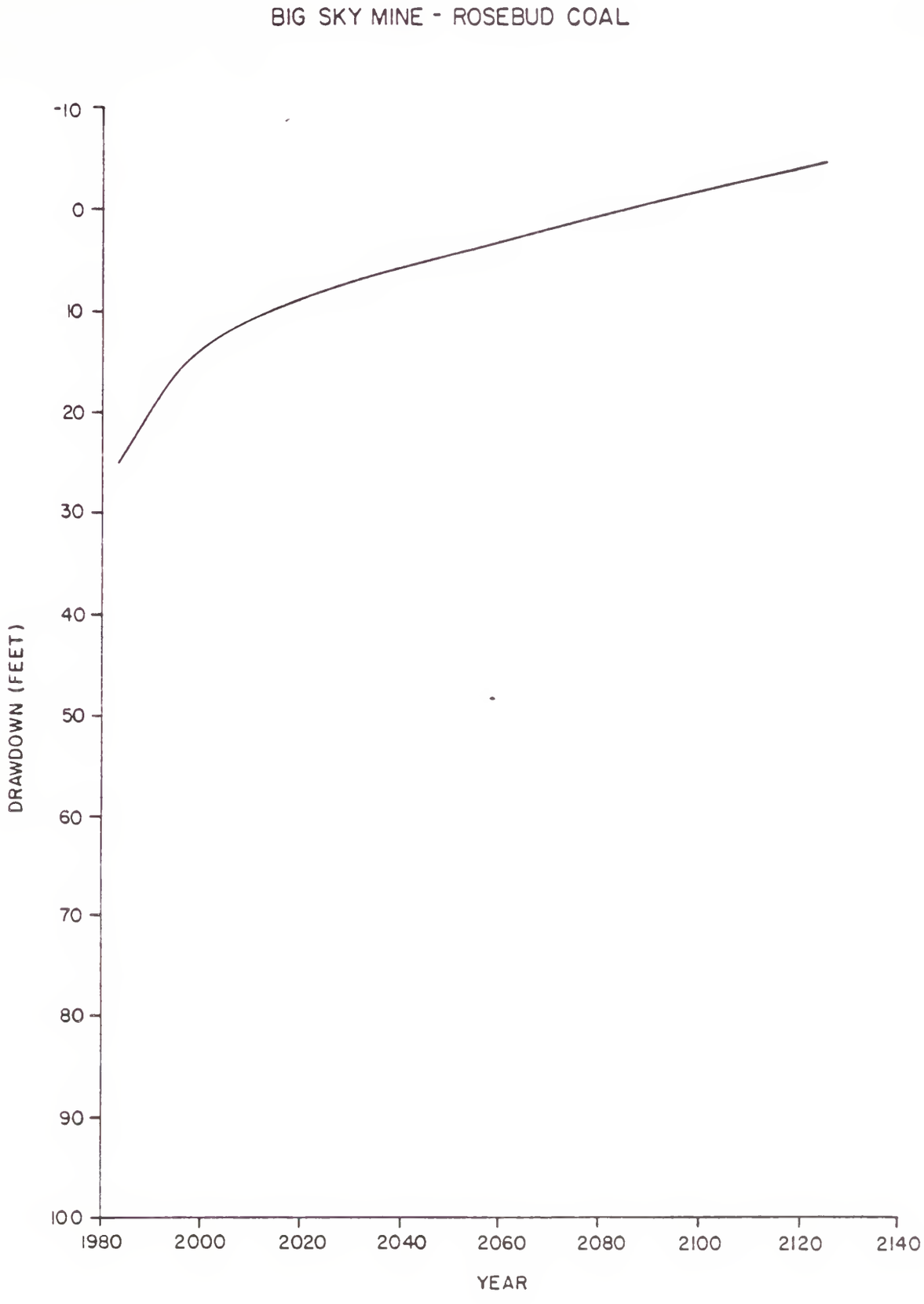


FIGURE III-9 TIME-DRAWDOWN PLOT, BIG SKY MINE

Exhibit 3

(2) Rosebud Overburden and Rosebud Coal

These aquifers will no longer be available for use in mined portions of Area C, having been replaced by Rosebud spoils. The TDS concentrations predicted for the spoils aquifer will be about one and one half the concentration in the existing Rosebud overburden. However, concentrations should still be within limits for stockwater use and would be suitable for livestock watering.

(3) Other Aquifers

None of these lower aquifers would be impacted sufficiently to affect their present or future uses.

b. Impacts in the Rosebud Mine Area through the Life of Mine and 100-Years Beyond

This section addresses the influences that existing and proposed mining activities would have on the regional groundwater system in the Rosebud Mine area. As in the previous section addressing the impacts in the first five years of mining, the impacts on the groundwater system during the life of the mine and 100 years after mining are addressed. The anticipated cumulative impacts have been predicted by analysis of the results obtained from the application of the two groundwater models to the regional hydrologic system over the long-term.

It has to be determined: 1) whether anticipated mining would deplete or contaminate aquifers to the extent present or future users would be adversely impacted; or 2) if groundwater discharge to surface waters would be depleted or contaminated and the extent to which potential surface water use will be affected.

1) Groundwater Flow

a) Impacts to mine area potentiometric levels

The data obtained from the application of the three-dimensional model provides predictive information for groundwater flow in the Rosebud mine area. The data generated by the model has been displayed as groundwater drawdown maps of the Rosebud Coal in Figures III-1, III-2, and III-3, for the years 1988, 2017, and 2118. 1988 is the last year of the Area C, Block I permit period. 2017 is the last year of mining and 2118 is one hundred years after the last mine pit has been spoiled. Drawdown is measured from 1983 potentiometric surface values.

From these maps, the amount of drawdown at various distances from the mine pits has been determined. Table III-2 is a tabulation of the maximum anticipated drawdown. The amount of drawdown is dependant on numerous factors. These factors include the upgradient or downgradient location of the spoiled pits; the proximity to surface discharge sites and the location of pre-1983 spoiled areas where increased recharge has taken place. Figures III-4 through III-9 are time-drawdown plots for the

Rosebud coal in the various mine areas. They represent drawdown versus time for a central point in the mine area. The values have been taken from the 0 radius column in Table III-2.

The increase in recharge is a result of the previously discussed increase in effective porosity of the spoils material. The potentiometric surface in the area of increased recharge to the spoils have, in some cases, returned to greater than original potentiometric levels. This is illustrated by the negative drawdown values on Figures III-4 and III-9.

b) Recharge/Discharge Relationships

The increased recharge and changes in the direction of groundwater flow in the mine area have and would cause changes in the flow patterns throughout the mine area. Potential impacts to the groundwater recharge/discharge relationship in the long term may involve: 1) the effect that mining and spoiling would have on the recharge to the aquifer, and 2) whether there would be a significant change in discharge to surface water.

After spoils replacement, the recharge to the Rosebud and McKay aquifers will increase. The negative drawdown values shown on Figures 4 and 8 indicate that recharge has been enhanced by mining. Table III-3 provides the discharges to the various surface drainages in the area prior to mining and at 5, 34, and 135 years after mining commences. An inspection of the data indicates that the cumulative discharge to the surface drainages in the mine area would decrease during the life of the mine. However, the amount of this decrease in discharge is not significant throughout the area. Individual drainage discharge variation is at times significant. Specifically, the 14.8 percent reduction in the combined East Fork Armells Creek and Stocker Creek in 2017. This combined reduction in discharge is 4 percent in 2118 and it can be assumed that it would recover to its original amount at some time after 2118. This reduction in groundwater discharge to the East Fork Armells Creek and Stocker Creek drainages would serve to lessen the severity of the downstream water logging problems presently occurring along East Fork Armells Creek.

The overall effect of mining in 2118 would be the 0.8 percent increase in discharge over pre-mining amounts. This is indicative of the increased recharge to the mine spoils throughout the area.

As outlined above, mining activity will not have a major impact on the quantity of flow in the valley fill system. However, the impact of non-mining activities, i.e. municipal and industrial development, would continue to impact the quantity of flow in the system.

The increase in population in Colstrip has resulted in an increase in municipal water use. This has resulted in an increase in the amount of sewage lagoon discharge to East Fork Armells Creek to 210 acre-feet/year (Hydrometrics, 1982). The discharge represents 20 percent of the

total surface flow in East Fork Armells Creek at the gauging station 7.5 miles downstream of Colstrip. This along with the increase in urban runoff and seepage and the increase in precipitation amounts in recent years (Brandt, 1981; Hydrometrics, 1981), results in increased flow in the valley fill system. The result has been an increase in valley fill groundwater levels and higher stream-flows in East Fork Armells Creek downstream of Colstrip. The increased levels and flow contribute to the water logging problems presently being experienced at the Lee Ranch downstream of Colstrip.

2) Groundwater Quality

Based on existing data, it is not likely that total dissolved solids (TDS) in the spoils would exceed a mean concentration of 3500 mg/l. The major cations and anions within spoil water are expected to be calcium, magnesium, sodium, and sulfate. Areas most likely to encounter significant groundwater quality changes are areas in which clay rich overburden materials occur within restored aquifers.

An estimate can be made of the time required for spoil water to recover to pre-mine conditions. This type of estimate involves a number of assumptions and involves the use of experimental data. Notably column leaching studies done by Van Voast et al., 1978, have been used, in which Rosebud spoils were leached with distilled water and the electrical conductivity of leachate was monitored over time, as an indication of changing water quality (lower E.C. is indicative of lower total dissolved solids).

In order to view this situation in light of the worst circumstances affecting spoils water quality the leaching studies results were used in conjunction with recharge rates to project the time for recovery of spoils water. Specifically the average recharge rates were used to calculate the total length of time necessary in order for a certain number of pore volumes to pass through the replaced spoil as unsaturated flow. Most investigations have used column leaching studies in conjunction with the resaturation of spoils and consequent through flow as groundwater levels recover. Such projections do not model the worst case since recovery and groundwater through flow occur more quickly than recharge. However recharge quantities can in no way be discounted as insignificant. For example, on an annual basis, at a recharge rate of 0.12 inches per year, recharge on just an acre of land amounts to 3,258 gallons.

Some of the assumptions and data used are as follows:

1. Greatest decline in EC takes place in the first 3.4 pore volumes, where the electrical conductively drops from an initial value of 11,000 to 4,000 micromhos per centimeter. Specific conductance continues to decline with leaching to a value of 1,500 micromhos per centimeter at 17 pore volumes (this represents better water quality than pre-mining conditions).

2. It is assumed that flow of groundwater into and through spoils will occur more quickly than unsaturated flow from recharge and hence the unsaturated flow component from recharge will be the limiting factor in terms of leaching and hence spoil water quality improvement.

3. It is assumed that a reasonable average for spoil thickness is 80 feet. Actual post-mining spoil thicknesses will vary betwen 0-150 feet.

4. It is assumed that spoils have an average porosity of 30%.

5. Model calibration has indicated that at equilibrium the undisturbed overburden has a recharge rate of 2.5×10^{-5} ft/day. For purposes of modeling it was assumed that spoils recharge would be 10% higher or 2.75×10^{-5} = 0.12 inches/year

Based on the data and assumptions it can be calculated that the 3.4 pore volumes will pass through the spoil in 8160 years, while it will take 40,800 years for 17 pore volumes to pass. It must be noted that existing field data shows that undisturbed overburden has mean groundwater E.C. values of 1563 mmhos/cm, undisturbed Rosebud groundwater mean values for E.C. of 1741 mmhos/cm and relatively fresh Rosebud spoil water has a mean E.C. value of 3,450 mmhos/cm. The reader is cautioned that the results of column leaching studies may be used to predict general trends but the actual E.C. values obtained from leaching tests are not indicative of anticipated water quality in Rosebud spoils.

The variability of groundwater discharge to surface water drainages will also have changing effects on the quantity of water available from the groundwater system in the Rosebud Mine area. This will be a result of increases or decreases in discharge to the valley fill system or the potential reduction in spring flows as discussed previously.

3) Water Use

The variability of the potentiometric surface in the Rosebud mine area over time will cause variations in the ability to recover water from the Rosebud coal.

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3) Water Use

The variability of the potentiometric surface in the Rosebud mine area over time will cause variations in the ability to recover water from the Rosebud coal.

2. Surface Water

A surface runoff model, HYMO (Hydrologic Model) was combined with a grid model of East Fork Armells Creek and Stocker Creek to describe the pre- and post-mine surface water flow regimes. The HYMO model was designed for forecasting floods, planning flood prevention projects, and general hydrologic research.

Another model, the grid model, was used to determine input parameters for the HYMO model as well as to forecast pre- and post-mine erosion magnitudes and to compare pre- and post-mine topographies (see Technical Support Document, Section B.3 for details). For the flood routing procedure of the HYMO model, East Fork Armells Creek and Stocker Creek were divided into subbasins (Figure III-10). These subbasins range from 0.14 square miles (mi^2) to 9.63 mi^2 (Table III-5), and have average slopes ranging from 0.038 feet per foot (ft/ft) to 0.109 ft/ft. Stream channels in these subbasins have slopes ranging from 0.003 ft/ft to 0.025 ft/ft. The grid model was used to compute slopes, hydrologic SCS curve numbers, and general soil losses from each subbasin (see Technical Support Document, Section B.3), and for computation of input parameters used in the HYMO model. The results of the grid and HYMO modeling used to predict impacts are presented in the following sections.

a. Impacts Through Five-Year Permit Period

1) Reclaimed Drainage Basin Characteristics

In area C reclamation will not have progressed very far during the first five years. In other areas mining will be on-going and therefore reclamation will be in progress throughout this period. Few cumulative impacts are anticipated. Over the short term some incipient gullying may take place in newly reclaimed areas. It is anticipated, however, that the mining company will re-grade those areas which begin to erode due to high intensity storms.

Generally the characteristics which a drainage basin may adopt will not be much different from premining conditions, but would take decades to become established.

2) Stream Channel Characteristics

Within the five year period it is not expected that stream channels will experience significant changes. Probably the most significant changes may occur below sediment retention ponds where clear, discharging water which will be released after large storm events will have a higher erosive potential. This may create some channel incision below retention ponds and slight deposition immediately above ponds. As ponds are removed (in other areas during the first five years) then slight aberrations in grade may cause the channel to undergo selective erosion and deposition in order to reestablish grade.

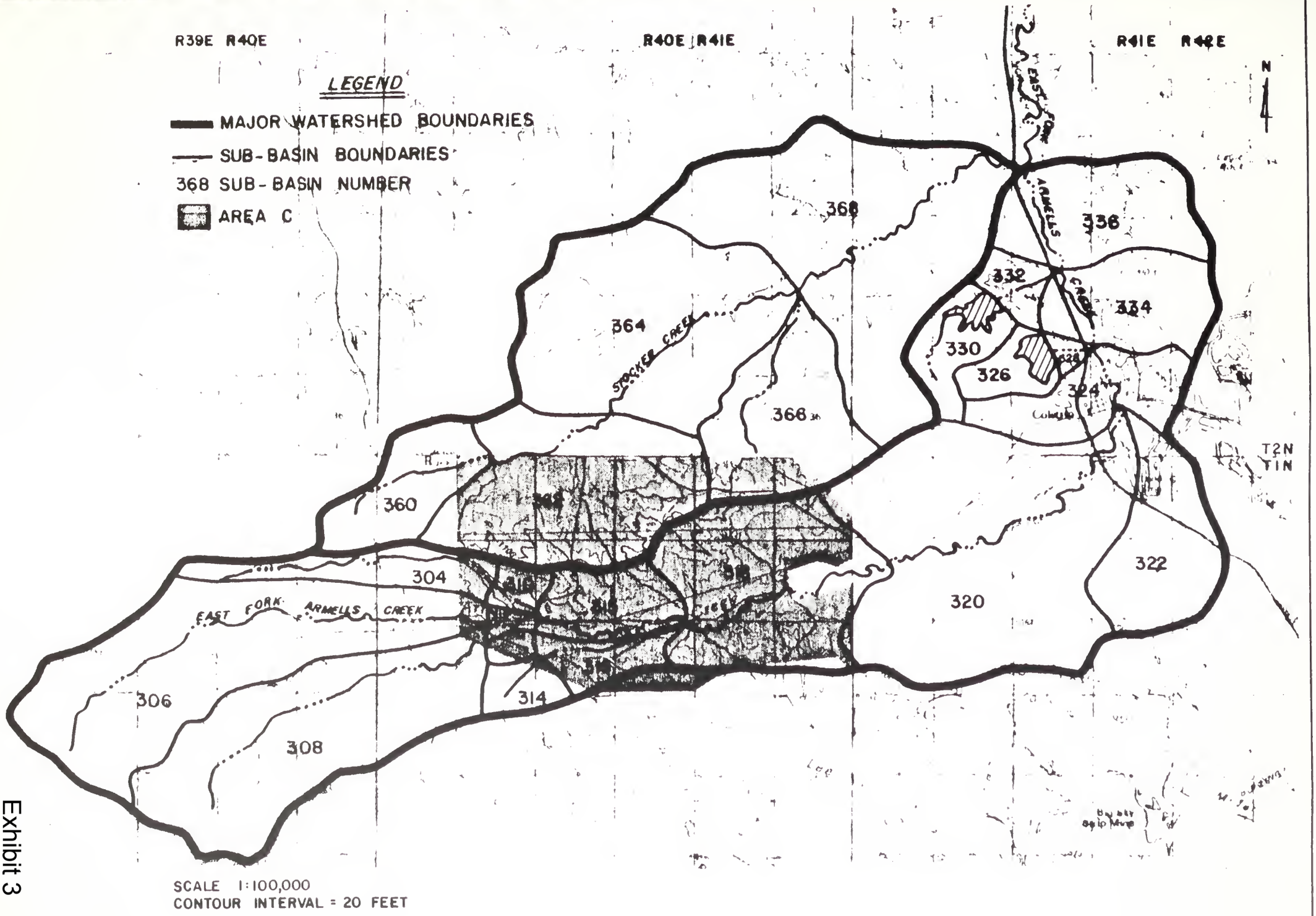


FIGURE III-10 HYDROLOGIC SUB-BASIN MAP, EAST FORK ARMELLS CREEK AND STOCKER CREEK, ROSEBUD MINE, MONTANA

Exhibit 3

TABLE III-5
SUBBASIN PARAMETERS, STOCKER CREEK
AND EAST FORK ARMELLS CREEK

Sub-basin Number	Area (Mi^2)	Pre-Mine Basin Slope (ft/ft)	Post-Mine Basin Slope (ft/ft)	Reach Length (mi)	Average Reach Slope (ft/ft)	Average Length Overland Flow (ft)	Pre-Mine Hydrologic Curve No.	Post-Mine Hydrologic Curve No.
EAST FORK ARMELLS CREEK								
304	1.43	0.048	0.050	4.14	0.023	347	79	76
306	7.84	0.109	0.109	8.42	0.022	425	71	71
308	6.43	0.100	0.100	5.98	0.025	381	73	73
310	0.38	0.066	0.070	0.59	0.010	347	79	61
312	0.14	0.043	0.045	0.87	0.008	425	75	61
314	0.74	0.038	0.040	1.04	0.024	356	75	74
315	1.58	0.042	0.046	3.28	0.004	430	76	61
316	1.18	0.047	0.050	2.20	0.008	473	73	62
318	5.20	0.045	0.043	4.93	0.004	637	69	63
320	9.63	0.049	0.047	6.47	0.004	764	73	69
322	2.92	0.054	0.053	3.09	0.018	731	73	69
324	2.07	0.048	0.048	1.34	0.004	461	74	71
326	0.86	0.052	0.054	1.04	0.020	312	72	67
328	0.14	0.044	0.044	0.47	0.016	272	69	69
330	1.06	0.049	0.055	1.93	0.022	259	76	67
332	0.73	0.057	0.057	1.10	0.014	398	74	74
334	2.33	0.064	0.061	1.70	0.004	408	71	66
336	3.06	0.058	0.058	2.27	0.003	293	77	74
Total	47.72	0.067	0.066	29.28	0.009	429	73	69
STOCKER CREEK								
360	1.99	0.049	0.050	2.62	0.016	601	69	68
362	5.10	0.046	0.048	1.98	0.008	566	72	64
364	6.80	0.059	0.059	3.84	0.006	439	76	76
366	3.63	0.058	0.058	2.51	0.013	421	71	68
368	8.59	0.054	0.054	5.48	0.004	375	76	74
Total	26.11	0.054	0.054	13.92	0.007	480	74	71
Combined	73.83	0.062	0.062	---	---	---	73	70

Exhibit 3

3) Basin Sediment Yields and Geomorphic Stability

Before vegetation is reestablished on reclaimed slopes, storm runoffs will induce high erosion and hence high sediment yields. Downstream sediment yield would not increase because the runoff from mined areas would be channeled through sediment retention ponds (water held in the ponds must be released within 15 days of the storm event).

During the life of the mine, the company would construct sediment ponds to control sediment and peak flow runoff from disturbed areas. A preliminary listing of proposed ponds as provided by Hydrometrics (written communication, 1982) is presented in the Technical Support Document. A compilation of information for the proposed sediment ponds by mine area follows.

Mine Area	Run off Volume[1] ac.ft.	Sediment Volume ac.ft.	Total ac.ft.
A	180	88.8	268.8
B	89.1	58.9	148
C Block 1	77.2	51.5	128.7
C	685.6	117.1	802.6
D	145	103.1	248.1

According to Western Energy (personal communication, 1982, Pete Norbeck), 50 percent of the structures will be installed and maintained at any given time, therefore the net storage per mine area is estimated to be approximately 135 acre feet for Area A, 74 acre feet for Area B, 115 acre feet for Area C, Block I, 400 acre feet for Area C and 124 acre feet for Area D.

If the average impoundment size is approximately 10 acre feet with a depth of 15 feet the impoundment surface area will be approximately 0.67 acres (personal communication, 1982, Pete Norbeck). If the water is retained in the structure for a period not to exceed 15 days, as stipulated by DSL, the potential evaporation rate would be approximately 0.16 feet.

Based on these assumptions the net evaporative consumption use from East Fork Armells, Stocker, Pony, and Cow Creek would be 65, 20, 1, and 1 acre feet per 10-year 24 hour storm.

The net impact to the hydrologic regime is a water reduction of less than 4% for East Fork Armells, 2% for Stocker, 0.2% for Pony, and 0.01% for Cow Creek.

Exhibit 3

There is no data available to estimate the seepage from the ponds to the valley fill aquifer system. If seepage does occur, it would attenuate away from the ponds. As the time from the occurrence of the event increases the seepage moving in the groundwater system would approximate the existing slope of the water table.

A simplified worst case assumption indicates that if the specific yield of the valley fill along East Fork Armells Creek is 0.2, the total area of the valley fill is approximately 30,000 acres and the valley fill is approximately 10 feet thick throughout the area there is roughly 60,000 acre-feet of water in the valley fill aquifer. If all of the runoff from the sediment ponds seeped into the East Fork Armells Creek drainage, which is not likely since some ponds are on other drainages and all of the water won't leak, it would represent only a one percent increase in the volume of water in storage in the aquifer. This one percent volume increase will translate into a water level increase which will very probably become subject to evapotranspiration and will be consumptively used.

In summary the seepage from sediment ponds to the valley fill groundwater system is not expected to impact the quantity or the quality of the valley fill aquifers.

Sediment ponds would have the effect of lowering and delaying peak surface flows along the drainages that they are on. The impact of this activity could be considered beneficial since this in effect lessens the effect of flood events.

It is probable that some geomorphologic changes would occur in the first five years. However those changes would all be confined to mined areas. Adverse changes which are possible include piping and differential erosion. A more detailed discussion is included in the TSD geomorphology section.

4) Flow Rate Analysis

Mining itself would have little effect on flow rate except to:

a) attenuate peak flows by impoundment and slow release, and

b) in some instances increase slow releases from retention ponds due to the addition of pit pumpage necessary because of direct precipitation into the pits.

A possibly greater change in flow within the East Fork Armells Creek drainage area may result indirectly from mining. Mining of additional coal is planned in conjunction with construction of additional power generating units in Colstrip. Operation of these units will require that more water be imported from outside the drainage basin to be used for cooling purposes. It is expected that addition of water to the

existing surge pond will result in higher losses to the alluvial system. These losses may magnify downstream drainage problems which already exist.

It is not possible to quantify the downstream flow increase from an expanded power generating facility. However, it is probable that these changes would overshadow direct mine induced changes to surface water flow.

5) Water Use

Stock watering will not be directly influenced at all by changes in surface water flow. Most flow diversion for irrigation takes place during high flows. Although extremely high flows would be trapped in some drainages by retention ponds prior to release for the most part the short term retention would have no influence on irrigation water use from an availability or suitability standpoint. Three ponds would be removed during mining of Area C, Block I (Figure III-11), when the ponds are restored water quality is expected to be the same as it is at the present.

6) Water Quality

Adverse surface water quality changes could only occur if degraded groundwater discharges to surface water, if surface water leaches salts exposed at the surface, or if other factors (such as the power plant expansion) contaminate surface water via groundwater flow.

It is not anticipated that groundwater would have any affects on surface water within the first five years of mining. It is also projected that the only run-off induced quality changes might be increases in sediment loads. However sediment loads would be largely removed in sediment retention ponds.

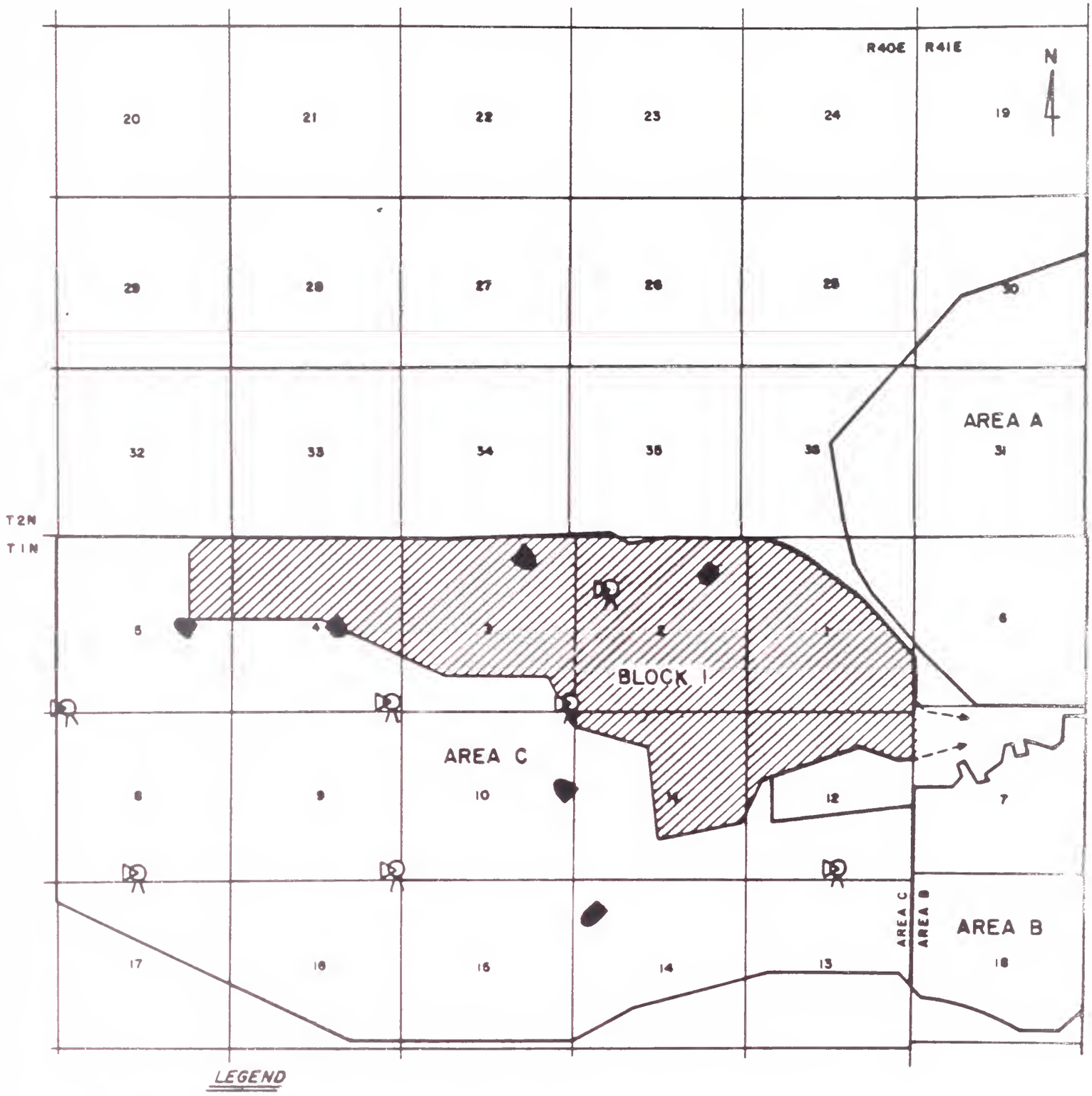
It is anticipated that increases in the wastewater treatment plant discharge and an increase in power plant capacity with attendent increases in cooling water may cause some minor changes in surface water quality. However the specifics of those increases and the dynamics of both engineered and natural improvement in water quality are indeterminate.

b. Impacts through Life of Mine and 100 Years Beyond

1) Reclaimed Drainage Basin Characteristics

The reclaimed drainage basins would approximate those of the pre-mining environment. Evidence from existing, reclaimed basins in the Colstrip area suggests that the reclaimed drainage basin characteristics would be strongly influenced by the engineering techniques and equipment used to reclaim the spoils.

After reclamation, it is likely that the channel network would expand, creating a higher density of short stream segments formed by headward erosion. Such a development would reflect an adjustment of the



LEGEND

AREA C, BLOCK I SCALE: 1"=4550'

WELL EQUIPPED WITH WINDMILL, 1 gpm
(WELLS ASSUMED TO BE DRILLED TO SUB-McKAY LEVELS)

STOCK POND, APPROX. 5 ACRE FEET

SOURCE: WESTERN ENERGY COMPANY (THESE PROPOSED LOCATIONS HAVE NOT BEEN REVIEWED OR APPROVED BY THE MONTANA DEPT OF STATE LANDS.)

FIGURE III-11 PROPOSED POST-MINE STOCK WATER USE, ROSEBUD MINE AREA, MONTANA

Exhibit 3

channel network to the reclaimed hydrologic system, similar to that observed in the currently reclaimed areas. If proper mitigations are performed, this impact would be minimal.

2) Stream Channel Characteristics

As planned by Western Energy, the development of channel profiles that are concave and without knickpoints will decrease the potential for widespread initial instability in the channel. However, both natural and man-induced processes are likely to result in changes to channel geometry, because the reclaimed ephemeral channels in this area will be as inherently unstable as the pre-mine ephemeral channels. The development of gullies can be expected (see Technical Support Document, Section B.4). If left unmitigated, gully development will be a serious impact, but probably no more so than already exists with pre-mine channels. During the bonding period, rills and gullies would be mitigated, but after bond release it would become the surface owners obligation.

Perhaps the most significant man-induced influence on the post-mining channels throughout the study area will be the construction of sediment ponds. Upstream of the ponds, changes in channel geometry may be induced by a new base level imposed on the system. This can result in a pattern of cut and fill similar to that observed in the undisturbed channels.

Downstream of the sediment ponds, further changes may occur in response to the reduction of peak flow magnitudes and the removal of sediment by the ponds. There could be two major consequences: channel incision and aggradation*. The result of these changes will be a reduction of the low-flow channel capacity (see Technical Support Document, Section B.4 for details).

If there is frequent intermittent flow in the channel, incision may occur below the sediment pond dam. This impact is considered insignificant considering the relatively short (10 to 20 years) life of the sediment ponds. However, if the ponds are to become permanent, this impact will become greater, possibly causing a lowering of base level downstream.

The most significant impact of the sediment ponds is likely to occur after reclamation, when the ponds are removed and the undersized, aggraded channels are again subjected to uncontrolled discharges from the basins. The probable effect may be an episode of high erosion and downstream sedimentation accompanying entrenchment of the main channel.

3) Basin Sediment Yields and Geomorphic Stability

On a large scale, the proposed reclaimed landscape appears to be stable, although increased rates of erosion may be associated with problems of subsidence or differential erosion at a highwall interface (see Geology, Section A).

The Universal Soil Loss Equation (see Technical Support Document, Section B.4) was applied to the grid model to predict post-mine erosion rates* in all basins and to compare these rates to pre-mining erosion. Results indicate that in general the post-mine erosion rates would be very close to, or slightly less than, pre-mining conditions. This is mainly due to the elimination of short, steep slopes in reclamation and an increase in vegetative cover, assuming reclamation is successful (Vegetation, Section G).

Figure III-12 illustrates the general post-mine erosion surface, showing the relative magnitudes of erosion rates. Figure III-13 illustrates those areas where the post-mine erosion rates exceed those of the pre-mining environment. Erosion rates during mining, however, can be expected to be greater than those in the pre-mining environment. Those areas where post-mine erosion is greater than pre-mine erosion were located along the permit boundaries in areas where post-mine slopes were greater than pre-mine slopes (Figure III-13). These areas, if properly stabilized, should not cause a serious impact. Basin sediment yields or the actual amount of sediment moved out of the basin, however, would be considerably less than the erosion rate due to deposition of eroded material while in transit. Sediment yields would be highly dependent on the efficiency of the reclaimed channels in transporting sediment.

Area-wide settling is common in most post-mining landscapes and occurs during the first ten years after the completion of contouring. A swell factor of 22 percent has been assumed. With time, these materials would settle and approach a density similar to that which existed prior to mining. Groenweld and Rehm (1980) indicate that there would be less settlement and it would occur more rapidly with sandy material as compared to silty material. Settlement is likely to be less significant at Colstrip than in many other sites because of the sandy character of the spoils.

Piping is a phenomenon associated with subsidence and may be a severe and long-term problem in the post-mine landscape. At the surface or near-surface, piping begins as a crack either in the surface of the exposed spoils or at the topsoil/spoil interface, allowing surface runoff to flow into the sub-surface of the spoils. However, surface cracking would not always result in the development of piping. Piping is most likely to occur when an avenue for potential water movement is present in the subsurface of the spoils. Such an avenue of flow can result from fracturing within the spoils due to settling between differentially compacted areas, or within areas of poorly compacted spoils. Such differential settlement is most likely at the highwall interface between coherent overburden and the spoils materials, and between areas of spoils handled by different equipment. If left unmitigated, piping and the consequent gullying it causes would be a serious impact to the stability of the reclaimed landscape.

4) Flow Rate Analysis

The HYMO model was used to compare pre- and post-mine surface flows. Surface flows occurring during mining were not evaluated quantitatively due to the changing nature of the drainages as reclamation

progresses. One of the impacts on surface flows during mining is attenuation of peak flows due to the impoundment of snowmelt and storm runoff in the sediment ponds. This impact would also cause base flow to be prolonged slightly due to the gradual release of flow from the ponds after treatment. The major impact to surface flows during mining, however, would be a decrease in total volume of flow from the mined areas due to increased evaporation and seepage from the sediment ponds and the use of sediment pond water for dust suppression.

Post-mine flow volumes and peak flows would be slightly reduced assuming that reclamation is successful, due to a slight increase in vegetation densities and infiltration rates. Tables III-6 and III-7 illustrate this difference between pre- and post-mining surface flows. Sediment ponds will have only a minor effect on the post-mine surface flow regime since most or all of these would be removed when the reclamation bond is released.

5) Water Use

Surface water use in the Colstrip area should not be significantly modified by mining. Slightly less water would be available for stock ponds during mining as a result of sediment impoundments and the resulting loss from seepage and evaporation; however, the water quality in the ponds should be the same as present water quality and would be suitable for present-day use.

Flood irrigation downstream from the townsite of Colstrip would likewise be little affected mining activities in the study area. Stream flow is used for irrigation only during periods of high flow when adequate quantities are available and the quality is good. This would continue to be the situation after mining and the water quality should be about the same. Water quality during low flow periods is suitable for livestock watering, and would remain so after mining. During mining, sediment ponds would cause peak flow attenuation that may have short-term affects on flood irrigation. Long-term effects (post-bond release) should be negligible, although a decrease in flow volume and peak flows is expected.

As indicated by Table III-3 groundwater discharges to surface water will not change significantly from the present.

a) Ponds

When the ponds are restored in the reclaimed mine area, the water quality is expected to be generally the same as the present pond quality. During precipitation events, low concentration water will be stored. This water will evaporate and increase in concentration with time, as it does under present conditions.

b) Springs

Any new springs issuing from the mined area would likely have TDS concentrations similar to the other springs in the area.

TABLE III-6
PRE- AND POST-MINE PEAK FLOWS
(in cubic feet per second)

	Recurrence Interval (Years)											
	2		5		10		25		50		100	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
East Fork Armells Creek at Stocker Creek (47.72 sq.mi.)	326	230	708	557	1070	880	1670	1430	2100	1840	2550	2260
Stocker Creek (26.11 sq. mi.)	218	163	457	302	676	583	1030	919	1280	1160	1540	1400
East Fork Armells Creek below Stocker Creek (73.83 sq. mi.)	541	391	1160	935	1740	1460	2700	2350	3380	2990	4090	3670

TABLE III-7
PRE- AND POST-MINE SURFACE FLOW VOLUMES
(in acre feet)

	Recurrence Interval (Years)											
	2		5		10		25		50		100	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
East Fork Armells Creek at Stocker Creek (47.72 sq. mi.)	292	190	725	536	1170	912	1960	1600	2550	2130	3183	2700
Stocker Creek (26.11 sq. mi.)	196	147	464	375	733	612	1210	1040	1560	1360	1930	1710
East Fork Armells Creek below Stocker Creek (73.83 sq. mi.)	488	337	1190	911	1900	1520	3170	2640	4110	3490	5110	4410

See Technical Support Document for detail

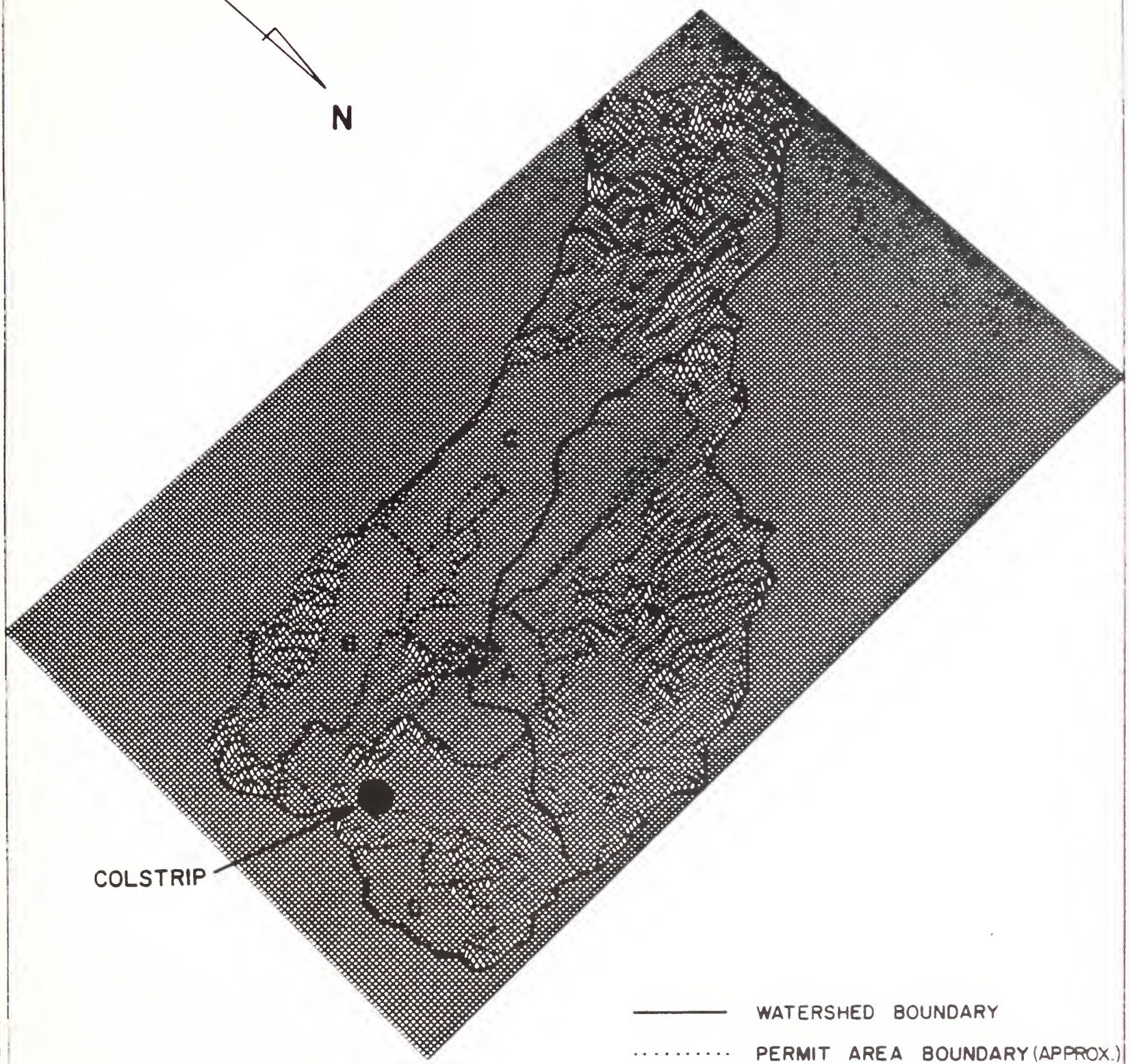


FIGURE III-12

COMPUTER-GENERATED POST-MINE EROSIONAL SURFACE, ROSEBUD MINE

Exhibit 3

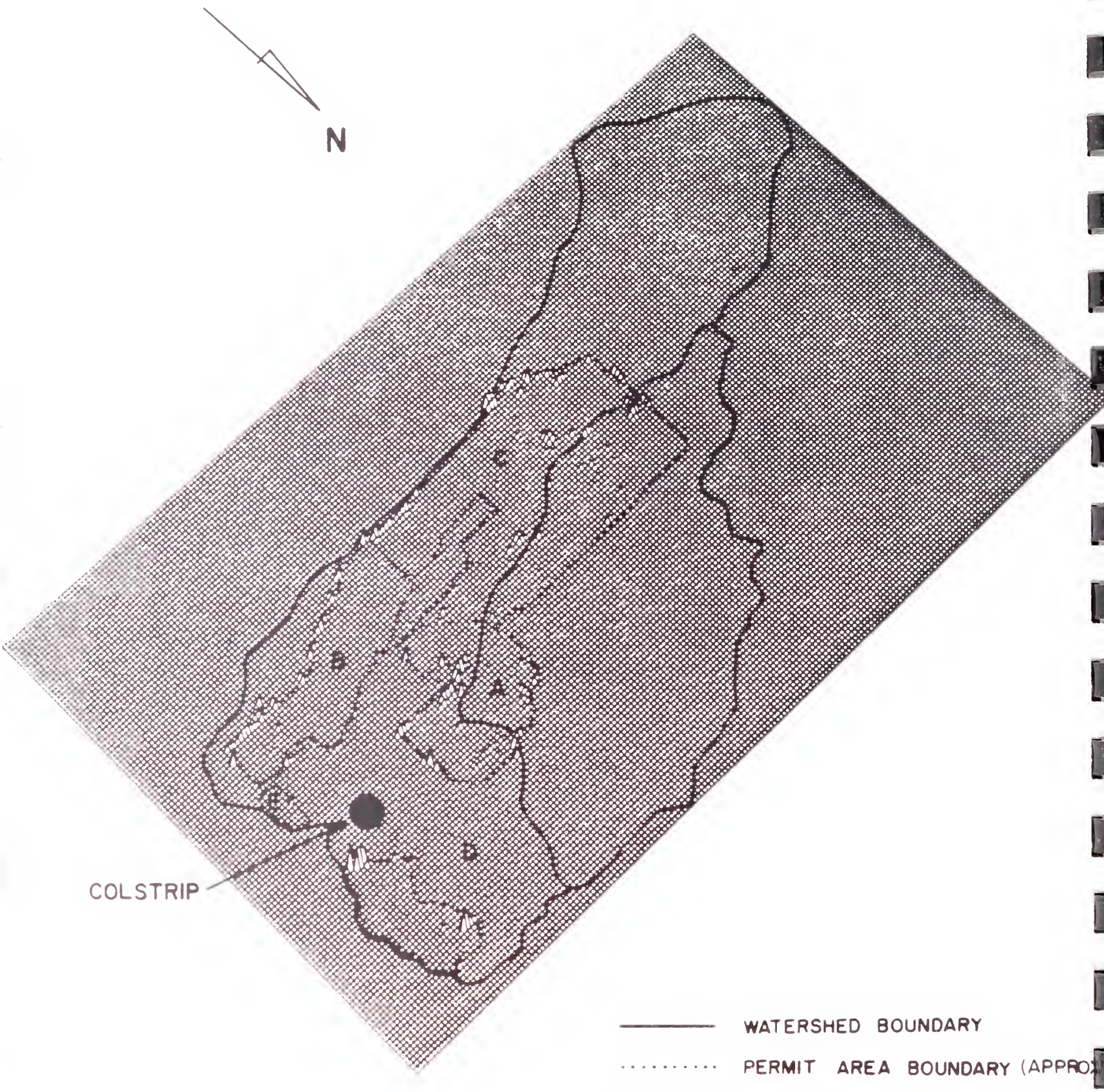


FIGURE III-13

COMPUTER-GENERATED POST-MINE EROSIONAL SURFACE, ROSEBUD MINE, WHERE POST-MINE EROSION EXCEEDS PRE-MINE EROSION

Exhibit 3

c) Streams

Water flowing across the surface of the reclaimed mine areas throughout the study area as a result of a storm or snowmelt runoff would have much lower TDS values than, for example, spoils water. This is because earth/water contact time is relatively short during runoff and the surface soils would be leached of soluble salts.

Water discharging from a mined area directly to streams during high flow should have a very small impact on stream quality.

During low flow conditions, any flow is predominantly groundwater from the valley fill. Existing average low-flow TDS values for drainages in the hydrologic study area are in the same range with predicted spoils water TDS values. Consequently, the influence of spoils water on base flow surface water would not be significant. And most importantly will not affect the use of water for stock watering purposes.

It is not possible to project cumulative changes in spoils water as it may migrate from one mined area to another. Concentrations of important constituents will increase at a lower rate as concentrations get higher. Also the rate of leaching is a function of the site-specific geologic and mineralogic conditions, the age of spoils and the rapidity with whch leaching occurs. For example unreclaimed spoils may produce low concentration leachate more quickly than reclaimed spoils because more water is trapped in unreclaimed spoils, causing anomolously high net infiltration rates.

d) Other Surface Water Features

Much of the activity in the vicinity of Colstrip has a greater potential for impacting study area surface water. Some of the activites include indirect contribution from the surge pond and fly ash pond, irrigation return water (both directly as runoff and indirectly as groundwater) and the seepage treatment plant discharge. It is apparent from the information on groundwater versus surface water levels that the surge pond, fly ash pond, and irrigation practices have an affect on surface water flows. With respect to the sewage treatment plant the average discharge is 130 gpm but there is no evidence that constituent levels present any difficulties for downstream users (irrigation and stock watering).

6) Water Quality

As stated previously the potential for surface water impacts due to mining are minimal. There are two possible ways in which a surface water quality change might take place: by changes induced directly from surface runoff/overland flow; and by changes induced due to modifications in groundwater quality which then discharges to the valley fill/surface water system.

During the long-term, little if any direct impact on surface water quality is anticipated due to runoff. Before mine bond release, any flow which occurs would be routed through sediment retention ponds where

sediment would be trapped. Water released should be cleaner than under natural conditions. After the bonds are released the sediment ponds would be removed. Due to the change in grade induced by the presence of the sediment ponds through the life of mine all surface water drainages would reestablish grade when the ponds are removed. This process would result in a small amount of channel incision (erosion) and deposition, but it is not anticipated that the phenomenon would produce noticeable increases in suspended sediment.

Because of post-mining vegetative reclamation requirements it is likely that for some period of time after vegetation is reestablished, mined areas would be more densely vegetated than non-mined areas. The effect of the extra vegetative cover would be to decrease sheet and rill erosion and decrease the peak flood flows by detaining some runoff and aiding infiltration. Storm runoff, for this reason may, in fact have less suspended sediment than during pre-mining flood flow conditions.

Greater potential exists for long-term affects on surface water quality via groundwater. This potential impact is examined in the following discussion.

To reiterate, normally no flow exists in East Fork Armells Creek above Colstrip or any of the tributaries to Rosebud Creek except during runoff periods. All groundwater which discharges from bedrock to East Fork Armells and tributaries to Rosebud Creek becomes part of the valley fill system but does not flow as surface water. Hence, although there is a potential for spoils water from various mined areas to affect valley fill water quality, only below Colstrip do the valley fill water levels get high enough for surface water flows to take place. Therefore, along East Fork Armells Creek only below Colstrip is there a potential for spoils water to affect surface water.

Assuming post-mining groundwater equipotentials are reestablished in approximate conformance with existing equipotentials, then groundwater flow lines would be similar to those under pre-mining conditions (shown on Figure II-10). Examination of this figure indicates that under existing conditions Areas C, B, and part of A plus the Big Sky Mine contribute to flow in Lee, Miller and Hay Coulee while Cow Creek receives contributions from Area D, E, and part of A. Pony Creek receives a minimal amount of flow from Area D.

In the Cow Creek Drainage, a water balance indicates the potential for all natural groundwater discharge from Areas D, E, and parts of A to move into Cow Creek alluvium and then be evapotranspired in areas identified as being subirrigated (Figure II-14. The potential for salt accumulation in these areas is uncertain, however, since salinity problems have been reported in subirrigated areas (DSL, 1980) the inflow of additional TDS would exacerbate the problem. Not included in the analysis are the systems input due to precipitation, snowmelt and runoff within the Cow Creek drainage.

A potential for additional salt loading on the Cow Creek system exists due to a proposed fly ash (scrubber sludge) pond in T1N, R42E, Section 5 and 6. It is uncertain whether the pond would be constructed

in colluvium or alluvium, however, it will clearly be constructed within the Cow Creek drainage area. The design specifications indicate a maximum seepage rate of 170 af/year of water with a TDS of 32,000 mg/l (10 times greater than background levels). Whether some leakage occurs into bedrock or whether effectively all of the seepage moves into Cow Creek alluvium depends upon the exact location of the ponds.

As indicated in the discussion on subirrigation along Cow Creek, the total computed potential evapotranspiration is 319 af/year. The available water from groundwater is 131 af/year (year 2118) while the fly ash pond would contribute another 170 af/year, for a total of 301 af/year. This would still be less than the total potential evapotranspiration.

The potential problem derives from the very severe salinity hazard posed by the fly ash pond water. Using the correlation TDS = 1081 E.C. + 1043 (TDS in mg/l, E.C. in mmhos), it can be calculated that a TDS of 32,000 mg/l correlates with an E.C. of 28,630 micromhos (See TSD, Figure B2-3). For a point of reference, water with an E.C. of 5,000 micromhos is classified as very high salinity water "not suitable for irrigation under ordinary circumstances" (USDA, 1954). This water moving into the valley fill or alluvial system, would be toxic (unusable) to vegetation and could create substantial areas of salt deposition in the Cow Creek drainage.

It should be pointed out that although seepage of high salinity water from the fly ash pond could cause severe impacts to the Cow Creek drainage, various mitigative measures are proposed.

These possible migitation and abatement measures are described as follows in a report by Hydrometrics, 1981, "Cumulative Hydrologic Impacts, Rosebud Mine, ..."

"... construction of a slurry trench to eliminate seepage through permeable material peripherial to the pond, the use of a pond liner in portions of the pond and installation of a groundwater interception system peripherial to the pond."

More specific design specifications are necessary before a judgment can be made about how successful each measure might be in reducing the potential problem. Each measure taken by itself would not be an absolute solution to the problem.

It is also important to determine (if only in an approximate manner) how mining could affect surface water quality versus the potential affects of activities not directly related to mining (e.g., operation of the power plant).

A mass balance estimate was made to approximate these changes. The approximation incorporates the following assumptions and postulates:

a. It is assumed that the valley fill/surface water is represented by a single water quality for low flow periods. This is reasonable since surface water flow comes from valley fill groundwater base flow during low flow periods.

b. In the mining scenario it is assumed that all of the water entering the valley fill system from groundwater has increased from 2,500 to 3,500 mg/liter TDS.

c. The "water balance" utilizes only the input parameters since none of the outputs (losses to the system) change because of mining or the other activities considered.

d. For most of the inputs to the surface water system reasonable TDS values are assumed. Although in some cases the actual values may differ somewhat from the values used in this approximation, the assumed reasonable values can be used in a trend analysis to determine the magnitude of change mining would have on surface water low flows.

e. It is assumed that the sewage treatment outfall as a constant contribution to baseflow below Colstrip. It is also assumed that only a small portion of the 204 acre-feet per year (afy) of runoff contributes to recharge of valley fill and hence contributes to baseflow. For these purposes it has been assumed that approximately 10 percent of runoff on 20 afy contributes to baseflow.

If all of the water input to the system is added and all of the TDS is added it is possible to project the composite resulting water quality.

VALLEY FILL/SURFACE WATER SYSTEM INPUT

Input	Amount of Input Acre feet per year (afy)	Estimated TDS value (mg/l)
Sewage outfall	210	1,000
Surge Pond	175	500
Boston Ash Pond	13	35,000
Cooling Tower and Blowdown Pond	24	10,000
Other Power Plant Processing Ponds	15	35,000
Annual Runoff	20	500
Groundwater Discharge to East Fork Armells Creek	146 (year 2118)	2,500[1] 3,500[2]

Total water = 603 afy or 7.72×10^8 liters/year

TDS = 3.26×10^{12} milligrams/year (no spoils water effects)

= 3.38×10^{12} milligrams/year (spoils water effects included)

[1] This value represents average pre-mining groundwater discharge to valley fill.

[2] This value represents average spoils water discharges to valley fill.

Exhibit 3

Mass balance calculations using the above data show the resulting surface water quality flow would be 4378 mg/l with mining affecting groundwater inflow to East Fork Armells Creek and 4222 mg/l with no mining.

It must be emphasized that the preceding calculations are useful in establishing trends. The trend indicates that all of the human activity (non-mining) in the Colstrip area will render changes in base-flow surface water quality due to mining difficult to detect.

C. CLIMATE

The proposed mining of Area C, Block I would not have any impact on the climatic regime in the area.

Ertec evaluated four possible avenues for climatic modification by the project:

1. Major increases in area atmospheric moisture content

2. Changes in surface albedo due to surface disturbance

3. Changes in increasing radiation caused by increased suspended particulate matter

4. Changes in cloud formation caused by increases in condensation nuclei (from suspended particulate matter)

There are no major sources of atmospheric moisture. Increases from vehicular exhaust and evaporation of water used for dust suppression would be very small compared to moisture levels needed to produce climate changes. Only a very small percentage of the disturbed acreage would have a significantly different color than the existing surface. Consequently, surface albedo would not be significantly altered by the project. As documented in the visibility degradation analysis in the air quality section, suspended particulate concentrations would have little effect on light transmission, thus there would be no expected change in incoming solar radiation. Finally, the particulate matter would occur close to the surface, where the availability of condensation nuclei is not the limiting parameter in cloud formations (Wallace and Hobbs, 1977).

D. AIR QUALITY

A mining development such as the proposed Area C operation can impact air quality in several ways:

- o It can increase the ambient concentrations of various pollutants in the air
- o It can increase the rate at which dust or other particulate matter settles on surfaces near the mining operation
- o It can degrade the ambient visibility in the area

In this assessment, an evaluation of each of these effects has been made. The basic methodology is to develop an inventory of the various project-related sources of air pollution emissions and estimate their emission rate. These estimates are then used, together with the meteorological data presented in Chapter II, as input to a mathematical simulation model of atmospheric pollutant behavior. The model provides estimates of increases in ambient concentrations expected from the proposed project. From these concentrations, deposition and visibility degradation can be estimated.

Both the state and federal governments require that proposed new sources be evaluated for potential air quality impacts. Government agencies have established legal limits on pollutant levels (Table II-8). Western Energy has applied for an air quality permit to construct and operate from the Montana Air Quality Bureau (MAQB) for the planned Area C, Block I operations. The MAQB has issued a preliminary determination to issue this permit. The Area C, Block I mining operation would be located on the boundary of a non-attainment area for TSP. Normally, a new project in such a location would be required to comply with the non-attainment provisions of the Clean Air Act amendments of 1977, which are now incorporated in Montana law. The Prevention of Significant Deterioration (PSD) requirements would not apply because Area C, Block I is located in a nonattainment area. The nonattainment regulations require that a source obtain an offsetting reduction in emissions equal to or greater than the proposed project emissions. Also, the new source is required to demonstrate that it will attain the lowest achievable emission rate (LAER). To be subject to the nonattainment review process of the Clean Air Act Amendments, a source must have at least 250 tons per year of nonfugitive emission. Since the nonfugitive emission estimates for the proposed Area C, Block I mining operations do not exceed this limit, the nonattainment review does not apply. However, Section 16.8.1401 of the Montana Air Quaility Rules still requires the LAER must be attained.

The only pollutant of major concern would be particulate matter. By far, the most significant component of the particulate matter emission would be fugitive dust from heavy equipment movement on the unpaved surfaces in and around the mine, and from coal and overburden handling. Major sources would include haul roads, draglines, wind erosion, scrapers, and bulldozers.

Although the crushing and conveying operations would be sources of dust emission, they are not "fugitive" sources since control equipment would be installed on these units to reduce dust emissions.

Additionally, small amounts of particulate matter and gaseous pollutants would originate from the exhaust of diesel equipment used in the mining operation. The most significant of these gaseous pollutants would be oxides of nitrogen (NO_x). Total annual emissions of NO_x are estimated to be 134 tons from diesel equipment and an additional 35 tons from blasting with an ammonium nitrate and fuel oil mixture. This emission rate could be expected to increase ambient nitrogen dioxide (NO_2) concentrations in the project area by a small percentage, but impacts would be restricted to the mine area alone and would be less than 20 percent of the ambient standard for annual-average NO_2 concentrations. Emissions of carbon monoxide (26 tons per year), hydrocarbons (9 tons per year), and sulfur dioxide (9 tons per year) would not constitute a significant impact on the project or regional area. Since these emissions would be small, and would not be likely to create any impact, only fugitive dust emissions are considered.

A summary of the emission inventory prepared by the air quality study team for this EIS (with the coordination and approval of the MAQB) is shown in Table III-8. Details of the computations can be found in the Technical Support Document. The emission inventory refers to emission rates characteristic of those expected if the Area C, Block I operations are in full production.

In addition to the emissions caused directly by the project, there would be secondary emission sources, resulting from the increase in population and services accompanying the project and emissions from other simultaneous new projects in the area. Table III-9 lists the other (nonproject) emission sources and the estimate of annual average emission rates. Emission rates are presented for two years. The year 1980 was selected to be representative of current emission rates while 1988 was selected to represent future conditions. These dates were selected primarily because data were readily available for these years. Details of the computations for these emission rates are presented in the Technical Support Document.

The Ertec Mining Air Quality (EMAQ) model was used to predict ambient concentrations resulting from the proposed Area C, Block I operations. The model is described in detail in the Technical Support Document. It is basically a Gaussian plume-based model that uses particle deposition based on the equations of Ermak (1977). Both annual-average and peak 24-hour average concentrations were calculated. The on-site meteorological data from the train loop station operated by Western Energy was used in the analysis. A full year of readings for the period of January through December, 1980 was sequentially analyzed in this study. Three geographical areas of interest were identified: the area immediately adjacent to the proposed mining operation (hereafter referred to as the mine area), the townsite of Colstrip, and the Northern Cheyenne Indian Reservation (NCIR). The mine area was selected because

TABLE III-8

EMISSION INVENTORY FOR AREA C OPERATIONS

Source	Annual Emission Rates (ton/year)	Maximum Short-term Emission Rates (ton/day)
Topsoil Removal	302.00	0.853
Overburden Removal (Dragline)	581.00	2.198
Overburden Blasting	1.20	0.009
Coal Blasting	2.60	0.016
Overburden Drilling	0.35	0.003
Coal Drilling	1.00	0.013
Coal Removal	68.20	0.297
Road Construction and Maintenance	210.00	0.868
Haul Roads - $CaCl_2$	62.20	0.271
Haul Roads - H_2O	100.50	0.438
Access Roads	7.30	0.021
Wind Erosion	555.00	1.521
Bulldozers	53.20	0.201
Emergency Stockpile	1.50	0.064
Coal Dumping*	0.48	0.002
Primary Coal Crushing*	0.56	0.002
Secondary Coal Crushing*	1.68	0.007
Conveyor Transfer Pts.*	5.60	0.024
Coal Screening*	2.80	0.012
Overland Conveyor*	2.52	0.011
TOTAL	1,959.69	6.831

* Not classified as fugitive dust

Exhibit 3

TABLE III-9

NONPROJECT EMISSIONS

Source	Annual Emission Rate (tons/year) 1980	1988
Other Western Energy Sources		
Area A	2,673	4,115
Area B	3,511	5,366
Area E	2,084	3,210
Peabody Big Sky Mine	1,502	2,426
Colstrip Units 1 and 2		
Stack Emissions	887	1,028
Lowering Wells	3	3
Crushing	1	1
Coal Piles	65	75
Colstrip Units 3 and 4		
Stack Emissions	0	3,582
Lowering Wells	0	6
Crushing	0	2
Coal Piles	0	15
Other Sources	2,927	3,169
TOTAL	13,656	22,998

Exhibit 3

TABLE III-9

NONPROJECT EMISSIONS

Source	Annual Emission Rate (tons/year) 1980	1988
Other Western Energy Sources	6,828	7,797
Peabody Big Sky Mine	1,502	2,426
Colstrip Units 1 and 2		
Stack Emissions	887	1,028
Lowering Wells	3	3
Crushing	1	1
Coal Piles	65	75
Colstrip Units 3 and 4		
Stack Emissions	0	3,582
Lowering Wells	0	6
Crushing	0	2
Coal Piles	0	15
Other Sources	2,927	3,169
TOTAL	12,213	18,104

Exhibit 3

impacts will be highest there; the town-site of Colstrip was selected because it is currently classified as not being in compliance with the air quality standards, and the NCIR was selected because it is classified by EPA as a Class I area and as such is accorded special consideration.

The analysis of impacts in the mine area is complicated by the presence of both attainment and nonattainment areas (for TSP). Figure III-14 shows isopleths of annual-average TSP concentration predicted to result from the proposed Area C operations. The isopleths include the contribution from both fugitive and nonfugitive emissions. As the figure shows, the proposed operations would increase TSP concentration in both the attainment and nonattainment areas. However, the mining operation would not be required by current Montana laws to include fugitive dust in the impact analysis. Because the nonfugitive dust emissions would be sufficiently small to escape nonattainment review, the mining operation would not be required to make a demonstration of compliance with the emission offset ruling. Since nonattainment and PSD would not apply to this project, the remaining discussion of the impacts does not reference the distinction between the attainment and nonattainment areas. Also, the remaining discussion addresses all particulate matter including both fugitive and nonfugitive emissions.

Table III-10 summarizes the results of the air quality modeling study. The annual-average TSP concentration predictions for the mine area (11 ug/m^3), when added to existing levels of approximately 25 ug/m^3, total 36 ug/m^3. Increased TSP in emissions from nonproject sources in the Colstrip area (see Table III-9) might result in a further increase in the mine area, on the order of 7 ug/m^3. This estimation is based on approximate calculations. Details of this estimate can be found in the Technical Support Document. Thus, total annual-average TSP concentrations in the mine area would rise to approximately 43 ug/m^3. This value is an arithmetic average and still well below the Montana air quality standard of 75 ug/m^3. Federal annual standards are geometric means and are expressed as both primary (75 ug/m^3) and secondary (60 ug/m^3). Since the arithmetic mean is always greater than the geometric mean, we can conclude that the predicted total TSP concentration in the mine area would not exceed federal annual standards.

The impact of the project on annual-average TSP concentrations in the townsite of Colstrip would be very slight. The predicted increase of 1.2 ug/m^3 would be less than the detection limit for most monitoring equipment and would be essentially equivalent to the cutoff EPA uses in determining if a source has an insignificant impact on a given receptor. The impact of increases in nonproject emission sources on Colstrip would be far greater. These emissions would be expected to worsen the existing air quality problem in Colstrip.

Annual-average TSP concentrations in the NCIR resulting from the project would be extremely low and can be disregarded completely.

Peak and second highest 24-hour TSP concentrations in the mine area would be around 38 ug/m^3. Existing peak 24-hour TSP concentrations would be around 90 to 100 ug/m^3, but the high impacts from the mining

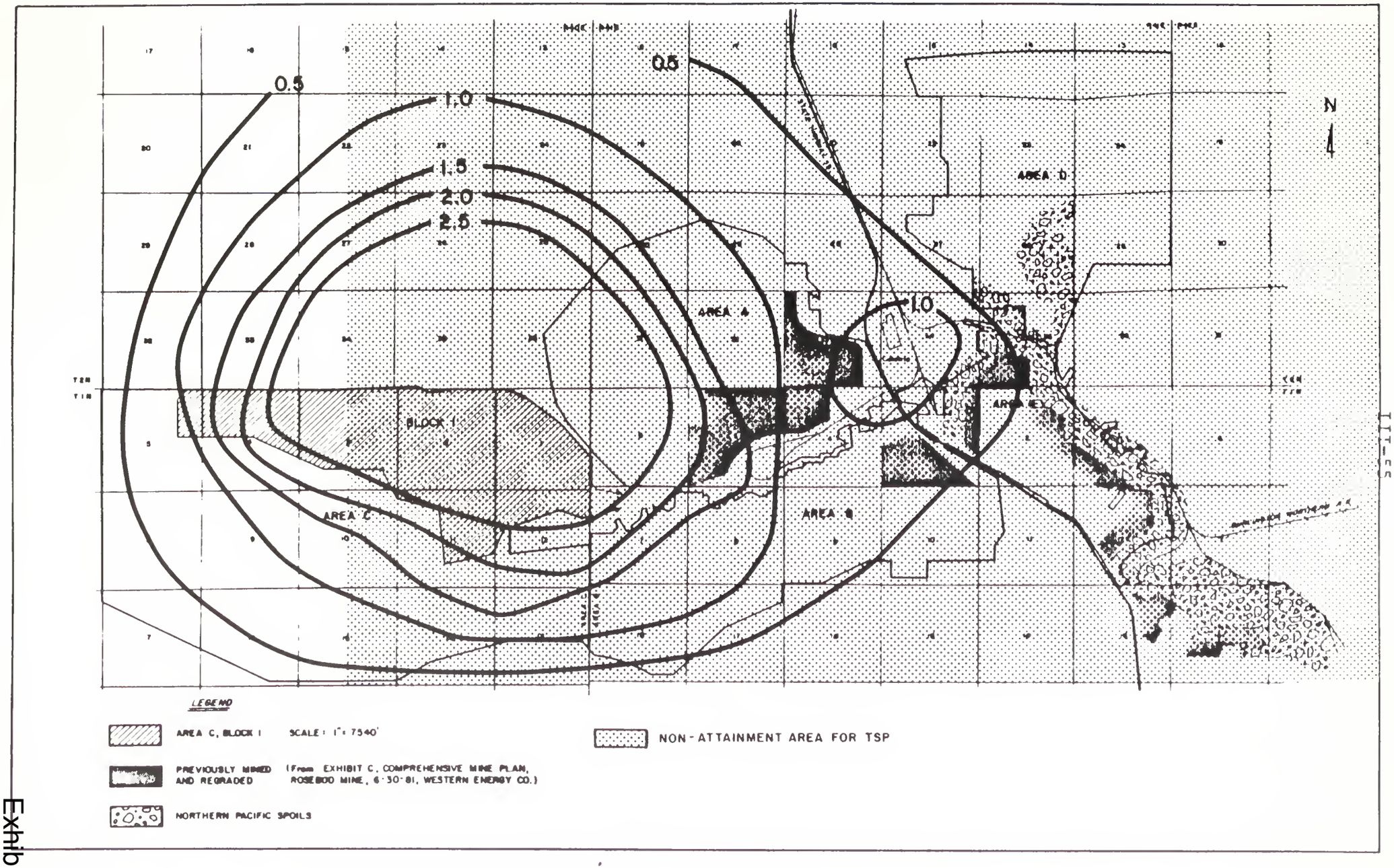


FIGURE III-14 ISOPLETHS OF ANNUAL-AVERAGE TSP CONCENTRATION IN ug/m^3 RESULTING FROM THE AREA C, BLOCK I OPERATIONS ALONE

Exhibit 3

TABLE III-10

PREDICTED TOTAL SUSPENDED PARTICULATE
CONCENTRATIONS IN MICROGRAMS PER CUBIC METER
RESULTING FROM THE PROPOSED PROJECT

Location	Annual-Average	24-Hour Average	
		Highest	Second Highest
Mine Area	11.50	38.1	30.9
Colstrip	1.20	4.6	4.4
Northern Cheyenne Indian Reservation	0.01 (negligible)	0.3	0.2

Exhibit 3

operation may not occur under the same meteorological conditions. Even with the worst-case assumption that these peaks overlap, the total value of 138 ug/m^3 would still be below both primary and secondary air quality standards. Impacts from nonproject sources in the area would not cause excursions of the standards at Area C.

The peak 24-hour impact of the mining operation on the townsite of Colstrip (less than 5 ug/m^3) would be inconsequential when compared to the existing peaks that occur there (during 1974 to 1979 Colstrip had measured peaks every year of over 350 ug/m^3). Therefore, the proposed mining operation would not be expected to have a significant impact on 24-hour concentrations in Colstrip. Nonproject emissions in Colstrip would increase 24-hour concentrations.

Peak impacts in the NCIR would be very low; they are not likely to be measurable.

The impacts caused directly by the project would be far below the primary standards, which are designed to protect human health. The townsite of Colstrip would be expected to continue to exceed the primary standard, due primarily to nonproject sources of emission. The high concentrations have not produced a hazard to health in the past primarily because of the high percentage of large particles, which pose less threat to human health than small particles. It is uncertain whether future particulate levels in Colstrip would constitute a health hazard. It is unlikely, however, that the proposed project would be a significant component to any potential threat to human health.

While producing large TSP concentrations, fugitive dust impacts do not pose as great a hazard to health as equivalent concentrations resulting from other sources. This is because much of the measured TSP in the fugitive dust impact is composed of particles greater than 15 micrometers in mass mean diameter. These large particles are removed by nasal hairs and mucous membranes prior to entering the lungs by inhalation. No adverse health effects have been reported from exposure to annual geometric mean TSP concentrations of 86 ug/m^3 in Colstrip during 1974 through 1979 (Montana Department of Health and Environmental Sciences, 1980).

Deposition of particulates in the project area would increase from existing 30-day average levels of approximately 7.4 grams per square meter on an annual-average basis to levels of approximately 8.6 grams per square meter at points separated from the mining operations by at least 500 meters. The 30-day average value for settled particulates regulated by Montana is currently being exceeded throughout much of the Colstrip area, including the project area. This would be expected to continue, and to increase in the project area. Values could be as high as 60 grams per square meter in the immediate area of the mining operation. However, at distances of 500 meters or more from the mining operation, peak values would be around 10 grams per square meter.

Visibility in the project area would decrease slightly as a result of the project. An increase in concentration from 25 to 42 ug/m^3 would produce a consequent decrease in ambient visibility from 35 to 27 miles. However, because the concentration impact would be very localized to the project area, this degradation is overstated. For lines of sight passing directly over the mining area and close to the ground, the impact will be in the range of 10 to 20 percent. For other vantages, the visibility degradation would be expected to be negligible. In particular, there would be no impact on visibility in the nearest Class I area, the Northern Cheyenne Indian Reservation. Another reason the impact is overstated is that the computation of visual range loss is based on particles of all sizes. Most visibility degradation occurs as a result of very small particles (less than one micrometer in size). Since less the ten percent of the Area C contribution can be attributed to these small particles, it is unlikely that any noticeable impact on visibility would occur.

E. NOISE

1. Construction Impacts

Among the first activities associated with the development of Area C, Block I would be the construction of shop and office facilitites and an overland conveyor from the mining area to the power generating station. This would require earth-moving and other construction equipment that would cause much higher than normal ambient sound levels in the construction vicinity.

The construction phases would generally include excavation, foundation work, erection, and finishing; the excavation phase would usually be the noisest. Typical sound levels produced by equipment used in the excavation phase are presented in Table III-11. A worst-case estimate of construction sound levels is derived by adding all the sources, weighted by the fraction of the work day the equipment is generally in operation. From Table III-4 the $L_{eq}(8)$ (i.e., the equivalent eight-hour sound level) at a distance of 50 feet from a point where all the equipment would be operating would be 92 dBA. However, because all the equipment would not be operating in the exact same location, this represents an upper limit to the construction noise level. Attenuation of this sound level due to distance alone would reduce construction noise levels to 72 dBA at a distance of 500 feet and to 52 dBA at 4,000 feet. The construction of the mine shops and offices would take place at a site more than seven miles from the townsite of Colstrip; due to distance attenuation alone, the $L_{eq}(8)$ construction noise would be reduced to 34 dBA, which would not be audible above to existing in-town sound levels.

2. Operation Impacts

During the operation of the proposed mine, heavy equipment would be used to remove the overburden and coal. Table III-12 lists the types and numbers of mining and reclamation equipment assumed to be in use at Area C. Overburden removal would probably occur full-time; coal removal would occur two shifts per day, five days per week. This equipment is likely to be in operation full-time during working hours. Field observations indicate that sound levels associated with existing overland conveyors are very low; because of these observations the conveyor noise was considered insignificant in comparison with other sources and was not included in the noise calculations.

Another source of noise due to mine operation would be blasting. Explosives are used in the removal of both overburden and coal. Unlike the continuous noise produced by mining equipment, blasting would occur intermittently and would be of very short duration. Approximately 136 overburden blasts and 320 coal blasts are expected each year. The noise produced by blasting depends on a number of variables, including the strength of the explosive charge and the amount of stemming placed behind the charge in the drill hole.

TABLE III-11

CONSTRUCTION EQUIPMENT NOISE PARAMETERS[a]

Equipment	Number	dBA @ 50'	Usage Factor
Air Compressor	2	81	1.00
Backhoe	1	85	0.16
Bulldozer	1	80	0.40
Generator	2	78	1.00
Jackhammer	1	88	0.10
Loader	1	79	0.40
Pump	2	76	1.00
Rock Drill	1	98	0.04
Shovel	1	82	0.40
Truck	1	91	0.40

[a] United States Environmental Protection Agency, 1971. Noise from construction equipment and operations, building equipment, and home appliances, NTlD300.l

TABLE III-12

MAJOR NOISE SOURCES DURING MINING

Equipment Type	Number in Service	Noise Level at 50 Feet (dBA)
Out-of-Pit Equipment		
Dragline	1	75
Overburden Drill	1	90
Coal Hauler	3	89
Bulldozer	3	86
Front-end Loader	2	79
Scraper	4	87
Combined Noise Level		98.3 dBA[a]
In-Pit Equipment		
Coal-loading Shovel	1	79
Coal Drill	1	90
Coal Hauler	3	89
Bulldozer	3	86
Combined Noise Level		96.7 dBA[a]

[a]Logarithmic addition of each continuously operated equipment piece (i.e., usage factor of 1) at a distance of 50 feet from a point where all pieces are operating simultaneously.

Exhibit 3

Noise regulations designed to protect a community's exposure to ambient noise generally consider time-averaged noise levels. For example, EPA's guidelines use an equivalent sound level averaged over 24 hours. EPA also has a standard that adds a 10 dBA penalty to ambient sound levels measured between 10:00 p.m. and 7:00 a.m. to account for the additional annoyance during sleeping hours. Due to time-averaging, the infrequent and brief blasting noise has very little impact on average community noise levels. The continuous operation of heavy mining equipment would be more likely to affect average noise levels.

To provide a worst-case estimate of noise impacts due to the proposed mining activities at Area C, Block I, an approach similar to that used in estimating construction impacts can be used. Table III-12 lists the major sources of noise due to mine operation and typical sound levels associated with each at a distance of 50 feet. The equipment is subdivided into overburden and coal removal equipment since these take place at different locations. Bulldozers and coal haul trucks were evenly divided between the coal mining activities, which take place in the pit, and overburden removal, which takes place at the perimeter of the pit. Because this equipment is assumed to be co-located, even though in reality the pieces move all over the mine area, the estimate of the combined noise level is conservative.

The wide range in blasting noise levels is indicated in the measurements shown in Table III-13. These observations have been collected from several locations and include a variety of blasting conditions. The maximum sound levels indicated in the table are instantaeous measurements rather than time-averages.

The most important criterion that influences the impact of sound is distance from the source. Sound energy diverges or spreads out, and thereby results in lower sound pressure with increasing distance. This decrease or attenuation of the sound pressure level results in a decrease of 6 dBA each time the distance from the source is doubled; each time the distance increases by a factor of ten, the sound level decreases 20 dBA.

This attenuation due to distance alone would result in a substantial reduction in Area C, Block I noise by the time the sound reached Colstrip. Since the distance from the nearest part of Area C, Block I to the townsite of Colstrip is approximately 19,200 feet, the 98 dBA produced by the mine equipment would be reduced by distance alone approximately 52 dBA to about 46 dBA in town. The last column in Table III-10 shows blasting noise levels normalized to a distance of 19,200 feet.

Other factors also influence sound propagation through the atmosphere. These include the absorption of sound energy by the atmosphere, the refraction of sound waves due to temperature or wind speed gradients, and ground effects. Absorption of the sound energy by the atmosphere is highly variable and depends on relative humidity, the frequency of the sound, and to a lesser extent, on ambient temperature. Between Colstrip and Area C, sound absorption by air with a relative humidity of 20 percent could attenuate noise by 20 to 30 dB at 500 Hertz and 5 to 10 dB at 250 Hertz, but affects the lower frequencies very little.

TABLE III-13

MEASURED SOUND LEVELS DUE TO BLASTING[a]

Type of Blast	Distance to Blast (feet)	Measured Maximum Sound Level (dBA)	Approximate Sound Level at 19,200 feet (dBA)[b]
Coal	1,500	79.0	57
Coal	8,000	66.1	58
Coal	8,000	65.7	58
Coal	5,000	80.4	69
Coal	5,000	83.1	71
Coal	6,500	74.9	65
Coal	6,500	75.0	65
Coal	11,700	55.5	51
Coal	12,500	60.2	56
Coal	20,500	55.4	56
Coal	12,400	66.1	62
Coal	17,000	75.3	74
Coal	23,000	54.5	56
Overburden	8,000	86.2	79
Overburden	16,000	65.2	64
Overburden	16,000	67.8	66
Overburden	18,500	57.2	57
Overburden	24,900	57.0	59
Overburden	13,000	62.1	59
Overburden	21,400	55.1	56

[a]Source: Foch and Oliver, 1980

[b]Attenuation due to divergence only; atmospheric absorption and ground cover attenuation are not included.

Exhibit 3

The grass groundcover in the Colstrip area will also attenuate sound from the mining area. Over the distance from the mine to the townsite, this is enough to completely attenuate ground level sound transmission.

Atmospheric stability and winds also affect sound propagation. During stable atmospheric conditions, the temperature of the air and the speed of sound increase with height and cause sound waves radiating from a source to bend toward the ground. Similarly, winds that increase in speed with height reduce upward sound divergence and can cause higher sound levels at a downwind receptor than during calm periods. Either of these can lessen the attenuation of sound due to groundcover and topography by returning sound waves from above back to ground level.

In summary, it is unlikely that the operation of mining equipment would normally be heard in the community of Colstrip. Despite the potentially high sound levels at the mine, distance and other attenuation factors are expected to reduce sound to relatively low levels before it reaches Colstrip. Of equal important is the masking effect provided by the relatively high ambient sound level that currently exists in Colstrip due to the generating plant. Therefore, except under especially adverse meteorological conditions, mine noise is not expected to be discernible in Colstrip, and should certainly not have any effect in terms of hearing damage.

Depending upon the blasting techniques employed and upon meteorological conditions, blasting noise might be audible in Colstrip. Based on the measurements displayed in Table III-13, blasting noise would be not likely to cause hearing damage, but might be an occasional nuisance.

F. SOILS

Western Energy has proposed to replace approximately 27 inches of subsoil and 8 inches of topsoil, a total of 35 inches of replaced soil on the mined area of Area C, Block I. The soils resources of the remainder of Area C are less well defined at this time. The depths of replaced soils in Area C could be less than this in some areas. The soils at the Rosebud Mine in general present few serious limitations for reclamation. The major impacts in Block I that could be expected from mining and the proposed reclamation actions would be alteration of the physical and chemical character of the soils in the disturbed area. These alterations would not be anticipated to prevent revegetation or to seriously alter the character of surface water dynamics in the area; however, the changes would be sufficient to alter the soil moisture regimes and infiltration and runoff conditions, limiting potential plant communities and agricultural uses in the area. Within the proposed conveyor corridor, 95 acres of the 225 acres to be disturbed have previously been disturbed by mining activities. The soils on the remaining 131 acres along the route are relatively similar to the soils in Block I, Area C, and the impacts are anticipated to be similar to those identified for the Block I mining area. Recommendations for possible mitigation for the impacts discussed below are included in Chapter IV.

1. Biological Impacts

Two major soil handling methods would be used in Area C, Block I. In early phases of mining and for all areas to be disturbed by support activities, soil materials would be salvaged as subsoil and topsoil and stored. After the third mining pass, topsoil and subsoil layers would be hauled directly to a scarified, regraded overburden surface whenever possible.

In both methods, soil organic matter, microbial populations, and reproductive plant parts would be disturbed and mixed into the entire topsoil salvage layer, reducing the quality of the soils at the surface and the likelihood of growth from small seeds. In the cases where soil materials are stockpiled and stored, it is probable that populations of soil microorganisms would decline (Miller and Cameron, 1976). Reproductive plant parts such as bulbs, tubers, seeds, and roots might be attacked by an increased population of pathogens during storage, reducing their viability. This will reduce "volunteer" establishment of native forbs, shrubs, and grasses not included in the seed mix, and might suppress establishment of some plants included in the seed mixes due to continued high pathogen levels after stored soils were replaced (Miller, R. M., 1982).

After stored soils have been replaced on the regraded spoil, microbial populations can be anticipated to reach pre-mining levels in one to two years, for all groups of microbes except the blue-green algae, which have not yet been documented as being capable of reestablishment (Miller, R. M., 1982; Mott, 1982), based upon research on spoils up to ten years

old. In addition, for the microbial groups that would become reestablished, different microbial species would generally be involved, which allows for restoration of basic nutrient cycling functions within the soil but might not replace functions that are limited to a few species, such as soil aggregation (Miller, R.M., 1982).

Organic matter would oxidize and decompose during topsoil storage. The result would be a decrease in available nutrients, reduced water and nutrient-holding capacity of the soil, and a reduction in soil structure. From present research data, the time required to restore soil structure is uncertain. Soil organic matter and nutrients would begin to build up once vegetation is reestablished on the replaced soil, as dead plant roots and litter begin to build up in and on the soil and supply nutrients. It might take up to 20 years before vegetation requirements and nutrients available in the soil system reach a balance (Woodmansee et al., 1978).

2. Physical Impacts

Physical alteration of the soils would result from salvaging, handling, and replacing soils in the mine area and from changes in the underlying material or overburden. Soil moisture availability has a strong influence on the present and potential vegetation in the area. Changes in bulk density, infiltration and runoff characteristics, depth to rock or impermeable layers, and soil textural variations would alter existing soil moisture relationships and influence survival and dominance of vegetative types.

a. Bulk Density

Plant root penetration might be limited by high bulk densities in the subsoil or at the regraded overburden contact. Weakly consolidated sandstone in the Colstrip area has been shown to resist root penetration at a bulk density of 1.5 g/cm^3 (Schafer et al., 1979).

Most natural soils of the Colstrip area do not exceed 1.6 g/cm^3 (Schaefer et al., 1977). Measurements on regraded spoil and replaced soils at the Rosebud Mine show a wide range of bulk densities in which bulk densities in excess of 1.7 g/cm^3 are relatively common (Schaefer et al., 1977; Dollhopf et al., 1981; Stark, unpub. data).

As bulk densities become higher, infiltration by water is decreased and accordingly, more soluble salts may become concentrated nearer the surface than would occur in a freely draining system. Plant rooting depths would be decreased, increasing the competitive edge of the shallow-rooted cool-season grasses at the expense of deep-rooted warm-season grasses. Reduced water available for vegetation would result from decreased infiltration and increased runoff, which would also increase the potential for soil erosion. Most of these effects would not be seen until soil bulk densities exceed 1.5 g/cm^3.

Ponderosa pine communities, although they occupy a relatively small proportion of the area to be disturbed (11 percent) are important for wildlife, aesthetics, and for supplying vegetative diveristy. Work by Stark (1982) has shown that bulk densities of 1.3 g/cm^3 or less in near-surface soils are ideal for ponderosa pine survival and regeneration. Therefore, for areas that have been identified as areas to be reestablished to ponderosa pine, bulk densities of 1.3 g/cm^3 in the soils will help insure the survival and regeneration of the trees. Additionally, the trees may take advantage of free water available in much more dense rock material at depth in natural settings (see Chapter II, Section F), therefore areas where overburden bulk densities exceed 1.5 g/cm^3 areas may not be of concern.

The areas in which increased bulk densities are likely to occur are impossible to predict due to high variability in spoil placement and the moisture conditions of spoil and overburden when they are being handled.

b. Soil Textures

The tendency of soils to become compacted during placement is influenced by soil texture. Texture also influences infiltration, runoff, erodibility, and accordingly, soil moisture regimes.

Mining would result in the disruption of large, discrete areas of soils with similar textures that characterize the pre-mined environment, and would produce a landscape in which high horizontal and vertical variability in overburden, subsoil, and topsoil texture would occur. In general, this high variability would be expected to occur in small, random areas, with general homogenization of the soil types over the large area resulting.

Loamy soils, which presently occupy 44 percent of the disturbed land area, would make up an estimated 58 percent (by volume) of the soils placed on the post-mined land area. Sandy soils would decrease from 44 percent to 36 percent of the land area after mining. Clinker soils would decrease from eight percent to four percent after mining, and unbaked shale and siltstone soils would decrease from four to one percent.

Overburden textures tend, overall, to be moderate, however, relatively thick zones exist in topographically high positions with high sand content (greater than 70 percent) (see Geology, Technical Support Document). Also, some thin lenses of clayey textures with clay contents exceeding state suspect levels of 40 percent exist, however, these are generally isolated, thin strata. If the high sand content overburden material was to end up at the surface of the overburden without mixing, it could create a droughty condition for many plants, especially shrubs and trees. If clayey material was to end up on the overburden surface, it could restrict water movement and rooting depth, which could reduce the vigor of some species and increse the survival of other species with no easily generalized impact.

The alteration in soil types would decrease the overall water storage capability of the landscape by decreasing infiltration. Surface

erosion can be expected to increase, especially during the high-intensity rainstorms characteristic of the region.

Shallow-rooted, cool-season grasses could be anticipated to dominate the reclaimed plant community because of their higher adaptability to a wide variety of soil conditions. This would reduce the management options and potential diversity of grazing systems in the post-mined area, especially when compared to the pre-mining potential. Without special management or soil handling, ponderosa pine and skunkbush sumac plant communities may not be able to compete for limited soil moisture to form self-sustaining stands.

3. Chemical Impacts

Soils would be replaced on the reshaped landscape to an average depth of 2.8 feet. Accordingly, the lower part of the rooting profile would be composed of overburden. Presently, approximately half of the soils of Area C, Block I have low soluble salt contents (electrical conductivities of less than 1.0 mmhos/cm) within a five-foot profile, while other soils, especially loamy and clayey soils near drainages, have moderate to high salt contents (electrical conductivities of 6 to 20 mmhos/cm) in the lower portions of their profiles. On the reclaimed landscape, mixed, regraded overburden with moderate salt content can be expected to prevail. This would result in a moderation of the extremes of osmotic stress encountered by vegetation in the area. Shrubs such as sagebrush species and woody plants common to riparian areas, would encounter improved condition within their broad salt tolerance ranges; whereas some salt intolerant species, such as ponderosa pine or skunkbush sumac, may exhibit reduced growth or vigor due to the salt content of the overburden (Stark, 1982).

Although some degree of overburden mixing can generally be assumed, this does not preclude the possibility of unmixed material occurring near the surface in some areas. As indicated in studies by Dollhopf et al. (1981), the intensity of overburden sampling in Area C, Block I (average drill hole spacing 1,600 feet) can be used to predict the character of overburden with only 45 to 60 percent confidence, and gives even less indication of values that may occur at any horizontal or vertical location in the replaced overburden.

All that can be stated with confidence using the overburden data from Area C, Block 1 is that the trace elements exceeding state suspect levels found consistently in the overburden holes do occur in the area to be mined, with no conclusions possible as to their presence or absence in other, unsampled overburden. Trace elements not found in exceedance levels in the overburden sampling are not necessarily absent in the unsampled overburden.

Overburden commonly exceeds DSL suspect levels for nickel, molybdenum, and electrical conductivity. Cadmium and manganese exceedances occur in a limited number of samples. Zinc and lead exceedances have been linked to contamination by pipe joint grease and are unreliable.

Table III-14 shows the relationships of the 27 overburden holes in Area C, Block 1 to the exceedance values identified in sampling.

Although no predictions can be made regarding the location or distribution of exceedance values in replaced spoils, Dollhopf et al. (1981) found that if materials containing exceedances were five percent or less of the total overburden sampled, they were not detectable in the spoil pile. Thus, it is unlikely that cadmium or manganese would be found in the regraded overburden to an exceedance level. Material occupying 5 to 15 percent of the overburden could not be detected half of the time (such as electrical conductivity), and material with exceedance values that occurred more than 15 percent of the time in the overburden would always be found in the spoil pile, generally diluted to some extent from their pre-mine concentration. Therefore, the overburden properties most likely to be found in concentrations exceeding DSL suspect levels in the reclaimed spoils include soluble salts (electrical conductivity), nickel, and molybdenum.

Soluble salt level (electrical conductivity) is of concern in the rooting zone because it can increase moisture stress in plants. Ponderosa pine have been noted as being less vigorous and able to regenerate in soils with moderate to high soluble salts (Stark, 1982). In general, the soluble salt level in a majority of the existing subsoils is higher than the amounts that can be expected in the regraded overburden.

Nickel is of concern in the rooting zone because it may interfere with plant physiological functions, especially iron uptake (Torrey, 1978). This effect may not be apparent because of the 2.8 feet of topsoil in which most plants will have their roots, however if iron chlorosis does appear in the revegetated area, amelioration with supplemental fertilizers would be possible.

Molybdenum is of concern when it occurs in forage and is consumed by ruminants such as cattle and sheep. Little has been quantified about how much molydbenum, as measured by acid-ammonium oxalate extraction in the soil, will occur in forage. It is known that legumes tend to concentrate molybdenum, and that most of the high molybdenum forage found naturally occurs in poorly drained soils (Kubota, 1977). Molybdenum causes copper deficiency reactions if the forage in which it occurs makes up a significant part of an animal's annual diet (Hornick et al., 1977). If excessive amounts of molybdenum were to occur in the near-surface spoils, the limited cover of legumes to be established on the post-mine surface and the likely limited areal extent of such excessive concentrations would probably limit the percentage of molybdenum-rich forage. This would mean that a minor portion of a grazing animal's diet in the area would include these forage sources, and so molybdenum would likely not be a cause for concern. Due to the unpredictability of unsampled overburden and the many unknowns involved in the uptake process (Lindsay, 1979), the only way to quantify this impact would be to measure levels of molybdenum in forage growing on the reclaimed surface and compare that to molybdenum concentrations in the pre-mine vegetation, pre- and post-mine soils, and root zones.

TABLE III-14

OCCURRENCE OF LEVELS OF EXCEEDANCES IN OVERBURDEN

AREA C, BLOCK I

	Electrical Conductivity	Nickel	Molybdenum	Cadmium	Manganese
Number of Holes with Exceedances	12/27	19/27	21/27	4/27	--
Percentage of Sampled 5' Intervals Containing Exceedances	10%	30%	29%	4%	5%
Suspect Level	4-6 mmhos/cm	1.0 ppm	0.3 ppm	0.1-1.0 ppm	60 ppm
Exceedance Values:					
Mean	6.8 mmhos/cm	1.9 ppm	0.46 ppm	0.88 ppm	80.5 ppm
Range	4.03-11.4 mmhos/cm	1.01-7.6 ppm	0.3-3.6 ppm	0.1-3.9 ppm	61.4-124.0 ppm

Exhibit 3

4. Agricultural Potential

Although loamy soil acreage would be increased over the whole area, sandy and loamy soils would be placed indiscriminately on the landscape. Sandy soils would not be placed in drainages or on slopes exceeding ten percent, as required by DSL. Previous cropping success has been limited to large areas of loamy and clayey soils that could be managed in a similar fashion. Cropping success has been sporadic on sandy soils due to low water availability. The patchy intermingling of loamy and sandy soils on the post-mined landscape would reduce the potential for crop production.

5. Area C, Block II

In the life of mine area, Block II, the proportion of loamy and clayey alluvial soils is greater, compared to other soil types, than in Block I. This soil group has the highest potential for subsoil layers containing excessive soluble salts, which might limit salvage depths. There is a possibility, therefore, that the overall depth of soils suitable for replacement on regraded surfaces may be less than in Block I. The overall higher clay contents in the soils of Block II could also result in a greater tendency for compaction during replacement.

G. VEGETATION

Existing vegetation on approximately 1,627 acres of land in Area C, Block I would be destroyed, beginning with construction of facilitites and continuing as mining progresses. For all of Area C, the amount of vegetation destroyed would be about 7,900 acres.

Through reclamation procedures planned for Block I by Western Energy, vegetation would be restored to the entire disturbed area. The revegetation effort should result in plant communities consisting primarily of native species. The seed mixtures that Western Energy plans to use are made up of native plants (Appendix G, Table 2) with the exception of four species, cicer milkvetch (Astragalus cicer), sanfoin (Onobrychis viciaefolia), Kentucky bluegrass, and Canada bluegrass (Poa compressa). Woody species would be included in the seed mixtures, and in addition, trees and some shrubs would be planted as tubeling transplants. A tree spade would be used to transplant approximately 50 larger trees. Stocking rates for ponderosa pine (Pinus ponderosa) and Rocky Mountain juniper (Juniperus scopulorum) are to be equivalent to pre-mine conditions with an allowance for expected mortality.

The success of revegetation efforts takes several years to judge because of the many factors that enter into the dynamics of community establishment. Most of the revegetation efforts of sufficient age at the Rosebud Mine for analysis used mixtures of introduced and native and introduced species. In these areas, forage production has been almost double that of the pre-mine vegetation; however introduced cool-season grasses have dominated the community to the exclusion of many warm-season grasses, perennial forbs, or shrubs (DePuit et al., 1980). No areas have been completed using the two-phase seeding approach proposed for Area C, Block 1. One study area for native plant establishment techniques was established in 1977, and has shown positive results for both broadcast and drill seeding techniques and several levels of seed application and species mixes (DePuit et al., 1980). It is probable that a protective cover of vegetation can be established on the post-mine area with forage productivity higher than pre-mine levels. It is not certain whether all of the criteria for bond release, however, would be met, as this has yet to occur in Montana.

While overall success of the revegetation plan would be expected, post-mining vegetation would vary considerably from the pre-mining plant communities. These impacts are as follows:

- Rangeland forage production is likely to exceed pre-mining production as forage grass species become dominant providing weather is favorable and proper management is applied to the area. This would not happen immediately, but is expected to occur within five to ten years after final seeding, following an initial flourishing of annual grasses and weedy species.

- Increase in forage production should be in the range of 25 to 50 percent. This assumes that Western Energy would follow a deferred rotation grazing system and proper grazing use after

vegetation is well established and that root-inhibiting compacted layers are not created during overburden grading or soil replacement operations. (See discussion, Section F.)

- The amount of land in rangeland vegetation would be greater than in the pre-mining state because the disturbed hayland and pasture acreage would be revegetated with native species. Tame pasture and hayland would be reduced from 334 acres to 104 acres after mining. This would result in a reduction of about 250 tons of hay annually, and the loss of some early spring grazing. These losses would be partially offset by increased acreages of range for forage production.

- Post-mining sites would probably have less vegetative diversity than pre-mining sites, particularly on areas reclaimed with stockpiled soils. Lack of commercial seed sources for some species, particularly forbs, may prevent their initial establishment on reclaimed areas. Diversity should increase with age in the reclaimed area due to infilling from adjacent natural seed sources. The rate of increase in plant diversity by invasion from undisturbed plant communities will be a function of the reclaimed area's proximity to the undisturbed areas and the natural plant species propagule dispersal mechanisms, and the availability of suitable micro sites.

- The frequency of some of the grasses and shrubs species dominant before mining would be reduced under the proposed reclamation plan. This would be especially true for increaser species that had assumed dominant positions due to historical use patterns. The impact would be generally favorable in that the reduced occurrence of these species would more nearly reflect the potential climax community.

  Grasses - Prairie junegrass, found in pre-mining communities with frequencies of 30 to 70 percent, would be significantly reduced. This species is not included in any of the proposed seed mixes due to the unavailability of commercial seed, so its occurrence on the reclaimed surface would depend upon natural regenerative processes.

  Needle-and-thread grass occurs with a 70 percent frequency in the pre-mined grassland and skunkbush sumac communities. Seed for this species is included in the suplemental seed mix and so it is anticipated to be present in all reclaimed areas, but with a lesser frequency than in the pre-mined sites.

  Shrubs - The overall acreage of shrub cover will be reduced by about 33 percent. Within these acreages, it would be likely that the frequency of shrubs would be reduced to less than in the pre-mine shrub acreages because of increased competition from reseeded grasses. Table III-15 compares the acreage of pre-mine vegetative communities with acreage proposed for reestablishment in reclaimed areas. As the table shows, the major decrease in shrub species will occur in the

TABLE III-15

CHANGE IN VEGETATIVE COMMUNITIES
BEFORE AND AFTER MINING
AREA C, BLOCK I

General Vegetation Type	Acreage to be Disturbed	Post-Mining Acreage After Reclamation
Grassland	631 acres	1,345 acres
Big Sagebrush/Grassland	87	78
Silver Sagebrush/Grassland	77	19
Skunkbush Sumac/Grassland	72	60
Rubber Rabbitbrush/Grassland	4	2
Ponderosa Pine/Grassland	135	60
Cropland	376	60
Hayfield and Pasture	230	0
Areas Generally Devoid[a] of Vegetation	15	3

[a] In pre-mined areas this includes clinker pits, rock outcrops, and ranch yards. In post-mined areas this includes recreated sandstone "knobs."

silver sagebrush and skunkbush sumac types. All of the acreages presented in Table III-15 assume successful revegetation and do not include natural invasion of shrubs into post-mined areas. This is not meant to imply that invasion of shrub species may not occur, rather that it is not known to what degree this may happen.

- The area and distribution of ponderosa pine communities would be reduced: 180 acres of this vegetative type will be disturbed by mining, and only 60 acres are proposed to be planted with ponderosa pine. With complete revegetation success, only 55 percent of the disturbed ponderosa pine type would be replaced. To date, the establishment of conifers on scraper-hauled and regraded spoils at Colstrip has not been successful to the point that would indicate that stands of trees equivalent to pre-mine density could be established by the reclamation methods proposed by Western Energy. Researchers working at Colstrip (Richardson, 1981; Stark, 1980) have generally agreed that competition for soil moisture between trees and grass is the chief factor affecting survival of ponderosa pine seedlings and transplants, as well as other woody species. The reconstructed soils, due to their loamy and bulk densities, favor moisture uptake through the extensive shallow fibrous root systems of grasses, giving these plants the competitive advantage over the deeper root systems of woody species (see Soils, Section F).

- Discrete range sites presently existing in Area C, Block I would not be restored in the reclamation process due to mixing of soils. This would constitute the loss of potential for separate and distinct plant communities inherent in the existing range sites, and the spatial, seasonal, and species diversity presently found in the area.

Western Energy has not submitted specific reclamation plans beyond Block I for Area C but, it is assumed that revegetation efforts would be subject to similar influencing factors described in Block I. Future reclamation plans would incorporate results from revegetation experience and studies on earlier reclaimed mined areas. Post-mining revegetation conditions would probably approximate Block I, but would reflect the specific reclamation plans and climatic and soils conditions under which the plans are implemented (see Sections F and G, Chapter III).

H. WILDLIFE

In general, the significant areas of concern for impacts pertain to disturbance to especially valuable habitats or features. Most notably, these include: the prominent sandstone outcrops/cliffs that have historically served as nesting habitat for several raptor species, including the golden eagle and prairie falcon; the wooded and shrubland habitats, which provide nesting sites, and forage and shelter; and perennial and seasonal sources of surface water available to wildlife. Two specific sites of special concern exist in Area C, Block I: a golden eagle nest site and a sharp-tailed grouse dancing ground. The U.S. Fish and Wildlife Service has recommended that the sandstone outcrop on which the golden eagle and prairie falcon nests are located not be destroyed (U.S.F.W.S., 1981). Also, DSL has requested a 100-meter buffer zone be left between the outcrop and the mine. Western Energy is continuing its sponsorship of mitigation investigations on sharp-tailed grouse, particularly dancing ground reestablishment. The anticipated mining pattern for the Area C, Block II life of mine would eliminate the sandstone cliff nesting sites as well as two sharp-tailed grouse dancing grounds. These nesting sites and dancing grounds may have regional importance to the raptor and sharp tail grouse populations.

Legal and illegal hunting, wildlife vehicle collision mortality, and other human-wildlife interactions could be expected to increase with new and expanded development. Thus, a somewhat greater disturbance from human presence, including vehicle collisions with wildlife, could be expected in the immediate Area C vicinity as mining begins. No impacts to wildlife are expected as a result of the location and operation of the conveyor. Except for one mile, the conveyor corridor is located in areas already disturbed by mining.

Nearly all of the area to be disturbed by the Area C mining operation currently serves as habitat for a variety of wildlife. The reclamation plan would alter the proportions and composition of habitat types somewhat. Some of these changes would be neutral to beneficial if realized, but others, especially the reduction of ponderosa pine and shrublands by more than 50 percent, would represent long-term negative change. A reduction in the overall diversity of available habitats can generally be expected to be reflected in reduced wildlife diversity. Pre- and post- mining vegetation types are compared in Section G, Vegetation. The following sections discuss the noteworthy mining impacts to wildlife groups in the vicinity of Area C.

1. Big Game

During the years of active mining, active mine areas may be less suitable for big game. However, the relatively low big game populations in the area in recent years and availability of alternative habitat in adjacent, undisturbed areas suggest that this impact may not be a significant limiting factor.

Because of the importance of ponderosa pine and shrub habitats to mule deer, the unknown efficacy of efforts to reestablish these habitats

after mining, and the proposed reduction of the ponderosa pine type on the area, suitability of the area for mule deer use is expected to be somewhat decreased by the proposed action. Reduction of sagebrush-grassland may make the area less suitable as pronghorn habitat.

Finally, habitat surrounding Area C is comparable to Area C, and may serve as alternative habitat. No evidence is available suggesting that deer or antelope populations in the area are presently limited by available habitat or food sources, so Area C does not appear to be critical to the welfare of deer and pronghorn in the study area.

2. Other Mammals

Although Area C mining activities would temporarily eliminate small mammal populations in the disturbed area, there is no indication that any especially sensitive species of small mammals would be affected by the mining operations. To the extent that the general small mammal population is important as a prey base for raptors, this prey base would be reduced until a diverse, stable vegetative community, adequate to support the kinds and numbers of small mammals present now, is re-established. Limited studies in various Colstrip area habitats, including reclamation sites, suggest that small mammal populations may be larger, though less diverse, at least in the early years of reclamation. However, the alteration of the proportions of various habitats could affect the relative attractiveness of the area to the different small mammal species. This is particularly true of species such as porcupine and chipmunks, which are associated with wooded and shrubby habitats; and rabbits and marmots, associated with rocky microhabitats.

3. Mammalian Predators

Mining in Area C, Block I would temporarily render disturbed areas unsuitable for mammalian predators because of the lack of prey and proximity to human activity. It is not certain how successful the plans for revegetation will be in supporting a prey base similar in numbers and diversity to that now on the site. Therefore, it is not known which predators will return to the area.

The coyote is the most common mammalian predator in the area, but since the coyote doesn't appear to be habitat- or food-limited in the area, the habitat loss asociated with disturbance of Area C development should not significantly affect local coyote populations.

4. Upland Game Birds

One sharp-tailed grouse dancing ground may be disturbed by haul road construction and use. Feeding and nesting habitat near this dancing ground would also be reduced. It is uncertain what effect the reduction in feeding and nesting habitat and the disturbance to the dancing ground will have on sharp-tailed grouse in this local area. Western Energy will attempt to replace the dancing ground in Area C if it is abandoned during the mining operations.

Other upland game birds, such as ring-necked pheasant, Hungarian partridge, Merriams' turkey, and sage grouse are infrequent in Area C and are thus not likely to be significantly affected by the Area C mining operation.

5. Waterfowl

Waterfowl nesting and feeding habitat in Area C would be reduced during active mining. Reclaimed areas should replace this loss. Mining would not be expected to have appreciable impact on waterfowl species.

6. Songbirds

The revegetation program would alter the relative proportions of songbird habitats in the disturbed area. A reduction of shrub and woodland bird species would be expected. For example the impact to cavity-nesters would be long-term.

7. Raptors

One golden eagle nest, which was active in 1978, has been documented in Area C. Golden eagles are regularly sighted, especially in the spring, in and near Area C (ECON, 1975, 1976, 1977, 1978, 1979; Western Energy, 1980). Eagles are protected by the Bald Eagle Protection Act of 1940 as amended in 1962 (16 USC 668a), which prohibits "taking" of eagles or their nests, active or inactive. "Take" is further defined as "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, or molest or disturb" (16 USC 668a). The Block I mining plan does not propose to physically disturb the nest site itself. The U.S. Fish and Wildlife Service has not yet determined whether or not the proximity of proposed mining activities to the nest site would constitute a disturbance within the definition of the law.

No specific studies have been conducted on hunting territories and food habitats of the golden eagles in the Colstrip area. Studies by Tyus and Lockhart (1979) suggested that breeding territories range from about 10 to over 20 square miles. Important food sources for golden eagles include rabbits, marmots, grouse and other species.

In addition to the possible reduction of hunting territory, the more direct threat of nest abandonment from direct disturbance exists. The sensitivity of raptors to disturbance varies tremendously between species and between individual pairs of the same species. Golden eagles and prairie falcons are both considered sensitive to human disturbance (Call, 1978).

Block I mining would also destroy some nesting and hunting habitat for other raptors, including a localized long-term reduction in mature ponderosa pine nest sites. Several of the raptors observed in Area C are

of both state and federal concern (Flath, 1981; Spear, 1980). Although present evidence is not adequate to assure revegetation would produce a raptor prey base comparable to present conditions, the area disturbed by Block I mining would be relatively small compared to the normal hunting range of most raptors in the area. It is not known whether a displacement of hunting territory out of the mine area will affect nest success.

8. Reptiles and Amphibians

Few reptiles and amphibians would be affected by mining in Area C. Hognose snakes (Heterodon sp.), of special concern in Montana (Flath, 1981), may be present, but this is not certain, as no special reptile surveys have been conducted. Rattlesnakes and other predatory reptiles would return to the area as reclamation progressed and prey populations began to recover in revegetated areas. Microhabitat changes, particularly reduced availability of rock habitats and winter denning areas after mining, may inhibit repopulation of reptiles.

9. Threatened and Endangered Species

No threatened or endangered species have been identified for Area C, Block I. If threatened or endangered species are found in or adjacent to Area C, consultation with the U.S. Fish and Wildlife Service would be undertaken and mitigation taken as necessary in compliance with the Endangered Species Act.

I. SOCIOLOGY AND ECONOMICS

1. Economic Condition

a. Employment and Population

Annual impact employment projections for Rosebud County and Colstrip are presented in Table 19 (Appendix I). Similar quarterly data is exhibited in Table 20 (Appendix I). As indicated by these tables, the impact employment in Rosebud County and Colstrip associated with the Area C work force addition peaks during the second quarter of 1983. However, when this additional work force is added to the baseline forecast, shown in Tables 10 and 11 (Appendix I), total employment in Rosebud County and Colstrip peaks the fourth quarter of 1982. Annual baseline and impact employment peaks in 1983 at 8,168 in Rosebud County. Projected county employment declines to 5,940 in 1985, stabilizing through 1995, and then rises to 6,596 in 2010. Area C increases the baseline county employment projections by 4.8 percent in 1983, 6.0 percent in 1990, and 5.8 percent in 2000.

In comparing 1982 and 1983 annual and quarterly peaks, it is important to note the differences between quarterly peaks and annual peaks. Annual data indicate that the peak baseline and impact population occurs in 1983 rather than 1982. When analyzed quarterly, peak baseline plus impact employment and population occurs during the fourth quarter of 1982, stabilizes through the second quarter of 1983, and then declines sharply during the third quarter of 1983. Although dependent on current construction schedules and nonlogged responses, the available data indicates that peak populations will begin during the last half of 1982 and extend through the first half of 1983.

The Area C addition is expected to result in about 210 new basic jobs between 1985 and 2010. These new jobs are projected to result in about 130 nonbasic, or derivative jobs for a total employment gain in Rosebud County of about 340 positions, or approximately six percent of projected baseline employment. The employment (basic/nonbasic) multiplier for the impact scenario is about 0.6, lower than that projected for the baseline conditions. This is because the basic impact employment includes nonlocal miners and construction workers and government services were not expected to expand much as a result of the Area C expansion.

The impacts of permanent mining and temporary heavy construction employment were treated separately in this analysis. Temporary heavy construction employment related to the proposed mining activities in Area C, Block I was assumed to have no effect on derivative employment in Rosebud County. The existing work force in trade and services was assumed to assimilate the additional temporary impact. Mining employment, on the other hand, was assumed to have an effect on support sector employment. Retail and service employers in the area were assumed to regard mining employment as long-term and to expand or build new facilities to accommodate the enlarged economic base.

Colstrip's annual impact and baseline population is expected to peak in 1983 at 7,259 persons. This figure, when compared with the 1982 fourth quarter peak of 8,205, emphasizes the importance of quarterly analysis. Annual peak 1983 employment and population for Rosebud County, including both baseline and impact forecasts, are 8,168 and 16,419 persons, respectively compared to the 1982 fourth quarter peak figures of 8,770 and 17,570 persons.

Population impacts for the temporary heavy construction work force in Area C, Block I were also assumed to be different from those for the more permanent mining work force. The projected impact work forces were residency-adjusted before the population impacts were computed to account for out-of-Rosebud County and out-of-Colstrip commuting. It was assumed that 30 percent of the construction work force and 37 percent of the mining work force would commute into Colstrip. Ten percent of the mining work force and 15 percent of the construction work force were assumed to commute into Rosebud County (Edwards, Reardon, Spiegel, Tomasik, 1982).

Population projections for Rosebud County and Colstrip are shown in Tables 19, 20, and 21 (Appendix I). Baseline and impact projections parallel those for employment, mentioned above. Rosebud County population is projected to peak during the fourth quarter of 1982 at 17,570. Annual population is expected to peak at 16,415 during 1983. It is projected to decline to 12,191 in 1985, and stabilize through the year 2000. Area C expansion will add between 5.5 and 5.8 percent to the projected county baseline population after 1985.

The population of Colstrip would be expected to peak at 8,205 residents the fourth quarter of 1982. About 60 percent of these residents would be temporary. Of the peak 1982 population, approximately 540 (about seven percent) would be attributable to the Area C expansion. The Colstrip population would remain at a relatively high level (8,096 residents) until the second quarter of 1983, when it would begin to decline. The maximum population attributable to Area C would occur at this time and would comprise about 816 persons (about ten percent of the total population). The latter population contribution would occur as the construction crews for generating Units 3 and 4 are declining and would slightly reduce the rate and prolong the period of population decline in Colstrip. The Area C operations would contribute approximately 250 permanent residents to the Colstrip population by late 1983. The total population of Colstrip is expected to stabilize at about 3,700 residents by 1985 or 1986, when all planned construction has ceased. At this time, the population attributable to the proposed operations at Area C, Block I would be about 12 percent of the total resident population.

b. Personal Income

Table 22 (Appendix I) presents mining and construction income, Montana personal income tax payments, and the Area C, Block I, work force for the forecast period 1982 to 2018. Total labor and proprietors' income in Rosebud County would increase as a result of the Area C expansion. In 1980 dollars, Area C would increase Rosebud County labor and

proprietors' earnings from a low of about 2.6 percent in 1982 to a high of about 11.2 percent in 2010. The continued industrialization of Rosebud County is not expected to significantly increase labor costs to local businesses. Also, the 1970-1979 trend in wages is consistent with local persons filling many of the new jobs (Polzin, 1981).

2. Social Life

The social impact of the population increase attributable to the Area C, Block I mine operations would be small in the context of the sizes of the total and transient populations induced by all development in Colstrip. Additional burdens would be placed upon some already overextended social and community service programs (e.g., formal recreation programs, shopping); these additional burdens will reduce the availability of such services and reduce the quality of social life to some unmeasured degree. The proposed project also would slightly prolong the period in which transient residents comprise a significant proportion of Colstrip's population. According to area informants, the presence of large numbers of transients within the Colstrip population inhibits the development of a community identity. The persons brought to Colstrip by the proposed project would be very similar to the present residents of Colstrip. As such, they are likely to share similar values, patterns of social interaction, and recreational habits. Their occupations and pay scales would also be identical to those of many present residents of Colstrip. Given this similarity, the impact of the proposed project upon the social life of Colstrip is expected to be minimal. The determination of minimal impact is based upon the similarity of newcomers and with consideration of the context of existing social life in Colstrip. That context is of an unstable social life for many, with relatively few of the social amenities many people have come to expect, a large proportion of people considered to be (and who consider themselves to be) transient, and widespread feelings of powerlessness, rootlessness and anonymity.

3. Social and Community Services

a. Law Enforcement

The Rosebud County Sheriff has indicated that anticipated population growth induced by the construction of Colstrip Units 3 and 4 and the Area C, Block I mine might require the addition of one deputy and one secretary to his Colstrip staff (Ash, 1982).

b. Fire Protection

The additional Colstrip population attributable to the proposed project would not be expected to have a significant impact upon the provision of fire protection services.

c. Sanitary Sewer

The additional Colstrip population attributable to the proposed project would not be expected to have a significant impact upon the local sanitary sewer system.

d. Water Supply

The additional Colstrip population attributable to the proposed project would not be expected to have a significant impact upon the local public water supply.

e. Solid Waste

The solid waste load is projected to increase about seven percent as a result of Area C. Solid waste collection capacity in Colstrip is adequate to serve projected peak populations. The capacity of the area waste disposal site is adequate for present and projected populations.

f. Social Welfare

The increase in population attributable to the proposed project would not be expected to have a significant effect on the provision of social welfare services in Colstrip.

g. Medical Services

Existing medical services and resources are inadequate to meet the present Colstrip residents' needs as well as the added population brought in by the proposed project according to the Montana Health Systems Agency. Mental health services are considered to be overextended at present; therefore, additional population growth would further aggravate this situation. Many rural communities in Montana also are similarly underserved and are apt to remain so because of their small populations and distance from major medical facilities. No specific estimates of the type of medical or other health manpower are available for Colstrip's projected peak populations. The difficulty of recruiting health manpower and the expense of health/medical facilities make it unlikely that the problem will be resolved in the near future, and certainly within the projected peak population period.

h. Housing

Table 23 (Appendix I) contains projections of housing demand in Colstrip as a result of the proposed project. The proposed project would create a 12 to 14 percent increase in Colstrip housing demand through 2010. Although the maximum housing demand of 295 units would be projected to occur in the third quarter of 1983, when reviewed in combination with the baseline projections, the maximum total housing demand of 2,943 units would be projected to occur in the fourth quarter of 1982. Peak housing demand would be projected to exceed the proposed housing unit supply by 60 units. This would not be considered problematic because of the possibility that more "doubling up" may take place

than is anticipated, or the schedule may lag, causing the projected fourth quarter housing impact to be delayed until early 1983, when the baseline housing demand would be smaller.

i. Education

Table 24 (Appendix I) shows the current and projected elementary (kindergarten through eighth grade) and high school (grades nine through twelve) enrollment in Colstrip School District #19 by year through 1985 and in five-year intervals thereafter to the year 2000. The increase in enrollment attributable to the proposed project is also identified in the table. During the next two years, elementary and high school student enrollment would be expected to increase substantially, with the addition of 496 new elementary and 192 high school pupils, primarily due to the anticipated increase in the size of the Colstrip Units 3 and 4 work force. Thereafter, school enrollment would decline and then stabilize in 1985; with a total of approximately 1,100 students, of whom about 30 percent will be in high school and the remainder in grades kindergarten through eight.

The increase in enrollment attributable to the proposed project would be small. Starting in 1982 with 56 students, the enrollment increment would increase to 143 students by 1985 and then stabilize at that general level thereafter.

With the completion of the new Pine Butte Elementary School by September 1982, the Colstrip school district would have sufficient capacity to educate all students attrbutable to Area C expansion and projected to reside in the area. Through 1984, there will be a continuing need for the modular, wood-frame classrooms that currently serve as the Pine Butte School. Thereafter, the new Pine Butte and Isabelle Bill Schools would have sufficient capacity for all elementary students. Also, the current high school facility can accommodate the projected enrollment increase. Given the small size of the existing high school classes there appears to be little need to add teaching staff at the high school level. Additional space for secondary students would be available in the fall of 1983 with the completion of the proposed new Colstrip High School.

4. Public Finance

The proposed project would add significantly to the taxable value for the county and both school districts.

The forecasted impacts of the proposed project on the fiscal condition of Rosebud County are presented in Table 25 (Appendix I). It should be noted that property taxes on non-Area C, Block I property are expected to decrease as the total taxable value of the county is increased by the Area C, Block I coal production and ancillary equipment. The net effect on taxable value in the county due to the two primary taxable components of the mine expansion, capital investment and gross proceeds,

is shown in Table 26 (Appendix I). The peak increase in taxable value due to Area C occurs in 1990. However, Table 27 (Appendix I) indicates that Area C constitutes an increasingly greater percentage of county taxable value through 2015 as the baseline taxable value diminishes. The increase in a given year in total taxable value under the balanced budget scenario forces mill levies down below those projected under the baseline scenario.

The net effects of the Area C expansion on Rosebud County local revenues and operating expenditures are shown in Table 28, Appendix I. At most the proposed expansion would result in an increase of approximately six percent in either operating expenditures or local revenues.

The projected impacts on the two school districts are shown in Tables 29 and 30 (Appendix I). Revenue and expenditure patterns similar to those occurring in the baseline projections are expected. However, revenues and expenditures are somewhat higher for the reasons discussed above. Mill levies in the balanced budget scenarios are somewhat lower, due to the effects of the Area C expansion on taxable value in the school districts.

The forecasted impacts of the proposed project on the Colstrip townsite finances are presented in Table 31, Appendix I. The net effects of the Area C expansion on local revenues and operating expenditures in the Colstrip townsite, as presented in Table 32 indicate that at most the proposed expansion would result in an increase of approximately 13 percent in either local revenues or operating expenditures. The influx of workers into the townsite would not be expected to significantly affect the level of services required, or the overall fiscal condition.

In addition to creating additional revenues for the local taxing jurisdictions, the Area C expansion would result in the payment of approximately $189 million (1980 dollars) in federal royalties, roughly half of which would be returned to the state, and payment of approximately $318 million in Montana coal severance taxes (Table 33, Appendix I).

J. LAND USE

1. Direct Impacts

The major direct impact on land use in Area C, Block I would be the addition of 1,627 acres of mining disturbance at the Rosebud Mine, which represents an increase of about 59 percent over the current disturbance at the Rosebud Mine complex. The change in land use patterns in Area C, Block I is presented in Table III-16.

Livestock grazing would be precluded on 1,006 acres (less than 0.04 percent of available rangeland in Rosebud County) during active mining and intial reclamation. After vegetation is reestablished (about three years after seeding, providing natural conditions warrant), limited grazing under the planned pattern can begin (see Section G, Vegetation). The planned deferred grazing pattern would continue until bond release (a minimum of ten years), after which normal ranching operations could resume.

Vegetative productivity would fluctuate during intial vegetation establishment due to such factors as early rapid growth from seeding operations and subsequent natural changes in species composition as the vegetative cover stablizes. Actual post-mining productivity under proper management would probably be higher than pre-mining levels (see Vegetation, Section G).

The amount of cropland that would be displaced by the proposed plan (about 606 acres) amounts to about 0.5 percent of the total cropland in Rosebud County. Since the cropland in Area C, Block I would be reclaimed as rangeland, (with the exception of about 60 acres disturbed by facilities, topsoil stockpiles, and haul roads that would be returned to cropland), this acreage would be unavailable for use as cropland until after bond release, at which time surface owners could put the reclaimed land to other uses. The suitability of irrigating cropland in the vicinity of Area C, namely along Stocker Creek and East Fork Armells Creek, could be diminished by mining activities if water quality were adversely affected (see Section B, Hydrology). This could affect about 1,825 acres of land in Area C that is potentially irrigable (Hydrometrics, 1981), although most of this acreage is not irrigated at present due to insufficient flow during the majority of years.

All projected mining and power generation in Rosebud County would displace livestock grazing on about 24,000 acres (less than one percent of the available grazing land in Rosebud County (Montana Department of State Lands, 1981). Mining activity in Area C, Block I would contribute to less than four percent of the total displacement. Similarly, the total projected acreage of consumed cropland due to mining and power generation in Rosebud County is about 800 acres (0.6 percent of the available cropland in Rosebud County) (Montana Department of State Lands, 1980). Mining activity in Area C, Block I would contribute to about 75 percent of the total consumption.

TABLE III-16

SUMMARY OF LAND USE IMPACTS
IN AREA C, BLOCK I

Land Use Category	Present Use	Use During Active Mining (1982-1987)	Post-Mining Land Use (After Reclamation)
Rangeland			
Grassland and Shrubland	1,724	853[a]	2,360
Ponderosa Pine	180	45	105
Cropland			
Grain Fields	436	60[a]	120
Hay Fields	334	104[a]	104
Mining Disturbance	0	709	0
Mine Facilities and Associated Disturbance	0	918	0
Other Land (Sandstone outcrops, clinker pits, and abandoned ranch yard)	19	4	4
	2,693 acres	2,693 acres	2,693 acres

Most of the county-wide displacement of rangeland would be temporary, except for about 890 acres that would be permanently converted to urban and industrial uses (Montana Department of State Lands, 1981). The proposed project in Area C, Block I would not be expected to contribute significantly to the increased urban and industrial land use, the bulk of which is due to the construction and operation of Colstrip generating Units 3 and 4.

Long-range changes in land use could occur with additional mining activity subsequent to the development of Area C, Block I. (See Sections F, G, and H, Chapter III.)

The conveyor corridor would cut through the cropped lands located inside the Area A loadout facility railroad loop. Approximately 70 acres are currently irrigated and produce approximately 2.0 tons of hay per acre annually. The corridor would occupy only 6.5 acres, but could prclude the irrigation on all or a portion of the remaining 63.5 acres for the life of the conveyor facility.

2. Indirect Impacts

The Colstrip Townsite Expansion Master Plan calls for increased housing, facilities, streets, and parks to meet the demands of power plant construction (Units 3 and 4) and coal mine expansion (Rosebud County Planning Board, 1980). This land use plan is expected to adequately incorporate population increases that could result from the development of Area C (see Section I, Sociology and Economics).

No adverse impacts are anticipated to federal planning as it pertains to the BLM's management Framework Plan.

K. TRANSPORATION

Development of Area C would bring in a maximum of about 302 workers during the construction phase, and a maximum of about 228 workers during the operation phase (see Section I, Sociology and Economics). Of these workers, approximately 30 percent would be expected to live outside Colstrip and commute into the area. During the construction phase, approximately 100 workers would be commuting into Colstrip, with about 40 workers living outside Rosebud County. Assuming that 50 percent of the workers would car pool, and 25 percent of those workers living in Billings or Miles City would use commercial bus service to Colstrip, the resulting traffic increase would be about 65 additional vehicles per day using FAP 37 and/or FAP 39 (or 33 additional vehicles along any given segment) distributed over three shift changes (Table III-17). Similarly, estimated traffic increase during the operation phase would be about 57 vehicles per day (or 28 additional vehicles along any given segment). These increases are less than five percent of current daily traffic levels, and should not have any significant impact, particularly with the completion of the proposed highway reconstruction (Rice, 1982). With the completion of Colstrip generating Units 3 and 4, traffic levels should decrease substantially.

Rail capacity would not be affected because all coal recovered in Area C would be transported to the Colstrip generating units by conveyor. The coal conveyor would undercross the county road, thereby causing no traffic interference.

The proposed plan would necessitate the permanent relocation of about four miles of the East Fork Castle Rock County Road (R140) to about 0.5 mile north of its present location, and about two miles of the East Fork Armells Creek County Road (R141) to about 0.50 mile south of its present location (Figure II-22). In their present location, these roads would be disrupted by mining activities. The Rosebud County Commissioners in Forsyth have determined that the proposed relocation would not adversely affect the public or the surrounding land owners (letter of November 13, 1981 to Western Energy Company). During mining years 21 through 34, County Road 141 would have to be relocated or closed because the road would be displaced by mining. The rebuilt road would comply with the standards set forth by the county commissioners in their letter of November 13, 1981.

TABLE III-17

POTENTIAL INCREASED DAILY TRAFFIC LEVELS

	Construction Phase (1982-83)		Operation Phase (1984-2010)	
	Workers	Vehicles[d]	Workers	Vehicles[d]
Living in Colstrip[a]	202	--	144	--
Communting Solo	40	40	36	36
Car Pooling[b]	50	25	42	21
Commercial Bus Service[c]	10	--	6	--
	302	65	228	57

[a] Assumes that workers living in Colstrip would not be commuting along major highways and may use Western Energy Company's shuttle bus service to the mine.

[b] Assumes 50 percent of commuting workers would carpool in groups of two.

[c] Assumes 25 percent of workers commuting from outside of Rosebud County would use commercial bus lines from Billings or Miles City.

[d] This represents total additional commuting vehicles. If half commute via northern routes to Colstrip and half via southern routes, increased vehicular traffic along any given segment would only be 50 percent of the represented number.

L. RECREATION

1. Urban Recreational Resources

All Colstrip Area Recreation and Parks Association (CARPA) recreational resources and facilities are used to capacity at present population levels and are considered inadequate to serve the existing population (see Chapter II, Section I). To date, CARPA reportedly has been unable to use school facilities for recreational purposes, due to scheduling conflicts. Colstrip is in need of additional multi-purpose recreation space, indoors and outdoors. The existing needs for space will not be met, even with the completion of the Stillwater Park in the fall of 1982 (Noyd, 1982). The project would sustain these use pressures by maintaining high population for an extended period; however, the long-term recreational needs would decline in direct proportion to the 45 percent decline in projected population between 1982 and 1983 with the completion of Units 3 and 4.

2. Impact on Nonurban Recreational Resources

Additional population growth attributable to the proposed Area C, Block I mine operation would impose no significant negative impact to the area's nonurban recreation resources.

M. CULTURAL RESOURCES

1. Area C, Block I

A summary of project impact to the nine cultural resources in Area C, Block I is presented in Table III-18. The mining would partially or totally destroy seven of these sites: Lynn's Square, Gene's Vision Quest, Cooley Site, Fadhl Kill Site, Fadhl Homestead, Tripoint, and Medicine Root sites. The Three Ring and the Farley Lookout sites are located adjacent to the mining areas and may be affected by erosion, vandalism, or off-road vehicle use.

Of the seven sites that would be destroyed, three (Lynn's Square, Gene's Vision Quest, and the Tripoint Sites) appear to be ineligible; and three (the Cooley, Fadhl Kill, and Fadhl Homestead Sites) appear to be eligible for nomination to the National Register of Historic Places. One site (the Medicine Root Site) needs additional testing before a National Register recommendation can be made. Of the two sites located adjacent to direct mining or construction activity areas, one (the Farley Lookout Site) appears to be eligible for nomination to the National Register. The other (the Three Ring Site) does not.

Mitigation, in the form of intensive data collection and recording or other approved methods, is required prior to the disturbance of those sites determined eligible for the National Register. Those sites determined ineligible have been fully recorded and the information placed on file.

2. One-Mile Buffer Zone

The purpose of the buffer zone survey was to locate and identify cultural resources that could be affected by blasting. Most prehistoric sites would not be affected with the exception of rock and rock shelters. Likewise, only historic sites with standing structures would be affected. However, all sites in the buffer zone may sustain increased deterioration through vandalism.

A summary of project impact to the 25 sites within the one-mile buffer zone around Area C, Block I is presented in Table III-19. Eleven of the 25 cultural resources have rock art or standing structures and could be affected by blasting. Of these, two (Doc Taylor Place and Muskrat Homestead) have been determined to be eligible for the National Register; one (Cooley Place Site) appears to be eligible for the National Register; seven appear ineligible for the National Register (Dusty Shelter, Castle Rock Post Office and Homestead, Caskey 310, Lovelace Memorial, Petro City, P.E. Davis Rock Art, and Connie's Gallery); and one (Forsite) needs testing before a National Register recommendation can be made.

The Sly Bison Site, which has been determined eligible for the National Register, and Insite sites, identified in Chapter II as potentially eligible, are prehistoric and neither contains rock art or

TABLE III-18

SUMMARY OF IMPACT TO CULTURAL RESOURCES
AREA C, BLOCK I

National Register Eligibility	Impact Assessment
Sites Considered Ineligible	
1. Three Ring Site (24 RB 1060)	1. Site may be impacted. Site is located between the boxcut and spoils reduction area, a road construction area, and a scoria pit. Impact assessment unnecessary if site is ineligible for National Register.
2. Lynn's Square (24 RB 1071)	2. Site would be destroyed. It is located within the highwall reduction area. Impact assessment unnecessary if site is ineligible for National Register.
3. Gene's Vision Quest (24 RB 1072)	3. Site would be destroyed. It is located partially within a topsoil stockpile area Impact assessment unnecessary if site is ineligible for National Register.
4. Tripoint Site (24 RB 873)	4. Site would be destroyed. It is located within the mining pit area. Impact assessment unnecessary if site is ineligible for National Register.
Sites Considered Eligible	
5. Cooley Site (24 RB 1059)	5. Site would be at least partially destroyed. The northern portion of the site is located within a road construction area, and a pit power feeder transmission line passes through the center of the site. Impact would be considered significant if site is determined eligible for National Register.

TABLE III-18 (Continued)

National Register Eligibility	Impact Assessment
6. Fadhl Kill Site (24 RB 299)	6. Site would be destroyed. It is located within a boxcut spoils reduction and road construction area. Impact would be considered significant if site is determined eligible for National Register.
7. Farley Lookout Site (24 RB 1058)	7. Site may be impacted. It is located adjacent to the highwall reduction area. Impact would be considered significant if site is determined eligible for National Register.
8. Fadhl Homestead Site (24 RB 884)	8. Site would be destroyed. It is located within the mining pit area and a road construction area. Impact would be considered significant if site is determined eligible for the National Register.
Sites Requiring Additional Work Before National Register Recommendation Can be Made	
9. Medicine Root Site (24 RB 879)	9. Site would be destroyed. It is located within the highwall reduction area. Impact assessment cannot be made without eligibility recommendations.

Exhibit 3

TABLE III-19

SUMMARY OF IMPACT TO CULTURAL RESOURCES

BUFFER ZONE

Sites	National Register Eligibility
Potential Impact from Blasting and Vandalism:	
1. Doc Taylor's Place Site (24 RB 1065)	Has been determined.
2. Muskrat Homestead Site (24 RB 313)	Has been determined.
3. Cooley Place Site (24 RB 1064)	Appears eligible.
4. Dusty Shelter Site (24 RB 1069)	Does not appear eligible.
5. Castle Rock Post Office and Homestead Site (24 RB 335)	Does not appear to be eligible.
6. Caskey 310 Site (24 RB 1076)	Does not appear to be eligible.
7. Lovelace Memorial Site (24 RB 301)	Does not appear to be eligible.
8. Petro City Site (24 RB 302)	Does not appear to be eligible.
9. P.E. Davis Rock Art Site (24 RB 875)	Does not appear to be eligible.
10. Connie's Gallery Site (24 RB 877)	Does not appear to be eligible.
11. Forsite Site (24 RB 878)	Requires additional work before eligibility recommendation can be made.
Potential Impact from Vandalism Only:	
12. Sly Bison Site (24 RB 267)	Has been determined.
13. Insite Site (24 RB 874)	Appears eligible.

Exhibit 3

TABLE III-19 (Continued)

SUMMARY OF IMPACT TO CULTURAL RESOURCES

BUFFER ZONE

Sites	National Register Eligibility
14. McDonald Quarry Site (24 RB 303)	Does not appear to be eligible.
15. Rabbit Ridge Site (24 RB 310)	Does not appear to be eligible.
16. Rocky Top Site (24 RB 1061)	Does not appear to be eligible.
17. Wheatfield Vista Site (24 RB 876)	Does not appear to be eligible.
18. Pottery Site (245 RB 1062)	Does not appear to be eligible.
19. Sunburn Out Site (24 RB 881)	Does not appear to be eligible.
20. Normand Estates Site (24 RB 883)	Does not appear to be eligible.
21. Pigeon Site (24 RB 880)	Does not appear to be eligible.
22. East Fork Site (24 RB 886)	Requires additional work before eligibility recommendation can be made.
23. How Dry I Am Site (24 RB 252)	Has been determined ineligible.
24. MAL 1401	Requires additional work to determine if this warrants a site description before National Register recommendation would be made.
Potential Impact from Road Relocation:	
25. Albino Deer Site (24 RB 885)	Requires additional work before eligibility recommendation can be made.

Exhibit 3

standing structures. Thus, they would not be affected by blasting. Similarly, the East Fork and Albino Deer sites and MAL 1401, which need testing would not be affected. The Albino Deer Site will, however, be affected by road location.

The remaining nine sites would not be affected by blasting as they do not contain rock art or standing structures and do not appear eligible for the National Register.

If those sites needing additional testing and/or determined eligible for the National Register are to be disturbed by future mining, further cultural resource work would be required. Mitigation, through recording or other approved method, is required for the sites with rock art and standing structures prior to disturbance. If the company locates previously unrecorded cultural resources, they must notify the appropriate agencies and take steps to assure that valuable information on the sites is not lost.

Similarly, the portions of Area C life of mine plan outside of the proposal Block I mine site would be surveyed and mitigation requirements met in accordance with the National Historic Preservation Act prior to permitting.

N. AESTHETICS

Mining in Area C, Block I, would change all of the aesthetic values in the area to some degree, and would change them most appreciably during the life of the mine. Colors, textures, contrast, and relief would all be significantly altered during mining and after reclamation. Overall relief would be approximately the same in the reclaimed spoils, but topographic breaks in the mined areas that previously existed due to sandstone and clinker outcrops would be gone. Ponderosa pines in the mine area would be lost, perhaps permanently, thus altering texture, color, and contrast in the post-mine landscape. The revegetated slopes would have a generally uniform color and texture over the entire mined area and a noticeable contrast at the disturbed/undisturbed interface.

For the life of the mine, the noise levels in the area would increase due to heavy truck traffic, dragline operation, periodic blasting, and the conveyor system operation. Post-mine noise levels would remain high until all of the Area C (beyond Block I) mining activity is completed. Post-mine noise levels would eventually revert to pre-mine levels.

CHAPTER IV
ALTERNATIVES TO APPROVING THE PERMIT AS PROPOSED

This chapter presents alternatives to approval of Western Energy Company's proposed mine plan. Both administrative and technical alternatives are considered.

Administrative alternatives available to the Department of State Lands and OSM include taking no action, denial of the permit, selective denial of portions of the permit, and approval of the permit, subject to stipulations. Possible stipulations that would reduce environmental impacts identified in Chapter III are discussed in this chapter as technical alternatives. Any of these alternatives could be implemented if necessary to reduce the environmental impacts of the proposed project.

This chapter also discusses technical alternatives to the proposed action, including alternative mining methods and alternative energy sources; however, the Department is not empowered to require Western Energy to adopt any of the technical alternatives presented herein.

A. ADMINISTRATIVE ALTERNATIVES

1. No Action

Policy dictates that the Department must either approve or deny an application for a mining and reclamation permit within 240 days after receipt of a complete application. OSM has no legally required deadline for approval.

Montana does not have a formal administrative alternative to "defer action" following the receipt of a complete application for a mining and reclamation permit; however, the state may deem an application incomplete if the mine plan fails to meet state requirements. This action would lead to a postponement of the action, which has the effect of deferral. However, the Secretary of Interior has authority to defer approval of a mine plan for appropriate reasons.

2. Denial of the Permit

If the Department and OSM find the mine plan does not conform to the requirements of Montana's permanent regulatory program (ARM 26.4.301 et seq.), or the Federal Lands Program, then the agencies are obligated to deny the permit application. In the case of denial, it is likely that Western Energy would propose an alternative mine plan within Area C.

No mining would occur in Area C until a revised mine plan was submitted and approved; until that time, the land would continue to be subject to the effects of natural processes and to further discretionary modifications by surface owners.

Denial of the permit would almost certainly delay Western Energy's scheduled October 1983 coal delivery commitment to Colstrip Unit 3. Inasmuch as the boilers for Units 3 and 4 are being manufactured to conform with the characteristics of the Rosebud coal proposed to be mined from Area C, permit denial would require Western Energy to either reapply for an Area C permit or find another source of Rosebud coal to meet their contractual commitment to supply coal to Colstrip Units 3 and 4.

In the event that the Area C, Block I permit application was denied, Western Energy would still have the option of applying for mining permits on other undeveloped leaseholds, which could eventually replace the volume of coal proposed to be mined from Area C, Block I. However, plans and approvals for a new mine would take several years at this point, and there is no evidence that mining activities in other undeveloped portions of Western Energy's leasehold would have any less impact than the mining proposed for Area C, Block I.

3. Selective Denial

The Department and OSM have the option of denying Western Energy permission to mine in specified areas within the proposed permit boundary because of special, exceptional, critical, or unique characteristics, or where mining would affect the use, enjoyment, or fundamental character of adjacent land exhibiting any of the aforementioned characteristics. The impact analysis presented in this EIS has not identified any such lands in or adjacent to Area C, Block I, but that does not preclude the disclosure of such lands during the review of this EIS or subsequent review by the DSL technical staff. Additional permit application review is ongoing.

4. Permit Approval with Additional Stipulations

Possible stipulations that would reduce adverse environmental impacts identified in Chapter III are discussed in subsection B.3 of this chapter (Alternative Measures to Mitigate Adverse Impacts). Conceivably, any of these measures could become stipulations to the permit, if approved.

B. TECHNICAL ALTERNATIVES.

Three technical alternatives have been considered: alternative energy sources, alternative mining methods, and alternative measures to mitigate adverse impacts.

1. Alternative Energy Sources

The need to mine in Area C, Block I is based on the continued demand for coal and a specific contract to supply Rosebud coal to Colstrip Unit 3. Inasmuch as the boilers for Units 3 and 4 are being designed to

accommodate the characteristics of the Rosebud coal, it does not appear likely that other sources of energy will replace Western Energy's market for Area C, Block I coal.

Alternative sources of energy, including oil and gas, nuclear, hydroelectic, solar, and geothermal, may replace or reduce the need for new coal-fired power plants in the future, but are not expected to replace coal-fired plants now in operation or under construction.

Fossil fuels such as natural gas and oil are being replaced by coal-fired units in response to the national move toward energy independence. Conversion of coal-fired boilers to oil or gas has been discouraged under federal policy. Electric generation from nuclear power has not increased as rapidly as once predicted because of high capital costs and a level of uncertainty concerning the safety of nuclear power plants. New sites for hydroelectric power generation are limited. Solar power (including direct conversion, wind, energy, and biomass utilization) is still in the developmental stage and is not likely to replace coal-fired generating units in the near future. Geothermal source areas are localized and it is unlikely that geothermal power will be able to provide electric power at the same scale as coal-fired generators.

Nationwide energy conservation programs have been demonstrated to reduce electric energy usage and slow the consumption of energy fuels, but it is unlikely that energy conservation measures alone would eliminate the need for additional power generation in the Pacific Northwest in the foreseeable future. Energy loads (from all energy resources) in the Northwest regional area have been projected to be insufficient to meet the area's needs through the year 1992 (Pacific Northwest Utilities Conference Committee, 1981).

2. Alternative Mining Methods

Several alternative methods to mine coal were suggested and subsequently discounted as being impractical in the Area B (Montana Department of State Lands, 1976) and Area B Expansion EISs (Montana Department of State Lands, 1980), including underground mining, auger mining, contour mining, and in situ mining. These methods have not been reintroduced as alternatives to the proposed mine plan for Area C, Block I because of the proximity of Area C to Area B and the similarity of conditions. The reader is refered to the discussion in the two referenced EISs if any further elaboration is needed regarding the rationale for eliminating these methods as viable alternatives to the proposed project.

In this section, two reasonable alternatives will be discussed: mining of the McKay coal seam and a realignment of the pits proposed at Area C, Block I.

a. Mining of the McKay Coal Seam

The Department could require Western Energy to mine the McKay coal, underlying the Rosebud seam, if the McKay coal proved to be marketable.

Exhibit 3

Currently it is not. Western Energy has been unable to find a suitable market for the McKay coal due to its inferior quality. The McKay has an average sulfur content of about 1.31 percent (by weight), which is half again as high as the Rosebud (at 0.87 percent). Additionally, there are other "problem" constituents in the ash, namely iron (Fe) and sodium (Na), whose percentages are greater than the Rosebud. Increased iron content promotes boiler slagging at normal operating temperatures and increased sodium content tends to promote boiler tube deterioration (Western Energy, 1981).

In recognition of these problems, the Montana Board of Natural Resources and Conservation has prohibited the use of McKay coal in Colstrip Units 3 and 4, both as an exclusive fuel source and in combination with Rosebud coal (Western Energy, 1981).

The possibility still exists that Western Energy could find a buyer for McKay coal or blended McKay-Rosebud coal, and the Department continues to encourage Western Energy to find such a market. If McKay coal was mined in Area C, Block I, special handling, new equipment, and a revised mine plan would be required to provide separate handling of the McKay coal. The current contract calls for the sale of Rosebud coal only from Area C, Block I, and the equipment that would be used to extract coal from Area C, Block I is contractually dedicated to the fulfillment of that contract. Under the terms of the contract, Western Energy cannot divert any dedicated production equipment to uses other than fulfillment of the contract. In effect, this restriction tends to eliminate the possibility of producing small quantities of McKay coal in response to intermittent market demand. Thus, Western Energy would need to purchase and dedicate additional mining equipment to mining the McKay seam, and make necessary modifications to the proposed mine plan, which is currently designed to recover the Rosebud seam alone.

The McKay seam averages about eight feet in thickness throughout the proposed mining area, and represents about ten million tons of coal. The interburden between the McKay and the overlying Rosebud seam averages about 23 feet in thickness. Western Energy contends that, given a market, only a large-scale contract (1.5 to 2 million tons per year) would prove to be economically feasible at this time. Mining of the McKay would cause an increase in the depth of the pit by about 31 feet, which would require a permanent adjustment to the proposed mining plan. Decreased sidewall angles would be required to accommodate a deepened pit, resulting in escalated costs to remove the overburden and a larger disturbance area.

Mining both the McKay and Rosebud seams in Area C, Block I would recover approximately one-third more coal per acre disturbed, resulting in a commensurate increase in severance tax royalties to the state and possibly slow the rate at which new acreage is disturbed at Colstrip. On balance, noneconomic environmental impacts would increase slightly as a result of taking both seams, especially as a result of increased surface disturbance and the mixing of interburden with overburden materials. Higher concentrations of total dissolved solids (TDS) would probably occur in the spoils groundwater (refer to the Technical Support Document).

Exhibit 3

b. Pit Realignment

On April 28, 1982 the BLM received bids on federal coal leases throughout the Powder River Basin, including tracts located within Western Energy's Area C mine boundary totaling 892.56 acres. Western Energy was the only bidder. The USGS and BLM are currently analyzing these bids. A legal challenge to the sale has been filed by the National Wildlife Federation in U.S. District Court.

In the event that these tracts are obtained, Western Energy has developed an alternative mining sequence in Area C, Block I (Figure IV-1) to accommodate these lease tracts. The revised mining sequence depicted in Figure IV-1 is considered to be a viable alternative to the proposed project, and as such, it has been assessed and compared with the impact from the proposed project.

1) Geology

Western Energy engineers indicated that the mining method would be somewhat altered in Block I if the pit realignment alternative was implemented (personal communication during the October 1981 mine visit). Specific overburden handling information was not available from Western Energy; however, the engineers did indicate that overburden in excess of 100 feet would be removed by scrapers and stacked prior to the dragline moving in to strip the remaining overburden.

Since the upper sections of deeper overburden are predominantly sandstone in Area C, Block I, the placement of this overburden during reclamation has a significant bearing on the replaced overburden geochemistry. If this high percentage sand material is not mixed with the dragline spoils, then the bulk geochemistry of the spoils would not be that of the composited hole geochemistry shown in Chapter II, Table II-2. Not mixing the sand and dragline spoils would result in relatively higher average trace metals content in the dragline spoils than that shown in Table II-1 for some of the interior holes in Area C. Also, placement of the high sand spoils over the dragline spoils during reclamation could result in near-surface spoils with sand contents in excess of DSL suspect levels (i.e., greater than 70 percent sand).

This alternative would involve removal of all the sandstone ridge in Area C, Block I, and would result in a greater alteration of the visual appearance of the reclaimed area. In addition, this alternative would leave essentially no undisturbed rock in the permit area, whereas the Block I plan leaves an undisturbed sandstone ridge in part of the southern permit area. Other impacts would be the same as those for the Block I mine plan.

The reorientation of the pits would result in an overall increase in coal recovery from the Area C, Block I permit area. The pit realignment alternative would add approximately 400 minable acres to the Block I permit area with in situ coal reserves of approximately 16.3 million tons in the Rosebud seam. The amount of this additional resource that Western Energy would recover in the first five years of mining with the revised pit orientation is not known, but it is likely that production would be approximately the same for either pit orientation for the first year.

Exhibit 3

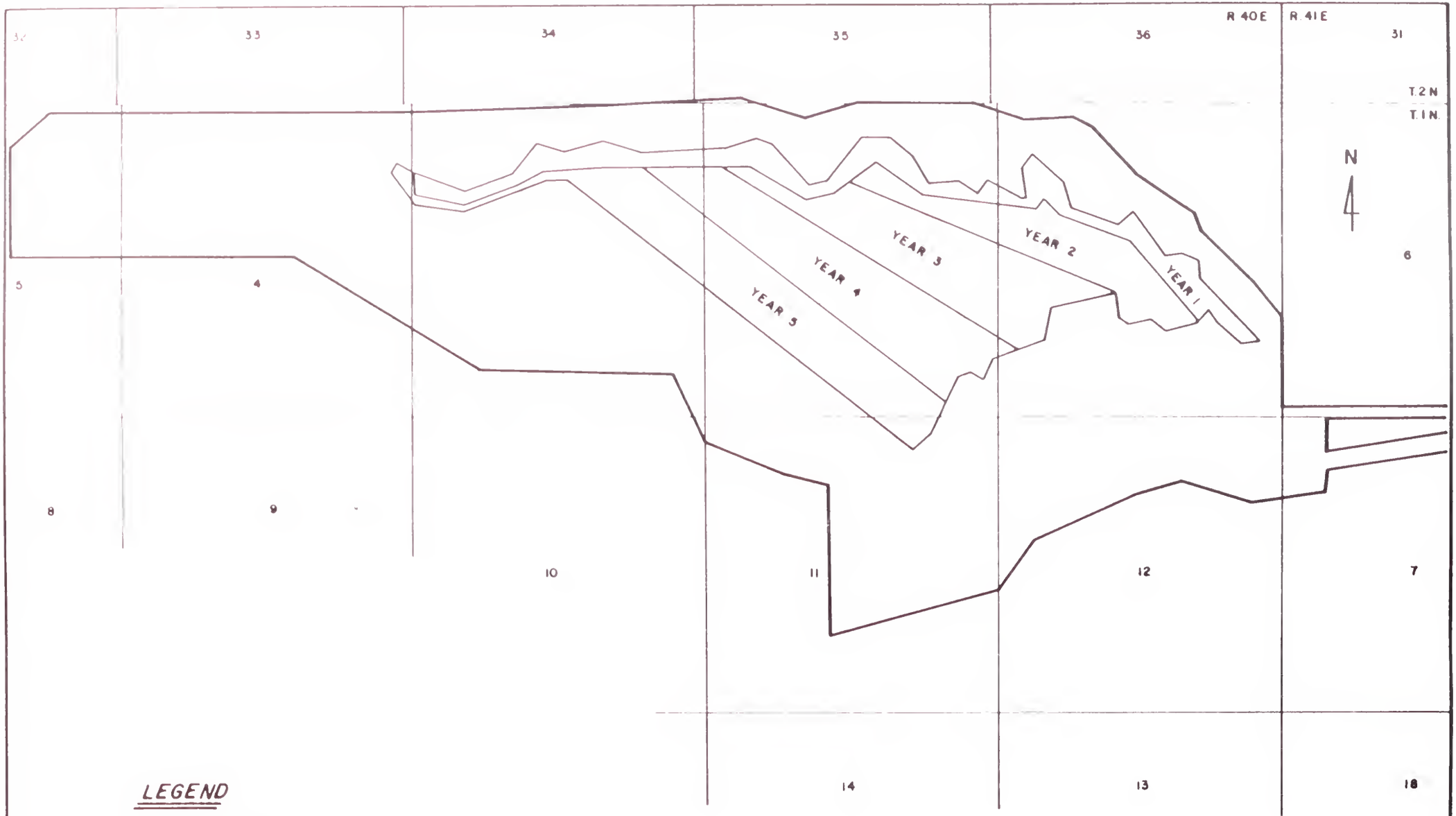


FIGURE IV-1 TECHNICAL ALTERNATIVE: REVISED MINING SEQUENCE AT AREA C, BLOCK I

Exhibit 3

2) Hydrology

The revised mining sequence would have no significant impact on groundwater flow. The nature of drawdown around the pit, the shape of a cone of depression in the Rosebud potentiometric surface and the extent of drawdown with time would remain effectively the same as they would be subject to the original mining sequence.

Since the revised mining sequence would disturb more area and would remove much of the sandy overburden prior to use of a dragline, some minor effects may result. First, the placement of sandy overburden at the surface unmixed with lower, finer spoil may slightly increase groundwater recharge potential. Second, if finer-grained spoils containing more leachable salts are mixed with sandy overburden, higher TDS values for groundwater may occur. Although this increase is not expected to be large, the exact increase in TDS concentrations cannot be accurately predicted with the existing data base.

3) Climate

No impact.

4) Air Quality

If the leases are acquired and the proposed mine plan is changed to reflect the alternative pit progression shown in Figure IV-1, the location of the sources of air emissions will change. However, because the coal and overburden removal rates do not change, the rates of emission would not change significantly. The alteration in pit location was examined in detail and the air quality model layout was revised to account for the different pit and spoil area locations. Trial calculations were performed and it was concluded that differences in air quality, deposition, and visibility impacts from those predicted in Chapter III would be very small and confined to the immediate area surrounding the mine. Therefore, the impacts predicted in Chapter III are assumed to apply to this alternative as well.

5) Noise

The impacts would be essentially the same as those for the proposed project, as discussed in Chapter III.

6) Soils

The reorientation of mining passes would result in the disturbance of more land by mining. Of the land to be disturbed, more undeveloped

rangeland supporting ponderosa pines and junipers would be disturbed. Suitable soils may not be available for successful reestablishment of even a portion of these vegetative types.

If excessively sandy overburden materials were placed near the surface (see Geology, Section A), the droughty condition of these materials as substrata would limit reestablishment and long-term vigor of some plant communities. Placement of excessively sandy overburden in areas that may experience gully development or the migration of headcutting would increase the potential of deep gully development.

The placement of sandy overburden material in the lower portions of mined-out pits would avoid this additional impact for the reoriented mine pits.

7) Vegetation

The reorientation of pits would result in the disturbance of additional conifer-shrubland and sagebrush shrubland areas. It is not certain whether ponderosa pine or skunkbush sumac, important species in the conifer-shrubland areas, can be reestablished on the regraded spoils (Section III-G). This alternative would result in an increase of good condition grassland for grazing and a decrease in vegetatively diverse types, especially ponderosa pine stands.

8) Wildlife

Wildlife effects of pit realignment would not be appreciably different. This alternative would disturb slightly more woodland, but as with the proposed action, would not disturb the golden eagle nest site. Of greater concern is the implied long-term commitment of the Block II alternative to a pattern of mining through the raised topography, which includes the sandstone cliff features of value as raptor nesting sites.

9) Sociology and Economics

Socioeconomic impacts would be identical to those described for the Block I plan, discussed in Chapter III.

10) Land Use

Most of the disturbance to cropland and rangeland under the pit realignment alternative would be similar to that identified under the proposed project. A portion of the cultivated field in the northwest section of the permit area that would be disturbed under the Block 1

mining plan would not be disturbed as a result of pit realignment. This amounts to about 80 acres of cropland that could remain in production for five additional years; however, the presence of mining activity on the northern portion of the field may make cultivation of the southern portion impractical. The extent of rangeland disturbance will be similar to that of the proposed plan, with a decrease in disturbed acreage in the northwest section of the permit area, and an increase in the disturbed acreage in the center of the permit area.

11) Transportation

Transportation impacts would be identical to those described for the Block I mining plan, discussed in Chapter III.

12) Recreation

Recreation impacts would be identical to those described for the Block I plan, discussed in Chapter III.

13) Cultural Resources

The impacts of the pit realignment alternative on the cultural resources located within Area C, Block I and its one-mile buffer zone cannot be made until the final archaeological report on the sites and the final mine plan have been released, reviewed by the Montana SHPO, and a determination of National Register eligibility has been made.

14) Aesthetics

The effect of pit realignment would not significantly differ from the impacts discussed for the proposed project, except that more forested acreage and more topographic diversity would be eliminated by mining through the sandstone ridge, instead of around its perimeter.

3. Alternative Measures to Mitigate Adverse Impacts

The following alternatives are presented as measures designed to mitigate the adverse impacts discussed in Chapter III.

a. Geology

Because of the significant increase in trace metal content in the five to ten feet of shale lying directly above the Rosebud coal, some method of selective removal of that zone in stripping overburden might be considered. A method that would prevent mixing that zone with other spoils and keep it below the top ten feet of reclaimed spoils would be very effective in minimizing, and in many cases eliminating, anomalous nickel, cadmium, and molybdenum values in the near-surface spoils. Possible methods include loading and hauling this material for later selective placement in the spoils or selective dumping of this material with the dragline to insure it does not end up on top of the spoils pile. The latter method would be more economical and probably easily achievable.

Field mapping could determine if significant faulting exists where it is inferred in portions of Block I. If present, then such faulting should be incorporated into Western Energy's surficial geology map and into the mine engineering plan for the pit realignment alternative mine plan. Engineering planning that recognizes any significant faulting could mitigate its effect on coal recovery in Area C.

Settlement problems can be mitigated with nominal bulldozer grading. It is expected that future subsidence problems will be small (under four feet of differential vertical displacement), can be mitigated by back-filling and regrading, and will occur soon after initial spoil grading. Subsidence problems are expected to be evident well before the end of the ten-year bonding period.

b. Hydrology

Western Energy's Rosebud Mine, Area C will affect the existing environment. Mitigation techniques proposed or recommended to alleviate long-term environmental degradation are presented in the following sections.

a) Groundwater

There are very few mining or engineering practices of a practical nature that can be used to mitigate potential groundwater impacts. However, one of the few possible means of mitigating groundwater flow changes is by employing truck-and-shovel mining methods instead of using a dragline. The nature of spoils (as replaced by truck-and-shovel) can be hydraulically different than spoils replaced by a dragline. A truck-and-shovel operation could create and replace spoils that more closely approximate the vertical permeabilities and porosities of undisturbed

coal and overburden. A truck-and-shovel operation tends to break up overburden less than a dragline, and can also recompact the spoils once they are replaced.

Greater compaction causes lower porosities in the spoils, which could allow for a quicker recovery of groundwater levels. Given a constant rate of inflow to spoils from any source, it would take, for example, half as long to fill up a given volume of spoils with 10 percent porosity as opposed to the same volume of spoils with 20 percent porosity. However in Area C, for example, the predominant source of groundwater recovery in reclaimed spoils would come from infiltration of precipitation. In this situation, the greater compaction of spoils by truck-and-shovel as opposed to a dragline operation would inhibit groundwater recovery because the extra compaction would limit vertical permeability, and hence infiltration. Since recharge from infiltration in Area C and most of the other mine areas is an important contribution to the regional flow system, it is important that recharge capacity be maintained. It appears that, all things considered, a dragline operation would create spoils more conducive to recharge and groundwater recovery than would a truck-and shovel operation.

b) Surface Water

The major impacts to the surface water regime from mining that can be mitigated are geomorphic instability and accelerated erosion. Geomorphic stability is largely determined by regional landscape units. In reclaimed areas, the stability of geomorphic landscape units is strongly influenced by reclamation techniques. Two of the primary factors that affect sediment yields from reclaimed landscape units are the nature of surficial materials and the topography, both of which should be the focus of design and management efforts. The following strategies were recommended by Ertec, Inc. to prevent instability and accelerated erosion.

o Alternative Reclamation Practices and Engineering Techniques

Studies on currently reclaimed areas suggest that infiltration rates and sediment yields from reclaimed sites are strongly correlated with the methods of topsoil placement and machine handling of the spoils. Dollhopf et al. (1977) determined that reclamation treatments (in this case, the use of bulldozers) that compact the spoils result in greater runoff and erosion rates. To avoid such problems, alternative reclamation practices, such as the use of chisel plowing techniques, could be employed.

o Soil Handling Mitigation Measures

Many of the soils in the Colstrip area are fairly erodible due to the high proportion of fine sands, which may result in high sediment yields from reclaimed areas. A range of measures (discussed in detail in Soils, Section F) could be applied to mitigate this effect. These measures could include mixing the salvaged topsoil or using surface stabilization techniques to minimize erosion prior to the successful establishment of vegetation.

o Topography Changes to Minimize Instability

Another factor that could be considered in large-scale landscape design is the post-mine topography. The current mine plan follows DSL regulations as to the gradient of reclaimed hill slopes. Slope length and shape also significantly affect erosion rates and must be considered in the landscape design. Experience gained during the early stages of reclamation could lead to the modification of the designed post-mine topography to minimize areas of potential instability.

o Subsidence and Soil Piping Mitigation

Geomorphic instability due to subsidence in the spoils materials may take three forms: area-wide settling, localized subsidence or collapse, and piping.

As discussed in Chapter III, area-wide settlement is likely to be less significant than in many other reclamation sites in Montana. However, the equipment used in handling the spoils is also a critical factor, and settlement is likely to be minimized if the reclaimed areas are contoured by scrapers rather than bulldozers, particularly if contouring is accomplished in winter (Groenweld and Rehm, 1980).

Localized subsidence, which may continue for a longer period following contouring, is also strongly affected by handling techniques and equipment. Groenweld and Rehm (1980) suggest that this type of subsidence can also be avoided if bulldozer contouring is restricted during winter months.

Mitigation measures to control piping and other types of settlement could include a range of controls on stability, such as: selective placement of spoils away from the geochemically active surface zone to mitigate surface cracking; selection of appropriate handling equipment; using techniques to avoid differential compaction, and an awareness of the importance of environmental factors, notably the potential freezing of spoils during contouring and reclamation.

o Gully Control

At the scale of the drainage basin within the mined area, stability can best be achieved by integrating the smooth upward-concave profiles of the reclaimed stream channels with the hill slopes within the basin, as well as with the upstream and downstream drainages. The reclaimed basins described in Western Energy's mine plan achieve this by approximating the original slope of the stream channels, and by grading the tributaries into the main channels so that no knickpoints are created. However, because of the inherently unstable nature of ephemeral drainage systems and the engineering considerations of reclamation, some instability problems may occur that require further mitigation measures. One of these problems is the development of gullies.

The relevant scales of operation for dealing with gully erosion include both the drainage basin, where runoff must be controlled, and the channel, where a stable form must exist. To be effective, attempts to control gullying must be comprehensive and the problems must be correctly identified. Gullies may develop from surface erosion when

runoff is concentrated by small depressions and knicks on a hill slope, or from subsurface erosion (piping) and the collapse of pipes. Measures to deal with the first type of gully development may not help and may even aggravate the problem of subsurface erosion. A further difficulty is in identifying the main source of sediment, which may be the adjacent hill slopes, the gully head, or the channel bed and banks further downstream.

Measures to control gullying should concentrate on reducing runoff. To control surface runoff, the stream channels, gullies, and surrounding headwaters can be mulched or vegetated to increase roughness, decrease flow velocity, and induce infiltration. The treatment can be supported by building temporary dams in each channel to trap sediment and thereby reduce channel depth and slope.

For subsurface erosion, a more uniform pattern of infiltration and soil water movement must be achieved. Mechanical measures such as diversion ditches and terraces often used to control surface runoff are inappropriate. By causing ponding, they provide a concentrated supply of water that may open a new piping system or increase erosion in an existing one. Control of subsurface erosion is best achieved by establishing a healthy grass cover, or where conditions are marginal for improved pasture, a mixture of shrubs, grasses, and trees. If tunneling has reached an advanced stage, the tunnels must be broken up by ripping prior to establishing the vegetative cover.

Conservation measures in the channel may include reshaping gullies to a more stable design. If such land-forming operations are impractical, simple mechanical controls can be employed such as earth and brush dams, boulders, or planks to form barriers across the channel. These induce sedimentation and change the slope in both the main gully and the tributaries. Such temporary dams have a high risk of failure. Therefore, they must be carefully constructed, anchored, and regularly maintained.

A range of stability problems can be associated with the mine highwall and its reclamation. These include gully incision on the highwall reduction slope, differential erosion between the coherent bedrock and the spoils, piping, and mass wasting at the highwall.

Many gullying and piping problems at the highwall may be managed using the techniques described above and the careful design of the highwall reduction slope to minimize instability. At a broader scale, an alternative approach to mitigating the problems of stream instability at the highwall may be by bluff extension. Using this approach, a step within the stream longitudinal profile may be left within the more resistant bedrock at the highwall. At the base of the bluff, an armored plunge pool can be constructed to dissipate the energy of the stream. Downstream from the plunge pool the stream flows at a gentler gradient over the more erodible reclaimed spoils, reducing the potential for incision and accelerated erosion. However, highwall stability problems may result using bluff extension methods, in the form of slumps and rockfalls. These concerns can be addressed throughout mining and reclamation and the appropriate actions taken to solve them.

o Roadway Sediment Mitigation

Within post-mine landscapes, which are stable at the large scale, problem areas may exist where erosion rates are extremely high and these areas are major sources of sediment. A problem that may be managed using agronomic or engineering techniques is that of increased erosion associated with roadways and other developments.

The main problems associated with roads are excess runoff, and the stability of the road cuts and fills. In erodible areas, roads may be placed on ridges to minimize the catchment area from which runoff originates. Even so, excess runoff cannot be entirely mitigated because whenever the ridge slopes into saddles or along spurs, erosion by overland flow and gullying can occur. Grass-lined side ditches, with regularly spaced culverts, could provide an effective method of runoff control. Various techniques to improve road cut and fill stability include: benching, which is used to reduce the overall slope angle of the bank, establishment of herbaceous plants, construction of diversion ditches and spillways to dispose of runoff, and use of erosion nets.

c. Climate

No recommendations.

d. Air Quality

A number of alternative stipulations were investigated. These include:

- Application of alternate dust palliatives to calcium chloride on the haul roads
- Addition of foaming agents to the coal to reduce dust production during handling
- Installation of water injection systems on the drilling units
- Enclosing the emergency stockpile

However, if all of the above measures were taken, dust emissions would be reduced by less than one percent. Therefore, these stipulations would not result in a significant change to the analysis of impacts.

e. Noise

Although ambient sound levels from Area C mining are not expected to be a significant nuisance in Colstrip, mine construction and operation activities may noticeably increase sound levels at locations closer to

the mine or at locations where ambient sound levels are now very low. Measures can be taken to reduce potential impacts due to equipment and blasting noise.

Noise produced by mining equipment is best minimized by using equipment designed to operate quietly. Proper muffling and maintenance of equipment during its operational lifetime is also effective.

Specific techniques are available for minimizing blasting noise. Special attention to overcharged blast holes, adequate stemming, covering the detonating cord, and using adequate burdens is important in minimizing noise production.

The special effect certain meteorological conditions can have on sound propagation through the atmosphere should also be considered. One rule of thumb for minimizing blasting impacts is to postpone the blast if a temperature inversion exists at less than 5,000 feet and the affected community is downwind of the blast. Since low temperature inversions are frequently observed at night and during the first several hours after sunrise, special care should be taken during these hours. Another rule of thumb is postponing blasting when the affected community is downwind and the wind speed is greater than 15 mph.

f. Soils

1) Selective handling of soil by textural types would mitigate against the elimination of diverse soil types and the related impacts of reduced vegetative diversity. This is presently being done to a limited degree in other areas at the Rosebud Mine for sandy soils (see discussion in Chapter III). Soils that must be stockpiled from haul roads, clinker pits, facility areas, the boxcut reduction zone, and the first three mining passes could be stored separately for placement in specific areas, increasing the long-term survival potential of some vegetative types.

The boxcut reduction zone and first three mining passes comprise 438 acres, including 86 acres of clinker soils. If salvaged to the depths shown in Appendix F, the clinker material from this area is sufficient to reclaim the entire 60-acre area projected for ponderosa pine plantings with total depth of 30 inches of mixed clinker soil material, or to reclaim a larger area with 10 to 12 inches of clinker material over a 15 to 20 inch loosened subsoil layer. Ponderosa pine have a higher tolerance for rock fragment content in soils, thus allowing salvaging to greater depths of this material than proposed. This would further maximize the use of this resource. This alternative would increase the likelihood of tree survival, and due to the location of ponderosa types on hill slopes, it would reduce the potential for erosion in these areas.

2) In the long term, cropping patterns after mining can be expected to follow the same pattern as on the pre-mine landscape, which is that only loamy and clayey soils can be cropped, because yields on these soils are consistent enough to allow economical cropping.

Therefore, areas in which cropland will be the post-mined land use should be respread with loamy or clayey soil materials. The isolated location of projected cropland areas (mine shop and topsoil stockpiles, see Figure I-8) will be helpful, in that the loamy and clayey soils salvaged from each area can be stored nearby for replacement. The only additional impact that will result will be a reduction in organic matter and soil microorganisms during storage and potential soil compaction during soil replacement (see following mitigations).

3) Topsoil degradation during storage is due in large part to oxidation of organic matter and the establishment of increased populations of pathogenic microbial species, which attack viable plant parts in stored soil (see Chapter III, Section F). A way to decrease both of these processes is to store dry soil, allow compaction of the pile as lifts are placed, and to leave as little surface area as possible within limits of the erosion criteria for stockpiles after the final stockpile configuration is completed.

4) The reduction of organic matter in the soil after storage, or to a lesser extent, after direct hauling, can be tempered by incorporating mulch on all reclaimed surfaces immediately after the first phase of seeding, or by using a cover crop as discussed in Section g. This will improve the moisture and nutrient holding capacities of the surface soil, reduce the tendency of the surface to crust, and improve infiltration. It will also provide a base for the reestablishment of important soil microorganisms.

5) Increased bulk density in applied soil layers can be mitigated by using the bulldozer-mounted ripper bars to scarify replaced soil. Spot-checking of subsoil bulk densities prior to the placement of the next lift would aid in identifying the areas where bulk densities exceed 1.5 g/cm^3. If ponderosa pine plantings are to be located on non-selecting handled topsoil, it may be necessary to achieve bulk densities of 1.3 g/cm^3 (Chapter III, Soils) or less.

g. Vegetation

1) Seeding Method

Although the two-phased revegetation method is expected to produce satisfactory results as stated in Chapter III, no data could be found recommending this method over more conventional seeding methods. While it was developed in an attempt to increase species diversity in reclaimed areas that had otherwise demonstrated limited diversity, it has two apparent drawbacks. One is the waiting period of up to three years between seeding sequences, which considerably delays the establishment of effective grass cover. The other is the possibility that aggressive annual weedy species may be equally or more competitive to the first planting sequence than the second seeding sequence would be. Weedy plants may also hinder establishment of the second phase.

A suggested alternative is one that has become standard for seeding native grasses in the Great Plains. This method entails growing an

adapted annual cover crop on a prepared seedbed to produce a standing stubble, and then direct seeding the desired mixture into the standing stubble. This method improves soil moisture, reduces soil temperatures, and has been shown to give a ten percent greater population of native grasses as opposed to using a protective cover of straw mulch (Schuman et al., 1980). Seeding could be done either in late fall or early spring and would require the use of a double-disk grass drill capable of seeding in untilled stubble and capable of handling the diverse seed mixture.

This method has the advantages of a firm seedbed, which is essential for warm-season grasses, good contact between seed and moist soil, greater soil moisture from trapped snow, reduced surface evaporation, and reduced soil temperature fluctuations. Erosion and weed infestation would also be minimized.

2) Establishing Conifers

The reclaimed soils at Colstrip are essentially grassland soils rather than woodland soils. Extensive experience with conifers as windbreak plantings (Ferber, 1974) and in forest plantings (Larson and Schubert, 1969) strongly suggests that young trees cannot compete with weeds and grass for moisture on grassland soils. To achieve success in reestablishing a conifer vegetative community, special measures to enhance the storage and availability of soil moisture must be employed.

(a) One alternative is to place rocky or coarse sandy soil having rapid infiltration and percolation at the surface to a zone below the reach of most grass roots (12 to 16 inches, Larson and Schubert, 1969). The porcelanite or clinker beds would provide a good source for materials to build this special soil.

(b) Another alternative entails regular maintenance practices to eliminate competing grasses and weedy forbs. Methods to accomplish this include cultivation, application of herbicides, mulching, or supplemental irrigation. One or more of these methods must be used to control competitive plants until root systems of the trees are well established.

Revegetated conifer zones would require an extended period of protection from grazing and trampling by livestock or wildlife. Fencing of these areas should be considered when the adjacent revegetated range site is ready for grazing use.

3) Reestablishment of Range Sites

Sandy and silty soil material should be identified, segregated, and reapplied on the graded spoils to reestablish areas of sandy and silty range sites in large enough areas to establish discrete plant communities. This would allow vegetative seed mixtures to be tailored to the adapted climax community for each soil. The proposed deferred-rotation-grazing system could then be applied to the reclaimed area in recognition of the specific growth habits of the key species on each site. This would allow for increased spatial and species diversity, and possibly lengthen the period of optimum grazing use on the reclaimed areas.

h. Wildlife

Where impact to important habitat components is unavoidable, it may be possible to mitigate or compensate for such impacts via the following activities:

- Continue sponsorship of investigations into restoration of conifer habitats with a long-term goal of establishing the extent and composition of habitat comparable to the existing conifer habitat. Because of the long recovery time for these woodlands, additional attention should be directed to establishing shrub communities to supply improved diversity, cover, and forage in the near term.

- Examine feasibility of creating cliff habitats where mining abuts steep and precipitous terrain.

- Evaluate design considerations for post-mining topography and anticipated post-mining hydrologic characteristics to provide comparable surface water supplies for wildlife and enhancement of these areas for wildlife use. These design features may include retention of sediment ponds, creation of small stock-pond type impoundments, or water-well aquifer pumping to stock ponds or tanks.

- Evaluate feasibility of incorporating plans to replace particular microhabitat features such as rock areas or brush piles.

i. Sociology and Economics

During the period of peak construction-induced population, 1982 to 1985, the Rosebud County Sheriff's Department should ensure that adequate coverage is available during the evening shift in the Colstrip area. If necessary, the department should hire an additional deputy for the area.

Solid waste collection should be limited to one day per week pickup, which normally is sufficient for residential purposes.

The Colstrip Mental Health Center may have to add part-time professional or paraprofessional staff.

The Sunlight Development Company should carefully monitor the housing supply/demand situation in late 1982. If more doubling up does not occur, or the construction schedules do not lag, a housing supply deficiency of about 60 units may occur. Adequate housing should be provided for all construction employees.

j. Land Use

Presently cultivated land could be reclaimed as cropland instead of as rangeland. The treatment of the land during reclamation would

not be much different under this scenario. Avoiding over-compaction of the overburden and avoiding pockets of high electrical conductivity would increase the crop potential of the reclaimed land (see Section F, Soils). Planting the reclaimed land to rangeland and allowing establishment of vegetation and nutrient cycling during the period prior to bond release would increase the potential for productive cropland after bond release. If the cultivated land was reclaimed to cropland instead of rangeland immediately after disturbance by mining activity, there would be an increase in erosion potential on that land due to a lack of vegetative cover during part of the year. Therefore, although immediate reclamation to cropland would result in harvestable crops at an earlier date, the long-range productivity of the cropland would be increased by allowing the land to return to rangeland prior to any post-mining cropping.

k. Transportation

No recommendations.

l. Recreation

The Stillwater Park Complex should be completed as soon as possible. CARPA and the school district should continue to explore means for cooperating on the availability and use of school facilities.

m. Cultural Resources

No mitigation plan is yet available for review.

n. Aesthetics

Mitigating measures to lessen the impact on aesthetic values include the construction of complex slopes on reclaimed spoils; leaving parts of the highwall as topographic breaks, especially where highwall reduction would necessitate timber removal; using neutral-colored paint on buildings, the coal conveyor, mining equipment, etc., appropriately colored to blend with the existing environment; controlling fugitive dust via the methods recommended in Section D (Air Quality); and eventual revegetation using plant species similar to adjacent undisturbed acreage. Such measures would tend to lessen the unnatural contrasts that occur during mining operations and would also enhance the natural contrast, color, and texture in the post-mine environment.

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CHAPTER V
CONSULTATION AND COORDINATION

A. DEVELOPMENT OF DRAFT ENVIRONMENTAL IMPACT STATEMENT

Information used in the preparation of this Draft Environmental Impact Statement was obtained from the following agencies and companies:

Federal Agencies

U.S. Department of Agriculture
- Agricultural Research Service
- Forest Service
- Soil Conservation Service

U.S. Department of Interior
- U.S. Geological Survey
- Bureau of Land Management

State Agencies

Montana Department of Health and Environmental Sciences
Montana Department of Highways
Montana Historical Society - State Historic Preservation Office
Montana Department of State Lands
Montana Department of Natural Resources and Conservation
Wyoming Department of Environmental Quality

Companies

Bison Engineering (Subconsultant - Air Quality)
Western Analysis, Inc. (Subconsultant - Socioeconomics)

The following individuals contributed to the preparation of this Draft EIS. Ertec's subconsultants included S. Larson (Pappadopolis & Associates), J. Gelhaus and M. Roach (Bison Engineering); D. Bourke, L. Rovig, S. Holtzmann, T. Klack, L. Priest (Western Analysis, Inc.); and A. Fricke and D. Nielsen. Other contributors are Ertec personnel.

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B. REVIEW OF THIS STATEMENT

In accordance with DSL's and OSM's regulations governing environmental impact statements (EISs), copies of this draft EIS will be made available to the public for comments and suggestions. All comments received will be carefully considered in the preparation of a final EIS. Written comments should be sent to Commissioner Gareth Moon, Department of State Lands, Capitol Station, Helena, Montana 59620.

The draft EIS is available for review in the following places:

- Montana Department of State Lands, 1625 11th Avenue, Helena, Montana
- Big Horn County Public Library, 419 North Custer Avenue, Hardin, Montana
- Miles City Public Library, 1 South 10th, Miles City, Montana
- The Rosebud County Library, 201 North 9th Avenue, Forsyth, Montana
- Bicentennial Library of Colstrip, 320 Water Avenue, Colstrip, Montana
- Parmley Billings Public Library, 510 North Broadway, Billings, Montana
- Sheridan County Fulmer Public Library, 320 North Brooks, Sheridan, Wyoming
- Montana State Library, 930 East Lyndale Avenue, Helena, Montana
- Office of Surface Mining, 1020 15th Street, Denver, Colorado
- Office of Surface Mining Area Office, 935 Pendell Blvd., Mills, Wyoming

A limited number of copies are available on request from the Department of State Lands, Capitol Station, Helena, Montana 59620.

Technical Support Documentation is on file with the following entities:

- Montana Department of State Lands Reclamation Division, 1625 11th Avenue, Helena, Montana
- Montana Department of State Lands EIS Team, 1539 11th Avenue, Helena, Montana
- Office of Surface Mining, Department of Interior, 1020 15th Street, Denver, Colorado

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- Bicentennial Library of Colstrip, 320 Water Avenue, Colstrip, Montana
- Western Energy Company

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CHAPTER VI

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CHAPTER VII

APPENDICES

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APPENDIX A

TABLE A-1

MONTANA DEPARTMENT OF STATE LANDS
SUSPECT LEVELS IN OVERBURDEN AND TOPSOIL MATERIAL

Analysis	Suspect Level
Electrical Conductivity	>4-6 mmhos/cm
Sodium adsorption ratio	>12 $(meq/liter)^{1/2}$
Mechanical analysis	Clay >40% Loamy sand and sand
Saturation %	none
pH	>8.8-9.0
PO_4-P	none
NO_3-N	variable
NH_4-N	unknown
Cd	>0.1-1.0 ppm
Cu	>40 ppm
Fe	unknown
Pb	pH < 6, >10-15 ppm pH > 6, >15-20 ppm
Mn	>60 ppm
Hg	>0.4-0.6 ppm
Se	>2.0 ppm
Mo	>0.3 ppm
B	>8.0 ppm
Zn	>30-40 ppm
Ni	DTPA extraction: >1.0 ppm

mmhos/cm = millimhos per centimeter (EC x 10^3 @ 25°C)
meq/liter = milliequivalents per liter
ppm = parts per million
DTPA = Diethylenetriaminpentacetic Acid

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APPENDIX B

TABLE 1

SUMMARY OF QUALITY OF WATER FROM THE SEVERAL AQUIFERS IN
AREA C AND THE ENTIRE ROSEBUD MINE AREA
(Concentrations Expressed in Milligrams per Liter Unless Otherwise Noted)

Aquifer	Number Wells	Specific Conductance Micromhos/cm	Total Dissolved Solids	Total Hardness	Calcium	Magnesium	Sodium	Bicarbonate	Sulfate	Chloride
Rosebud Spoils										
Average Rosebud Mine	35	3,639	3,298	2,354	336	363	166	700	2,015	23
Range	35	1,576-10,825	1,044-10-619	548-6,251	64-580	84-939	20-1,648	205-3,750	417-1,587	0.0-177
Valley Fill Material										
Average Area C	8	2,660	2,460	1,530	169	264	157	538	1,350	16
Average Rosebud Mine	40	2,982	2,767	1,778	257	268	177	536	1,629	20
Range Area C	8	1,670-4,040	1,350-4,680	837-2,430	114-287	135-417	46-279	486-581	584-2,500	2-45
Range Rosebud Mine	40	1,670-4,530	1,340-5,160	837-3,240	114-718	129-613	46-493	183-678	584-3,140	2-95
Rosebud Overburden										
Average Area C	3	2,046	1,782	1,168	172	180	110	491	955	15
Average Rosebud Mine	22	1,491	1,246	844	102	143	82	481	620	12
Range Area C	3	620-2,968	400-2,536	309-1,794	53-262	43-276	11-176	310-662	74-1,472	8-30
Range Rosebud Mine	22	500-3,150	335-3,098	306-1,794	19-278	43-297	7-462	21-1,202	71-2,056	1-81
Rosebud Coal										
Average Area C	14	1,850	1,660	921	138	148	131	466	794	8
Average Rosebud Mine	55	2,111	1,888	1,206	176	186	132	573	985	14
Range Area C	14	540-5,540	334-6,520	239-2,840	42-284	33-517	11-536	304-684	57-3,390	1-32
Range Rosebud Mine	55	540-5,540	334-6,520	142-3,590	29-581	17-521	10-536	25-1,128	57-3,390	0.5-109
Rosebud/McKay Interburden										
Average Area C	2	2,415	2,180	1,125	201	152	221	555	1,112	6
Average Rosebud Mine	15	2,173	1,770	1,044	211	123	176	503	959	12
Range Area C	2	1,940-2,890	1,660-2,700	1,050-1,200	156-246	143-162	104-338	540-570	774-1,450	4-8
Range Rosebud Mine	15	703-3,760	538-3,590	282-3,085	45-815	35-323	21-565	56-832	158-2,170	0.8-28
McKay Coal										
Average Area C	8	2,470	1,910	643	115	86	362	493	986	8
Average Rosebud Mine	42	2,606	2,295	1,147	195	161	279	531	1,296	12
Range Area C	8	957-3,730	616-2,650	64-1,370	15-247	6-183	34-748	391-554	149-1,560	2-16
Range Rosebud Mine	42	750-9,130	546-9,843	37-7,630	6-540	0.2-945	31-748	22-914	121-7,560	2-189
Sub-McKay										
Average Area C	2	2,335	1,900	1,008	154	152	232	341	1,068	7
Average Rosebud Mine	7	2,646	2,182	855	152	116	377	471	1,240	9
Range Area C	2	2,190-2,480	1,600-2,200	695-1,320	117-192	98-206	157-299	193-489	917-1,200	7-8
Range Rosebud Mine	7	1,330-4,140	946-3,210	211-1,740	47-265	16-263	120-995	273-554	35-1,990	2-14

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TABLE 2

Chemical Data Showing Change in TDS Concentration with Time for Valley Fill Wells Suspected of Being Contaminated with Spoils Water

Well Number	TDS Concentration in mg/l				
	1974	1975	1976	1979	1980
P-01	1,790	1,990	1,982	2,690	2,790
P-02	--	2,190	--	2,590	2,730
P-03	--	2,380	2,410	2,690	2,820
P-05	--	2,000	--	4,840	5,110

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TABLE 3

Comparison of TDS for Wells WA-133 and WA-135 with other Valley Fill Wells in Cow Creek and Pony Creek Basins East of Northern Pacific Mined Area

Well Number	Date	TDS Concentration in mg/l	Location
Potentially Affected Alluvial Wells			
WA 133	4/24/81	3,930	Cow Creek
WA 135	4/24/81	4,340	Cow Creek
S 05	12/18/79	5,890	Cow Creek
S-13	12/18/79	4,440	Cow Creek
Unaffected Wells			
WA 132	4/24/81	2,980	Cow Creek
WA 134	4/21/81	2,590	Cow Creek
WA 136	5/12/81	3,290	Cow Creek
WA 137	5/12/81	3,130	Cow Creek
WA 112	12/05/79	1,860	Pony Creek
Undesignated	Undated	2,340	
Undesignated	Undated	2,960	
Undesignated	Undated	2,090	
Undesignated	Undated	3,290	

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TABLE 4

Chemical Data Showing TDS Concentration for McKay Wells S-04, S-08, and WM-127

Well Number	Date	TDS Concentration mg/l	Date	TDS Concentration mg/l
S-04	9/25/73	1,160	7/20/77	5,356
	6/06/74	1,340	3/30/78	9,843
	9/30/75	5,610	2/13/79	5,599
	1/14/76	3,870	8/14/79	6,544
	4/14/76	6,030	2/19/80	5,255
	6/23/76	10,182*		
	8/17/76	7,910	Average	5,725
	10/07/76	6,876		
	4/07/77	4,585		

* Sum of dissolved constituents

Well Number	Date	TDS in mg/l
S-08	9/25/73	2,860
	6/06/74	2,980
	3/30/78	2,960
	10/30/79	3,570
	12/18/79	3,590
WM-127	5/12/81	7,490
	8/15/81	7,420

APPENDIX B

TABLE 5

SURFACE WATER GAGING STATIONS, COLSTRIP AREA

Station	Owner	Location	Grid-East	Grid-North
CG-01		01N41E08ADAC	48,000.00	43,000.00
CG-02		01N41E02DDAD	64,800.00	45,600.00
CG-03		01N42E19DBCC	72,900.00	62,300.00
CG-04		02N41E33CABA	50,800.00	52,600.00
CG-05		02N41E33DDDD	54,200.00	50,400.00
SW-01	WECO	02N41E28AAD	54,200.00	59,400.00
SW-1A	WECO	02N41E27BCCC	54,700.00	58,200.00
SW-2A	WECO	02N42E31CADC	72,400.00	51,800.00
SW-09	WECO	02N40E33DABC	21,600.00	52,400.00
SW-10	WECO	01N41E07AAA	43,600.00	44,400.00
SW-11	WECO	01N40E11DAD	33,500.00	40,800.00
SW-12	WECO	02N41E16BBA	50,400.00	71,100.00
SW-13	WECO	01N40E07CCC	7,700.00	39,500.00
SW-14	WECO	01N41E03BBBB	54,700.00	50,100.00
SW-15		01N41E09BCAA	50,400.00	43,300.00
SW-17	MBMG	03N41E28CCD	50,300.00	87,800.00
SW-18	WECO	01N40E15BBC	22,900.00	38,300.00
SW-19	MBMG	02N41E34BDB	55,900.00	53,800.00
SW-20		01N41E08BACC	45,300.00	43,700.00
SW-21	MBMG	02N41E09BCB	49,500.00	74,900.00
SW-22	MBMG	02N41E28AABD	53,800.00	60,100.00
SW-23	MBMG	01N41E08ABB	47,100.00	44,600.00
SW-24	WECO	01N41E08ABA	47,600.00	44,700.00
SW-25	WECO	02N41E34CCC	55,500.00	50,700.00
SW-26	WECO	01N41E03ACCB	57,300.00	48,200.00
SW-27	WECO	01N41E03BBBB	54,700.00	49,900.00
SW-30		01N41E07ABCB	41,500.00	44,100.00
SW-35	WECO	01N40E11CCAA	74,400.00	50,800.00
SW-40		02N41E30CDAB	40,800.00	56,700.00
SW-45		02N40E34CBAC	23,700.00	52,300.00
SW-50		01N40E05ABCB	15,000.00	49,500.00
SW-55	WECO	01N40E11CAD		
SW-60	WECO	02N42E32CBDD	67,800.00	51,700.00
SW-61	WECO	01N40E10CDDC	24,900.00	39,500.00
SW-64	WECO	02N41E21DCA	53,000.00	62,000.00
SW-65	WECO	01N41E08AABD	48,400.00	44,400.00
SW-66	WECO	01N41E07ABCB	41,500.00	44,100.00
SW-67	WECO	01N41E03BBBC	54,700.00	49,800.00
SW-68	WECO	01N40E11DADD	33,500.00	40,800.00
SW-70		02N41E14DCA	63,300.00	66,900.00
SW-75		01N40E17BBBA	70,000.00	61,900.00

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TABLE 6

LIST OF TOTAL DISSOLVED SOLIDS FOR SAMPLES COLLECTED BY THE U.S.G.S. AT SEVERAL SITES IN THE ARMELLS AND ROSEBUD CREEK BASINS

Stream Discharges for East Fork Armells near Colstrip at Time of Sample Collection is Presented

	Instantaneous Discharge in Cubic Feet Per Second	EF Armells Near Colstrip	Armells Near Forsyth	WF Armells Near Forsyth	Rosebud Near Colstrip	Rosebud Above Pony Creek	Cow Creek Near Colstrip
			(Total Dissolved Solids in Milligrams Per Liter)				
Oct.			2,240		782	832	
Nov.			939	2,510	708	794	
Dec.			3,010	5,660	974	1,030	
Jan. 1975	169	178	3,830	4,520	940	959	
Feb.			1,890	3,810	904	774	
March	21	719	379	383	198	214	
April	2.5	4,110	3,380	4,550	1,000	1,150	
May	6.4	3,310	2,970	3,270	703	790	
June	2.6	3,930	4,030	4,450	632	693	
July			3,410	4,550	669	686	
Aug.			3,840		707	728	
Sept.	2.7	2,060	2,880		709	796	
Oct.	3.7	2,000	3,170	5,710	771	815	
Nov.	1.4	3,370	2,560	4,800	756	899	
Dec.	1.7	3,720	4,100		857	963	
Jan. 1976	1.1	3,690	4,080		887	910	
Feb.	4.3	2,970	2,580	2,730	830	1,040	
March	2.3	3,150	2,780	4,840	738	811	
April	2.4	3,130	4,210	4,850	857	912	
May	5.4	2,860	2,950	4,660	715	830	
June	1.4	3,490	4,190	5,030	728	801	
July	1.6	3,230	3,300		659	627	
Aug.			2,370		758	841	
Sept.			2,330		810	971	
Oct.	1.2	3,890	3,300		839	895	
Nov.	1.5	3,480	3,730		943	1,000	
Dec.	1.4	4,090	4,310		918	996	

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TABLE 6 (Continued)

	Instantaneous Discharge in Cubic Feet Per Second	EF Armells Near Colstrip	Armells Near Forsyth	WF Armells Near Forsyth	Rosebud Near Colstrip	Rosebud Above Pony Creek	Cow Creek Near Colstrip
		(Total Dissolved Solids in Milligrams Per Liter)					
Jan. 1977	0.73	4,320	3,680		870	940	
Feb.	4.2	3,030	992	1,570	869	704	
March	.22	4,170	3,910	5,540	811	871	
April	.70	4,580	3,520	5,210	555	588	
May	2.0	4,130	2,070	4,450	646	658	
June	.01			2,830	646	700	
July			2,360		741	801	
Aug.					802	897	
Sept.	.51	4,430			895	981	
Oct.	.79	3,890			799		
Nov.						912	
Dec.	.86	4,180			888		
Jan. 1978							
Feb.	.75	4,020			871		
March	1.9	3,850	418		878		
April	2.3	4,000	4,470		782		
May	8.9	2,970	1,680		754		
June	2.5	3,850	4,100		855		
July	.28	3,850					
Aug.			2,710				
Sept.			2,290		843		
Oct.	.51	4,260	4,470		857		
Nov.							
Dec.	1.9	3,950	4,160		953		
Jan. 1979							
Feb.					938		
March	56	985	586				
April	4.5	3,180	3,170		914		
May	3.0	3,880	4,200		753		
June	1.1		4,520		763		
July			2,860		802		

Exhibit 3

APPENDIX B

TABLE 6 (Concluded)

	Instantaneous Discharge in Cubic Feet Per Second	EF Armells Near Colstrip	Armells Near Forsyth	WF Armells Near Forsyth	Rosebud Near Colstrip	Rosebud Above Pony Creek	Cow Creek Near Colstrip
			(Total Dissolved Solids in Milligrams Per Liter)				
Aug.			2,360		813		
Sept.			2,070		916		
Oct.	.83	4,260	3,570		911		7,900
Nov.							5,495
Dec.	.46	3,880	4,010		936		
Jan. 1980	.49	4,700	5,050		955		
Feb.	1.3	3,580	4,200		924		5,420
March	2.3	3,380	3,010		690		3,110
April	.80	3,970	3,600		806		4,470
May	E.04	4,560	3,570		949		4,610
June	4.1	2,530	3,890		814		3,930
July							
Aug.							
Sept.	.51		2,670				
Oct.	E.05	4,390	1,030		1,010		5,180
Nov.	.28	5,040	1,640				5,510
Dec.					1,000		
Jan. 1981	.69	4,170	4,000		1,090		4,740
Feb.	1.5	3,700	1,860		768		3,860
March	1.1	4,240	3,190		1,150		4,480
April	.84	3,740	3,350		1,010		4,490
May	7.8	1,130	3,360		971		3,050
June							
July					1,050		
Aug.			1,830		1,080		
	MEAN:	3,525	3,031	4,155	833	833	4,732

EF - East Fork
WF - West Fork
E - Estimate

Exhibit 3

APPENDIX B

TABLE 7

Chemical Data for Surface Water Stations
In Vicinity of Area C, Block I
On East Fork Armells and Stocker Creek

Date	SW-09 TDS Concentration	Date	SW-65 TDS Concentration
7-25-73	2740	5-12-81	4580
6-08-79	3490	5-21-81	3620
8-06-79	3490		
11-29-76	*5180-4880		
6-15-80	*4240-3950		
9-17-80	*5180-4460		
2-03-81	2910		
3-11-81	2690		

*Duplicate sample collected

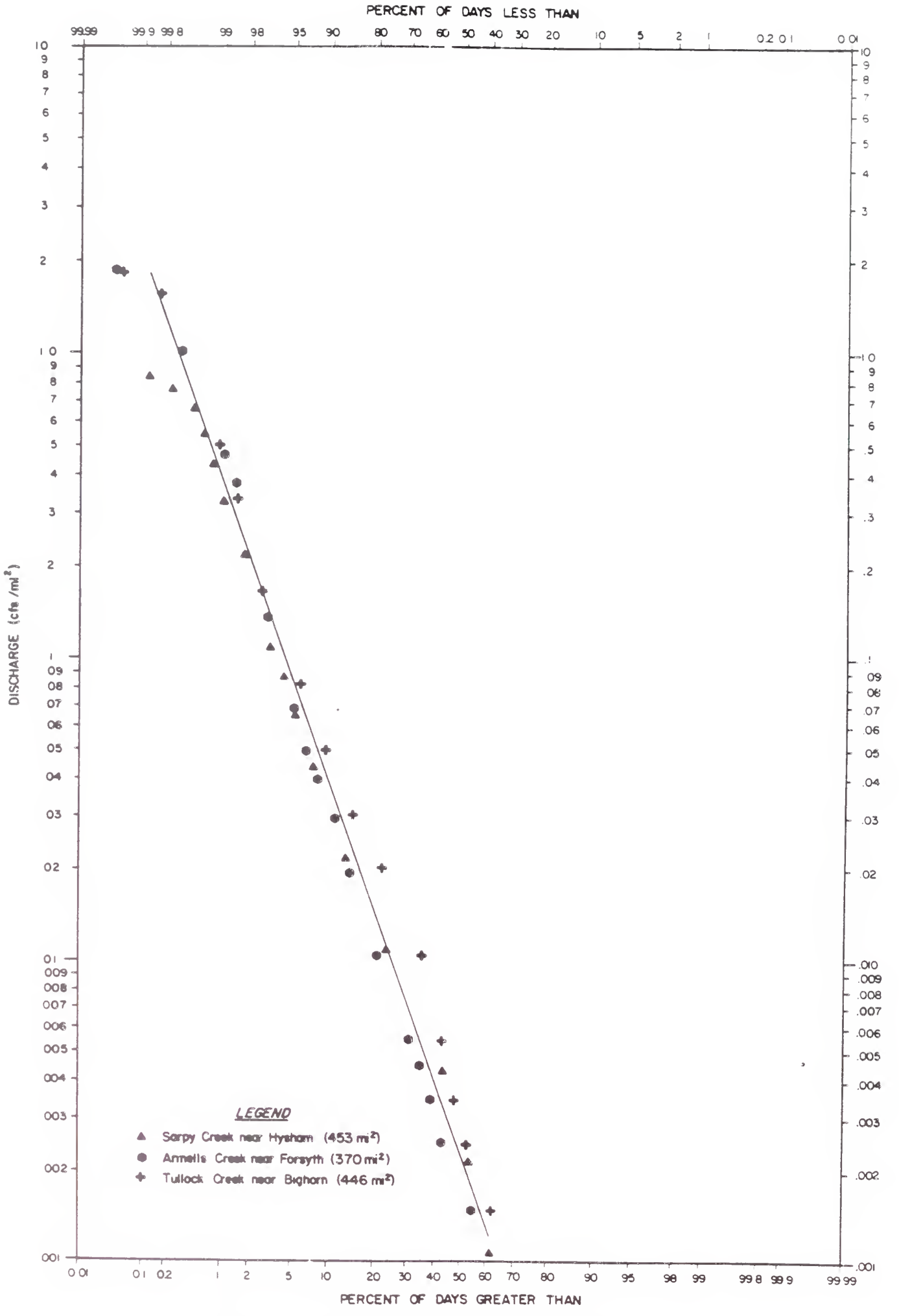
TABLE 8

Chemical Data for Springs
In Vicinity of Area C, Block I

CONCENTRATIONS OF MAJOR CONSTITUENTS FOR SPRINGS
(In mg/l)

	TDS	Ca	Mg	Na	HCO_3	SO_4	Cl	N
SP-01	5,310	580	520	220	900	3,090	98	2.10
SP-02	470	77	54	4	360	65	11	12.38
SP-03	4,930	300	430	490	570	2,970	21	0.04
SP-04	3,240	240	350	190	520	1,901	9	0.11
SP-05	5,160	290	610	240	630	3,080	27	0.02

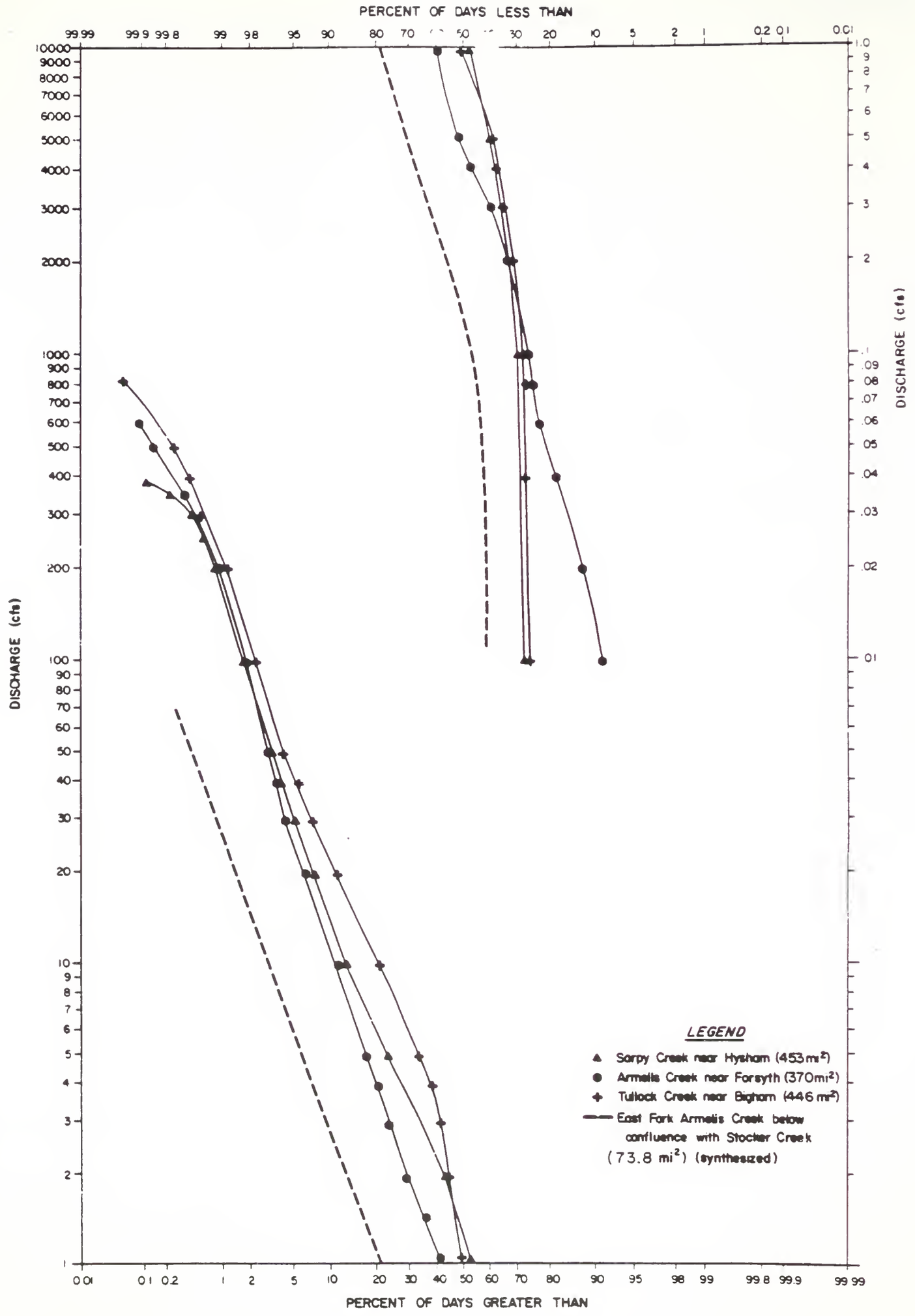
Exhibit 3



PROBABILITY OF FLOW OCCURRENCE PER SQUARE MILE OF DRAINAGE AREA

APPENDIX B FIGURE 1

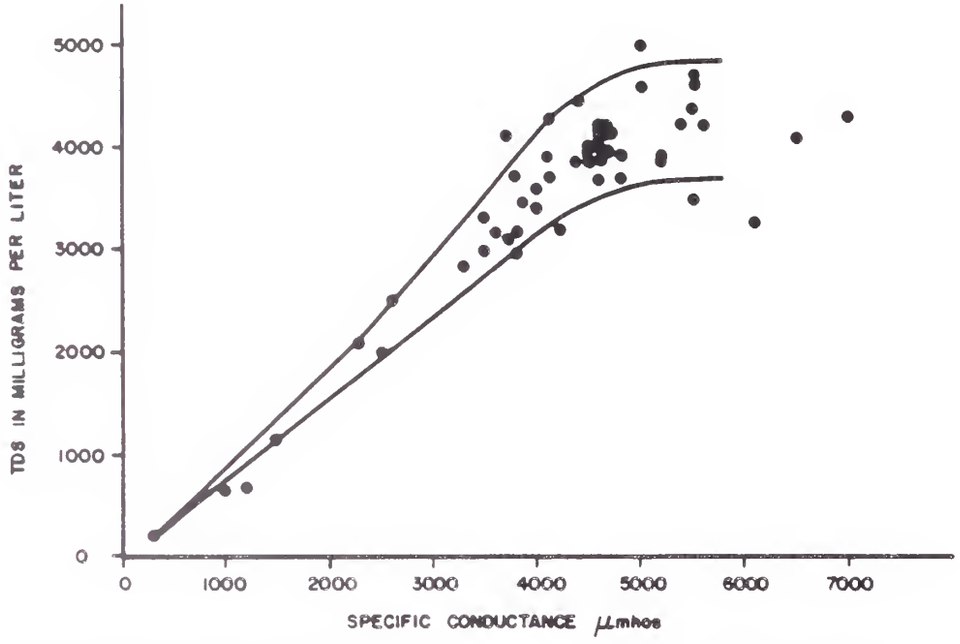
Exhibit 3

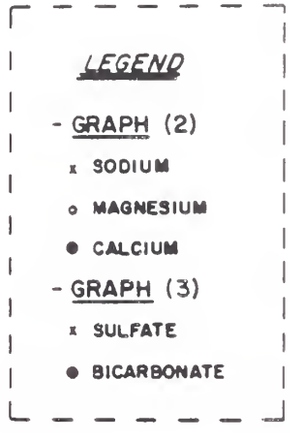


PROBABILITY OF FLOW OCCURRENCE IN DAYS

APPENDIX B FIGURE 2

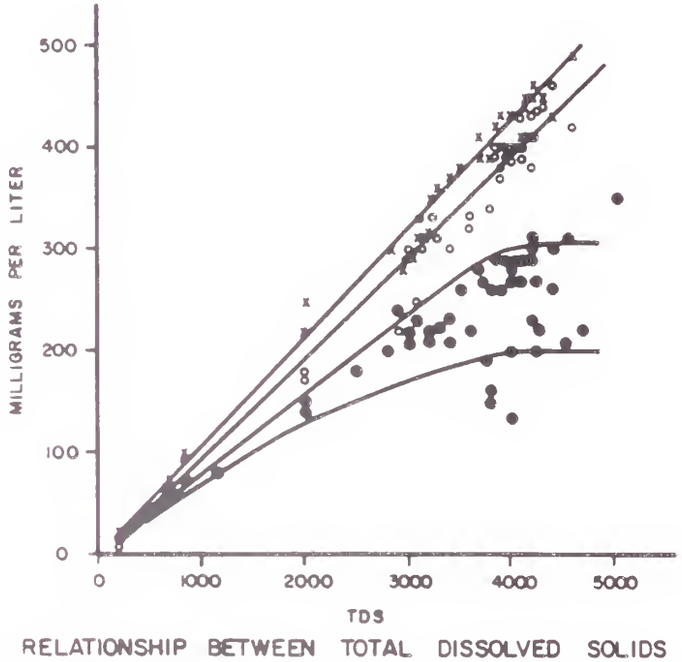
Exhibit 3





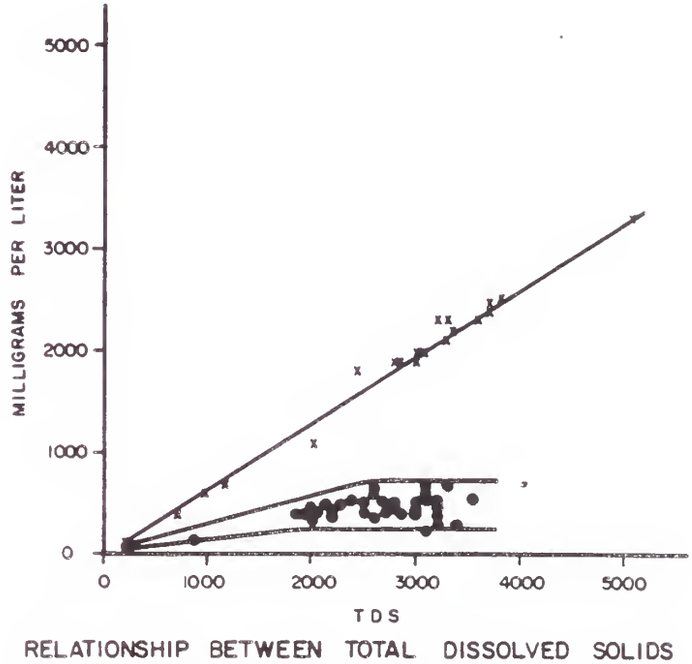
RELATIONSHIP OF SPECIFIC CONDUCTANCE TO TOTAL DISSOLVED SOLIDS FOR EAST FORK ARMELLS CREEK AT USGS STATION NEAR COLSTRIP, MONTANA

(1)



RELATIONSHIP BETWEEN TOTAL DISSOLVED SOLIDS AND SODIUM, MAGNESIUM, AND CALCIUM FOR EAST FORK ARMELLS CREEK AT USGS STATION NEAR COLSTRIP, MONTANA

(2)



RELATIONSHIP BETWEEN TOTAL DISSOLVED SOLIDS WITH SULFATE AND BICARBONATE FOR EAST FORK ARMELLS CREEK AT USGS STATION NEAR COLSTRIP, MONTANA

(3)

APPENDIX B
FIGURE 3 RELATIONSHIPS BETWEEN SELECTED CHEMICAL CONSTITUENTS FOR EAST FORK ARMELLS CREEK AT USGS STATION NEAR COLSTRIP, MONTANA

Exhibit 3

APPENDIX F

TABLE 1

SOIL CHARACTERISTICS OF MAPPING UNITS BY GENERAL SOIL GROUPS

ALLUVIAL LOAMY AND CLAYEY SOILS

Soil Mapping Unit	Slope (%)	Dryland Capability	Acreage to be Disturbed	Salvage Depth Topsoil	Salvage Depth Subsoil	Limitations
16A Kremlin loam	0-2	3e	71.3	1.0'	3.5'	Occassional high salts in subsoil
16C Kremlin loam	2-8	3e	108.0	1.0'	3.5'	Occassional high salts in subsoil
37A Lonna silt loam	0-2	3c	110.7	1.0'	3.0'	Occassional high clay High salts in subsoil
37C Lonna silt loam	2-8	3e	126.0	1.0'	3.0'	Occassional high clay High salts in subsoil
37D Lonna silt loam	8-15	4e	10.3	1.0'	3.0'	Occassional high clay High salts in subsoil
49A Yamac loam	0-2	3e	11.7	1.0'	2.5'	Occassional high salts in subsoil
49C Yamac loam	2-8	3e	108.7	1.0'	2.5'	Occassional high salts in subsoil
49D Yamac loam	8-5	4e	42.1	1.0'	2.5'	Occassional high salts in subsoil
59C Kobar silty clay loam	2-8	3e	4.6	0.5'	2.5'	Moderate to high clay, high salts in subsoil
72B Vanstel silt loam	0-4	3e	23.6	1.0'	1.0'	Occassional high clay
72D Vanstel silt loam	4-8	3e	0.7	1.0'	1.0'	Occassional high salts at surface
92C Delpoint loam	4-8	3e	9.4	0.5'	2.5'	High clay, occassional high salts
92D Delpoint loam	8-20	4e	65.9	0.5'	2.5'	High clay, occassional high salts
311 Havre loam	0-4	3w	0.9	1.0'	0.5'	Occassional high salts
7E Ustic Torriorthents	0-20*	3w-4e	15.9	1.0'	2.5'	Occassional high salts
			709.8	(Represents 44% of area to be disturbed)		

* Reflects slopes occurring in Area C.

Exhibit 3

APPENDIX F

TABLE 1 (Continued)

SANDY RESIDUAL SOILS

Soil Mapping Unit	Slope (%)	Dryland Capability	Acreage to be Disturbed	Salvage Depth Topsoil	Salvage Depth Subsoil	Limitations
13C Busby fine sandy loam	2-8	4e	301.8	0.5	2.0	Excess sand
13D Busby fine sandy loam	8-15	4e	238.6	0.5	2.0	Excess sand
23C Cooers loam	2-8	3e	59.5	1.0	2.5	Excess sand
131E Busby-Yetull-Rock Outcrop Complex	8-25	6e	65.3	0.5	1.5	Excess sand, depth to rock
132E Busby-Reidel Complex	8-25	6e	43.6	0.5	1.5	Excess sand, depth to rock
183E Busby-Rock Outcrop Complex	8-25	6e	1.3	0.5	1.0	Excess sand, depth to rock
			710.1	(Represents 44% of area to be disturbed)		

SCORIA SOILS

Soil Mapping Unit	Slope (%)	Dryland Capability	Acreage to be Disturbed	Salvage Depth Topsoil	Salvage Depth Subsoil	Limitations
121E Birney-Kirby Channery loams	4-25	6e	50.9	0.5	1.0	Depth to rock
122D Birney-Cooers-Kirby Complex	2-15	6s	56.6	0.5	1.5	Depth to rock
123E Birney-Kirby Channery loams, moist	15-25	6e	10.5	0.5	1.0	Depth to rock
125E Birney-Kirby-Cabbart Complex	15-25	6e	15.2	0.5	1.5	Depth to rock
127F Birney-Kirby-Cabbart Complex	25-70	7e	4.8	0.5	1.5	Depth to rock, slope limits salvaging operations
			138.0	(Represents 8% of area to be disturbed)		

Exhibit 3

APPENDIX F

TABLE 1 (Continued)

UNBAKED SHALE AND SILTSTONE SOILS

Soil Mapping Unit	Slope (%)	Dryland Capability	Acreage to be Disturbed	Salvage Depth Topsoil	Salvage Depth Subsoil	Limitations
84D Cabbart loam	4-15	6e	7.1	0.5'	1.0'	Depth to rock, high clay, high salts
184F Cabbart-Yawdim-Rock Outcrop Complex	15-70	7e	22.9	0.5'	0.0'	Depth to rock, high clay
188E Delpoint-Cabbart loams	15-25	6e	2.7	0.5'	0.5'	Depth to rock, high clay, high salts
493E Yamac-Cabbart loams	8-25	6e	5.7	0.5'	1.0'	Depth to rock, high clay, high salts
741C Delpoint-Rentsac loams	2-8	4e	30.5	0.5'	1.0'	Depth to rock, high clay
			68.9	(Represents 4% of area to be disturbed)		

Exhibit 3

APPENDIX G

TABLE I

RANGE PRODUCTION, VEGETATIVE PRODUCTION,
AND INITIAL STOCKING RATES FOR NATIVE
VEGETATIVE COMMUNITIES IN
AREA C, BLOCK I

General Vegetative Type[a]	Sub-type	Range Condition Class[b]	Present Initial Stocking Rate aum/ac.[c]	Present Total Annual Veg. Production lbs./acre[b]	Potential Veg. Production lbs./acre[c]	Potential Initial Stocking Rate aum/ac.[c]
Grassland	loamy, silty soils	Fair	.15	564	1050-2200	.45
	sandy soils	Fair	.15	564	1000-2300	.45
Sagebrush-Shrubland	big sagebrush	Fair	.15	692	1050-2200	.45
	silver sagebrush	Fair	.15	1000	1050-2200	.45
	"gumbo knob"	Poor	.05	306	500-1100	.23
Conifer-Shrubland	skunkbush sumac	Good	.25	1025	900-2400	.45
	ponderosa pine	Good	.20	356	500-1200	.23

[a] Shown on Figure II-11

[b] Source: 1979 Vegetation Report for mining Area C for Western Energy, ECON, Inc.

[c] Source: SCS-Montana Technical Guide, Section II-E-8, current figures (3/82) for Miles City field office.

Initial stocking rates are intended to be used as a guide for grazing management. Actual stocking rates will vary depending upon the class of livestock, season of use, and characteristics of the site.

Exhibit 3

APPENDIX G

TABLE 2

PROPOSED REVEGETATION APPROACH
AREA C, BLOCK I

PHASE I - SUPPLEMENTAL GRASS, FORBS, AND SHRUB MIXTURE

This seed mixture will be broadcast onto prepared seedbeds in all reclaimed areas during the first optimal seeding period following soil placement.

Common Name/Scientific Name	Percent of Mix (PLS)
Side-oats grama/*Bouteloua curtipendula*	28
Needle-and-Thread/*Stipa comata*	15
Indian ricegrass/*Oryzopsis hymenoides*	10
Fourwing saltbush/*Atriplex canescens*	5
Winterfat/*Ceratoides lanata*	10
Blue grama/*Bouteloua gracilis*	10
Lewis flax/*Linum lewisii*	5
Prairie coneflower/*Ratibida columnifera*	5
Western yarrow/*Achillea millefoluim lanulosa*	5
Purple prairie clover/*Petalostemon purpureum*	2.5
White prairie clover/*Petalostemon candidum*	2.5
Cicer milkvetch (Lutana)/*Astragalus cicer*	1
Sainfoin (ESKE)/*Onobrychis viciaefolia*	1

Seeding rates 13 lbs./acre of pure live seed (PLS), with an additional 5 lbs. PLS/acre of sterile wintergraze.

Exhibit 3

APPENDIX G

TABLE 2 (Continued)

PHASE II - REVEGETATION AREA SEED MIXTURES

These mixtures will be drill seeded one to three years after the first phase supplemental mixture is planted. Seeding rates will be 20 pounds of pure live seed (PLS) per acre, with an additional five pounds (PLS) of the sterile hydrid wintergraze included to increase cover. Areas have been delineated based upon topographic position on the post-mined topography.

Lowland/Drainage Seed Mixture - 84 acres

Common Name/Scientific Name	Percent of Mix (PLS)
Rosana Western Wheatgrass/*Agropyron smithii*	30
Slender Wheatgrass/*A. trachycaulum*	20
Thickspike Wheatgrass/*A. dasystachyum*	10
Mountain brome/*Bromus marginatus*	10
Kentucky bluegrass/*Poa pratensis*	10
Canada bluegrass/*P. compressa*	10
Canada wildrye/*Elymus canadensis*	10

Uplands Grass Mixture - 821 acres

Common Name/Scientific Name	Percent of Mix (PLS)
Rosana Western wheatgrass/*Agropyron smithii*	40
Critana thickspike wheatgrass/*A. dasystachyum*	25
Slender wheatgrass/*A. trachycaulum*	5
Green needlegrass/*Stipa viridula*	30

Of the areas planted with this mix, tubeling shrubs grown in a greenhouse from locally collected seed will be planted on the following acreages:

21 acres - Big sagebrush/*Artemisia tridentata*

18 acres - Silver sagebrush/*Artemisia cana*

11 acres - Skunkbush sumac/*Rhus trilobata*

1 acre - Rubber rabbitbush/*Chrysothamnus nauseous*

1 acre - Skunkbush sumac and Rubber rabbitbrush

Exhibit 3

APPENDIX G

TABLE 2 (Continued)

Steep Uplands Grass Mixture - 600 acres

Common Name/Scientific Name	Percent of Mix (PLS)
Green needlegrass/*Stipa viridula*	50
Rosana western wheatgrass/*Agropyron smithii*	15
Critana thickspike wheatgrass/*A. dasystachyum*	30
Slender wheatgrass/*A. trachycaulum*	5

Of the areas planted with the mix, tubeling shrubs will be planted on the following acreages:

63 acres - Big Sagebrush

41 acres - Skunkbush sumac

2 acres - Rubber rabbitbrush

Conifer Zone Grass Mixture - 61 acres

Common Name/Scientific Name	Percent of Mix (PLS)
Green needlegrass/*Stipa viridula*	40
Side-oats grama/*Bouteloua curtipendula*	40
Indian ricegrass/*Oryzopsis hymenoides*	10
Rosana western wheatgrass/*Agropyron smithii*	5
Critana thickspike wheatgrass/*A. dasystachyum*	5

Of the areas planted with the mix, nine acres will be planted with tubelings of skunkbush sumac.

In any of the areas in which sandy soils may occur, e.g., the Uplands, Steep Uplands, and Conifer Zone, an additional "patch seeding" approach will be used. Sandy soil materials of one acre or less in size will be seeded with the following mixture of warm season grasses at a rate of 40 lbs./acre PLS:

Big bluestem/*Andropogon gerardii*

Sand bluestem/*A. hallii*

Little bluesteam/*Schizachyrium scoparium*

Prairie sandreed/*Calamovilfa longifolia*

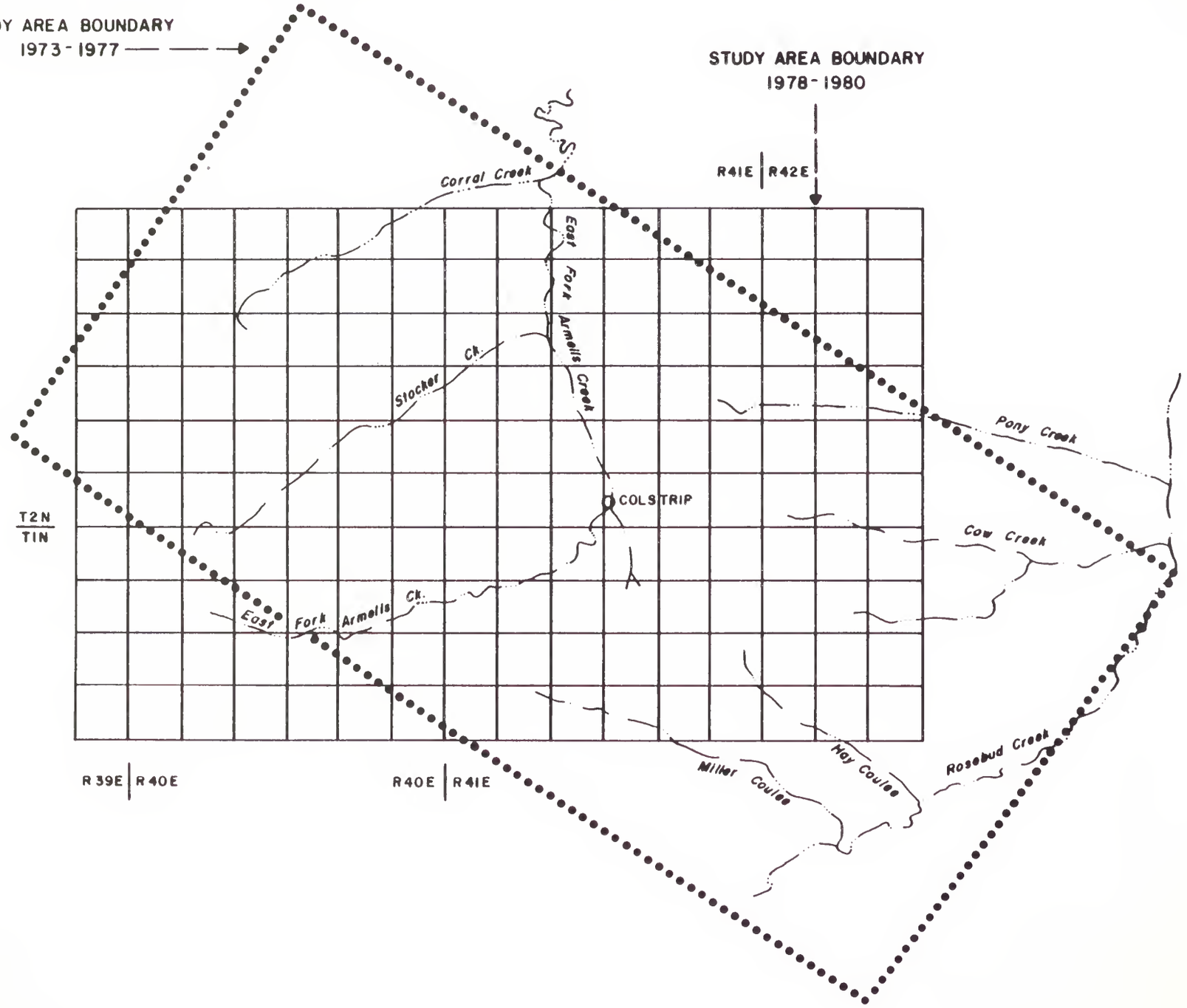
Exhibit 3

APPENDIX G

TABLE 2 (Continued)

Additional shrubs and trees will be transplanted by utilizing a tree spade and transplanting mature stock from potentially disturbed areas onto regraded areas. Any of the numerous shrub and tree species occurring in Area C, Block I may be handled in this way.

Exhibit 3



APPENDIX H

FIGURE 1 MAP OF ROSEBUD MINE WILDLIFE STUDY AREA

Exhibit 3

APPENDIX H

TABLE 1

SUMMARY OF PRONGHORN ANTELOPE AERIAL SURVEYS AND RESULTS
WILDLIFE STUDY AREA 1974 - 1980

Year	Number of Flights	Total Air Hours	Obser-vations Per Hour	Fawns Per 100 Does	Percent Herd Composition		
					Male	Female	Young
1974	14	24.1	37.5	40	25	54	21
1975	24	37.9	29.6	20	20	67	13
1976	23	41.7	21.7	18	18	69	13
1977	20	31.1	25.8	31	12	67	21
1978*	23	31.5	25.9	34	18	61	21
1979*	17	31.5	15.6	49	15	57	28
1980*	21	33.2	24.1	59	12	55	33

* Study area was reduced in 1978 from 200 sq. mi. to 160 sq. mi., of which approximately 80 percent was included in the original 200 sq. mi. study area.

Exhibit 3

APPENDIX H

TABLE 2

SUMMARY OF MULE DEER AERIAL SURVEYS AND RESULTS

WILDLIFE STUDY AREA

Year	Number of Flights	Total Air Hours	Obser-vations Per Hour	Fawns Per 100 Does	Percent Herd Composition		
					Antlered	Antlerless	Young
1974	10	24.1	31.9	68	13	52	35
1975	23	37.9	22.4	70	14	50	36
1976	23	41.7	21.1	62	12	54	34
1977	19	31.1	19.2	57	11	57	32
1978*	22	31.5	12.7	64	15	52	33
1979*	24	31.5	14.6	78	12	49	39
1980*	30	33.2	15.2	56	15	54	30

* Study area was reduced in 1978 from 200 sq. mi. to 160 sq. mi., of which approximately 80 percent was included in the original 200 sq. mi. study area.

Exhibit 3

APPENDIX H

TABLE 3

MAMMALS EXPECTED IN SOUTHEASTERN MONTANA*

Common Name (Scientific Name)	Colstrip[1]	Special Concern[2]	Thompson[3]
Insectivora:			
Masked shrew (Sorex cinereus)	X		
Hayden shrew (Sorex haydeni)			X
Preble's shrew (Sorex preblei)			X
Merriam's shrew (Sorex merriami)		X	
Chiroptera:			
Little brown myotis (Myotis lucifugus)	X		
Long-eared myotis (Myotis evotis)			X
Small-footed myotis (Myotis leibii)	X		X
Long-legged myotis (Myotis volans)			
Silver-haired bat (Lasionycteris noctivagans)			
Big brown bat (Eptesicus fuscus)	X		X
Hoary bat (Lasiurus cinereus)			X
Townsend's big-eared bat (Plecotus townsendii)		X	X
Lagomorpha:			
Nuttall's cottontail (Sylvilagus nuttallii)	X		
Desert cottontail (Sylvilagus audubonii)	X		X
Snowshoe hare (Lepus americanus)			
White-tailed jackrabbit (Lepus townsendii)	X		X
Rodentia:			
Least chipmunk (Eutamias minimus)	X		X
Yellow-bellied marmot (Marmota flaviventris)	X		X
Richardson's ground squirrel (Spermophilus richardsonii)	X		
Thirteen-lined ground squirrel (Spermophilus tridecemlineatus)	X		X

* Nomenclature follows Jones, et al, 1979; distribution information from Hall, 1981; Burt and Grossenheider, 1964; Flath, 1981; and Thompson, 1982.

1 Denotes species seen during the Rosebud Mine Wildlife Studies (Ecological Consulting Service, 1972, 1973, 1974, 1975; ECON, 1976a, 1977a, 1978, 1979; Western Energy, 1980).

2 Denotes species listed by Flath, 1981.

3 Denotes species listed as known from latilongs 33 or 43 by Thompson (1982).

Exhibit 3

APPENDIX H

TABLE 3 (Continued)

Common Name (Scientific Name)	Colstrip[1]	Special Concern[2]	Thompson[3]
Black-tailed prairie dog (Cynomys ludovicianus)	X	X	X
Fox squirrel (Sciurus niger)			X
Red squirrel (Tamiasciurus hudsonicus)			X
Northern pocket gopher (Thomomys talpoides)	X		X
Olive-backed pocket mouse (Perognathus fasciatus)			X
Ord's kangaroo rat (Dipodomys ordii)	X		X
Beaver (Castor canadensis)	X		X
Western harvest mouse (Reithrodontomys megalotis)	X		X
Deer mouse (Peromyscus maniculatus)	X		X
White-footed mouse (Peromyscus leucopus)	X		X
Northern grasshopper mouse (Onchomys leucogaster)	X		X
Bushy-tailed wood rat (Neotoma cinerea)			X
Meadow vole (Microtus pennsylvanicus)	X		X
Long-tailed vole (Microtus longicaudus)			X
Prairie vole (Microtus ochrogaster)	X		X
Sagebrush vole (Lagurus curtatus)			
Muskrat (Ondatra zibethicus)	X		X
House mouse (Mus musculus)	X		X
Meadow-jumping mouse (Zapus hudsonius)	X		X
Western jumping mouse (Zapus princeps)			
Porcupine (Erethizon dorsatum)	X		X
Carnivora:			
Coyote (Canis latrans)	X		X
Red fox (Vulpes vulpes)	X		X
Swift fox (Vulpes velox)		X	X
Black bear (Ursus americanus)			X
Raccoon (Procyon lotor)	X		X
Ermine (Mustela erminea)			X
Long-tailed weasel (Mustela frenata)	X		X
Black-footed ferret (Mustela nigripes)**		X	
Mink (Mustela vison)			X
Badger (Taxidea taxus)	X		X

** Endangered species (Federal Register, 1980)

Exhibit 3

APPENDIX H

TABLE 3 (Continued)

Common Name (Scientific Name)	Colstrip[1]	Special Concern[2]	Thompson[3]
Striped skunk (Mephitis mephitis)	X		X
River otter (Lutra canadensis)			X
Mountain lion (Felis concolor)			X
Bobcat (Felis rufus)	X		X
Artiodactyla:			
Elk (Cervus elaphus)	X		X
Mule deer (Odocoileus hemionus)	X		X
White-tailed deer (Odocoileus virginianus)	X		X
Pronghorn (Antilocapra americana)	X		X
Mountain sheep (Ovis canadensis)			X

APPENDIX H

TABLE 4

BIRDS EXPECTED IN SOUTHEASTERN MONTANA*

Common Name (Scientific Name)	Colstrip[1]	Special Concern[2]	Skaar[3]
Gaviiformes:			
Common loon (Gavia immer)	X		X
Podicipediformes:			
Horned grebe (Podiceps auritus)	X		X
Eared grebe (Podiceps caspicus)	X		X
Western grebe (Aechmophorus occidentalis)	X		X
Pied-billed grebe (Podilymbus podiceps)	X		X
Pelecaniformes:			
White pelican (Pelecanus erythrorhynchos)	X		X
Double-crested cormorant (Phalacrocorax auritus)			X
Anseriformes:			
Whistling swan (Olor columbianus)			
Canada goose (Branta canadensis)	X		X
Snow goose (Chen hyperborea)			
Mallard (Anas platyrhynchos)	X		X
Black duck (Anas rubripes)			X
Gadwall (Anas strepera)	X		X
Pintail (Anas acuta)	X		X
Green-winged teal (Anas carolinensis)	X		X
Blue-winged teal (Anas discors)	X		X
Cinnamon teal (Anas cyanoptera)	X		X
American widgeon (Mareca americana)	X		X
Shoveler (Spatula clypeata)	X		X
Wood duck (Aix sponsa)			X
Redhead (Aythya americana)	X		X
Ring-necked duck (Aythya collaris)	X		X
Canvasback (Aythya valisineria)	X		X
Lesser scaup (Aythya affinis)	X		X
Common goldeneye (Bucephala clangula)	X		X
Bufflehead (Bucephala albeola)	X		
Ruddy duck (Oxyura jamaicensis)	X		X
Common merganser (Mergus merganser)			X

* Distribution information from Robbins et al., 1966.

1 Denotes species seen during Rosebud Mine Wildlife Studies.

2 Denotes species listed by Flath, 1981.

3 Denotes species listed by Skaar, 1975, as present in latilongs 34 or 43.

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APPENDIX H

TABLE 4 (Continued)

Common Name (Scientific Name)	Colstrip	Special Concern	Skaar
Falconiformes:			
Turkey vulture (Cathartes aura)			X
Goshawk (Accipiter gentilis)		X	
Sharp-shinned hawk (Accipiter striatus)			X
Cooper's hawk (Accipiter cooperii)	X	X	X
Red-tailed hawk (Buteo jamaicensis)	X		X
Swainson's hawk (Buteo swainsoni)	X		X
Rough-legged hawk (Buteo lagopus)	X		X
Ferruginous hawk (Buteo regalis)	X	X	X
Golden eagle (Aquila chrysaetos)	X	X	X
Bald eagle (Haliaeetus leucocephalus)**	X	X	X
Northern harrier (Circus cyaneus)	X		X
Osprey (Pandion haliaetus)		X	X
Prairie falcon (Falco mexicanus)	X	X	X
Peregrine falcon (Falco peregrinus)**		X	
Merlin (Falco columbarius)	X	X	
American kestrel (Falco sparverius)	X		X
Galliformes:			
Ruffed grouse (Bonasa umbellus)			X
Sharp-tailed grouse (Pedioecetes phasianellus)	X		X
Sage grouse (Centrocercus urophasianus)	X		X
Ring-necked pheasant (Phasianus colchicus)	X		X
Chukar (Alectoris graeca)			X
Hungarian (Gray) Partridge (Perdix perdix)	X		X
Turkey (Meleagris gallopavo)	X		X
Ciconiformes:			
Great blue heron (Ardea herodias)	X		X
American bittern (Botaurus lentiginosus)			X
Gruiformes:			
Whooping crane (Grus americana)**			X
Sandhill crane (Grus canadensis)			X
Virginia rail (Rallus limicola)			
Sora (Porzana carolina)			X
American coot (Fulica americana)	X		X
Charadriiformes:			
Killdeer (Charadrius vociferus)	X		X
Mountain plover (Eupoda montana)		X	X
Black-bellied plover (Squatarola squatarola)			
Common snipe (Capella gallinago)	X		X

** Endangered species (Federal Register, 1980)

Exhibit 3

APPENDIX H

TABLE 4 (Continued)

Common Name (Scientific Name)	Colstrip	Special Concern	Skaar
Long-billed curlew (Numenius americanus)		X	X
Upland plover (Bartramia longicauda)	X		X
Spotted sandpiper (Actitis macularia)	X		X
Solitary sandpiper (Tringa solitaria)	X		X
Willet (Catoptrophorus semipalmatus)	X		X
Greater yellowlegs (Totanus melanoleucus)	X		X
Lesser yellowlegs (Totanus flavipes)			X
Least sandpiper (Erolia minutilla)			X
Long-billed dowitcher (Limnodromus scolopaceus)	X		X
Semipalmated sandpiper (Calidris pusilla)			X
Western sandpiper (Erunetes mauri)			X
Marbled godwit (Limosa fedoa)			
American avocet (Recurvirostra americana)			X
Wilson's phalarope (Steganopus tricolor)	X		X
Northern phalarope (Lobipes lobatus)			X
Herring gull (Larus argentatus)			X
California gull (Larus californicus)			X
Ring-billed gull (Larus delawarensis)	X		X
Franklin's gull (Larus pipixcan)			X
Common tern (Sterna hirundo)	X		
Black tern (Chlidonias niger)	X		
Columbiformes:			
Rock dove (Columba livia)			X
Mourning dove (Zenaida macroura)	X		X
Cuculiformes:			
Yellow-billed cuckoo (Coccyzus americanus)			X
Black-billed cuckoo (Coccyzus erythropthalmus)	X		X
Strigiformes:			
Barn owl (Tyto alba)			X
Screech owl (Otus asio)			
Great horned owl (Bubo virginianus)	X		X
Pygmy owl (Glaucidium gnoma)		X	
Burrowing owl (Athene cunicularia)	X	X	
Barred owl (Strix varia)		X	
Long-eared owl (Asio otus)	X	X	
Short-eared owl (Asio flammeus)	X		X
Saw-whet owl (Aegolius acadicus)		X	X

Exhibit 3

APPENDIX H

TABLE 4 (Continued)

Common Name (Scientific Name)	Colstrip	Special Concern	Skaar
Caprimulgiformes:			
Poor-will (Phalaenoptilus nuttallii)			X
Common nighthawk (Chordeiles minor)	X		X
Apodiformes:			
Chimney swift (Chaetura pelagica)			X
White-throated swift (Aeronautes saxatalis)	X		X
Coraciiformes:			
Belted kingfisher (Megaceryle alcyon)	X		X
Piciformes:			
Common flicker (Colaptes auratus)	X		X
Red-headed woodpecker (Melanerpes erythrocephalus)	X		X
Lewis' woodpecker (Asyndesmus lewis)			X
Yellow-bellied sapsucker (Sphyrapicus varius)			
Hairy woodpecker (Dendrocopos villosus)			X
Downy woodpecker (Dendrocopos pubescens)	X		X
Black-backed three-toed woodpecker (Picoides arcticus)			X
Passeriformes:			
Eastern kingbird (Tyrannus tyrannus)	X		X
Western kingbird (Tyrannus verticalis)	X		X
Cassin's kingbird (Tyrannus vociferans)			X
Say's phoebe (Sayornis saya)	X		X
Least flycatcher (Empidonax minimus)			X
Dusky flycatcher (Empidonax oberholseri)	X		X
Western wood pewee (Contopus sordidulus)	X		X
Olive-sided flycatcher (Nuttalornis borealis)			?
Horned lark (Eremophila alpestris)	X		X
Violet-green swallow (Tachycineta thalassina)	X		X
Tree swallow (Iridoprocne bicolor)			X
Bank swallow (Riparia riparia)	X		X
Rough-winged swallow (Stelgidopteryx ruficollis)	X		X
Barn swallow (Hirundo rustica)	X		X
Cliff swallow (Petrochelidon pyrrhonota)	X		X
Purple martin (Progne subis)	X		X
Blue jay (Cyanocitta cristata)			X
Steller's jay (Cyanocitta stelleri)			
Black-billed magpie (Pica pica)	X		X

Exhibit 3

APPENDIX H

TABLE 4 (Continued)

Common Name (Scientific Name)	Colstrip	Special Concern	Skaar
Common raven (Corvus corax)			X
Common crow (Corvus brachyrhynchos)	X		X
Pinyon jay (Gymnorhinus cyanocephala)	X		X
Clark's nutcracker (Nucifraga columbiana)			
Black-capped chickadee (Parus atricapillus)	X		X
White-breasted nuthatch (Sitta carolinensis)	X		X
Red-breasted nuthatch (Sitta canadensis)	X		
Brown creeper (Certhia familiaris)			X
Dipper (Cinclus mexicanus)			
House wren (Troglodytes aedon)	X		X
Long-billed marsh wren (Telmatodytes palustris)			X
Canyon wren (Catherpes mexicanus)			X
Rock wren (Salpinctes obsoletus)	X		X
Mockingbird (Mimus polyglottos)	X		
Catbird (Dumetella carolinensis)	X		X
Brown thrasher (Toxostoma rufum)	X		X
Sage thrasher (Oreoscoptes montanus)			X
American robin (Turdus migratorius)	X		X
Swainson's thrush (Catharus ustulatus)			X
Gray-cheeked thrush (Catharus minimus)			X
Veery (Catharus fuscescens)			X
Townsend's solitaire (Myadestes townsendi)	X		X
Eastern bluebird (Sialia sialis)	X	X	X
Western bluebird (Sialia mexicana)	X	X	?
Mountain bluebird (Sialia currucoides)	X		X
Golden-crowned kinglet (Regulus satrapa)			
Ruby-crowned kinglet (Regulus calendula)			
Water pipit (Anthus spinoletta)			
Sprague's pipit (Anthus spragueii)			
Bohemian waxwing (Bombycilla garrula)	X		X
Cedar waxwing (Bombycilla cedrorum)	X		X
Northern shrike (Lanius excubitor)	X		X
Loggerhead shrike (Lanius ludovicianus)	X		X
Starling (Sturnus vulgaris)	X		X
Solitary vireo (Vireo solitarius)			X
Red-eyed vireo (Vireo olivaceus)	X		X
Warbling vireo (Vireo gilvus)			X
Black and white warbler (Mniotilta varia)			X
Orange-crowned warbler (Vermivora celata)			X
Yellow warbler (Dendroica petechia)	X		X
Yellow-rumped warbler (Dendroica auduboni)			X
Ovenbird (Seiurus aurocapillus)			X
Northern waterthrush (Seiurus novaboracensis)			X
Yellowthroat (Geothlypis trichas)	X		X

Exhibit 3

APPENDIX H

TABLE 4 (Continued)

Common Name (Scientific Name)	Colstrip	Special Concern	Skaar
Yellow-breasted chat (Icteria virens)			X
American redstart (Setophaga ruticilla)	X		X
House sparrow (Passer domesticus)	X		X
Bobolink (Dolichonyx oryzivorus)		X	
Western meadowlark (Sturnella neglecta)	X		X
Yellow-headed blackbird (Xanthocephalus xanthocephalus)	X		X
Red-winged blackbird (Agelaius phoeniceus)	X		X
Northern oriole (Icterus galbula)	X		X
Brewer's blackbird (Euphagus cyanocephalus)	X		X
Common grackle (Quiscalis quiscula)	X		X
Brown-headed cowbird (Molothrus ater)	X		X
Western tanager (Piranga ludoviciana)	X		X
Black-headed grosbeak (Pheucticus melanocephalus)			X
Lazuli bunting (Passerina amoena)			X
Dickcissel (Spiza americana)		X	X
Evening grosbeak (Hesperiphona vespertina)	X		X
Cassin's finch (Carpodacus cassinii)			?
Gray-crowned rosy finch (Leucosticte tephrocotis)	X		X
Black rosy finch (Leucosticte atrata)			X
Pine siskin (Spinus pinus)	X		X
American goldfinch (Spinus tristis)	X		X
Red crossbill (Loxia curvirostra)	X		X
Rufous-sided towhee (Pipilo erythrophthalmus)	X		X
Lark bunting (Calamospiza melanocorys)	X		X
Savannah sparrow (Passerculus sandwichensis)	X		X
Grasshopper sparrow (Ammodramus savannarum)	X		X
Baird's sparrow (Ammodramus bairdii)			
Vesper sparrow (Pooecetes gramineus)	X		X
Lark sparrow (Chondestes grammacus)	X		X
Dark-eyed junco (Junco hyemalis)	X		X
Tree sparrow (Spizella arborea)			X
Chipping sparrow (Spizella passerina)	X		X
Clay-colored sparrow (Spizella pallida)			X
Brewer's sparrow (Spizella breweri)		X	X
Harris' sparrow (Zonotrichia querula)			X
White-crowned sparrow (Zonotrichia leucophrys)	X		X
Lincoln's sparrow (Melospiza lincolnii)			X
Song sparrow (Melospiza melodia)	X		X
Snow bunting (Plectrophenax nivalis)	X		X
McCown's longspur (Rhynocophanes mccownii)	X		X
Chestnut-collared longspur (Calcarius ornatus)			X

Exhibit 3

APPENDIX H

TABLE 5

REPTILES AND AMPHIBIANS EXPECTED IN SOUTHEASTERN MONTANA*

Common Name (Scientific Name)	Colstrip[1]	Special Concern[2]	Thompson[3]
Tiger salamander (Ambystoma tigrinum)	X		X
Plains spadefoot (Scaphiopus bombifrons)			X
Western toad (Bufo boreas)			?
Rocky Mountain toad (Bufo woodhousei)			X
Great Plains toad (Bufo cognatus)			X
Dakota toad (Bufo hemiophrys)			X
Boreal chorus frog (Pseudacris triseriata)			?
Leopard frog (Rana pipiens)	X		X
Bullfrog (Rana catesbiana)			X
Snapping turtle (Chelydra serpentina)	X	X	X
Painted turtle (Chrysemys picta)	X		X
Spiny softshell (Trionyx spiniferus)		X	X
Sagebrush lizard (Sceloporus graciosus)	X		X
Eastern short-horned lizard (Phrynosoma douglassi)			X
Plains hognose snake (Heterodon nasicus)	X	X	X
Yellow-bellied racer (Coluber constrictor)	X		X
Bull snake (Pituophis melanoleucus)	X		X
Milk snake (Lampropeltis triangulum)			X
Common garter snake (Thamnophis sirtalis)	X		X
Plains garter snake (Thamnophis radix)			
Wandering garter snake (Thamnophis elegans)			X
Prairie rattlesnake (Crotalus viridis)	X		X

* Information from Stebbens (1966) maps and text.

1 Denotes species seen in the Rosebud Mine Wildlife Studies.

2 Denotes species listed by Flath, 1981.

3 Denotes species listed from latilong 33 or 43 by Thompson, 1981.

APPENDIX I

TABLE 1

PERSONAL INCOME, BY MAJOR SOURCE
ROSEBUD COUNTY AND MONTANA, 1970 and 1979
(In Thousands of 1980 Dollars)

	Rosebud County				Montana			
	1970		1979		1970		1979	
	1980 Dollars	Percentage of Total	1980 Dollars	Percentage of Total	1980 Dollars	Percentage of Total	1980 Dollars	Percentage of Total
Total Personal Income	$33,201	100.0	$67,282	100.0	$ 4,697,355	100.0	$ 6,787,331	100.0
Labor and Proprietors' income	26,181	78.9	56,412	83.9	3,661,398	77.9	4,930,531	72.7
Farm	6,221	18.7	1,830	2.7	533,570	11.4	326,483	4.8
Agricultural services, other	306	.9	301	.5	13,011	.3	23,148	.4
Mining	1,286	3.9	14,085	20.9	125,642	2.7	208,172	3.1
Construction	710	2.1	7,301	10.9	256,081	5.5	408,330	6.0
Manufacturing	2,177	6.6	2,421	3.6	397,178	8.5	537,739	7.9
Transportation, Public Utilities	3,528	10.6	6,124	9.1	335,892	7.2	548,160	8.1
Trade	2,564	7.7	4,066	6.1	626,110	13.3	903,224	13.3
Finance, insurance, and real estate	278	.8	896	1.3	136,134	2.9	238,870	3.5
Services	4,006	12.3	10,598	15.8	482,594	10.3	774,948	11.4
Federal government	1,929	5.8	2,752	4.1	305,926	6.5	341,728	5.0
State and local government	3,096	9.3	6,038	9.0	449,260	9.6	619,729	9.1
Dividends, interest, and rents	5,253	15.8	10,064	15.0	696,787	14.8	1,289,958	19.0
Transfer payments	4,332	13.1	7,353	10.9	519,436	11.1	889,869	13.1
Social security contributions and residence adjustments	-2,564	-7.7	-6,547	-9.7	-180,266	-3.8	-323,027	-4.8

Source: U.S. Bureau of Economic Analysis, 1981.

Exhibit 3

APPENDIX I

TABLE 2

PERSONAL INCOME BY BROAD CATEGORIES
ROSEBUD COUNTY, 1970 to 1979
(In Thousands of 1980 Dollars)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Total personal income	$33,201	$31,764	$36,696	$52,345	$51,750	$72,037	$63,611	$60,348	$71,642	$67,282
Labor and proprietors' income	26,181	25,228	30,823	46,055	44,893	70,453	61,614	53,086	62,269	56,412
Farm	6,221	4,128	6,609	13,955	6,983	2,587	-804	-701	6,820	1,830
Agricultural services, other	306	223	259	186	200	215	419	318	311	301
Mining	1,286	1,601	2,279	7,202	7,505	11,562	13,760	13,283	14,320	14,095
Construction	710	436	947	1,653	5,177	37,590	19,820	11,308	7,957	7,301
Manufacturing	2,177	2,395	2,389	1,871	1,909	1,675	1,271	752	1,385	2,421
Transportation, Public Utilities	3,528	3,380	3,850	4,157	4,401	4,223	4,975	5,435	5,439	6,124
Trade	2,564	2,697	3,025	3,280	3,484	4,191	4,117	3,619	3,717	4,066
Finance, insurance and real estate	278	355	488	513	564	544	827	846	859	696
Services	4,086	4,592	5,215	6,840	7,706	8,049	9,428	10,153	10,856	10,598
Federal government	1,929	2,161	2,343	2,439	2,672	3,049	2,501	2,634	2,744	2,752
State and local government	3,096	3,260	3,419	3,959	4,292	4,768	5,300	5,439	5,861	6,038
Dividends, interest, and rents	5,253	4,837	4,448	5,595	6,587	6,820	7,610	8,713	9,546	10,064
Transfer payments	4,332	4,477	4,515	5,050	5,449	6,173	7,010	7,100	7,119	7,353
Social security contributions and residence adjustments	-2,564	-2,758	-3,088	-4,355	-5,179	-19,409	-12,623	-8,551	-7,292	-6,547

Source: U.S. Bureau of Economic Analysis, 1981

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APPENDIX I

TABLE 3

PER CAPITA PERSONAL INCOME
ROSEBUD COUNTY AND MONTANA, 1970 to 1979
($1930)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Rosebud County	$5,493	$5,204	$5,217	$7,633	$6,613	$7,463	$6,434	$6,213	$7,555	$6,948
Montana	$6,803	$6,533	$7,257	$7,982	$7,776	$7,563	$7,745	$7,747	$8,503	$8,601
Percentage of Montana	80.8	79.7	78.8	95.6	85.1	98.7	83.1	80.2	88.9	80.8

Source: U.S. Bureau of Economic Analysis, 1981

Exhibit 3

APPENDIX I

TABLE 4

EMPLOYMENT, BY INDUSTRY,
ROSEBUD COUNTY AND MONTANA, 1970 and 1979

	Rosebud County			
	1970		1979	
	Number	Percentage of Total	Number	Percentage of Total
Total	2,465	100.0	4,472	100.0
Agriculture	704	28.3	587	13.1
Mining	43	1.7	434	9.7
Construction	29	1.2	282	6.3
Transportation, communication, and public utilities	184	7.5	369	8.3
Manufacturing	214	8.7	163	3.6
Trade	217	8.8	432	9.7
Finance, insurance, and real estate	19	.8	65	1.5
Services	391	15.9	1,051	23.5
Federal government	107	4.4	163	3.6
State and local government	330	13.4	557	12.5
Nonfarm proprietors	228	9.2	369	8.3
	Montana			
Total	279,091	100.0	373,409	100.0
Agriculture	39,882	14.3	35,017	9.4
Mining	6,547	2.4	7,737	2.1
Construction	11,180	4.0	15,608	4.2
Transportation, communication, and public utilities	17,308	6.2	23,265	4.9
Manufacturing	23,963	8.6	28,907	7.8
Trade	48,575	17.4	73,566	19.7
Finance, insurance, and real estate	7,832	2.8	13,261	3.6
Services	38,458	13.8	60,594	16.2
Federal government	18,253	6.6	23,696	6.4
State and local government	41,376	14.7	52.759	14.1
Nonfarm proprietors	25,717	9.2	38,999	10.5

Note: Details may not add due to rounding.

Source: Western Analysis, Inc., 1982

Exhibit 3

APPENDIX I

TABLE 5

EMPLOYMENT BY INDUSTRY,
ROSEBUD COUNTY, 1970 to 1979

	1970	1971	1972	1973	1974	1975	1976	1977[a]	1978[a]	1979[a]
Total Employment	2,405	2,709	2,871	3,235	3,600	4,977	4,415	4,088	4,263	4,472
Agriculture	704	710	696	681	692	658	610	562	534	587
Mining	43	79	104	209	283	392	416	365	372	434
Construction	29	25	39	76	190	1,354	656	345	267	292
TPUC	184	181	192	193	212	210	226	313	349	369
Manufacturing	214	230	265	192	180	160	185	86	124	163
Trade	217	242	268	312	347	412	425	367	400	432
FIRE	19	26	37	43	49	50	61	59	61	65
Services	391	520	570	727	827	809	905	1,002	1,108	1,051
Federal government	107	110	118	116	137	154	132	142	152	163
State and local government	330	353	367	393	419	441	455	480	530	557
Nonfarm proprietors	228	233	215	233	274	330	344	367	366	369
Unemployment rate	3.1	3.0	3.2	3.2	3.6	3.3	5.8	6.9	5.9	5.0

[a]Adjustments were made to REIS data for the years 1977 through 1979 to reflect employment figures supplied by Montana Power Company, Western Energy Company, Peabody Coal Company and Long Construction.

Source: U.S. Bureau of Economic Analysis, 1981
Montana Department of Labor and Industry
Western Analysis, Inc., 1982

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APPENDIX I

TABLE 6

BASIC AND DERIVATIVE EMPLOYMENT
ROSEBUD COUNTY, 1970 and 1979

	1970	1979	Change 1970-1979
Basic industries	1,306	2,380	1,074
Agriculture	704	587	-117
Mining	43	434	391
Construction (part)	11	238	227
Manufacturing (part	201	145	-56
Trade (part) and tourism[1]	49	64	15
Transportation, public utilities and communications	109	312	203
Government (part)	41	63	22
Other basic industries	148	537	389
Derivative industries	1,159	2,092	933
Construction (part)	18	44	26
Manufacturing (part)	13	18	5
Trade (part)	179	386	207
Finance, insurance, and real estate	19	65	46
Services (part)	244	506	262
Government (part)	396	657	261
Other derivative industries	290	416	126

[1]Includes hotels and motels plus estimated retail trade employment serving nonresidents.

Source: Western Analysis, Inc., 1982

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APPENDIX I

TABLE 7

PERCENT CHANGE IN POPULATION
COLSTRIP, MONTANA, ROSEBUD COUNTY, MONTANA, AND MONTANA
1970 - 1980

	1970 Population	1980 Population	Percent Change
Colstrip	250*	3,258*	1200
Rosebud County	6,032	11,379*	189
Montana	694,409	786,690	13

*estimated

Source: U.S. Bureau of the Census
Montana Department of Administration
Western Analysis, Inc., 1982

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TABLE 8

POPULATION BY AGE AND SEX, ROSEBUD COUNTY AND COLSTRIP, MONTANA
1970 - 1980

	Colstrip, Montana						Rosebud County, Montana					
	Male		Female		Total		Male		Female		Total	
	1970	1980	1970	1980	1970	1980	1970	1980	1970	1980	1970	1980
5	12	196	13	192	25	388	298	645	311	669	609	1,314
5-9	14	223	14	203	28	426	339	582	352	560	691	1,142
10-14	15	165	14	170	29	335	372	561	333	532	705	1,093
15-19	12	142	11	103	23	245	276	560	271	497	547	1,057
20-24	7	123	9	167	16	290	165	493	210	539	375	1,032
25-34	15	383	14	348	29	731	353	1,022	342	1,005	695	2,027
35-44	14	245	14	187	28	432	337	699	309	564	646	1,263
45-54	14	121	13	103	27	224	346	821	307	456	653	977
55-64	11	95	10	51	21	146	261	453	236	349	497	802
65 +	12	26	12	15	24	41	304	300	310	372	614	672
Total	126	1,719	124	1,539	250	3,258	3,051	5,836	2,981	5,543	6,032	11,379

Source: U.S. Bureau of the Census
Western Analysis, Inc., 1982

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TABLE 9

POPULATION BY AGE AS A PERCENT OF TOTAL POPULATION
COLSTRIP, MONTANA AND ROSEBUD COUNTY, MONTANA
1970 - 1980

	Percent of Total Population			
	Colstrip		Rosebud County	
Age	1970	1980	1970	1980
5	10.0	11.9	10.1	11.6
5-9	11.2	13.1	11.5	10.0
10-14	11.6	10.3	11.7	9.6
15-19	9.2	7.5	9.1	9.3
20-24	6.4	8.9	6.2	9.1
25-34	11.6	22.4	11.5	17.8
35-44	11.2	13.3	10.7	11.1
45-54	10.8	6.9	10.8	8.6
55-64	8.4	4.5	8.2	7.1
65 +	9.6	1.3	10.2	5.9

Source: U.S. Bureau of the Census.

Exhibit 3

APPENDIX I

TABLE 10

BASELINE EMPLOYMENT AND POPULATION FORECAST
ROSEBUD COUNTY AND COLSTRIP, 1980 - 2018

	1980	1981	1982	1983	1984	1985	1990	1995	2000	2010	2018
Agriculture	582	577	572	567	562	557	549	542	525	502	502
Mining	436	451	466	466	466	466	466	466	466	466	466
Construction	1,040	1,702	3,047	2,729	1,150	281	147	147	147	147	147
Manufacturing	145	185	193	195	198	200	212	222	233	249	249
TPUC	362	400	511	588	676	702	702	702	702	702	702
Trade	47	48	50	51	52	53	56	58	62	68	68
FIRE	0	0	0	0	0	0	0	0	0	0	0
Services	562	579	596	614	632	651	710	755	828	940	940
Government	64	64	84	101	85	67	70	70	70	70	70
Nonfarm Proprietors	10	11	11	11	11	12	13	13	14	16	16
Total Basic	3,248	4,017	5,530	5,322	3,832	2,989	2,925	2,975	3,047	3,160	3,160
Total Nonbasic	2,153	2,249	2,384	2,469	2,565	2,608	2,631	2,712	2,842	3,055	3,055
Total Employment	5,401	6,266	7,914	7,791	6,307	5,597	5,556	5,687	5,889	6,215	6,215
Rosebud Population	11,379	12,945	15,974	15,699	13,078	11,527	11,210	11,420	11,608	12,253	12,253
Net Migration	1,421	1,502	2,843	-504	-2,866	-1,548	-1,278	-311	-306	N/A	N/A
Colstrip Population	3,258	4,493	6,926	6,727	4,680	3,442	3,221	3,253	3,287	3,384	3,384

Source: Western Analysis, Inc., 1982

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APPENDIX I

TABLE 11

BASELINE QUARTERLY EMPLOYMENT AND POPULATION FORECAST
ROSEBUD COUNTY AND COLSTRIP, 1982 - 1983

	1982				1983			
	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q
Agriculture	574	573	571	570	569	568	566	565
Mining	466	466	466	466	466	466	466	466
Construction	2,389	2,910	3,418	3,470	3,347	3,121	2,495	1,954
Manufacturing	192	193	193	194	194	195	195	196
TPUC	470	510	526	539	549	576	610	615
Trades	50	50	50	50	51	51	51	51
FIRE	0	0	0	0	0	0	0	0
Services	589	594	598	603	607	612	616	621
Government	75	75	87	98	101	101	101	101
Nonfarm proprietors	11	11	11	11	11	11	11	11
Total Basic	4,816	5,382	5,920	6,001	5,895	5,701	5,111	4,580
Total Nonbasic	2,342	2,382	2,397	2,413	2,430	2,458	2,489	2,498
Total Employment	7,158	7,764	8,317	8,414	8,325	8,159	7,600	7,078
Rosebud Population	14,552	15,697	16,726	16,913	16,662	16,372	15,357	14,399
Colstrip Population	5,780	6,712	7,539	7,665	7,528	7,280	6,449	5,646

Source: Western Analysis, Inc., 1982

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TABLE 12

Projections of Baseline Personal Income
Rosebud Count, Selected Years, 1980-2018
(In Thousands of 1980 Dollars)

	1980	1981	1982	1983	1984	1985	1990	1995	2000	2010	2018
Agriculture	4,610	4,780	4,955	5,138	5,327	5,522	6,448	7,070	7,628	9,022	9,022
Mining	12,842	13,044	12,987	12,918	13,583	14,048	16,556	19,519	28,323	42,330	42,330
Construction	24,295	39,918	72,056	66,403	28,862	8,015	4,836	5,391	6,023	7,472	7,472
Non-Agriculture	36,187	39,214	43,505	46,897	50,312	51,397	60,382	69,235	81,323	107,987	107,987
Property & Transfer	18,005	18,618	19,239	19,887	20,557	21,250	24,682	28,199	33,056	44,252	44,252
Social Insurance Contribution	-5,058	-6,292	-8,664	-8,525	-6,366	-5,126	-5,743	-6,467	-8,544	-11,076	-11,076
Total:	90,881	115,574	144,078	142,718	112,275	95,106	107,161	129,414	147,809	199,987	199,987
Population	11,379	12,945	15,974	15,699	13,078	11,527	11,210	11,420	11,608	12,253	12,253
Per Capita	7,986	8,928	9,019	9,090	8,585	8,250	9,559	11,332	12,733	16,321	16,321

Source: Bureau of Economic Analysis, U.S. Department of Commerce
Western Energy Company
Western Analysis, Inc.

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TABLE 13

BASELINE PROJECTIONS OF HOUSING DEMAND IN
ROSEBUD COUNTY AND COLSTRIP

	Actual	Projected Housing									
	1980	1981	1982	1983	1984	1985	1990	1995	2000	2010	2018
Rosebud County											
Population	11,379	12,945	15,974	15,699	13,038	11,527	11,210	11,420	11,608	12,253	12,253
Households	3,764	4,415	5,624	5,534	4,530	3,952	4,062	4,326	4,534	4,882	4,882
Colstrip											
Population	3,258	4,493	6,926	6,727	4,680	3,442	3,221	3,253	3,287	3,384	3,384
Households	1,050	1,521	2,451	2,355	1,527	1,042	1,016	1,070	1,114	1,171	1,171

Source: U.S. Bureau of the Census
Sunlight Development Company
Western Analysis, Inc., 1982

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TABLE 14

ROSEBUD COUNTY, COLSTRIP HIGH SCHOOL DISTRICT #19 AND COLSTRIP ELEMENTARY SCHOOL DISTRICT #19, SELECTED PUBLIC FINANCE DATA 1970 and 1980

	1970	1980
Rosebud County		
Total revenues	$2,636,911	$4,596,312
Total expenditures	2,204,047	4,255,762
Mill levies	48.33	25.16
Colstrip High School District #19		
Total expenditures	$177,024	$810,720
Total general fund budget	129,312	665,040
Mill levies	17.62	9.42
Colstrip Elementary School District #19		
Total expenditures	$89,089	$907,554
Total general fund budget	59,906	799,871
Mill leview	17.08	10.33

Source: Montana Superintendent's Office of Public Instruction.
Montana Taxpayers Association.
Rosebud County Annual Financial Reports.
Rosebud County Audit Reports.
Western Analysis, Inc., 1982

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APPENDIX I

TABLE 15

BASELINE PUBLIC FINANCE PROJECTIONS, ROSEBUD COUNTY, FY1981-2018
($1980)

Year	Total Expenditures	Operating Expenses	Operating Expenses/Capita	Total Revenues	Local Revenues	Property Taxes
1981[1]	$3,942,496	$3,198,206	$247	$5,084,336	$2,555,514	$1,585,875
1982	4,750,516	4,102,382	257	4,750,516	3,322,869	2,115,264
1983	4,935,613	4,299,451	274	4,935,613	3,532,543	2,334,545
1984	4,281,593	3,745,485	286	4,281,593	3,112,770	2,114,781
1985	3,901,887	3,425,709	297	3,901,887	2,871,682	1,992,055
1990	3,880,759	3,425,289	306	3,880,759	2,878,885	2,023,445
1995	3,918,076	3,489,456	306	3,918,076	2,897,434	2,025,968
2000	3,969,539	3,535,289	306	3,969,539	2,935,491	2,059,320
2005	4,069,721	3,624,512	306	4,069,721	3,009,576	2,115,735
2010	4,181,224	3,723,817	306	4,181,224	3,092,033	2,173,746
2015	4,041,587	3,599,456	306	4,041,587	2,988,771	2,069,254
2018	4,041,587	3,599,456	306	4,041,587	2,988,731	2,069,254

Mill Levies

1981[1]	15.46	1995	13.33
1982	21.89	2000	18.36
1983	19.87	2005	21.90
1984	14.03	2010	24.40
1985	11.40	2015	22.49
1990	11.39	2018	22.49

[1]1981 uses actual data and may not represent a balanced budget.

Source: Western Analysis, Inc., 1982

Exhibit 3

APPENDIX I

TABLE 16

BASELINE PUBLIC FINANCE PROJECTIONS, COLSTRIP HIGH SCHOOL DISTRICT #19, 1981-2018
($1980)

Year	Total Expenditures	Operating Expenses	Operating Expenses/Capita	Total Revenues	Local Property Taxes[1]	Mills[2]
1981[3]	$2,720,067	$2,423,750	$5,315	$2,607,378	$1,633,150	19.11
1982	3,887,458	3,736,615	5,315	3,887,458	2,401,655	25.77
1983	4,691,790	3,630,310	5,315	4,691,790	3,248,258	27.18
1984	3,565,004	2,524,740	5,315	3,565,004	2,561,083	18.48
1985	2,881,248	1,855,019	5,315	2,881,248	2,143,631	12.89
1990	2,746,986	1,738,084	5,315	2,746,986	2,055,866	15.16
1995	2,748,332	1,754,030	5,315	2,748,332	2,050,871	17.48
2000	2,719,931	1,775,291	5,315	2,719,931	2,014,016	23.15
2005	1,826,153	1,796,552	5,315	1,826,153	1,111,784	14.74
2010	1,853,167	1,823,128	5,315	1,853,167	1,128,230	16.14
2015	1,550,609	1,525,474	5,315	1,550,609	944,029	13.02
2018	1,550,609	1,525,474	5,315	1,550,609	944,029	13.02

[1]Property taxes generated from district mill levies only.
[2]Mill rates for district levied taxes only (e.g., General Fund, Transportation Fund, Bus Reserve Fund, [3]Comp. Insurance Fund, and Adult Education Fund).
[3]1981 is actual data and may not represent a balanced budget.

Source: Western Analysis, Inc., 1982

Exhibit 3

APPENDIX I

TABLE 17

BASELINE PUBLIC FINANCE PROJECTIONS, COLSTRIP ELEMENTARY SCHOOL DISTRICT #19, 1981-2018
($1980)

Year	Total Expenditures	Operating Expenses	Operating Expenses/Capita	Total Revenues	Local Property Taxes[1]	Mills[2]
1981[3]	$3,876,011	$2,972,071	$3,412	$3,780,895	$2,635,917	30.25
1982	5,456,974	4,741,567	3,531	5,456,974	3,628,452	39.91
1983	5,574,639	4,768,202	3,657	5,574,639	3,735,732	34.71
1984	4,200,948	3,438,261	3,791	4,200,948	2,921,893	23.42
1985	3,018,641	2,291,300	3,435	3,018,641	2,078,035	13.87
1990	2,744,094	2,143,585	3,435	2,744,094	1,864,127	15.26
1995	2,663,348	2,167,632	3,435	2,663,348	1,773,509	16.79
2000	2,509,176	2,188,243	3,435	2,509,176	1,610,876	20.56
2005	2,257,227	2,222,596	3,435	2,257,227	1,344,825	19.80
2010	2,288,625	2,253,512	3,435	2,288,625	1,363,531	21.66
2015	1,911,839	1,882,507	3,435	1,911,839	1,139,048	17.45
2018	1,911,839	1,882,507	3,435	1,911,839	1,139,048	17.45

[1]Property taxes generated from district mill levies only.
[2]Mill rates for district levied taxes only (e.g., General Fund, Transportation Fund, Bus Reserve Fund, Debt Service Fund, Comp. Insurance Fund).
[3]1981 is actual data and may not represent a balanced budget.

Source: Western Analysis, Inc., 1982

Exhibit 3

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TABLE 18

BASELINE PUBLIC FINANCE PROJECTIONS, COLSTRIP TOWNSITE, 1980-2018
($1980)

Year	Total Expenditures	Operating Expenses	Operating Expenses/Capita	Total Revenues	Local Revenues
1980[1]	$4,813,065	$ 701,250	$215	$5,223,915	$1,112,100
1981	2,167,249	1,061,249	236	2,580,281	1,474,281
1982	1,950,726	1,800,726	260	2,347,354	2,197,354
1983	2,230,903	1,930,903	287	2,373,842	2,073,842
1984	1,404,834	1,404,834	300	1,415,990	1,415,990
1985	1,033,214	1,033,214	300	1,041,419	1,041,419
1990	966,874	966,874	300	974,552	974,552
1995	976,480	976,480	300	984,234	984,234
2000	986,686	986,686	300	994,521	994,521
2005	1,001,095	1,001,095	300	1,009,044	1,009,044
2010	1,015,803	1,015,803	300	1,023,871	1,023,871
2015	848,303	848,303	300	855,041	855,041
2018	848,303	848,303	300	855,041	855,041

[1]1980 is actual data and may not represent a balanced budget.

Source: Sunlight Development Company.
Western Analysis, Inc., 1982

Exhibit 3

APPENDIX I

TABLE 19

PROJECTED POPULATION AND EMPLOYMENT IMPACT, AREA C EXPANSION, ROSEBUD COUNTY AND COLSTRIP
1982 - 2018

	1982	1983	1984	1985	1990	1995	2000	2010	2018
Mining	4	121	205	211	205	211	208	228	228
Construction	140	181	0	0	0	0	0	0	0
Total Basic	144	302	205	211	205	211	208	228	228
Total Nonbasic	2	75	127	132	129	135	136	153	153
Total Employment	146	377	332	343	334	346	344	381	381
Rosebud Population	271	720	646	664	632	653	637	706	706
Colstrip Population	224	532	432	441	422	436	410	469	469

Source: Western Analysis, Inc., 1982

Exhibit 3

APPENDIX I

TABLE 20

PROJECTED POPULATION AND EMPLOYMENT IMPACT, AREA C EXPANSION, ROSEBUD COUNTY AND COLSTRIP, 1982 - 1983

	1982				1983			
	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q
Mining	2	4	4	6	6	120	161	197
Construction	12	57	144	347	204	368	128	25
Total Basic	14	61	148	353	210	488	289	222
Total Nonbasic	1	2	2	3	3	75	100	123
Total Employment	15	63	150	356	213	563	389	345
Rosebud Population	28	117	278	657	392	1,063	751	675
Colstrip Population	21	98	230	540	323	816	537	456

Source: Western Analysis, Inc., 1982

Exhibit 3

TABLE 21

Baseline and Impact Population
Comparisons - Rosebud County and Colstrip
1980 to 2018

	1980	1981	1982	1983	1984	1985	1990	1995	2000	2010	2018
Rosebud Baseline Population	11,379	12,945	15,974	15,699	13,078	11,527	11,210	11,420	11,608	12,253	12,253
Area C Impact Population	-0-	-0-	271	720	646	664	632	653	637	706	706
Total Population	11,379	12,945	16,245	16,419	13,724	12,191	11,842	12,073	12,245	12,959	12,959
Percent Change	0.0	0.0	1.7	4.6	4.9	5.8	5.6	5.7	5.5	5.8	5.8
Colstrip Baseline Population	3,258	4,493	6,926	6,727	4,680	3,442	3,221	3,253	3,287	3,384	3,384
Area C Impact Population	-0-	-0-	224	532	432	441	442	436	410	469	469
Total Population	3,258	4,493	7,150	7,259	5,112	3,883	3,643	3,689	3,697	3,853	3,853
Percent Change	0.0	0.0	3.2	7.9	9.2	12.8	13.1	13.4	12.5	13.9	13.9

Source: Western Analysis, Inc.

Exhibit 3

APPENDIX I

TABLE 22

PROJECTED PERSONAL INCOME TAX PAYMENTS TO MONTANA, AREA C EXPANSION, 1982-2018
($1980)

	1982	1983	1984	1985	1990	1995	2000	2010	2018
Total Earnings	$4,013,543	$8,372,084	$5,975,353	$6,360,577	$7,283,035	$8,796,060	$12,642,032	$20,710,608	$20,710,608
Income Tax	140,014	289,501	212,420	229,741	262,918	317,538	456,377	747,652	747,652
Area C Workforce	144	302	205	211	205	211	208	228	228

Exhibit 3

Source: Western Analysis, Inc., 1982

APPENDIX I

TABLE 23

PROJECTIONS OF HOUSING DEMAND DUE TO AREA C EXPANSION, COLSTRIP, 1982- 2018

	1982			1983									
	2Q	3Q	4Q	1Q	2Q	3Q	1984	1985	1990	1995	2000	2010	2018
Baseline households	2,366	2,687	2,731	2,685	2,578	2,237	1,527	1,042	1,016	1,070	1,114	1,171	1,171
Impact population	98	230	540	323	816	537	432	441	422	436	410	469	469
Impact households	37	90	212	127	295	177	127	131	133	143	139	162	162

Source: U.S. Bureau of the Census
Sunlight Development Company
Western Analysis, Inc., 1982

Exhibit 3

APPENDIX I

TABLE 24

ACTUAL AND PROJECTED SCHOOL ENROLLMENTS DUE TO AREA C EXPANSION, COLSTRIP SCHOOL DISTRICT #19
1981-2000

	Total Enrollment			Area C Mine Increment (included in total)		
Year	Elementary (K-8)	High School (9-12)	Total	Elementary K-8)	High School (9-12)	Total
1981[1]	848	322	1,170	0	0	0
1982	1,218	491	1,709	40	16	56
1983	1,344	514	1,858	87	33	120
1984	997	402	1,399	97	39	136
1985	771	331	1,102	100	43	143
1990	749	322	1,071	97	42	139
1995	764	328	1,092	99	43	143
2000	777	333	1,110	101	43	144

[1]Actual

Source: Western Analysis, Inc., 1982

Exhibit 3

APPENDIX I

TABLE 25

ACTUAL AND PROJECTED FISCAL CONDITIONS DUE TO AREA C EXPANSION, ROSEBUD COUNTY, 1981-2018
(1980 Dollars)

Year	Total Expenditures	Operating Expenditures	Total Revenues	Local Revenues	Property Taxes[1]	Area C Property Taxes[2]	Mills
1981[3]	$3,942,496	$3,198,206	$5,084,336	$2,555,514	$1,585,875	$ 0	15.46
1982	4,830,285	4,171,980	4,830,285	3,378,417	2,150,325	0	21.54
1983	5,159,821	4,496,635	5,159,821	3,692,403	2,330,264	109,197	19.83
1984	4,490,850	3,930,497	4,490,850	3,264,292	2,028,970	188,037	13.46
1985	4,124,143	3,623,043	4,124,143	3,034,594	1,925,549	178,744	11.02
1990	4,097,591	3,618,401	4,097,591	3,039,234	1,938,945	196,620	10.91
1995	4,142,113	3,688,984	4,142,113	3,063,111	1,918,741	223,073	12.63
2000	4,201,124	3,741,540	4,201,124	3,106,749	1,915,212	257,115	17.07
2005	4,321,891	3,849,096	4,321,891	3,196,057	1,946,387	288,387	20.15
2010	4,446,090	3,959,707	4,446,090	3,287,903	1,994,747	304,249	22.39
2015	4,115,695	3,665,456	4,115,695	3,043,575	1,814,936	313,219	19.72
2018	4,115,695	3,775,456	4,115,695	2,817,260	1,969,909	313,219	19.72

[1] Property taxes collected on non-Area C taxable value from impact district mill levies.
[2] Property taxes collected on Area C coal production and equipment from impact district mill levies.
[3] 1981 is actual data and may not represent a balanced budget scenario.

Source: Western Analysis, Inc., 1982

Exhibit 3

TABLE 26

Projected Increase in Taxable
Value in Rosebud County
Due to Area C Expansion
1983 - 2018 ($ 1980)

	Capital Investment Taxable Value	Gross Proceeds Taxable Value
1983	$4,729,809	$ 776,250
1984	4,412,140	9,557,100
1985	4,100,502	12,118,950
1990	2,824,599	15,195,600
1995	2,040,490	16,624,000
2000	1,480,954	13,579,200
2005	1,084,989	13,227,300
2010	795,641	12,792,600
2015	583,457	15,297,300
2018	583,457	15,297,300

Source: Western Energy Company
Western Analysis, Inc.

Exhibit 3

TABLE 27

Percentage Change in Rosebud County Taxable Value Due to Area C Expansion, 1981-2018 ($ 1980)

	Baseline Taxable Value	Impact Taxable Value	Percent Net Change
1981	$ 78,058,934	$ 78,058,934	0.0 %
1982	99,827,548	99,827,548	0.0
1983	117,499,048	123,005,107	4.69
1984	150,731,745	164,700,985	9.27
1985	174,726,388	190,945,840	9.28
1990	177,704,247	195,724,446	10.14
1995	151,939,673	169,604,163	11.63
2000	112,180,950	127,241,104	13.42
2005	96,596,749	110,909,038	14.82
2010	89,088,647	102,676,888	15.25
2015	92,020,587	107,901,344	17.26
2018	92,020,587	107,901,344	17.26

Source: Western Analysis, Inc.

Exhibit 3

TABLE 28

Net Effects of Area C Expansion
on Local Revenues and Operating
Expenditures, Rosebud County, 1981- 2018 ($ 1980)

	Net Change Operating Expenditures	Net Percent Change	Net Change Local Revenues	Net Percent Change
1981	$ -0-	0.0 %	$ -0-	0.0 %
1982	69,598	1.70	55,548	1.67
1983	197,184	4.59	159,860	4.53
1984	185,012	4.94	151,522	4.87
1985	197,334	5.76	162,912	5.67
1990	193,112	5.64	160,349	5.57
1995	199,528	5.72	165,677	5.72
2000	206,251	5.83	171,258	5.83
2005	224,584	6.20	186,481	6.20
2010	235,890	6.33	195,870	6.33
2015	66,000	1.83	54,804	1.83
2018	66,000	1.83	54,804	1.83

Source: Western Analysis, Inc.

Exhibit 3

APPENDIX I

TABLE 29

ACTUAL AND PROJECTED FISCAL CONDITIONS DUE TO AREA C EXPANSION,
COLSTRIP HIGH SCHOOL DISTRICT #19, 1981- 2018
(1980 Dollars)

Year	Total Expenditures	Operating Expenditures	Total Revenues	Local Property Taxes[1]	Area C Property Taxes[2]	Mills[3]
1981[4]	$2,720,067	$2,423,750	$2,607,378	$1,633,150	$ 0	19.11
1982	4,011,722	3,858,865	4,011,722	2,477,309	0	26.59
1983	4,983,542	3,917,333	4,983,542	3,275,018	150,862	27.40
1984	3,802,728	2,758,610	3,802,728	2,458,000	247,812	17.74
1985	3,124,375	2,094,205	3,124,375	2,088,063	203,586	12.55
1990	2,979,307	1,966,639	2,979,307	1,939,613	257,693	14.30
1995	2,986,056	1,987,900	2,986,056	1,908,232	287,368	16.27
2000	2,941,447	1,993,215	2,941,447	1,831,826	317,051	21.05
2005	2,069,280	2,035,737	2,069,280	1,058,839	200,964	14.04
2010	1,860,100	1,829,948	1,860,100	948,155	184,296	13.56
2015	1,455,730	1,432,133	1,455,730	727,026	159,240	10.03
2018	1,455,730	1,432,133	1,455,730	727,026	159,240	10.03

[1]Property taxes collected on non-Area C taxable value from impact district mill levies.
[2]Property taxes collected on Area C coal production and equipment from impact district mill levies.
[3]Mill rates for district levied taxes only (re: Table 2.4.4-3).
[4]1981 is actual data and may not represent a balanced budget.

Source: Western Analysis, Inc., 1982

Exhibit 3

APPENDIX I

TABLE 30

ACTUAL AND PROJECTED FISCAL CONDITION DUE TO AREA C EXPANSION,
COLSTRIP ELEMENTARY SCHOOL #19, 1981-2018
(1980 Dollars)

Year	Total Expenditures	Operating Expenditures	Total Revenues	Local Property Taxes[1]	Area C Property Taxes[2]	Mills[3]
1981[4]	$3,876,011	$2,972,071	$3,780,895	$2,635,917	$ 0	30.25
1982	5,611,091	4,893,382	5,611,091	3,724,023	0	40.97
1983	5,956,782	5,144,831	5,956,782	3,779,291	193,333	35.11
1984	4,523,872	3,756,689	4,523,872	2,811,572	314,788	22.53
1985	3,318,674	2,586,730	3,318,674	2,036,306	220,484	13.59
1990	3,030,173	2,425,274	3,030,173	1,772,979	261,589	14.52
1995	2,956,403	2,456,191	2,956,403	1,668,988	279,119	15.80
2000	2,788,277	2,463,062	2,788,277	1,490,645	286,516	19.02
2005	2,553,771	2,514,590	2,553,771	1,256,636	264,866	18.51
2010	2,606,104	2,566,120	2,606,104	1,277,027	275,655	20.29
2015	2,037,436	2,006,177	2,037,436	976,384	237,493	14.95
2018	2,037,436	2,006,177	2,037,436	976,384	237,493	14.95

[1]Property taxes collected on non-Area C taxable value from impact district mill levies.
[2]Property taxes collected on Area C coal production and equipment from impact district mill levies.
[3]Mill rates for district levied taxes only (re: Table 2.4.4-3).
[4]1981 is actual data and may not represent a balanced budget.

Source: Western Analysis, Inc., 1982

Exhibit 3

APPENDIX I

TABLE 31

Actual and Projected Fiscal Condition Due to Area C Expansion
Colstrip Townsite, 1980- 2018
(1980 Dollars)

	Total Expenditures	Operating Expenses	Total Revenues	Local Revenues
1980[1]	$4,813,065	$ 701,250	$5,223,915	$1,112,100
1981	2,167,249	1,061,249	2,580,281	1,474,281
1982	2,008,965	1,858,965	2,418,421	2,268,421
1983	2,383,607	2,083,607	2,537,850	2,237,850
1984	1,534,511	1,534,511	1,546,697	1,546,697
1985	1,165,592	1,165,592	1,174,848	1,747,848
1990	1,093,549	1,093,549	1,102,233	1,102,233
1995	1,107,358	1,107,358	1,116,151	1,116,151
2000	1,109,759	1,109,759	1,118,572	1,118,572
2005	1,132,873	1,132,873	1,141,869	1,141,869
2010	1,156,586	1,156,586	1,165,771	1,165,771
2015	905,037	905,037	912,224	912,224
2018	905,037	905,037	912,224	912,224

[1]1980 is actual data.

Source: Western Analysis, Inc.

Exhibit 3

TABLE 32

Net Effects of Area C Expansion on
Local Revenues and Operating Expenditures
Colstrip Townsite, 1980-2018 ($ 1980)

	Net Change Operating Expenditures	Net Percent Change	Net Change Local Revenues	Net Percent Change
1980	$ -0-	0.0 %	$ -0-	0.0 %
1981	-0-	0.0	-0-	0.0
1982	58,239	3.23	71,067	3.23
1983	152,704	7.91	164,008	7.91
1984	129,677	9.23	130,707	9.23
1985	132,378	12.81	133,429	12.81
1990	126,675	13.10	127,681	13.10
1995	130,878	13.40	131,917	13.40
2000	123,073	12.47	124,051	12.47
2005	131,778	13.16	132,825	13.16
2010	140,783	13.86	141,900	13.86
2018	140,783	13.86	141,000	13.86

Source: Western Analysis, Inc.

Exhibit 3

TABLE 33

Montana Coal Severance Tax and
Federal Royalty Payments on Area C
Coal Production, 1983-2018 1980)

	Federal Royalties Payments	Montana Coal Severance Tax Payments
1983	$ 52,500	$ 517,500
1984	647,500	6,371,400
1985	822,500	8,079,300
1990	6,020,000	10,130,400
1995	6,180,000	10,416,000
2000	5,359,000	9,052,800
2005	5,226,750	8,818,200
2010	5,060,000	8,528,400
2015	6,003,000	10,198,200
2018	6,003,000	10,198,200

Source: Western Energy Company
Western Analysis, Inc.

Exhibit 3

APPENDIX M

TABLE 1

CULTURAL RESOURCE SURVEY SUMMARY

Date of Survey	Survey Organization	Survey Report Title (Report Date)	Portions of Area C, Block 1 Included in Survey	Portions of Buffer Zone Included in Survey
1971	University of Montana Statewide Archaeological Survey	1971 Archaelogical Survey, Western Energy Co. Lands, Rosebud County MT (September 1972).	T1N, R41E, Sec. 7	T1N, R41E, Secs. 5, 6, 7, 8 T2N, R41E, SE1/4 Sec. 31
1973	Mineral Research Center Montana College of Mineral Science and Technology Foundation	Western Energy Co. Archaeological Investigations. Rosebud County, MT (1973).	T1N, R40E, Sec. 1-5, 11, 12	T1N, R41E, Sec. 17, 18 T1N, R40E, Sec. 1, 4, 5, 9-15 T2N, R40E, SE1/4, Sec. 36 T2N, R41E, NW, NE, SW1/4, Sec 31
1979	Cultural Resources Division Montana Tech Alumni Foundation Mineral Research Center	Reassessment of Cultural Resources on Western Energy Co. Area A. Rosebud County, MT (1979).	None	T2N, R41E, NW1/4, NW/NE1/4 and NE/SW1/4, Sec. 31
1979	Cultural Resources Division Montana Tech Alumni Foundation Mineral Research Center	Archaeology Report - Cultural Resources on Area B. Rosebud County, MT (1980).	T1N, R41E, E1/2/NE1/4/NE1/4 Sec. 7	T1N, R41E, Sec. 5, 6, 7, 8, 17, 18 T1N, R40E, Sec. 5, 9, 12, 13
May-June 1978 and May-June 1979	Cultural Resources Division Montana Tech Alumni Foundation Mineral Research Center	Cultural Resources Inventory and Assessment: Mining Area C Extension and One-Mile Buffer (1980).	T1N, R41E, Sec. 7	T2N, R40E, Sec. 31-36 T1N, R40E, Sec. 6, 7, E1/2, Sec. 8 T1N, R41E, Sec. 6, 7, 18 T2N, R41E, Sec. 31
1981	Cultural Resources Division Montana Tech Alumni Foundation Mineral Research Center	Report Not Yet Available	All of Area C, Block 1	All of buffer except T1N, R40E, Sec. 5-8, 17 and 18 T2N, R41E, Sec. 31 T2N, R40E, Sec. 6-8 and Sec. 31-36

Exhibit 3

APPENDIX M

TABLE 2

CULTURAL RESOURCES SUMMARY
AREA C, BLOCK I

Site Name	Site Number	Site Description	National Register Eligibility
Preshistoric:			
1. Cooley Site	24 RB 1059	Middle Archaic-Late Prehistoric Period temporary campsite.	Appears eligible. SHPO determination not yet made.
2. Medicine Root Site	24 RB 879	Late Plains Archaic occupation site with subsurface cultural deposits.	Additional testing recommended.
3. Fadhl Kill Site	24 RB 299	Late Prehistoric Period bison impoundment, kill, and processing site with subsurface cultural deposits. May also be a prehistoric occupation site.	Appears eligible. SHPO determination not yet made.
4. Tripoint Site	24 RB 873	Archaic-Late Prehistoic Period hunting lookout, lithic workshop, and temporary occupation site without subsurface cultural deposits.	Does not appear eligible. SHPO determination not yet made.
5. Farley Lookout Site	24 RB 1058	Hunting lookout and temporary campsite without subsurface cultural deposits.	Appears eligible. SHPO determination not yet made.
Historic:			
6. Fadhl Homestead	24 RB 884	Historic 1920s homestead complex including 13 standing wood frame structures.	Appears eligible. SHPO determination not yet made.

Exhibit 3

APPENDIX M

TABLE 2 (Continued)

Site Name	Site Number	Site Description	National Register Eligibility
Unknown:			
7. Three Ring Site	24 RR 1060	Three stone circles of unknown cultural or temporal affiliation.	Does not appear eligible. SHPO agrees.
8. Lynn's Square	24 RB 1071	Rectangular sandstone rock structure of unknown cultural or temporal affiliation.	Does not appear eligible. SHPO agrees.
9. Gene's Vision Quest	24 RB 1072	Two rock structures on knoll crests. The cultural or temporal affiliation is unknown.	Does not appear eligible. SHPO agrees.

Exhibit 3

APPENDIX M

TABLE 3

CULTURAL RESOURCES - SUMMARY
BUFFER ZONE

Site Name	Site Number	Site Description	National Register Eligibility
Prehistoric:			
1. McDonald Quarry Site	24 RB 303	Quarry site; stone procurement site	Does not appear eligible. SHPO agrees.
2. Rabbit Ridge Site	24 RB 310	Lithic scatter	Does not appear eligible. SHPO agrees.
3. Insite Site	24 RB 874	Lithic scatter/temporary occupation site with subsurface cultural deposits	Appears elgible. SHPO determination not yet made.
4. Wheatfield Vista Site	24 RB 876	Lithic scatter/temporary occupation site	Does not appear eligible. SHPO determination not yet made.
5. Forsite Site	24 RB 878	Lithic scatter/temporary occupation site within small rock shelter with sub-surface cultural deposits	Additional testing recommended.
6. Pottery Site	24 RB 1062	Lithic and ceramic scatter/ temporary occupation site	Does not appear eligible. SHPO determination not yet made.
7. Rocky Top Site	24 RB 1061	Lithic scatter/temporary occupation site	Does not appear eligible. SHPO agrees.
8. Sunburn Out Site	24 RB 881	Lithic scatter/lithic preparation, temporary occupation, and hunting lookout site with some subsurface cultural deposits	Does not appear eligible. SHPO determination not yet made.
9. Pigeon Site	24 RB 880	Lithic scatter	Does not appear eligible. SHPO determination not yet made.

Exhibit 3

APPENDIX M

TABLE 3 (Continued)

Site Name	Site Number	Site Description	National Register Eligibility
10. Dusty Shelter Site	24 RB 1069	Temporary occupation site within small rock shelter	Does not appear eligible. SHPO concurs.
11. Normand Estates Site	24 RB 883	Lithic scatter/temporary occupation and hunting lookout site	Does not appear eligible. SHPO determination not yet made.
12. East Fork Site	24 RB 886	Lithic scatter/possible camp or occupation site with subsurface cultural deposits	Additional testing recommended.
13. Albino Deer Site	24 RB 885	Lithic scatter/possible campsite with subsurface cultural deposits	Additiona testing recommended.
14. How Dry I Am Site	24 RB 252	Lithic scatter	Has been determined ineligible.
15. Sly Bison Site	24 RB 267	Bison kill site	Appears eligible. SHPO concurs.
16. ------	MAL 1401	Lithic scatter/may be a site	N/A
Historic:			
17. Castle Rock Post Office and Homestead Site	24 RB 335	1919 Homestead and site of first post office in the area	Does not appear eligible. SHPO concurs.
18. P.E. Davis Rock Art Site	24 RB 875	1892-1918 Historic rock art graffiti site	Does not appear eligible. SHPO determination not yet made.
19. Caskey 320 Site	24 RB 1067	Historic homestead site	Does not appear eligible. SHPO concurs.

Exhibit 3

APPENDIX M

TABLE 3 (Continued)

Site Name	Site Number	Site Description	National Register Eligibility
20. Doc Taylor's Place Site	24 RB 1065	1912 Homestead site	Does not appear eligible. SHPO disagrees.
21. Muskrat Homestead Site	24 RB 313	Historic homestead site	Does not appear eligible. SHPO disagrees.
22. Cooley Place	24 RB 1064	Historic homestead site near prehistoric Cooley Site	Appears eligible. SHPO determination not yet made.
Multi-Component:			
23. Lovelace Memorial Site	24 RB 301	Prehistoric and historic rock carvings	Does not appear eligible. SHPO agrees.
24. Petro City Site	24 RB 302	Prehistoric lithic scatter in association with prehistoric and historic petroglyphs	Does not appear eligible. SHPO agrees.
25. Connie's Gallery Site	24 RB 877	Prehistoric petroglyphs and historic rock art dating from 1876	Does not appear eligible. SHPO determination not yet made.

Exhibit 3

Letter No. 1

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Billings Area Office
Federal Building, Room 3035
316 North 26th Street
Billings, Montana 59101-1396

IN REPLY REFER TO

ES

June 18, 1982

RECEIVED
JUN 22 1982
STATE LANDS

Mr. Gareth Moon
Commissioner
Department of State Lands
Capitol Station
Helena, MT 59620

ATTN: Mr. Kit Walther

Dear Mr. Moon:

We have reviewed the DEIS for Western Energy Company's Rosebud Mine, Area C, Block 1, Colstrip, Montana. We found that the DEIS adequately describes impacts on fish and wildlife resources that would be expected to occur from the proposed five-year life of the mine development.

The following comments refer to specific sections of the DEIS.

Page III-57; 7. Raptors - This section of the DEIS describes protection provided eagles by the Bald Eagle Protection Act of 1940, as amended in 1962 (16 U.S.C. 668a). The section further states that the U.S. Fish and Wildlife Service has not yet determined whether or not the proximity of proposed mining activities to the existing nest site would constitute a disturbance within the definition of the law. It is our opinion that because the nest site has not been active since 1978, and because a 100-meter buffer zone between the outcrop containing the nest and the mine has been established (DEIS III-55), that "disturbance" within the definition of law will not occur as a result of implementation of the five-year permit to mine. If the nest should become "active" prior to or after the commencement of mining, then a re-evaluation of disturbance conditions would be required. } A

Page IV-2 ;3. Selective Denial - This section discusses the selective denial option available to the Department and OSM for denying mining in specified areas within the proposed permit boundary. Identification of lands for selective denial during the EIS review process is solicited. The U.S. Fish and Wildlife Service has previously recommended to the Department that the sandstone outcrop which provides valuable raptor } B

Exhibit 3

VIII-1

John C. Wood

A. Your comment is noted. Western Energy will if permitted report annually the atatus of nest activity. Should the nest become active, a reevaluation of "disturbance" condition will be requested of FWS.

B. Your comment is noted. At such time Western Energy submits its Block II mine plan the apecial, exceptional, critical or unique characteriatica of the referenced sandstone outcrop in Section 11 will be evaluated in detail.

nesting habitat and is located in Section 11 immediately adjacent to Area C, Block 1, not be permitted for mining. This outcrop would appear to meet the special, exceptional, critical or unique requirements and should be considered for selective denial during the Area C, Block II permit review.

We appreciate the opportunity to review and comment on this DEIS.

Sincerely,

John G. Wood
Acting Area Manager

cc: Director, Montana Department of Fish, Wildlife, and Parks, Helena, MT
Regional Director, USFWS, Denver, CO (ENV)

Exhibit 3

Letter No. 2

United States Department of the Interior

GEOLOGICAL SURVEY
Water Resources Division
Federal Building, Drawer 10076
Helena, Montana 59626

June 22, 1982

Mr. Kit Walther
EIS Team Leader
Montana Department of State Lands
1539 11th Avenue
Helena, MT 59620

Dear Mr. Walther:

We appreciated the opportunity to review the Draft Environmental Impact Statement for Western Energy Company's Rosebud Mine Area C, Block 1. Our review was limited to the hydrologic sections of the EIS and the Technical Support Document. Our comments are listed on the attached enclosure.

In general we feel that the documents adequately address the major hydrologic concerns. Most of our comments are of an editorial nature and are intended to clarify wording. The few technical issues raised should be easily rectified.

Feel free to call if our comments are unclear. We will be happy to expand or clarify the brief statements listed on the enclosure.

Sincerely yours,

Joe A. Moreland

Joe A. Moreland
Acting District Chief

Enclosures

Joe A. Moreland

Thank you for your review and comments on the Area C, Block 1 EIS. Responses to your comments are presented in the order submitted.

Exhibit 3

Comments pertaining to the draft EIS

p. II-1 ¶1 It is the Tongue River Member of the Paleocene Fort Union Formation. The current wording makes it sould like three formations.

p. II-5 ¶2 Explain the significance of exceeding DSL suspect levels (There is no level for sand in Appendix A).

p. II-7 Show number of samples on which these percentages in the table are based.

p. II-13 ¶4 linear porosity is not an appropriate term. The sediments may exhibit anisotropy with the direction of higher permeability being parallel to dragline movement.

Also reference this statement on the anisotropy of spoils material unless ERTEC determined it themselves.

Mention the number of spoils aquifer tests that the mean is based on.

Why no standard deviations, too, when a mean has been calculated?

p .II-16 ¶1 Transmissivity values don't decrease. The rate of recovery changes, which indicates a boundary.

¶2 Aquifer tests in clinker will not confirm areas of recharge. They will only tell you about the hydraulic characteristics of the aquifer.

p. II-18 ¶2 Being confined by a coal seam is not a reason for lower T's. In fact, you would have a fully saturated interval, which for similar K's, would lead to the opposite conclusion.

p. II-19 ¶9 Velocities don't "have" conductivity. Needs clarifying.

p. II-21 fig Averaging 8 years of water levels for a dynamic system is questionable. The lack of uniformity in the spoils may be due to this averaging.

p. II-22 ¶5 Precipitation is lowest from Nov, to March. Delete "precipitation is higher and."

p. II-24 fig Areas where the Rosebud Coal has been removed need to be delineated, and contours removed if present.

Exhibit 3

Joe A. Moreland

Page II-1, Paragraph 1
The wording has been clarified to read the Tongue River Member of the Paleocene Fort Union Formation.

Page II-5, Paragraph 2
The information is given in Section A of the Technical Support Document.

Page II-7
The information is given on page 1 of Section A of the Technical Support Document.

Page II-13, Paragraph 4
The term linear porosity has been deleted and changed to permeability. The statement was made based on personnel communication with Peabody Coal Company personnel.

Table II-3 shows the number of aquifer tests conducted in the spoils that the mean and median values are based on. More important than standard deviations are statements regarding the high variability of transmissivities which are made on II-13, II-14, II-16, and II-18. We have included an addition to the technical support document which lists standard deviations.

Page II-16, Paragraph 1
The statement is not necessarily true. Transmissivity is a measure of the rate at which fluid of a certain viscosity will move through a unit width of an aquifer under a unit hydraulic gradient. It is based on the saturated thickness which all other things being equal decreases at a boundary as water is withdrawn because of more rapid drawdown in those areas. In any case the authors have identified the cause of the decrease as a low permeability boundary.

Page II-16, Paragraph 2
Wording in the EIS has been changed accordingly.

Page II-18, Paragraph 2
The statement has been removed from the EIS.

Page II-19, Paragraph 9
The statement has been clarified to indicate that the coals are the better aquifers in the area.

Page II-21, Figure
The values were not averaged. The most representative value or the value that occurred most often was used in the development of the potentiometric map.

Page II-22, Paragraph 5
The phrase precipitation is higher has been deleted.

Page II-24, Figure
The areas where Rosebud coal has been removed have not been included on this figure because it overly complicates the figure. The intent of this figure is to define regional flow patterns within the Rosebud coal.

p. II-25 ¶2 The diagram, fig. II-9, shows <u>two</u> normal faults. Another discrepancy is the delineation of only one fault on fig. II-13.

¶2 Faulting is the underlying reason for the coal seam being exposed.

¶2 Because transmissivities are as great or greater than those in the coal, isn't horizontal flow across the fault just as likely as vertical flow?

¶2 Do you know the coal is offset? Without your control shown on fig. II-9, there appears to be many questionable inferences.

p. II-25 ¶3 You have indicted on pg. II-18 ¶2 that the interburden is confined (saturated) by the Rosebud coal seam.

Water may be leaking into the interburden from either coal seam, but not both in the same place.

p. II-25 ¶4 & 5 "Controlled" is a poor choice of words; perhaps "similar."

p. II-25 ¶6 The first mode of communication should include all major water-bearing strata, not just the McKay.

p. II-26 fig Should show control points.

Water levels of the Rosebud and McKay should be similar at the fault if there is enhanced vertical connection along it.

p. II-28 ¶2 Prior to the removal of the Rosebud coal, vertical leakage would have been downward to McKay according to the hydraulic gradient illustrated on fig. II-9. When the Rosebud is removed, the unconfined water level in the spoils will probably be lower than the McKay water level (at least initially), thereby reversing the gradient and causing upward leakage from the McKay.

p. II-29 fig Rosebud outcrop is really a subcrop under valley fill. The terms "gaining" and "losing" stream refers to a stream-valley fill interaction, not a bedrock-valley fill interaction.

Exhibit 3

Joe A. Moreland (Cont.)

Page II-25, Paragraph 2
The appropriate wording change has been made.

Page II-25, Paragraph 2
Structural contour maps generated from data supplied by Western Energy Company indicate that in some areas there is up to 160 feet of displacement within a 5000 foot distance. Visual inspection of mining in Area B, which is south of the proposed fault, shows only a 12-20 foot flexure in the coal. It is the author's opinion that there is at least one offset feature within the faulted zone. Whether it is a normal or reverse fault is speculative based on a map prepared by the Geological Survey. Based on flow modeling, potentiometric map development and well test data, it is Ertec's opinion that the zones where flexure and faulting are present represent areas of increased vertical permeabilities. This is not to say all flow is vertical in these areas.

Page II-25, Paragraph 3
The paragraph has been modified to indicate that the source of recharge is variable depending on location.

Page II-25, Paragraphs 4 and 5
The wording has been modified.

Page II-25, Paragraph 6
The appropriate change has been made.

Page II-26, Figure
The results of the three-dimensional flow modeling indicate that there is approximate 0.5-2 feet of difference in water levels along the fault zone. Figure II-13 shows the location of the cross-section. Figure II-13 is a regional map showing general trends in recharge and discharge. Scale is too large to display data points.

Page II-28, Paragraph 2
As a result of modeling we agree with your conclusion.

Page II-29, Figure
The terminology is used loosely in this figure to indicate areas where water is either entering the valley fill system or leaving the system. Since there is no sustained flow in East Fork Armells Creek above Colstrip there cannot be gaining or losing streams.

VIII-5

p. II-28 ¶7 Ground water contours don't need to come to the surface for discharge to occur e.g. pumpage from wells; discharge due to a vertical hydraulic gradient.

p. II-30 ¶2 How did you determine that valley fill recharges bedrock in the vicinity of the surge pond? Fig. II-11 shows insufficient data for analysis in this area. Also, upstream and downstream of this area, fig. II-11 shows discharge from the bedrock system and discharge from the ground water system, respectively.

p. II-30 ¶1 Fig. II-11 shows recharge <u>from</u> bedrock above Colstrip, not recharge <u>to</u> bedrock as stated here.

p. II-37 ¶4 Why is an agricultural economy viable if the ground water quality is poor for irrigation?

p. II-38 ¶2 Please discuss "natural causes."

¶2 What geochemical and hydrologic processes were responsible for the impacts shown in some of the wells?

p. II-39 ¶1 Why not show a standard deviation for TDS in Area B also?

p. II-39 ¶4 What is a "predominant" range if the range is 684 to 3,500? Is it one standard deviation, or some percentage of samples about a mean, etc?

p. II-39 ¶5 Delete "TDS" in second to last line on page.

p. II-40 ¶1 What about ion exchange from the clays in the interburden to account for sodium?

¶2 How do you know that sodium sulfate waters predominate when at the bottom of the page you have data for 2 wells in the sub-McKay in Area C and one is magnesium sulfate?

Exhibit 3

Joe A. Moreland (Cont.)

Page -28, Paragraph 7
The discussion refers to natural discharge. If discharge occurs then the gradient will become vertical upward at the discharge but the water table surface will also intersect the groundwater surface.

Page II-30, Paragraph 2
The determination was made as discussed in the referenced paragraph. Figure II-11 shows insufficient data to draw conclusions about whether alluvium s recharging bedrock or not upstream from the surge pond.

Page II-30, Paragraph 1
The sentence has been modified.

Page II-37, Paragraph 4
The major agricultural economy in Area C is livestock. Although groundwater quality is poor for irrigation, it is considered "fair to good" for stockwater. Therefore, groundwater quality has not been a limiting factor to livestock production in the area.

Page II-38, Paragraph 2
The natural causes of high salt concentrations would include leaching of excessive salts from areas more rich in clay and, hence in captured salts of various kinds, and concentration caused by evapotranspiration losses. The authors have not speculated on causes for higher levels in some of these wells except to say that spoils leaching is apparently responsible for many of these elevations. However it is recognized that alluvial TDS levels in the headwaters of Cow Creek may tend to be naturally high relative to alluvial TDS values in adjacent drainages.

Page II-39, Paragraph 1
See response page II-13, paragraph 4 regarding standard deviations.

Page II-39, Paragraph 4
The range given was an eye approximation made by recognizing that values of TDS over 50,000 mg/l and less that 10 mg/l were unrealistic.

Page II-39, Paragraph 5
The wording has been changed.

Page II-40, Paragraphs 1 and 2
The ion exchange in the interburden could add to the sodium concentrations. It was the author's opinion based on the location of wells and water quality that the faulting was the avenue for contamination.

The statement is based on data for the entire study area and not just on Area C.

p. II-40 #5 Alternately, if you are basing predominant sodium-sulfate water in sub-McKay on what is in the McKay coal, you've neglected the magnesium-sulfate water in areas B, E, D, etc. In this paragraph, you're implying downward movement along faults. In #2, it was upward movement along faults.

p. II-41 #2 Thirty-six percent does not constitute "most of the wells" but the highest percentage in any single aquifer.

p. II-54 sec. f The section on ground-water recharge deals solely with valley fill. Shouldn't something be said about bedrock aquifers too or indicate that they were dealt with in previous section?

p. II-54 general Where are the recharge and discharge numbers for the bedrock aquifers in Area C?

p. III-6 #4 Reference some of these conclusions.

P. III-7 #5 Disrupting the Rosebud overburden which is the source of water for 30% of wells seems to be significant, although this impact could be mitigated.

#8 What drawdown criteria was used to determine the maximum radius of significant influence?

p. III-10 #1 Due to the change in Table III-9 on Errata sheet, can you explain the +47% change in discharge on East Fork Armells?

Joe A. Moreland (Cont.)

Page II-40, Paragraph 5
The discussion did not indicate the location of areas where faulting and direction of movement is thought to play a role in water quality.

Page II-41, Paragraph 2
The appropriate change in the text has been made.

Page II-54
The text has been modified to indicate that bedrock discharge/recharge relationships were discussed on page I-28, section 3.

Page II-54, General
Recharge and discharge values for bedrock have been determined as a result of modeling (calibration). They have not been included in the EIS because the numbers, out of a particular context, are misleading. In order to make sure of these values a complete regional water balance would have to be conducted, which is beyond the scope of the project. The recharge and discharge values have been included in the TSD.

Page II-6, Paragraph 4
The references have been added.

Page II-7, Paragraph 5
Western Energy has committed to replacing overburden wells with deeper wells. The increased cost of pumping is discussed in the Hydrology impacts section in the EIS.

Page II-7, Paragraph 8
Because of the overall accuracy of the model it was decided that a drawdown of one foot would be considered as a significant change.

Page III-10, Paragraph 1
The errata sheet was in error. A technical problem in the model with spoiling areas along streams was encountered. The error was corrected and a new table compiled (see response to letter #17, J.R. Lee).

Letter No. 3

United States Department of the Interior

BUREAU OF MINES

WESTERN FIELD OPERATIONS CENTER
EAST 360 3RD AVENUE
SPOKANE, WASHINGTON 99202

June 28, 1982

JUN 29 1982

Mr. Kit Walther
EIS Team Leader
Montana Department of State Lands
1539 11th Avenue
Helena, Montana 59620

Re: Western Energy Company's Rosebud Mine
Area C, Block I
Rosebud County, Montana
Draft Environmental Impact Statement (DEIS)

Dear Mr. Walther:

We wish to thank you for this opportunity to review the Draft Environmental Impact Statement (DEIS) for Western Energy Company's proposed Area C coal mine near Colstrip, Montana. Personnel of the Western Field Operations Center have reviewed the DEIS primarily from the standpoint of potential impacts of the project on other mineral resources.

Known mineral resources in the project area include three coal seams, oil, gas, uranium, sand and gravel, and clay. The resources that would be directly effected by the project are coal and oil and gas. Only the Rosebud coal seam will be mined, leaving the McKay and Stocker seams in place because they are considered to be subeconomic at this time. Unfortunately, the latter two seams will never be more nearly economic to mine than at the same time as mining proceeds on the Rosebud seam. This loss (possibly irretrievable) is adequately pointed out in the text. Oil and gas are not currently being produced in the immediate project area. Should oil or gas be discovered in the area at a later date, mining of the coal would not preclude oil and gas production.

Thus, we anticipate no significant adverse impacts on mineral resources, other than the coal loss described in the text, and have no objection to the DEIS as written.

Sincerely,

G. A. Kingston, Chief

G. A. Kingston

Thank you for reviewing the Area C, Block I Draft EIS. Your comments have been noted.

VIII-8

Exhibit 3

Letter No. 4

RECEIVED
JUN 28 1982
STATE LANDS

Department of Energy
Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

In reply refer to: SJ

June 25, 1982

Gareth Moon, Commissioner
Montana Dept. of State Lands
1625 Eleventh Avenue
Helena, MT 59601

Dear Mr. Moon:

We have reviewed the draft environmental impact statement (EIS) on Western Energy Company's Rosebud Mine Area C, Block 1, and offer the following comments:

1. The EIS does not address the purpose and need for the electricity that will be produced from the additional mining area, and } A

2. The discussion of technical alternatives on pages IV-2 and IV-3 does not adequately reflect the latest load forecasting data. A copy of Bonneville Power Administration's load forecast is attached for updating page IV-3. } B

Nicholas J. Stas
Acting Environmental Manager

Attachment

Nicholas J. Stas

A. Refer to page IV-3 of the DEIS for explanation.

The fuel to be burned at Colstrip Unit 3 is to be supplied completely from Area C. In a recent injunction hearing, Montana Power testified that it is important for Unit 3 to come on line as scheduled for several reasons (Rose, 1982):

- Delay in bringing Unit 3 on line will add to an existing potential electric power deficit supply problem in Montana and the Pacific Northwest.
- Replacement power for Unit 3 is estimated to cost $29 million per month, and would be oil- or gas-fired electric generation.
- If oil or gas cannot be purchased, or if other sufficient oil- or gas-fired generation capacity cannot be found in the northwest power grid, then replacement power for Unit 3 would not be available and it is likely that curtailment of electric power to consumers in Montana and the Pacific Northwest might become necessary.
- The projected energy deficits might result in brown-outs and black-outs in the region.

B. The referenced publication cites a high load growth projection of 2.5 percent annually from 1980-2000, and a low-growth projection of 0.8 percent per year. However, coal mined from Area C is not subject to the vagaries of a changing market. Area C coal is under contract to Montana Power Company.

Exhibit 3

Letter No. 5

Forsyth, Montana
Irior 2 July 2, 1982

Mr. Kit Walther
EIS Team Leader
Dept. of State Lands
1539 11th Ave.
Helena, Montana 59620

Re: Draft EIS-WECo.
Area C: Block 1

JUN 30 1982

Dear Sir:

The subject statement bears little resemblence to the treatise we were promised, a cumulative study of the impacts of mining the Rosebud coal vein and aquifer at and near Colstrip. The references cited at the back of the volume show the only "input" into the creation of the text came from the files or oracles for the Mining Company, or some out of state Consultants here to make Big Bucks!

At the meeting called by the Dept. of State Lands for the purpose, presumably, of obtaining our cooperation in the writing of a Cumulative Impact Statement relating to the affects of mining the Rosebud coal vein, last fall, we were happy to oblige the request. Evidently, it wasn't needed, because we were never called upon to offer suggestions, or provide any kind of input. It was strictly, apparently, a public relations stunt. We were deceived!

On who'se shoulders lies the blame for this deception?

To address this manuscript briefly:

The map, p. II-21, Fig. II6 is reported to indicate the direction of flow of the "spoils aquifer." What it really indicates is the direction the aluminum tubes were and are laid from the active mine site to the tributaries draining the area.

Because there is not one shred of evidence, to date, to show any "spoils aquifer" has originated, the reference to a "spoils aquifer" must be eliminated from the text, unless DSL can show a log; a location in the mine spoils of each area which has any kind of aquifer characteristics. Can you?

The spoils wells are shown on the map to be immediately down syncline from the waste water discharge points. Those drilled to the alluvium are simply picking up the quantity of water discharged during the mine operation. They are not showing water is making it's way through the spoils, but that the mine affluent discharged as "waste water" is degrading the alluvial waters, and very probably, lower aquifers as the McKay and Sub McKay, whatever it is?

It was a clever devise when one of the staff of DSL told the N.F.R.C. not to protest the issue of the Extension for Area E. Even the final Statement relative to Area E contained such dire information, no Permit should have been granted, but, because the State had little opposition, it was granted.

Exhibit 3

Patty Kluver

A. During preparation of the plans of study (POSs) for the Area C and Comprehensive EISs a public participation meeting was held in Colstrip. In addition, written public comments to the draft plans were solicited. Additional public participation was invited subsequent to issuing the draft EIS. As a result of public comment on the draft, the cumulative hydrologic assessment has been expanded to clarify the impact analyses and address specific public concerns.

B. Figure II-6, page II-21 only shows potentiometric surface of spoils groundwater and the direction of groundwater flow through the mine spoils. It does not indicate the direction pit water is being pumped to sediment ponds or tributary drainage of the area for retention.

C. There are a number of spoils wells in Area A and E and in the Northern Pacific spoils that have water in them, indicating that groundwater flow is being reestablished in the spoils.

D. The spoils wells referred to are actually alluvial monitoring wells in Cow Creek and its tributaries. The waste water discharge points are sediment ponds that receive waters pumped out of the mine pits. These waters are either groundwater discharged from the Rosebud Coal into the pits or surface runoff. They are waste waters only in the sense that they are not used within the mine area for dust suppression or other purposes. The quality of these waters is as good as waters normally discharged to the Cow Creek alluvial system by the coal seams, and in some cases during high surface runoff, ma be of much better quality.

E. Your comment is noted. The Department of State Lands and Office of Surface Mining believe that cumulative hydrologic assessment presented in the Final EIS adequately address the NEPA and MEPA requirements for a cumulative impact assessment. See also response to comment A above.

That same staff member from DSL advised those who might protest the Area E Extension permit, Rather than protest at Area E, wait for the Big One, Area C.

No reason was ever given for this clever conclusion, so we can only presume we know why the former staff member of DSL advised in that manner, ...but, we waited for the Big One!

What did we get? Well, it is another little pithy replica of the EIS publications by the Mining Company, containing a few facts; some probables, some innuendos, and a lot of trash.

Rembmber when it was announced in the paper, DSL says no more permits will be issued until a cumulative impact statement is written? This Impact Statement was supposed to be produced for Area C, and evidently Ertec came up with something, but they must not be very proud of it! There are only five copies, two for DSL; two for the WECo. parimeter, and one for the lowly Office of Surface Mining. We, who's lives and livelihoods are at stake did not receive a copy of this Epic. Small wonder! We weren't asked for input into it, either. . . . . and that is the fallacy in allowing the applicant Company to pay for its own Environmental Impact Statement.. Not only do they pay for it, but they write it according to their own interests, and according to their own time schedule.

SO WHAT IF THERE IS NEED TO HURRY SO THAT THE APPLICANT COMPANY CAN MEET IT'S CONTRACTS AND COMMITMENTS IN OCTOBER, '83?

Maybe they should have started planning the EIS a little earlier! The Company demand for a permit places the Dept. of State Lands in a demeaning and compromising position. It also makes those of us in the out-back region surrounding Colstrip feel the Dept. of State Lands is little but a "tool" of the applicant Company.

E

This EIS would lead one to believe there was little Iron to be found in the waters of the spoils around Colstrip. The statistics quoted refer only to TDS measurements. To counter this erroneous claim, enclosed is a snapshot (Ex. 1) taken at a culvert which drains mine water from a sediment pond in Area E. To what does the EIS team attribute the color of the water, in this picture taken by this writer in July, 1979?

F

Ex. 2 is a copy of the U.S.G.S. data for Rosebud near Colstrip which shows two methods for measurement of Iron. Total Recoverable is one, and the less accurate is Total Dissolved. Obviously, Ertec had access to both measurements, but, since Total Dissolved doesn't pick up an ingredient that is practically insoluble, the Iron measured within E.P.A. criteria. How devious can one become?

G

Patty Kluver (Cont.)

F. Such a determination cannot be made from a polaroid snapshot. There are a number of things that could be responsible for such coloration and without a surface water sample the responsible constituents cannot be positively identified.

G. The measurements for Total Dissolved Iron and Total Recoverable Iron are equally accurate. Total Recoverable Iron measurements will include all iron in the water sample including suspended insoluble iron and iron sediment. The authors did have the data that you mention.

Exhibit 3

I.)
Draft EIS
WECo. Area C: Block 1

Had ERTEC kept the word it gave us at the meeting requested by Dept. of State Lands, we would have told them of some off-site-specific problems they should be aware of.

An example is Ex. 3, a copy of a U.S.G.S. map of the area East-so. east Colstrip. On the map we submit are circles drawn around Domestic wells which have become contaminated by Iron. Having read the criteria published by E.P.A. relating to Iron, even without the learned hand of science, one can be quite assured the trouble-maker is the intrusion of too much Iron.

By adding Exhibits 1, 2, and 3 together, and by reading Ex. 4, a copy of the Iron criteria appearing in the bulletin, Quality Criteria for Water, published by the Environmental Protection Agency, even an ignorant layman as this writer can come to a conclusion.

What is the conclusion drawn by the Dept. of State Lands?

The above mentioned map does not show, by any inference, the extent of wells that have been damaged by Iron in the past ten years. It only shows those located on the map that this writer knows about in this immediate vicinity. A few miles north, a new well struck Iron laden water at 500 ft., just north of the mouth of Cow Creek incidently! And on down Rosebud creek, there are more. } H

In the oral testimony presented at Colstrip, June 14th, I mentioned the primary faults in Area C. Their destruction can lead to total disaster for those depending on shallow wells with windmills, as most of us in the vicinity of the Western Energy and Peabody mine digs do. Yet, on page III-11 is another of those charts of illusion. Groundwater provides the source for all of our pasture wells and springs, with the wells served by windmills. Can you imagine the cost of running an electric line to well locations scattered throughout a 20 section pasture? In addition, there would be the cost of drilling a new well, at $9.50 per foot, plus motor, etc. } I

It is apparent that no one who wrote the estimate appearing on page III-11 has ever had to "pull" a well in 20 below zero weather, or even break trail to it through the snow, to get the equipment in to "pull" it. } J

Following the Public Hearing regarding the Montco mine, the Dept. of State Lands people were quoted as saying, "There is no way we can deny a coal stripmine permit," according to our staff Attorney!"

Obviously, there is need of the opinion of a second Attorney. } K

Exhibit 3

Patty Kluver (Cont.)

H. The wells mentioned here are not within the hydrologic study area (see Figure II-3 in DEIS). Unless DSL and OSM have additional information on the depth of these wells, the aquifers they are completed in, water quality analyses at the time of completion and over time, the type of well, and other pertinent data, we cannot make any conclusion regarding possible contamination of such wells.

I. Coal companies are required by law to replace water supplied that are affected by contamination or loss of quantity due to mining. The coal company would bear the expense of replacement.

J. Your comment is noted.

K. The comment may have been taken out of context. This is true if the coal company's application is determined complete and the mining and reclamation plans proposed by the company meet the standards of Montana's Strip and Underground Mine Reclamation Act and Rules as well as other environmental regulations of the state (i.e., air and water quality acts).

The Dept. of State Lands does not have to rely on the "toughest stripmine and reclamation laws in the nation." There are laws regarding surface and groundwater which apply very well.

From a publication titled Family Legal Guide comes the following quote: p. 779.

> "Underground and percolating water: Three different rules relate to the use of underground, or percolating waters. The common law rule regards water beneath the surface as the property of the landowner. His exclusive ownership is modified, however, in states that (1) require the water to be used for a beneficial purpose, (2) do not protect a use motivated solely by malice toward neighboring landowners, or (3) have a statute prohibiting the waste of underground water.
> The reasonable use rule permits only uses that are reasonable in the light of the circumstances, particularly when the uses affect neighboring landowners.
> The prior appropriation doctrine recognizes state ownership of percolating waters and protects appropriators (private property owners) in order of their seniority."

Is the discharge of groundwater, contaminated by mine spoils, onto the property of others considered putting it to beneficial use?

Is the discharge of mine "waste water" so that it finds its way into, under and onto the property of a neighbor putting it to reasonable use?

} L

The Dept. of State Lands is charged with the duty to protect the interests of all the landowners in Montana. If it continues the policy of granting permits to mine it has in the past, there can be only one comparison.

To grant a permit for Area C: Block 1 could be compared to the British government if they had sold the Falklands to Argentina for some royalties and Argentine severence pesos.

} M

Sincerely,

Patty Kluver
for Genie Land Co.

L. Under Montana law, a discharge of groundwater or "wastewater" is not considered a reasonable or beneficial use. "Beneficial use" in the Montana Water Law means "a use of water for the benefit of the appropriator..." In some instances, water rights are filed on wastewaters and groundwater discharges that are put to beneficial use by the appropriator (i.e., irrigation). There is no drainage law in Montana that gives the landowner a relief from damages incurred by drainage from adjacent lands. The only relief is through case law and the courts. However, the Montana Strip Mine Law provides authority to the State to deny an operating permit if a proposed mine operation would cause adverse hydrologic impacts which would impair present and future land and water uses.

M. Your comment is noted.

Letter No. 6

msu
COLLEGE OF AGRICULTURE

DEPARTMENT OF ANIMAL & RANGE SCIENCES
MONTANA STATE UNIVERSITY BOZEMAN 59717

June 29, 1982

Mr. Kit Walther
EIS Team Leader
Montana Dep't. of State Lands
1539 11th Ave.
Helena, MT 59620

Dear Mr. Walther:

Having reviewed the draft EIS for Western Energy's Rosebud Mine Area C, Block 1, I have the following comments:

- Vegetation Section (p. II78-II82) is well done. } A
- Alternative (a) p. IV-17 is more desirable than alternative (b) for establishing conifers because of the reduction in long term fuel and labor commitment and the increased potential for seedling establishment and survival. } B
- Appendix G, Table II - Kentucky Bluegrass (Poa pratensis) is an undesirable increaser whose current existence in the proposed mining area is probably due to the overgrazing of the 1880's and 1890's. The establishment of the other usable livestock and wildlife forage species would be greatly enhanced if this species was eliminated from the proposed mixture. } C

I would be happy to explain any of my comments further should you need me to do so. My phone number is 994-3721.

Yours truly,

Clayton B. Marlow
Assistant Professor

CBM:gmb

Clayton B. Marlow

A. Thank you. Your comment is noted.

B. Your comment is noted.

C. The Montana Department of State Lands does not believe that Kentucky bluegrass (Poa pratensis) is an undesirable species in the Lowland/Drainage Seed Mixtrue as proposed by the Western Energy Company. Kentucky bluegrass is an efficient sod-forming species and for this reason has been included in the mix to be used on easily eroded drainage areas. Kentucky bluegrass is also a good forage grass for both livestock and wildlife and has not proven to be a problem increaser in the Colstrip area. It should be noted that the grass in question makes up only 10 percent of the seed mix to be planted in about 5 percent of the total reclaimed area.

Exhibit 3

Letter No. 7

United States Department of the Interior
NATIONAL PARK SERVICE
ROCKY MOUNTAIN REGIONAL OFFICE
655 Parfet Street
P.O. Box 25287
Denver, Colorado 80225

IN REPLY REFER TO
L7619 (RMR-PC)

Mr. Kit Walther
EIS Team Leader
Montana Department of State Lands
1539 11th Avenue
Helena, Montana 59620

Dear Mr. Walther:

We have reviewed the draft environmental impact statement for Western Energy Company's proposed Area C coal mine and determined that the proposed mine would not have impacts or potential impacts on any present, proposed, or potential unit of the National Park System or any other areas or features where the National Park Service has program responsibilities.

Sincerely,

Richard A. Strait
Associate Regional Director
Planning and Resource Preservation

Richard A. Strait

Thank you. Your comment is noted.

Exhibit 3

Letter No. 8

WESTERN ENERGY COMPANY

111 N. BROADWAY BILLINGS MT 59101 (406) 252 2277

July 1, 1982

Mr. Kit Walther
EIS Team Leader
Montana Department of State
Lands
1539 11th Avenue
Helena, MT 59620

JUL 06 1982

RE: Comments - Area C, Block I DEIS

Dear Mr. Walther:

Western Energy Company's technical staff has reviewed the draft environmental impact statement recently published for Area C, Block I. In general, we see no major problems with the DEIS. However, we do wish to submit the following comments in hopes of clarifying a few points which were made in the hydrology section of the document.

Western Energy Company disagrees with the statement (see page II-20 and Figures II-8 and II-10) that, "A major recharge area appears to be located in the vicinity of Area C". Based on Western Energy's hydrological investigations, there appears to be recharge to Area C from the west from alluvium, bedrock, and vertical infiltration. As stated by Ertec, the amount of vertical infiltration is very small. The configuration of the potentiometric surfaces shown in Figures II-8 and II-10 result from kriging data which is averaged from 1973 and 1981. Western Energy feels that the potentiometric maps supplied with the Area C, Block I application SMA00105 (Exhibits R-1 and R-2) are accurate site specific representations of the potentiometric surfaces of the Rosebud coal and the McKay coal. A

On page II-22, the statement, "Where Rosebud spoils become part of the valley fill groundwater flow system, spoils water migrates laterally into valley fills", cannot be substantianted by Western Energy's data or by data presented in the draft EIS. Examination of figures II-6 (page II-21) and figure II-7 (page II-23) show that alluvial water levels are higher than water levels in the spoils. Therefore, interchange of water between these two units would have to be from the alluvium to the spoils. Data presented by Dolhopf (1977, page II, figure 5, attached) suggest that East Fork Armell's Crek alluvium is not in contact with Area B spoils. Recent drilling by Western Energy Company in the railroad loop (holes EX 158-165) and the log for Well P-06 indicate a substantial volume of undisturbed bedrock between East Fork Armell's Creek and alluvium and spoils. The northeast quarter of the northeast quarter of Section 4, T1N., R1E, was not mined and there are not areas where Area A spoils are in direct contact with East Fork Armell's Creek gravel aquifer. B

Exhibit 3

VIII-16

Chris Cull

A. The FEIS reflects wording changes to indicate that the area in question is not a major recharge area for the aquifers in question. There is probably some recharge throughout the entire area. The potentiometric maps have insignificant variations from the referenced exhibits.

B. After discussions with Western Energy concerning well locations and review of the monitored logs it is clear that the Area A spoils are not in direct contact with Armells Creek alluvium. The question concerning Area B cannot be resolved with present data. Detail of future mining plans was not sufficient to acurately determine potential areas where spoils and alluvial material will be in contact. Since mining in Area C will proceed across East Fork Armells Creek, eventually spoils and alluvium will be in contact.

The inferred fault or faults shown on Figure II-9 and discussed in the text cannot be substantiated by Western Energy's drilling redords. The attached cross sections, through Areas A and F (Figure 1) at approximately the location of the cross section on page II-26 and through Area C (Figure 3) across the inferred fault show minor folding but no displacement. These cross sections were drawn using holes drilled for outcrop delineation (locations shown on Figures 2 and 4). } C

Thank you for the opportunity to comment on the Area C draft environmental impact statement.

Cordially,

CHRIS CULL
Manager, Operational Permitting

CC:kk

C. The structural contour maps prepared from Western Energy core hole data show over 100 feet of displacement in a 3,800 feet distance in the Rosebud coal. This is an anomolous dip for the study area. The U.S.G.S. has indicated that a possible fault exists in the area. It is the opinion of the authors that there is fraturing and displacement associated with the structural feature described.

Exhibit 3

Letter No. 9

United States Department of the Interior

MINERALS MANAGEMENT SERVICE
RESTON VA 22091

In Reply Refer To:
MMS-Mail Stop 650

Mr. Kit Walther
EIS Team Leader
Montana Department of State Lands
1539 11th Avenue
Helena, Montana 59620

Dear Mr. Walther:

The Minerals Management Service, U.S. Department of the Interior, has reviewed the Draft Environmental Impact Statement (DEIS) for Western Energy Company's Proposed Rosebud Mine, Area C, Block 1, and we offer the following comments for your consideration.

The DEIS is well written and includes up-to-date literature sources, a realistic assessment of the reclamation potential of the mine, impacts to the biological community, and the agricultural utility of the land. The sections on hydrology appear to be well done, and the assessment of potential impacts on surface and ground water quality are, in general, realistic. } A

Specific Comments

Page 1, paragraph 6, line 6. This line should read ". . . a slight increase in electrical conductivity . . . ." } B

Page ii, paragraph 7. It is suggested that this sentence be changed to read, "These changes would reduce the postmining potential for crop production and . . . ." } C

Page iv, paragraph 3, last sentence. Some further explanation is required to overcome an apparent contradiction here. "Compared to the premining (1978) conditions, productivity for livestock grazing would increase; however, the potential productivity (total biomass production) of the postmined area would be lower . . . ." } D

Page II-22. The statement is made that there are places in the vicinity of the proposed mine where Rosebud spoils are located adjacent to the valley fill material and occasionally become incorporated into the valley fill ground water system. The description of these areas in the EIS would suggest that some weathering occurs. } E

JUL 06 1982

Andrew V. Bailey

A. Comment noted.

B. DSL and OSM believe that the present wording is correct.

C. Comment noted. While that potential exists it is not certain.

D. Productivity for livestock grazing and total biomass production are not perfectly correlated. The components of biomass contribute to productivity for grazing.

E. Comment noted. Where spoils are exposed to the atmosphere they are exposed to weathering.

Exhibit 3

Page II-48, paragraph 3. This paragraph discusses the concentrations of trace metals, noting that mercury was high at several sampling points. However, the potential for increased concentrations of trace metals, such as mercury, as a result of mining and associated oxidized spoils was not addressed, nor was further discussion of this point made except to note that some of the high results were believed to be a result of laboratory error. Since mercury is an important trace metal associated with coal and tends to increase where coal or spoils have had an opportunity to weather, these findings warrant a more complete discussion in the EIS. We recommend that the final EIS include additional discussion of the sampling sites where high mercury concentrations occur. The discussion should state whether or not such sites are in the areas potentially impacted by existing Rosebud spoils and provide some insight as to the source of the mercury. If the sites are found in areas influenced by the Rosebud spoils, then the projected water quality impacts should be amended accordingly. F

Page III-55, H. Wildlife, paragraph 1. We note that Western Energy Company states that seasonal sources of surface water which are now available to wildlife will be impacted by proposed mining activities. We also noted this observation in section B, Hydrology on pages III-6 through 25. The draft document did not provide an assessment on the value of surface water bodies (springs and stock ponds) for wildlife nor the anticipated impact of wildlife if these water sources are removed or rendered unuseable by proposed mining activities. G

Within the same paragraph, Western Energy Company states that the U.S. Fish and Wildlife Service recommended the sandstone outcrop on which golden eagle and prairie falcon nests are located be protected. Also, the Montana Department of State Lands recommended a 100-meter buffer zone be established between the mine and the outcrop. Western Energy Company states further in this paragraph that preliminary life of mine for Area C, Block II, would eliminate the outcrop. No other discussion is made as to whether or not Western Energy Company is or is not going to protect the sandstone outcrop. We recommend that the Office of Surface Mining require the applicant to make a decision on whether it will or will not protect the golden eagle nest outcrop and provide the rationale for its decision. H

Thank you for the opportunity to comment on this DEIS.

Sincerely,

Andrew V. Bailey

Andrew V. Bailey
Acting Associate Director,
Onshore Minerals Operations

F. It is very likely that field sampling techniques or laboratory error are responsible for these values, and it is not felt that further discussion is warranted without reliable data. Discussions with personnel at the National Water Quality Laboratory of the USGS corroborate this conclusion. Two factors support this contention.

1. 0.03 to 0.04 mg/l are equal to 3 to 4 mg/l, which are values that are very unlikely in nature. These occur alongside data taken from the same locations at different sampling times that show no detectable evidence of mercury.

2. Mercury is commonly encountered as a contaminant in field and laboratory settings. Contamination can come from a number of sources, most notably mercury contained within the manometer type stream flow gauges (commonly used at the same time a sample is collected) and mercuric chloride, commonly used to preserve nutrient samples, being incompletely removed from glassware in the laboratory.

G. The impact of mining in Area C, Block I upon surface water bodies was determined to be minimal and hence the corresponding impact to wildlife using such areas would also be insignificant.

H. Please see comment A and DSL's response to comment A in the letter from the Fish and Wildlife Service. The Western Energy Company as agreed to establish a 100 meter buffer zone around the subject sandstone outcrop area. In addition, the company has committed to identifying the buffer zone boundary with a one-wire fence and with signs indicating the area as a disturbance limit to mining related activities. To the extent reasonably possible, the company has also agreed in their mining and reclamation plan to minimize other types of activity in this area.

Letter No. 10

Forsyth, Mt.
July 4, 1982 JUL 8 1982

Mr. Brace Hayden, Administrator
Reclamation Division
Dept. of State Lands
Capital Station
Helena, Montana 59601

Re: WECo, Area C: Block 1

Dear Brace:

Enclosed is a "supplement" to the critique I mailed you prior to July 2nd. In the ones sent to Kit Walther and to Gareth Moon, there was a copy of the testimony I presented at the May 12th Water Quality Bureau Hearing relative to the renewal of a discharge permit. Since I had already mailed you a copy of the testimony, it is left out of this enclosure. I hope you haven't filed it in the "deep six drawer."

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Thought I'd report some words of encouragement to you. It seems the quest for more funds for enforcement and investigation for DSL, etc. is really in the works. It probably won't get anywhere, because M.P.C sure doesn't want any close scrutiny, but, working on the Republican side, maybe a bit of negotiation could be done. I'm planning to work on the other side, too, because it is that important to me, and I'm more D than R, but neither, really. There doesn't seem to be much to vote for either way, or against.

You can't imagine the frustration and hopelessness I feel re: Area C: Block 1. The "mitigating measures" so clearly point out that WECo. will get their way, and to heck with those who stand in their way.

I hope the hail didn't damage you or your property too much. It must have been terrible, but it is a part of living in Montana, and I wouldn't want to live anywhere else. I like the challenge.

My very best to you personally, Brace.

Sincerely,

Patty Kluver

Patty Kluver

The Montana Department of State Lands and the Office of Surface Mining believe that in reviewing the Area C, Block 1 application, they have treated the concerns of the public and the Western Energy Company equally. We appreciate the comments you have offered both written and oral, and have tried our best to address each of them adequately. We have expanded the areas of concern to you in the cumulative hydrologic sections in Chapter III of the FEIS.

Letter No. 10

Forsyth, Montana
Prior to July8, 1982

Re: Draft EIS-WECo.
Area C: Block 1
Supplement to critique
mailed prior to July 2, 1982

Mr. Kit Walther
EIS Team Leader
Dept. of State Lands
1539 11th Ave.
Helena, Montana 59620

RECEIVED
JUL 7 1982
STATE LANDS

Dear Sir:

On Page one, (1) of the written testimony sent to your office prior to July 2nd, paragraph seven (7) evidently needs clarification!

The paragraph does not explain that the spoils wells are recharged by the use of aluminum tubes extending from the active mine pit, on the surface of the spoils, to sediment ponds in the older mine area of Area C. The drainage from those sediment ponds is what is influencing the quality and quantity of the spoils wells, located where no coal strip-mining has ever been accomplished because the area where they are located is the site of "burn." A

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While the article projects the accomplishments of the reclamation team of M.S.U., they admit they have not solved the question of reclamation of mined lands to date. In spite of the high cost, they will continue to apply and improve on the scientific studies they have made thus far.

The contents of the paragraphs in sub-title More Questions, 4th page of the enclosure, are particularly pertinent, because they put the lie to the claims for reclamation projected by the WECo., Draft EIS, Area C; Block 1. B

The last page of this enclosure points to the degradation that Plant 3 will add to the pollution already in the air from Plants 1 and 2 at Colstrip. The additional damage from Plant 3 could very well make the ranching business down wind from the plants untenable. Perhaps that is what the applicant Company would prefer, but, the Dept. of State Lands is charged with an obligation to the afflicted ranch land as well as to the royalties and severance income to the State coffers. C

Exhibit 3

Patty Kluver (Cont.)

A. Please see the response to comment D of your July 2, 1982 letter.

B. Thank you for subaitting this information.

C. Possible impacts to ranching downwind of Colstrip 3 and 4 have been reviewed through the permit process relative to that project and in the Colstrip Units 3 and 4 EIS. The Department of State Lands does not have regulatory authority in relation to the air pollution emissions of Colstrip 3 and 4. The impact to ranching as a result of Colstrip 3 and 4 air emissions is projected to be minimal.

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The EIS Team who will make the decision relative to mining of Area C: Block 1 must be aware that summer is the time on all ranches when work-days are long, so that we can provide for our livelihoods. Because of this, it is apparent that this writer will have no time to rush over to Colstrip to "brief" the ERTEC study, which probably says little that would meet with the dis-favor of the applicant Company. Certainly, it could not be objective.

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In an effort to show you of the DSL who will make this momentous decision, one that could make or break the ranching business of this area, may I extend you a cordial invitation to come to our ranch. If you will accept the invitation, in approximately 4 hours of your day, you can be shown the adverse affect of coal strip-mining on Cow Creek, and could also be shown an area where there is little impact from mining yet, on Pony Creek and Spring Creek. The mining of Area C: Block 1 could spell the doom of the two above named drainages, as well as many others in the region.

Please consider this list request, and you can schedule the visit phone to 347-5590.

Most Sincerely,

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Patty Kluver (Cont.)

D. Your comment is noted.

E. The Commissioner of the Montana Department of State Lands and the Secretary, U.S. Department of the Interior will make the decision as to whether to grant or deny a surface mining permit for Area C, Block I.

F. Thank you for the opportunity to visit your ranch during the growing season. The Department of State Lands will make an effort to do this very soon.

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Patty Kluver (Cont.)

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Exhibit 3

DEPARTMENT OF HEALTH & HUMAN SERVICES

Letter No. 11
Office of the
Principal Regional Official

Region VIII
Federal Office Building
1961 Stout Street
Denver CO 80294
ROFEC

June 16, 1982

Mr. Allen D. Klein
Administrator
Western Technical Center
Office of Surface Mining
State of Montana
Capitol Station
1625 11th Avenue
Helena, Montana 59620

Dear Mr. Klein:

We have reviewed the DEIS on the Western Energy Company's proposed Area C Coal Mine near Colstrip, Montana.

The DEIS indicates that the impact of this proposed mining operation on human service agencies in the vicinity would be minimal, "due to the similarity of existing and incoming work forces."

Rosebud County Welfare Office agrees with this conclusion. The community of Colstrip has already experienced a large population increase due to other related projects now in place. Colstrip will soon receive a special grant from the Montana Coal Board as a result of severance tax receipts. This grant will be used primarily to hire additional social services professional staff.

We suggest that comments on this DEIS be solicited from the Montana Department of Social and Rehabilitation Services.

Sincerely yours,

E. W. McIntire
Director, ROFEC

JUN 1982
RECEIVED

E. W. McIntire

Your comments are noted. The Montana Department of Social and Rehabilitation Services (SRS) name was mistakenly dropped from the DEIS mailing list. SRS will be sent a copy of the FEIS.

Exhibit 3

Letter No. 12

NORTHERN PLAINS RESOURCE COUNCIL

Field Office
Box 858
Helena, MT 59601
(406) 443 4965

Main Office
419 Stapleton Building
Billings, MT 59101
(406) 248 1154

Field Office
Box 886
Glendive, MT 59330
(406) 365 2525

JUL 08 1982

Gareth Moon
Commissioner
Montana Department of
State Lands
1625 Eleventh Ave
Helena, Montana 59601

June 6, 1982

RE: Rosebud Mine Area C, Block I Draft Environmental Impact Statement.

We appreciate the opportunity to comment on the Draft Environmental Impact Statement (DEIS), for the proposed Rosebud Mine Area C, Block I permit application.

Prior to addressing the DEIS, we would like to submit for the record the "scoping" comments of the Rosebud Protective Association (RPA) that were brought to the attention of the Montana Department of State Lands (DSL) and the Earth Technology Corporation (ERTECH) at a meeting on December 16, 1981. We ask that these comments be included in the record to establish that many of the concerns raised at that "scoping" meeting were not adequately addressed in the DEIS. Some of these include: the restoration or replacement of aquifers, the cumulative impacts on hydrology from mining and industrial development at the Colstrip complex, and necessity for addressing the "last" or phaseout cycle of development. A

The Office of Surface Mining (OSM), and DSL by not requiring that supplemental field work, particularly as it might relate to hydrologic studies, have violated the intent and the language of the Memorandum of Understanding between them, ERTECH and Western Energy Company (WECo). The MOU required them to determine "whether adequate baseline and environmental data already exist and no further baseline monitoring is required". Obviously, more data is required to establish an adequate baseline. The MOU also required ERTECH to assist in this effort by reviewing and documenting the type, quality and quantity of information in the environmental assessments prepared for or on the industrial complex at Colstrip. The EIS does not address the adequacy of the type, quality or quantity of the information available except to note where there is a "lack of information available (Appendix B to these comments). B

Exhibit 3

Russ Brown

A. All scoping comments, except for the request for analysis of the phaseout cycle of the Colstrip complex have been addressed in the Final EIS. The authors will address the phaseout cycle of the Colstrip operation in the forthcoming Comprehensive EIS. A draft of the Comprehensive EIS will be available for public review in August 1982.

B. Terms of the Memorandum of Understanding and Contract with Ertec did not specify supplemental field work for preparation of the Area C EIS. The agreement requires Ertec to utilize existing environmental data, based on an evaluation of its adequacy, to prepare the analyses of environmental impact. Existing data has been evaluated by OSM and DSL and determined adequate for determining baseline conditions for purposes of Western Energy's Area C, Block I mine plan.

We requested at a very early date that verification as to the quality and quantity of data be undertaken in order to insure that a comprehensive hydraulic study be completed. In a written response to these "scoping" concerns, Bruce Hayden, Administrator Reclamation Division, DSL states "the Plan of Study did not budget for field verification of well locations, therefore verification will be limited to cross checking existing data sources. This effort will be extended to Area E and the surge and fly ash ponds to the extent that ERTECH is able to obtain data from WECo and other sources". (March 1, 1982 letter to Russ Brown, NPRC Staff) C

The DEIS does note that lack of data prevented ERTECH from making statements about much of the hydrologic regimes. Yet, why didn't the DEIS make any recommendations that further testing be done? Are DSL and OSM satisfied with the amount of data available? Was an analysis done on the quality and quality of water in the existing and proposed fly ash ponds? Weren't industrial impoundments, both present and proposed supposed to be part of the cumulative hydraulic assessment? According to Mr. Tom Hastings, the hydrologic assessment for Area C and the Comprehensive EIS were completed as of the hearing on June 11. As a result of the findings in the DEIS and due to subsequent comments, is any further analysis planned? D

The Area C EIS is supposed to be a site specific EIS for a mine permit application. It is also supposed to be used as a baseline reference document for all future assessments done at the Rosebud Mine. However, since there is inadequate data available for the Block I permit area, analyses were extrapolated from areas A,B,E, & D. Do the DSL and OSM consider this kind of extrapolation a valid approach upon which to base permit decisions? The State in a 10/2/81 letter to WECo points out that "each mine in Montana is in a different hydrologic situation and that the WECo plan is more expansive than any other mine in the State". Is there in fact information available for Area D for example, that can be accurately extrapolated and applied to Area C? E F

A major problem for those attempting to analyze the DEIS is the number of references to the various Technical Support Documents that were prepared in conjunction with the EIS. Compounding the problem with the continual references to the TSD's has been the difficulty in obtaining access to these documents. G

In an October 2, 1981 letter to Mr. Art Neill of WECo, DSL points out that a cumulative hydrologic assessment must be [illegible] prior to any permit issuance. This has not been [illegible] to issue a permit without further hydrologic studies [illegible] undertaken [illegible] Admin. Sec. 82-4-227(3)(a) and also, [illegible] this information, DEIS that indicates that affirmatively [illegible] Sec. 82-4-231(1)(III)(A) has been complied with. H

Exhibit 3

Russ Brown (Cont.)

C. Your comment is noted. These were the conditions of the Memorandum of Understanding and contract with Ertec. Hydrologic data in the technical support document used in the ground water modeling was verified in cases where more than single data sources were present.

D. The authors believe the existing data base was adequate to make the hydrologic assessments of the Rosebud Mine and Area C, Block I mine plan. As required by the Montana Strip and Underground Mine Reclamation Act, Western Energy will be required to continue hydrologic monitoring of its activities and routinely report results to the Department for its evaluation. Analyses were conducted on the existing fly ash ponds as part of the modeling effort. Data indicate that the existing fly ash ponds leak very small amounts of water which then flows downgradient and becomes diluted in the surge pond area. A "worst case" evaluation of the impact of the proposed fly ash pond on the Cow Creek alluvial system is included in the final EIS. Please refer to Chapter III, Hydrology.

E. The Comprehensive, not the Area C EIS, will serve as the reference document for future EISs for the Rosebud Mine.

F. The authors did not find hydrologic data from Area C, Block I significantly different from other areas of the Rosebud Mine. Based upon a comparison between the site specific Area C, Block I hydrologic data and other data in surrounding areas it was felt Area C, Block I was hydraulically very similar to the areas surrounding it. These similarities and those differences which may occur are discussed in Chapter II, Section b. The similarities and the amount of data for Area C, Block I were determined sufficient for modeling the hydrologic system.

G. NPRC was sent a copy of the Hydrology section of the Technical Support Document (TSD). The entire document is available for review at the locations listed in the EIS.

H. The Final EIS for Area C, Block I includes an expanded cumulative hydrological assessment. Please see Chapter II.

SUMMARY

On page ii of the summation, it is noted that "the concentrations of total dissolved solids(TDS) in the spoils aquifer would be approximately twice that of the present Rosebud coal and overburden aquifers" It then points out that spoils water would follow the regional south east flow direction and eventually reach Cow Creek. Where else is the effect of this spoils water reaching Cow Creek addressed in the DEIS? Was the effect of this high TDS water and the proposed fly ash pond on Cow Creek calculated or included in the cumulative hydrologic assessment? I

We would also like to request that the language in the summation that states that "an indirect impact from mining may result" be changed to "another impact from mining that would result is....."(DEIS p. ii 3 para.) J

p. iv 4 para. recovered is mispelled.

SCOPE OF THE ANALYSIS

The DEIS assumes that WECo will be able to implement its Block II life of mine plan If this assumption is valid, why hasn't more information been presented or made available for the Block II mine plan? Are OSM and DSL proposing to issue a supplemental EIS or just extrapolate from the already inadequate data base? Does OSM and DSL feel that enough information exists to justify a permit decision on Block II. K

The DEIS states that "approval of a permit is a process separate from the EIS." Does this imply that when the public participates in the EIS review, they are not having any input into the decision of whether or not to issue a strip mine permit? L

It is also stated in the DEIS that "the comprehensive EIS will address the cumulative impacts of all the proposed mining .....and industrial activities in the area". Isn't the Area C EIS bineg used as a data base for the comprehensive EIS? Were other projects for which there are no EIS's available considered during the preparation of this EIS? M

The DEIS mentions that "all but one mile of the conveyor system will pass thru areas presently permitted". Is this "one mile" within the Area C permit application? We request that the route of the conveyor system be clearly identified in a map or diagram in the Final EIS (FEIS). N

DESCRIPTION OF THE EXISTING ENVIRONMENT

For the purposes of this document, is the Cow Creek drainage considered a part of the Armells Creek system or as a separate drainage? O

The EIS states that only those aquifers above the Mckay coal seam would be physically disturbed. Would the existence of fractures that might allow groundwater movement once an impermeable layer is removed constitute a physical disturbance? P

An analysis of the McKay coal seam at the Rosebud Mine and Peabody's Big Sky mine show similarities in BTU and chemical composition. Why is the McKay seam considered marketable at Q

Exhibit 3

Russ Brown (Cont.)

I. A more specific discussion of the effects of spoils water quality and the proposed fly ash pond on Cow Creek have been added to Chapter III, Hydrology.

J. These impacts (i.e., population increases, increases in power facilities) are not directly attributable to the activity of mining and therefore are considered indirect.

K. Until Western Energy submits a complete application for Block II and mine plan to DSL and OSM no detailed site specific impact analysis about this area can be made. At this time there is not sufficient information for the agencies to make a permit determination on Block II. In some cases (i.e. hydrology and socio-economics) the information was presented for all of Area C. Once an application for a mine plan has been received a determination will be made as to the type of environmental document which will be developed for Block II.

L. No. Both processes provide mechanisms for public involvement. Although the EIS is a distinct and separate document for the permit evaluation document both are an integral part of the decision making process. Comments received on either or both documents are used in the permit decision making process.

M. The Area C EIS will be used as one of the data bases for the Comprehensive EIS. Other data sources will include existing EISs prepared for Colstrip Areas A, B, and E, Peabody's Big Sky Mine, Colstrip Generating Units 3 and 4, etc. These five data sources were used in preparing portions of the Area C, Block I EIS. In addition extensive data, for which mine plans had not been submitted, were also utilized in preparing the Area C EIS. These included data for the Area B extension, Area C-Block II, Area D, and additional proposed mining in Area A.

N. Portions of the conveyor not within previously permitted areas are within the proposed Area C mine area. A map of the conveyor system is shown in the text.

O. No, Cow creek is part of a separae drainage (Rosebud Creek).

P. The less permeable interburden will not be removed. There will be an increase in vertical leakage from the lower aquifers as summarized in Chapter III of the FEIS.

Q. Because Western Energy Company does not have a buyer for the McKay Coal while Peabody does.

at the Big Sky mine and not at the Rosebud mine?

The DEIS states that "in some instances, the characteristics of Area C, Block I are different from the hydrologic study area as a whole." (DEIS p. II-10) It would be helpful if the DEIS summerized these differences at this point. R

When discussing the permeability of the rubble zone as a contributing factor in the large range of transmissity values, could this be factored our more accurately? (DEIS p. II-13). The DEIS further states that "generally the hydrologic conductivity values were the same". In what instances, or under what circumstances have they been found to deviate? S

On p. II-14, the diferrences in range of transmissivity in E. Fork Armells Cree and Stocker Creek is discussed. The DEIS points out that only six tests have been conducted on the Stocker Creek drainage. It then concludes that "due to the greater number of tests performed on the East Fork Armells Creek, the mean values of these aquifers is more representative of shallow transmissive characteristics". Does this mean that the number of tests is the determining factor in cumputing transmissity? While 6 test might not be statistically significant, if an equal number of tests had been taken in both Creeks, might not the conclusion have been different? T

Clinker has been reported to have local hydrologic significance. Why then have no tests been performed in the clinker to determine its role in the hydrologic system at and around the Rosebud Mine? (DEIS II-16) U

Early in the DEIS is the statement that "the properties identified for water bearing units are constant throughout the hyfrologic study area. (DEIS II-13) However, the rest of the EIS goes on to describe how the lithologic, structural, amount of clinker and chemical composition (to name a few) are different for each water bearing unit. With so many critical determing factors different for each unit, and considering the lack of data for many of these strata, how can the properties identified for the water bearing strata be consistant? This crucial invalid assumption seems to be used as a blanket rationalization for thelack of hydrologic information available for discussion in the DEIS. V

What is the significance of one observation well in the overburden not being effected by a drawdown test at a pumped well? (DEIS II-16) Is it legitimate for the EIS to infer from one pumped well test that "the two aquifers are not connected in that area" Wouldn't the presence of a confined or unconfined aquifer at that point make a difference in the test results? Also how is "area" defined in this context? W

When the DEIS is discussing the character of the spoils groundwater system, it states that it is generally unconfined. However, it then goes on to say that evidence exists to suggest that it may be confined (DEIS II-20). Is this uncertainty due to a lack of data? X

R. Pages II-10 through II-19 of the DEIS and the initial pages of Chapter II of the FEIS address these differences.

S. Presently, variations cannot be more accurately described. Hydrologic conductivity values vary in the spoils due to lithologic variation in the material. The variations do not appear to be statisticlally significant however more data would be needed to describe the phenomena. The discussion of spoil aquifer properties was primarily a general evaluation of physical and hydraulic properties as defined by limited research. It is very often difficult to complete wells in spoil and conduct hydraulic conductivity tests without biasing the result. The bias occurs because it is difficult to install wells in coarse rubble and it is also difficult to run tests in such wells since water runs out so quickly that neither a constant or falling head test can be monitored.

T. The referenced sentence has been deleted in the FEIS because of confusion over its intent. The sentence was not meant to imply the transmissivities for East Fork Armells Creek (EFAC) were representative of both Stocker and EFAC alluvium. The 29 tests conducted in EFAC alluvium are representative of EFAC only and those tests conducted in Stocker Creek are prepresentative of Stocker Creek only.

The conclusions may or may not have been different. I would be highly speculative to comment on aquifer hydrologic properties without data to support the statement.

U. Clinker occurs in the mine area as outcrops along stream valleys and tributaries. Rosebud clinker occurs along the northern edge of Area C and is an area of ground water discharge. Similar outcrops occur along East Fork Armells Creek north of Colstrip, and are also areas of ground water discharge from the coal seams. Extensive areas of Rosebud, McKay and Sawyer clinker crop out north, west and south of Cow Creek, and form resistant bluffs. These appear to be areas of recharge for the Cow Creek drainage system. Because of the extremely permeable and porous nature of clinker, it is able to absorb and transmit large quantities of water. The location of clinker mainly in discharge zones in the Rosebud mine area means that the clinker will have very little effect on the recharge capacity of the reclaimed mine areas. Additional testing of the clinker in the Rosebud Mine area would not significantly enhance the understanding of the hydrologic system.

V. There are local variations of hydrologic properties throughout the study area. Each hydrologic unit has been examined and a constant set of values assigned to each unit throughout the hydrologic study area. Therefore each unit has different properties and these have been described in the document.

W. At the location of the observation well and within the area of influence of pumping at that well there is no evidence of hydrologic connection. It is proper to infer that the results of the testing cited demonstrate a lack of connection. Whether this relationship is maintained without discontinuities throughout the study area is unknown. For that reason the intent of their relationship has been limited to the "area" in which testing occurs. Results of this testing do not allow for an exact definition of "area".

(See X. on next page)

Exhibit 3

P. 5 was identical to P. 4

Exhibit 3

SOCIO-ECONOMICS

The DEIS notes that "coal mining in Rosebud County would cease after the year 2018" (DEIS II-92). Does this assume that no other strip mine permits will be issued in the future? We would like to request that an analysis be prepared on the socio-economic and fiscal impacts that will result from the cessation of mining at Colstrip. } Y

P. II-101 "percentage is mispelled.

SOLID WASTE

The DEIS discusses the collection and burial of solid wastes in the old mine cuts that have been sealed with clay. When did this sealing take place? What have been the findings from the monitoring reports? Who are they submitted to? Have they been? } Z

HOUSING

The DEIS doesn't reflect the assumptions that are made in the MONTCO draft environmental impact statement that a large percentage of Montco's workers will reside in Colstrip. Is this an invalid assumption? If the State feels that it is not, then it should be factored into this analysis. } AA

CULTURAL RESOURCES

The survey of cultural resources seems thorough. It is unclear however if the Block II mining plan would have more of an impact on cultural resources than Block I. Is this the case?

Prior to the issuance of the FEIS, are any consultations proposed with Native Americans to discuss possible concerns under the American Religious Freedom Act of 1978? } BB

ANALYSIS OF IMPACTS

The DEIS notes that "overburden sampling on a grid pattern with hole density similar to that of Area C (1500-2000 ft.). is only about 50% reliable in predicting the occurence of unsuitable overburden material" How does the State propose to improve this flip of the coin accuracy? What would be a realistic frequency to improve on the sampling technique? } CC

Exhibit 3

X. The base of the spoils apparently exhibits confined characteristics. The upper parts of the aquifer spoils are unconfined characteristics. It is clearly atated on page II-20 that groundwater in spoils is generally unconfined but that it appeara that confining condition may occur in some areaa. The information indicating confined conditiona include the height of the piezometric aurface and with respect to the top of the spoil in that location.

Y. No it does not. The 2018 analyais is made becauae Western Energy's comprehenaive mine lan projecta mining to that period of time. The socio-economic effects of ceaaation of mining at Colatrip will be addressed in the forthcoming Comprehenaive EIS for the Colstrip area.

Z. The burial of solid waste in the old mine cuts ia done by Rosebud county under a permit from the Montana Department of Health and Environmental Sciences. Prior to the uae of the pit aa a landfill by the County on December 17, 1981, the old cuts were aealed with clay. Monitoring reports for the landfill are being aubmitted to the Solid Waste Bureau semi-annually. These reports indicate that no trenda are occurring dow gradient of the landfill. Recent aampling for aresenic indicate arsenic doea not occur in detectable levela.

AA. In keeping with aite specific EISs the Area C impact acenario aasnmes that no other new mines would be developed. This allows the analysis to focus on the probable impacts of the propoaed section rather than maaking them behind a acren of other projecta aaumed into exiatence. The Comprehenaive aaaeaament document currently being prepared will addreaa the effects of poaaible mines.

BB. Block II mining will not have more of an impact on cultural resources than Block I mining. Sites determined to be eligible for the National Register of Historic Places will be mitigated according to an approved plan prior to disturbance. P.L. 95-341, the American Indian Religious Freedom Act, recognizes the constitutional right of Native Americans to practice their traditional religions. Most landa affected by this law are managed by the Forest Service and the National Park Service. Since mining of Area C would occur on private lands and there are no American Indian cemetaries which were in uae at the time of Federal aubjugation or are there within the proposed mining are physical locations to which American Indians have traditionally had accesa, the agencies will not be pursuing this matter further.

CC. The Department's guideline of a 2000-foot grid sampling pattern for overburden characterization haa been in effect aince about 1975. Based upon aome research findings since then, primarily those of Dollhopf et al. (1978, Reaearch Report #135) and Dollhopf et al. (1981) as referenced in Chapter VI of the DEIS and baaed upon experience gained in reviewing a large quantity of overburden information in the paat aeveral yeara, DSL is currently reviewing ita guidelinea regarding overburden aampling proce-durea. (Pleaae aee the "note" in paragraph 4 of page III-3 in the DEIS.) Hopefully, this review will result in a guideline that will effectively and efficiently provide the amount of information necesaary to make aound evaluationa of overburden quality. The frequency and pattern of overburden aampling that will "realiatically" accomplish this goal will be suggested when a draft reviaion to the current guidelines ia diatributed for comment.

What does WECo propose to do to avoid leaving cuts of coal when faults are encountered? (DEIS III-4) } DD

In general on hydrology. It seems that ERTECH spent so much time developing a groundwater model that major, significant impacts were lost in the shuffle. For example, when were the present and proposed fly ash ponds dropped from the groundwater study? } EE

DD. Western Energy would have a number of options available should they encounter suddenly deeper coal due to the inferred fault discussed in Chapter II. Western Energy could continue to use the dragline to recover the deeper coal. This might require further handling of spoils requiring that it be cast closer to the boxcut in order to gain spoil space. In this case it may be necessary to leave behind one or two cuts of coal. Trucks and shovels, as another option, could be used to move spoils out of the way to gain spoils space needed to recover the the deeper coal. However, the EIS does not conclude that major displacement is present in Block I and Western Energy does not foresee major faulting causing a problem with coal recovery in Block I. Faults inferred by the EIS in Area C, Block I have displacements of less than 30 feet which would not affect coal recovery.

EE. Ertec did not overlook significant impacts while the proces of refining the groundwater model. A discusion of the model and hydrologic impacts used by Ertec are discussed in the Final EIS, Chapter III, Hydrology.

In Appendix B to these comments we list numerous instances of major data deficiencies. In those areas where there is a noted lack of data, rendering analysis impossible, what does DSL and OSM propose to be done? Do the respective agencies concur that Sec 82-4-222(1)(l) is not presently being complied with? FF

The DEIS states that the only water bearing unit of significance that will be effected is the Rosebud coal seam. Will the removal of this seam increase the hydrologic significance of the Rosebud /McKay interburden ot other strata? GG

On page III-11 5. the terms lower aquifers and deeper aquifers are interchanged. Is this meant to be? HH

The DEIS states that replacement wells will be drilled into the sub-McKay aquifer. What is the water quality of the sub-MaKay aquifer? We would like to point out that it was difficult to reference well data to map correlations. Would it be possible to clarify this situation? II

The DEIS states that the TDS concentrations predicted for the spoils aquifer should be suitable for livestock watering in emergencies. Isn't this in violation of the States duty to protect the hydrologic balance of a water system? JJ

The DEIS discusses the dilution of TDS in spoils over time. What sort of time frame is being discussed? Was the February 1982 VAn Voast Open File report on spoils quality included in this analysis? If more data was available, would it be possible to better predict the dilution effect on spoils water quality? KK

The DEIS states that flood irrigation downstream from the town of Colstrip would be little effected by Area C, Block I mining. Would the effect from mining Block II be similar? More importantly, did the model used predict the effect on flood irrigation from all the cumulative(life of mine) impacts and all Colstrip related industrial facilities? LL

The DEIS concludes that "the cumulative surface water impacts from mining are insignificant" This statement seems to ignore the relationship between surface and groundwater systems. We take particular exception to the statement that "any cumulative impact on stream quality would be insignificant.....Groundwater inflow to the streams from the valley fill during low flow conditions would be the same and slightly more concentrated that at the present.....and not distinquishable from the present variation in stream quality". (DEIS III-25). Does this statement apply to stream quality before mining and industrial development began? Also, why does this conclusion differ form those of the DEIS and FEIS on Area E, not only in area E, but from proposed mining in areas B & D? Finally, does this statement reflect the effets of all the mining and industrial related facilities on Cow Creek Armells Creek and other drainages in the area? MM

Exhibit 3

FF. Please refer to response to comment MMM. No, OSM and DSL do not concur that Section 82-4-222 (1) (L) MCA is not presently being complied with.

GG. The significance of deeper aquifers as water producing units will increase. It has determined that the lower aquifers can support the increased stress. Increased costs are discussed in Chapter III.a. of the FEIS.

HH. Lower and deeper are used synonomously.

II. The water quality of the Sub-McKay aquifer is of suitable quality for domestic use. We are sorry it is difficult to locate well locations on the map but the map scale make this problem difficult to rectify.

JJ. This statement was incorrect in the draft EIS and has been changed in the final. While groundwater of the East Fork Armells Creek and Stocker Creek would have a higher TDS concentration after mining it would still be suitable for liveatock purposes as indicatd by water quality criteria for livestock.

KK. Any attempt at predicting a return to premining water quality would be extremely speculative. The Van Voast report was reviewed prior to preparing the Final EIS. The Final EIS discuases the length of time for return to premining water quality conditions (Chapter III, Hydrology).

LL. Only known quantifiable impacts were evaluated. These include, the surge pond, fly ash ponds, power plant ponds, aewage effluent, and changes in discharge due to mining. Existing water levels were used in the model which reflect effects of irrigation.

MM. The statement is made based on several items; the analysis of surface water quality data from East Fork Armells Creek above Colstrip although there have been very few flow events in the upstream portion of the creek to sample. The relationship between groundwater discharge and streamflow was included in the analysis as well as a review of groundwaier quality in wells that are now between mined areas and surface drainages.

To some degree, this applies to premining conditions, however, there is little data to form a pre-mining base since mining has been going on in the area since the 1920's. This statement doea not differ from the Area E EIS for cumulative surface water impacts.

Refer to response in paragraph LL.

AIR

What restrictions, if any, does Colstrip's being a "non-attainment" are have on mining development at the Rosebud Mine? NN

The DEIS states that "the projects" TSP would not effect the Northern Cheyenne Indian Reservation (DEIS III-38) Does this apply just for Area C or for the likfe of mine and all related industrial facilities? OO

SOILS

Would the changes in the soil moisture regimes and run-off conditions lower the agricultural productivity of the area? PP

What kind of plant pathogens might "attack" stored reproductive plant parts? QQ

The DEIS state that "bulk densities are impossible to predict" Is this always the case? Can problems created by high bulk densities be mitigated at a later date? RR

CHEMICAL IMPACTS

The vague statement concerning the frequency or quantity of trace elements (DEIS III-47) illustrates the necessity for aquiring more data. Would more data collection enable more to be said about the location, frequency and quantity of trace elements that may be found in the overburden? SS

The proportion of loamy and clayey soils in Block I as compared to Block II is noted on III-50. However this comparison raises more questions that it answers. Why weren't more direct comparisons made between the impacts expected from Block II and Block I ? TT

WILDLIFE

The Block II mining plan would destroy the sandstone cliff eagle and prairie falcon nesting sites and two sharp-tailed grouse dancing grounds. Does the State propose to selectively deny these areas? Furthermore, would the mining in Block II constitute a "taking" as defined in 16 USC 668a ? UU

CULTURAL RESOURCES

Has a mitigation plan been submitted for those sites found to be eligible for the National Register? Can the State issue a permit until such a plan is submitted and approved? VV

ALTERNATIVES

The DEIS states that policy dictates that the department must either approve or deny an application.....within 240 days of receipt of a "complete application". Would the State please define what they interpret a complete application to be? Does the State have any guidlines or time limits to determine when an application must be complete, or could the process of sending deficiency letters continue indefinitely? WW

Exhibit 3

Russ Brown (Cont.)

NN. Due to the fact that the Area C operation is located partially within a non-attainment area, the application of Lowest Achievable Emission Rate (LAER) must be applied. LAER generally refers to the most stringent air pollution emission limitation achieved in practice by similar sources. The effect of this requirement is that the emission control limitations placed on the Area C operation are more stringent than would be the case if the operation were located in an attainment area. The Air Quality Bureau (AQB) has deemed the emission control technologies and practices to be utilized in Area C to constitute LAER. The specific control requirements are discussed in the Western Energy's Air Quality permit application and in AQB's air quality permit analysis.

OO. Just for Area C.

PP. Page III-50 of the DEIS discusses the expected effects of mining on water availability and on the agricultural (crop) potential of the proposed distribution of various textural classes of soils in the post-mining landscape. Other changes that could adversely affect post-mining soil moisture conditions, such as increased runoff and reduced infiltration, include loss of soil structure and soil apoil compaction due to equipment handling and traffic. These latter changes can be reversed or mitigated by sufficient vegetative development and subsequent organic matter accumulation in soils by ripping or scarification of soil/spoil materials, and by handling soil materials during relatively dry periods of the year when compaction can be expected to be minimal.

QQ. Several kinds of pathogens may attack stored reproductive parts, including certain species of bacteria and fungi.

RR. The actual statement in the DEIS is "the areas in which increased bulk denaities are likely to occur are impossible to predict due to...." (Please see paragraph 2 on page III-46.) Problems created by high bulk densities could be mitigated after topsoil placement and initial seeding. This could be done by a deep ripping implement or "subsoiler." Complete reseeding would probably be necessary following such a treatment.

SS. Additional data collection could give OSM and DSL more information concerning the trace elements in overburden. However, your question regarding trace elements is associated with the overall question of overburden sampling pattern and intensity which is discussed in response to comment CC.

TT. Significantly less information is available for the specific actions proposed for Block II, because it waa not included in the existing permit application for Area C.

UU. OSM and DSL do not propose to firmly resolve these Block II mining problems until such time as an application is received showing whether or not WECO proposes to mine the nesting sites and dancing grounds. A selective denial decision will be made by the State after a permit application is received. The statutory provisions you cite (16 USC 168a) applies to the taking of bald and golden eagles and their nests for scientific, cultural and religious purposes etc. and establishes a permit system for such uses. A 1978 amendment to this law allows the Secretary of Interior to permit the taking of golden eagle nests that interfere with resource development or recovery projects. A decision regarding WECO compliance with this law as amended may have to be made by the Secretary when the Block II application is reviewed.

Were any other studies other than the Pacific Northwest Utilities Conference Committee Report (PNUCC) of 1981 utilized in the DEIS alternative energy section? This forecast estimates a load growth of 3.2% annually. The credibility of PNUCC's projections are dubious at best since they have been steadily revised downward since 1977. In fact, the 1982 PNUCC forecast uses a projected growth rate of 2.1%. } XX

It is disappointing to see an EIS gloss over the basic assumptions that will justify the need for Area C and future mining at Colstrip and the vicinity, namely the energy demand forecast. Lower energy demand growth due to price-induced conservation has caused the deferment or cancelling of power plants such as WPPSS 1,4 & 5, Creston 1-4, Pebble Springs 1 & 2 and the deferment of Montana Power Co's own Resource 89. } YY

It is foolish to merely write conservation off. The Northwest Electrical Power Planning and Conservation Act mandates the use of all cost-effective conservation prior to any thermal development. In fact, the "Model Electric Power and Conservation Plan for the Pacific Northwest" developed by the Northwest Conservation Coalition concludes that no further power plants will be necessary until at least the year 2000. } ZZ

Will the final EIS reflect more realistic demand scenarios? This would necessitate the use of up to date forecasts and a broader spectrum of independent forecasts. We suggest that the analysis done by the Washington State legislature on regional energy needs and WPPSS 4 & 5 might be a good place to start. } AAA

The DEIS is unclear concerning the "pit realignment" proposal and the Block II mining plan. Are they different proposals? Are both dependent on Federal leases? } BBB

We would like to request that the following stipulations (at a minimum), be required prior to the issuance of a strip mine permit for Area C. } CCC

* That selective handling of the material with significant trace metal content be undertaken to insure that it will be kept below the top ten feet of spoils. Does DSL propose to stipulate this?

* Does the DSL propose to have WECo or ERTECH do more mapping of the faults to insure that maximum recovery of coal is achieved and to further the understanding of hydrology in the area? } DDD

This DEIS is supposed to include in its analyses all the activities that might have an effect on groundwater in the area. Isn't the statement on p. IV-10 6. a. then in error? If it was determined that the cumulative impacts of mining and industrial related activities would irreperably damage the hydrologic balance of a water system, could DSL limit or deny a permit based on the combined effects of mining and the industrial complex? We submit that they do have the authority. } EEE

VV. WECO's consultant is now preparing a mitigation plan for those sites in Block I determined to be eligible for the National Register of Historic Places. Approved mitigation plans not eligible have been mitigated already by virtue of their thorough recording. Permit approval is not contingent upon completion of mitigation. Stipulations will be added to the permit if necessary.

WW. With regard to the statutory provision of making a permit decision within 240 days of the receipt of a complete application, DSL defines a complete application to be one that has all of the necessary data and other information to determine whether or not the company's mining and reclamation plan complies with all the requirements of the Act and DSL's rules adopted pursuant to the Act. DSL interprets the act to require that an application completeness decision be made within 240 days of the receipt of an application or application revision. DSL's goal is to send a letter (regarding completeness) within 60 days of the receipt of an application or application revision. The process of sending deficiency letters potentially could go on indefinitely or the Department could deny the permit on the grounds that the application is incomplete, this requiring the company to reapply.

XX. Yea, one other used was the Bonneville Administrations Forecase of Electricity Consumption in the Pacific Northwest 1980-2000 (Division of Power Requirements, Draft 1982). The rest of your comment is noted.

YY. Your comment is noted. Regardless of the accuracy of any specific energy demand forecast, Montana Power Company and others have contracted to purchase the Area C coal.

ZZ. Your comment is noted. Area C coal is dedicated to generating Units 3 and 4.

AAA. Because Western Energy has a long term contract (35 years) with Montana Power for coal from Area C electricity demand in the Pacific Northwest would not affect ultilization of Block I coal. Additional analysis of demand scenarios would therefore not add substantively to the environment statement.

BBB. Mining of Block II would require that Western Energy realign its pits in Area C, Block I. Plans for realignment would be submitted as part of Western Energy's Block II mine plan application which is dependent upon the issuance of a new federal coal lease.

CCC. This is required by law and addressed in WECO's application. As such it would be redundant to make it a permit stipulation.

DDD. If the Department finds upon further investigation that faulting would interfere with Western Energy's dragline operations and the recovery of coal, it would require further mapping by Western Energy. Although the faults are inferred, Western Energy data does not indicate a situation of faulting (or folding) exists that would result n coal being left unmined within the Area C, Block I permit application area.

EEE. The authors find no error with the statement that Area C will affect the existing hydrologic environment. It if was determined that the cumulative impacts of mining at Colstrip would damage the hydrologic balance to the degree of impairing or irrepuably damaging beneficial use DSL could limit or deny a permit. Industrial activity at Colstrip was included in the long-term hydrologic baseline to which the impacts of coal mining were added.

* Does the DSL plan on requiring WECo to reclaim the aquifers that are destroyed by mining? Do they have the authority to make this kind of condition? } FFF

* Does the State propose to stipulate that chisel plowing techniques be employed? } GGG

* The DEIS states that several soil mitigation measures could be employed. Which of these will the DSL insist on? } HHH

* What techniques or stipulations will the State be requiring from WECo to offset piping and other possible settling problems? } III

CONCLUSION

The DEIS for the Area C, Block I mine permit application is inadequate as adecision making document or as a planning tool. } JJJ
The paucity of data on hydrology speaks for itself. We are also deeply concerned with the EIS's brief review of the effects of the "pit relignment" or the Block II mining plan. What will be the effects of Block II on Armells Creek? In the Block II proposal wouldn't WECo be mining right across the creek? } KKK

The whole discussion on the impacts of mining on water qaulity and quantity is rendered meaninjless by the lack of data and the omission of the effects of all the industrial facilities. Until this data gap is closed the mining permit submitted by WECo has not complied with Section 82-4-222(1)(l), and the State may not approve this application until the requirements of 82-4-223(3)(a) are met. This has not been done. } LLL

We thank you for the opportunity to comment.

Sincerely,

Russ Brown

Russ Brown
NPRC Staff

cc: OSM

encl/prb

FFF. DSL's Rule 26.4.642 (2) for the Strip Mine Act states that "Backfilled materials shall be placed to minimize adverse effects on groundwater flow and quality to minimize off-site effects, and to support the approved land use ..." DSL has determined that the mine plan submited by WECO is in compliance with this rule.

GGG. Western Energy has proposed to chisel plow the replaced soil as indicated in the 2nd full paragraph on page 1-14 of the DEIS.

HHH. The only soils related measure that DSL is considering requiring in addition to those proposed in WECO's mining and reclamation plan is:

"Western Energy Company shall submit a plan for reestablisiment of plant rooting zones which are compatible with the intended post-mining plant communities. The plan must take into account plant rooting composition and condition (26.4.711)."

III. The Department is not proposing any specific messures at this time to prevent possible piping or settling problems. WECO would be required in the normal course of operations to monitor, regrade, retopsoil, and/or reseed areas that are subject to these occurrences. Please see the response to Nick Golder's comments J and L for further discussion of this subject.

JJJ. Your comment is noted.

KKK. The effects of mining Block II on East Fork of Armells Creek has been addressed in the cumulative hydrologic impact section of the FEIS. A detailed analysis of Block II impacts on East Fork of Armells Creek will be made when Western Energy submits its Block II mine plan. Western Energy mine Block II would mine through East Fork Armella Creek.

LLL. Your comment is noted. Please see resonse to comment D.

NPRC AREA C Comment

APPENDIX B MMM

The following section is intended to highlight the sections of the hydrologic study about which no comments can be made or conclusions reached due to a lack of data. Western Energy and Hydrometrics have repeatedly stressed the number of hydrologic data points that are already on record. It is apparent that the location and quality of these data points are inadequate.

We would appreciate a response as to what is being proposed for each of the following areas to provide the information necessary to make a cumulative hydrologic analysis of the Rosebud Mine area.

* The DEIS notes that in some areas, the overburden includes clinker, which is usually brittle and highly fractured. According to Dollhoph (1978), fracturing in the clinker creates potential areas groundwater recharge or discharge. However, there have been no aquifer tests in the clinker at the Rosebud Mine to confirm this postulate. (DEIS II-16) } 1

* Available information indicates that the sub-McKay is a confined aquifer system, however very little hydraulic data exists for the sub-McKay. (DEIS II-18) } 2

* "VERY LITTLE HYDRAULIC DATA EXISTS FOR AREA C" (DEIS II-19) } 3

* The DEIS points out that "the McKay Coal and the Rosebud McKay interburden Area C hydraulic characteristics can not be compared to the hydrologic study area test results because only one aquifer test was performed in each aquifer. (II-19) } 4

* There seems to be some confusion whether the groundwater in the Rosebud spoils is confined or unconfined. "The groundwater in the spoils is generally unconfined; however, it should be noted that there is evidence to suggest that spoils water may be confined in some areas" (II-20). Would more data enable a more definitive statement to be made? } 5

* The DEIS notes that "there is not enough water level data for the Rosebud overburden to construct an accurate potentiometric map for the overburden.....The source of water in the overburden is probably due to direct infiltration from precipitaion, but may also be due to upward leakage from the Rosebud coal (II-22) } 6

* The DEIS also admits that "As with the Rosebud overburden, the nature of flow in the Rosebud/McKay interburden has not been well defined" (II-25) } 7

* The DEIS points our that "although a large percentage of wells are completed in the sub-McKay unit there is little specific data on the nature of the groundwater flow." (II-25) } 8

Exhibit 3

Russ Brown (Cont.)

MMM. Appendix B

1. As discussed previously, the clinker occupies areas of groundwater discharge in the Rosebud mine area. Because of this and the Department's experience with clinker in other mines, it was not thought necessary to require aquifer tests in clinker in the Rosebud Mine area. They would not significantly enhance the understanding of the hydrology of the area.

2. Available information indicates the sub-McKay is adequate for development as an alternative groundwater source once the Rosebud coal is mined. Since this is the only foreseeable use of the sub-McKay, and since Western Energy has committed to replacing any water supply destroyed by mining, it was felt that no additional data was necessary to characterize aquifer characteristics of the sub-McKay.

3. This phrase was deleted from the final EIS. The Department feels there is sufficient data available to characterize the hydrology of Area C.

4. Although there is insufficient data for a statistical analysis, the Department feels there is sufficient data available over the mine area. To characterize the McKay coal and Rosebud-McKay interburden. These characteristics are relatively uniform over the mine are and additional data collection was not deemed necessary for the permit decision.

5. Whether the groundwater in the Rosebud spoils is confined or unconfined depends on a number of factors: 1) the texture and lithology of the spoils, 2) the thickness of the spoils, 3) the proximity of the outcrop area, and 4) the location of the monitoring well with respect to rubble zones in the spoils. It was not considered necessary to have a detailed understanding of the confined versus unconfined nature of groundwater in the spoils when so many factors can affect that aquifer property.

6. Due to the extremely discontinuous nature of lithologic units within the overburden, a representative potentiometric surface map cannot be constructed. Because textures and lithologies display rapid lateral and vertical variation, it would be impossible to drill sufficient wells to characterize and delineate each individual unit. The recharge capacity of the reclaimed spoils will approximate the recharge capacity of pre-mining conditions.

7. The lithologic units comprising the interburden are highly discontinuous and generally fine-grained. Because of this, the construction of a representative potentiometric map is not possible (see answer to 6 above).

8. Most of the wells completed in the sub-McKay are domestic or stock wells for which water level and aquifer test data are difficult or impossible to obtain. Because of well construction and the fact that the wells are generally pumped frequently, accurate water level data are not available. The large number of wells completed in the sub-McKay is indictive of its viability as a groundwater resource.

* What do all the questionmarks on Figure II-19, p. II-DEIS refer to? } 9

* The following statement is indicative of why this permit cannot be granted until much more data is gathered and analyzed. "as an area of groundwater recharge, Area C ultimately contributes to flow in tributaries to Rosebud Creek. A paucity of hydraulic and hydrogeologic data specific to Area C, and Area C Block I precludes a more detailed comparison between groundwater flow in Area C and the study area as a whole. (DEIS II-33) } 10

MMM. Appendix B (Cont.)

9. We think you are referring to Figure II-9. The question marks are inferred locationa of the potentiometric aurface and fault planes in the McKay and Roaebud Coal aeams.

10. While it ia true that groundwater from Area C ultimately contributes to flow in tributariea to Roaebud Creek, available data indicates that thia component of flow ia inaignificant compared to that contributed from other recharge areas.

Exhibit 3

RECEIVED

JUL 8 1982

STATE LANDS

COMMENTS ON THE DEIS FOR WESTERN ENERGY'S ROSEBUD MINE, AREA C Letter No. 13

It is good to see the progress that has been made by Western Energy in the area of revegetation. I wish there was reason to feel encouraged about progress made in the area of hydrology.

It seems reasonable to assume that landowners down-gradient from a mine should be able to expect no significant change on their property regardless of what their upstream neighbors' business happens to be. If, due to mining, there is a change in water quantity, quality or placement outside of the mine's boundaries, then this becomes a case of tampering with property belonging to someone else. I assume the State does not intend to be supportive of violating property rights as a matter of course. Is that assumption correct? This draft EIS seems to indicate a lack of concern for what impacts mining might cause on the land downgradient from the mine. A

The DEIS points out that mining will deteriorate spoils water to about double the normal TDS concentrations (pg. III-11). Pg. III-15 says the high concentration spoils water will migrate further with time and the estimation is that it will migrate about one-third mile per year. I saw no estimate on whether it would take decades, centuries or eons to flush out the spoils leachate. I did not see any mention made of what effect the leachate would have on the down-gradient property, especially where the water comes near enough to the surface to deposit the dissolved solids when the water evaporates. What is the scenario you predict on this? B

I found no mention of provision to improve the quality of the polluted water recieved by down-gradient neighbors, nor is there mention of compensation to them for detrimental changes on their property. What is the State's thinking on this? C

The section on cumulative impacts on pg. III-25 only touched on one corner of cumulative impacts of good and bad water due to mining. Nearly all of the water storage ponds at Colstrip are there because of the mining. Without mining those ponds would not be there. Therefore it seems to me to be an exercise in semantics, rather than objective assessment, to say "surface water hydrology impacts from mining are insignificant." Leaking and draining storage ponds have to be a very significant part of the water quality and quantity problems that are now apparent. To omit such major sources of surface and underground water in the Colstrip area's environment certainly does not lend an aura of credibility to an environmental impact statement. D

There also has been a tendency to address water quantity separately from water quality. I recommend you employ some "general practitioners" that are equipped to take an overview of the whole issue. The too-narrow scope of the "specialists" allows insufficient perspective to arrive at a cumulatively total picture. DSL personnel have said there has to be a cumulative hydrologic assesment done of the whole mining complex before another permit is issued. The word "cumulative" speaks to me of adding together the total, not discussing isolated parts of the total. E

I saw no mention in this DEIS of the existing and proposed fly ash (or sludge) ponds, although in years ahead they are very likely to emerge as the most dangerous part of a hydrologic time bomb. Unless there has been a recent change, there are not nearly enough monitoring wells to keep track of the underground movement of the toxic water that has to be radiating out through the porous soils at the existing fly ash pond. Perhaps the estimation of one-third mile per year (pg III-15) might be plugged into this case also. However, it seems reasonable to assume that the velocity would vary considerably depending on slope, type of soil, existing water channels, etc. What are your plans to correct problems with this toxic water before it spreads further? F

The proposed fly ash pond on the Cow Cr. drainage has the probability of causing more long term damage than the existing fly ash pond can be expected to cause. The aquifer water that makes Cow Cr. a subirrigated creek could be expected to carry the toxic seepage away from the pond area and on downstream quite rapidly. Additionally, the MPC plan wherein vegetation would be left in place in the bottom of the pond would, according to my experience, increase infiltration of that toxic water into the soil. What is your assessment of this plan?

Condition 12d of the DNRC Board order of July, 1976 says that sludge ponds shall G

Exhibit 3

Nick Golder

A. The Montana Strip and Underground Reclamation Act contains numerous safeguards designed to protect downstream property owners from the effects of surface coal mining. The Department of State Lands must enforce such safeguards or is subject to a suit of mandamus. The state does not intend to violate property rights.

B. A discussion of how long it takes for spoils water quality to return to premining conditions has been added to the FEIS (Chapter III, Hydrology).

C. Project water quality changes downstream for Colstrip are not anticipated to be detrimental to the present or future users.

D. All cumulative hydrologic impacts of mining in the Colstrip area are addressed in the FEIS. The most severe water quality roblem at Colstrip is that cussed by the surge pond. Water quality deterioration from power plant pond seepage is also addressed in the FEIS.

It was not the author's intent to play with semantics relative to "mining" and "non-mining" affects. The FEIS assesses the hydrologic influences of the actual mining rocess as well as the effects of other activities which are related to mining such as the fly ash and surge ponds, etc.

E. Chapter III, Hydrology 1. Groundwater of the FEIS describes the groundwater model used to characterize the hydrologic system. Included is a description of the modeling concepts and inputs used by the researchers.

F. OSM and DSL appreciate your concern relative to both the existing and proposed fly ash ponds. These issues have been dealth with in the final EIS within the impacts secion, Chapter III, Hydrology. In brief, the data indicassaate that the existing fly ash pond is leaking only a very small amount but if it were leaking large quantities of fluid, the water would move downgradient into the surge pond where dilution would mask the contamination. With respect to the proposed fly ash pond, Montana Power Company proposes some specific mitigation measures to prevent fly ash pond contamination from entering the Cow Creek alluvial system. The FEIS addresses what the impacts on Cow Creek water quality and land use would be if maximum leakage from the proposed fly ash pond occurred.

G. To reiterate, the Montana Power Company is proposing mitigating measures with respect to the proposed fly ash pond. It is true the vegetation left in place within the pond prior to filling would result in a higher initial seepage becaus the plant roots could provide vertical conduits for flow. It is also true that the nature of fly ash ponds is to seal themselves over time. This is the probable reason that no contamination or evidence of leakage exists downsgradient from the existing fly ash ponds.

be completely sealed, including a plastic membrane if necessary. There has been a lot of semantic gymnastics about this particular issue, but the long-term effects of this are far too serious to play games with now. Does DSL have plans of how to handle this toxic seepage as per DNRC's condition? H

The horse appears to already be out of the barn on the existing fly ash pond. That toxic material has been radiating out for some time. It is imperative that properly located monitoring wells be drilled at various down-gradient locations and that mitigating measures be taken as soon as possible to keep the toxic material corralled as much as possible. I

In the last sentence on pg. III-18 I notice the word "reclamation" is used where it seems "revegetation" would more accurately describe the situation. In the previous paragraph is brief mention of subsidence or differential erosion at the highwall interface. I expect it would be very fortunate if it only occurs there, but I do expect it to be worse along the pit walls. This is an important factor to be considered in reclamation, but is seperate from revegetation itself. J

On pg. III-19 it says that with time the spoils will settle to a density similar to the pre-mining density. This seems quite reasonable. It is as used there will be a 22% swell factor in the spoils. Does this mean it will settle 22 feet per 100 feet of backfilled pit by the time settling is completed? Do you expect differential settling as is so common with fill dirt in non-mine situations? If not, why not? Do you expect spoils to settle to pre-mining density within ten years? K

What mitigating measures do you have in mind where you anticipate possible subsidence, differential erosion or piping? Do you anticipate any possibility of areas becoming too unstable to be safe to drive machinery over? L

It seems to me that true reclamation should be a composite of three things: stable, self-sustaining vegetation; stable, unpolluted aquifer water passing across the minesite and continuing on as it has done for centuries with the surface water handled similarly; and the soil stabilized so that subsidence and piping are not problems, and erosion is no greater than in centuries past. If there is a decision to accept less than this, then that decision should be common knowledge so that the American people have a better idea of the true costs of stripmining. M

Nick Golder

Nick Golder
Forsyth, MT

Exhibit 3

H. Regulatory responsibility for proper design and construction of the fly ash pond lies with the Montana Department of Natural Resources and Conservation. We concur that the fly ash pond needs to be properly constructed and that the potential for adverse impacts resulting from leakage could be very real if proper construction and mitigation measures are not invoked.

I. A very small amount of seepage and contamination of groundwater is occurring from the existing fly ash pond. This contamination is not affecting and will not affect any groundwater users. The level and type of contamination occurring is not classified as toxic. There are existing monitoring wells down gradient of the fly ash pond. The wells indicate only a minor amount of seepage.

J. Your comment is noted. We agree that subsidence would occur along the spoils/bedrock interfaces of the end (pit) walls however we do not feel the problem would be any greater than along the highwall. Western Energy would be required to correct any subsidence problems that arise during the bonding period. Because there are presently no predictive methods available to evaluate potential for subsidence it is not possible to determine the amount of subsidence to be expected in an area of spoils replacement.

K. The 22 percent swell factor is a volumetric measure not a linear measure. The actual linear settlement is not predictable. Refer to the Geologic Hazards Section, Chapter III of the FEIS, for discussion of the settlement issue. Density reestablishment cannot be predicted.

L. Mitigation measures to treat subsidence problems would be applied at the time problems occur. In some cases, areas where unusual subsidence is anticipated, special compaction techniques could be used to reduce the changes of subsidence. Once subsidence occurs the effected area would be regraded, topsoiled and reseeded. In some cases, topsoiling and revegetation might be delayed temporarily to allow for complete settling before topsoil is spread.

M. Your comments are noted. The criteria you list are all standards by which the Montana Department of State Lands and OSM will use to determine whether or not coal mine reclamation is successful.

Letter No. 14

DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES
ENVIRONMENTAL SCIENCES DIVISION

TED SCHWINDEN GOVERNOR — COGSWELL BUILDING

STATE OF MONTANA

(406) 449-3948 — HELENA, MONTANA 59620

July 6, 1982

Kit Walther
EIS Team Leader
Department of State Lands

JUL 10 1982

Dear Kit:

After reviewing the draft environmental impact statement (EIS) for Western Energy Company's Area C Colstrip Mine for possible air, water and solid waste disposal impacts, the Solid Waste Management Bureau (SWMB) had the following comments:

The draft EIS indicates all wastes will be collected and disposed of in the Rosebud County landfill at Colstrip. The draft doesn't say what kinds of wastes these will be. The current license conditions prohibit semi-liquids, liquids and hazardous wastes. The present general contractor maintains an unlicensed disposal site somewhere in the Colstrip area by claiming the exclusion in Section 75-10-214 MCA. SWMB has no information as to what types of wastes are disposed of at that site.

In summary, the proposal for solid waste disposal presented in the draft EIS appears adequate, but the SWMB needs the following information to fully evaluate this adequacy:

1. Specifically what types of wastes will be generated and disposed of in the Rosebud County site. } A

2. Detailed location of the Bechtel disposal site and specific description of the materials to be disposed. } B

Thank you for the opportunity to comment on the impact statement.

Sincerely,

Thomas M. Ellerhoff
Technical Writer

jg

Exhibit 3

A. Wastes associated with mining are disposed of in accordance with sections 26.4.505 and 26.4.507 of the Montana Department of State Lands rules adopted pursuant to the Montana Strip and Underground Mine Reclamation Act and the Western Energy Company Area C, Block I application indicates that they will comply with these rules. Mineral seams are required to be buried under a minimum of 4 feet of the best available non-toxic, non-combustible materials. Also acid forming, toxic-forming, combustible or any other waste material identified by DSL, that are exposed, used, or produced during mining must be covered with a minimum of 8 feet of the best available non-toxic, non-combustible material.

Non-coal wastes include, but are not limited to, grease, lubricants, paints, flammable liquids, garbage, abandoned machinery, lumber, and other combustibles generated during mining activities. These materials are required to be placed and stored in a controlled manner in a designated portion of the permit area. Placement is required to be done in such a manner as to ensure that: 1. leachate and surface runoff do not degrade surface and groundwater, 2. fires are prevented, and 3. the area remains stable and suitable for reclamation. Western Energy has indicated that liquid, semi-liquid and hazardous wastes will not be disposed of in the Rosebud County landfill and that most, if not all, of the liquid and semi-liquid waste are reprocessed (personal communication with Chris Cull, Western Energy Co. on 7/23/82). The Western Energy Company's Rosebud Mine Complex does not generate hazardous wastes.

B. Because the DSL does not permit Bechtel for the construction of Generating Units 3 and 4, information regarding Bechtel's disposal sites was submitted to DSL as a part of Western Energy's permit application. Bechtel claims exclusion from permitting of this site on the grounds that they are disposing of their own wastes on their own property. The Montana Department of Natural Resources and Conservation has indicated that under the Unit 3 and 4/Conditions of Certificate issued to MPC no restrictions have been made on Bechtel or MPC for waste disposal.

Letter No. 15

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
1860 LINCOLN STREET
DENVER, COLORADO 80295-0699

JUL 13 1982

Ref: 8MO

JUL 21 1982

Mr. Kit Walther
EIS Team Leader
Montana Department of State Lands
1539 11th Avenue
Helena, Montana 59620

Dear Mr. Walther:

We have completed our review of the draft environmental impact statement for Western Energy Company's proposed Area C coal mine near Colstrip, Montana. The EIS appears to be complete and well written.

We suggest that the EIS more clearly state that modeling indicates that the mine neither causes nor contributes to a violation of Montana nor National Air Quality Standards. The mine is located in a "clean" part of the non-attainment area. A

The mine appears to meet applicable state and federal water and reclamation standards. This would depend, of course, on the issuance of necessary permits by the various state and federal agencies.

As stated in the EIS, the larger and regional impacts in the long-term Western Energy mining plan will be covered under a separate EIS process.

According to EPA's rating system for draft impact statements, this EIS is rated LO-1 (lack of objections - sufficient information).

If you have any questions, please contact Mr. Gene Taylor in our Montana Office, Helena, at 449-5486.

Sincerely yours,

Steven J. Durham
Regional Administrator

Steven J. Durham

A. A square area 18 kilometers by 18 kilometers, centered on Colstrip, has been designated "nonattainment" for TSP. The Area C mining operations are bisected by the boundary of this area. However, all the high measured concentrations within this NA area are located in a much smaller area, far away from the proposed mining operations. As the EIS states, the impact of the project on the area of high measured concentrations (town of Colstrip) is negligible. However, it is incorrect to state that the impact of the project on the nonattainment area is negligible. From a regulatory standpoint, all portions of the nonattainment area are accorded equal protection from further degradation. The comprehensive EIS will expand upon the current and future TSP levels in and around Colstrip. The Area C project is exempt from nonattainment review, therefore no action to redesignate the Area C mining area to an attainment status will be made -- but it is precisely such an action which would be necessary to treat the "clean areas" of the nonattainment area any different from the areas truly violating the NAAQS.

Exhibit 3

Letter No. 16

MONTANA POWER COMPANY
GENERAL OFFICES 40 EAST BROADWAY BUTTE MONTANA 59701 • TELEPHONE 406/723 5421

July 2, 1982

JUL 06 1982

Mr. Kit Walther
EIS Team Leader
Montana Department of State Lands
1539 11th Avenue
Helena, MT 59620

RE: Comments on Draft Environmental Impact Statement -
Western Energy Company's Rosebud Mine, Area C, Block 1

Dear Mr. Walther:

On behalf of the Colstrip Project, Montana Power Company has the following comments on the Draft EIS for Area C, Block 1, Rosebud Mine:

1. Pages II-30 and II-33 of the Draft refer to "leakage" from the Colstrip Project surge pond. The term used suggests an unexpected or accidental movement of water, but in fact, seepage up to about 112 gpm was fully anticipated and specifically authorized by the State Board that permitted the facility. Recent indications suggest the actual seepage from the surge pond is less than this amount. } A

2. Figure II-12 depicts a cross-section across the surge pond but omits the subsurface concrete cut-off wall in place in each abutment. This wall is a major seepage reducing measure. } B

3. As depicted by Figures II-11 and II-12, the surge pond is located over valley fill material. In fact, the surge pond is generally underlaid by bedrock. Only a small strip of valley fill material or alluvium underlays the pond. } C

4. The section on noise (page II-69) should include the noise mitigation efforts of the Colstrip Project. Stack noise silencing or muffling equipment has been installed on Colstrip Unit #2 and is planned for installation on Unit #1. Silencer equipment has been purchased for Colstrip Units #3 and #4. When all four } D

D. T. Berube

A. The influence of the surge pond is discussed in the EIS. The terms leakage and seepage were considered to be synonomous.

B. Your comment is correct. The graphic was intended as a rough schematic.

C. Your comment is correct (see above).

D. Your comment is noted. The authors, who obtained information on stack noise silencing equipment from the Becthel Corporation, were notified in writing by the Western Energy Company that the Montana Power Company considered such data confidential. Thus all references to this data were deleted from the EIS.

Exhibit 3

units are operating at full load, Montana Power Company expects that the noise level at the property boundary will not exceed about 50 dBA.

Sincerely,

D. T. Berube

D. T. Berube
Colstrip Project Manager

EFB/by/22-23

Exhibit 3

J.R. Lee
Box 2
Forsyth, Mt 59327
Ph (406) 356-7574
July 5, 1982

Letter No. 17

JUL 07 1982

Mr. Joe Walther
Team Leader
Montana Dept of State Lands
1539 11th Avenue
Helena, Mt 59620

Dear Mr Walther,

In reading the draft EIS for Western Energy Company's proposed Area C coal mine near Colstrip, Mt. I would like to comment on the damage to the lower lying sub-irrigated areas along the East Fork Armells Creek on my ranch 6 to 10 miles downstream from Colstrip.

It appears that the EIS was careful not to include these areas in its study other than a casual statement or two concerning possible problems downstream. } A

My ranch has probably suffered more damage than all the studied areas put together, because all the waste water, seep water, mine water, and sewage disposal water eventually piles down on the ranch which has the low lying hay meadows and a creek channel not deep enough to carry this water without raising it so close to the surface that the meadows are swamping up and are now heavily alkalied.

This summer once again my higher-lying meadows and benches have a decent hay crop, and the lower lying meadows produce just weeds and foxtail due to damage from the Colstrip Complex's water.

Your corrected Table III-3 of June 7, 1982 shows an anticipated 45% increase in the East Fork Armells Creek from 1983 to 1987. I absolutely do not know what to do with the presently expanded water much less a 45% increase by 1987. } B

I ask you not to gloss over my damage but to study these areas downstream where heavy damages are found and are certain to be increased by the added water from Area C. } C

Thank you

Sincerely,

J.R. Lee

Exhibit 3

J.R. Lee

A. Thank you for your comment. Please see the cumulative hydrologic impact section, Chapter III, Hydrology in the Final EIS for coverage of the referenced areas.

B. The 47% increase in flow in East Fork Armells Creek was incorrect because of a technical error in data input to the model. Because of the data input error, groundwater was allowed to discharge to the creek that was actually flowing in the aquifers below the creek. Within the model, nodes (data points) located along East Fork Armells Creek were allowed to discharge groundwater to the stream or the valley fill system if the bedrock aquifer water level was above the stream bed. It happened that a portion of three of these nodes were also mining and spoiling locations. After the node was spoiled it was not reset as a creek discharge node. The effect of this was to cause the node to have a constant water level assigned to it without stream discharge. The flow through the node below the creek bottom was therefore inadvertently added into the stream flow component. In reality the number was bedrock flow and not stream flow.

Because of this error, each of the 9800 nodes was individually checked to make sure that the same type of error was not occurring elsewhere. Additional quality assurance checks involving location, extent and elevation of mining nodes were also performed so that the Department of State Lands and its contractor could be certain of the model being free from data input errors.

C. See response to comment A above.

Letter No. 18

United States Department of the Interior

BUREAU OF RECLAMATION
Upper Missouri Region
P.O Box 2553
Billings, Montana 59103

JUN 16 1982

IN REPLY
REFER TO UM-150
125.-

JUN 14 1982

Mr. Kit Walther
EIS Team Leader
Montana Department of State Lands
1539 11th Avenue
Helena, MT 59620

Dear Mr. Walther:

Western Energy's mining proposal for Rosebud Mine Area C, Block 1

(DES 82-31) should have no effect on projects of the Bureau of Reclamation.

Effects on hydrology appear to have been adequately addressed.

Sincerely yours,

Joseph B. Marcotte, Jr.
Regional Director

Joseph B. Marcotte, Jr.

Thank you for your comment.

Exhibit 3

AREA C PUBLIC HEARING COMMENTS

June 14, 1982

Nick Golder:

I'm Nick Golder and I'm here representing Rosebud Protective Association. I really don't have a whole lot to say. I got my copy of that thing last Thursday or Friday and so far I've read about six pages in it and with the exception of two of our members why we just simply haven't had a chance to look at it so I guess we'll have to basically put in written testimony. I would like to say that what I hear of it why, what little I've read into it, I'd like to comment that we were told that before any further permits were issued there would be a cumulative hydrologic impact assessment done on the whole mine area here and I have the impression that it has not been done. We're concerned about the off-site hydrologic impact, off the mining area and we're very concerned about what leaks out of the Fly Ash Pond and into the subsurface and on down Armells Creek and I understand that hasn't been addressed at all in here. I think that's a pretty serious oversight. I assume you people will take care of that. I don't have anymore to say about that right now.

Nick Golder

Thank you for your comments. Please refer to the section on Cumulative Hydrologic Impact, Chapter III for discussion of off-site hydrologic impacts of Western Energy's Rosebud Mine.

Exhibit 3

Patty Kluver:

The hydrology section of this draft EIS we are addressing tonight reports there is a paucity of data concerning Area C, Block I pertaining to the hydrology. One can only ask; why? There's been ample time since the permit for plan 3 and 4 was granted to obtain baseline data for Hay Coulee, Lee Coulee, Richard Coulee, and Miller Coulee. There is only one conclusion that can be drawn from this paucity. No one, not the Department of State Lands, the State Water Quality Bureau, or the ambitious mining company obtained any baseline data for the East Fork of Armells Creek or for Cow Creek until after the mining had commenced and the ground water was degraded beyond redemption. By not establishing a baseline criteria the mine companies and various agencies of state government can find themselves in the clear when the contaminating ground water makes way through the mineral and metal laden spoils to new outlets down the syncline in the Rosebud coal vein aquifer. While that water perculating from the mine is generally unfit for domestic, livestock, or irrigation use because there is no record of how it was there is no way for the victim of the degredation to prove that the degredation is or was caused by stripmining the Rosebud coal aquifer. One has to have the facts to prove in order to make the mining company pay for its destruction. The investigative enforcement agencies of our state government failed us in that regard. It appears they are ready to repeat the past performance. Of course I understand the situation. Were it not for the stripmining of coal, many of the personnel of those departments would be in the same positions as the miners in Butte. Indeed it is a difficult role those heads in staff of the various appointed agencies of Montana government must play. The short-term advantages are with the coal industry, while the long-term story is like that of the Anaconda Copper Company and the Berkley Pit. A

Recently I obtained an article that was titled the Next Energy Crisis, with a second lead, Water, Water Running Out. The article began with this paragraph of horror. The United States has entered a period of grave crisis with both quality and quantity of its water and though that crisis is duplicated elsehwere and not only as one might expect, among the highly industrialized region it is here that it is likely to be felt with particular intensity. Yet this cherished natural resource is admittedly destroyed by the mining of the very aquifers through which it flows at the Rosebud and Big Sky Mines. To replace the loss, the coal companies attempt to reestablish an assemblence of an aquifer by throwing in the empty coal pit, the very earth which coal has been a few eons filtering out. Minerals and heavy metals are reintroduced into the ground water to flow out somewhere, to contaminate the streams, wells, and springs down syncline; as in Cow Creek. This EIS refers to the area C as a recharge area. It speaks little of the fault except to say they hamper coal mining. It is those faults through which the Rosebud vein becomes an aquifer and it is more than just an aquifer, its also a perched water table. B C

Some years ago our ranch was visited by Roger Wright and the late Overt Rye. It was in response to my complaint that mining was damaging our artesian wells east of Colstrip. Mr. Rye employed a chief geologist at the time from Montana Power Company who said the mining couldn't be

Exhibit 3

Patty Kluver

A. Montana Department of State Lands and the Office of Surface Mining have found the present data base sufficient to make a hydrologic assessment of impacts of the Area C, Block I Mine and Rosebud Mine. Analysis of baseline data has shown that groundwater quality has not been degraded "beyond redemption" and that benefitical water uses have not been impaired because of mining at Colstrip.

B. Your comment is noted. Please refer to Chapter III, Hydrology for the assessment of the significance of the impacts.

C. It is true that evidence indicates Area C is a local recharge area. Existing data and results of groundwater modeling indicates that groundwater flow is continuous across the fault zone and that the Rosebud aquifer is continuously saturated both upgradient and downgradient of the fault zone. Please refer to Figure II-9 in the EIS. There is no evidence that water in the Rosebud is a perched aquifer.

damaging. We must be 200 feet lower than the coal seam. At that time I hand't to become a student of geology and I did try to argue with Mr. Wright. If this incident were to have to have occurred today, I would respond to Mr. Wright, what do you think the water in the coal vein does? Stop at the end of the seam? There is little use in recounting the destruction of north Cow Creek at the hands of Western Energy Company. Because of them and because of the Montana Power Company pitchs for putting their solid waste disposal and other assorted disposals down syncline from their town we have the dubious distinction of having partial ownership of the first Love Canal in southeastern Montana. The reason I mention Cow Creek is because just as surely as coal burns into ash, the people along the Rosebud drainage around the bend, southwest of Cow Creek will know the decline in water supplies, the degredation of the water available that we already have. D

The DSL is obliged by law to recheck this volume and its contents because of Section 82-4-227. It reads the Department may not approve an application for a strip or underground coal mining permit or major revision unless the application affirmatively demonstrates that, part B, the proposed strip and underground coal mine operation would not interrupt, discontinue, or preclude farming on alluvial valley floors that are irrigated or naturally sub-irrigated, materially damage quantity or quality or water in surface water or underground water that supply these water floors in subsection 3 (b)ii.

In addition, on October 2, 1981, the Montana DSL sent a letter to Art Neill of Western Energy Company stating no further permits will be granted until a cumulative hydrology assessment is done. It has not been done. It has not even addressed the proposed fly ash pond on Cow Creek, estimated to leak over 54 million gallons a year into that luckless tributary to the Rosebud. May I point out the regulation 824-227-3a. Read them again and again when you consider this application. E

We have here a map which we obtained at grave financial costs. It is one like the Department of State Lands received with their first application for exploration, August 6, 1978. For some unaccountable reason, the map has disappeared from the files in Helena. If you want one, you can get it from a mining company as we did. Not only does this map show the fault extending along the north side of Area C, Block I but what the EIS calls the vertical fault or a right angle fault extends down to the south. From the description refered to in the EIS this is the site of the new county road from Colstrip to Castle Rock. Not only do my neighbors and friends travel on that little used, to quote the EIS, road but so do mining executives from Westmoreland, state officials, going from one mine to the other, so does the school bus on which my grandchildren will probably ride. You walk through this section of unmined land between Area A and B, weakened by blasting and mining on either side, that really poses the character of this company you would oversee. Of course the company doesn't have children to be concerned with, it just has subsidiaries. F

Thank you.

Exhibit 3

Patty Kluver (Cont.)

D. Your comment is noted.

E. The EIS presents a cumulative hydrologic assessment of hydrologic impacts of the Rosebud Mine. Based on modeling of surface and groundwater systems cumulative impacts were assessed for the five year permit period, life of mine and 100 years beyond. The proposed fly ash pond and its effects on Cow Creek are presented in the final draft EIS, Chapter III, Hydrology.

F. Your comment is noted.

Exhibit 3

The printing and distribution costs were paid by Western Energy Company pursuant to Title 75, Chapter 1, Part 2 MCA.

APPENDIX I

Western Energy Company
Rosebud Mine

Cumulative Hydrologic Impact Assessment

Amendment AM4

Exhibit 2

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Acronyms used within this document.	
Acronym	**Definition**
AM4	Amendment 4 permit application
ARM	Administrative Rules of Montana
CHIA	Cumulative Hydrologic Impact Assessment
CIA	Cumulative Hydrologic Impact Area
DEQ	Department of Environmental Quality
DNRC	Department of Natural Resources and Conservation
EFAC	East Fork Armells Creek
EPA	U. S. Environmental Protection Agency
GWIC	Groundwater Information Center
HHS	Human Health Standard
LOM	Life of Mine
MBMG	Montana Bureau of Mines and Geology
MCA	Montana Code Annotated
MPDES	Montana Pollutant Discharge Elimination System
MSUMRA	Montana Strip and Underground Mine Reclamation Act
MWQA	Montana Water Quality Act
NRWQC	National Recommended Water Quality Criteria
NSDWR	National Secondary Drinking Water Regulations
OSMRE	Office of Surface Mining Reclamation and Enforcement
PHC	Probable Hydrologic Consequences determination document
PMT	Postmine Topography
SMCRA	Surface Mining Control and Reclamation Act
SMP	Surface Mine Permit
SWL	Static Water Level
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
USGS	United States Geological Survey
WFAC	West Fork Armells Creek

1.0 INTRODUCTION

The Montana Department of Environmental Quality (DEQ) is the regulatory authority for coal mining operations in the state of Montana. *See* §§ 82-4-203(15), 205, MCA. The state implements the Montana Strip and Underground Mine Reclamation Act (MSUMRA or the Act) which is set forth in §§ 82-4-201 through 254, Montana Code Annotated (MCA), and the administrative rules pursuant to the Act Administrative Rules of Montana (ARM) 17.24.301 through 17.24.1826. The Federal Office of Surface Mining Reclamation and Enforcement (OSMRE) implements the Surface Mining Reclamation and Control Act of 1977 (SMCRA), and has granted primacy to DEQ as the regulatory agency for coal mining in Montana. As such, DEQ is responsible for the review and decisions on all permit applications to conduct surface coal mining operations within the state with oversight from OSMRE.

This assessment of cumulative hydrologic impacts (CHIA or this Assessment) is prepared by DEQ as part of the written findings for Amendment 4 (AM4), initially submitted to DEQ by Western Energy Company (SMP C1984003B) in June 2009. It includes an analysis of anticipated hydrologic impacts associated with proposed additional mining in Area B of the Rosebud Mine (**Figure 1-1**).

2.0 REGULATORY ENVIRONMENT

Under MSUMRA, DEQ must prepare this Assessment as part of the written findings the DEQ must issue when it approves a permit or an amended permit. *See* ARM 17.24.314(5); 17.24.405(1).

In pertinent part, MSUMRA conditions approval of an application for coal mine operating permit on demonstration by the applicant that "the assessment of the probable cumulative impact of all anticipated mining in the area on the hydrologic balance has been made by the department and the proposed operation of the mining operation has been designed to prevent material damage to the hydrologic balance outside the permit area." § 82-4-227(3)(a), MCA; *see also* ARM 17.24.405(6)(c).

This requirement was adopted to make MSUMRA's requirements equivalent to an identical requirement in the Surface Mining Control and Reclamation Act of 1977. *See* Chapter 550, Laws of 1979. Neither SMCRA nor the applicable federal rules provide a definition of "material damage" or "designed to prevent material damage." [1] However, MSUMRA was amended to define "material damage" in 2003. *See* 2003 Mont. Laws p. 651, 655 (Ch. 204, § 2)(adopting definition for "material damage"). MSUMRA defines "material damage" as follows:

> *"with respect to protection of the hydrologic balance, degradation or reduction by coal mining and reclamation operations of the quality or quantity of water outside of the permit area in a manner or to an extent that land uses or beneficial uses of water are adversely affected, water quality standards are violated, or water rights are impacted. Violation of a water quality standard, whether or not an existing water use is affected, is material damage."*

§ 82-4-203 (32), MCA. MSUMRA also provides a definition of "hydrologic balance":

> *"the relationship between the quality and quantity of water inflow to, water outflow from, and water storage in a hydrologic unit, such as a drainage basin, aquifer, soil zone, lake, or reservoir, and encompasses the dynamic relationships among precipitation, runoff, evaporation, and changes in ground water and surface water storage."*

§ 82-4-203 (24), MCA.

[1] On July 17, 2015, the Office of Surface Mining, Reclamation, and Enforcement proposed to adopt a definition of the term "material damage to the hydrologic balance outside the permit area." The proposed definition is:

> [A]ny adverse impact from surface coal mining and reclamation operations or from underground mining activities, including any adverse impacts from subsidence that may occur as a result of underground mining activities, on the quality or quantity of surface water or groundwater, or on the biological condition of a perennial or intermittent stream, that would—
>
> (a) Preclude any designated use under sections 101(a) or 303(c) of the Clean Water Act or any existing or reasonably foreseeable use of surface water or groundwater outside the permit area; or
>
> (b) Impact threatened or endangered species, or have an adverse effect on designated critical habitat, outside the permit area in violation of the Endangered Species Act of 1973, 16 U.S.C. 1531 et seq.

This rulemaking proceeding is pending as of the date of this Assessment. *See* Federal Register, Vol. 80, No. 143, July 27, 2015 (82 Fed. Reg. 44436 at 44473).

MSUMRA does not define "prevent" or "designed to prevent." Accordingly, "designed to prevent" should be understood according to its plain meaning within its statutory context. "Prevent" means "to stop (something) from happening or existing." (Merriam-Webster on-line dictionary: http://www.merriam-webster.com/dictionary/prevent). Therefore, "designed to prevent material damage" means designed to stop material damage from occurring.

An assessment of proposed "measures to be taken during and after mining activities to minimize disturbance to the hydrologic balance on and off the mine permit area, and prevent material damage to the hydrologic balance outside the permit area." ARM 17.24.314(1) must consider the context of the proposed action. This Assessment considers measures and cumulative impacts for the rather limited proposed expansion of Area B of the Rosebud Mine. Accordingly, CHIAs incorporated into the findings of other current Rosebud Mine permits, Area A, Area C, and Area D are not modified or amended by this Assessment for the Area B extension. Although this Assessment considers possible cumulative impacts of mining under the other Rosebud permits and the Big Sky Mine, as explained below, the expanded operations proposed for Area B do not intensify or augment potential impacts that assessed in the CHIAs prepared for the other Rosebud Mine permits.

2.1 MATERIAL DAMAGE CRITERIA

Following the general principles explained above, material damage criteria are established for the evaluation of both groundwater and surface water quality and quantity, and are used to determine whether water quality standards and beneficial uses of water, including water rights, outside the permit boundary have been or are expected to be impacted by mining activities.

Material damage criteria include applicable numeric and narrative water quality standards, and criteria established to protect existing beneficial uses of water. Baseline water quantity and quality is compared against changes or anticipated changes in quantity and quality associated with mine activity to determine if uses have been impacted or water quality standards exceeded outside the permit boundary.

The Montana Water Quality Act (MWQA), codified at §§ 75-5-101 through 75-5-410, MCA, is the primary basis for water quality protection in the state of Montana. Rules promulgated under the authority of MWQA establish surface water and groundwater standards (ARM 17.30, Subchapters 6, 7, and 10) to protect the designated beneficial uses of state waters. Numeric standards published in Circular DEQ-7, Montana Numeric Water Quality Standards (MDEQ, 2012), were developed using guidance from the Environmental Protection Agency (EPA) that includes:

- National Recommended Water Quality Criteria (NRWQC) developed under Section 304(a) of the Clean Water Act
- Drinking Water Lifetime Health Advisory (HA) and Maximum Contaminant Levels (MCL) developed under the Safe Drinking Water Act

Montana's surface water and groundwater rules also contain narrative standards (ARM 17.30.620 through 17.30.670, and 17.30.1001 through 17.30.1045, respectively). The narrative standards are designed to address water quality for which sufficient information does not yet exist to develop parameter-specific numeric standards. These narrative standards are established to protect beneficial uses from adverse effects, supplementing the existing numeric standards.

The interruption or diminution of a surface water or groundwater supply to the extent that an existing use is precluded is considered material damage. When material damage occurs mitigation is required; mitigation would include dependable, long-term replacement of a resource [ARM 17.24.314(1)(c) and 17.24.648] or treatment to return water to the quality needed for the designated use or to meet numeric state standards, if exceeded [ARM 17.24.631(4)].

2.1.1 Surface Water Material Damage Criteria

Material damage to surface water occurs when, because of mining, any of the following are met:

- Surface water quality standards outside of the permit area are violated
- Land uses or beneficial uses of water outside of the permit area are adversely affected to the extent that an existing use is precluded
- A surface water right is adversely impacted

Material damage criteria for surface waters[2] include the numeric water quality standards established in Circular DEQ-7 (where applicable) and water use criteria established for parameters where specific numeric standards have not been developed. Beneficial uses of surface waters are established according to stream water use classification. Specific water quality standards (along with general provisions) protect the established beneficial uses for each classification [ARM 17.30.620]. Surface water quality standards contained in ARM 17.30.620 through 17.30.670 vary according to stream classification. Surface waters in the Colstrip area are classified as C3 surface waters [ARM 17.30.611(1)(c)].

Beneficial uses of C3 waters are given in ARM 17.30.629:

> *"Waters classified C-3 are to be maintained suitable for bathing, swimming, and recreation, and growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl, and furbearers. The quality of these waters is naturally marginal for drinking, culinary, and food processing purposes, agriculture, and industrial water supply. Degradation which will impact established beneficial uses will not be allowed."*

As defined by 82-4-203(18), MCA, ARM 17.24.301(39), and ARM 17.30.602(10), an ephemeral stream ("ephemeral drainage way") flows only in direct response to precipitation in the immediate watershed or in response to the melting of a cover of snow and ice, and which has a channel bottom that is always above the local water table. As defined in 82-4-203(29), MCA, ARM 17.24.301(61), and ARM 17.30.602(61), an intermittent stream is a stream or reach of a stream that is below the local water table for at least some part of the water year, and obtains its flow from both surface runoff and ground water discharge. According to ARM 17.30.637(4), ephemeral streams are not subject to the specific water quality standards of ARM 17.30.620 through 17.30.629 (including Circular DEQ-7, Montana Numeric Water Quality Standards). Applicable water quality standards for ephemeral surface waters are therefore narrative standards and also include the General Treatment Standards (ARM 17.30.635), General Operation Standards (ARM 17.30.636), General Prohibitions (ARM 17.30.637), and other descriptive portions of the surface water quality standards.

[2] "Surface waters" means any waters on the earth's surface including, but not limited to, streams, lakes, ponds, and reservoirs; and irrigation and drainage systems discharging directly into a stream, lake, pond, reservoir, or other surface water. Water bodies used solely for treating, transporting, or impounding pollutants shall not be considered surface water. [ARM 17.30.602(31)]

All surface water in the greater Colstrip area, with the exception of ponds used for treating and impounding pollutants, are state waters as defined in 75-5-103(34), MCA. A subset of state waters are classified as high quality waters under 75-5-103(13), MCA. High-quality waters are state waters that support one or more of the designated uses for their classification and have flow or surface expression for more than 95 days during most years. Under the definition of high quality waters in 75-5-103(13), MCA, many wetlands and premine ponded features would be considered high quality waters. The requirement of high quality waters to have flow or surface expression for more than 95 days would result in a subset of state waters that would be similar to but not identical to the subset of state waters that would be defined as intermittent or perennial streams under 82-4-203, MCA and ARM 17.24.301. As a result, intermittent streams are state waters but not necessarily high quality waters. High quality waters are protected from nondegradation from point sources. Discussion of nondegradation policy and protection can be found in **Section 2.1.3**.

Standards for electrical conductivity (EC) and sodium adsorption ratio (SAR) set forth by ARM 17.30.670(4) apply to tributaries of Rosebud Creek.

Numeric surface water standards for perennial and intermittent streams are in **Table 2-1**. The parameter list includes only selected parameters known to be potentially associated with coal mining impacts monitored by Montana coal mines. These numeric water quality standards apply to perennial/intermittent streams but not to ephemeral streams.

The predominant beneficial use of surface water in the area is drinking water for livestock and wildlife. Water quality guidelines established for livestock use are based on limits for livestock consumption found in documents published by the Montana State University Extension Service (Sigler and Bauder, 2012; Hutcheson, 2001). **Table 2-2** lists the parameters of concern and guideline limits for livestock water quality. These limits are not enforceable standards but are used by DEQ for guidance in evaluating suitability of pre- and postmine water quality for livestock use. It is common for water quality in the area to naturally exceed these livestock water quality guidelines.

In addition to the livestock guidelines, a chronic aquatic life limit of 230 mg/L for chloride is also used in this document to assess the suitability of surface water to support aquatic life. The EPA lists a chloride chronic limit of 230 mg/L and an acute limit of 860 mg/L for freshwater sources, but DEQ does not have a numeric limit for chloride. Recent studies on a small subset of macroinvertebrate species has indicated that toxicity can be caused by sulfate and/or chloride (Elphick et al., 2011; Iowa DNR, 2009; Soucek et al., 2011). The toxicity of sulfate and chloride are interdependent, and are also dependent on hardness. **Table 2-3** lists a water quality guideline for sulfate to protect for aquatic life use. While these toxicity values were developed for macroinvertebrates commonly found the Midwest, some of the indicator species used can also be found in Eastern Montana streams. As with **Table 2-2**, **Table 2-3** is not an enforceable standard, and it serves only as guidance for evaluating the suitability of pre- and postmine water quality for aquatic life use.

Surface water runoff models are also used to assess water quantity impacts to downstream users and uses from the capture and/or attenuation of storm runoff. Runoff from areas disturbed by mining operations is required to be managed in a manner that prevents surface water pollution (e.g. prevents increased suspended solids, changes in pH, increases in metals of concern, etc.) outside the permit area to the extent possible with the best technology currently available (ARM 17.24.633).

Impacts to surface water supply and water rights are evaluated with respect to regional and local impacts to surface water resources and natural variations in seasonal and yearly runoff. Mitigation for the loss of a beneficial use of surface water or a water right requires provision of a dependable, long-term replacement water resource of acceptable quality for the designated use and adequate quantity to support the existing and/or planned future use [ARM 17.24.314(1)(c) and 17.24.648].

Material damage criteria are therefore a combination of applicable narrative standards, numeric standards, and livestock beneficial use criteria. Impacts to surface water rights are evaluated on a case-by-case basis, and include an analysis of climatic conditions and the natural availability of surface water.

2.1.2 Groundwater Material Damage Criteria

Groundwater material damage occurs when any of the following circumstances occur because of mining:

- Groundwater quality standards outside of the permit area are violated
- Beneficial uses of groundwater outside of the permit area are adversely affected to the extent that an existing use is precluded
- A groundwater right is adversely impacted

Protection of groundwater quality for beneficial uses is based on narrative standards set forth in ARM 17.30.1006 and numeric standards for individual parameters in Circular DEQ-7. Beneficial uses listed by ARM 17.30.1006 are in **Table 2-4**. DEQ-7 numeric groundwater standards are human health standards. Numeric standards for parameters monitored by the mines are listed in **Table 2-1**.

Groundwater in the Colstrip area exhibits a locally variable, natural specific conductance that spans Class I, Class II and Class III, with Class II and Class III most common. For all groundwater classes, concentrations of parameters for which human health standards for groundwater are not listed in DEQ-7, there is to be no increase of a parameter to a level that renders the waters unsuitable for existing or anticipated uses, or harmful, detrimental, or injurious to the beneficial uses listed for the class (ARM 17.30.1006).

Existing beneficial uses of groundwater outside the permit boundary include livestock and domestic use. Wells completed in alluvium and shallow aquifers typically only supply livestock water. Water quality guidelines established for livestock use are shown in **Table 2-2** (see discussion in **Section 6.3**). The limits are not enforceable standards but are used by DEQ for guidance in evaluating suitability of pre- and postmine water quality for livestock use. Locally, groundwater quality in the area naturally exceeds these livestock water quality guidelines.

As wells completed in the coal or other shallow units typically deliver inadequate amounts of water for sustained domestic use, domestic wells typically have completion depths in sandstone units in the underburden. The location of private wells and water rights are discussed in **Section 6.0**, Water Resource Uses.

Water levels and water quality are monitored inside and outside the permit boundary to establish baseline conditions and measure subsequent changes during and after mining. Analytical results of water quality parameters most likely to be affected by mining are compared to standards to determine suitability of the water for current and anticipated uses. Groundwater level decline outside the permit

boundary must not impact a use to the extent that groundwater supply for the use is no longer adequate. Baseline water levels or water quality that are marginally supportive of a given use are more vulnerable to changes that may cause material damage than water levels or water quality more supportive of an established use.

2.1.3 Nondegradation of Water Quality

Montana's nondegradation policy is codified at Title 75, Chapter 5, Part 3, MCA and implemented in the ARM Title 17, Chapter 30, Subchapter 7. As stated in ARM 17.30.703, this policy applies to any activity of man resulting in a new or increased source that may cause degradation of state waters. All state waters are subject to Tier 1 nondegradation policy which means that existing and anticipated uses and the water quality necessary to protect those uses must be maintained and protected. *See* ARM 17.30.705(2)(a). Authorization is required to degrade any high quality water per ARM 17.30.705(2)(b). An authorization to degrade follows a detailed process described in 75-5-301(5)(c), MCA and the supporting administrative rules. As stated in 75-5-303(3)(c), MCA, existing and anticipated uses must be protected even with an authorization to degrade.

The material damage determination in the context of permit review is a design review function (*see* 82-4-227(3)(a), MCA) that is not intended to serve as a groundwater discharge permit or an authorization to degrade. The process for authorization to degrade is not appropriate during MSUMRA permit review absent objective evidence of a discrete, quantifiable, potential point-source discharge to be evaluated. *See* ARM 17.30.707 and 708. At such time as of a discrete, quantifiable, potential point-source discharge outside the permit area is indicated, the process for an authorization to degrade may be warranted. Accordingly, except for potential discharges to tributaries of Rosebud Creek which would be subject to numerical standards for specific conductivity and sodium adsorption ratio under ARM 17.30.670(4), the parameters of concern for potential point-source discharges to surface and groundwater are subject to narrative standards for salinity which permit changes to water quality that do not have a measurable effect on an existing or anticipated use or cause measurable changes in aquatic life or ecological integrity. *See* ARM 17.30.715(1)(h).

Section 75-5-317, MCA, establishes categories and classes of activities that cause nonsignificant changes in water quality from the process for an authorization to degrade. These activities include, in pertinent part:

> *"(2)(a) existing activities that are nonpoint sources of pollution as of April 29, 1993;*
>
> *(2)(b) activities that are nonpoint sources of pollution initiated after April 29, 1993, when reasonable land, soil, and water conservation practices are applied and existing and anticipated beneficial uses will be fully protected;"*

The definition of point source is found in 75-5-103(29), MCA:

> *'"Point source" means a discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, or vessel or other floating craft, from which pollutants are or may be discharged.'*

Point sources for surface waters at Area B and other areas of the Rosebud Mine comply with the nondegradation rules through their MPDES permit. *See* ARM 17.30.629(2)(i). Protection from point source pollution is ensured by the MPDES discharge permit.

A source is a "nonpoint source" when "the source of pollutants which originates from diffuse runoff, seepage, drainage, or infiltration." ARM 17.30.602(18). New source discharges to groundwater from mineralized spoil recharge water are exempt from the nongradation policy under 75-5-317(2)(b), MCA, "when reasonable land, soil, and water conservation practices are applied and existing and anticipated beneficial uses will be fully protected." "Reasonable land, soil, and water conservation practices" in turn means

> *"[M]ethods, measures, or practices that protect present and reasonably anticipated beneficial uses. These practices include, but are not limited to, structural and nonstructural controls and operation and maintenance procedures. Appropriate practices may be applied before, during, or after pollution-producing activities. "*

ARM 17.30.602(23). Nonpoint source discharges by mineralized mine spoil water qualify for nonsignificance status because the mine operation applies "reasonable land, soil, and water conservation practices" that include measures to protect present and reasonably anticipated beneficial uses of groundwater such as backfill and regrading of spoil, contouring spoil backfill to approximate premine topography including drainage morphology and density, revegetation of disturbed soil, reestablishment and protection of riparian areas, drainage control, and impoundments which detain surface runoff or for sediment control and management of pit and runoff water. *See* ARM 17.30.602(23).

The protection of existing uses of state waters is honored by MSUMRA's protection of water rights and private wells from mining impacts [ARM 17.24.314(1)(b)]. MSUMRA and attending administrative rules also require implementation of reasonable land, soil and water conservation practices [e.g. ARM 17.24.314(1)(a); ARM 17.24.314(2)(a) and (b); ARM 17.24.701(1) and (3); and 82-4-231(1), MCA].

2.2 CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT

The Cumulative Hydrologic Impact Assessment (CHIA) includes an assessment of the Probable Hydrologic Consequences (PHC) of the proposed operation that is submitted by the operator with the application. The PHC determination is prepared by the applicant [ARM 17.24.314(3)] and approved by the regulatory authority (DEQ). Prior to making a permitting decision, DEQ makes an assessment of all hydrologic impacts of the proposed operation as well as existing, previous, or anticipated mining that may collectively impact surface and groundwater systems. The CHIA analysis must determine whether the proposed operation has been designed to minimize impacts to the hydrologic balance on and off the permit area and prevent material damage outside the permit area [ARM 17.24.314(5)].

CHIA development involves the analysis of critical aspects of the hydrologic system within a defined cumulative impact area to predict the type and magnitude of impacts to the hydrologic system from proposed and existing mining. The CHIA process includes the following: 1) define the area to the studied, 2) describe the hydrologic system, the baseline values, and subsequent changes, 3) identify hydrologic resources likely to be affected, 4) develop criteria for evaluating the impacts, 5) estimate the impacts of mining on hydrologic resources, and 6) make a material damage determination and prepare a statement of findings.

3.0 PROPOSED PERMITTING ACTION

The Rosebud Mine and Big Sky Mine are located adjacent to one another outside the town of Colstrip in Rosebud County, Montana, approximately 123 miles east of Billings, Montana and 36 miles south of Forsyth, Montana **(Figure 1-1**). Western Energy Company submitted permit amendment application AM4 that, if approved, would increase the mine permit area of Rosebud Mine Permit Area B (SMP C1984003B) by adding 49 acres to the current permit area of 6,182 acres, 146 acres of additional disturbance, and approximately 12.1 million tons of coal (**Figure 3-1**) . If approved, AM4 mining represents an 8.3% increase in the amount of Rosebud coal aquifer removed.

3.1 BACKGROUND & MINING HISTORY

Colstrip was established by the Northern Pacific Railway in 1924 as a company town to provide coal for the company's steam locomotives. Northern Pacific mined about 44 million tons of coal from the Rosebud coal seam (MDSL and OSMRE, 1983) and by 1958 had disturbed approximately 1,800 acres of land around what are now Area D and Area E of the Rosebud Mine, and Pit 6, a former permit area south of Area E. In 1958, the railroad switched to using diesel locomotives and the Colstrip mine was shut down. In 1959, Montana Power Company purchased the rights to the mine and the town. In 1966, Montana Power Company formed a wholly owned subsidiary, Western Energy Company, to manage and develop the Colstrip properties. Western Energy Company began mining in Pit 6 in 1968. Western Energy Company became a subsidiary of Westmoreland Mining, LLC, when Westmoreland purchased the Rosebud Coal Mine in 2001.

Mining permitted under MSUMRA was active in Rosebud Mine Area D from 1986 to 2013. Mining in Area E was permitted in 1976. Mining in Area E was completed by late 1986 and reclamation was completed by 1996. Mining in Pit 6, located south of Area E, was completed in the middle 1970's with much of the reclamation completed by the late 1970's. Final reclamation of Pit 6 (roads, facilities, ponds) was completed in 2004 and the permit area was released from bond in 2006.

Mining in Area A, Area B and Area C began prior to enactment of MSUMRA, but mining was permitted under MSUMRA when it was enacted in 1973. Mining and reclamation activities in Area A began in 1975. Mining was idled in Area A in 2000 but resumed in 2014. Mining at the northeast end of Area B began in 1976. By the early 1980's, mining in Area B moved southwest, taking advantage of shallow coal adjacent to East Fork Armells Creek (EFAC). By the middle 1990's, mining in Area B expanded to the west along EFAC. Mining in the east and west part of Area B has moved to the south, away from EFAC and remains active. Mining in Area C began in 1983 and was extended to the north and west under subsequent permit revisions. Mining in the north part of Area C was completed in 2010. Mining in the west part of Area C began in 2007 and remains active. Mining also remains active in the central part of Area C.

The Big Sky Mine lies immediately south of the Rosebud Mine. Due to its proximity to and shared hydrogeologic system with the Rosebud Mine, the Big Sky Mine is included in the cumulative impact area (CIA) and CHIA analysis. There are two permit areas in the Big Sky Mine, Area A and Area B. Peabody Coal Company began mining at Area A in 1969, prior to passage of laws that regulated coal mining. Area A mining and reclamation plans were permitted in 1973 under the Strip and Underground Mine Siting Act and later under MSUMRA with several permit revisions, expansions and consolidations until mining was completed in September 1989. Reclamation in Area A was largely completed by 1992. Pre-law mining areas in Area A were released from bond in 2014. Area B was permitted in 1988. Area B

Mining activities began in 1989 and were completed in December 2003. Reclamation was completed by 2007. Phase I and Phase II bond release have been completed in Area B and 731 acres have been released from Phase III.

3.2 CURRENT MINING OPERATIONS

Strip mining at the Rosebud Mine, and formerly at the Big Sky Mine, consists of topsoil salvage, overburden removal to expose the coal seam, and removal of the coal seam. Blasting is used to fracture overburden prior to removal by the dragline. Once exposed, the Rosebud coal seam is blasted to fragment it for removal by electric shovel or loader. Haul trucks deliver the coal to the conveyor terminal and the coal is transported via conveyor to the Colstrip power plant. Overburden from each successive cut is used to backfill the previous cut. Overburden backfill material is commonly referred to as spoil. The backfilled spoil is regraded to an approved postmine topography and the salvaged topsoil or other suitable material is spread on the surface. Seeding and planting of approved vegetation follows.

The Rosebud Mine currently has a total permit area of approximately 25,752 acres in five individual permit areas: Area A, Area B, Area C, Area D, and Area E. The mine areas include federal, state, and private surface ownership. Mineral ownership is divided between federal, state, and private entities. In 2014, active mining at the Rosebud Mine took place in Area A, Area B, and Area C. Coal removal in Area D was completed in early 2013; final pits are still being backfilled and the surface regraded to the approved topography. Annual coal production from the mine is approximately 12 million tons.

There are two mine areas at Big Sky Mine, Area A and Area B, totaling 7,191 permitted acres. Both areas have been backfilled, graded, contoured, and vegetated and are progressing toward qualification for Phase III and Phase IV bond release.

4.0 REGIONAL OVERVIEW

The permit and proposed amendment area is located in Colstrip, Montana, in the north part of the coal-rich Powder River Basin, which covers an area of approximately 7,765 square miles (Haacke and others, 2013) (**Figure 4-1**). The climate is semi-arid. Typical vegetation includes silver sagebrush-mixed grasslands, mixed grasslands, ponderosa pine-mixed grassland, and areas of improved pasture and wetlands.

Exposed rocks are sedimentary and of early Tertiary age. Differential erosion of rocks of varying hardness and resistance is the main process active in forming the present landscape. Interbedded claystones, siltstones, coals, and sandstones are often capped by resistant "clinker" mesas and ridges. The siltstones and claystones tend to be easily eroded, while the sandstone and clinker, a term used to describe the baked sedimentary rock formed during natural burning of coal beds, are more resistant to erosion. Sheet and rill erosion are active geomorphic processes in the upper drainage basins, and mass wasting occurs locally along the steep-walled ridges. Ephemeral streams occur throughout the area, with less common intermittent to perennial drainages.

4.1 CLIMATE

The climate of southeast Montana is classified as semi-arid continental. Precipitation and temperature measurements have been collected at the mine and also at the nearby climate stations at Colstrip and Billings, MT (National Weather Service Cooperative Observer ID 240807). Climate data are available from the Western Regional Climate Center (WRCC (b), 2014).

Storms often produce highly localized precipitation events in the Colstrip area. Graphs representing precipitation and temperature based on data collected between 1981 and 2010 are shown in **Figure 4-2.** The 30-year average annual precipitation at Colstrip is 14.45 inches. The average peak precipitation month is June with 2.67 inches; minimum precipitation occurs in January with only 0.37 inches. Highest average temperatures are in July and August at approximately 70^0F. December through February are the coldest months with average temperatures between 26^0F and 28^0F. The largest amount of precipitation in the last 30 years occurred in 2011 when the area received almost 24 inches of rain, a 65% increase over the 30-year average.

The closest pan evaporation station to Colstrip is at Yellowtail Dam, MT. Pan evaporation measured at Yellowtail Dam averaged 47.56 inches between 1948 and 2005, the most recent period of record available (WRCC, 2014 (a)). A pan coefficient of 0.7 to 0.8 is typically applied to the pan evaporation data to obtain an estimate for evaporation from a surface water body. Assuming a factor of 0.75 for the pan evaporation average at Yellowtail Dam, the approximate annual evaporation at the Rosebud Mine is 35.67 inches. Evaporation is greatest from April to September with peak evaporation in July.

4.2 TOPOGRAPHY

The Rosebud and Big Sky mines lie within the unglaciated Missouri Plateau, a division of the Northern Great Plains physiographic province. In the Colstrip area, the landforms have developed on the essentially flat-lying Tertiary sediments of the Fort Union Formation.

The topography is characterized by gently sloping valleys bounded by moderately steep to very steep ridges capped by isolated sandstone and clinker mesas. Surface elevations above mean sea level range from approximately 3,100 feet along East Fork Armells Creek (EFAC) north of Colstrip to over 4,000 feet to the south and southwest, near the headwaters of EFAC. Surface slopes vary from near zero to 30 percent in the vicinity of the divide between Big Sky Area A and Area B, and slopes become as steep as 45 percent or more in the higher elevations in the Little Wolf Mountains.

In the Colstrip area ephemeral to intermittent streams have incised the sedimentary sequence, exposing the gently dipping coal seams. EFAC is an ephemeral to intermittent stream that flows through the Rosebud Mine between Area B and Area C to the west, and Area A and Area B to the east. Rosebud Mine Area A, Area B, Area C, and the west part of Area D drain to EFAC. Rosebud Mine Area E, the east part of Area D, and the Big Sky Mine drain to Rosebud Creek. EFAC enters the Yellowstone River west of Forsyth, MT and Rosebud Creek enters the Yellowstone River at Rosebud, MT.

4.3 GEOLOGY

The coal producing region of southeastern Montana is located in the northernmost extent of the Powder River Basin (PRB). The PRB is an asymmetrical structural and topographic basin approximately 230 miles long and 100 miles wide, oriented southeast to northwest in northeast Wyoming and southeast Montana (**Figure 4-1**). The basin dips more steeply on the western side, where it is bounded by the Bighorn Mountains, and has a more gentle dip to the east where it is bounded by the Black Hills. Sedimentary rocks within the Basin have a maximum thickness of about 18,000 feet and represent rocks of Paleozoic through Cenozoic age. The basin interior is characterized by a gently dipping, wide expanse of lower Tertiary rocks, including the Paleocene Fort Union Formation and the Eocene Wasatch Formation (**Figure 4-3**). Most of the Wasatch Formation has been removed by erosion in the Colstrip area.

Quaternary alluvial and colluvial deposits in the Colstrip area are generally unconsolidated clay, silt and sand and typically occur in ephemeral drainages or areas of lower elevation in the stream and valley bottom areas. Alluvial deposits are generally less than 40 feet in thickness. Most coal production in the Powder River Basin is from the 2,300 foot to 6,000 foot thick Fort Union Formation. In the Colstrip area, coal production comes from mining coal seams in the Tongue River Member of the Fort Union Formation. Thin, discontinuous siltstone, claystone, and sandstone beds bound the coal seams. These sedimentary units typically are high in sulfate bearing minerals (e.g. gypsum and anhydrite), are moderately to highly alkaline, and are moderately high in soluble salts.

The depositional setting of the Fort Union Formation is characteristic of braided stream, floodplain and peat accumulating swamp environments (Flores et al., 1999). An oxidized, reddish and highly erosion resistant rock known as “clinker” commonly caps ridges and plateaus. Clinker formed when coal beds burned and baked the adjacent sediments into oxidized, vitreous and often brecciated rocks.

The package of Tongue River Member siltstones, claystones, and sandstones above the first mineable coal seam is termed overburden and ranges from a few feet to approximately 300 feet. The same lithologies separate the Rosebud coal and McKay coal and are referred to as interburden, which ranges from as little as three to 5 feet thick to 75 feet. The stratigraphic units below the McKay coal are referred to as underburden. Like the overburden and interburden, the underburden is composed of siltstones, claystones and sandstones.

The Rosebud Mine is located at the northern extent of the Rosebud and McKay coal beds (**Figure 4-4**). The Rosebud coal is 18 feet to 23 feet thick. At the Big Sky Mine, the Rosebud coal seam is reported to be 23 feet to 26 feet thick (BSCC, 1988). The McKay coal ranges between 7 feet and 10 feet thick. The Rosebud coal is mined at the Rosebud Mine and was the main target of mining at the Big Sky Mine. In limited areas of Big Sky Mine Area A, the McKay coal was also mined.

Structural imprint on the mine areas is subtle. The dip of the beds is one to two degrees to the southeast. The Ashland syncline, a west –northwest trending shallow structural trough cuts the southwest quarter of T1N, R40E in Area C of the Rosebud Mine. Several normal faults of small displacement (generally less than 100 feet) have been mapped or inferred from aerial photos in the mine areas. Fault orientation ranges from northeast to northwest.

The Big Sky Mine Area B permit application describes the local geology (BSCC, 1998). The coal seams have a generally flat structure with subtle domes and depressions with a symmetrical anticline, the axis of which parallels Lee Coulee. This structure is subtle, with the flanks and southeast plunge dipping less than one degree, and with smaller, local structures obscuring it at some localities. A few low-displacement, high-angle faults are mapped in the vicinity of the mine.

5.0 CUMULATIVE IMPACT AREA

A cumulative hydrologic impact area (CIA) is defined by ARM 17.24.301(32): '"Cumulative hydrologic impact area" means the area, including, but not limited to, the permit and mine plan area within which impacts to the hydrologic balance resulting from the proposed operation may interact with the impacts of all previous, existing and anticipated mining on surface and ground water systems'." Anticipated mining" includes the entire projected life through bond release of all permitted operations and all operations required to meet diligent development requirements for leased federal coal for which there is actual mine-development information available. The size and location of a given CIA depends on the surface water and groundwater system characteristics, the hydrologic resources of concern, and projected impacts from the operations included in the assessment. For this CHIA, a surface water CIA and a groundwater CIA are delineated to assess impacts associated within these distinct hydrologic resource areas (**Figure 5-1**).

5.1 SURFACE WATER CUMULATIVE IMPACT AREA

The surface water CIA includes all areas that may see a measurable change in water quantity or water quality due to mining activities at the Rosebud Mine and Big Sky Mine. The cumulative impact area covers upstream portions of West Fork Armells Creek to the confluence with Donley Creek, East Fork Armells Creek to the confluence with Stocker Creek, and Rosebud Creek to the confluence with Spring Creek. The CIA boundaries are established down gradient from potentially affected streams and springs, and include all surface water monitoring stations to allow assessment of impacts to stream water quality and quantity. Only impacts from coal mining are included in the CHIA, and although the power plant, power plant ash ponds, the town of Colstrip, and active agricultural activities are within the CIA, the impacts from these sources are only mentioned when their impacts are measured in data collected by the coal mines.

5.2 GROUNDWATER CUMULATIVE IMPACT AREA

The groundwater CIA includes the limits of all mining-induced groundwater impacts or potential impacts based on the hydrology of the mines and adjacent area. Potential impacts to groundwater include changes to water level or water quality such that the resource is no longer available or suitable for established uses. Results of two transient groundwater flow models in the Rosebud Mine, one for permit areas A, B, and C (Western Energy Company, 2014) and one for Area D (Western Energy Company, 1999), and the currently observed drawdown and recovery at the reclaimed Big Sky Mine are the basis for determining the extent of drawdown impacts for the CIA. Mining-induced water quality impacts are determined and evaluated based on observed changes to baseline water quality and anticipated changes based on location of resources and their potential to be affected.

6.0 WATER RESOURCE USES

Historic and current surface and groundwater uses in and adjacent to the mine area include domestic, livestock, wildlife, and industrial. These are also the anticipated postmine uses of water in the area. Private wells located within and immediately adjacent to the CIA were identified from the Montana Bureau of Mines and Geology Groundwater Information Center (GWIC). Registered surface water and groundwater rights were identified from records at the Montana Department of Natural Resources and Conservation (DNRC). Groundwater users (wells and groundwater rights) are shown in **Table 6-1** and located on **Figure 6-1;** surface water users (surface water rights) are shown in **Table 6-2** and located on **Figure 6-2.**

As shown in **Table 6-2**, surface water rights outside of the permit boundaries in each of the major drainages are dominated by a few users. Except for two springs in the upper most headwaters, water rights on East Fork Armells Creek upstream of the state highway are all held by the Booth Brothers Land and Livestock Company. Surface water rights in Stocker Creek are equally divided amongst Booth Brothers Land and Livestock Company and Great Northern Properties Ltd (GNP). Pony Creek surface water rights are divided between GNP, Genie Land Co, and the Garfield family. Cow Creek water rights are divided between Genie Land Co and the PPL power plant. Water rights are held by Greenleaf Land and Livestock Co and GNP in Miller Coulee. Lee Coulee water rights are predominately held by Bailey. WFAC water rights are held mostly by GNP and KL Ranch LLC, excluding the mine. Finally, Spring Creek water rights are held by a variety of users including GNP, the Valdez and Beverly Trust, Cornwell Land and Livestock Co, and Genie Land Co.

The mine operator must replace water rights or water supply interrupted by strip or underground mining (ARM 17.24.648). Supply of water for domestic, agricultural, industrial or other legitimate use of surface or groundwater is protected from diminution, contamination or interruption resulting from coal mining.

6.1 DOMESTIC

Domestic use is listed in GWIC or DNRC records for numerous wells within the groundwater cumulative impact area. Domestic wells in the area generally produce water from sandstone units in the deeper underburden because it is the most reliable resource. The Rosebud coal and other shallow units generally cannot deliver adequate and/or sustainable amounts of water for domestic use. The municipal public water supply for the town of Colstrip relies on water from the Yellowstone River stored in Castle Rock Lake. Total municipal usage is estimated at 630 acre-feet per year (MDSL and OSMRE, 1983).

6.2 INDUSTRIAL

Industrial users include the Rosebud Mine and the Colstrip Power Plant. A 29-mile long pipeline from the Yellowstone River brings water to Colstrip for use at the power plant. The water is stored in a large pond known as Castle Rock Lake, a reservoir located on the west side of town adjacent to Rosebud Mine Area A. The power plant uses 90 to 95 percent of the annual reservoir storage with the overwhelming majority of that water lost to evaporation through cooling processes, from pond surfaces and in dust suppression. The Rosebud Mine utilizes municipal water for most uses. Shallow wells formerly used by the Rosebud Mine have been abandoned. As part of the mining operations, water retained in sediment

ponds and pits is applied to roads to control dust. The Big Sky Mine used a production well completed in the underburden. This well has been converted to livestock supply.

6.3 LIVESTOCK

Water for livestock is the most common use of surface and shallow groundwater in the CIA. Surface water, springs, and groundwater wells in the CIA area provide drinking water for livestock. Water quantity and quality in surface water, springs, and shallow wells are variable and may change seasonally with the availability and use of the water source. Based on reported completion depths, stock wells are completed in alluvium, overburden, Rosebud or McKay coal, and underburden. Wells completed in deeper, underburden units provide a more consistent and reliable water source. A number of groundwater rights are listed for stock water use at springs in the CIA. Spring sources include alluvium, overburden or coal units. Surface water rights within the CIA for livestock are typically directly from the source or at a stock pond.

Water quality guidelines for livestock used in this CHIA are based on limits for livestock consumption found in documents published by the Montana State University Extension Service (Sigler and Bauder, 2012, Hutcheson, 2001). **Table 2-2** lists the parameters of concern and guideline limits for livestock water quality. These limits are not enforceable standards but are used by DEQ for guidance in evaluating suitability of pre- and postmine water quality for livestock use. Locally, water quality in the naturally exceed these livestock water quality guidelines.

There is a lack of consensus in the scientific and agricultural communities on the appropriate or acceptable concentration of livestock drinking water quality. This is especially true for the constituents with narrative standards, such as sulfate and TDS. The guidelines presented for Montana are within the limits for sulfate and TDS determined in a risk assessment for livestock drinking water that incorporated an extensive literature research with empirical data from Wyoming ranchers (Geomega, 2007).

Trace metal concentration limits are more uniform among published studies, often using the HHS as the standard for livestock. Surface water and shallow groundwater in eastern Montana are highly variable and locally may be marginal for supporting livestock. Yet, surface and shallow groundwater have supported ranching in Montana for more than a century.

6.4 AQUATIC AND WILDLIFE HABITAT

In semi-arid Eastern Montana, wetlands are predominately found by springs, stock ponds, and intermittent reaches of drainages. Many stock ponds and intermittent reaches are fed by springs. Wetland inventories and assessments are required in baseline surveys to satisfy the requirements to assess the hydrologic resources, vegetative communities, and wildlife habitat. An inventory of wetlands that may be impacted by mining activities are also required to be submitted to the Army Corps of Engineers to determine federal jurisdictional status. If a wetland is considered jurisdictional, the Army Corps of Engineers can require mitigation to offset the impact to wetland resources in the area.

At both the Rosebud and Big Sky mines, baseline surveys and mining occurred before requirements for wetland inventories and assessments were enacted, and consequently there is no comprehensive list of premine wetland sites or their areal extent for the mines. The most complete wetland survey for the area was done for the Rosebud Mine in 1995, and the areas delineated as potential wetland habitat are shown in **Figure 6-3** (MME, 1995). In addition, aquatic life surveys were conducted on EFAC and other

locations prior to or shortly after mining started (**Table 6-3**). Results from these surveys are difficult to use for premine and postmine comparison due to different sampling techniques, but the survey results give a qualitative representation of the aquatic habitat and community.

7.0 MONITORING PROGRAM

Surface water and groundwater monitoring programs are required to meet permit obligations pursuant to ARM 17.24.314, ARM 17.24.645 and 17.24.646. Monitoring results from the Rosebud Mine and Big Sky Mine are the basis for assessment of mining impacts on water resources. The monitoring plan has been designed to collect water quantity and quality information in order to address the questions: 1) To what extent are impacts to the hydrologic balance occurring on or off the permit area as a result of mining operations, and 2) Is material damage occurring as a result of mining operations?

The monitoring plan identifies site locations, hydrogeologic units monitored, sampling frequency, and parameters. Quality assurance is an integral part of sampling and analytical requirements. As mining proceeds or the potential for additional impacts are recognized, the monitoring plan is revised to accommodate changes, including replacement of monitoring sites or development of new sites. Monitoring is required to continue through the final phase of bond release.

In addition to monitoring commitments required by the mine permits, the Rosebud Mine and Big Sky Mine also monitor MPDES-regulated discharges. Big Sky MPDES Permit No. MT-0000884 authorizes discharges to Lee, Emile, Miller and Hay coulees. Rosebud Mine MPDES Permit No. MT-0023965 authorizes discharges to Stocker Creek, Hay Coulee, South Fork Cow Creek, Cow Creek, East Fork Armells Creek, Castle Rock Reservoir, Spring Creek, West Fork Armells Creek, Black Hank Creek, Donley Creek, Lee Coulee and Pony Creek.

7.1 SURFACE WATER

Surface water monitoring at the mines includes stream, spring (and seep), and pond sites. Currently required analytical parameters and methods for surface water monitoring are in **Table 7-1**. The surface water monitoring plans for the Rosebud and Big Sky mines are in **Table 7-2**. The current and historic monitoring sites are shown in **Figure 7-1**. This figure shows that the current surface water monitoring network at the Rosebud Mine is a fraction of the total number of sites that have been monitored. Most of the stream monitoring and sampling was conducted in the early to middle 1980's, and more surface water quality data exists for this time period than any other. Analysis of impacts to surface water from mining is greatly complicated by the inconsistent temporal and spatial distribution of surface water data collection and from the inherent nature of ephemeral stream hydrology.

The Rosebud Mine implements and complies with MPDES permits at 151 drainage outfalls. Of the 151 individual outfalls, 60 discharge to East Fork Armells Creek, 16 discharge to West Fork Armells Creek, 24 discharge to Stocker Creek, 13 discharge to Spring Creek, nine discharge to Pony Creek, seven discharge to Lee Coulee, 20 discharge to Cow Creek, one discharges to Black Hank Creek and one discharges to Donley Creek. A total of 126 discharge events were reported for the period of record from December 1999 through June 2011. Thirty-seven discharges were to Stocker Creek, 31 were to West Fork Armells Creek, 29 were to East Fork Armells Creek, 13 were to Pony Creek, nine were to Cow Creek, six were to Spring Creek, and one was to Black Hank Creek. Sixty-nine of the 151 outfalls are associated with reclaimed drainages and are covered under Western Alkaline Coal Mining standards. The Federal Environmental Protection Agency (EPA) established Western Alkaline standards that require coal mine operators to implement best management practices (BMPs) so that postmine lands are reclaimed to mimic natural conditions that were present prior to mining activities. A total of 181 monitored discharge events were reported for the period of record from December 1999 through 2013. Thirty-one discharges

were to Stocker Creek, 29 were to West Fork Armells Creek, 107 were to East Fork Armells Creek, seven were to Pony Creek, six were to Spring Creek, and one was to Black Hank Creek.

7.2 GROUNDWATER

Monitoring takes place in each potentially affected hydrologic unit at the mines. Water level and water quality data have been collected from monitoring wells at and adjacent to the Rosebud Mine and Big Sky Mine since the 1970's. As there was no monitoring required prior to passage of MSUMRA, there is no baseline for some of the earliest mining disturbance. The first monitoring wells were installed by the MBMG (from 1973 to 1975) to study the impacts of mining on the hydrologic system. Many of these wells have a long monitoring history and some remain active. Mine-wide installation of monitoring wells at the Rosebud Mine by Western Energy Company began in 1979 and additional wells have been installed as mining expanded. Peabody Energy began installation of monitoring wells at Big Sky Mine Area A in the middle 1970's after mining had begun. Installation of wells in Big Sky Area B in the middle 1980's recorded baseline conditions prior to the beginning of mining.

The currently approved groundwater monitoring parameters at the Rosebud Mine are in **Table 7-3.** The currently approved groundwater monitoring parameters at Big Sky Mine are in **Tables 7-4** and **7-4A**. The monitoring plan for Rosebud Mine is in **Table 7-5** and well locations are on **Figure 7-2**. The monitoring plan for the Big Sky Mine is in **Table 7-6** and the well locations are shown on **Figure 7-3**.

8.0 BASELINE HYDROLOGIC CONDITIONS

The goals in establishment of baseline hydrologic conditions are to characterize the local premine hydrology, understand the regional and local hydrologic balance, and identify potential water resources or uses that could be affected by the mining operation. Monitoring surface water and groundwater prior to mining is key to understanding the hydrologic condition and informs the regulating agency of the potential for and location of impacts. Hydrologic monitoring was not required by statute prior to enactment of MSUMRA in 1978, thus there is no baseline data for some mine areas. Prior to enactment of MSUMRA, mining began in Area D, Area E, Pit 6 and parts of Area A and Area B of the Rosebud Mine, and at Big Sky Mine Area A.

Although the majority of existing hydrologic information was collected after mining operations began, the substantial data sets developed over the last 30 years of monitoring provide insight into baseline conditions based on observed water quality and quantity trends. Up gradient groundwater quality data from all monitored units are representative of baseline water quality, as areas up gradient of mining have not been impacted by mine activity.

8.1 SURFACE WATER BASELINE

Baseline surface water conditions were derived from a network of surface water monitoring stations (springs/seeps, streams, ponds) established during initial permit development. Characterizing background conditions for surface water quantity for the drainages crossing the mine areas requires years of measurements in a variety of precipitation events and climate conditions. Premine water monitoring sites located at the downstream end of the mine permit boundary have limited use in establishing a long-term record of premine conditions because mining upstream of the stations occurred within 2 years after the sites were installed. In many cases mining occurred upstream of the sites before the start of monitoring.

For baseline analysis, surface water samples are broken into two categories: streams and stock ponds, and springs. Springs are analyzed separately as they are sourced from groundwater but the sampling location, often a man-made pond or stream bottom, may also be influenced by surface water sources. For this CHIA, stream and pond water quality samples were chosen as representing baseline conditions if the sample was taken before mining commenced upstream of the sampling location.

Within the CIA, many springs, seeps, and spring-fed ponds have been identified and monitored. Most springs in the area produce only small rates of flow (a few gpm) and many become dry for extended periods of time. However, these springs provide an important source of water for livestock and wildlife while they are flowing. All of the major near-surface aquifers have been identified as a source for springs: clinker, Rosebud coal, McKay coal, and sub-McKay sandstones. Some reclaimed areas have developed springs sourced from spoil.

8.1.1 Regional Drainage System

The region is drained by tributaries of the Yellowstone River. The Rosebud Mine intersects eight major drainages. Area A drains to both Stocker Creek and East Fork Armells Creek. Area B is immediately south of East Fork Armells Creek, however a small portion of the permit area crosses the divide into the Lee Coulee drainage. Area C spans multiple drainage basins including East Fork Armells Creek, Stocker Creek, West Fork Armells Creek, and a small portion is located in the Black Hank Creek basin. Area D is located

at the intersection of four drainage divides: Spring Creek, Pony Creek, Cow Creek, and East Fork Armells Creek. Area E is located in Cow Creek and East Fork Armells Creek drainage basins. Pre-law mining in Pit 6 occurred in areas that drain to Cow Creek and Hay Coulee. Most of the mining occurred in the headwaters of the drainages and left the main channels of the drainage basins undisturbed. Area C mined through the upstream-most channel of Stocker Creek. Mining occurred within a few hundred feet of the East Fork Armells Creek main channel, but no mining has disturbed the actual creek bed. Haul roads and county roads cross the main channel.

The Big Sky Mine is situated among coulees that drain east-southeastward into Rosebud Creek. These include, from north to south, Emile (or Coal Bank) Coulee and Miller Coulee in Big Sky Area A, and Lee Coulee in Big Sky Area B. Emile Coulee is a tributary to Miller Coulee and is analyzed as part of Miller Coulee in this CHIA. The coulees are generally ephemeral. Miller Coulee and Emile Coulee are ephemeral. Lee Coulee is ephemeral above and at the upper end of Big Sky Area B, and downstream of Big Sky Area B. Within Big Sky Area B, there is a wet reach confined within the permit area about 1.5 miles long that sustained small ponds, flowing reaches, and sub-irrigated rangeland before mining (**Figure 6-3**). The wet reach discontinues and the stream is again ephemeral before Lee Coulee exits the Big Sky Area B permit boundary. Lee Coulee extends from about one mile upstream of the Rosebud coal outcrop to near the McKay coal outcrop. The wet reach is an intermittent stream, but contains short reaches within it that may be perennial. This reach has been the focus of special studies to evaluate conditions within the reach both before mining and as mining approached the area. Mine reclamation included a plan to reproduce the wet reach.

8.1.2 Surface Water Quantity

Judgments on the nature of flow in the creeks within the CIA monitored by the Rosebud Mine and Big Sky Mine can only be made at locations with surface water monitoring sufficient to determine the nature of flow. With the exception of some intermittent stream reaches and stock water ponds, the surface water that is monitored by the mines in and near the Rosebud and Big Sky mines are ephemeral, flowing only in response to precipitation events or snowmelt, or for short reaches below the issue point of springs or seeps. Reaches of some of the larger drainages within the CIA but downstream of the stream monitoring network may also be intermittent (e.g. West Fork Armells Creek (WFAC), East Fork Armells Creek (EFAC), Spring Creek, and Hay Coulee).

Long term monitoring at Rosebud and Big Sky indicates some stream segments that have had periods of flow that would be classified as intermittent. These monitored intermittent stream segments include one on Stocker Creek, two on upper EFAC, one on Lee Coulee, and most of Cow Creek. With the exception of the mainstem of Cow Creek, these stream segments are isolated and do not provide connectivity to downstream perennial water bodies (e.g. Rosebud Creek and lower EFAC). Rosebud Creek is perennial within the CIA. Stream flow measurements on Stocker Creek indicate that some upstream sections may be intermittent after heavy precipitation years when clinker and alluvium are temporarily recharged. There are likely other reaches on the impacted drainages that behave similarly where intermittent flow may occur for one or two years after a large precipitation year. While no long term continuous flow monitoring equipment has been installed on WFAC, there are eighteen springs within the CIA that have been monitored in this drainage, and there are likely reaches of spring-fed intermittent streams on WFAC.

The criteria for determining if a stream reach is ephemeral, intermittent, or perennial differs between an MPDES discharge permit and MSUMRA mining permit. The MPDES program considers the flow regime

for large segments of streams when characterizing receiving waters, and consequently Stocker Creek, EFAC, and Lee Coulee are currently designated as C-3 ephemeral for the purposes of the MPDES discharge permits for the Rosebud Mine and Big Sky Mine. In the context of MSUMRA, however, some monitored segments of EFAC, Stocker Creek, and Lee Coulee have had enough continuous flow to classify small reaches of the stream as intermittent per ARM 17.24.301(61).

The site with the longest record of monitoring upstream of mining disturbances at the Rosebud Mine is SW-75 on East Fork Armells Creek. This station is on a part of the creek that rarely experiences flows and has numerous data gaps in the flume's flow record. This location is not representative of baseline conditions at other segments of the stream. For instance, other segments of EFAC may have had baseflow or ponded water for many months of the year, but these locations were not regularly monitored. With only one continually monitored site upstream of mining, natural flow conditions along the entire reach of EFAC cannot be established by the existing record of empirical measurements. Similarly, none of the other drainages have a large enough data set to characterize natural flow conditions before mining. On Stocker Creek, WFAC, Spring Creek, Pond Creek, and Cow Creek mining started in the basins near the drainage headwaters, and consequently baseline data is extremely limited. For these drainage basins, there is no ability to place sites upstream of mining to contemporaneously monitor natural and mine-impacted flow conditions.

In basins with insufficient data, premine water quantity can be roughly estimated by using flow data from a comparable undisturbed basin. The natural ranges of peak flows can be calculated for a number of recurrence intervals in similarly sized basins monitored by the USGS (**Figure 8-1**). The USGS also offers a service to estimate peak flows in Montana from the simplistic basin characteristics of size, location, and elevation using a method developed by Parrett and Johnson (2004). Both of these techniques along with calculated peak flows at long-term monitoring stations operated by the Rosebud and Big Sky mines are shown in **Table 8-1**.

Table 8-1 shows that the peak flows calculated from empirical data collected at mine-monitored sites SW-55, B33FL, SW-75, and SW-65 are all much smaller than peak flows estimated by the Parrett and Johnson (2004) method or peak flows calculated from empirical data collected at similarly sized drainage basins by the USGS. As mentioned above, the mine-monitored sites suffer from numerous data gaps in the record that can lead to erroneous calculated peak flows. The records at these sites are also in average daily flow, and the true peak flow of an event will always be higher than the maximum average daily flow that is shown in the table. In stream dams and changes in stream bed permeability also have a significant impact on peak flows which are not accounted for in the Parrett and Johnson method. Additionally, monitoring sites downstream of mine impacts may experience reduced flows due to the use of sediment ponds on contributing upstream tributaries. Sediment ponds can remain in place for decades during mining and reclamation, and they are typically sized to retain a 10-yr, 24-hr storm event. Consequently, for storm events smaller than the theoretical 10-yr, 24-hr, the ponds can potentially fully retain runoff from downstream channels. As seen in **Table 8-1**, peak flows in all but the largest drainages range by at least one order of magnitude between the 2 year and 100 year recurrence storms.

8.1.3 Surface Water Quality

As with water quantity data, little baseline surface quality water data is available for Pony Creek, Spring Creek, Miller Coulee, and Cow Creek. Because the drainages are mostly ephemeral, many drainage basins have a poor distribution of stream and pond sample points (**Figure 8-2**). More data was collected on EFAC and WFAC. In the early 1980's, a series of synoptic runs were conducted on EFAC where water

quality was sampled from multiple locations on the same day. This resulted in a large number of data points, but this sampling methodology also resulted in very few sampling locations that were used for repeated sampling. The synoptic runs allow for an evaluation of changes in water quality as water flows downstream through areas not impacted by mining, though active mining, and on into the town Colstrip. WFAC has a larger quantity of baseline sampling because mining commenced in this basin later than other sections, allowing for a longer baseline monitoring period.

In general, baseline water quality in any given drainage channel or pond is variable, but some water quality parameters showing a strong seasonality (**Figure 8-3** and **Figure 8-4**). Water quality samples from streams and ponds have lower total suspended sediment (TSS) in the winter and early spring because the ground remains frozen during runoff events. Runoff in the early and middle spring can often represent the majority of water volume carried by the stream all year. Conversely, water quality samples from streams and ponds collected in the summer have higher TSS. Not only is the ground unfrozen and dry in the summer but storm events tend to be locally intense and of short duration. These precipitation events in turn create flashy, erosive flows through the drainages. Total dissolved solids (TDS) concentration and its major constituents do not show a strong seasonal change, in part because the data set used to make **Figure 8-3a** is mainly from sites on ephemeral drainages. The elevated concentration of dissolved analytes from October water quality samples is a result of sampling bias – all of the October samples used to create **Figure 8-3a** were from the Lee Coulee wet reach.

A comparison of water quality between drainage basins (**Figure 8-4)** shows a wide range in water quality. None of the drainages have a distinct chemical signature that would distinguish water from one basin from other surface water in the area. Individual sampling sites may have a unique chemical composition due to a combination of water sources (e.g. groundwater from various aquifers, municipal water drinking water from Castle Rock Reservoir, municipal waste water, etc.).

For sample sites with contributions from baseflow and runoff, there could be strong seasonal changes in water quality as the mixture of groundwater, snow melt, and runoff changes through the year. **Figure 8-3b** shows data collected along the wet reach of Lee Coulee. October samples have elevated calcium, magnesium, potassium, sodium, and sulfate compared to other samples taken in other months. This difference is likely from an increase in baseflow contribution to the wet reach of Lee Coulee in October.

Some spring water quality is also seasonally-dependent if the spring's source aquifer is influenced by precipitation. Spring water samples collected from ponded areas can also receive runoff contributions which can influence the measured water quality. Baseline spring water quality will be discussed on an individual basis in **Section 9.0**.

8.2 GROUNDWATER BASELINE

Baseline describes the condition that exists prior to influence or potential influence of mining on a groundwater resource. Although baseline data is available for many mine areas, early mining preempted baseline data gathering in some areas of disturbance. Pre-law mining in Rosebud Mine Area E, Pit 6 and the south part of Area D, as well as Big Sky Mine Area A preempted collection of baseline data. The easternmost part of Rosebud Mine Area A and the southeast part of Area B were mined in the middle 1970's prior to the widespread installation of monitoring wells. Alluvial and bedrock wells installed in the early 1980's adjacent to EFAC between Rosebud Mine Areas A and Area B, began gathering data after mining had begun in the middle 1970's. Even though baseline data are absent from some areas, more than thirty years of monitoring data indicates change or lack of change to groundwater adjacent to

mined areas and is an insight to the effects of mining on groundwater resources. As mining typically does not affect water quality up gradient of mining, data from up gradient wells remain representative of background water quality.

Selecting wells and time periods as representative of baseline requires some level of judgment and discretion by the observer. One must have insight into if and when a long-term monitoring site became influenced by mining. Climate plays a significant role in the change in groundwater level and it is not always straightforward when to attribute a change in water level or quality to climate versus mining, particularly in alluvial wells.

Only water quality analyses that include all major ionic parameters were chosen to represent baseline water quality. Samples with obvious analytical errors such as reported lab errors, unbalanced charges, and obvious analytical or recording errors (e.g. analyte concentration that exceeds the total dissolved solids (TDS) concentration in a sample) were not included.

A number of wells that recorded baseline data are still active, although most have been mined through or abandoned for another reason. As the currently active monitoring sites may not have the exact location or completion as the baseline wells, direct comparison between baseline and current water quality is generally, but not directly, comparable.

8.2.1 Groundwater Regime

The local groundwater regime lies within the regional regime, although the systems may not be in direct connection. To understand the system response to stresses from mining, components of the local groundwater system must be understood. These components include recharge, discharge, aquifer parameters, water levels, flow, and water quality.

8.2.1.1 Regional

In the Montana part of the Powder River Basin, the regional aquifers are part of the terrestrial Upper Cretaceous geologic units that crop out north of Colstrip near the Yellowstone River (**Figure 4-3**). The Bearpaw Shale, at a depth of approximately 2,000 feet below the Colstrip area (Slagle and others, 1983), forms the lower confining unit for the overlying Fox Hills and Hell Creek formations. Together the Fox Hills and lower Hell Creek formations form a deep, artesian sandstone aquifer as much as 2,500 feet thick (Lewis and Hotchkiss, 1981). This regional aquifer flows north toward the Yellowstone, Powder, and Tongue rivers. Yields to domestic and stock wells generally are less than 70 gallons per minute (gpm) and may flow as much as 20 gpm under artesian pressure along major river valleys (Slagle and others, 1983). TDS concentration reportedly ranges between 600 mg/L and 3,500 mg/L based on data developed from the Montana Groundwater Assessment Program of MBMG. In the Colstrip area, the aquifer occurs at depths greater than can be economically tapped for stock or domestic supplies.

A confining unit in the upper Hell Creek Formation underlies the Paleocene Tullock member of the lower Fort Union Formation, where the fine-grained sandstones and coal beds of the Tullock aquifer generally averages a yield of 15 gpm (Lewis and Hotchkiss, 1981). A confining layer known as the Lebo Shale overlies the Tullock aquifer and underlies the Wasatch-Tongue River Formation aquifer. This aquifer produces about 8 gpm from sandstone and coal units and represents the local aquifer system (Slagle and others, 1983).

8.2.1.2 Local

The shallow, local water bearing strata in the Colstrip area include alluvium/colluvium, and bedrock units of the Tongue River Member of the Paleocene Fort Union Formation. Within the mine area the bedrock hydrogeologic units are designated as overburden, Rosebud coal, interburden, McKay coal, and underburden. Due to the low conductivity of the fine grained, laterally discontinuous and thinly bedded claystones, siltstones, and silty sandstones that make up the overburden and interburden units, they generally are not regarded as aquifers, although locally they may offer a limited water supply. Due to the lateral continuity and secondary permeability created by fracturing, the Rosebud and McKay coal seams are the most reliable sources of shallow groundwater in the area. However, the low transmissivity and low yield from the coal seams makes them a less than desirable source as a dependable water supply. The most reliable water supply comes from sandstone units in the underburden and thus most wells are completed in the underburden.

8.2.1.2.1 Aquifer parameters

The material making up the valley fill in the stream bottoms and adjacent terraces consists of alluvial and colluvial deposits of interbedded silts, sands, and gravel that are generally less than 40 feet thick. The hydraulic conductivity of these deposits is highly variable. Aquifer tests results from Rosebud Mine and Big Sky Mine are summarized in **Table 8-2** and **Table 8-3**. These results show a wide range of hydraulic conductivity. Depending upon location, the Rosebud and McKay seams may be confined or unconfined. Confined coal aquifers in the area are estimated to have a storage coefficient of .0001 (Western Energy Company, 1997).

8.2.1.2.2 Flow

Flow in the alluvial aquifers follows the gradient of the individual drainage. Flow direction in the bedrock aquifers is generally controlled by bedrock geologic structure. The series of low-displacement, down dropped normal faults across Rosebud Mine permit areas A, B and C influence flow direction from the highlands to the west, up gradient of mining. This is demonstrated by the potentiometric surfaces of the Rosebud coal and McKay coal **(Figure 8-5** and **Figure 8-6**). A sizeable stock pond is coincident with the groundwater mound between the west end of Rosebud Mine Area B and south part of Area C. An apparent recharge area also is visible in the higher elevations at the northeast part of Big Sky Mine Area A. In Rosebud Mine Area D and Area E, and at the Big Sky Mine, flow direction is south southeast toward Rosebud Creek.

Where saturated, alluvial and overburden aquifers are usually unconfined and represent the local water table. Depending on location, the Rosebud coal may be confined or unconfined. The McKay coal is typically confined. Both coals become unconfined and thinly saturated as they approach the crop limits. They are usually dry at the outcrop. Underburden wells typically have a substantial hydraulic head. A vertical downward gradient between all stratigraphic intervals is prevalent in all mine areas.

8.2.1.2.3 Recharge and Discharge

Recharge depends largely on lateral up gradient flow. Vertical infiltration from precipitation is limited by low precipitation and a high evaporation rate. There is some local recharge from snowmelt and precipitation in drainages and depressions. Fractured clinker permits greater infiltration of precipitation and surface flow and locally may be a source of recharge. Mine pits, sediment ponds, and stock ponds are also sources of local recharge. Local bedrock discharges are to alluvium and springs. Outcrop margins are generally dry except in EFAC and Lee Coulee, which have intermittent reaches fed by bedrock aquifers.

Lateral up gradient flow of saturated Rosebud coal is generally from the west at the Rosebud Mine and from the north to northwest at the Big Sky Mine (see **Figure 8-5**). Due to the removal of the Rosebud coal and aquifer during mining, each pit area creates a groundwater depression, which means that it is down gradient in all directions from adjacent, saturated Rosebud coal or saturated spoil. Where mining extends to the up gradient coal crop margin, normal lateral recharge is eliminated as the Rosebud coal does not extend up gradient. This condition exists in Area A, the north part of Area C and Area D. As a result recharge to these areas and the development of a spoil aquifer will take longer than mine areas with up gradient recharge.

8.2.1.2.4 Water Quality

Early water quality samples from wells and springs in the Colstrip area indicate a wide range of dissolved solids concentrations, from 420 mg/L to 5,860 mg/L (Van Voast et al., 1977). The chemical character of water from any of the bedrock aquifers is similar, but ionic concentration commonly varies from location to location. Aquifer mineralization and chemical signature cannot be used to distinguish stratigraphic position, location in the flow system, or areal distribution of aquifers. At the Rosebud Mine, total dissolved solids concentration (TDS) generally increases with increasing bedrock aquifer depth.

Sulfate is the predominant anion in most groundwater, generally followed by bicarbonate, although bicarbonate dominates in some samples. Calcium, magnesium, sodium, sulfate, and bicarbonate typically comprise more than 97 percent of all dissolved constituents in groundwater. Potassium and chloride are also common, but usually in very low concentrations. The quality of groundwater in the Colstrip area is a product of salt dissolution and, to a lesser degree, cation exchange. Salts are produced in recharge areas by weathering and oxidation and are then dissolved by percolating groundwater.

8.2.2 Alluvial Baseline

The unconsolidated geologic deposits of hydrologic interest in the immediate vicinity of the Rosebud Mine are Quaternary age alluvium and colluvium. Alluvium at the Rosebud Mine is found in EFAC (areas A, B and C), Stocker Creek (Area C), Cow Creek (Area D), Pony Creek (Area D), Spring Creek (Area D), and the tributaries to these drainages. At the Big Sky Mine, alluvium is found in Emile Coulee (Area A), Miller Coulee (Area A), and Lee Coulee (Area B).

The valley fill material that makes up the alluvium is typically composed of differing amounts of silt, sand, and gravel depending on degree of stream development. Alluvial thickness in the drainages varies depending on extent of drainage development and may be thinly saturated, seasonally saturated, or unsaturated. Alluvium is not regarded as a reliable source of water in the Colstrip area, although locally and seasonally it may serve as a source of livestock drinking water. Most of the streams are ephemeral and flow only in response to precipitation or runoff events. Alluvial monitoring well hydrographs reflect seasonal water level fluctuation, with levels rising in response to snowmelt and precipitation in spring and early summer, and declining in late summer and early fall. Many baseline measurements in alluvial wells were taken during periods of drought in the 1970's and 1980's. This strongly affects alluvial water levels and water quality. Alluvium is recharged mainly by precipitation and spring runoff events. Discharges from Rosebud coal and McKay coal contribute locally to flow and alluvial recharge in EFAC and Lee Coulee.

As indicated by Piper plots **(Figure 8-7** and **Figure 8-8)** and box and whisker plots **(Figure 8-9** and **Figure 8-10)** of single, initial baseline samples taken from alluvial monitoring wells at Rosebud and Big Sky mines, the dominant cations are magnesium and calcium, followed by sodium. The dominant anion is

sulfate. Rosebud Mine alluvial baseline samples have higher median concentrations of TDS and higher conductivity than the Big Sky alluvium largely due to higher concentrations of sulfate, magnesium, calcium, and sodium. In contrast to Big Sky Mine alluvium, Rosebud Mine alluvium has a higher median conductivity than bedrock water bearing units. Specific conductivity measurements place alluvial groundwater at the Rosebud and Big Sky mines into Class ll and Class lll groundwater. The median concentration at both mines is Class III.

8.2.2.1 East Fork Armells Creek

EFAC is an ephemeral to intermittent stream that flows through the Rosebud Mine. It flows between Area A and Area B in the east (downstream) part of the mine area, and Area B and Area C to the west (upstream). Most of the creek bed upstream of Area A is dry. Short stretches of intermittent flow have been identified downstream (see surface water discussion of EFAC). Ponded sections, facilitated by the presence of four small dams built to retain water for livestock, contribute to intermittent flow conditions. The stream has eroded through stratigraphically lower units as it flows downstream.

The thickest alluvial deposits at the Rosebud Mine are in EFAC where alluvium ranges to 40 feet. During baseline in the late 1970's through 1980's, water levels measured in alluvial wells reflect a period of drought. Initial water measurements indicate that alluvial wells contained between 11 feet and 35 feet of water, with an average of approximately 20 feet. During baseline, recharge to EFAC alluvium was restricted to stream flow and bedrock aquifers that subcrop and outcrop in the valley fill. Logs from wells installed in EFAC alluvium show gravel deposited onto Rosebud coal in Section 15, T2N, R40E and lateral to McKay coal in Section 4, T2N, R41E. Up gradient of Area B, alluvium is bounded by overburden and does not receive significant groundwater recharge.

Aquifer tests conducted in EFAC alluvium produced a lognormal mean conductivity of 3,865 gpd/ft and a lognormal mean storage coefficient estimated at 0.002 (Western Energy Company, 1984). Groundwater flow is variable, ranging between 18 gpm to 158 gpm.

Because early mining took place at the east end of Rosebud Mine Area B and Area A, there are few baseline samples from alluvium in easternmost EFAC. Changes to alluvial water quality recorded from wells in the east part of the drainage are discussed in the groundwater impacts section (**Section 9.2.5.1.1**). TDS concentrations of initial baseline samples in the central and west part of the drainage range from 1,330 mg/L to 4,680 mg/L. The average and median are 2,302 mg/L and 1,900 mg/L, respectively. Based on electrical conductivity, EFAC alluvial groundwater is Class ll and Class lll. During early observations of alluvial water quality in EFAC Van Voast et al., 1977, identified that TDS concentrations in EFAC were 50 percent greater downstream from the town of Colstrip than upstream of Colstrip. Early water chemistry also identified that water in alluvium upstream from Colstrip is chemically similar to water in the adjacent McKay coal bed.

8.2.2.2 Stocker Creek

Stocker Creek is an ephemeral stream that drains the north parts of Rosebud Mine Area C and the northwest part of Area A, joining EFAC north of Colstrip. Mining initiated in Area C in 1984 and in Area A in 1988 represents the first potential mining effects to Stocker Creek alluvium. Alluvial thickness in Stocker Creek ranges from 13 feet to 34 feet and wells have a saturated thickness of between five feet and 18 feet. Initial water level measurements in Stocker Creek wells indicate the alluvium held between two feet and 18 feet of water. TDS concentrations from initial baseline samples ranged from 1,720 mg/L

to 5,360 mg/L, with an average and median of 2,861 mg/L and 2,545 mg/L, respectively. Groundwater in these wells ranges between Class ll and Class lll.

8.2.2.3 Upper West Fork Armells Creek

The west and northwestern most parts of Rosebud Mine Area C drains to West Fork Armells Creek (WFAC). Baseline measurements began in the early to middle 1980's. Mining began in 2001 in the north part of Area C and in 2008 in the west part of Area C. Alluvial thickness ranges from nine feet to 19 feet and initial water levels in monitored wells ranged from two feet to 11 feet. TDS concentrations in initial baseline samples ranged from 1,800 mg/L to 5,230 mg/L, with an average TDS of 3,440 mg/L and a median of 3,570 mg/L. Groundwater in these wells is in the range of Class ll and Class lll.

8.2.2.4 Pony Creek and Cow Creek

Cow Creek, South Fork Cow Creek and Pony Creek are ephemeral tributaries to Rosebud Creek and drain Rosebud Mine Area D and Area E. Surface flow in Pony Creek and Cow Creek is ephemeral and occurs only during runoff events. Although monitoring of the alluvium in these drainages began as early as 1981, the results do not represent baseline as there was pre-law disturbance in the headwaters of these drainages.

Pony Creek flows east from Area D. Measurements in Pony Creek were taken as early as 1983 from a two- foot deep alluvial monitoring well near the head of the drainage at the permit margin. The well was often dry and monitoring was discontinued in 2007. As consultants to the Colstrip power plant, Battelle, a science and technology company, has installed and monitored wells in both Cow Creek and Pony Creek for water level and water quality changes associated with the Talen Energy power plant ash ponds in Cow Creek. Battelle's investigations indicate that Pony Creek has less than a foot of unsaturated, fine-grained alluvium (PPNL, 2000).

Cow Creek alluvial wells are mainly in the upland tributaries of the drainage. Monitoring wells in Cow Creek indicate alluvium in the main channel is 14 feet to 18 feet thick, with water levels between 6 feet and 16 feet below surface. The drainage is underlain by underburden and water levels in this unit suggest that it discharges locally into overlying alluvium (PPNL, 2000).

Aquifer pumping tests were completed in six wells in Cow Creek alluvium (Western Energy Company, 1983). Transmissivity estimated from these tests ranged from 350 gpd/ft to 72,000 gpd/ft. Test of five wells completed in tributary alluvium ranged from less than one gpd/ft to more than 6,000 gpd/ft.

Initial water quality samples (taken in 1982) from two wells in Cow Creek had a TDS of 2,060 mg/L and 3,120 mg/L. Two initial samples from wells in Pony Creek were 1,570 mg/L and 1,860 mg/L.

8.2.2.5 Spring Creek

Spring Creek flows northeast from Rosebud Mine Area D. Five alluvial wells were installed in Spring Creek or its tributaries in 1982 to 1984. The wells were dry or infrequently held a scant amount of water during the monitoring period that lasted through 1997. No water quality measurements were taken.

8.2.2.6 Miller Coulee and Emile Coulee

At the Big Sky Mine Area A, alluvial wells were installed in Miller and Emile coulees in the 1970's and early 1980's, after pre-law mining in the area had begun. Thus, the earliest monitoring data does not reflect baseline conditions but serves to document subsequent changes associated with mining and

reclamation in Area A that is discussed in the impacts section of this document. Both permit areas in Big Sky Mine (Area A and Area B) drain to Rosebud Creek, a perennial creek that empties into the Yellowstone River near Forsyth, Montana. Alluvial thickness in Miller and Emile coulees ranges between 12 feet and 31 feet. Changes to alluvial groundwater in these two drainages are discussed under the groundwater impacts section (**Section 9.2.5.2.1**).

8.2.2.7 Lee Coulee

Lee Coulee is an ephemeral to intermittent stream that flows through Big Sky Mine Area B into Rosebud Creek. Alluvial thickness varies from 28 feet in the upland part of the monitored drainage to almost 40 feet in the downstream area. Yields of 5 gpm to 50 gpm were measured during aquifer testing in alluvium of upper Lee Coulee. Baseline water level measurements in Lee Coulee and associated drainages ranged from dry to almost 40 feet of water in a well immediately up gradient of the Rosebud crop line (BSCC, 1988).

In uppermost Lee Coulee groundwater is discharged to the alluvial aquifer principally from the overburden aquifer and to a lesser degree from the coal and interburden aquifers. Where the main drainage widens and the coal crops are further upslope and away from the stream, alluvial water is lost to the underburden sandstone. Further downstream and still within the permit boundary, the saturated underburden discharges to the alluvium.

Water quality samples were collected as early as 1984 from a monitoring well network that spanned the length of the stream. The best water quality was near the head of the stream. TDS concentrations ranged from 436 mg/L to 3,630 mg/L, with an average and median of 1,956 mg/L and 1,840 mg/L, respectively.

8.2.3 Overburden Baseline

Bedrock strata above the Rosebud coal are referred to collectively as overburden. Overburden ranges in thickness from a foot or less near the coal crop to 250 feet in Rosebud Mine Area C. It consists of thin, discontinuous beds and lenses of brown to grey siltstone, claystone, and silty sandstones. Clinker is also found as overburden. Overburden locally may be recharged by snowmelt and rainfall, especially where clinker is exposed. Clinker thickness ranges from as little as 10 feet to 300 feet (Vuke et al., 2001). From a hydrogeologic perspective, these deposits are very permeable but generally the saturated thickness of clinker deposits is limited. Groundwater that is present in these deposits at the Rosebud Mine tends to be perched and is often hydraulically isolated from the underlying strata.

Where available, overburden groundwater is typically unconfined, perched, and produces little water although saturated thickness as great as 68 feet is reported at Big Sky Area B Mine (BSCC, 1988). Springs sourced by overburden have been identified at both the Rosebud Mine and Big Sky Mine. Rosebud Mine overburden has a wide range of transmissivity values, from 1 gpd/ft to 79,000 gpd/ft (**Table 8-2**; MDSL and OSMRE, 1983) which may be attributable to the variable lithologies in the overburden. Transmissivity values (**Table 8-3**) from aquifer tests in overburden at Big Sky Mine Area B ranged from 19.4 ft^2/day to 29 ft^2/day (3.7 gpd/ft to 209 gpd/ft) (BSCC, 1988).

In initial baseline samples from both the Rosebud and Big Sky mines, overburden water quality is dominated by sulfate, magnesium, and calcium, although it also trends to bicarbonate and sodium in some samples (**Figure 8-7;** and **Figure 8-8**). TDS in the overburden aquifer has a wide range in concentration, from 136 mg/L to 6,280 mg/L at the Rosebud Mine, and 356 mg/L to 3,920 mg/L at the

Big Sky Mine (**Figure 8-9** and **Figure 8-10**). Averages and medians for TDS from overburden at the two mines are 1,564 mg/L and 1,480 mg/L at the Rosebud Mine, and 1,666 mg/L and 1,200 mg/L at the Big Sky Mine. At the Big Sky Mine, overburden median TDS concentration and conductivity are lower than in the other water bearing units. Overburden baseline conductivity ranged from 455 μS/cm to 6,280 μS/cm at the Rosebud Mine and from 660 μS/cm to 4,310 μS/cm at the Big Sky Mine, which places overburden groundwater in Class I, Class II and Class III. Most wells produce Class II water. Locally, overburden baseline water quality meets suitability guidelines for livestock.

8.2.4 Rosebud Coal Baseline

The Rosebud coal aquifer is the aquifer most disturbed by mining because it is removed during mining. A full thickness of the Rosebud coal ranges between 18 feet and 25 feet and averages 22 feet. Pit margins commonly mark the extent of coal in most mine areas. Flow in the coal aquifers is controlled by secondary permeability caused by fractures. The results of aquifer tests in the Rosebud coal at the Rosebud Mine and Big Sky Mine are in **Table 8-2** and **Table 8-3,** respectively. As in all of the shallow, local bedrock aquifers, the main source of recharge originates from uplands west of active mining in the Rosebud Mine and north of mining in Big Sky Mine. Alluvium in downstream reaches of EFAC overlies Rosebud coal, forming a hydrologic connection between the two units.

The Rosebud coal aquifer may be confined or unconfined locally in both the Rosebud Mine and Big Sky Mine. Typically, unconfined conditions exist nearer the crop line. The Rosebud coal aquifer in Rosebud Mine Area C originally was confined near the middle of the permit area, with confined heads ranging between 30 and 70 feet above the top of the unit. The Rosebud coal was unconfined in all areas of Area D prior to mining. At Big Sky Mine Area B, the Rosebud coal aquifer was confined in the north and northwest parts of the permit area and unconfined in the south and southeast parts prior to mining. Although pressure head or water level have changed, the local status (confined or unconfined) of the Rosebud aquifer at Big Sky Area B remains as it was pre-mining.

The most common anion in baseline Rosebud coal groundwater samples from the Big Sky Mine Area B is sulfate (**Figure 8-7** and **Figure 8-8**). Anionic composition of Rosebud coal groundwater at the Rosebud Mine is equally sulfate and bicarbonate. Major cations in Rosebud coal groundwater at both mines are calcium and magnesium although sodium is dominant in some samples from Big Sky Area B. TDS concentration in Rosebud coal baseline samples ranged from 332 mg/L to 6,660 mg/L (average = 1,678 mg/L; median = 1,220 mg/L) at the Rosebud Mine and from 1430 mg/L to 4,300 mg/L (average = 2,411 mg/L; median = 2,020 mg/L) at Big Sky Area B (**Figure 8-9** and **Figure 8-10**). Based on specific conductivity, Rosebud coal groundwater at the Rosebud Mine is Class I, Class II and Class III, with most samples falling into Class II. At Big Sky Area B, Rosebud coal groundwater is Class II and Class III.

8.2.5 Interburden Baseline

The interburden between the Rosebud and McKay coal seams ranges in thickness from 10 feet to over 100 feet with an average thickness of 40 feet to 60 feet. Like the overburden, it is composed mostly of thin, discontinuous beds of siltstone and claystone and is not considered a productive water bearing stratum. It has the lowest geometric mean hydraulic conductivity of all water bearing units in the Rosebud Mine and Big Sky Mine (**Table 8-2** and **Table 8-3**). Locally, as in the east part of Area B at Rosebud Mine, the interburden may be saturated and appear to be in hydraulic connection with the McKay coal. In Rosebud Mine Area D where the interburden is notably thin, it has heads that vary to above the base of the Rosebud coal. At Big Sky Mine Area B, the interburden in the north and northwest part of the permit area is in hydraulic connection with the McKay coal.

As in most of the shallow aquifers, in interburden baseline samples, sulfate is the dominant anion. (**Figure 8-7** and **Figure 8-8**). At the Rosebud Mine, magnesium and calcium are the dominant cations. However, interburden samples at the Big Sky Mine have notably higher medians of sodium and potassium than at the Rosebud Mine (**Figure 8-9** and **Figure 8-10)**. Interburden baseline TDS concentrations at the Rosebud Mine range from 112 mg/L to 5,990 mg/L, with an average and median of 1,912 mg/L and 1,680 mg/L, respectively. Groundwater class includes Class I, Class II and Class III. Big Sky Mine Area B baseline interburden has a range of 1,720 mg/L to 3,670 mg/L with an average and median of 2,620 mg/L and 2,595 mg/L, respectively.

8.2.6 McKay Coal Baseline

The McKay coal is eight to 12 feet thick. It was the target of early mining in Big Sky Mine Area A, but has not been mined elsewhere in the Colstrip area. The McKay coal aquifer is generally confined except near outcrop boundaries. In Big Sky Area B, the McKay coal aquifer is confined more commonly in the northwest than the southeast. It was confined throughout Rosebud Mine Area C prior to mining with more than 100 feet of head commonly measured in monitoring wells. In Area D, it and was unconfined only in the northwest permit area.

As in the Rosebud coal, permeability in the McKay coal depends on the secondary permeability of fracturing. Based on aquifer tests, the McKay coal has a smaller range of hydraulic conductivity than the Rosebud coal (**Table 8-2** and **Table 8-3**).

In baseline samples, the water quality of the McKay coal is dominated by sulfate with few samples ranging to bicarbonate (**Figure 8-7**, **Figure 8-8**, **Figure 8-9**, and **Figure 8-10**). None of the baseline samples from Big Sky Area B are dominated by bicarbonate, only sulfate. Samples from the Big Sky Mine are not as dominated by calcium and magnesium as at the Rosebud Mine, and more commonly range to sodium. Potassium concentrations also typically are higher at Big Sky Mine Area B. McKay coal groundwater at both mines generally contains more sodium and potassium than the Rosebud coal. TDS concentrations in McKay coal baseline samples from the Rosebud Mine range from 380 mg/L to 5,770 mg/L, with an average of 1,213 mg/L and a median of 1,970 mg/L. At the Big Sky Mine Area B, TDS concentrations in McKay coal baseline samples range from 1,660 mg/L to 3,510 mg/L, with an average and median of 2,425 mg/L and 2,440 mg/L, respectively.

8.2.7 Underburden Baseline

The term “underburden” describes all strata below the McKay coal. It is generally composed of the same, fine-grained rock types found in the overburden and interburden but is distinguished by widespread sandstone and silty sandstone units with greater hydraulic conductivity and more reliable groundwater yield than found in overlying aquifers. The water bearing units are generally 50 feet to 100 feet or more below the McKay coal. It is the best shallow groundwater resource in the mine area and is utilized for domestic and livestock supply.

Monitoring wells in the underburden are completed at various depths, with an average of approximately 200 feet but a range to over 500 feet. Some contain as little as 19 feet of water and others as much as 330 feet of water. The head in some of the deeper underburden wells suggests that the aquifer is confined. Aquifer tests on three underburden wells near Rosebud Mine Area C had a transmissivity range from 58 gpd/ft to 933 gpd/ft with a lognormal mean of 205 gpd/ft (Western Energy Co., 1984). The underburden aquifer is both confined and unconfined in Big Sky Area B, with saturation measured

between one foot and 35 feet in unconfined locations with confined sections measuring almost 150 feet. The underburden maintains the downward vertical gradient common between the shallow aquifers in the area.

As in all the shallower aquifers, baseline water quality in the underburden is dominated by sulfate as the major anion. Calcium and magnesium are the dominant cations, but samples commonly trend to sodium as the dominant cation (**Figure 8-7**, **Figure 8-8**, **Figure 8-9**, and **Figure 8-10**). At the Rosebud Mine, underburden baseline samples had TDS concentrations that ranged from 890 mg/L to 4,460 mg/L, with an average of 2,034 mg/L and median of 1,905 mg/L. Baseline underburden samples at Big Sky Area B had TDS concentrations that ranged from 1,150 mg/L to 4,540 mg/L, with an average of 2,205 mg/L and median of 2,035 mg/L.

Baseline underburden groundwater is Class II and III at both the Rosebud Mine and Big Sky Mine Area B. Underburden wells are typically suitable for livestock use, and some are marginally suitable for domestic use.

9.0 HYDROLOGIC IMPACT & MATERIAL DAMAGE ASSESSMENT

As required by ARM 17.24.314(5), DEQ must provide an assessment of the cumulative hydrologic impacts of the proposed operation and all anticipated mining upon surface and groundwater systems in the cumulative impact area. The assessment must be sufficient to determine if the proposed amendment (AM4) at the Rosebud Mine has been designed to minimize impacts to the hydrologic balance inside and outside the permit area and to prevent material damage to the hydrologic balance outside the permit area.

9.1 MINIMIZATION OF IMPACTS AND PREVENTION OF MATERIAL DAMAGE

Montana's Strip and Underground Mine Reclamation Act requires permit holders to employ measures to minimize disturbance to the hydrologic balance on and off the mine plan area and to prevent material damage to the hydrologic balance outside the permit area. Per ARM 17.24.314(1), the proposed measures must minimize disturbance to the hydrologic balance sufficiently to sustain the approved postmining land use and the performance standards of ARM 17.24 subchapters 5 through 12, and must provide protection of:

> *"(a) the quality of surface and groundwater systems, within both the proposed mine plan and adjacent areas, from the adverse effects of the proposed strip or underground mine operations;*
> *(b) the rights of present users of surface and ground water; and*
> *(c) the quantity of surface and ground water within both the proposed mine plan area and adjacent areas from adverse effects of the proposed mining activities, or to provide alternative sources of water in accordance with ARM 17.24.304(1)(e) and (f) and ARM 17.24.648, where the protection of quantity cannot be ensured."*

Among these measures are requirements and performance standards given for a variety of processes and activities. These include requirements and standards for drainage control, pond design and maintenance, sediment control, road design and maintenance, reclamation, permitted discharges to surface water, and protection of undisturbed drainages.

Specific provisions for protection of and minimization of impacts to groundwater include requirement for prevention or control of harmful mine drainage into groundwater (ARM 17.24.643), restoration of the approximate recharge capacity (ARM 17.24.644), selective placement of acid and toxic forming materials in mine backfill to prevent leaching (ARM 17.24.501, 17.24.643), and permanent sealing of drilled holes (ARM 17.24.632).

In addition, adherence to Best Technology Currently Available (BTCA) and Best Management Practices (BMPs) in the design and implementation of facilities, equipment, devices, systems, methods, and techniques is required for the minimization of hydrologic disturbance. These requirements and performance standards established in ARM 17.24 subchapter 5 through subchapter 12 are incorporated into mine operation and reclamation plans.

As defined by Montana statute [82-4-203(32), MCA], "material damage means, with respect to protection of the hydrologic balance, degradation or reduction by coal mining and reclamation operations of the quality or quantity of water outside the permit area in a manner or to an extent that land uses or beneficial uses of water are adversely affected, water quality standards are violated, or

water rights are impacted. Violation of a water quality standard, whether or not an existing water use is affected, is 'material damage'". Each mine permit application must be designed to prevent material damage to the hydrologic balance outside the permit area [ARM 17.24.314(1)].

9.2 MINING IMPACTS

Impacts to the hydrologic system are expected as a result of mining. Groundwater and surface water will experience both short term and long term impacts that include diminishment of surface water flow due to sediment ponds placed below mine disturbance, drawdown of groundwater levels or declines in pressure head, and changes in water quality in both surface water and groundwater. Impacts to surface and groundwater are discussed in detail below.

9.2.1 Historic, Pre-law Mining

Mining in the Colstrip area by Northern Pacific (NP) from 1925 to 1958, left approximately 2,100 acres of pre-law mine spoils ("NP spoils") at or adjacent to Rosebud Mine Area D and Area E. Another pre-law area known as Pit 6, located adjacent to and south of Area E and was mined during the 1960's and 1970's. Extensive areas of Big Sky Mine Area A were also mined prior to enactment of MSUMRA. The mines are held to the reclamation standards in the law and rules in effect at the time of mining.

Approximately 460 acres of unreclaimed mine spoils and open pits remained in the current Area D permit boundary when Western Energy Company began mining Area D in 1986. Although the area had not been reclaimed, 40 to 50 years of vegetation colonization had occurred, resulting in development of grasses, forbs, shrubs and some trees in favorable habitats. Western Energy Company reclaimed parts of the pre-law disturbance adjacent to permitted mining, but small areas of pre-law mining disturbance remain unreclaimed. Pre-law spoils and pits significantly altered the pre-1925 (unmined) drainage topography, intercepting undisturbed areas above and creating large areas of internal drainage within the Cow Creek drainage basin and within the East Fork Armells Creek drainage basin.

9.2.2 Alluvial Valley Floors

As defined in 82-4-203(3)(a) and (b), MCA, "'Alluvial valley floor' means the unconsolidated stream-laid deposits holding streams where water availability is sufficient for subirrigation or flood irrigation agricultural activities. The term does not include upland areas that are generally overlain by a thin veneer of colluvial deposits composed chiefly of debris from sheet erosion and deposits by unconcentrated runoff or slope wash, together with talus, other mass movement accumulation, and windblown deposits".

MSUMRA requires that DEQ not approve an application for mining an alluvial valley floor (AVF) unless certain requirements are met [82-4-227(3)(b)(i)and (ii), MCA]. To make an AVF determination DEQ must make a finding regarding the existence of an AVF within or adjacent to any surface mine permit application in accordance with ARM 17.24.325.

In *re Permanent Surface Mining Regulation Litigation*, 1980 U.S. Dist. LEXIS 17722, at *70-71 (Dist. D.C. 1980), Judge Flannery noted that an alluvial valley floor must satisfy both geologic criteria and hydrologic criteria which together provide sufficient water to sustain agricultural activities. Thus, the key to the existence of an AVF is the presence of both geomorphic characteristics and water availability which together support agricultural activities, and unless both sets of criteria are met, an AVF does not exist.

The alluvial valley floor (AVF) decisions in the Colstrip area were made in the early to middle 1980's (**Table 9-1**). The Office of Surface Mining, Reclamation, and Enforcement (OSMRE) made a negative AVF decision for Big Sky Mine's Coalbank (Emile) Coulee in its December 1979 Technical Environmental Assessment (TEA) of the area based on the failure to meet the geomorphic criteria for stream channels. The Department of State Lands concurred with OSMRE's findings in a memo dated October 14, 1982. The memo stated that "Coalbank Coulee is cut in consolidated bedrock and subsequently filled with slope wash colluvial material. No alluvial terraces are present and the area …has historically been used as undeveloped rangeland" and "does not meet the requirements of an AVF as defined by ARM 26.4.325."

A more comprehensive study was conducted by Peabody Coal Company in the Lee Coulee AVF study, including detail on geomorphic features, soils, vegetation, irrigation, subirrigation, hydrology, and present and historic land use. In March 1986, The Department of State Lands published an AVF decision document for Lee Coulee. The determination stated that the Lee Coulee valley "contains alluvial fans, isolated terraces, residual surfaces, and aeolian deposits. As a result of this geomorphic description, the Department has determined that Lee Coulee and its tributaries meet the definition of upland areas, and therefore, do not satisfy the geologic criteria of an alluvial valley floor."

In the Rosebud Mine area, AVF decisions were made for East Fork Armells Creek, Stocker Creek, Pony Creek, Spring Creek and Cow Creeks. Only a part of Cow Creek and a downstream section of East Fork Armells Creek affirmatively met the definition of an alluvial valley floor. The decisions were based on rules in effect at the time of the decisions [per ARM 26.4.325(2)(b)]. These rules were similar but not identical to the current rules. [Note: A rule update subsequent to early AVF determinations has renumbered ARM 26.4.325(2)(b) to ARM 17.24.325(2)(b)].

The Cow Creek Alluvial Valley Floor Investigation in 1984 (Western Energy Company, 1984), notes that the agricultural land use in the Cow Creek Study area had been affected by construction activities associated with Montana Power Company's ash disposal pond. Alluvial/colluvial deposits along the main Cow Creek channel were excavated to provide materials for pond construction. This took hay fields out of production, including moisture-enhanced areas of vegetation. The total area of cropped fields was reduced from 338 acres to 279 acres.

The area of EFAC between Stocker Creek and Corral Creek (north of the surface water and groundwater CIA boundaries) is the only AVF identified in the Colstrip area. This section is downstream of the town of Colstrip and is subject to impacts from numerous sources other than mining. Changes in water level and water quality can be expected from leaks from ash ponds associated with the Colstrip Power Plant, discharge from municipal utilities in the town of Colstrip, and infiltration from the water storage facility known as Castle Rock Lake. There are no surface water sites within the AVF reach that have been monitored since 1985. A USGS stream gauge and sampling site has the longest record spanning 1975 to 1985.

9.2.3 Mine Surface Facilities

Rosebud Mine surface facilities are located in Area A and Area C. The Area A facilities are at the mine entrance, on the north side of EFAC. The facilities include an office complex and supporting infrastructure, shop for heavy equipment maintenance, warehouse, storage tanks for non-hazardous liquids, fuel storage and dispensing sites, lined sewage lagoons and evaporation ponds for wastewater.

The Area C facilities area is smaller but has similar support facilities that provide the same services found in Area A. Field support facilities include mobile oil and fuel trucks and electrical substations.

The Big Sky Mine also had similar support facilities in Area A. As the Big Sky Mine is in full reclamation, surface facilities are no longer present. Sampling and cleanup of surface contaminants was completed as part of the facilities closeout. Groundwater monitoring for contaminants in the former facilities area is ongoing.

9.2.3.1 Surface Facilities Impacts to Groundwater and Surface Water

Due to its close proximity, the water resources most likely to be affected by Rosebud Mine Area A facilities is the alluvial aquifer and surface water in EFAC. Increase in the concentration of chloride in surface water and alluvium from the use of magnesium chloride for road stabilization is evident in water quality samples of EFAC in Area A and Area B. Magnesium chloride salt is easily dissolved in water, and due to chemical properties of chloride that facilitate mobility, it has most likely moved into the surface and shallow groundwater system adjacent to the facilities area via infiltration from sediment ponds. Monitoring wells adjacent to roads in more remote areas of the mine also have elevated concentrations of chloride that likely results from the use of road stabilization compounds.

Infrequent releases and incidental spills onto the ground at fueling stations are excavated immediately and placed in the Rosebud Mine Area A landfarm for treatment. There is no indication of petroleum contamination in surface water or groundwater at the Rosebud Mine or Big Sky Mine.

The lack of nitrate nitrogen in water quality samples from EFAC alluvial wells indicates that the stream is not receiving contamination from the Rosebud Mine Area A sewage lagoons. Waste water from vehicle wash bays at maintenance shops in both Area A and Area C are routed to lined ponds for evaporation. Water quality analyses do not indicate contaminated fluids have leaked from these ponds.

9.2.4 Surface Water

Potential impacts to surface water from mining include impacts to wetlands, streams and springs. Determination of impacts has been hampered by sparse premine data due to pre-law and early mining in some drainage basins.

9.2.4.1 Wetlands

The oldest comprehensive wetland inventory for the Rosebud Mine was done in 1995 to determine jurisdictional status of wetlands and other waters of the U.S. (MME, 1995). At the time of the report, 66 wetlands comprising 27 acres of land were identified within and adjacent to the Rosebud Mine permit areas A, B, C, D, and E using the 1987 Corps of Engineers Wetlands Delineation Manual (**Figure 6-3**). Because the study was done during mining, many of the wetland features within the mine area occur around the edges of and downstream of temporary sediment control ponds. Other wetlands are associated with stock ponds and dikes created by ranchers to retain surface water. Almost half of the wetlands acreage was associated with the Area C permit, and these wetlands are predominately located in the West Fork Armells Creek watershed downstream of springs, and will not be affected by the proposed action.

Pond PO-151 is a permanent impoundment located immediately to the east of the power plant facilities within the Rosebud Area D permit. This pond has been left as a permanent impoundment for wildlife use and stock watering after mining at the southwest end of the current mine area. The pond is an

internal drainage within the Cow Creek basin. The pond was intended to replace some of the water resources and aquatic habitat associated with former pre-law Northern Pacific pit ponds. Surface runoff is not likely to overflow the deep closed basin because the pond surface is approximately 40 feet below the lowest surface outlet to Cow Creek tributaries. Groundwater recharge from the pond may supplement down gradient springs, stream reaches, and ponds in nearby tributaries. No water quality or quantity data has been collected at PO-151 and no wetland assessment has been done at the pond to determine the quality of habitat the pond is providing. The 1995 survey did not identify the perimeter of the pond as a wetland. PO-151 will not be affected by the proposed action.

The proposed AM4 amendment and associated disturbance area in Rosebud Area B do not contain any springs or stock water ponds. The amendment area would mine through upstream ephemeral reaches. No wetlands have been identified in the amendment area.

9.2.4.2 Changes to Surface Water Hydrology by Drainage

A discussion of impacts to surface water is given below. For each drainage basin, setting & mining history, pollutant sources and pathways, and relevant monitoring data are discussed. Impacts to the drainage basins below fall under the following categories:

- Alterations in surface and or spring flows from source aquifer drawdown
- Alterations in surface flows from disturbance of the watershed and stream channels
- Removal of tributary sources during mining
- Surface water quality changes from changes in source groundwater quality
- Surface water quality and quantity changes from MPDES discharges to surface water
- Water quality changes from runoff from mining infrastructure (roads & industrial facilities)

9.2.4.2.1 **Cow Creek**

Cow Creek and South Fork Cow Creek drain east to Rosebud Creek, with the ephemeral headwaters of these streams located within the Rosebud Area D and Area E permit boundaries. Pre-law mining occurred in Cow and South Fork Cow Creek drainages leaving behind spoil ridges and unreclaimed pits, altering the natural drainage pattern of the upper watershed. The last mine cut in the Cow Creek drainage was in Area D in 2010. Presently, there is no mining occurring in the Cow Creek drainage, and mine pits have been filled and are in various phases of reclamation.

In addition to mine-related impacts, east of the mine area, the Colstrip power plant uses ponds for the storage of ash in the Cow Creek basin (see **Section 9.3.1** on impacts to alluvial wells).

Premine baseline surface water data is limited due to the extensive pre-law mining in the headwaters of Cow Creek, and do not allow meaningful comparisons of pre and postmine water quality and quantity conditions. The most extensive set of surface water data comes from one monitoring station: spring SP-26 located adjacent to Area D mining.

In the Rosebud Mine Area D permit and previous CHIAs, SP-26 was predicted to potentially experience decreased flow from mining. Spring SP-26 is located in an upper Cow Creek tributary on the life of mine disturbance boundary and a quarter mile south of the nearest mine cut. The spring is within the permit boundary. It is sourced by the McKay coal aquifer, and the McKay coal was not mined in the area. The area up gradient of the spring has a large outcrop of clinker, and the clinker and coal units may be in communication with each other. The spring was not disturbed, but a portion of the drainage area upstream of the spring has been disturbed.

Prior to mining, flow at SP-26 was observed to range between 3 gpm to less than 0.5 gpm with a median of 1 gpm (**Figure 9-1**). The lowest flow measurements were made in the late fall and winter when the spring could have been partially frozen. In late 1996 water levels in the nearby McKay well WM-125 rose by approximately 0.3 ft and remained near 3,254.5 ft until 2002. When mining started up gradient in 2001, SP-26 experienced a delayed reduction in water quantity while WM-125 responded more immediately. Water levels decreased in WM-125 by up to 0.4 ft, and flow from SP-26 decreased by almost 0.5 gpm, and the spring was reported as dry or nearly dry on multiple field visits during this time. Spring flows during these time periods reflect the variability in precipitation over the monitoring period. In late 2005 water levels and flows started to recover in WM-125 and SP-26, respectively. Similarly, recovery of water levels and coincides with a series of years in the middle to late 2000's with higher than average precipitation. The spring and well are located in the vicinity of a large clinker area.

Water quality (TDS) during this period reflects the variability in precipitation (**Figure 9-1**). Prior to 2006, TDS in SP-26 had shown seasonal variation on the order of 250 mg/L or less. After 2006, seasonal variation in TDS increased up to 800 mg/L. There are no obvious means for mining to have introduced higher TDS water to SP-26: there are no large sediment ponds upstream of SP-26 that could have leaked into the source aquifer; up gradient spoils have only one to two feet of water so the spoils remain almost dry, and the McKay aquifer was left intact. TDS measured in WM-125 does not strongly correlate with TDS measured at SP-26. The increase in TDS could be a result of increased flushing of previously unsaturated horizons from years with increased precipitation, thereby increasing seasonal TDS concentrations at this spring. Regardless of the cause of the temporary increase in TDS and decrease in flow, the spring is within the permit boundary so the requirement to prevent material damage does not apply. Furthermore, because the premine water quantity has returned to the spring thereby providing the same premine beneficial use to the area, any disturbance of the hydrologic balance is minimal. The proposed action will not affect the Cow Creek drainage basin.

9.2.4.2.2 East Fork Armells Creek

EFAC is divided into two segments for the purpose of issuing MPDES permits: an upper section that encompasses the headwaters down to the state highway and a lower section that includes the segment from the state highway to the confluence with West Fork Armells Creek. For analysis of surface water impacts in this CHIA, this division is important as the two segments of the creek behave differently and therefore have different applicable standards.

Upper EFAC is predominately ephemeral and is flanked by active mining activity along most of its length. Some channel segments of the upper section have defined channels while other segments have less defined channel bottoms. In many places in the upper section, the stream bottom has been widened by cattle (see **Appendix A**). Small reaches of flowing water exist, and these are associated with instream stock dams. While livestock grazing and channel use by livestock occurs in areas upstream of mined areas, coal mining activity (open pits, reclaimed lands, sediment ponds, roads, mining facilities, and associated infrastructure) dominates the potential anthropogenic pollutant sources in upper EFAC.

Lower EFAC has large reaches with intermittent to perennial flow. While no coal mining occurs adjacent to lower EFAC, the reach is influenced by coal mining activity upstream and in Area D. In addition to upstream coal mining, anthropogenic sources affecting water quality and quantity in lower EFAC include:

- runoff and infiltration from recreational and residential lands
- runoff from road and transportation infrastructure

- sewage treatment plant discharges
- runoff and infiltration from agricultural lands
- Infiltration from industrial treatment ponds

Mine pits adjacent to EFAC in areas A, B, and C were initiated close to the alluvium in the 1980's and 1990's and have progressed away from the creek. The dewatering of adjacent strata and the withholding of runoff in ponds and pits have contributed locally to lower water levels in the alluvium and reduced the volume of baseflow in EFAC where alluvial water contributed to streamflow. Spatially and temporally limited surface water flow data, however, precludes more meaningful analysis of past flow losses from alluvial depletions.

Pit water meeting the MPDES discharge standards has been discharged via MPDES outfalls directly into EFAC, and there has also been seepage from sediment ponds into the alluvium. Since a new and more reliable continuous flow monitor was installed in late 2011 at SW-55, located immediately upstream of the state highway crossing of EFAC, it has recorded the presence of water for almost all of 2012 (**Figure 9-2**), a relatively dry year. The upgrade in instrumentation is also coincident with a period of increased discharges to EFAC. Crest gauge data combined with the continuous recorder at SW-55 indicates that this area may routinely have flowing or ponded water for months out of the year. The flow data coupled with observations during regular mine inspections of EFAC indicate that the reach between the Area A facilities area and the Area A Tipple has intermittent to perennial water, at least since 2011. Sources of water in this reach may be from discharges and infiltration from sediment ponds up gradient and adjacent to this stream reach as well as baseflow from alluvial groundwater. This reach currently may be artificially enhanced by discharges and infiltration. Conversely, drawdown in the alluvium from mining may have greatly reduced the contribution of natural baseflow from the alluvium in this area in the past. The history of the presence and absence of water in this reach can only be speculated due to lack of surface water monitoring between the Area A facilities and the Area A Tipple after baseline data collection, long periods of poorly functioning instrumentation, and few water quality samples from SW-55.

Aquatic life surveys were conducted in the middle to late 1970's along EFAC and Rosebud Creek. Total counts of macroinvertebrates were low, and sampling methodologies differed between the 1976 and 1978 studies. Additionally, samples taken in November and December are outside of the range of months now accepted for macroinvertebrate studies. The 1970's surveys are only used as a general analysis of stream habitat conditions and are not used to determine specific stressors (e.g. inorganics, organics, metals, sediment, temperature, or water quantity). In general, taxa richness was similar at all the sites sampled along East Fork Armells Creek (**Table 6-3**). Of the three years sampled, the highest number of taxa was in 1978. As 1978 was one of the wettest years (**Figure 4-2**), the stream habitat was likely enlarged from the extra runoff and baseflow. The 1970's surveys provide an indication of the presence or absence of aquatic life but cannot be used to assess the quality of the habitat or stream water. The surveys indicate that, in the past, there has been sufficient water at the sites that were sampled to provide aquatic habitat and support a number of aquatic species.

The 1995 wetland assessment identified two reaches on EFAC between the Area A Tipple and SW-55 as wetlands (**Figure 6-3**). This section of EFAC has been observed in recent years to have larger stretches of intermittent to perennial water with wetland vegetation than was identified in 1995 (see **Appendix A**, photos 5 – 7 and 10 – 12). Since it is unlikely that the 1995 assessment missed wetland features that were present in this reach, it can be concluded that the extent of the 1995 wetland area has grown. This area was also chosen to be sampled in the 1970's as part of a macroinvertebrate inventory. The site

chosen was immediately upstream of the Area A mine entrance and has been observed to have at least intermittent water since 2011. In the 1981 report, the sampling location was described as having insufficient flow for macroinvertebrate sampling. “The site was located at a point above which streamflow seldom occurred. Standing or slow moving water is usually present below Station No. 3 and reflects the effects of groundwater contribution” (Schwehr, 1981).

In 2014, another macroinvertebrate survey was conducted in the stream reach between the Area A Tipple and SW-55. The sampling methodology, which followed DEQ’s WQPBWQM-009 (2012), differed from the methodologies used in the previous studies so that taxa richness may not be directly comparable. However, the survey demonstrated that a diverse community of macroinvertebrates was using the stream reach. Therefore, the reach currently meets the narrative standard of providing a beneficial use for aquatic life.

Figure 9-93 shows sulfate through time at various intermittent reaches on EFAC, and samples that would violate the guideline sulfate toxicity threshold listed in **Table 2-3** are circled in red. Sulfate limits for aquatic life are typically 2,000 mg/L due to the very high hardness of the stream water. Even in baseline samples, the sulfate thresholds for aquatic life were exceeded. Macroinvertebrate communities in Eastern Montana are likely adapted to high sulfate water.

In the 1980’s, when mining was closest to EFAC and many of the ponds next to EFAC were the most active, water quality samples from ponds near EFAC in the reach between the Area A Tipple and SW-55 routinely had chloride concentrations over 100 mg/L. Chloride concentration in mine pit water is not usually elevated above background levels, and consequently the chloride in these samples from the 1980’s is not attributed to natural groundwater or spoils. As mining moved away from the stream into the basin’s headwaters, the concentration of chloride in the ponds declined. The high chloride at this time was likely from operational activities, such as the use of magnesium chloride on active haul roads. Presently, high chloride concentrations are found in surface water and alluvial water samples in the reach between the Area A Tipple and SW-55. In 2012, chloride concentration in surface water in this reach was as high as 464 mg/L. From 2012 through 2014, 4 out of 5 samples from SW-55 had chloride concentrations above 100 mg/L. SW-55 receives flow from runoff events, MPDES discharges, and baseflow from alluvium (**Figure 9-2**). Groundwater infiltrating from ponds at the power plant flows towards the stream and mixes with alluvial water by SW-55. Bottom ash and flyash ponds within 0.7 miles of SW-55 have had chloride concentration that ranged from 181 mg/L to 807 mg/L (PPL Montana, 2014). The high chloride concentration at this site is likely from flushing of chloride in the soil and alluvium by the WECo Area A facilities in addition to chloride from the leaking power plant ponds. The current uses of the water in the vicinity of the intermittent reaches are for livestock, wildlife, and aquatic life. Further downstream on EFAC, the water is also used for irrigation. Because the stream still maintains its C-3 uses (primarily aquatic life, non-salmonid fishes, and agriculture) per ARM 17.30.629, the beneficial use of the stream is still maintained. The proposed mine plan is designed not to contribute additional chloride to the stream because lignin sulfonate will be used on roads instead of magnesium chloride.

While the reach of EFAC between the Area A tipple and SW-55 has seen an artificial increase in surface water due to mine operations, other reaches have experienced a reduction in intermittent and ephemeral flows. Capture and containment of water in sediment control ponds from ephemeral tributaries in mined areas can decrease the amount of runoff and/or flow delivered to EFAC. The sediment ponds cause a reduction in storm-driven flows in EFAC.

Baseflow in EFAC by SW-55 is predicted to experience a postmine increase in TDS of 13%, elevating the average concentration of TDS to almost 2,600 mg/L (Western Energy Company, 2015). The increase in TDS comes from spoil replacing the Rosebud coal as the aquifer feeding baseflow to the stream. This increase will not occur until the spoil has resaturated and groundwater flows from the spoils to the alluvium of EFAC. The proposed action will increase the volume of spoils generated by the mine, and groundwater from the recharged spoils may ultimately become baseflow in the creek. The postmine water quality should continue to support livestock use, although the water quality in the stream may be diminished from premine quality. Western Energy Company will continue to periodically conduct macroinvertebrate surveys to monitor the vitality of both aquatic life and habitat available in EFAC. Surface water quality and quantity sampling will continue at SW-55 on EFAC. Because the creek should be able to support its designated beneficial uses, even when spoil water contributes to baseflow, the proposed mine plan is designed to prevent material damage.

SP-28, located close to the EFAC channel, was listed as destroyed by mining in the 1986 baseline observations for the Rosebud Mine Area B permit. In November 1979 this spring was estimated to have between 5 and 10 gpm of discharge and was thought to originate from the overburden. The spring was likely destroyed in 1983 when a mine cut went through the area immediately upstream of the spring. While no data was collected on the spring's water quality or quantity (besides the one estimated flow), the discharge from the spring would have likely contributed to surface water flow in EFAC near the Area A tipple. The proposed action will not create additional disturbance to this area.

Two sections of upper EFAC (a reach in T1N R40E Section 8 and a reach in T1N R40E Section 15) were identified in the middle 1980's as possessing intermittent to perennial flow (**Figure 6-3**), and both of these reaches are currently observed as being ephemeral (see **Appendix A**, photos 3 and 17). The reach through T1N R40E, Section 8, is upstream of mining in Areas B and C and directly upstream of a large stock dam (PO-937) on EFAC. The reach through T1N R40E Section 15 is also upstream of an instream dam.

The Section 15 reach contains a premine stock pond built directly into the channel, and the approximately 20-foot thick alluvium. This portion of EFAC has a small segment of alluvium directly on top of the Rosebud Coal; upstream the alluvium sits on overburden and downstream the coal has been eroded away and the alluvium sits on top of interburden (**Figure 9-92**). The Section 15 reach was included in an aquatic and stream water quality survey done prior to mining in the area in 1970's. At this time, the reach was described as follows: "There has always been sufficient flow [below the small impoundment on the creek] to sample for water chemistry, however, flow is often too low to sample for invertebrates… This is one of the few locations on the creek upstream from Colstrip which has at least some flow through most of the year…" (Schwehr, 1981). In the Area B permit, the baseline description of the area was of "A short reach of East Fork Armells Creek in the northwest quarter of Section 15 hav[ing] flow throughout the year. A flow of 12 gpm at the west edge of Section 15 was measured in June of 1984. There was no flow at this point in August of 1984 although approximately 10 gpm was flowing into PO-929" (WECo, 1986). A 1995 wetlands survey identified the reach as having a segment of wetlands (MME, 1995), and water quality samples from this stretch were collected from approximately 1977 through 1983. In field visits in 2014, DEQ staff observed this area as a dry grassy channel bottom with some riparian trees (**Appendix A**, Photo 18 and 19).

Alluvial water levels in EFAC near the Section 15 reach started to steadily decline starting in the mid 1980's and continued to decline through the 1990's (**Figure 9-92**). Mining adjacent to the reach started in 1992 and was as close as 300 feet to the channel. The longest monitored alluvial well, WA-209,

started to decline in water levels in 1989 with the biggest decreases occurring in 1993 and 1995. Water levels in WA-209 dropped a total of approximately 10 feet before going dry in 1999, and the well has been dry ever since. The alluvial water levels indicate that this area experienced both natural (starting in the mid to late 1980's) and mine-related (steep declines in 1993 and 1995) drawdown. The nearest spoil well, WS-191, is located in the B Extension area (the B-extension pit was mined in 1999), and the well has been dry since installation in 2008. There are no spoil wells currently north of the Section 15 reach in the areas that were mined in the early to middle 1990's. No records exist on the historic status of the instream dam in this section through the years, but the dam is currently intact. The dam may have been the source of some of the water in the stream, but from the early descriptions of the reach, the reach may have been a gaining reach for at least some parts of the year during the 1970's and early 1980's. Mining activities such as cutting off tributaries to EFAC could have reduced the amount of runoff reaching the Section 15 instream pond and reach. This section may see a return of some instream ponding once the upstream sediment ponds are removed. The resaturation of the spoils and restoration of the premine groundwater gradient may also help to restore some baseflow. If flow returns, postmine water quality will depend on both runoff water quality from tributaries and possibly on spoil water quality. There are no surface water rights listed with the DNRC for East Fork Armells Creek through Section 15.

In summary, it is unknown whether there was premine baseflow in EFAC in Section 15, nor is the quantity of water known. Statements as to the nature of this section premine are anecdotal. Since the nature of this section was not well documented in the 1970's, past material damage to this section cannot be determined. While macroinvertebrates were documented using the water in Section 15 in the 1970's, it is unknown if water was present every year, only in wet years when runoff accumulated behind the instream dam, or only after years where the alluvium was saturated to the point of baseflow. Without knowing the true nature of the stream flow and the interaction between groundwater and surface water, a determination of material damage cannot be made.

Alluvial wells near the Section 8 reach measured a decline in water levels of approximately 5 feet from 1980 (the earliest measurement) through 1985. The years from 1983 through 1985 were below normal precipitation years (**Figure 4-2**). From 1985 until 2011, water levels were relatively stable and changed by less than 2 feet. After the large 2011 precipitation event, water levels have increased by 8 to 10 feet in the alluvial wells near Section 8. No observations were made of the presence or absence of surface water in the Section 8 reach after the 2011 recharge. The Section 8 reach may only be fed by baseflow after large recharge events and may be normally dry. Since this reach is also upstream of PO-937, the observed water in the 1980's may actually have been ponded water that was backed up into the reach from the instream dam. Alluvial water levels near the Section 8 and 15 reaches are discussed in **Section 9.2.5.1.1**.

Regardless of the nature of the reaches in Section 15 and Section 8, the proposed permitting action will have no effect on the reach. Therefore, DEQ finds that the proposed action is designed to prevent material damage to these reaches.

One spring has appeared in reclamation in Rosebud Mine Area C permit within the EFAC basin. Spring SP-46A has been monitored since 2001 (**Figure 9-3**), and is thought to be sourced from spoil water. TDS in the spring water has generally increased since monitoring began. The increase in TDS is mainly a result of increasing sulfate with minor contributions from small increases in calcium, magnesium, and sodium. In contrast, bicarbonate has decreased in concentration over time.

While changes to EFAC have been seen adjacent to the Rosebud Mine (areas A, B, and C), the magnitude and extent of surface mining impacts to EFAC downstream of mining (Colstrip and beyond) are difficult to quantify because of the contributions of additional industrial and municipal surface and groundwater water impacts in the Colstrip area. Proposed amendment AM4 would not significantly increase anticipated hydrologic impacts to surface water resources within and adjacent to the mine area or downstream in EFAC. Water quality of runoff in well vegetated postmine channels is expected to be similar to premine runoff water quality. During mining and while vegetation is re-establishing, sediment ponds and other best management practices would treat or retain runoff thus preventing excess sediment from entering EFAC. After the final stage of reclamation (phase IV bond release), surface water quality from the disturbed East Fork Armells Creek tributaries should be similar to premine water quality with no water quality changes expected for stock or wildlife use in the reclaimed drainages. Postmine baseflow in EFAC by SW-55 will be influenced by spoil water quality, and the baseflow will have increased TDS, mainly in the form of increased sulfates. The mining from AM4 will create increase the amount of spoils, but groundwater in these spoils will not move to EFAC.

9.2.4.2.3 Lee Coulee

The Lee Coulee drainage flows to the southeast into Rosebud Creek, and is predominantly ephemeral with some intermittent reaches. Mining in the Lee Coulee drainage began at the Big Sky Mine Area B in the early 1990's. The final pit at the Big Sky mine was mined in 2003. The Rosebud mine's Area B has cuts permitted within the Lee Coulee drainage basin along the drainage divide between EFAC and Lee Coulee.

Water quality in Lee Coulee is highly variable due to a mixture of runoff dominated flows and some reaches with groundwater dominated baseflows. The intermittent reach within the permit boundary experiences both types of flow regimes; at station BRTFL on the intermittent reach section, measured TDS (1984 through 1997) ranged from 220 mg/L during a February sampling event to 4,330 mg/L during an October sampling event. Median measured TDS was 2,700 mg/L.

Impacts to Lee Coulee surface water flow from mining are monitored at flume BS33FL which is located downstream of all mining in Lee Coulee (**Figure 9-4**). Starting in the 2000's, large flow events at BS33FL have become less frequent. Upstream of mining, at flume BPSFL, flows have become less frequent in general, although large flow events have become more frequent and larger. The changes in flows at both of these monitoring sites coincide with mining in the area and a climate period where annual precipitation varied widely. The change in flow characteristics in Lee Coulee downstream of mining are a combination of a shift in precipitation patterns as well as reduction in flow due to mining operations. The following paragraphs describe impacts from mining that have been observed in Lee Coulee.

Discharge of water to Lee Coulee from Big Sky ponds B-9 and B-22 began in late 1989 and in 1994, respectively, and ceased in June 1997. Monitoring wells below these discharge points experienced ground water level rises on the order of 10 to 15 feet, peaking in about 1995 to 1996 at wells closest to the discharge point. A 14-foot ground water level rise was observed downstream, outside the permit area, at well BAL2711. At this well, the peak occurred in about 1996 to 1997. The artificially recharged alluvial groundwater moved slowly down Lee Coulee. No significant changes to Rosebud Creek water quality were observed during this time (**Figure 9-5**).

The last of the sediment retention ponds were removed from Lee Coulee in 2013 allowing more runoff to leave the mine. The removal of the ponds will not likely degrade water quality leaving Lee Coulee and entering Rosebud Creek because the reclaimed mine area is well vegetated and flatter than premine.

The flatter and well vegetated reclamation area will result in less sediment and runoff leaving the site compared with premine.

Lee Coulee had a 'wet reach' through the Big Sky Mine Area B which was used by wildlife and was fed by baseflow from overburden and Rosebud coal aquifers from the north and northwest. The reach was intensively studied between 1989 and 1995 to determine the premine characteristics and to monitor impacts during the initial years of mining. This reach contains three dugout instream depressions which were likely created for livestock watering. Aquatic life and vegetation surveys focused on the three ponded areas where surface water would linger the longest throughout the year, although some samples were also collected in other segments of the creek. The aquatic life surveys concluded that the most upstream site had less diversity than the two sites downstream. The reduced diversity was theorized to be associated with increase stress on the ecosystem due to a more ephemeral setting with more sediment in the pond (BSCC, 1997). Overall, the taxa that were found had a high tolerance for poor water quality and stagnant water conditions. Taxa richness declined coincident with increased mining activities in the drainage (**Table 6-3**).

Pit dewatering and drawdown of coal, overburden, and adjacent alluvial aquifer water levels reduced and even eliminated intermittent flows in the Lee Coulee wet reach. The intermittent Randy Thomas site (BRTFL) is within the Lee Coulee wet reach, and flow monitoring recorded reduced baseflows beginning in 1994 after groundwater levels were drawn down by mining of adjacent pits (**Figure 9-4**). Mining drawdown appeared in alluvial wells in this area in 1993. Runoff events at the BRTFL site were also captured by upstream sediment ponds and mine pits. Stream baseflows are predicted to recover as backfilled spoil material saturates (see **Section 9.2.5.2.7**). The re-constructed portion of the wet reach of Lee Coulee has yet to exhibit persistent flowing water as of the end of the 2013 water year, but the unmined section of the wet reach has been observed to have water and riparian habitat (see **Appendix A**, photo 14). Monitoring stopped at the BRTFL site in 2001 and resumed at the same location in 2014 to determine if baseflow is recovering.

Two postmine end-pit ponds were created during reclamation in tributaries to the main Lee Coulee drainage (see **Appendix A**, photos 15 and 16). These ponds were left to provide postmine wetland and wildlife habitat as well as livestock drinking water, and the ponds are fed by up gradient unmined coal aquifers.

The quality and quantity of postmine spoils water entering Lee Coulee from the Big Sky Mine and its alluvium will largely dictate postmine surface water conditions in the coulee. As a result of mining and reclamation in Lee Coulee, there is a potential for change from premine conditions in the location and timing of groundwater flow from bedrock to the Lee Coulee wet reach. The quality of groundwater that will eventually discharge from spoils at the west end of the Big Sky Mine, adjacent to and within Lee Coulee will affect the restored wet reach. Both mining in Big Sky Area B and Rosebud's Area B could contribute spoil water to this reach. As this reach is entirely contained within Big Sky's permit boundary, changes to water quality will not result in material damage. Because Lee Coulee is ephemeral below the Big Sky mine permit boundary, this spoil water is unlikely to reach Rosebud Creek via surface water flows. **Figure 9-93** shows sulfate concentrations through time in the intermittent reach of Lee Coulee. Compared to EFAC, Lee coulee has fewer exceedances of the guideline sulfate criteria. Postmine baseflow from spoils could result in increased sulfate in this reach. The potential impact to the macroinvertebrate community is not known; the species found during premine studies are common in Eastern Montana and therefore they may be adapted to high sulfate water.

Springs within the Lee Coulee basin have been noted off the main drainage channel and toward the drainage divide. SP-78 is located immediately outside of the southern boundary of Rosebud Mine Area B. This spring was noted in the Rosebud Mine Area B baseline survey as discharging an estimated 4 gpm in May 1986 with an overburden source. This spring has not been observed since the initial baseline survey, but it was predicted by the mine to possibly experience a reduction in flow from mine-related drawdown. Further south in the Lee Coulee basin there are five springs that were monitored by the Big Sky Mine. These are Bailey Spring, Gumdrop Spring, Headwater Spring, P.P. Seep, and Section 29 Spring.

Water quality samples were collected from P.P. Seep from 1985 through 1995, and the median field conductivity during that period was 1,053 μS/cm. During baseline observations in 1985, it was noted that the seep dried up during the late summer and came back in the late fall. The seep has now been dry for years. Headwater Spring has been monitored for water quality since 1985 and is still actively monitored. This spring tends to have less than 1 gpm of flow at the time of monitoring (usually visited in March or April and again in August or September). A perched overburden aquifer on top of clinker is theorized as the aquifer source for the spring, and it was thought mining would not impact the spring. Field conductivity has remained consistently between 2,000 μS/cm and 3,000 μS/cm. Gumdrop Spring has consistently had water since the start of monitoring and usually has less than 1 gpm of flow during semiannual observation. The Section 29 Spring was sampled for water quality from 1989 through 1992, and in the early nineties it was mined through. It is unknown if another spring will return to the area. Median conductivity measured in the field was 1,706 μS/cm during the monitoring period. The land around Bailey Spring was undisturbed by mining, and the spring has never been monitored or sampled.

The proposed expansion of mining in Rosebud Area B in AM 4 is will not affect the water quality in the Lee Coulee drainage. Spoil water from Area B AM 4 cuts will not contribute to surface flow.

9.2.4.2.4 Miller Coulee

Little flow or water quality data has been collected in Miller Coulee due to the age of the mine disturbance. Mining at Big Sky Area A started before baseline hydrologic data was required, and consequently no baseline data exists for the drainage. Although the edges of the mined area are blended into the steeper topography, the middle of the mined area was reclaimed to a landscape of low relief with hay fields at the southern portion of the permit area. The mined area is also in the headwaters of the drainage. Due to these factors, flow in the area is ephemeral.

In Miller Coulee, a seep fed by spoil water has developed in the drainage bottom (see **Appendix A**, photo 13). Water quality samples were collected from the seep at 6 locations in May 2011 and May 2012. TDS ranged from 4,110 mg/L to 5,590 mg/L in 2011 and from 3,840 mg/L to 22,100 mg/L in 2012. In 2011, the full analytical suite in Big Sky Mine's monitoring plan was completed for the samples. Sulfate was the dominant ion in the samples with concentration ranging from 2,580 mg/L to 3,910 mg/L, and the second major component was bicarbonate with concentrations ranging from 455 mg/L to 823 mg/L. Despite the high sulfate concentration, pH measured in the field remained neutral to alkaline: 6.9 to 7.9. In this area, high TDS is not correlated with a notable increase in metals or trace element concentration.

In 2012, the year with the highest measured TDS concentrations, only TDS, conductivity, and pH were measured, and consequently it is unknown what cation, anion, or combination of analytes contributed to the extremely high TDS. In 2012, two samples taken from small pools of ponded water in the seep area had TDS concentrations over 10,000 mg/L. These sites had more than a 4-fold increase from 2011 to 2012. This large increase in one year is may be a result of evaporative concentration in the pooled

water and is not an indication of large changes in spoil water quality. TDS concentration in spoil up gradient of the seep has ranged from 3,510 mg/L to 4,510 mg/L, which is similar to the range of TDS concentration (3,840 mg/L to 5,590 mg/L) in the seep samples from 2011 and 2012 when the two samples over 10,000 mg/L are excluded. This area of Miller Coulee was mined prior to the enactment of SMCRA in 1978, and therefore material damage criteria do not apply. Furthermore, because the proposed mining in AM4 will not contribute water to Miller Coulee, the proposed action is designed to prevent material damage.

9.2.4.2.5 Pony Creek

The Pony Creek drainage is monitored by the Rosebud Mine for potential impacts from mining and by PPL as a reference creek in a program to monitor for power plant impacts to Cow Creek drainage. Consequently, a large data set has been created on water quality and quantity for the creek, springs, and alluvium in Pony Creek.

In their PHC analysis of hydrologic impacts from mining in Rosebud Area D, Rosebud Mine predicted that spring SP-24, located near the head of Pony Creek, could potentially experience significant impacts to quantity and quality from mining. Spring SP-24 has a source in Rosebud coal, and the spring feeds a pond, PO-917, created by the landowner for livestock use. The spring was expected to experience reduced flow during mining and increased dissolved solids concentrations after mining. The spring was not consistently monitored for water levels during mining and no flow measurements were taken. The spring was reported as dry for a number of years after 1992 and water level monitoring was subsequently abandoned. Water quality samples were taken through the middle 1990's at SP-24, indicating that the spring was not continuously dry. Three water quality samples from the middle 1990's are much higher in TDS than all of the other water quality samples (**Figure 9-6**). Ignoring the three outlier samples from the 1990's, starting in 2006, the TDS concentration has been elevated by approximately 200 mg/L to 500 mg/L. The cause for this increase is not known, and the change could be some combination of changes in precipitation patterns, evaporation at the sampling point, and changes to groundwater from mining operations (e.g. drawdown in the coal aquifer, artificial recharge from sediment ponds, etc.). TDS from spring GSP-7 is also shown in **Figure 9-6** for a comparison. GSP-7 is over 4.5 miles downstream from SP-24 in the Pony Creek drainage, and the source aquifer is unknown. This spring is outside of the influence of the Area D mine and shows variation in concentration from sources unrelated to mining. TDS concentration varies widely from a minimum of approximately 300 mg/L to a maximum of 3,300 mg/L. As demonstrated by GSP-7 and the middle 1990's data at SP-24, variation of water quality at springs unaffected by mining can be on the same order of magnitude or greater than increases that may be attributable to mine practices. The conditions in Pony Creek do not indicate the existence of material damage at this time because changes in water quality cannot be correlated with mining activities. The proposed mining in AM4 will not contribute water to Pony Creek, therefore the proposed action is designed to prevent material damage.

9.2.4.2.6 Rosebud Creek

Impacts to Rosebud Creek would come from changes in water quality and quantity in major tributaries including Lee Coulee, Miller Coulee, Cow Creek, Pony Creek, Hay Coulee, and Spring Creek. Because upstream mining disturbance is more extensive in Lee Coulee, Miller Coulee, Cow Creek, and to a lesser extent, Pony Creek, mining impacts are most likely in these drainages, but have been predicted to be insignificant below their junctions with the much larger Rosebud Creek drainage (**Table 9-2**). Because of more limited surface disturbance in Hay Coulee and Spring Creek, mining impacts to these surface water systems are expected to be limited to the upper reaches of the drainages within and near mined areas, and would be difficult to detect in the lower reaches near Rosebud Creek.

Two stations on Rosebud Creek upstream (BURCXS) and downstream (BUSGS) of Lee Coulee were used to determine if hydrologic impacts to Lee Coulee could be detected in Rosebud Creek. TDS is shown in **Figure 9-5** as a general indicator of changes in water quality. In general, the variation in TDS between the two stations is usually less than 100 mg/L, and the station downstream of Lee Coulee recorded higher TDS than the station upstream of the creek. Flow measurements were taken on the same day at the two stations from 1989 to 1993, and these measurements indicate that Rosebud Creek may be a losing reach around the confluence with Lee Coulee. Using the flow measurements in conjunction with water quality samples, a total dissolved solids load was calculated for these two monitoring stations. The salt load reveals that Rosebud Creek gains salt between these two monitoring points. The concentration of TDS measured at the downstream station has not increased over time, and similarly no trend can be seen in the difference in concentration between the upstream and downstream stations.

Figure 9-5 shows that most water quality samples collected since 1980 on Rosebud Creek near Lee Coulee have exceeded the water quality standard for specific conductance defined in ARM 17.30.670. While most samples exceed the standard for specific conductance, they also are mostly are below the standard for SAR. One sample collected in 1990 was excessively high for SAR, but analysis of the complete analytical data set indicates that this high SAR is likely due to a reporting error; the sample had an anomalously high sodium and low sulfate indicating that these two analytes may have been transposed during reporting.

The proposed action is designed to prevent material damage to Rosebud Creek because as of 2013, there has not been a change in water quality in Rosebud Creek that can be directly attributable to mining in Lee Coulee, Miller Coulee, Cow Creek, Pony Creek, Hay Coulee, and Spring Creek. The drainage area and volume of water carried by Rosebud Creek is much larger than the volume of water contributed by Lee Coulee, and consequently the water chemistry of Rosebud Creek is dominated by runoff and groundwater contributions upstream of Lee Coulee.

9.2.4.2.7 Spring Creek

The Spring Creek drainage immediately downstream of mining in Rosebud Area D contains seven springs and three stock ponds. Five springs and two stock ponds are currently sampled for water quality: SP-23, SP-43, PO-921 in one tributary and SP-44, SP-90, SP-91, and PO-808 in a more eastern tributary to Spring Creek. Baseline data on these surface water sites mainly consisted of one or two water quality samples before mining which is inadequate to characterize the range of water quality that would have been seen at the springs and ponds in the absence of mining. Flows have not been measured at the springs, but some water depth measurements have been taken.

Impact analysis by Western Energy Company for the Area D PHC focused on spring SP-23 in this drainage. Spring SP-23, in upper Spring Creek just north of Rosebud Area D mining disturbance, is in a narrow canyon bottom below the Rosebud coal outcrop at the base of a 10 foot to 15 foot Rosebud-McKay interburden sandstone headcut. The spring is within the permit boundary. The top of the McKay coal is exposed on an adjacent canyon wall. SP-23 was predicted to be potentially impacted during mining by disturbance of the source aquifer and by interception of upstream surface runoff by the mine. After mining, Spring SP-23 was predicted to possibly experience increases in total dissolved solids from up gradient mine spoils contributions, however, changes to water quality may take decades before they are realized due to the very slow recharge rate in the spoils aquifer. The impacts to SP-23 were predicted to be small because of limited mining impacts expected in the McKay aquifer, and smaller contributions assumed from up gradient Rosebud coal and overburden sources. To date, TDS

concentration from summer samples in SP-23 has increased over time from approximately 1,000 mg/L in 2000 to over 3,200 mg/L by 2013 (**Figure 9-6**). Potential changes to pond water quality downstream of SP-23 are less evident due to the variable mixing of spring water and runoff water. However, any changes in water quality or quantity would not be material damage because the spring is within the mine's permit boundary.

Spring SP-43 has also experienced an increase in TDS concentration, although the data set is limited to four samples. TDS has increased at SP-43 from approximately 2,000 mg/L to over 4,000 mg/L. Trends in water quality for other springs are more difficult to quantify due to the small number of samples and yearly variability in water quality.

Increasing TDS concentration in SP-23 and SP-43 are not correlated with changes in precipitation, and up gradient spoils are unlikely to have saturated to a level to cause discharge into the springs. The cause of the increase in TDS cannot be attributed to a single mechanism, and may be within the natural variation of the system. There are sediment retention ponds, ponds 80 and 80A, along the mine disturbance boundary up gradient of the springs. No discharge or pond water quality or quantity data have been collected at these ponds and outfalls, and therefore there is currently no evidence to link spring water quality changes to mining operations. If spring water quality is affected by sediment retention ponds at the margins of mining, water quality should return to near baseline water quality as reclamation progresses in Area D and ponds are removed. The proposed mining with AM4 will not affect the Spring Creek drainage, and therefore the proposed action is designed to prevent material damage.

9.2.4.2.8 Stocker Creek

Mining in Rosebud Mine's Area C permit has disturbed the headwaters of Stocker Creek. The Area C mine facilities is also located in the headwaters. The creek is mostly ephemeral, but intermittent flow has been observed in some sections, especially after the 2011 recharge event. Springs are found in the drainage basin's headwaters and provide water to stock ponds and short downstream reaches. Water quality can be naturally poor in some spring-fed ponds. For instance, pond PO-938 which is located immediately north of the Area C facilities, is sourced by spring SP-03 (see **Appendix A**, photo 1). Both the spring and pond have sulfate over 2,500 mg/L with one sample from SP-03 in 1986 having a sulfate concentration of 8,100 mg/L. These sulfate levels are not attributable to mining disturbance because operations did not start up gradient of the spring and pond until the 1990's. High chloride (over 20 mg/L) has also been found in surface water samples prior to mining. Many of the areas with high chloride were located next to the county road, which was unpaved at that time. High chloride was also detected on Stocker Creek all the way down to its confluence with EFAC and in springs far removed from mining impacts. High chloride in the late 2000's may be attributable to mine operations, agriculture, or county road maintenance, but a definitive source for the chloride has yet to be identified.

Stocker Creek flume SW-65 has been monitored since the early to middle 1980's and is one of the few sites with a continuous recorder located in an intermittent flow reach (see **Appendix A**, photo 2). The Stocker Creek flume is approximately 0.6 miles downstream of mining in Area C. Although there are a number of gaps in the record, the site has had stream flows in this reach of Stocker Creek that are variable in periodicity ranging from weeks in the spring snowmelt period to nearly perennial flow in wetter years (**Figure 9-7**). The Rosebud Mine has also discharged pit water into the stream at various times during mining, including in 2005 and 2006, which can be seen in **Figure 9-7**. Stocker Creek at SW-65 went through a prolonged period from 1999 through 2009 when no flows were recorded with the continuous recorder. However, crest gauge readings indicate that water did occasionally flow in the stream. If the continuous recorder was functioning properly, this drier period may only have had very

short ephemeral flows such that the daily flows averaged out to zero. In 2012, the site experienced a long period of flow for almost the entire year. The flow in 2012 is a result of the 2011 precipitation event which recharged the alluvium and possibly some shallow perched aquifers in the Stocker Creek drainage. Water quality samples taken in February and May of 2012 had TDS concentrations of 3,940 mg/L and 4,610 mg/L for daily average flows of 0.14 cfs and 0.08 cfs respectively.

The proposed mining with AM4 will not affect the Stocker Creek drainage, and therefore the proposed action is designed to prevent material damage.

9.2.4.2.9 West Fork Armells Creek

Impacts to WFAC surface water resources occur in the upper portion of the drainage. Mining along the drainage divide between WFAC and Stocker Creek occurred from 2001 through 2007, and mining in the Rosebud C West area started in 2008 (**Figure 9-8**).

Springs are prevalent in the WFAC drainage. Actively monitored springs SP-34, SP-35, SP-37, SP-63, SP-67, and SP-76 are part of the surface water monitoring network used to monitor for potential impacts to surface water resources from mining. These springs were monitored due to their potential to be impacted by mine-caused drawdown in their source aquifers. SP-34 and SP-67 are derived from an overburden aquifer, SP-35 and SP-37 are from the Rosebud aquifer, SP-76 is from a Rosebud and clinker aquifer, and SP-63 is from the McKay aquifer. All of the springs have seasonal changes in TDS and ponded water levels (**Figure 9-8**). TDS measured at these springs varies widely from around 800 mg/L (SP-37) to over 3,700 mg/L (SP-63). While some springs, such as SP-37 and SP-67 have relatively consistent TDS concentrations through time, other springs such as SP-63 and SP-34 have had large changes in TDS through time. SP-63 has had large changes in chloride concentration. The two highest concentrations, 40 mg/L and 43 mg/L, were in late 2005 and 2011 respectively. These years correspond with high precipitation years. SP-63 is downstream from a county road and the mine's haul road. The high chloride at this site may be related to runoff laden with magnesium chloride mixing with the spring water at the sampling point, however trends in magnesium concentrations were not correlated with trends in chloride concentrations at this spring. Even when mining was closest to the springs, in the early to middle 2000's, the springs were observed to produce similar water quantity to the baseline condition.

One small spring has appeared in reclamation in Rosebud Mine's Area C permit within the WFAC basin. Spring SP-112A is sourced from recharge in spoil water but is located on an unmined area north of the Area C pits. In contrast to SP-46A, the other newly emerged spring in Area C, there is no trend in water quality from 2011 through 2013 (**Figure 9-3**). Compared to the first sample collected in 2008, the concentration of TDS has decreased by over 1,000 mg/L.

The proposed mining with AM4 will not affect the West Fork Armells Creek drainage, and therefore the proposed action is designed to prevent material damage.

9.2.4.3 Postmine Topography

9.2.4.3.1 Disturbance Area & Basin Size

The main impact to surface water hydrology from open pit mining is the disturbance of drainage basins and channels and the subsequent changes in the timing and volume of sediment and runoff from disturbed areas. During mining, runoff from disturbed areas is routed to sediment ponds where the water is either discharged downstream, retained and used in mine operations, infiltrates, or evaporates. The amount of anticipated mine-impacted land is shown in **Table 9-2**. As seen in **Table 9-2**, the total life of mine disturbance area is a significant portion of some drainage basins such as Lee Coulee, EFAC

upstream of the junction with Stocker Creek, and Stocker Creek. The overall impacted area of the greater Armells Creek watershed is 8% and the area impacted in Rosebud Creek's watershed is 1%. Inclusion of pre-law mining would increase the total disturbance area due to coal mining.

The proposed postmine topography (PMT) and reclamation plan alters the shape of the sub-basins and drainage characteristics (**Table 9-3**; **Figure 9-9**). Alteration of drainage basins has already occurred because reclamation has been ongoing at the mines for decades. Most changes to major drainage divides have occurred from mining in Rosebud's Area D. Area D is located on top of drainage divides that separate four drainage basins: EFAC, Cow Creek, Pony Creek, and Spring Creek.

The proposed increase in mining in AM4 would result in an expansion of the life of mine disturbance area. The proposed mine cuts would be located near the drainage divide with Rosebud Creek and cut into small tributaries of EFAC. These tributaries have already been partially mined through, and many of the lower reaches of the tributary drainages have already been reclaimed. The existing haul roads that would be used to access the additional proposed mining areas were built along the premine drainage channels, and these roads are proposed to be reclaimed as the postmine tributary channels. Because the proposed expansion of mining would be within the EFAC drainage basin, the proposed expanded mining operations in Area B would not alter the size or shape of the EFAC drainage basin.

9.2.4.3.2 Aspect & Slope

Analysis of slope and aspect premine and postmine is done by comparing digital rasters derived from premine and postmine topographic contours provided by the mine. While an approved postmine topography (PMT) is required of the mine as a permit condition, the PMT is rarely built exactly as it is initially drawn. For example, changes in the location of spoil piles, haul roads, and volumes of spoil may lead to deviations from the approved PMT plan. The PMT provides a general plan for the postmine landscape, and therefore any analysis done with the PMT is only an estimate of what the reclaimed landscape will be.

The proposed AM4 mine plan would include mining into steeper, more diverse upland and ridge topography. These areas would be reclaimed to less steep terrain with fewer headwater tributaries and reduced topographic diversity. A comparison of the distribution of slope within the permit area from the premine topography and the proposed postmine topography indicates that the proposed postmine topography would decrease the area with less than 6% slope and increase the area with slopes between 6% and 14% (**Figure 9-10**). Slopes steeper than 14% would be reduced. Compared to the currently approved PMT, the proposed PMT would have less area of steeper slopes.

The increase in areas with slopes between 6% and 14% mainly comes from drainage bottom side slopes formed by reclamation of haul roads as incised drainages. The ephemeral tributary drainages would be reclaimed as wider, incised drainages than existed premine. The analysis of change in slope does not account for topography smaller than 30 square feet (the spatial resolution chosen by DEQ for the analysis of the topography), and small-scale topography may account for a large portion of Rosebud Mine Area B premine topographic diversity, particularly in the areas nearest the drainage divide. Narrative commitments in the permit commit the Rosebud Mine to adding topographic diversity beyond what is drawn on the PMT.

The compass orientation or aspect of slopes in Area B will also change in the proposed reclamation plan. In general, compared to the premine landscape, the AM4 PMT would reduce the premine north and northeast facing slopes in favor of more east and southeast facing slopes. Again, this change is largely a

result of the wide haul road drainages that will run mostly south to north and have east and west facing slopes. The changes in aspect and slope may result in less and shorter snow retention as well as affect the composition of vegetative communities that reestablish during reclamation. Postmine reductions in premine slope complexity, drainage density and topographic diversity would result in fewer leeward slopes for snow drift accumulation and storage and reduced soil moisture variability. Related hydrologic changes would include longer overland flow paths, greater infiltration losses from surface runoff, and reduced peak flows and runoff volumes.

The cumulative impact of mining on slope and aspect is shown by drainage in **Figure 9-11** and **Figure 9-12**. Most drainages will contain fewer steep slope areas as rugged areas are replaced by more gentle rolling topography. Steep areas within reclamation come mainly from high wall reduction areas where steeper topography may be permitted to replace premine features. Steep areas also may occur along new stream valleys that are usually along haul roads and final mine pits. Shallower slopes are predicted to lead to less runoff and erosion during storm events; shallower slopes result in lower runoff velocities which allow for more infiltration time and less energy for sediment transport. Changes to aspect in the drainage basins are mostly minor due to the size of the drainage basins compared to the area disturbed by mining. Most expanded mining, however, would occur in the headwaters of the drainages, and consequently changes to aspect, even if it is a minor percentage of the total drainage area, may have measurable impacts to the surface water hydrology. The headwater areas of drainages are the steepest and often the most topographically diverse areas of a drainage basin.

The proposed changes to the post mine topography do not indicate the existence or the possibility of material damage because the topography approximates the premine topography. Consequently, water retention and runoff is expected to be sufficiently similar that downstream water users will be able to receive a similar quantity of water after mining to the premine condition.

9.2.4.3.3 Runoff Modeling

Changes in theoretical runoff volume and flow are modeled using HEC-HMS and HEC-GeoHMS, a software program for modeling storm-driven runoff developed by the Army Corps of Engineers. For this analysis, a hydrograph from a single hypothetical storm event is modeled over ephemeral drainages, and consequently the model cannot give a seasonal or yearly average. The model simulates runoff from a summer storm event when the ground has low residual moisture and the drainages have no baseflow. All drainages are modeled as ephemeral because there is insufficient data to model intermittent reaches of Lee Coulee or East Fork Armells Creek or the contributions from springs to baseflow in some drainage reaches. Similarly, in stream stock ponds are not modeled due to a lack of data on the volume of the ponds and the amount of seepage through the dam and pond floor. Even with all of these limiting assumptions, the premine and postmine models allow for a comparison of changes in runoff flow from changes in topography.

The HEC-HMS model is a simplistic representation of the ephemeral drainages. The model results presented in this report are only meant to demonstrate the effect of changes to stream length, drainage basin size, and infiltration rates on the response of theoretical storm-driven runoff events and are not meant to be used for predicting actual premine or postmine channel flows. A detailed list of input parameters for the models is included in **Appendix B**.

Inputs for the HEC-HMS model are taken from the premine and postmine topography (**Figure 9-9**). All calculations of premine and postmine channels and basins are derived from a digital elevation model created from the premine and postmine contour lines submitted by the mines. While basin shapes do

not differ from those derived by the mine operators, channel lines differ because of different methodologies to derive channel lines from topographic models. For instance, in some areas the HEC-HMS model does not include subchannels to the detailed level drawn by the Rosebud Mine, while in other areas the HEC-HMS model may draw more channels than was included on the maps provided by the mine.

Curve numbers (CNs) are derived from national land use and soil maps as described in **Appendix B**. Curve numbers differ from the simplified estimates reported in the Rosebud Mine permit due to different methodologies used to estimate the curve number or the hydrologic condition, a qualitative assessment of vegetative density and establishment. Consequently, runoff estimates from the model presented in the CHIA will differ from those presented in the mine permits. Without intensive field measurements, the true curve numbers for the area cannot be known, and both DEQ and mine estimates are made with equally valid yet different assumptions. Postmine curve numbers are estimated from averaging premine soil properties within the life of mine disturbance boundary and recalculating the curve number within each mine permit area. This method of averaging assumes that the only postmine change in soil is a mixing of the premine condition and that no additional compaction occurs during reclamation. Premine and postmine vegetative communities are assumed to be similar.

As a consequence of these assumptions, the only differences between premine and postmine runoff models are a result of a change in the topography or curve number. Consequently, the models differ in drainage basin size and shape, stream lengths, basin slope, average basin curve number, and channel slope. Models are created for East Fork Armells Creek, Stocker Creek, West Fork Armells Creek, Cow Creek, Spring Creek, Pony Creek, Lee Coulee, Miller Coulee, and Hay Coulee. A series of storms are modeled to demonstrate the response of the basins to a variety of precipitation events. A 2-yr 24-hr (1.5 inches of rain), 10-yr 24-hr (2.45 inches of rain), 25-yr 24-hr (3.0 inches of rain), and 100-yr 24-hr (3.8 inches of rain) NRCS Type II storm was modeled. The resulting peak flow, time of peak flow from the start of the storm, and total runoff volume are presented in **Table 9-4**.

As shown in **Table 9-4**, East Fork Armells Creek, Stocker Creek, and Lee Coulee are modeled as experiencing measurable (more than a few percent change) decrease in runoff volume and peak discharge for at least some of the storm events. West Fork Armells Creek is modeled as experiencing a measurable decrease in runoff volume for the 2-yr 24-hr storm but an increase in runoff volume for the 10-yr 24-hr storm. Peak discharge is modeled as increasing for all of the modeled storm events. As would be expected, the drainages with the largest changes in modeled runoff characteristics are also the drainages with the greatest mine disturbance relative to their entire basin size (**Table 9-2**). Most changes to runoff characteristics are from changes in average curve numbers for the subbasins and not from changes in basin size or drainage reach characteristics. Many of the major drainage basin channels, such as EFAC, are outside of the permit boundary and do not change from the premine to the postmine model. Basin morphological characteristics such as overall slope and area are proposed to be reclaimed to similar premine conditions. As stated earlier, estimation of curve numbers is one of the most imprecise model properties and subject to the widest variation in possible valid postmine values.

Since the AM4 amendment area is upstream of current mining activities in Area B and would not disturb new drainage basins, the amendment would not result in any further decrease in natural runoff to drainages downstream of the mine during operations. Premine and proposed postmine drainage basin size, land use, and vegetation are similar enough that no significant change in the quantity of runoff or peak discharge is expected between the currently approved postmine reclamation plans and the proposed postmine reclamation plans. The proposed action is designed to prevent material damage to

the hydrologic balance because the difference between the premine and post mine drainage basin size, land use, and vegetation, should not result in an increase in total suspended solids from the premine condition, and the runoff volume and timing should be sufficiently similar that downstream users may receive similar quantities of water to the premine condition.

9.2.4.3.4 Effects of Ponding During Mining

Retention of runoff water in sediment control ponds and the discharge of water from these ponds change the natural surface water hydrology. Sediment ponds at the Rosebud and Big Sky mines are generally designed to retain runoff from storms up to 2.4 inches (10-yr, 24-h recurrence), and typically have additional storage volume for three or more years of projected sediment loss from disturbed drainages above them. Design requirements for sediment ponds result in at least temporary interception of all but the largest storm or snowmelt runoff events. Snowmelt runoff (usually in February or March) and successive spring storms (heaviest from April through June) can result in more frequent pond discharges from precipitation. Dewatering of mine pits into ponds can also result in planned discharges at any time of the year. Sediment control ponds are unlined and therefore pond water also infiltrates into shallow groundwater aquifers.

Multiple sediment ponds in drainages with significant mining activity can impact local hydrologic patterns during mining. The type and extent of impacts depend on site specific factors, including: number of active ponds, level of mining activity, amount of pit pumping, and the timing and magnitude of storm and snowmelt runoff. The cumulative effects of Rosebud Mine sediment ponds on EFAC surface flow and chemistry below the mine permit area are further complicated by the Colstrip power plant and municipal water uses within and adjacent to Colstrip.

Seepage losses and surface discharges of stored runoff or pit water from disturbance perimeter sediment ponds can affect flows in down gradient alluvial aquifers and streams. The effects of individual sediment ponds would generally be limited to adjacent streams and their alluvial aquifers, unless pond contributions are significant relative to those of the receiving channel or aquifer. For example, an intermittent to perennial flow reach was created in an ephemeral reach of Lee Coulee below Big Sky Mine pond B-9, which discharged nearly continuously from November 1989 through November 1991, and from April 1993 through September 1995. Big Sky Mine pond B-22 had similar discharges from September 1994 through July 1996 and from September 1996 through June 1997. Similar changes in surface flow regimes resulted from episodes of pit pumping from Rosebud Mine Area B pits with discharges to East Fork Armells Creek above Colstrip (most recently in October 1999 through April 2000 and March 2012 through June 2012).

Sediment pond discharges usually meet MPDES water quality effluent limitations. A list of exceedances of MPDES water quality limits since 2010 is given in **Table 9-5.** The two enforced violations were for exceeding total suspended solids limits: 70 mg/L (daily maximum). In typical discharges, water quality is similar or lower in suspended solids than storm runoff from local undisturbed drainages. In pond discharges with large amounts of groundwater from pit pumping, dissolved solids are usually higher than in ephemeral runoff from local undisturbed drainages. The 2012 MPDES discharges into EFAC shown in **Figure 9-2** were comprised mainly of pit water, and large discharges into EFAC can significantly increase flows in the creek.

Pond discharges are controlled and regulated under the MPDES permit, and adherence to the MPDES permit ensures that material damage will not happen outside of the mine permit.

9.2.4.4 Surface Water Quality: Analytes with Multiple Sources

Surface water quality impacts were analyzed by grouping large amounts of surface water data into five-year increments. **Figure 9-13** through **Figure 9-17** are spatial maps showing aggregated time frames. These maps show water quality for springs, ponds, and streams. Springs are sourced from a variety of aquifers ranging from alluvium to sub-McKay, and spring water is often ponded and may receive some runoff contributions.

9.2.4.4.1 Boron

Boron is a trace element naturally found in soils, sea water, and some rocks. Boron is essential for healthy plant and animal growth, but high concentrations can lead to boron toxicity in both plants and animals. As of 2014 there are no DEQ-7 human or aquatic health limits for boron (**Table 2-1**). However, livestock water quality guidelines and EPA long-term health advisory guidelines recommend boron to be less than 5 mg/L in water (**Table 2-2**). Boron concentrations in coal vary by depositional environment as coal deposited in brackish environments will have higher concentrations than coal deposited in freshwater environments. As a result, boron in some coalfields may be more concentrated than in others.

Median baseline concentrations of dissolved boron from 932 samples from stream, spring, and pond water is 0.2 mg/L with a 75th percentile at 0.38 mg/L and a 90th percentile at 0.91 mg/L. Fifteen of the 25 baseline monitoring sites with boron above the 90th percentile were east of the state highway in Cow Creek, Pony Creek, and Spring Creek with the other 10 monitoring sites in Lee Coulee, Stocker Creek, and EFAC (**Figure 9-13**). Baseline samples were collected in years ranging from 1972 to 2013 with the majority of samples taken in the 1980's and 1990's. Data collected from sites during non-baseline has a median concentration of 0.24 mg/L with a 75th percentile at 0.6 mg/L and a 90th percentile at 1.2 mg/L.

Bottom ash, which is known to contain elevated concentrations of boron, was approved to be used on haul roads in permit Areas A, B, C, and D in 2000 with the stipulation that visual vegetation monitoring be conducted along the haul roads and that samples be taken from the bottom ash stockpiles to analyze for boron. Bottom ash use on haul roads was reported in 2000, 2009, and 2012. Use of bottom ash on roads has not been correlated with high boron concentrations in downstream surface water sampling locations. High boron concentrations in Spring Creek, Pony Creek, and a tributary to Cow Creek downstream from Area D were measured before bottom ash was used along the haul roads, and elevated boron has not been detected in EFAC where haul roads adjacent to the creek were also approved for bottom ash application. High boron concentrations are also not associated with coal or spoil aquifers. Boron is almost always below 1 mg/L in spoil wells and is not found in spoil wells at concentrations above 1.4 mg/L.

Elevated concentrations of boron in EFAC are likely from water leaking from the power plant ash ponds and ponds at the power plant facilities mixing with EFAC surface water. Boron is part of a group of elements known as oxyanions (along with As, Mo, Sb, Se, and V) which are most mobile in the neutral to moderately alkaline pH range (Jones, 1995). Since groundwater in the Colstrip area is moderately alkaline, boron is expected to be very mobile. Boron oxides from ash become dissolved in water and are easily leached from the ash particles where it can then rapidly travel downstream or down gradient. Boron detected in tributaries in Cow Creek down gradient from the ash ponds and slurry pipelines is from the leaking ash ponds and former leaks in the pipelines. Boron in samples from the power plant's facilities ponds have ranged from 0.2 mg/L to 854 mg/L (PPL, 2014). The wide range of concentration is a result of various amounts of dilution in the ponds; some of the power plant ponds receive water from multiple sources.

An additional source of boron at some surface water sites may also be from air-borne sources. According to Finkelman (1995), boron is mostly bound to the organic constituents of coal. Boron is an element whose behavior is somewhere between a volatile element (becomes depleted in the solid phase and enters a gas phase during combustion) and a semi-volatile element (volatilizes but will condense onto ash particles). Meij (1995) reported on the concentration of trace elements from different phases of ash collection at coal power plants in the Netherlands. In the study boron was found to be successively concentrated from the original coal into the bottom ash and even more into the fly ash. Boron that is volatilized and emitted from the power plant may subsequently fall onto vegetation and open surface water down wind of the facility. Some of the monitoring sites with high boron are also downwind from the Colstrip power plant and/or the Colstrip Energy Limited Partnership (CELP) facility (**Figure 9-14**). The amount and concentration of boron leaving the power plant as gas from the emission stacks is unknown, and therefore the likelihood of an airborne source for high boron in surface water samples in Spring Creek, Pony Creek, and Cow Creek cannot be determined.

Spring Creek, Pony Creek, and some northern tributaries of Cow Creek are hydrologically disconnected from the power plant ponds and infrastructure yet also exhibit high boron in surface water samples. Since the early 1980's, when data was first collected in and around Rosebud Mine Area D permit, some springs, ponds, and alluvial wells have shown concentrations of boron routinely greater than 1 mg/L. Pond PO-917 is within the Area D permit, but it is on an undisturbed segment of Pony Creek (**Figure 9-13**). Since sampling started in 1981 the pond's water quality samples have routinely had boron concentrations above 5 mg/L with four samples above 10 mg/L. No increasing or decreasing trend is apparent in the pond's boron concentrations. Some springs, such as GSP-6 (also known as SP-25) and SP-23, have shown gradual increasing trends in dissolved boron through time. Other springs and ponds, especially within the Spring Creek drainage, do not have a long enough sampling history to indicate a long-term trend in concentrations. For instance, SP-90 has only been monitored since 2011 but the concentration of dissolved boron was above 8 mg/L for all four sampling events. Elevated boron in alluvial wells samples are found along Cow Creek, upstream of pond PO-917 in Area D and along East Fork Armells Creek as it passes through Colstrip (**Figure 9-13**; **Figure 9-14**).

The cause of the elevated boron in and around Area D is unknown, but the appearance of high boron is not correlated with mining events or operational practices. Analysis of overburden and interburden samples show that boron is occasionally present at high concentrations (> 5 mg/L). Soil samples have also been tested for boron prior to disturbance, but soil is not tested for chemical composition after reclamation. Some soil samples have been found to contain high boron concentrations. The mechanism (e.g. anthropogenic sources vs natural processes) that results in high boron in some soil sample is not known. It is unknown if the concentration of boron in Area D and Area E soils downwind of the power plant are higher than boron concentrations found in soils from areas upwind of the power plant. The surface water sampling sites in Area D are mainly along the burn line. Wells in this area that are completed in clinker, coal, and interburden layers also have high boron concentrations (> 1 mg/L). The burned and partially burned coal in this area may be releasing organically bound boron. Surface water at the monitoring locations may be mixing with groundwater sources high in boron.

Because there is no numeric standard, boron would cause material damage only if concentrations were sufficiently high to impair uses of the surface water. As indicated, coal mining does not appear to release boron into the environment; burning coal releases mobile boron into the environment. Therefore, while there are some areas within the mine permit boundary and near the permit boundary with elevated concentrations, there is no evidence to indicate that the mine has caused or exacerbated high boron

concentrations. The mine and the proposed action in AM4 is designed to prevent elevated boron that would hinder a use of the surface water.

9.2.4.4.2 Chloride

As of 2013 there are no DEQ-7 human or aquatic health limits for chloride (**Table 2-1**). Chloride occurs in coal in two main forms. First, it can be dissolved in pore water trapped inside of the coal. This mode is more likely to occur in coals that formed under brackish conditions. The second form can be as anions adsorbed onto the organic compounds and surfaces of coal (Finkleman, 1995). Weathered coal rapidly becomes depleted in chloride because chloride is highly mobile and will readily be transported (Goodarzi, 1995). Wet scrubbers, which are employed by the power plant, remove most of the chloride.

Figure 9-15 shows that surface water with high chloride concentration has been present since monitoring started. Median baseline chloride concentration from 876 baseline (premine) samples from streams, springs, and ponds is 7 mg/L with the 75th percentile at 12 mg/L and the 90th percentile at 21 mg/L. Data collected from sites during non-baseline has a median concentration of 10.9 mg/L with a 75th percentile at 25 mg/L and a 90th percentile at 60 mg/L. Some areas have seen an increase in chloride through time. The distribution and likely sources of high chloride concentrations can be divided into the following categories:

1) High concentrations in surface water downstream of the power plant ash ponds. Water samples from ash ponds suggest that the power plant captures a large amount of chloride. Since chloride is highly mobile, it readily infiltrates from the ponds into the groundwater whenever there is seepage from the ponds. Chloride concentration in power plant ponds ranges from 20 mg/L to 31,900 mg/L (PPL, 2014).

2) Moderately elevated concentrations in drainage reaches downwind of the power plant and far from county roads. Moderately high concentrations of chloride have been detected in Pony Creek and Cow Creek downwind of the power plant. The contribution of precipitated airborne emissions of chloride versus other sources cannot be discerned from the monitoring data. Monitoring sites next to the Area D permit boundary tend to have lower chloride than sites further downstream which indicates that the source of elevated chloride is not likely from the mine.

3) High concentrations in drainage reaches that cross county roads. Magnesium chloride may have been used along county roads, and the possibility of its usage is suggested by high concentrations of chloride in drainages near road crossings. For instance, high chloride has been found consistently in the Stocker Creek drainage, WFAC, and upstream EFAC before any mining occurred upstream of the sampling points in the 1980's. These creeks are crossed by unpaved county roads.

4) High concentrations in drainage reaches along haul roads, and near mine facilities. Magnesium chloride was used at the mines along unpaved haul roads and facility areas for dust control. It has also been applied to roads used by the power plant to access bottom ash and fly ash ponds. Bottom ash has also been used to a limited extent along haul roads and power plant roads. Some of the roads maintained by the power plant go near the permit boundaries for Rosebud Area D and Area E, and consequently surface water structures, such as sediment ponds, managed by the mine could have high chloride from mine and/or powerplant activities. An example of such a pond is PO-004. Chloride concentrations have been measured in Area E pond PO-004 as high as 366 mg/L in 1984. This pond still routinely has chloride concentrations above 100 mg/L. The location of this pond upstream of the roads used to access the power plant ash ponds precludes the association of high

chloride with the use of magnesium chloride on power plant roads. The chloride may be related to the movement of residual chloride left over from when mine haul roads crossed upstream of the pond. Salts may still be in the soil and may still be leaching into the pond.

An example of high chloride concentrations resulting from mine activities can also be found in Miller Coulee at the Big Sky Mine. High chloride concentration in Miller Coulee during mining is primarily a result of pond APD7400 (**Figure 9-15**). From 1990 through 2000, when monitoring of the pond ceased, chloride concentrations were at concentrations in the 100's mg/L to 1,000's mg/L. Prior to 1990, the chloride concentration in this pond was less than 10 mg/L. The source of the large increase in chloride is unknown but likely related to road maintenance use of magnesium chloride. During mining, the pond was adjacent to a main haul road.

Because there is no numeric standard in the DEQ-7, chloride would cause material damage only if concentrations were sufficiently high to impair uses of the surface water. As indicated, coal mining does not directly appear to release chloride into the environment; burning coal does release mobile chloride into the environment. Mine operations have and practices have contributed chloride to drainage ways, primarily through the use of magnesium chloride on the roads. However, current and future practices at the Rosebud Mine stop the use of magnesium chloride. Therefore, the proposed action in AM4 is designed to prevent elevated chloride that would hinder a use of the surface water.

9.2.4.4.3 Fluoride

As of 2013 fluoride is listed as a toxic pollutant for human health in DEQ-7 (**Table 2-1**). Median baseline fluoride concentration from 893 samples from stream, pond, and spring water is 0.25 mg/L with a 75th percentile at 0.54 mg/L and a 90th percentile at 0.61 mg/L. As seen in **Figure 9-16**, sites located east of the power plant have higher fluoride than monitoring sites west of the power plant and highway.

From 1985 to 1992, fluoride was included in the suite of analytes for power plant monitoring sites on Pony Creek and Cow Creek. From 1990 to 1992, abnormally high fluoride concentrations were detected in both of these drainages compared to the concentrations that were recorded in prior years. The only sampling sites downstream of the power plant facilities and ponds were on Cow Creek. The analytical suite for these sites does not currently include fluoride, which precludes the determination of current fluoride concentrations at the monitoring sites. Instead of being an indicator of anthropogenic pollution, the high fluoride concentrations from the power plant samples could be a result of changes in the resolution of the analytical method. However, higher than background fluoride concentrations have also been consistently seen in alluvial and spring water samples collected by the Rosebud Mine in the northern tributaries of Cow Creek. A contemporary comprehensive survey of surface water and alluvial water throughout Pony Creek and Cow Creek would be needed to determine if fluoride is still present in the basins at the concentrations seen in the early 1990's.

To date, elevated or increased concentrations of fluoride in drainage ways and springs have not been associated with mining in the Colstrip area. Like boron, fluoride is preferentially organically bound in coal, and fluoride can be release with the burning of coal. Because fluoride has not been linked to mining or operational activities, the mine is designed to prevent material damage from fluoride above the DEQ-7 human health limit.

9.2.4.4.4 Nitrate (as N)

Due to ambiguity in past methods used by the mines, nitrate plus nitrite as nitrogen and nitrate as nitrogen are shown together in **Figure 9-17**. High nitrogen may be in surface water samples due to residual chemicals from blasting materials, from agricultural activities, or from city runoff and municipal sources. In **Figure 9-17**, samples above the human health limit of 10 mg/L are shown as dark red. Many of the highest values have been detected downstream of active mining and in areas actively used by livestock. Recent samples (2000 - 2013) with the highest nitrate concentrations near mining activities were found in the Spring Creek drainage downstream from Rosebud Mine Area D. EFAC between Rosebud Mine Area A and B had high nitrate concentrations in the 1980's through middle 1990's. This is coincident with the time that mining was active adjacent to the drainage. The drainage bottom is also actively used and historically used by cattle. Most of the high concentrations in surface water have been below the nitrate-nitrite human health limit of 10 mg/L.

The additional mine cuts are along the EFAC and Miller Coulee drainage divide, over 6,000 feet from the nearest major stream channel, EFAC. From past observations in monitoring wells, this distance should be sufficient to prevent (through dilution) high concentrations of nitrate from blasting from entering the stream via spoil recharge and ultimately alluvial contributions to baseflow. Therefore, the proposed action is designed to prevent material damage to surface water resources from high nitrate concentrations.

9.2.4.5 Exceedances of Water Quality Standards

For intermittent and perennial waters, DEQ-7 numeric water quality standards must be met for aquatic life and human health. A summary of exceedances of the current DEQ-7 standards from the earliest sampling events to 2013 is presented in **Table 9-6**, **Table 9-7**, and **Table 9-8**. As stated in **Section 8.1.2**, MPDES currently considers SW-55 and SW-65 to be within an ephemeral stream segment, and consequently MPDES does not currently apply DEQ-7 aquatic life standards to the discharge water quality.

For the purposes of the material damage determination under MSUMRA, SW-55 and SW-65 are included in **Table 9-7** for the purpose of determining if there is material damage to aquatic life. As seen in **Table 9-6**, samples collected before (considered baseline) and after mining commenced upstream both had many exceedances of DEQ-7. Some metals with low DEQ-7 limits, such as cadmium, had a decrease in exceedances after mining started. This decrease is likely an artifact of later sample dates for the data collected after the start of mining. Cadmium detection limits have become progressively smaller, and the analysis results in many earlier samples with reporting concentrations at or near their reporting limit resolution exceeding the 2012 limit. The percentage of exceedances in water quality samples for nitrate plus nitrite in EFAC through Colstrip and total copper in Stocker Creek at SW-65 after the start of mining are both significantly higher than the number of exceedances in other drainages for these analytes. The high nitrate plus nitrite in EFAC through Colstrip is a result of municipal inputs and urban runoff which are not associated with mining. The high total copper in Stocker Creek is associated with high TSS in the water quality samples. The high TSS results in larger concentrations of all metals that were monitored. The baseline samples for Stocker Creek at SW-65 were low TSS samples and consequently had lower total metals. None of these exceedances are attributable to coal mining.

The exceedances listed in in **Table 9-6** are not persistent nor was any trend of increasing concentration through time found for the analytes with DEQ-7 standards. Aluminum and total iron standards were exceeded at higher rates than other metals, but these two metals are naturally occurring at high concentrations in the region, as evident by the high number of exceedances found in the 'baseline'

group. There is no evidence from the surface water monitoring program of systematic exceedances of DEQ-7 standards for surface water that can be attributed to coal mining that would result in a violation of a water quality standard.

The exceedances of DEQ-7 standards described in **Table 9-6** or **Table 9-7** do not directly indicate the existence or likelihood of material damage attributable to mining because there are many variables which change between the baseline and mining-affected data sets. There are differences in the seasonal distribution and consequently types of flows sampled, differences in the spatial distribution of sites, differences in the sampling frequency, and differences in the types of surface water that were sampled. There has been an increase in the rate of exceedances in some streams for some analytes with livestock thresholds. For instance, there was a higher rate of exceedances for sodium, magnesium, and manganese after the start of mining compared to baseline in Pony Creek. As with the exceedances of the DEQ-7 standards, increased exceedances of the livestock thresholds cannot be directly attributed to mining due to differences in sampling locations, surface water type (springs vs ponds vs streams), and seasonal variations. Water quality trends at long term monitoring sites, such as the sites discussed in **Section 9.2.4.2**, are a more appropriate indicator of potential changes in water quality from mining.

9.2.5 Groundwater

Open pit coal mining removes overburden and coal then backfills each successive pit with the broken overburden material (spoil) from the previous cut as mining progresses. As coal seams are shallow aquifers in the Colstrip area, there are impacts to groundwater and associated parts of the hydrologic system. Potential hydrologic changes include:

- Declines in water level or pressure head in mined aquifers
- Potential water level declines or changes in pressure head in stratigraphically adjacent aquifers
- Removal of alluvial material and/or interception of alluvial water adjacent to recoverable coal
- Changes in groundwater flow direction and gradient near the pit areas due to water level declines or changes in hydrologic head
- Removal of springs or diminished flow in springs
- Creation of localized recharge due to ponding in pits and sediment control structures
- Reduction in infiltration and recharge in disturbed clinker areas
- Increases in alluvial recharge and alluvial water levels due to discharge of pit water into tributaries
- Water quality decline in alluvial aquifers due to lowered water levels
- Water quality decline in alluvial aquifers due to pumping or seeping of impounded pit or sediment pond water into drainages
- Creation of a spoil aquifer with hydrologic properties different than the strata it replaced
- Poor spoil water quality due to dissolution of salts from overburden minerals
- Potential decline in water quality in adjacent aquifers and surface water due to movement of spoil water
- Potential water quality decline in springs adjacent to mining due to diminished flow or introduction of spoil water

The two main impact categories are changes in water level (or pressure head) and water quality. The evaluation of impacts to water levels is based on analysis of observed changes in monitoring well water levels as mining approaches and exits from an area. Observations include the amount of decline in water level (or pressure head) and the amount of time it takes for recovery. Variation in annual precipitation

affects water levels, especially in shallow aquifers, and thus climatic effects must be considered in the analysis of water level response.

Box and whisker plots show concentrations of the major water quality analytes by aquifer from baseline and recent samples at the Rosebud Mine (**Figure 8-9** and **Figure 9-18**) and the Big Sky Mine (**Figure 8-10** and **Figure 9-19**). The plots represent single, initial samples from baseline wells and the single most recent sample from each currently monitored well. The baseline and recent plots represent two snapshots in time and thus do not show the natural variability observed over time that often occurs at a monitoring site. For a number of reasons, the two populations (baseline and recent) are not directly comparable and differences in concentration between the two time periods should not be interpreted to construe changes attributable to mining. In the 20 to 30 years since baseline, many of the baseline wells have been lost to mining or another reason and thus the monitoring wells representing current water quality are not the same, or in the same location, as those representing baseline. Another problem in comparing the two populations is the affect that a change in detection limits can have on medians. For example, the recent detection limit for potassium at the Rosebud Mine is much higher than the one used in baseline. Thus, the statistics for baseline concentrations may have lower values.

The plots are useful for a general comparison of spoil water quality with that of baseline and current water quality from bedrock aquifers. Spoil is elevated in median as well as maximum concentrations of TDS, bicarbonate, sulfate, and calcium.

The best insight to changes in water quality attributable to mining comes from examining water quality at individual monitoring sites in the following sections. Water quality impacts are assessed by evaluating changes in analytical concentrations through time based on proximity to mining and other potential influences such as climate. TDS as an indicator of the degree of water mineralization is the primary indicator of a change in water quality and reflects changes in measured analytes, but largely reflects the change in sulfate concentration, and to a lesser degree, calcium and magnesium. Although conductivity is often used as an assessment of water quality, TDS is a better laboratory measurement of total mass in the sample. TDS concentration is the main water quality indicator used in several hydrologic studies in the area (Van Voast et al. 1977; Van Voast et al. 1988).

9.2.5.1 Rosebud Mine

9.2.5.1.1 Alluvium

Alluvial water levels and quality may be impacted by mining in a number of different ways as described in **Section 9.2.5**. Some monitoring well hydrographs indicate that climate, particularly rainfall and snow melt, dominates most alluvial water levels. In other cases, the data is insufficient to allow determination of whether water levels have responded to mining or climate. Observed and potential impacts to alluvial groundwater quantity and quality are discussed specifically below for each drainage in the CIA.

Area A, Area B, and Area C

In the west part of the Rosebud Mine (Area A, Area B, and Area C), alluvium is found in EFAC, Stocker Creek, the upper reaches of WFAC, and tributaries to these drainages. There are 27 active alluvial monitoring wells in this part of the mine (**Figure 9-20**). Many of the wells have been recording water level and water quality for three decades or more.

East Fork Armells Creek

EFAC is an ephemeral to intermittent stream located between Area A and Area B in the east part of the mine area, and Area B and Area C upstream to the west. Most of the creek bed upstream of Area A is

dry, however intermittent stretches have been identified (see surface water discussion for EFAC). Historically, small dams built to create instream ponds for livestock water have facilitated the intermittent stretches.

EFAC has eroded through stratigraphically lower units as it flows downstream; this is important to the evaluation of impacts in a given stretch of stream. Upstream of Area B, alluvium is bounded by overburden. Downstream, near the western edge of Area B and Area C, the alluvium comes into contact with the Rosebud coal (**Figure 9-21**). Further downstream the alluvium intersects Rosebud coal and then the interburden. Between Area A and Area B, the stream has eroded through the interburden and into the McKay coal. Thus, there is an increase in groundwater connection from the Rosebud coal and the McKay coal to the alluvium. However, the contribution of groundwater from the coal units to the alluvium is small compared to the up gradient alluvial source of groundwater (Western Energy Co., 2014, 2015).

Due to its location, EFAC has been subject to impacts from mining in Area A, Area B, and Area C. Mining was active at the easternmost end of Area B beginning in the middle 1970's. Mining has remained active in Area B almost continuously as the permit area extended to the south, away from EFAC. Initial mine pits in the east end of Area A were opened in the middle to late 1970's and were located relatively close to the north side of the stream. Mining in the 1980's and 1990's closely followed the coal crop line immediately adjacent to the stream in Area B. Although mining near the stream in Area A was active into the early to middle 1990's, it did not take place as close to the stream as mining in Area B. Area C pits near the stream were opened in the early 1990's and were active until 2010.

The greatest impacts to the stream and associated alluvium have been observed in the down gradient, east end of Area B. Alluvial wells record a marked decline in water levels here in the early to middle 1980's. There were implications for stream flow with the decline in EFAC alluvial water levels. As a mainly ephemeral stream dominated by runoff from snow melt and rainfall, EFAC would be expected to continue to have regular flows associated with runoff events. Thus, a decline in alluvial water levels does not mean the stream went dry. In ephemeral parts of the stream, alluvial water levels do not intercept the stream bottom and contribute to base flow. In areas where the alluvial water level does intercept the stream bottom intermittently, periods of flow may be shortened due to diminished base flow.

The extent of water level impacts to EFAC alluvium is difficult to assess from hydrographs (**Figure 9-22** and **Figure 9-23**) due to the influence of climate on water levels. Water levels recorded from alluvial wells along the entire length of EFAC reflect a period of drought in the late 1970's through the 1980's, with recovery beginning in the early 1990's. A shorter, less dramatic response to below average precipitation began again in the early 2000's, followed by a rise in water level in the late 2000's in response to above average precipitation. The introduction of water to the stream via MPDES discharges has tended to mitigate drawdown of alluvial water levels. The rising alluvial water levels observed in many monitoring wells between Area A and Area B reflects not only unusually high precipitation in 2011 and 2013, but also the release of water to the stream under the mine's MPDES permit from sediment ponds that intercepted increased runoff due to the precipitation events. Water levels are currently at or above premine levels in most alluvial wells. Other potential sources of water to the stream include leakage from sediment ponds, and wastewater in holding ponds and the leach field in the Area A facilities. The amount associated with these sources is thought to be insignificantly small (Western Energy Co., 2015).

As mining moved to the south, away from the stream in Area B, alluvial water levels began to recover. The interconnectedness of the alluvium and the reclaimed pit in the east end of Area B is evidenced by the rapid recharge of the spoil near the stream compared to the relatively poor water level recovery in spoil more distant (south) from the stream. Even though mining has been close to the stream in the more up gradient areas of EFAC, the hydrologic dynamic appears different than that seen down gradient. The drawdown effect of mining near the stream is recorded on the hydrographs of wells WA-114 and WA-209, suggesting a connection between Rosebud coal and alluvium. The precipitous water level drop in well WA-114 in 1984 is likely associated with nearby mining in Area B. Well WA-209 has been dry since 2000, likely in response to adjacent mining in Area C beginning in 1992. Well WA-114 has shown a recovery in water level while WA-209 remains dry. Recovery in WA-114 is likely a response to a number of factors: above average precipitation in 1993 and 1994, concurrent increase in the release of pit and pond water to the stream, and the movement of mining away from the stream. Although alluvial water is contributing to the recharge of spoil in the east part of Area B, the west (upstream) part of Area B spoil, like WA-209, remains dry to poorly saturated. However, up gradient of WA-209, water levels in Rosebud monitoring well WR-136 (see **Section 9.2.5.1.3**) suggest that the recovery of water levels from mining related drawdown in the middle 1990's was facilitated by recharge via EFAC alluvium beginning in 2011, coincident with a period of high precipitation.

Mining near WA-104 in the middle 1990's likely explains the decline in water level in this well at about the same time, although it is anomalous in its earlier water level character compared to other alluvial wells. It shows an increase in water level at the same time most other wells are showing a decline in response to drought. Wells WA-171 and WA-214, located up gradient of mining, show no effects from mining but record a strong effect from higher than normal precipitation in recent years. Due to their up gradient distance from mining, wells WA-215 and WA-118 also remain unaffected by mining. These wells serve as control wells to help determine the effects of climate verses mining on water level.

Water chemistry in EFAC alluvium varies widely, in both time and location. **Figure 9-22** and **Figure 9-23** show that water quality in the alluvial wells generally corresponds to water level. An increase in saturation results in an increase in TDS and a decline in saturation results in a decrease in TDS. This is notable in both up gradient and down gradient alluvial wells whether they are subject to mining influences or not. Potential sources contributing to the increase in TDS include spoil, MPDES discharges, leaking sediment ponds and/or pits, and infiltration from water used in the facilities area. Each of these potential sources was evaluated in the PHC (Western Energy Co., 2015).

Contributions to groundwater from the facilities area in Area A are evident from the concentration of chloride detected in surface water and alluvial groundwater samples. Magnesium chloride is used as a road surfacing material to control dust in the facilities area. As chloride occurs predominately as the highly mobile free chloride ion, it is chemically inert and passes easily through the unsaturated zone into groundwater. Although the use of magnesium chloride has been discontinued in the Area A facilities, chloride levels in EFAC will remain elevated until magnesium chloride remaining in the soil has been flushed from the system by precipitation and runoff. Contribution of water to the stream and alluvium from other facility uses (e.g. drain field serving the Area A office, lawn irrigation, and equipment cleaning ponds) was analyzed to be of such a comparatively low volume that it would not contribute measureable amounts of TDS to the system.

MPDES discharges were considered to be a potential contributor to the rise in TDS. However, TDS concentrations in discharges between 1999 to 2014, had an average and median of 1,589 mg/L and 1,210 mg/L, respectively. During the period of high precipitation and correspondingly high MPDES

discharges between 2011 and 2014, the average and median TDS of the (planned and unplanned) discharges was 1,724 mg/L and 1,780 mg/L, respectively. All of the discharges were below baseline (PHC average of 2,299 mg/L) and current alluvial well TDS concentrations, indicating that they are not directly responsible for the TDS increase observed in EFAC.

Saturating spoil near the stream in Area A and the northeast part of Area B was examined as a contributor to TDS. The Rosebud Mine PHC Addendum (Western Energy Co., 2015) indicates that, based on comparison of water levels in spoil and alluvium, Area A spoil water is moving toward EFAC alluvium but movement of Area B spoil water toward alluvium is unlikely. Based upon a simplified mass balance calculation, the current contribution of Area A spoil to the observed increase in TDS in EFAC alluvium is approximately three per cent.

Due to the widespread correlation of water quality and water level in alluvial wells, the reason for the increase in TDS is attributed to an increase in water level from natural recharge as well as MPDES discharges. Impacts to alluvial water from permitted operational discharges are expected to continue as long as there is mining in the EFAC basin although the volume will be dependent on weather patterns, with greater discharge occurring during periods of higher than normal precipitation. Alluvial TDS concentration is predicted to decline along with decreasing water levels after MPDES discharges to EFAC stop.

Flow from Area A spoil is predicted to impact water quality in downstream EFAC between Area A and Area B (Western Energy Co., 2015). Based on average TDS concentrations observed in spoil and alluvial baseline (in the wells used to develop the mass balance calculations at the east end of EFAC), post-mining alluvial TDS concentration is projected to be approximately 2,751 mg/L, equivalent to a 13% increase over the 2,299 mg/L baseline concentration (Western Energy Co., 2015). Due to the apparent connection between Rosebud coal and alluvium in the vicinity of WR-136 in Area C, resaturated spoil in this area may also contribute to an increase in TDS in EFAC alluvium. This estimation was conducted specifically for TDS, however because TDS and conductivity typically are linearly related, the results can be reasonably applied to conductivity. Average baseline conductivity in EFAC alluvial groundwater was 2,650 µS/cm, thus a 13% increase would result in an average postmine conductivity of 2,995 µS/cm, both Class III groundwater. The average conductivity at the most downgradient EFAC wells (P-01 through P-05) between Area A and Area B was 2,692 µS/cm when mining began nearby in 1975. This value falls within the conductivity range for Class III groundwater and a 13% increase in conductivity (to 3,042 µS/cm) would not change the groundwater class.

Current uses of EFAC alluvium are limited to drinking water for livestock and wildlife. Ionic water quality components of greatest concern for livestock include TDS and sulfate. Recommended upper concentration limits (**Table 2-2**) are 4,999 mg/L for TDS and 2,500 mg/L for sulfate. Initial sample analyses from each of 15 EFAC wells were chosen by DEQ to represent EFAC baseline throughout the stream length (**Appendix D**). TDS concentrations among these wells ranged from 1,300 mg/L to 4,680 mg/L (SC=1,720 µS/cm to 4,530 µS/cm) with an average and median of 2,302 mg/L (SC=2,650 µS/cm) and 1,900 mg/L (SC=2,390 µS/cm), respectively. Sulfate in these wells ranged from 640 mg/L to 3,010 mg/L with an average and median of 1,276 mg/L and 1,010 mg/L, respectively. Down gradient wells, which represent the area of greatest water quality decline, currently report concentrations of 2,300 mg/L (SC=2,620 µS/cm) (WA-101) to 4,220 mg/L (SC=4,330 µS/cm) (WA-131) for TDS (and conductivity), and 1,270 mg/L (WA-101) to 2,670 mg/L (WA-131) for sulfate. As discussed above the potential changes to water quality in EFAC alluvium are small in comparison to the observed variability and are unlikely to

impact livestock or wildlife drinking water use, or the listed uses for Class II or Class III groundwater, thus material damage to these uses is not indicated or predicted.

Private wells completed in EFAC alluvium may be affected by changes in water quality. A number of wells are located near EFAC between Rosebud Mine Area A and Area B, and Area B and Area C. Reported use of the wells in GWIC includes domestic and stock water. Many of the wells are completed in sub-McKay (underburden) units but some have shallow completions that suggest alluvium is the water source. Alluvial wells in and adjacent to the permit areas are at risk for changes in water quality. These include wells 17, 19, 20, and 79.

Private well 79 is located between Area B and Area C in Section 12 (T1N, R40E). Monitoring well WA-104 (**Figure 9-20**) is completed near well 79. The current water level in WA-104 is close to the original (1979) level and the current (2013) TDS concentration of 1,890 mg/L (SC = 2,380 µS/cm) is close to the earliest measurements (1979/1980) of 1,650 (SC = 1,950 µS/cm) and 1,840 mg/L (SC = 2,050 µS/cm). Assuming that WA-104 is representative of water in well 79, there are no changes to water quality from those observed at baseline and the water remains suitable for use as stock water. For the same reason no changes in water quality indicate possible harm, detriment, or injury to listed uses of water in this well. Contribution of spoil water from Area C is expected to be relatively small compared to the overall volume of alluvial groundwater flowing through EFAC and is not expected to elevate water quality components significantly to affect the use. Sulfate, as the critical groundwater component, would have to increase from the current level of 921 mg/L to 1,500 mg/L to meet the threshold limit for livestock water quality (**Table 2-2**). Even if the same magnitude of change occurred in this section of EFAC alluvium as was predicted for lower EFAC (13%), that water would remain within the conductivity range for Class II groundwater and would not be rendered harmful, detrimental, or injurious to a listed use for Class II water (ARM 17.30.1006) or unsuitable for a current or anticipated use. Furthermore, the proposed action will not exacerbate or intensify any adverse impacts from contributions of spoil water from Area C.

Private wells 17, 19, and 20 are located in Section 8 (T1N, R41E), between monitoring wells WA-114 and WA-128 and near WA-101 between Area A and Area B. The monitoring wells currently show increases in water level and TDS concentration as result of mining (**Figure 9-22**)(see **Section 9.2.5.1.1**). TDS concentration has increased due to increase in sulfate, magnesium, calcium, sodium, and chloride. The GWIC database indicates the private wells are listed for domestic use. Premine water quality was marginal Class II to Class III groundwater, with TDS (and conductivity) in monitoring wells ranging between 1,380 mg/L and 2,220 mg/L (1,770 µS/cm and 2,550 µS/cm). The most recent measurements in TDS (and conductivity) range from 1,890 mg/L to 2,890 mg/L (2,620 µS/cm and 3,330 µS/cm). There have been no increases in trace metals and no DEQ-7 human health standard has been exceeded. The residence where the wells are located is not occupied, is owned by Western Energy Company, and is within the permit boundary. According to Western Energy Company these wells are used only for livestock (Pers. comm., Western Energy Co. personnel, 2015). Sulfate, the most sensitive component of drinking water for livestock, remains within guideline recommendations. Initial calcium and magnesium concentrations were above the livestock guideline criteria. Calcium concentration has increased above the lower end of the initial concentration range (132 mg/L to 312 mg/L) but not at the upper end (153 mg/L to 264 mg/L). Magnesium concentration increased above the initial range (146 mg/L to 207 mg/L) at both the lower and upper ends of the range (201 mg/L to 307 mg/L). Current sulfate concentrations are 921 mg/L at WA-104, 1,270 mg/L at WA-101, and WA-114 at 1,660 mg/L. The alluvial water currently remains marginally suitable for domestic, livestock, and wildlife use. This change in conductivity from

the Class II to Class III groundwater range does not render the water harmful, detrimental, or injurious to a listed use for Class II groundwater.

Continued change to EFAC alluvial water quality is predicted post-mining due to infiltration of spoil water from the south part of Area A and the north part of Area B. Assuming postmine reestablishment of flow equilibrium, mass balance calculations estimate that average TDS in alluvium between areas Area A and Area B is expected to experience a 13% increase over the baseline TDS of 2,299 mg/L (SC = 2,650 µS/cm), yielding a TDS average concentration of approximately 2,751 mg/L (SC = 2,995 µS/cm)(Western Energy Co, 2015). Average alluvial water quality both premine and postmine indicates Class III groundwater is typical. At this concentration, water quality should remain suitable for livestock and wildlife use. This change in groundwater quality does not render the water harmful, detrimental, or injurious to a listed use for Class III water (ARM 17.30.1006), and no numeric standards are predicted to be exceeded, thus no material damage is expected.

As stated above, water chemistry in EFAC alluvium varies widely, in both time and location. Based on observed changes and predicted changes in water quality, conductivity at some, but not all, monitored sites has changed or may change from the conductivity range for Class II to the range for Class III groundwater. For all groundwater classes, concentrations of parameters for which human health standards are not listed in DEQ-7, there is to be no increase of a parameter to a level that renders the waters harmful, detrimental, or injurious to the beneficial uses listed for the class (ARM 17.30.1006). The primary difference between listed uses for Class II and Class III groundwater is that the listed use for "public and private water supplies" in Class II water is replaced by "drinking" in the listed uses for Class III water. Both "public and private water supplies" and "drinking" were at best marginally supported by EFAC alluvial groundwater in the baseline condition, and the predicted increases will not cause harm, detriment, or injury to this marginal support. After the observed and anticipated changes in water quality, EFAC alluvial groundwater will continue to be marginally suitable for the current and anticipated uses of EFAC alluvium as drinking water for livestock and wildlife.

Material damage to the EFAC alluvium is not indicated. Mining in the cuts proposed in AM4 is not expected to contribute to the decline in water quality in EFAC. Also, changes in water quality attributable to other permitted areas of the Rosebud Mine are not expected to result in material damage to the EFAC alluvium. Specific changes at individual wells are difficult to predict due to the variable nature of alluvial and spoil water quality, both spatially and temporally. It is likely that some wells which are just below the threshold of Class II/Class III water would change to fall within the conductivity rage of Class III, however this type of change also occurs naturally (see **Figure 9-23**, well WA-104) and in much larger magnitude than a 13% change. No material damage is indicated because any mine related water quality changes are not likely to be distinguishable from natural variations.

Stocker Creek

Stocker Creek is an ephemeral stream that drains the north parts of Area C and the northwest part of Area A, joining EFAC north of Colstrip. There are seven active alluvial monitoring wells (**Figure 9-24**) in Stocker Creek and its tributaries. Most of these wells have been active since baseline in the late 1970's and early 1980's. Mining in the Stocker Creek watershed in Area C took place as early as 1984 and continued through 2007. Mining in the part of Area A that drains to Stocker Creek began in 1988 and continued through 1994. Stocker Creek also drains the mine office and facilities in Area C.

Alluvial thickness ranges from 13 feet (WA-217 and WA-160) to 34 feet (WA-109) and saturated thickness has ranged up to 20 feet. Most wells have maintained some level of saturation even during

periods of low precipitation. The hydrographs of most of the wells show a similar water level response. They also reflect the climate effects observed in EFAC wells. Mining does not appear to have affected water levels in Stocker Creek alluvium.

As noted in EFAC alluvial wells, water quality in some Stocker Creek wells appears to correspond to water level, with TDS increasing with increasing water level as observed in WA-160, WA-164, WA-169, and WA-217. Current water levels in these wells are at or above baseline. Other wells have a relatively constant TDS through time (e.g. WA-168) or do not correlate closely with water level (WA-109). Poorest water quality is associated with wells WA-164, WA-168, and WA-169, located in the middle to upper section of the drainage. Initial samples from wells except WA-217 represent baseline. Baseline TDS concentrations range from 2,006 mg/L to 5,360 mg/L, with a median of 2,545 mg/L and an average of 3,024 mg/L. Average TDS concentrations in the wells during mining ranged from 2,096 mg/L to 4,045 mg/L, with an average TDS concentration of 3,922 mg/L. The lack of increasing TDS concentration through time suggests there have been no impacts to water quality attributable to mining operations in the Stocker Creek drainage.

The proposed AM4 mining in Area B will not affect water quality and water quantity in Stocker Creek. Only a small part of Area C is drained by Stocker Creek and no measurable impacts to water level or quality are anticipated with the recovery of the groundwater system. No material damage has been observed or is expected in the Stocker Creek alluvial groundwater.

Upper West Fork Armells Creek

The west and northwestern most part of Area C drains to West Fork Armells Creek (WFAC). There are five active alluvial wells in the upper reaches of the ephemeral drainage and its tributaries (**Figure 9-25**); all but one has been active since the early 1980's and all have collected baseline data. Baseline measurements began in the early to middle 1980's in most wells and in 2003 for well WA-218. Mining began in 2001 in the north part of Area C and in 2008 for the west part of Area C. Reclamation of the north part of Area C is complete; the west and central parts are actively mined.

Alluvial wells are shallow in Upper WFAC, with depths ranging from nine to 19 feet deep. Saturated thickness ranges as high as 20 feet in WA-190, but is less (nine to 15 feet) in the other wells. The water levels from WA-199, WA-218 and WA-186 have the same trends seen in alluvial wells throughout the mine area that reflects a response to climatic changes (discussed above in the section on EFAC). There are numerous springs in many of the tributary drainages; many supply water to nearby livestock ponds. The hydrograph from WA-204 has a "flashy" signature that likely reflects the influence of upstream spring SP-55 and associated ponds. Wells WA-186, WA-190, WA-218, and WA-199 are downstream from springs that may influence water level. Water seeping from ponds may also affect water quality. Based on monitoring data, it does not appear that water levels in alluvial wells have been affected by mining.

Average TDS concentrations during baseline ranged from 2,318 mg/L to 3,800 mg/L, with medians from 2,150 mg/L to 3,770 mg/L. The average TDS concentrations subsequent to mining ranged from 2,115 mg/L to 5,255 mg/L with medians from 1,840 mg/L to 5,255 mg/L. Wells WA-218, WA-204, WA-186 and WA-199 have shown increases in TDS associated with a recent rise in water level. This is a common response in alluvial wells throughout the mine and is not a result of mining but rather additional ions that come into solution with an increase in precipitation and subsequent rise in water levels. WA-190 is the exception to this trend, as it has maintained a relatively steady TDS concentration as water levels have risen.

There is no indication that water quality changes in Upper WFAC are the result of mining. The proposed AM4 mining in Area B would not affect water quality and water quantity in WFAC. No material damage has been observed or is expected in the WFAC alluvial groundwater.

Area D and Area E

Pony and Cow Creeks

In the east part of the Rosebud Mine, Area D and Area E are drained by Pony Creek, Cow Creek and South Fork Cow Creek. Cow Creek, South Fork Cow Creek and Pony Creek are ephemeral tributaries to Rosebud Creek. Although there is a considerable history of groundwater monitoring in the alluvium of these drainages, mining and associated disturbance was active in the Cow Creek and South Fork Cow Creek drainages prior to requirement for baseline data. There are currently ten wells monitored in these drainages (**Figure 9-26**).

Pacific Northwest National Laboratory/Battelle-Pacific Northwest Division (PNNL) oversees monitoring and reports on surface and groundwater monitoring results in Cow Creek and Pony Creek under contract with the Colstrip Power Plant (PNNL, 2014). A power plant effluent holding pond complex is near the headwaters of Cow Creek. The ponds receive scrubber slurry pumped via pipeline from power plant units 3 and 4. Monitoring in the Cow Creek drainage documents impacts from the slurry ponds. For comparison with measurements in Cow Creek, Pony Creek is used as a "control" drainage as it is similar geologically to but hydrologically isolated from Cow Creek.

Pony Creek flows east from Area D. Baseline and subsequent measurements in Pony Creek by the Rosebud Mine were taken from a two-foot deep alluvial monitoring well (WA-178) near the head of the drainage. As the well was often dry, monitoring was discontinued in 2007. Western Energy Company and PNNL actively monitor wells in other stratigraphic units in Pony Creek but there are no active monitoring wells completed in alluvium.

Cow Creek and South Fork Cow Creek flow eastward to Rosebud Creek. There are eight alluvial wells monitored in the headwaters of Cow Creek and two wells are monitored near the head of South Fork Cow Creek (**Figure 9-27**). As there was premine disturbance up gradient of these drainages, there is no baseline data. Most alluvial monitoring began in 1981.

Cow Creek alluvial wells are mainly in the upland tributaries of the drainage. Water levels in WA-142, WA-145, WA-146 and WA-147 are influenced by stock ponds. The other Cow Creek wells have hydrographs that mainly reflect the same climatic conditions commonly seen in alluvial well levels throughout the mine area. Well WA-132 is the most down gradient well. It typically contains between four feet and seven feet of water and is intermittently dry. Likewise, WA-133 most commonly contains from less than one foot to four feet of water. Wells WA-136 and WA-137 are in South Fork Cow Creek. The hydrograph of WA-136 suggests that an up gradient pond periodically influences the water level response in this well. There is no evidence that alluvial water levels have been affected by mining.

The TDS concentration in some wells has varied over a significant range, whereas other wells have remained relatively steady in water quality. Current (2011-2014) TDS concentrations range from 3,010 mg/L (WA-134) to 6,040 mg/L (WA-142), with an average and median of 3,893 mg/L and 3,380 mg/L, respectively. The highest concentrations are in adjacent wells WA-142 and WA-145, both located less than a mile north of the ash ponds. TDS concentrations in WA-145 have ranged as high as 15,400 mg/L.

All of the wells have water quality affected by activity associated with management of the Colstrip power plant ash. Repeated breaks and leaks in the pipeline moving the ash slurry from the power plant to the ponds has affected monitoring wells in tributaries upslope and up gradient of the ash ponds. The ash ponds are also leaking effluent to the area. The slurry and water from the ash ponds are typically high in TDS but also has higher than normal concentrations of boron, chloride and fluoride that distinguish it from alluvial, bedrock or spoil aquifers. All of the alluvial wells in Cow Creek and South Fork Cow Creek have elevated boron and fluoride concentrations, and many have high chloride concentrations. An unexplained increase in potassium concentration occurred in the wells beginning in approximately 1995. No elevated concentrations in other analytes, including trace metals, are reported in alluvial well analyses.

As Pony and Cow Creek exhibit impacts attributable to operation of the power plant, there is no evidence that the mining has or will materially impact the water quality in these creeks. The proposed AM4 mining in Area B would not affect water quality and water quantity in Pony or Cow Creek alluvium. No material damage has been observed or is expected in the Pony or Cow Creek alluvial groundwater.

Spring Creek

Spring Creek flows to the north of Area D, opposite the direction of groundwater flow. Five alluvial wells were installed in Spring Creek or its tributaries in 1982 to 1984. Most of the wells were dry during the monitoring period that lasted through 1997. Wells that infrequently contained scant water were monitored until 2007 before monitoring was discontinued. Due to the direction of groundwater movement and the lack of water in the alluvium, it is unlikely that impacts from spoil will affect the drainage. The proposed AM4 mining in Area B would not affect water quality and water quantity in Spring Creek alluvium. No material damage has been observed or is expected in the Spring Creek alluvial groundwater.

9.2.5.1.2 Overburden

Overburden wells generally do not show a response to mining until active mining is nearby. The lack of responsiveness in the wells is attributable to the discontinuity and low permeability of the strata, which is characterized by claystones and siltstones. The lack of response in overburden wells demonstrates that most of the overburden strata are hydraulically isolated from the underlying Rosebud coal and water in the overburden is often perched. Even though overburden wells locally may contain 30 feet or more of water, poor yield and the lack of horizontal continuity of water bearing zones in the overburden makes it a poor source for reliable production. Few overburden monitoring wells are currently active as most have been removed by mining.

Overburden will continue to be removed and spoiled into the pit as mining continues in Area A, Area B and Area C. As discussed below, proposed mining in AM4 will remove additional overburden in the east part of Area B but will not affect overburden water levels or water quality in other permit areas of the Rosebud Mine. No material damage has been indicted in overburden groundwater and none is expected to occur.

Area A

Mining in Area A has taken advantage of low cover coal near the crop lines, leaving an undisturbed area ringed by pits. Well WO-105 is the only active overburden well in Area A and has been monitored since 1981 (**Figure 9-28**). Mining in the area began as early as 1975 and continued through 2000. The continuous decline in water level since approximately 1990 is likely in response to mining **(Figure 9-29)**. Water level has declined from approximately 13 feet to seven feet of water currently in the well.

Water quality in the well was consistent until the most recent sample, when it went from a TDS near 2,100 mg/L to 10,000 mg/L. The reason for the increase is likely associated with reported surface damage to the well or activity in preparation of the area for impending mining.

Area B

Four overburden wells are active in Area B (**Figure 9-30** and **Figure 9-31**). With a head of approximately 46 feet, WO-160 lies at the southeast edge of mining and has shown a slight decline of less than two feet in water level with the nearby approach of mining (**Figure 9-29**). WO-162 is located near the last cut in the west part of Area B. It experienced a drop in water level in 1998 when mining moved close to the well and has continued a slow downward trend for a total decline of approximately six feet. Approximately 104 feet of head remains in the well. WO-171 is located more than a mile west of mining in Area B and Area C and while it shows two abrupt declines in water level, the declines are not readily explained by changes in mining operations. The relatively steady decline in WO-173 began long before mining reached the area in late 1999. The punctuated rate of decline in 2000 may be in response to nearby mining. Mining persisted through 2007, shortly before decline in this well ended. At the most, a decline of between 12 feet and 14 feet is attributable to mining.

Water quality in the overburden wells is highly variable, ranging from a TDS of less than 500 mg/L in WO-160, to an isolated maximum of 3,350 mg/L in WO-173, although average TDS in this well is closer to 1,500 mg/L. WO-162 has shown an increase in TDS concentration from 1,100 mg/L to 1,900 mg/L as the well declined in water level. The increase in TDS in recent samples is most likely a direct response to the approach of mining.

Mining associated with AM4 will remove additional overburden in the proposed mine cuts area at the east part of Area B. This will increase the disturbance and volume of spoil but is not anticipated to interrupt overburden groundwater resources outside the mine area because the overburden wells are hydraulically isolated from the underlying Rosebud coal and because the water bearing zones in the overburden demonstrate poor yield and a lack of horizontal continuity. Based on the private well inventory, there is no indication that the overburden groundwater is used as a resource in this area. AM4 mining is not expected to cause material damage to the overburden groundwater.

Area C

Four overburden wells have remained active in Area C since the early to middle 1980's (**Figure 9-32**). WO-168, located near the edge of mining in the south part of Area C, was in decline when mining began to influence the well, causing a sharper drop between 2005 and 2006 (**Figure 9-29**). Due to distance from mining (approximately 3,000 feet) well WO-172 remains unaffected by mining and reflects changes in water level attributable to climate or other influence. Despite the close proximity of mining to WO-178, it has not shown a water level response. WO-181, located in the west part of Area C, south of mining, responded to nearby mining with approximately two feet of decline in water level between 2011 and 2012.

Water quality is closely correlated with changes in water level in WO-172. The remaining overburden wells do not appear to have TDS concentrations strongly correlated with water level. TDS concentrations among the wells are highly variable, ranging from less than 500 mg/L to over 6,000 mg/L. There is no change in water quality in wells that show a change in water level precipitated by mining. Due to its location upgradient, proposed mining in Area B will have no impact on water quality or quantity in Area C overburden.

Area D
Seven overburden wells were completed in Area D (F**igure 9-33**). Four wells located in the east fingers of Area D were dry when installed. The remaining three wells (WO-104, WO-106, and WO-175) were located more interior to the permit area and recorded drawdown associated with mining before they were mined-out (**Figure 9-34**). WO-104 had as much as 38 feet of water when installed and was already in decline, likely in response to climate as mining in the area was not active until late 1980's. WO-106 measured up to 20 feet of saturation and WO-175, located near the crop line, had 18 feet. The sharp decline in WO-175 beginning in 1999 is attributed to mining.

Even as mining neared the wells, TDS concentrations in the wells remained low, ranging from 306 mg/L to 819 mg/L, likely reflecting local recharge via clinker, which is typically lower in TDS. As mining removed most of the coal resource in Area D, there are no currently active Area D wells for comparison. Due to its location, proposed mining in Area B will have no impact on water quality or quantity in Area D overburden.

Area E
Overburden well WO-174 remains active in Area E (**Figure 9-33**). Located at the west margin of mining, monitoring at this well began in 1983. Recent measurement indicates that the well contains 67 feet of water. Compared to hydrographs in adjacent areas of the Rosebud Mine, including wells not affected by mining, the hydrograph for WO-174 has a characteristic trend that suggests a water level response to climate effects rather than mining (**Figure 9-34**). Changes in water level do not correspond with the conclusion of mining (1986) or completion of reclamation (1996) although these events may contribute to water level changes reflected by the hydrograph.

Generally, water quality in WO-174 appears to respond to water level, with increasing TDS concentration corresponding to increasing water level. TDS rose from 1,070 mg/L to 1,610 mg/L with an 11-foot increase in water level. The increase in TDS is not attributable to spoil. The direction of groundwater flow places WO-174 up gradient of the area mined in Area E; thus it is up gradient of spoil. Additionally, spoil saturation remains below the elevation of the overburden. Due to its location, proposed mining in Area B will have no impact on water quality or quantity in Area E overburden.

9.2.5.1.3 Rosebud Coal
The Rosebud coal is the aquifer most directly affected by mining as it is the target of coal removal. Locally the aquifer is dewatered as each mine cut is sequentially developed. Monitoring wells indicate that drawdown near the pit areas can be substantial, but the close proximity of the crop line to the pits limits the extent of drawdown north and east of the permit areas. Therefore, the greatest extent of drawdown in Rosebud coal outside the mine area is to the south of the Rosebud Mine.

Area A
There are three active Rosebud coal wells in Area A (**Figure 9-28**) and they have been monitored for more than 30 years. All have recorded the effects of mining on water level with observed declines in the early 1980's through the early 1990's, depending on the location of mining in proximity to a given well (**Figure 9-35**). Drawdown was also observed in wells WR-110 and WR-105, two wells that were removed by mining. A few years (1979 - 1981) of steady water level in WR-105 prior to mining associated decline represents background water level and water quality. Approximately 30 feet of water level decline was measured in this well. The 10-foot recovery of water level in WR-127 is likely due to infiltration of adjacent ponded surface water. Rising water level that began in 1993 in WR-104 is likely due to recharge

resulting from the collection of pit water immediately south of the well while mining was in hiatus. The recent decline in water level in this well beginning in 2012 is likely due to pit pumping in preparation for resumption of mining. At this time, active Rosebud monitoring wells indicate that the unmined Rosebud coal remains under confining pressure.

As represented by TDS concentration, water quality in the Area A Rosebud monitoring wells is highly variable. Initial measurements range from 494 mg/L (WR-110) to 2,780 mg/L (WR-105). WR-104 and WR-127, both show increases in TDS concentration over the life of the well. The rising TDS concentration in WR-104 likely has been influenced by pit water which had concentrated dissolved salts due to evaporation during a 14 year mining hiatus in Area A. The rising trend in WR-127 may be due to influences from nearby spoil (e.g. WS-113), but most likely this well is strongly affected by infiltration of surface water from ponds and ditches in the mine facilities area. High chloride (64 mg/L) and magnesium (339 mg/L) concentrations in this well (9/21/2011 sample) is characteristic of dissolved magnesium chloride that was applied to road surfaces in the facilities area. WR-130 shows water level with a repeated response to mining during the times it was active in adjacent (east) pits, although water quality has not shown a significant change. Water level and water quality have been relatively static since the last mine cut in 2000. TDS concentration has declined somewhat since the initial sample and currently is close to 1,000 mg/L.

Mining resumed in the east pit of Area A in 2014. Continued mining will increase the drawdown in the Rosebud coal, increase the volume of spoil, and the recovery time of water levels. The drawdown model predicts a maximum of 20 feet of Rosebud coal drawdown in the southwest part of Area A in 2011 and 2020 (see **Section 9.2.7**). The remainder of the area is predicted to have 10 feet of drawdown. By 2026 drawdown is expected to have recovered to approximately 10 feet.

As the Rosebud coal crop line defines the extent of the pit, there will be no lateral up gradient movement of Rosebud coal groundwater into Area A spoil from the normal flow direction (from the west) to provide recharge. Recharge will depend on surface sources such as infiltration from precipitation events and ponds.

Area A spoil is dry except for the south part of the mined area adjacent to EFAC. The movement of spoil water to EFAC is discussed in **Section 9.2.5.1.1**, under EFAC and in **Section 9.2.8**. The mining proposed in Area B in AM4 will not influence the groundwater water level or water quality in Rosebud Mine Area A due to the discontinuity of Rosebud coal between Area A and Area B. Because the Rosebud coal in Area A does not extend beyond the permit boundaries there is no potential for material damage to the Rosebud coal groundwater in Area A.

Area B

Seven active Rosebud coal wells in Area B have been monitored since the early 1980's (**Figure 9-30** and **Figure 9-31**). Many of the wells at the west end of Area B (WR-124, WR-125, WR-164, WR-162, and WR-173) experienced a water level decline in the 1980's, prior to the approach of mining in areas adjacent to the wells (**Figure 9-36**). This widespread drawdown response was likely due to climate. However, mining effects are suggested by the abrupt change in water levels observed from the late 1990's to early 2000's in WR-164, WR-162, and WR-173. Total water level decline ranged from approximately six feet to 14 feet and is, at least in part, attributable to mining. Thirty to 35 feet of head remains in these wells, indicating that they remain confined aquifers. Only WR-173 has begun to show recovery.

Due to its location over a mile from mining, it is unlikely that the decline in water level in well WR-125 reflects mining activity. Well WR-124 is close to mining. The decline beginning in approximately 2000 may reflect activity in Area C; however, the steep recovery has brought water levels to within three feet of the initial measurement in 1980.

Wells WR-205, WR-160, WR-101, and WR-161 record the response of the Rosebud coal in the east part of Area B. Mining affected drawdown was underway when WR-205 and WR-160 were installed. Recovery and then renewed decline in WR-160 corresponds to the timing of nearby mining activity. Ten feet of recovery in this well was observed when nearby mining ended in 2007. Resumption of mining nearby caused a subsequent decline. The Rosebud coal in this area is has a head of approximately 40 feet. WR-205, located immediately adjacent to EFAC alluvium, has recovered to a steady water level since middle 2007 and has a head of 34 feet. The early measurements of WR-101 and WR-161 reflect baseline. WR-101 and WR-161 recorded approximately 60 feet of head decline prior to being mined out. Rosebud coal and clinker monitoring wells ("WX" wells) adjacent to the coal outcrop along EFAC (**Figure 9-37**) measured an abrupt decline in head between seven feet and 35 feet when mining began at the east end of Area B. An equally abrupt recovery began shortly thereafter, likely due to infiltration of water from EFAC alluvium.

Wells in the west part of Area B had baseline TDS concentrations ranging from 758 mg/L (WR-162) to 2,390 mg/L (WR-125). These wells have shown variability in TDS concentration; change in water level and water quality response are not strongly correlated. The most recent (2013) sample from well WR-173 had a reported TDS concentration of 6,460 mg/L. This is a reporting error as confirmed by the fact that the conductivity and all analytes in the analysis do not reflect a dramatic increase but remain near previous concentrations typical of this well.

Baseline water quality in the east part of Area B is represented by early measurements in WR-101 and WR-161 and in monitoring wells installed in 1983 ("WX" wells), prior to the beginning of mining adjacent to EFAC. A single water quality sample was taken from most of these wells. Water quality as represented by TDS concentrations ranges from 520 mg/L to 1,880 mg/L. WR-160 has shown a mostly steady increase in TDS from 626 mg/L to 2,730 mg/L. WR-205 has had a variable TDS throughout the life of the well ranging from 1,990 mg/L to 2,850 mg/L TDS. Based on distance from EFAC, WR-205 is the only well likely to be affected by alluvial water quality. WR-205 and WR-124 are the only two wells experiencing increasing water levels and the only two wells close enough to EFAC to be influenced by alluvial water levels and water quality. As WR-124 is up gradient of mining, alluvium adjacent to the area (west end of Area B) is not likely to have been impacted by mining. Down gradient, at well WR-205, the rise in water level is assumed associated with the rise in alluvial water level. The rise in down gradient EFAC alluvial water level is attributed to both increase in precipitation during recent "wet years" and to MPDES discharges from the Rosebud Mine which has in turn caused on increase in alluvial TDS concentration (see discussion on EFAC alluvium).

Drawdown, including pressure head, associated with currently approved mining in Area B was modeled (see **Section 9.2.7**) to be 90 feet at the end of 2011. Removal of additional coal proposed in AM4 will extend the mining period in Area B and cause additional drawdown in the Rosebud coal. The increased drawdown from mining AM4 is expected to be 40 feet over that expected to occur in currently approved mining. This is discussed in greater detail in **Section 9.2.7**, Groundwater Flow Models. No private wells are located in the Rosebud coal in the area of increased drawdown, thus there is no potential for material damage to water quantity. An increased volume of spoil would also be created in mining AM4 resulting in a longer period for recovery of water levels and water quality. The potential effects of this

additional spoil on water quality in the Rosebud coal southeast of Area B is discussed in **Section 9.2.5.1.7**, under Area B.

Area C

There are six active Rosebud coal monitoring wells in Area C (**Figure 9-32).** These wells have been collecting data for three decades or more (WR-103, WR-121, WR-126, WR-136, WR-168, and WR-181) **(Figure 9-38**). They are located at various distances outside the pit areas and thus record the response of groundwater outside the immediately affected area. Numerous other wells removed during mining record the response of the system within the mine pit area. Hydrographs from three of these wells are shown on **Figure 9-38**. Many of the wells outside of mining in the south and west part of Area C (e.g. WR-103, WR-121, WR-168, and WR-136) record a water level response similar to the one seen in the west part of Area B (discussed above). Specifically, there was marked water level decline in the 1980's to middle 1990's, prior to mining near these wells. The hydrograph during this period indicates a response to climatic conditions throughout the mine area.

The response of groundwater levels to mining overprinted on climate-initiated water level changes makes it difficult to interpret and assess the extent of each source of change. Based on timing of mining and water levels, well WR-103, located approximately a half-mile up gradient from the nearest pit area, does not appear to have been influenced by mining but shows an abrupt rise in water level in response to above average precipitation in 2011. The steepened decline in well WR-121 in 2007 was likely a response to mining, although the well was in decline in response to climatic conditions prior to commencement of nearby mining. It currently contains approximately seven feet of water. Well WR-126 is located near the Rosebud outcrop, is shallow (20 feet) and is responsive to surface infiltration. This well contained less than six feet of water when installed and maintained saturation during mining. It went dry in 2002 during a time of below normal precipitation but resaturated to premine level when precipitation returned to near normal amounts. Well WR-136 probably was affected by mining as early as 1995 due do its close proximity to mining in both Area A and Area B. However, it was already declining by this time in response to climate or another influence. This well has recently recovered to higher than its initial (1985) water level and has 54 feet of head. Due to its location adjacent to EFAC and downstream from a stock pond, this well is also sensitive to infiltration of shallow groundwater. Mining likely affected water levels in WR-168 in 2006 or later, creating up to six feet of drawdown. Approximately seven feet of water remains in this well. The drawdown response to mining is distinctive in WR-181, resulting in a decrease of approximately 28 feet of head. Forty feet of head remains in this well. West of WR-181, monitoring well WR-231 located a mile and a half west of WR-181 and outside of Area C, has recorded 11 feet of head loss, with a remaining head of 85 feet. By comparison, WR-238 located approximately a mile northwest of the pit lies near the outcrop and has shown no drawdown response and maintains 59 feet of head.

Wells removed by mining (WR-112, WR-117, and WR-169) that were chosen to represent the response to mining in various parts of the Area C pits, show a baseline period followed by a decline as mining approached. WR-112 in the north part of Area C records a response to climate conditions until mining encroached in approximately 2003, causing a brief decline before the well was removed. The well contained between five feet and seven feet of water prior to removal by mining. Well WR-117 located in the east part of Area C, shows an abrupt decline in 1985 when mining came within 800 feet of the well. Prior to its removal, there was approximately 35 feet of head in the well indicating that the Rosebud coal at this location was confined. Well WR-169 in the central part of Area C was confined with 42 feet of head before mining moved within 1,500 feet of the well, causing it to drop 18 feet.

Water quality in Area C is highly variable with background TDS concentrations ranging from less than 500 mg/L (WR-117) to more than 5,000 mg/L (WR-103). Some wells have shown a change in TDS concentration with a change in water level, whereas others have not. WR-121 decreased in TDS concentration when head declined. Well WR-126 experienced a marked changed in water quality from as low of 2,100 mg/L in baseline to a peak of over 8,000 mg/L. When WR-126 went dry and recovered three years later, TDS concentration rose from 3,190 mg/L to over 8,000 mg/L. As a result of its shallow depth (20 feet) and a location immediately adjacent to the county road, this well has been subject to surface influences on water quality. This is evidenced by high concentrations of chloride and magnesium from road stabilization compounds, and higher than normal boron concentrations that suggest the use of coal ash as a road stabilizer. High concentrations of nitrite-nitrate suggest influence from agricultural practices or other local source. The water quality changes are not attributed to spoil water as nearby spoil well WS-122 contains only four feet of water and is down gradient of WR-126. The last sample (12/2013) from well WR-136 spiked approximately 800 mg/L in TDS concentration. This coincides with rising water levels and may be influenced by proximity to EFAC alluvium. The remaining wells (WR-103, WR-121, WR-168, WR-181) have not shown significant water quality changes.

Due to the direction of groundwater flow, Area B mining, including that proposed in AM4, is not expected to increase drawdown or otherwise impact the Rosebud coal groundwater in or near Area C. In 2011, maximum drawdown in Area C was modeled to be 60 feet (see **Section 9.2.7**, Ground Models). By 2020 drawdown is modeled to be 70 feet. By 2026 drawdown is expected to recover to 60 feet. Currently, Area C spoil has experienced little recharge. Saturation of spoil in the north part of Area C will depend on vertical infiltration as the mine area is defined on three sides by the coal crop line, including to the west, which is the up gradient direction of lateral groundwater flow. This means there is no up gradient recharge from the Rosebud coal into the north part of Area C. Although the drawdown here was relatively small (modeled at 10 feet) because of the scant amount of water here in the Rosebud coal, it is anticipated that it will take a substantial amount of time to saturate the spoil in this area. The remainder of Area C will receive lateral recharge to coal and spoil. Upon saturation, migration of spoil water in the direction of natural groundwater flow will be limited by the coal crop line, which defines the down gradient margins of mining in Area C. No material damage to Rosebud coal groundwater has been observed or is expected. Drawdown in the Rosebud coal will not impact any groundwater users and the coal crop line location immediately downgradient of the mine pits limits migration of spoil water into the Rosebud coal groundwater. A possible connection of the Rosebud coal with alluvium in the southwest part of Area C (as suggested by the response of WR-136) suggests EFAC may be subject to spoil water from Area C assuming a local hydrologic connection with the alluvium. Based on the response of monitoring wells (discussed above), connection between the Rosebud coal (or spoil) and the stream appears limited. The impacts of Area C mining on EFAC alluvium is discussed in **Section 9.2.5.1.1**.

Area D

There is one active Rosebud coal monitoring well in Area D (**Figure 9-33**). This well (WR-134) is at the outcrop margin, less than four feet deep and intermittently dry (**Figure 9-39**). It rarely contains more than two feet to three feet of water. Fifteen monitoring wells installed to monitor the Rosebud coal were removed during mining. The limited extent of saturated Rosebud coal remaining in Area D precludes well installation adjacent to the pit areas post-mining. Monitoring wells removed during mining record the response of the Rosebud aquifer as mining took place. Prior to mining, the Rosebud coal in Area D was unconfined. Groundwater on the north side was scant, ranging from less than one foot to four feet. Up to 25 feet of water was measured in more centrally located wells. Well WR-107 was located in the southwest part of the permit area and had a saturated thickness of 16 feet to 20 feet. Most water level fluctuations in this well reflect responses to climate with mining likely responsible for

the dip in level in 1991. Well WR-118 represents conditions in the southeast arm of the permit area. It contained 12 feet of water prior to being affect by mining in 1987. Well WR-123, with between 16 feet and 25 feet of water, recorded water level response to climate before being affected by mining in 1989. Wells WR-131 and WR-132 were located at the north edge and northeast arm of the permit area, respectively. With between a foot and three feet of water in these two wells, they showed little response to mining when it encroached in middle 2000.

A wide range of TDS concentration characterized Area D Rosebud coal water quality. TDS concentration ranged between 476 mg/L and 6,645 mg/L, with an average of 2,406 mg/L and a median of 1,577 mg/L, respectively. As commonly observed in other permit areas, TDS concentrations often declined coincident with declines in water level. Elevated boron concentrations ranging from 2 mg/L to 3.1 mg/L in well WR-107 suggest influence by power plant ponds located approximately a mile south. Anomalous but less concentrated boron (0.7 mg/L to 2.7 mg/L) was found in samples from WR-118, WR-131, and WR-183. The source of the boron in these wells is undetermined.

Area D is geologically isolated from impacts associated with proposed AM4 mining. Because of this geological isolation, there is also no potential for material damage to groundwater in the Rosebud coal from Area D mining.

Area E

Four Rosebud coal monitoring wells in Area E have been active since the early 1980's (**Figure 9-33**). The east part of Area E, including part of the area on which the Colstrip power plant facilities are located, was mined pre-law, prior to passage and implementation of MSUMRA in 1978. Thus, the wells do not represent a baseline period.

WR-174, located at the west margin of mining, shows the greatest fluctuation in water level and appears to be in a confined part of the Rosebud aquifer at this location, with a total head of 53 feet (**Figure 9-40**). The water level decline in the middle to late 1980's likely represents a combination of drawdown associated with mining, which ended in late 1986, as well as an extended period of low precipitation. Water levels in this well began to rise coincident with the completion of reclamation in 1996. Return to initial water levels in this well took place with above average precipitation in recent years. By contrast, well WR-108 located a short distance up gradient of mining, has a relatively small water level fluctuation of two feet or less most of the time. The total head in this well is 41 feet. As this well was drilled two feet into McKay coal, it may be influenced to some extent by the head and water quality in the McKay coal.

Wells WR-128 and WR-129 are located in an erosional remnant of coal, near the margins of the Colstrip power plant effluent pond for Units 3 and 4. The pond was built in the middle 1980's. As evidenced by water quality, well WR-129 has been affected by the pond. However, well WR-128 has also been affected by the pond. Due to the small area of Rosebud coal in which these wells are located, they contain little water, generally between seven and 11 feet. Rosebud coal in WR-129 is only five feet thick and is overlain by 72 feet of highly permeable clinker.

Water quality in the Rosebud coal wells in Area E is highly variable, ranging from less than 1,000 mg/L in WR-128 and WR-174, to slightly over 6,000 mg/L in WR-129. Water quality in WR-174 appears correlated somewhat with water level, with TDS increasing with increasing water level. Elevated concentrations of boron and chloride, two analytes used to characterize water quality affected by coal ash, are in samples taken from WR-128 and WR-129. Increased potassium concentrations in samples

taken in 1996 and later from wells WR-108, WR-128, and WR-129 also characterizes these wells. The source of the potassium has not been identified. Potassium does not represent a hazard or concern.

Drawdown in Area B overlaps that of Rosebud Mine Area E. Drawdown from additional mining in Area B as proposed in AM4 is not expected to extend into Area E by the time mining in AM4 would be completed in 2026 (see **Section 9.2.7**). However, recovery of water levels and water quality in Area E may be extended somewhat, as Area B is up gradient of Area E and a source of lateral recharge to Area E. Upon saturation of Area B spoil, groundwater is anticipated to move beyond the permit boundary to the east southeast, toward the down gradient crop line in Area E, the former Pit 6 mine area, and Big Sky Area A and Area B. With the exception of Area B spoil well WS-158, which has a higher TDS, spoil water quality in Area B and Area E (including Pit 6) is within the same range (see **Figure 9-56**). Area B spoil is not expected to cause decline in water quality in Area E. As discussed above, no material damage has been indicated in Rosebud coal groundwater as a result of Area E mining and none is predicted to occur as a result of current or future Area B mining.

9.2.5.1.4 Interburden

The interburden, like the overburden, is composed of thin, discontinuous beds of low conductivity sedimentary rock. Locally, water in the interburden may be in communication with underlying McKay coal where there is sufficient pressure head. The interburden is of low yield and not utilized as a water resource.

Area A

Two active interburden wells remain in Area A (**Figure 9-28**). Well WI-111 (**Figure 9-41**) is located in the east part of Area A, immediately west of mining. Mining recently resumed at this location after a hiatus of 14 years. The pit remained open since mining of the last cut in 2000 and held water for much of the time the area was in hiatus. Early mining (1978) south of well WI-111 may have caused water levels to decline prior to well installation and the upward trend characteristic of this well may represent recovery. However, the well maintained a gaining water level trend, as did the McKay well (WM-129) at the same location, when mining was nearby in the 1990's, suggesting that it was insulated from mining effects. Well WI-111 now has a head of 65 feet and the McKay has a 70-foot head. The water level measurements from these two wells are similar enough to infer that the McKay coal and overlying interburden are in communication.

Well WI-102 is located in the southeast part of Area A near the margin of early (1979) mining. The earliest water level measured in this well was 1980, indicating that it was installed after mining and therefore likely records the recovery of the interburden water levels. It currently contains more than 80 feet of water. Adjacent wells in the McKay coal (WM-130) and spoil (WS-106) show the same increasing water level trend as WI-102. Similar water levels suggest that these wells are in communication. Location of these wells adjacent to a pond is a likely source of the recharge.

Interburden wells removed during mining include WI-101 and WI-112. WI-101 was located in the northwest part of Area A and contained approximately 62 feet of water at initial measurement. A declining trend characterized this well from the first measurement even though mining in the area did not begin until the middle to late 1980's. The abrupt rise in water level near the end of well life likely reflects well failure as mining approached. By contrast, well WI-112 never contained more than a foot of water and gives no clear indication of being impacted prior to removal.

Water quality in Area A interburden wells is variable within a given well and between wells. Well WI-111 showed a decline and then an increase in TDS, dropping from 1,840 mg/L (SC = 2,350 μS/cm) to 877 mg/L (SC = 1,370 μS/cm) and later returned to initial TDS concentration range. The reason for the variation is not clear and there is no clear correlation with mining activity other than the possible effect of standing water in the pit contributing to the decline in water quality. McKay well WM-129 is in likely communication with WI-111, has also shown a decline and subsequent rise in TDS concentration, and is now at 1,740 mg/L (SC = 2,310 μS/cm). TDS is slightly higher in the McKay coal well. TDS in well WI-102 climbed from 1,980 mg/L (SC = 2,130 μS/cm) to as high as 3,480 mg/L (SC = 3,460 μS/cm), but is now at 2,850 mg/L (SC = 2,800 μS/cm). The spoil well at this location has lower TDS concentrations (3,440 mg/L) than found in WI-102 at the time of its highest TDS concentration although it could influence water quality given the fact that water levels suggest it is in communication with the interburden.

Area B mining proposed in AM4 is not expected to affect interburden in Area A. No material damage has been observed in the interburden groundwater in or near Area A and none is expected. Well WI-102 may show a water quality impact from mining, but this well is located within the permit boundary and migration of water in the interburden is limited by the low permeability of this unit.

Area B

There are eight active interburden monitoring wells in Area B (**Figure 9-30** and **Figure 9-31**). The wells at the east end of Area B (WI-157, WI-159, WI-184, and WI-185) show a rising water level trend that represents a recovery subsequent to drawdown associated with mining (**Figure 9-42**). These wells were installed within the mined area after reclamation was complete. The strength of the rising trend, particularly at the far east end of Area B, is due to hydrologic connection between water in EFAC alluvium and spoil and bedrock units that experienced drawdown during mining. McKay coal, spoil and interburden in this area have nearly identical water levels suggesting that they are in hydrologic communication.

Interburden wells in the southwest part of Area B (WI-162 and WI-164) recorded drawdown associated with mining. Mining in this part of Area B began more than a decade after mining in the east part of Area B. Within the past few years, these wells have begun to show a slight recovery. McKay wells WM-162 and WM-164 show the same water levels and response as the interburden wells at the same location. Recovery to the wells is laterally from the west but is limited by their location near the active pit.

Wells WI-157, WI-159, and WI-184 have shown increases in TDS coincident with increasing water level. Among the interburden wells in Area B, WI-159 has the highest TDS concentration at 4,390 mg/L. The adjacent spoil well, WS-159, at the same water level as WI-159, has a TDS of 4,220 mg/L, suggesting that it may be contributing to interburden water quality at this location. WI-157 and WI-184 remain below a TDS concentration of 2,400 mg/L at this time. Nearby spoil well WS-157 has a TDS concentration at 2,670 mg/L (SC = 2,830 μS/cm). Well WI-184 lies adjacent to spoil well WS-184 with a nearly identical water level. They have TDS concentrations of 2,360 mg/L (SC = 2,480 μS/cm) and 2,350 mg/L (SC = 2,490 μS/cm), respectively. Nearby alluvial wells WA-126 and WA-128 have TDS concentrations of 3,070 mg/L (SC = 3,890 μS/cm) and 2,890 mg/L (SC = 3,330 μS/cm), respectively. Alluvial water is currently the main source of recharge to spoil and interburden at this location and generally shares a similar chemistry and quality.

WI-160 is in the east part of Area B but lies in an undisturbed area, south of pits mined as recently as 2007. TDS concentration in this well has increased from 418 mg/L (SC = 718 μS/cm) to as high as 1,360 mg/L (SC = 1,780 μS/cm) and now measures 1,180 mg/L (SC = 1,570 μS/cm). Similar increases occurred in the adjacent Rosebud coal well, WR-160. The most likely cause of water quality change is associated with changing water levels due to mining.

WI-185 has shown a decline in TDS concentration during a rise in water level. The TDS concentration in this well currently is below 1,000 mg/L and is similar to TDS in interburden wells WI-162 and WI-164. WI-162, WI-164, and WI-173 have shown a decline in TDS concentration with decline in water level. These wells have a TDS concentration of between 1,100 mg/L and 1,300 mg/L.

Interburden in the east part of Area B is relatively thin and appears to be hydrologically connected with the Rosebud coal and McKay coal. Based on the response of interburden wells in the east part of Area B, the proposed mining in AM4 is expected to cause additional interburden drawdown in the immediate vicinity of the mined area. This will result in longer water level recovery of depressed water levels in interburden. No physical disturbance of the interburden is expected. Upon saturation, the overlying spoil may diminish interburden water quality in the area of the AM4 pits where the interburden water level is near the base of the spoil. This change in interburden water quality is not expected to render the interburden groundwater: 1) unsuitable for existing and anticipated uses; 2) harmful, detrimental, or injurious to beneficial uses; or 3) cause exceedances of narrative or DEQ-7 standards outside the Area B permit boundary. Thus, no material damage is expected.

Area C

Seven interburden wells remain active on the periphery of mining in Area C **(Figure 9-32**). Wells impacted by mining typically have an abrupt decline in water level, as exhibited by WI-181, located adjacent to mining in the west part of Area C (**Figure 9-43**). Wells WI-171 and WI-172 remain approximately a mile and a half-mile, respectively, from the limits of mining at Area C and have not been affected by mining. The persistent, long-term decline in these wells was in progress when these wells were installed, long before the nearest mining began in 2006 and 2010. Although located immediately adjacent to mining that took place in 1984, WI-153 had a relatively small response and quick recovery and has maintained approximately 20 feet to 24 feet of water. A nearby well, WI-186, installed after mining, appears to record a recovery, although what appear to be errors in measurement cast doubt on data from this well. Well WI-168 would have been affected by nearby mining between the late 1990's and 2011 and the relatively small decline during this period may be associated with mining. Although immediately adjacent to mining in 2003 through 2008, well WI-178 appears minimally affected.

Water quality among the wells is variable, with TDS ranging from 500 mg/L to 5,000 mg/L. Most wells range between 2,000 mg/L and 3,500 mg/L and have shown declines and increases in TDS concentrations. Wells WI-171 and WI-172 are outside areas impacted by mining and changes in the wells are not attributable to mining. Well WI-178 is outside but immediately adjacent to mining and may be experiencing an increase in TDS associated with drawdown. A slight upward trend in TDS concentration had begun before WI-181 became affected by mining. The well with the most significant change in water quality is well WI-186, with a rise from an initial measurement of 504 mg/L to 4,670 mg/L, before dropping to a current concentration of 3,380 mg/L. The rise correlates with an initial increase in water level. Spoil well WS-186 is located near WI-186 but has been intermittently dry and has not had sufficient water to sample. Because it has been dry to scantly saturated, the spoil well is not suspected as the source of the increased TDS. This well is relatively shallow at a completion depth of 65 feet. Atypical increases in chloride (from 5 mg/L to 32 mg/L) and in nitrite-nitrate (from 0.05 mg/L to as

high as 13.9 mg/L) are associated with the water quality changes at this well. Its location in a hayfield and adjacent to a county road subjects this well to anthropogenic sources of contamination associated with agriculture and road maintenance and may explain the observed water quality changes.

Due to the direction of groundwater flow, Area B mining, including mining proposed in AM4, is not expected to impact Area C interburden. No material damage is indicted to the interburden groundwater near Area C and none is expected to occur.

Area D

Only one active interburden monitoring well remains in Area D (**Figure 9-33**). WI-110 is a shallow well with a water level that varies between three and 10 feet (**Figure 9-44**). The "flashy" water level on the hydrograph is due to the shallow depth and tendency of the well to be affected by infiltration from runoff and precipitation. The well has variable water quality but generally has a trend of increasing TDS over time. The source of change in water quality is not clear. An adjacent McKay coal well (WM-128, located stratigraphically below WI-110) shows no trend of increasing TDS and is somewhat lower in concentration at 2,210 mg/L than WM-128 at 2,800 mg/L. Adjacent spoil well WS-129 (located stratigraphically above well WI-110) is dry and thus is not the source of declining water quality in WI-110.

Interburden wells removed during mining generally showed a water level decline as mining approached. Some wells showed an abrupt increase in water level before being removed that was likely due to well failure from blasting as mining drew near. The amount of water in the interburden measured in the wells ranged from 18 feet to 55 feet. Water quality as represented by TDS was highly variable, ranging from 700 mg/L TDS in well WI-183 to 7,000 mg/L in well WI-114. Interburden thickness ranged between 18 feet and 30 feet, and water levels between the interburden and McKay coal maintained a downward vertical gradient.

Area D is geologically isolated from impacts associated with proposed AM4 mining. No material damage to the interburden groundwater is expected near Area D or has been observed to date.

Area E

There are eight active interburden monitoring wells in Area E (**Figure 9-33**). All of them have been active since the early 1980's and most record increases in water level since installation. The 10-foot decline in WI-174 through 1988 reflects drawdown associated with the final stages of mining (**Figure 9-45**). As drawdown was active at the time measurements in the well began, the original water level is unknown. Water level recovery in this well appears to be continuing based on the upward trend on the hydrograph. WI-106 and WI-117 record the end of the water level decline followed by decades of recovery. WI-182 is also likely recovering from drawdown associated with mining. The steady climb in water level observed in WI-116 may be associated with recovery of postmine water level but is also heavily influenced by its location immediately adjacent to the Talen Energy ponds, as are the other monitoring wells in this location (e.g. WM-135, WS-116). WI-107, WI-108 and WI-109 water levels are influenced by their proximity to the power plant ash ponds in the Cow Creek drainage. The amount of water in the interburden wells varies from 11 feet (WI-109) to 55 feet (WI-116). Most wells contain less than 25 feet of water.

Water quality, as represented by TDS concentration, is variable in Area E interburden wells, ranging from less than 1,000 mg/L to greater than 4,000 mg/L. WI-108 has a high variability but no trend of increasing concentration. This well is located at the southeast corner of the ash pond in the Cow Creek

drainage and has been affected by leaks from the pond as well as pumping wells (as exhibited by the water level hydrograph for this well) designed to capture affected groundwater. Most of the interburden wells in Area E appear to be affected by poor quality water from the plant area or ash ponds, based on the presence of higher than background boron concentrations. Background boron concentrations in Rosebud Mine aquifers typically contain no more than 0.5 mg/L. Area E interburden wells consistently in the initial boron concentration range are WI-107 and WI-174 (**Figure 9-46**). Boron concentrations in the remainder of the wells have shown increases in concentration and range from 0.6 mg/L to 1.3 mg/L. A single analysis from WI-108 ranges to almost 10.0 mg/L. Water quality in well WI-174 improved coincident with drawdown (TDS concentration declined from 2,430 mg/L to 1,140 mg/L currently) and has maintained this quality as water levels recovered.

AM4 proposed mining in Area B is not expected to affect interburden in Area E. For the reasons stated above, Area E interburden groundwater has shown no evidence of material damage and none is expected. Water quality impacts noted above are all attributable to the Talen Energy plant area and ash disposal ponds.

9.2.5.1.5 McKay Coal

The McKay coal ranges between eight and 23 feet thick and averages approximately 18 feet thick. It is not physically disturbed by mining and lies below the Rosebud coal a few feet to tens of feet, depending on the thickness of the interburden. The McKay coal typically is confined and generally has a pressure head of tens of feet except near outcrop limits, where the aquifer becomes unconfined. Most McKay coal within the mined areas has experienced a slight decrease in head due to mining.

Area A

Five McKay coal monitoring wells have been active in Area A for more than 30 years (**Figure 9-28**). Well WM-105 lies the farthest from mining, northwest and just outside the permit boundary, approximately a half-mile from mining. The hydrograph for WM-105 generally shows three feet to four feet of variation in water level during the monitoring period that subtly reflects climatic changes rather than the effects of mining (**Figure 9-47**). Thus, WM-105 represents background conditions at this location. The total head at this well is currently 104 feet.

Based on proximity to and timing of mining, well WM-104, located interior of mining, likely experienced drawdown associated with mining during 1993-1994, although the amount is uncertain due to climate influences suggested by the hydrograph trend. Water levels have shown at least 10 feet of recovery from a low in 1994 and have remained approximately steady since 1999. The temporary five-foot increase in water level during higher than normal precipitation in 2011 illustrates the susceptibility of this well to climate effects. The water elevation (total head of 124 feet) in this well is the same measured in adjacent Rosebud well WR-104, suggesting that they are hydraulically connected. The interburden between the two coal units at this location is 54 feet. McKay coal wells in Area A have a head between 72 feet and 124 feet.

Wells WM-103, WM-129, and WM-130 show increasing head through time, although the setting of WM-103 and WM-130 is substantially different from WM-129. WM-130 is located at the south margin of early reclamation near a perennial pond. The increasing head in this well likely reflects recovery of head lost during early mining. However, the pond likely contributed to the 13-foot rise in water level. Interburden well WI-102 is located adjacent to this well and shows the same increase in water level. WM-103 is located adjacent to a cut off loop meander of EFAC that is used as a pond to capture runoff from the tipple area. The close proximity of this pond affects the water level in the monitoring well.

WM-129 is located in the eastern interior of Area A, close to the last mining cut (taken in 2000). It has also shown an increase in water level of approximately 13 feet with a nearly constant upward trend since the middle 1980's. Adjacent interburden well, WI-111, also showed an increase in water level of the same magnitude. The increase may reflect a recovery of earlier drawdown but is likely also affected by water that has collected and ponded in the adjacent idle pit.

With the exception of WM-129, TDS concentration does not vary much within a given well. WM-129 has varied from 984 mg/L to 1,990 mg/L without a consistent trend. Average water quality among the wells varies from 1,723 mg/L (WM-103) to 3,036 mg/L (WM-105). There is no indication that water quality in these wells has been influenced by mining.

Mining resumed in the east pit of Area A in 2014. Continued mining will increase the decline of head in the McKay coal although it will not physically disturb it. The interburden separation between spoil and McKay coal is sufficient to protect it from effects of spoil water quality. The drawdown model (see **Section 9.2.7**) predicts drawdown of between 10 feet and 15 feet in the McKay coal in 2011 and 2020, with the greatest drawdown in the southwest part of Area A. Approximately 15 feet of drawdown, limited to the south edge of the permit area, is projected to remain in 2026 at the end of mining in AM4.

Because the TDS concentrations in McKay wells in Area A show no variability attributable to mining operations, no material damage has been observed or is expected to occur in groundwater in the McKay coal near Area A.

Area B

McKay coal monitoring wells (**Figure 30** and **Figure 31**) abandoned or removed during mining record loss of head in the aquifer (**Figure 9-48**) as mining approached. Wells in the southwest part of Area B (WM-100, WM-113, and WM-163) showed the least amount of head loss, with declines between four feet and nine feet. Remaining head ranged between 67 feet and 90 feet in these wells. McKay wells removed from the east end of Area B (WM-161, WM-106) experienced head declines of 44 feet and 57 feet, with 58 feet and 106 feet of remaining head. Baseline TDS ranged from 426 mg/L to 1,830 mg/L (average of 1,011 mg/L). After mining began to affect water levels in the wells some of them experienced changes in TDS, both increases and decreases, with a range from less than 100 mg/L to 1,833 mg/L. Increase in TDS concentrations due to infiltration from spoil is not a likely cause for increasing TDS as the spoil in this area remained dry to scantly saturated at the time these wells were in place. Interburden water quality generally has a lower TDS than the McKay wells and is not a likely source of increase in McKay water quality. The source of the change remains undetermined.

Eight active McKay coal wells have water level observations that date from the early to middle 1980's **(Figure 9-49**). The four active wells in the northeast part of Area B (WM-158, WM-159, WM-184, and WM-185) record head gains of between 12 feet and 20 feet. The gain appears ongoing as of the last measurements. As these four wells were installed in reclamation, the trend of increasing water level reflects recovering pressure head lost during mining. Current head in these wells ranges from 54 feet (WM-159) to 81 feet (WM-184).

The four active McKay wells to the southwest (WM-139, WM-162, WM-164, and WM-173) record declines in head of between nine feet and 26 feet and have a remaining head of between 87 feet (WM-173 and WM-139) and 110 feet (WM-164). These wells were in place during mining and are located outside mine disturbance. A gently declining trend observed in most of these wells at the time monitoring began is likely climatic in origin. A sharp drop in head on the hydrographs point to the time

the well responded to mining. The decline in these wells appears to have ended and a slight recovery begun.

Well WM-139 records a continuous gentle decline beginning in 1984, lasting until 2008. The nearest mining (in Area C) is located approximately 1,200 feet from this well and was not active until 2005. It does not appear that this well has been affected by mining.

Along with a decline in water level, well WM-162 shows a trend of declining TDS, from a high concentration near 3,000 mg/L to a concentration hovering consistently above 1,000 mg/L in the last decade. WM-184 has a trend of increasing TDS from 902 mg/L to 1,530 mg/L which may be the result of water quality changes attributable to infiltration from overlying interburden (TDS = 2,360 mg/L) and spoil (TDS = 2,350 mg/L) water. The remaining wells do not exhibit strong trends or significant changes in TDS. The average TDS among the wells ranges from 1,109 mg/L to 2,550 mg/L.

Modeled drawdown in 2011 (see **Section 9.2.7**) estimated a maximum of approximately 30 feet of decline in McKay coal head, centered in the east central part of Area B. At the end of currently approved mining in Area B (2020), drawdown is expected to remain approximately the same. Mining proposed in AM4 would increase the amount of drawdown in the McKay coal to 35 feet but would not measurably increase the extent. Due to the substantial confining pressure in the McKay coal, significant head is expected to remain even with the predicted drawdown. As the McKay aquifer will remain intact and connected to up gradient flow, recovery is expected to reach former water levels but may take longer with the additional AM4 mining. The separation between the base of spoil and the top of the McKay coal is approximately 10 feet in the vicinity of the cuts proposed in AM4. The narrow separation makes it more likely that McKay coal water quality may be affected by spoil water quality. In the east part of Area B where water level recovery is underway in all units, only one well (WM-184) has shown a marked increase in TDS concentration (from 902 mg/L to 1,530 mg/L). This suggests that if there is substantial decline in McKay coal water quality, it will be local in extent. Any local decreases in water quality in the McKay coal groundwater in Area B are not expected to spread beyond the permit boundary and constitute material damage.

Area C

The drill logs of the eight active McKay monitoring wells in Area C (**Figure 9-32**) show much of the McKay coal is less than 10 feet thick. Only one well (WM-181) monitors McKay coal as thick as 12 feet. All of the water levels measured in the McKay coal aquifer indicate that it is under confining pressure with heads as great as 104 feet (WM-107)(**Figure 9-50**).

WM-181, located approximately 1,500 feet southwest of the active pits had a 16-foot drop in water level after 2007 that is likely associated with mining. The period between the early abrupt increase in water level followed by an abrupt decrease some three years later likely represents measurement or calculation errors. Last measurement shows a slight increase in water level that may indicate the beginning of water level recovery.

WM-153 and WM-186 are both located along the north edge of mining in the east part of Area C. Mining in the area began near the outcrop in 1984 and continued through the early 1990's. The hydrograph for both of these wells shows a period of variable water level during this time with a loss of head between 2 feet and 6 feet. Both wells have recovered to premine levels. The irregularity of the water level measurements in WM-107 between 1988 and 2003 suggest a problem with the well or in the measurements taken at this well. WM-107, like WR-103 (discussed above), is located outside the permit

area, southwest of mining. The period of decline in this well occurred prior to the time that it could have been influenced by mining.

The drop in water level in well WM-178 in 2007 reflects the beginning of a four-foot head loss in response to mining. Current water levels have returned to premine levels.

The decline observed in monitoring in well WM-191 is not likely associated with mining. Monitoring in this well did not begin until late 2002 and it remains over a mile from nearest mining. WM-201 was installed in reclamation in the north part of Area C and reflects rising head associated with recovery after mining.

Water quality in the Area C McKay coal wells has been relatively consistent in some wells and more variable in others. TDS concentrations have ranged between 2,000 mg/L and 3,500 mg/L with the exception of concentrations in WM-107 and WM-186. WM-107 reached a concentration as high as 4,740 mg/L before returning to a concentration that is currently 2,760 mg/L. WM-186 has shown an increase from a concentration of approximately 500 mg/L to a current concentration of 2,250 mg/L. Adjacent interburden well WI-186 has also experienced a substantial increase in TDS concentration, suggesting that both wells are influenced by a similar source. Nearby spoil wells WS-122 and WS-186 contain five feet and 16 feet of water, respectively. Historically these wells have been dry to intermittently dry and have not been sampled for water quality. The thickness of the interburden ranges from 23 feet (WI-153) to 57 feet (WI-186) and is generally considered protective of the McKay coal water quality as the vertical conductivity of the interburden siltstones and mudstones is low.

Maximum drawdown in McKay coal in Area C was modeled to be 25 feet by 2011 (see **Section 9.2.7**). Further decline in head is predicted to be 30 feet in 2020 and to remain at 30 feet in 2026. Given the amount of potentiometric head in the McKay coal, the decline in head is not expected to be significant. As the McKay coal is not physically disturbed and remains laterally continuous up gradient, recovery of head is expected. Changes to the McKay coal water quality are not expected to result from mining and no material damage is expected to occur.

Area D

Five active McKay monitoring wells remain in Area D (**Figure 9-33**). Thickness of the McKay coal in Area D averages approximately eight feet but increases to 12 feet in the center of the permit area, where the McKay is at a greater depth. The McKay coal was confined throughout Area D except near the outcrop, with heads of up to 24 feet. Heads are lower in the north part than the central and south part of Area D. Drawdown ranged from none to as much as 13 feet during mining. Many hydrographs from the active wells indicate that an increase in water level is taking place, as evidenced by the water level in well WM-189 (**Figure 9-51**). Well WM-189 was installed to replace well WM-110 that was removed by mining in 1991. Current water levels are equivalent to premine levels with approximately 34 feet of head in the well.

The poorest water quality (TDS = 3,300 mg/L - 5,400 mg/L) was measured in historic wells along the north edge of Area D, whereas the best water quality is found in the southeast leg (e.g. active well WM-125, TDS = 1,500 mg/L) where clinker is common. Water quality is variable among the active wells, ranging from 1,500 mg/L (WM-125) to as high as 4,150 mg/L (WM-188). The TDS concentration in well WM-188 is higher than the spoil well (WS-188) at the same location (TDS = 1,700 mg/L). There is no indication that water quality in the McKay coal is being affected by spoil or has otherwise changed due to mining.

The McKay crop line is exposed around the north, west, and east sides of Area D, meaning that it is not connected to up gradient lateral flow. Additional recharge to the McKay coal will come from infiltration through the Rosebud/spoil or directly from precipitation when the McKay coal is near the surface. An interburden thickness of 18 feet to 30 feet offers protection to the McKay coal from infiltration of spoil water. No material damage to groundwater in the McKay coal has been noted near Area D. Area D is geologically isolated from impacts associated with proposed AM4 mining, thus precluding the potential for material damage.

Area E

There are 12 active McKay coal monitoring wells in Area E, including three that were installed in the former Pit 6 permit area (**Figure 9-33)**. The average McKay coal thickness in Area E is nine feet. As much of the mining in Area E was pre-mining there were no baseline data gathered to compare to current data. However, the active wells have more than 30 years of data. All of the wells indicate a confined aquifer and most have a head of 30 feet or more. A number of the wells have rising water levels that represent recovery subsequent to mining drawdown (**Figure 9-52**). Wells WM-127, WM-136, and WM-138 have variable water levels that reflect power plant ash pond water management. Pumping wells have been installed along the periphery of the pond to control movement of groundwater away from the pond.

Most of the mine monitoring wells were installed after mining concluded, including areas along the east margin of Area E and Pit 6 that were mined pre-law. However, well WM-174 located near the last mine cut was installed in time to record drawdown at the end of mining and subsequent water level recovery. Well WM-135 began a marked upward trend in 1988 and steadily gained 30 feet over a period of 10 years. This well is located immediately adjacent to ponds at Colstrip power plant that have likely contributed to the water level and water quality of this well. Well WM-124 has also gained approximately 30 feet of water, likely due to its location on the southeast side of the ash ponds in Cow Creek drainage.

Water quality in the Area E McKay wells is highly variable. The wells (WM-121, WM-122, and WM-123) south of the Area E permit, in the former Pit 6, have TDS concentrations that average 500 mg/L or less. With the exception of wells WM-127, WM-135, and WM-182, TDS concentration in the Area E McKay wells typically is 2,500 mg/L or less. Boron concentrations greater than background (background = 0.5 mg/L or less) in a number of the wells suggests nearby ash ponds have influenced their water quality (**Figure 9-46**). These include WM-126, WM-127, and WM-138. As discussed above, the water level and chemistry of WM-124 is influenced by the nearby ponds at the power plant. The greatest water quality anomaly in the area is the stable, long-term TDS concentration of 7,500 mg/L to 8,000 mg/L in well WM-127 (WR-129 at this location also has a relatively high TDS concentration). At 11 feet of saturation, WM-127 contains the least amount of water of any well in Area E. It contains anomalous amounts of dissolved iron, chloride, magnesium, and sulfate. The concentrations of all analytical components are higher in this well than any other Area E spoil well. For this well and all other McKay wells in Area E, there is no indication that spoil water is influencing water chemistry.

Mining in Area A and Area B has created drawdown in the McKay coal that extends into Area E and adds to the drawdown created by mining in Area E (see **Section 9.2.7**). Modeling for 2026, the year AM4 mining is to conclude, shows water level recovery underway with the eastern extent of the drawdown cone lessening in Area E. Except for areas under the influence of power plant activities (e.g. WM-127 and WM-138), hydrographs indicate that water levels in the McKay coal are recovering and are expected

to continue this trend. Due to activity associated with the power plant it is difficult to tell if mining has impacted or will impact the water quality in Area E. The unusually low TDS that characterizes McKay coal groundwater in former Pit 6 indicates no mining or power plant impacts at this location. As described above, no material damage has been indicated to McKay groundwater in or around Area E and none is expected to occur.

9.2.5.1.6 Underburden

Underburden monitoring wells are completed in water bearing strata below the McKay coal in every permit area of the Rosebud Mine. Well depth varies from 130 feet to over 400 feet and usually represents the first water bearing zone below the McKay coal. The variation in depth results in different water elevations and water quality. Underburden wells monitor mining associated drawdown and water quality changes, including potential downward migration of water from the spoil.

Examination of water levels and water quality in the underburden wells through time indicates that the underburden remains largely unaffected by mining in much of the Rosebud Mine. Although water levels in some areas appear to show a response to mining, there is no indication that spoils water is affecting the underburden aquifer water quality. Mining proposed in AM4 is not expected to cause water level or water quality changes in underburden groundwater. No material damage has been observed to underburden groundwater at the Rosebud Mine and none is anticipated.

Area A

Rosebud Mine Area A has one active underburden well (WD-107) located approximately 500 feet west and up gradient of mining (**Figure 9-28** and **Figure 9-53**). It is 203 feet deep. Monitored since 1981, this well predates the beginning of local mining in 1987 and has shown no significant changes in water level or water quality since mining began. Another well (WD-109) located two miles northwest of Area A and over a mile from mining in Area C, has been monitored since 1982 and remains unaffected by mining

Area B

Rosebud Mine Area B has six active underburden wells (**Figure 9-30** and **Figure 9-31**). They range in depth from 147 feet to 425 feet. Except for the deepest well (WD-195), the wells appear to have an upward gradient with more than 100 feet of head. Except for the deepest well (WD-195), wells have a head of more than 100 feet, suggesting there is an upward gradient between the underburden and overlying units in some areas (**Figure 9-53**).

Mining in Area B began in the late 1970's at the far east end and followed the crop line southwest along EFAC through the middle 1980's to the line between section 7 (T1N, R40E) and section 12 (T1N, R41E). Mining further to the southwest began in the middle 1990's. Well WD-100, completed some 130 feet below the Rosebud coal, monitored water level and water quality in the northeast part of Area B from 1979 until removed ahead of mining in 1986. By early 1981, the well was showing a decline in water level although mining was a mile away. The final measurement in 1986 indicates a total water level decline of almost 50 feet. The decline in water level closely mimics hydrographs of adjacent wells WR-101 and WM-106, suggesting the cause for the decline was mining related.

Wells installed in 1982 and later in northeast Area B (WD-159, WD-160, and WD-184) have a hydrograph that shows an initial short, sharp decline that was in progress at the time of installation (1982-1985), likely representing a response to mining that was already in progress. It was followed by a gain in head of between 12 feet and 20 feet until approximately 2002-2003. The persistent, relatively steep rise in head into the late 1990's in these deep wells is observed in every stratigraphic interval monitored in this

part of Area B. The rise most likely represents recovery from an earlier decline in head like the decline observed in WD-100. Subsequent, short-lived declines like the ones seen in WD-184 likely reflect renewed mining near the well. Recent water level fluctuations are in response to climate.

Two underburden wells located farther to the southwest were installed in 2008-2009. WD-195 is a mile west and up gradient of mining and appears to have had no response to mining. WD-196 is in reclamation and shows a slight increase in water level, but whether the increase is due to recovery or a response to climate is uncertain.

Except for WD-160 and WD-196, the wells have maintained relatively consistent water quality, suggesting they have remained isolated from other water sources during changes in water level. TDS concentration currently ranges from 221 mg/L to 3,090 mg/L. WD-160 showed a strong increase in TDS concentration after the first sample and then a precipitous decline in 1998, to an uncharacteristically low TDS range of less than or equal to 200 mg/L, where it has remained. A possible explanation is that a different, secondary water source reached the well. However, surface water or groundwater in the vicinity with this low of a TDS concentration has not been identified. WD-196 experienced a slight increase in TDS concentration with increased water level.

The decline in underburden head in the east part of Area B appears to be a response to the unloading of overlying units removed during mining, rather than a direct hydrologic connection to the shallower units. Underburden will likely continue to have this response as mining continues in Area B. With the lack of direct hydrologic connection and a significant thickness of low conductivity material between underburden and the overlying McKay coal, no change in water quality from spoil water is expected.

Area C

Area C has 10 active underburden wells (**Figure 9-32** and **Figure 9-54**). Wells with a long record outside or on the periphery of mining (WD-178, WD-181, WD-187, and WD-194) span baseline, mining and post-mining monitoring. They show no significant changes in water level or water quality**.**

Well WD-186 was installed in 1986, soon after mining in the area was finished, and is completed 150 feet below the base of spoil. Well WD-186 showed a slight increase in water level in 1991 and has shown a trend of increasing TDS, from 694 mg/L to 2,660 mg/L that began shortly after installation. The increase in TDS is mainly due to increases in sulfate, but includes increases in calcium, magnesium, chloride, iron, and manganese. Well WD-153, located approximately a mile to the west and up gradient of WD-186, was installed after reclamation and a few years later than WD-186. Samples from WD-153 have somewhat variable concentrations of TDS, ranging from 2,710 mg/L to 3,250 mg/L, but also unusually elevated concentrations of iron and chloride. The water quality in WD-186 is within the range of that in WD-153. Spoil in this area is dry (e.g. WS-120 and WS-186) and therefore could not be contributing to the water quality change in the underburden. The location of WD-186 adjacent to the county road may influence water quality (e.g. chloride and magnesium increases) as identified in other monitoring wells located adjacent to the road.

New underburden wells (WD-198, WD-199, WD-200, and WD-201) were installed within the last few years in the former pit area. These wells have only a few measurements to date. Well WD-200 was installed in 2012 in the same location and approximate depth as WD-179, which was removed by mining in 2008. Plotting the two on the same graph (**Figure 9-54**) shows the water level has remained the same, but TDS is slightly higher. The remaining new wells have water quality that is comparable to background measurements from underburden wells.

Area D

There are four active underburden wells in Area D (**Figure 9-33** and **Figure 9-55**). The active wells are located outside the margins of mining (WD-105, WD-106) or in reclamation in the "fingers" that extend northeast (WD-202) and southeast (WD-197) of Pony Creek. Active wells and wells that were removed during mining recorded water level changes over decades. Some water level changes may be in response to mining but others appear to be responses to unidentified stresses. Well WD-103, completed some 140 feet below the Rosebud coal, appears to respond to mining that took place in 1987, approximately a half-mile to the east, but an earlier, less dramatic decline beginning in 1980 is likely in response to a period of below average precipitation. The substantial and persistent drop in water level in well WD-152 and coincident increase in TDS concentration that began in 1982 is in response to a stress other than mining, as mining was not active in the area until 2002. Water level decline was underway in WD-105 when it was installed in 1981, prior to any mining in Area D. A decline of approximately 13 feet in WD-105 that began in 2002 may have been, at least in part, associated with mining. The earlier drawdown suggests that the response of the well may be limited to climate related factors. WD-106 shows no evidence of being influenced by mining. Wells WD-197 and WD-202 are in reclamation and fall within water level and water quality range of background underburden measurements.

Recent TDS concentrations in the wells range from 1,460 mg/L to 2,700 mg/L. Water quality has remained stable in most of the wells. TDS concentration in WD-106 declined in the first 10 years after installation but has remained stable since 1990. There are no water quality impacts from mining.

Area E

There are three active underburden wells in Area E that were completed in or at the margins of reclamation (**Figure 9-33** and **Figure 9-55)**. Completion depths range from 160 feet (WD-104) to 500 feet (WD-174, WD-182). All wells show steadily increasing water levels and declining to steady TDS concentrations. Water level increases range from approximately seven feet to 13 feet. The water level response in WD-104, the well with the shallowest completion, did not begin until eight to 10 years later than the other two underburden wells. The increasing water level trend in WD-174 and WD-182 began at about the same time that mining concluded in Area E, suggesting that the increasing trend represents a recovery, although these two wells were completed some 250 feet below the Rosebud coal. Current TDS ranges from 1,040 mg/L to 1,470 mg/L. None of these wells have water quality that suggests they have been impacted by mining.

9.2.5.1.7 Spoil

Water saturates the broken overburden material spoiled into each previously mined out cut as the next cut is opened. Most water entering the spoil is from laterally adjacent Rosebud coal, although ponds and other surface water sources contribute to recharge where available. Thickness of the spoil varies from as shallow as 15 feet to 150 feet, although most spoil wells are completed at less than 100 feet.

Water levels in spoil vary widely and depend upon a number of hydrologic factors. Proximity to recharge has the greatest influence on spoil saturation. Areas where mining is active restricts recharge and promotes drawdown, thus slowing spoil saturation. Recharge from up gradient Rosebud coal is often intercepted by active or open pits from reaching down gradient reclamation. However, in some instances, standing pit water and ponds contribute locally to spoil recharge, as do streams and alluvium. In some permit areas, such as Rosebud Area A and Area D, vertical recharge increases in importance due to the erosion of laterally up gradient water bearing units (e.g. overburden, Rosebud coal). Vertical

recharge in the Colstrip area occurs slowly due to low precipitation. Spoil water recovery throughout much of the mine areas remains depressed at this time and will remain strongly influenced by mining activities until final reclamation is completed.

Aquifer tests in spoil wells indicate that spoil has the ability to recharge and the flow system to recover. Eleven tests of mine spoil hydraulic conductivity in the Colstrip mines were completed using a bailer recovery method (Van Voast et al., 1977). The values generated were in the same general range as those for undisturbed coal-bed aquifers. Eight spoil wells at the Rosebud Mine were tested and found to have transmissivity ranges from 28 gpd/ft to 2,955 gpd/ft (Western Energy Co., 1984). This implies that spoil has the ability to conduct groundwater similar to the Rosebud coal prior to mining and will not restrict post-mining groundwater flow. Due to the increased porosity or void spaces created by the broken overburden material that forms the spoil aquifer, vertical conductivity and storage coefficient for spoil is expected to be somewhat greater than that of the Rosebud coal it replaced.

Prediction of spoil water quality is complex and has been approached in numerous ways. Van Voast and Reiten (1988) observed that southeast Montana mines averaged an increase in mine spoil of 50 to 200 percent over that of undisturbed aquifers. Geochemical conditions simulated in the laboratory with bench scale column-leach and paste-extract leaching tests using overburden materials suggest that the dissolved-solids concentrations in the backfill water reach a maximum during initial saturation and then decrease to an equilibrium level after one or more pore volumes of water pass through the backfill (Van Voast and Reiten, 1988).

The water chemistry of spoil water in future mine areas is anticipated to be comparable to that currently observed, although water quality in spoil can be highly variable, even within a local area. The timing for improved spoil water quality will vary from location to location and is dependent on spoil mineralogy, local hydrologic character of the disturbed areas including recharge rate and flow rate, timing of reclamation of up gradient areas, extent of up gradient mining, restoration of hydraulic gradients and source and quality of recharge. In general, spoil water quality is expected to recover to near premine water quality as salts are flushed through the spoil.

Forty-four spoil wells are active in the Rosebud Mine. Many wells show some level of recovery but others remain dry or have insufficient water for sampling. Twenty-five spoil wells from throughout the permit areas have a history of water quality sampling (**Figure 9-56**).

The greatest chemical changes in spoil water compared to Rosebud coal water chemistry are increases in TDS concentrations driven by increases in sulfate, calcium, magnesium and bicarbonate (**Figure 9-18**). Comparisons among the latest samples (2012-2014, one sample from each currently monitored well) show spoil TDS concentrations ranging from 1,830 mg/L to 7,690 mg/L (median = 3,690 mg/L; average = 3,963 mg/L). Current Rosebud coal TDS concentrations range from 594 mg/L to 6,460 mg/L (median = 2,620 mg/L; average = 2,674 mg/L); overburden ranges from 359 mg/L to 7,720 mg/L (median = 3,610 mg/L; average = 3,799 mg/L). Currently, spoil TDS concentration represents an increase of 2% of the median and 4% of the average TDS concentration in overburden water, and an increase of 41% of the median and 48% of the average TDS concentration in the Rosebud coal aquifer at the Rosebud Mine. Given the fact that overburden composes the spoil, it is no surprise that spoil water quality most closely resembles that of overburden.

Area A

Ten spoil wells are active in Area A although only seven have sufficient water to monitor (**Figure 9-28** and **Figure 9-57**). Many of them were installed in the early 1980's in the south and east part of the permit area, where the earliest mining took place. Wells along the south edge of Area A, near EFAC, have 21 feet to 46 feet of water. Many of these wells are located near ponds which are contributing to the local recharge. Wells adjacent to EFAC are also the shallowest wells as they are located near the Rosebud coal outcrop. Spoil wells along the east margin of Area A (WS-100, WS-101) contain 13 feet to 20 feet of water, but wells immediately to the west (WS-102, WS-103) are dry. WS-107 is in close proximity (1,000 feet) to an open pit that collects water and may have contributed to rising water levels. Water levels remain depressed in the west part of the permit area and spoil is dry (e.g. WS-123). As coal is removed to near the crop margins, there is no lateral up gradient source of groundwater to the west, which will slow spoil saturation.

Six active spoil wells in Area A have decades-long histories of regular water quality analyses. Some wells show increases in TDS through time coincident with rising water levels (WS-100, WS-113, and WS-115). The highly variable water quality in WS-114 is the result of infiltration of surface water (with lower TDS concentration) due to the location of this well in a ponded drainage. Most of the spoil wells have relatively high TDS concentrations, but WS-107, with 22 feet of water, remains in the range of background Rosebud coal water quality. Many of the spoil wells have high chloride concentrations (>20 mg/L), especially in more recent analyses. This reflects the susceptibility of the wells to surface infiltration from runoff from roads where magnesium chloride is used. Higher than normal iron (1 mg/L - 13 mg/L) in some of the wells (WS-106, WS-113,WS-114, and WS-115) and high nitrate (up to 34 mg/L) in wells WS-100 and WS-107 may be due to surface infiltration.

Average TDS for Area A spoil wells is 3,299 mg/L, with a range of 2,045 mg/L to 4,122 mg/L. TDS concentrations from the most recent samples range from 1,880 mg/L (WS-107) to 4,530 mg/L (WS-115). Wells WS-100 and WS-113 continue to show increasing concentrations of TDS.

Trace elements from Area A spoil well samples that exceed human health standards (HHS) established in DEQ-7 include nitrate (nitrite-nitrate as NO_3), cadmium, and zinc. With the exception of nitrate, the exceedances are represented by single analyses from a given well and none are recent (see **Section 9.2.6**). Nitrate concentrations above the HHS of 10 mg/L are persistent in well WS-100, ranging as high as 34 mg/L in 2012 and 24 mg/L in 2014. Well WS-100 has not shown significant changes in recent water levels or other analyte concentrations. Nitrate as high as 19 mg/L was analyzed from a sample of well WS-107 as recently as 2005, but currently is at 1.5 mg/L in this well.

Residual nitrate from blasting explosives used in mining is one source of nitrate in mine spoil, but the appearance of nitrate from explosives more than 30 years after reclamation is unusual. Well WS-107 is in a hay field, although the farmers reportedly do not use fertilizer (Western Energy Co., 2014, personal communication). Well WS-100 is located in a field used for cattle grazing. See **Section 9.2.6.10** for further discussion of nitrate HHS exceedances in mine groundwater.

The Rosebud coal crop line defines the extent of mining in Area A. As there is no lateral up gradient recharge, precipitation and surface flow will be the source of recharge for spoil. Upon saturation, flow direction will be to the east-southeast toward the coal crop. Prior to mining the coal crop was dry and is expected to remain dry on the north, west and east sides of the permit area as the hydraulic properties of spoil are expected to be the same as the Rosebud coal. The Rosebud Mine PHC Addendum (Western Energy Co., 2015) indicates that, based on comparison of water levels in spoil and alluvium, Area A spoil

water is moving toward EFAC alluvium. Based upon a simplified mass balance calculation, the contribution of Area A spoil to the observed increase in TDS in EFAC alluvium currently is approximately three percent. Impacts to EFAC discussed in **Section 9.2.4.2.2**, **Section 9.2.5.1.1**, and **Section 9.2.8** indicate that the contribution from Area A spoil to EFAC alluvium water quality is estimated to reach 13 percent. As described in the sections referenced above, no numerical standards are expected to be exceeded and water quality of the alluvium and stream are expected to meet the requirements of beneficial uses, thus no material damage is expected.

Area B

Nine spoil wells are currently active in Area B although only eight contain water (**Figure 9-30** and **Figure 9-31**)**.** Spoil in the northeast part of Area B has shown a strong water level recovery over a period of approximately 30 years. Saturated thickness ranges between 21 feet and 63 feet (WS-118, WS-157, WS-158, WS-159, and WS-184) (**Figure 9-58**). As water levels are highest in the four wells closest to EFAC, surface and alluvial water are the most likely sources of recharge. As the stream has eroded through the Rosebud coal in this area, the coal outcrop is close to the stream and associated alluvium.

By contrast, the spoil wells in the southwest part of Area B (WS-185, WS, 189, WS-190, and WS-191) contain three feet or less of water or remain dry (WS-190, WS-191). Mining is more recent in this part of Area B and wells were installed after 2000. Factors contributing to less recovery in this area include the relatively recent completion of reclamation, the existence of open pits and active mining south of reclamation, and, unlike the northeast part of Area B, Rosebud coal in this area was deeper and did not crop out as close to the stream. Also, intermittent stretches of EFAC are at the northeast end of Area B and thus more water is available for recharge.

Water quality samples are currently collected from the five spoil wells in the northeast part of Area B. Most wells have increased in TDS concentration since installation. The average TDS concentration of the wells with current water quality analyses is 3,686 mg/L, with the average TDS of individual wells ranging from 1,827 mg/L (WS-184) to 7,332 mg/L (WS-158). TDS concentrations of the most recent samples range from 2,350 mg/L (WS-118, WS-184) to 8,030 mg/L (WS-158). WS-158 is notably higher in all major analytes and is more variable in TDS concentration than other Area B spoil wells, although water levels in this well are stable. This well has the highest average TDS of all spoil wells monitored at the Rosebud Mine.

Trace elements reported from Area B spoil wells that exceed human health standards (HHS) established in Circular DEQ-7 include nitrate, cadmium, and lead. The exceedances are represented by single analyses in a given well and none are more recent than 1982 for nitrate, 1991 for cadmium, and 1993 for lead. The appearance of lead above the standard in three wells during a single sampling event in 1993 suggests a problem in quality control during sample collection or lab analysis (see **Section 9.2.6**).

Mining proposed in AM4 would increase the amount of drawdown in Area B and would increase the recovery time of water levels. As more coal is removed with proposed mining, the volume of spoil would be increased. An increase in spoil volume would result in additional dissolved solids with concentrations similar to that observed in existing Area B spoil wells.

Upon saturation, movement of water from some of the Area B spoil is anticipated to be to the southeast rather than toward EFAC (Western Energy Co., 2015). Movement of Area B spoil water toward EFAC alluvium is likely to be limited to the northeast portion of Area B, and these impacts are discussed in **Section 9.2.5.1.1**. Spoil water from the southern and western parts of Area B will be directed to the area

between the Rosebud Mine and the Big Sky Mine, and eventually to the Big Sky Mine permit areas. The distance between the Rosebud Mine and Big Sky Mine ranges between approximately a half-mile and two miles. Rosebud coal water quality in the area between the two mines (outside the permit areas of both mines) is variable and is currently unaffected by spoil. North of mining in Big Sky Mine Area A, Rosebud coal ranges in TDS concentration from 611 mg/L (SC = 881 µS/cm) in ARCM67 (reported from a single sample in 1996) to an average of 2,056 mg/L (SC = 2,400 µS/cm) in well ARC53. North of Big Sky Area B, Rosebud coal well BRC513 reported a TDS concentration of 4,300 mg/L (SC = 4,100 µS/cm) and BRC1313 has a TDS concentration that has declined with declining water level, from a high of 2,460 mg/L (SC = 2,540 µS/cm) to low of 770 mg/L (SC = 1,100 µS/cm).

Area B spoil water quality, described above, averages 3,686 mg/L and, in general, exceeds the quality of Rosebud coal between the two mines. Mixing of spoil with the background Rosebud coal water will take place as groundwater from the spoil moves to the south. There are no wells identified in the private well inventory that are completed in the Rosebud coal in the area between the Rosebud Mine and Big Sky Mine. No uses are expected to be impacted and numeric water quality standards are not expected to be exceeded based on spoil water quality. Due to the natural spatial and temporal variability of water quality in Area B spoils, the unmined coal between Area B and the Big Sky Mine, and Big Sky Area A spoils there is no generally accepted methodology to predict impacts with any certainty. Due to a large deposit of clinker throughout much of the area between the two mines, enhanced aquifer recharge will serve to dilute spoil water quality impacts in this area, therefore it does not appear that a parameter will increase to a level that renders the water unsuitable for domestic use or livestock and wildlife watering, or harmful, detrimental, or injurious to the beneficial uses listed for Class II and Class III groundwater. As such, no material damage is expected.

Area C

There are eight active spoil wells in Area C (**Figure 9-32**). Most are dry or have little water and, therefore, water quality samples are limited. Area C has been the focus of mining in recent years and has numerous open pits that impair saturation of spoil. Well WS-121 was installed in 1997 and has had a slow but steadily rising trend (**Figure 9-59**). With 14 feet of water, it records the greatest amount of recharge of any well in the central part of Area C. Three other nearby spoil wells register three feet (WS-120), four feet (WS-122) and six feet (WS-186) of water, with most of the recharge taking place since 2011. Well WS-197 is in the west part of Area C and records approximately 18 feet of water.

Only two wells monitor spoil water quality at this time, WS-121 and WS-197; the remaining wells have insufficient water for sampling. TDS concentration in WS-121 has increased with rising water level from 2,150 mg/L to as high as 7,360 mg/L. The most recent TDS concentration in this well is 6,420 mg/L. Average TDS of well WS-121 is 5,722 mg/L and average TDS concentration in WS-197 is 3,733 mg/L. This well also has relatively high concentrations of chloride (up to 58 mg/L). High chloride is typically attributed to use of magnesium chloride on roads. There has been no exceedance of an HHS in any Area C spoil water quality analysis.

Currently, Area C spoil has experienced little recharge. Saturation of spoil in the north part of Area C will depend on vertical infiltration as the mine area is defined on three sides by the coal crop line, including the west, which is the up gradient direction of lateral groundwater flow. This means there is no up gradient recharge from the Rosebud coal into the north part of Area C. Although the drawdown here was relatively small (modeled at 10 feet, see **Section 9.2.7**) because of the small amount of water in the Rosebud coal, it is anticipated that it will take a substantial amount of time to saturate the spoil in this area. The remainder of Area C will receive lateral recharge to coal and spoil. Upon saturation, migration

of spoil water in the central part of Area C will be toward the coal crop line, which defines the down gradient margins of mining. The coal crop line was generally dry prior to mining. The saturated thickness of the coal thins toward the crop line due to evapotranspiration as a result of the slow movement of Rosebud coal groundwater.

A possible connection of the Rosebud coal with alluvium in the southwest part of Area C (as suggested by the response of WR-136) suggests that up to a half-mile stretch of EFAC may be subject to spoil water from Area C if there is substantial hydrologic connection with the alluvium. Based on the analysis of contributions from Area A to EFAC alluvium, input from Area C spoil into the stream is expected to be small but may contribute to diminished water quality in EFAC. This migration of spoil water from Area C is not expected to render any down gradient water unsuitable for domestic use or livestock and wildlife watering, or harmful, detrimental, or injurious to listed beneficial uses or cause the violation of any DEQ-7 numeric standard, as discussed in **Section 9.2.5.1.1**. As such, material damage is not expected.

Area D

There are 10 active spoil wells in Area D (**Figure 9-33**). Mining in Area D was completed in early 2013 and reclamation continues in 2014. Most spoil wells were installed between the late 1990's and early 2000's in the older, south permit area. These wells (WS-125, WS-126, WS-127) have the most recharge with 20 feet to 32 feet of water (**Figure 9-60)**. Pond 151, a permanent pond in reclamation, is likely providing recharge to this area. The west part of Area D (WS-128) has recovered 12 feet of water. The remaining wells are thinly saturated and contain less than one foot to eight feet of water.

The shallow aquifers in Area D were only thinly saturated prior to mining due to lack of up gradient recharge, creating a "high and dry" setting for Area D. Therefore, water in Area D spoil will depend upon infiltration and is expected to be slow in forming an aquifer.

Six wells are sampled for water quality. Water type in Area D spoil is unusually variable and includes calcium-magnesium sulfate, sodium sulfate, and calcium-magnesium bicarbonate. The average TDS concentration for the wells ranges from 1,853 mg/L (WS-188) to 7,882 mg/L (WS-127). The current average TDS concentration for spoil wells in Area D is 4,492 mg/L with a median of 4,500 mg/L. There are anomalously high levels of chloride (56 mg/L, average) and magnesium (1,092 mg/L, average) in analyses from well WS-127 that are assumed to be from the use of magnesium chloride on the haul road adjacent to the well. This well also contains elevated nitrate levels that have consistently exceeded the human health standard. Since the initial sample from this well (1999), nitrate concentrations have been as high as 50 mg/L. The most recent sample (2011) had a concentration of 7.6 mg/L. Nitrate from blasting explosives used in mining is one source of nitrate in mine spoil. The well is located in a reclamation field that supports grazing and is less than 500 feet from a permanent pond used for cattle drinking water.

Other exceedances of human health standards have been identified for cadmium (two samples), and zinc (one sample). The exceedances are represented by single analyses from different wells and are only slightly above the standard. None of the exceedances are from recent samples.

The isolation of Area D from laterally up gradient and down gradient groundwater sources limits spoil recharge, but also limits the effects of spoil to groundwater. Saturated thickness of Rosebud coal groundwater thins as it approaches the coal crop. At the crop line, Rosebud coal is typically dry. The low conductivity and slow movement of Rosebud coal groundwater results in evaporation as groundwater moves toward the coal crop. There is a possibility that spoil water may cause springs at the down

gradient crop line but no Rosebud coal springs were noted in baseline. Migration of spoil water from Area D is not expected to render any down gradient water unsuitable for domestic use or livestock and wildlife watering, or harmful, detrimental, or injurious to listed beneficial uses, or cause the violation of any DEQ-7 numeric standard. Therefore, material damage is not expected.

Area E

There are eight active spoil wells in Area E, including three wells in the former Pit 6, a premine area located immediately south of Area E that was released from bond in 2006 (**Figure 9-33)**. A few of the spoil wells in Area E remain poorly saturated to unsaturated (WS-130, WS-109)(**Figure 9-61**). WS-116 is recording the greatest saturation. It has seen a steady climb of more than 30 feet in water level since installation in 1981 and now has 37 feet of saturation. It is located immediately south of the Colstrip power plant and likely receives recharge from adjacent power plant ponds. Wells at the south end of the permit area (WS-124, WS-117) and in former Pit 6 (WS-110, WS-111, and WS-112) have had a slow rise in water level and currently contain 10 feet to 21 feet of water.

Average TDS concentrations in these wells range from 1,491 mg/L to 4,575 mg/L. The average TDS of these wells is the lowest average for all permit area spoil wells. Most of the spoil wells have seen a rise in TDS concentration since monitoring began but the increase is greater in some wells than others. The exceptions are WS-111 and WS-112 in the former Pit 6 area, which have seen slight declines in TDS concentrations even as water levels rose. The three Pit 6 wells (WS-110, WS-111, WS-112) have a water type that is characterized by calcium-magnesium bicarbonate or magnesium bicarbonate and lower TDS and sodium concentrations than most spoil wells throughout the mine. This suggests better spoil quality or better quality (lower TDS) recharge to the Pit 6 area than is characteristic of the larger mine area.

Well WS-116 had two consecutive analyses of lead above the human health standard of 0.015 mg/L. Samples in 1993 and 1995 had lead concentrations of 0.05 mg/L and 0.02 mg/L, respectively. Six subsequent samples, from 1998 – 2013, have reported non-detect or very low (0.00021 mg/L) concentrations of lead. No other samples from Area E spoil wells have reported analyte concentrations that exceed human health standards.

Upon sufficient saturation, Area E spoil groundwater will move east toward the down gradient crop line. The crop line marks the extent of mining and approximates the Area E permit boundary. As discussed previously, the Rosebud crop line is generally dry. Migration of spoil water from Area E is not expected to render any down gradient water unsuitable for domestic use or livestock and wildlife watering, or harmful, detrimental, or injurious to listed beneficial uses or cause the violation of any DEQ-7 numeric standard and material damage is not expected.

9.2.5.2 Big Sky Mine

9.2.5.2.1 Alluvium

Area A

Four alluvial wells remain active in Area A (**Figure 9-62**). They are located below the extents of mining in Miller Coulee (AAL51) and Emile Coulee (AAL12, AAL14, and AALM70) (**Figure 9-63**). All of the wells have relatively shallow completions (12 feet to 31 feet) and have been continuously monitored for three to four decades. Current water levels are among the highest levels measured in the wells, with between 11 feet (AALM70) and 24 feet (AAL51) of saturation.

The three closely spaced wells in Emile Coulee are located among cultivated fields. They currently have TDS concentrations that range from 1,950 mg/L (AAL12) to slightly greater than 4,000 mg/L (AAL14,

AALM70). Well AAL14 temporarily reached TDS concentrations as high as 8,080mg/L, mainly due to significant increases in sodium and sulfate. These increases may have been caused by mining, but have not impacted beneficial uses and no numerical standards (except for nitrate-nitrite, discussed below) have been violated, thus material damage has not occurred. Current water quality trend are stable to improving, thus material damage is not expected in the future. All three of the wells in Emile Coulee have reported nitrate-nitrite nitrogen concentrations as high as 20 mg/L. Due to the shallowness of the wells and the absence of significant nitrate-nitrate nitrogen in spoil water quality analyses, the high nitrate-nitrite concentrations in the alluvial wells are attributed to agricultural sources rather than mining, thus the nitrate-nitrite exceedance are no considered material damage.

Miller Coulee well AAL51 currently has a TDS concentration of 4,270 mg/L. TDS concentration in this well has not varied significantly. All reported nitrate-nitrite nitrogen concentrations are less than one mg/L. The proposed AM4 mining will not affect alluvial water quality in Area A.

Area B

Eighteen alluvial wells **(Figure 9-64**) monitor alluvium in Lee Coulee, both up gradient and down gradient of mining. In the upland well (BAL2011), almost 28 feet of alluvium is holding approximately three feet of water. Alluvial thickness in the downstream area ranges to almost 40 feet with 30 feet of water at the confluence of Rosebud Creek (BAL3511). Measurements from wells in the more central part of the permit area indicate that the alluvium generally holds six to 12 feet of water.

By their nature, alluvial wells have variable water levels reflecting seasonal and climatic changes. Most of the wells in Area B have hydrographs that indicate a return to baseline or higher water levels. Exceptions are three wells (BAL2011, BAL2321, and BAL2361) at the upstream extent of the mine area. The wells currently show a loss of five feet to 13 feet. Decline in these wells began before mining encroached on the adjacent area. Down gradient mining likely would not affect the availability of groundwater in well BAL2011 and mining upstream in the west part of Rosebud Area B was not active until after 2000. Coal removal took place immediately adjacent to BAL2321 and BAL2361 and may have disrupted water to the alluvium. Wells further down gradient (BAL9031, BAL9041) have either recovered to premine levels or were not affected. A feature common to alluvial wells in the central part of the permit area and extending to wells more than a mile south of the permit boundary is a rise in water level of between six and ten feet that began in 1993, peaked in 1996 and subsequently fell to previous levels. Although some water level rise during this period may be attributable to above average precipitation, MPDES discharge from sediment ponds was the source for most of this temporary increase in water level. Water quality changes marked by an increase in TDS commonly accompanied the rise in water level. TDS concentrations have remained somewhat elevated even though water levels decreased to or near levels that existed in 1992, prior to the increase from MPDES releases (e.g. BAL2521, BAL2711, and BAL3511).

TDS concentration appears to vary with changes in water level in a number of wells, increasing with increases in water level and decreasing when water levels decrease. This may be explained by increased dissolution of minerals in the alluvium with increased volume of water. Baseline TDS concentrations varied from 615 mg/L (BAL2011) to 3,920 mg/L (BAL9031). Current TDS concentrations range from 460 mg/L to 4,230 mg/L. TDS remains higher than baseline in many of the wells, coincident with higher water levels in many cases, but not all. Flow of spoil water into the alluvium at this time is unlikely, as the spoil remains thinly saturated. As spoil saturation increases it is likely that it will influence alluvial water quality, but is not expected to impact uses outside the permit area of the Big Sky Mine.

Wells BAL9081 and BAL2611, located in a tributary on the north side of Lee Coulee, have an upward trend in TDS concentration due to releases or infiltration of water from an upstream sediment pond. Water from the pond is of higher salinity than alluvial water due to the concentration of salts in the pond. As this pond was recently reclaimed, the TDS concentration is expected to attenuate with time. Downstream wells in Lee Coulee that have increased TDS concentrations (e.g. BAL2521) may also be affected by water from the sediment pond, although these wells have had a relatively consistent TDS concentration of approximately 2,500 mg/L for five or more years. Water from stock ponds upstream of wells located further north in the permit area (e.g. BAL9031 and BAL2411) may have caused increases in TDS concentrations in these wells.

Private wells potentially affected by mining include alluvial wells in lower Lee Coulee below the Big Sky Mine permit boundary. These are designated as wells number 2 and 3 (**Table 6-1**). Alluvial monitoring wells in lower Lee Coulee (**Figure 9-67**) recorded increases in water level and TDS resulting from MPDES permitted releases of water from sediment ponds and Big Sky mine pits (see **Section 9.2.7.2.1**). Water levels declined but remain above premine levels, which may be due to precipitation. TDS remains elevated above premine levels but may decline if water levels further decline, as the water level and TDS appear closely correlated in alluvial wells. TDS concentration in monitoring well BAL2711 varied from 1,630 mg/L to 1,800 mg/L before the rise in water level. TDS in this well now varies between 2,350 mg/L to 2,520 mg/L after reaching a peak of 3,010 mg/L. Monitoring well BAL3111 recorded similar TDS concentrations. Increases in TDS resulted mainly from increases in calcium (originally 159 mg/L, now 208 mg/L), magnesium (originally 167 mg/L, now 238 mg/L), sodium (originally 118 mg/L, now 152 mg/L), and sulfate (originally 955 mg/L, now 1,340 mg/L). There were no increases in trace metals, most of which remain below analytical detection. The use of wells 2 and 3 is stock water. Calcium and magnesium concentrations in pre-mining samples from Lee Coulee alluvial monitoring wells were above the suggested upper limit guideline concentrations for livestock water quality (**Table 2-2**) and are now higher. Although the water quality in these wells is above guideline levels for calcium and magnesium, the critical component, sulfate, remains below the guideline threshold limit. The alluvial water remains suitable for livestock at current concentrations. The change in water quality should not render water unsuitable for domestic use or livestock and wildlife watering, or be harmful, detrimental, or injurious to a listed use for Class II groundwater. The proposed AM4 mining will not affect alluvial water quality in Area B.

9.2.5.2.2 Overburden

Area A

One overburden well, AOVM73, remains active in Area A (**Figure 9-65**). It is located immediately northwest of the permit boundary. The well experienced more than 20 feet of drawdown and has shown almost no recovery since water levels reached the end of a precipitous decline in late 1984 (**Figure 9-66**). Decline attributable to mining began after 1982, as mining did not approach this well until that time. There are 26 feet of water remaining in the well. The few historic overburden wells that were in the mined area indicate there was little water in the overburden, ranging from a foot or less (AOV23) to 18 feet (AOV24).

Well AOVM73 is the only overburden monitoring site with water quality data. TDS concentration increased slightly, from 3,070 mg/L to 3,360 mg/L, during the 14 years that it was measured. No impacts are anticipated on Area A groundwater from the proposed AM4 mining. Material damage has not been observed and is not expected.

Area B

The eight remaining overburden wells (**Figure 9-67**) are located at elevations above the pit areas, near or outside Area B permit boundaries. Initial heads in these wells ranged from 13 feet to 68 feet, with the lowest head in the southwest permit area. All wells showed decline during mining and most have begun to recover as evidenced by increasing water levels (**Figure 9-68**). Residual drawdown currently ranges from zero (BOV1012, BOV412, and BOV512) to almost 13 feet (BOV612).

Water quality in the overburden wells has shown no significant changes with the change in water level. Premine TDS concentrations ranged from as low as 360 mg/L (BOV2012, inactive) to as high as 4,720 mg/L (BOV1012). Currently active wells have TDS concentrations that range from 960 mg/L (BOV612) to 3,880 mg/L (BOV1012). No impacts are anticipated on Area B groundwater from the proposed AM4 mining. Material damage has not been observed and is not expected.

9.2.5.2.3 Rosebud coal

Drawdown created by mining in Rosebud Mine Area B overlaps that created by mining in Big Sky Mine Area A and Area B. Mining proposed in AM4 does not significantly increase the amount or extent of drawdown in the Big Sky Mine and is not expected to significantly delay saturation of spoil water. Currently, spoil water quality in both permit areas of the Big Sky Mine is of poorer quality than spoil water in Rosebud Mine Area B. Rosebud Mine Area B spoil water is not expected to further lower the quality in Big Sky Mine spoil.

Area A

The six remaining Rosebud monitoring wells (**Figure 9-65**) are located near the reclaimed pit margins. Water level response to mining in the west part of the permit area is documented in wells ARC30 and ARC66, which have shown 10 feet and seven feet, respectively, of water level increase (**Figure 9-66**). This may be because ARC30 was not installed until 1977, after pre-law mining to the east, and ARC66 was installed in 1984 after nearby mining was complete. Therefore, these wells likely are recording recovery of Rosebud coal water levels. The amount of head currently measured in the wells is approximately 36 feet. The remaining four wells (ARC52, ARC53, ARCM63, and ARCM67) were installed prior to mining and all recorded a loss in head that currently ranges from 51 feet (ARCM67) to nine feet (ARC52). All but one well (ARCM67) has shown a recovery in pressure head. The amount of head measured in these wells ranges from to 41 feet to 43 feet in the wells north of mining (ARC52, ARCM63, and ARCM67) to 22 feet in ARCM63, northwest of mining. Recharge of the Rosebud coal appears to occur in the highlands between the two mines, but recovery of water levels near Big Sky Area A will likely be slower because some of this water is diverted to the Rosebud Area B mine pits.

Well ARC30 has a lengthy record of water quality measurements with a TDS concentration that remained near 4,500 mg/L for decades. The current TDS concentration of 3,930 mg/L is approximately the same as the initial concentration in 1982. The three wells (ARC52, ARC53, and ARCM67) north and up gradient of the pit area have TDS concentrations that range between 511 mg/L and 742 mg/L. The two wells to the west of the pit area have remained relatively unchanged with TDS concentrations of 3,260 mg/L to 3,550 mg/L (ARCM63) and 1,830 mg/L to 2,160 mg/L (ARC66). Water quality in the Rosebud coal in Area A is not expected to be affected by the proposed AM4 mining. No material damage in the Rosebud coal groundwater has been indicated or is anticipated.

Area B

There are eleven active or recently active Rosebud coal monitoring wells in Area B, all of which recorded premine water levels and quality (**Figure 9-67**). Premine heads in Area B Rosebud coal indicate that

some areas of the aquifer were unconfined and others were confined. East of the pit, between Area A and Area B, premine heads ranged between 80 feet (BRC613) and 50 feet (BRC1713). In the upland area northeast of mining, immediately adjacent to the permit boundary, the head measured 172 feet (BRC513) (**Figure 9-69**). In the upland area between Rosebud Mine Area B and Big Sky Mine Area B (BRC 1313 and BRC113), heads ranged between 45 feet and 71 feet. West of the mine, heads were as high as 84 feet (BRC213). In contrast, heads in the southwest pit area were as low as nine feet near the crop line (BRC1213) and much of the area is unconfined (BRC9163, BRC413, and BRC713).

All of the Area B Rosebud monitoring wells showed a decline in head in response to mining. However, most wells record at least a slightly recovering water level. At this time, remaining head declines range from zero (complete recovery) to 24 feet, with an average of approximately 10 feet. The advance of mining in Rosebud Mine Area B appears to have stalled recovery of Rosebud coal levels between the two mines (BRC1313). The proposed AM4 mining is expected to continue to delay recovery of Rosebud coal water levels north of Big Sky Area B.

Changes in up gradient water quality vary from declines in TDS (BRC1313) to variable TDS (BRC613, BRC1713) to stable water quality (BRC1013, BRC1513). In the currently active wells, premine TDS ranged from 4,450 mg/L (BRC1013) to 1,370 mg/L (BRC213, BRC413). Recent measurement from the active wells ranged from 4,080 mg/L (BRC1013) to 380 mg/L (BRC1713). The poorest water quality, both premine and currently, is located in the east part of the permit between Area B and Area A (BRC1013, BRC1513, and BRC1713). Water quality in the Rosebud coal in Area A is not expected to be affected by the proposed AM4 mining. No material damage in the Rosebud coal groundwater has been indicated or is anticipated.

9.2.5.2.4 Interburden

Area A

No interburden wells were installed in Area A.

Area B

The eight remaining interburden wells lie near or outside of the permit boundary (**Figure 9-67**). Most of the wells experienced a decline in head associated with mining at either Big Sky Mine Area B or Rosebud Mine Area B (**Figure 9-70**). Most of the declines began in or soon after 1989, the year mining began in Big Sky Area B, or in the middle 1990's, when mining in the west part of Rosebud Mine Area B began. Head declines in the interburden wells ranged from 2 feet to 20 feet and many wells have recently begun to show a slight recovery. Current heads range from 48 feet to 128 feet. In wells BIN117, BIN517, and BIN1317 the interburden head is almost equivalent to that in the Rosebud coal and an upward gradient exists between interburden and Rosebud coal at well BIN217.

Wells with a history of water quality measurements indicate that TDS concentrations have remained consistent or have declined. Baseline TDS concentrations ranged from 1,850 mg/L to 3,800 mg/L. Current TDS concentrations range from 510 mg/L to 4,150 mg/L. The proposed AM4 mining is not expected to have an impact on interburden water quantity or quality in Area B. No material damage has been noted or is expected to occur.

9.2.5.2.5 McKay coal

Area A

One McKay coal well, located in the southwest permit area, remains active (**Figure 9-65)**. The water level response of this well (AMC20) is similar to that of nearby historic wells (AMC25, AMC32) (**Figure 9-71**).

The wells are adjacent to pre-law mine areas that, along with mining inside the permit area in the middle 1970's, may have caused or contributed to the drawdown recorded in 1975-1977. A rise in water levels suggesting post mining recovery began shortly thereafter. Water level has been relatively steady in AMC20 since the late 1970's and is assumed to have fully recovered. The total head in this well is currently almost 62 feet. The McKay coal at this location was confined prior to mining and has remained confined. Historic wells near the east margin of mining indicate that the McKay coal was confined in locations away from the crop line (AMC59) and unconfined near the crop line (AMCS25). The increase in water level between 1975 and 1983 in these two wells suggests a response to above average precipitation during this period.

TDS concentration in the wells in the southwest corner of the permit area appears to have remained relatively steady during the monitoring period. TDS concentration in the currently active well, AMC20, varies between 2,770 mg/L and 3,180 mg/L. Adjacent historic wells were slightly higher in TDS concentration and increased slightly from 3,850 mg/L to 4,210 mg/L during the monitoring period. The proposed AM4 mining is not expected to affect water quantity or quality in the McKay coal at Area A. No material damage to McKay coal groundwater is indicated or is expected to occur.

Area B

Eleven McKay coal monitoring wells remain active in Area B (**Figure 9-67**). They are located outside of the mine pit areas. Water levels in the currently active wells indicate that much of the McKay coal outside the mine area was confined prior to mining and remained confined after mining. The exceptions are wells BMC1614, located over a mile east of mining, and BMC714 located in the southwest part of the permit area where saturation in the overlying aquifers was also comparatively sparse (**Figure 9-72**). Many of the historic McKay coal wells that were located in the pit areas indicate that much of the McKay coal in this area was unconfined prior to mining, particularly at lower elevations near the McKay coal outcrop. As with the overlying aquifers discussed above, most of the active wells show a recovering water level. Residual drawdown in the active wells ranges from zero (BMC1514) to 16 feet (BMC214), with current heads ranging as high as 152 feet (BMC114). Upland wells subject to impacts from Rosebud Mine Area B (BMC1314, BMC 514, and BMC114) show only a slight recovery. Three of the currently monitored McKay wells (BMC714, BMC1014, and BMC1614) have water levels that have increased since baseline, gaining rather than losing water during active mining. Hydrographs throughout the Colstrip area show similar water level responses that are assumed to be climate related.

TDS during baseline ranged between 1,630 mg/L and 3,700 mg/L with an average of approximately 2,200 mg/L. Most of the McKay coal wells measured throughout the life of the mine indicate that TDS has varied somewhat with varying water levels, but generally, recent TDS concentrations are not significantly different from baseline. The proposed AM4 mining is not predicted to cause impacts to McKay groundwater at Area B. Material damage has not been observed and is not expected.

9.2.5.2.6 Underburden

Area A

The nine active underburden monitoring wells (**Figure 9-65**) are located south of the Rosebud and McKay coal crop and are relatively shallow, ranging from 40 feet to 116 feet deep. Five of the wells (ASM2, ASMTW1, ASMTW2, ASMTW3, and ASMTW4) are within a few hundred feet of one another in the south part of Area A, near the former facilities area (**Figure 9-73**). Wells ASMTW1 through ASMTW4 were located around the "truck wash" area. Equipment was washed on a graded area and runoff was retained in an adjacent pond. These wells show a steep initial increase in water level followed by a steep decrease and then somewhat variable levels since 2002. The wells in the central part of the permit area

(ASMM27, ASMM32, ASMM69) have water levels three to eight feet greater than initial measurements in the mid 1970's, likely in response to recent above normal precipitation.

Initial TDS concentrations varied from 2,190 mg/L to 5,930 mg/L with an average of 3,202 mg/L and a median of 2,530 mg/L. TDS concentration has remained relatively steady in some wells (ASM2, ASMM27), decreased in conjunction with water level changes in others (ASMM32, ASMM69), and increased in the ASMTW wells. Increases in TDS concentration in the ASMTW wells was immediate and remains higher (3,590 mg/L to 4,650 mg/L) than baseline (2,390 mg/L to 2,680 mg/L). The ASMTW wells show notable increases in analytes associated with road stabilizing and cleaning products, including increases in boron, chloride, magnesium, sulfate, and sodium. No increases in other trace metals were observed and all analytes have declined from high concentrations. Well ASM2, located 700 feet to the southwest of the ASMTW wells, has not shown a change in TDS that indicates interception of water moving from the ASMTW wells. Because the impacts to water quality observed at the truck wash have not migrated beyond the permit boundary, no material damage has occurred. Current water quality trends are generally improving at the truck wash wells and well ASM2 has not indicated migration of the lower quality water, therefore future material damage is not expected.

Area B

There are 20 active underburden wells in Big Sky Area B (**Figure 9-67**). The wells can be divided into "shallow" and "deep" underburden wells depending upon their location. Underburden wells above the Rosebud coal crop line are referred to as "deep" wells (**Figure 9-74**), and many are located in upland areas near or outside the permit boundary. The wells located below the crop line in the eroded drainage of Lee Coulee are referred to as the "shallow" wells (**Figure 9-75**). The deeper wells have heads between 45 feet and 171 feet and the shallower wells have heads between 16 feet and 107 feet. Many of the "shallow" wells have hydrographs characteristic of alluvial wells with seasonal variations in level over a relatively narrow range.

Most of the well hydrographs suggest water levels are subject to influence by climate. Most show a rise in water level of varying amounts between 1993 and 1997, a period of average to above average precipitation that ended the drought of the prior decade. Many of the hydrographs show a return to lower water levels with the advent of a period of below average precipitation that followed. A period of generally above average precipitation influenced the subsequent water level rise seen in many wells. Although a similar water level response is observed in many wells regardless of location, the "shallow" wells located in Lee Coulee and side tributaries were heavily influenced by MPDES discharges to the drainage and this likely is the reason for the rise in water level in these wells. Unlike other wells with a variable water level, a steady and significant water level decline is observed in wells BSM115 and BSM515 for a head loss of 14 feet and 8 feet, respectively. Both of these wells are located in the north permit area, between Rosebud Mine Area B and Big Sky Mine Area B. Activity at Rosebud Mine may have influenced the response of these wells. A head of 171 feet remains in BSM115 and 99 feet remains in BSM515. The spike in water levels in BSM9035 and BSM215 likely represents well failure. Both are now recording water levels close to those of the McKay coal.

Water quality in the "deep" wells appears to have changed little from baseline. TDS concentrations in most wells range from slightly below 2,000 mg/L to 2,500 mg/L. Two wells (BSM915/915R and BSM1715) have TDS concentrations between 3,300 mg/L and 3,500 mg/L that have not changed significantly since baseline. Baseline TDS concentrations in the "shallow" wells ranged from 4,500 mg/L to as low as 1,520 mg/L. Four of the wells (BSM2535, BSM2615, BSM9085, and BSM9095) have shown increases in TDS and one (BSM2415) has shown a decline. Despite the difference in depth (102 feet vs.

25 feet), two of the wells (BSM9085 and BSM2615) located in a drainage south of the pit area began to experience an increase in concentration in 1994 characterized by increases in chloride, sodium, calcium, magnesium and sulfate, causing TDS concentration to rise from a premine concentration of approximately 1,500 mg/L to 3,240 mg/L. These wells likely have been influenced by an upstream pond that has concentrated salts due to evaporation and periodically discharged or allowed water to infiltrate downstream. This pond has been recently reclaimed and water quality should return to lower concentrations with time. Well BSM2535 approximately a mile downstream from BSM2615, may also have been affected by the upstream pond, showing increases in TDS beginning at about the same time. Water quality at this well has remained stable with a TDS of approximately 2,300 mg/L since 1998. Well BSM9095, located in the center of the permit area near the coal crop, has increased approximately 1,000 mg/L to 3,710 mg/L in TDS concentration and appears to be on a continuing upward trend. Most of the increase in TDS concentration is attributable to an increase in sulfate. The source of this increase has not been identified and will continue to be monitored.

The proposed mining in AM4 is not anticipated to affect underburden water quantity or quality near Area B. Although some impacts to shallow underburden wells are noted above, all are within the permit boundary and these impacts are not expected to spread outside the permit boundary. No material damage has been observed and none is expected.

9.2.5.2.7 Spoil

Area A

Ten spoil wells are active in Area A (**Figure 9-65)**. They contain water columns of between 10 feet and 76 feet, with the least water in wells near the location of the Rosebud coal crop. All of the wells are showing continued increases in saturation (**Figure 9-76**).

Current TDS concentrations range from 2,250 mg/L (ASP61) to 14,100 mg/L (ASP22). The average concentration is 5,346 mg/L and the median is 3,990 mg/L. In comparison, TDS concentrations in the Rosebud coal ranged from 711 mg/L to 3,820 mg/L, with an average of 2,362 mg/L and median of 2,110 mg/L. Currently, the highest concentration in a spoil well is in ASP22, which contains approximately 18 feet of water and lies in a pre-law mining area. TDS concentrations at this well have been as high as 19,200 mg/L, measured in 1987. A slightly declining trend over the past 22 years has brought current concentrations to 14,100 mg/L. Chloride concentration has been extremely high (156 mg/L - 430 mg/L), along with magnesium (849 mg/L to 1,740 mg/L), sodium (980 mg/L to 2,400 mg/L), and sulfate (4,830 mg/L to 11,400 mg/L). Trace elements and metals that are unusually and persistently high include boron (up to 1.9 mg/L), copper (up to 0.178 mg/L), manganese (up to 5.59 mg/L), and molybdenum (up to 1.3 mg/L). The chemical signature of water from this well suggests that that it is affected by road stabilization materials (magnesium chloride), cleaning compounds (boron, sodium and sulfate) and unknown sources of trace metals such as copper and molybdenum. There is no record of the mining activity in this pre-law area. Spoil well ASPP18 located approximately 30 feet to the southwest has approximately the same completion depth and water level but had a TDS of 4,050mg/L at the last measurement (1999), and no evidence of elevated concentrations in analytes like those in ASP22. This suggests that the poor quality water characteristic of ASP22 is very limited in extent. No impacts to Area A spoil water are expected from the proposed AM4 mining. Mining has been completed in Area A for over 25 years and no migration of spoil water impacts outside of the spoils has been observed, thus future migration of spoil water down gradient is not expected to cause conditions which would render water unsuitable for domestic use or livestock and wildlife watering, are harmful, detrimental, or injurious to listed beneficial uses, or cause exceedances of numeric water quality standards and material damage is not anticipated.

Area B

Ten spoil wells record the recovery of water levels in Big Sky Area B (**Figure 9-67**). The saturated thickness in the wells ranges from zero (BSP9936) to almost 19 feet (BSP9966), with an average of 12 feet among the nine wells that contain a measurable amount of water (**Figure 9-77**). A few wells have reached or are close to comparable water levels observed during premine measurements in the Rosebud coal. Spoil well BSP1216 contains nine feet of water and has a water level that is within a foot of the premine water level in a Rosebud coal well at the same location. The premine water level in a Rosebud well in the same location as spoil well BSP816 was approximately four feet above the water level in the spoil well. The spoil well currently contains almost 11 feet of water. None of the other spoil wells are paired with premine Rosebud wells for comparison of recovery to premine water levels. Spoil wells located further north (e.g. BSP9976 and BSP9966) have a slightly greater saturated thickness (17-19 feet) than the spoil wells to the south, but they remain far below the heads measured in the currently active, upland Rosebud coal monitoring wells. The upland wells have pressure heads that are not expected to be replicated in the homogeneous spoil when fully saturated, and thus the water level measured in the spoil will not be the same as that of the Rosebud coal wells. Water in the Rosebud coal to the north remains a source of lateral recharge to spoil wells in the former pit areas.

Water quality in the spoil wells is relatively poor, with a range in TDS concentrations from recent samples of between 2,800 mg/L and 5,280 mg/L, and an average of 3,897 mg/L (median = 3,160 mg/L). Four of the wells (BSP816, BSP1216, BSP9926R, and BSP9956) show a rising trend in TDS coincident with a rise in water level. No impacts to Area B spoil water are expected from the proposed AM4 mining due to the distance between the proposed cuts and the Area B spoils. Future migration of Area B spoil water down gradient is not expected to cause conditions which would render water unsuitable for domestic use or livestock and wildlife watering, or, are harmful, detrimental, or injurious to listed beneficial uses, or cause exceedances of numeric water quality standards. Therefore material damage is not anticipated.

9.2.6 Water Quality Exceedances

Determination of water quality exceedances is based on:

- Changes in groundwater quality that cause a change in beneficial uses based on narrative standards (17.30.1006)
- Exceedance of HHS in DEQ-7

As explained in **Section 2.1.2**, this CHIA assesses possible violation of water quality standards for groundwater by applying the standard for the parameters of concern, salinity, which is governed by the narrative standard set forth in ARM 17.30.1006. Accordingly, the CHIA assesses whether a parameter may increase to a level that would render the waters unsuitable for domestic use or livestock and wildlife watering, or harmful, detrimental, or injurious to the beneficial uses listed for the classification of the groundwater.

Water quality samples that have an analyte that meets or exceeds the human health standards established in Circular DEQ-7 are listed in **Table 9-9** for the Rosebud Mine and **Table 9-10** for the Big Sky Mine. Analyses are conducted per the requirements of the monitoring and sampling plan for each mine. Groundwater sample results are reported as dissolved concentrations. **Section 9.2.6.2** through **Section**

2.6.2.10 discuss the exceedances listed in those tables. Mining related water quality exceedances have not migrated beyond the permit boundary.

9.2.6.1 Adversely Affected Land Use or Beneficial Use of Groundwater

Beneficial uses of groundwater in the Colstrip area include domestic supply and stock drinking water. Potential effects to beneficial uses of groundwater from mining include diminishment of supply so that it is no longer available for uses, and/or change in water quality so that it is no longer suitable for uses. Drawdown of water level (or diminishment of pressure head) in an aquifer is the most likely impact to private wells outside the permit area. Wells completed in Rosebud coal are the most susceptible. Wells in the underburden typically are deep enough to be protected from drawdown which would make the supply insufficient for the use. Potential drawdown impacts to private wells are discussed in more detail in **Section 9.2.7.1**.

Up gradient drawdown in affected aquifers generally does not cause changes to water quality, although a number of other factors may alter water quality. Spoil water generally is of poorer quality than Rosebud coal or McKay coal and may impact wells down gradient of mining. The Rosebud coal crop is close to down gradient pit margins in many permit areas and thus limits the lateral extent of potential down gradient exposure to spoil water in the Rosebud coal. Wells completed in McKay coal that are overlain by a sufficient thickness of interburden are generally protected from vertical infiltration of spoil water. The McKay coal crop line is also located near mining limits and thus limits laterally down gradient impacts to that unit. Water bearing zones in the underburden are usually deep enough to be protected from vertical infiltration of spoil water.

Shallow wells in the alluvium of EFAC and Lee Coulee are wells most likely to be affected by water quality changes attributable to mining. Alluvial wells in Rosebud Mine and Big Sky Mine have experienced mining-related increases in TDS concentrations from rising water levels due, in part, to MPDES discharges. Increases in TDS are also linked to infiltration from sediment ponds or infiltration from spoil where mining has taken place adjacent to stream margins. Discussions in **Section 9.2.5.1.1** and **Section 9.2.8** discuss current and expected impacts to EFAC alluvium. Water quality projections indicate that EFAC alluvial water quality will not render water unsuitable for a domestic use or livestock and wildlife watering; or harmful, detrimental, or injurious to listed beneficial uses. Thus, material damage will not occur. If material damage unexpectedly occurs such that water quality becomes unsuitable for uses based on the narrative and numeric standards for groundwater listed in 17.30.1006, the operator will mitigate the damage, including replacing the water supply (ARM 17.24.648).

9.2.6.2 Arsenic

The Rosebud Mine began sampling groundwater for arsenic in the late 1990's, thus there are no baseline samples for arsenic within the mined area. Up gradient wells or wells outside the limits of mining that have not been affected by mining are considered to represent background concentrations. Most of the arsenic exceedances are from one sample taken from a well. Review of the sample history for wells with a single arsenic exceedance confirms that the remainder, and typically more recent, arsenic analyses are either non-detect or are below standard limits. Five wells have two or more arsenic concentrations at or above the human health limit of 0.01 mg/L. The samples ranged between 0.01 mg/L and 0.019 mg/L.

The wells with two or more arsenic exceedances include:

- WA-214 had two samples at 0.014 mg/L and 0.01 mg/L. This is an alluvial well up gradient of mining, west of Area B. Due to the up gradient location of this well, the appearance of arsenic in this well is not associated with mining.
- WD-195 had three consecutive samples from 2009 to 2011 that ranged between 0.013 mg/L and 0.019 mg/L. This is a deep, up gradient well and the appearance of arsenic in this well is not attributable to mining.
- WI-153 had three samples above the arsenic standard that ranged from 0.012 mg/L to 0.018 mg/L. This is a relatively shallow (42 feet) interburden well in Area C at the north edge of mining. The water level and water quality have shown little variation throughout the life of the well. Unusual or anomalous concentrations of analytes in this well include boron above 1 mg/L and dissolved iron as high as 9.6 mg/L. The appearance of arsenic at or above 0.01 mg/L correlates with iron at 8.57 mg/L or higher. Rosebud and McKay wells at this location (WR-126 and WM-153) have detectable arsenic concentrations at or below 0.0005 mg/L. The McKay well also has higher than usual boron and iron, but it remains lower than in WI-153. Spoil well WS-122 at this location has not had enough water to sample and is not a likely source of the arsenic. Well WI-186, some 4,700 feet down gradient to the east, shows effects from surface uses such as road stabilization materials, but does not contain arsenic above 0.005 mg/l. The source of the arsenic in WI-153 is unknown. It is not associated with spoil water and may be associated with surface uses. There are no down gradient users near well WI-153.
- WM-189 is in the mined out area in Area D and had two samples with arsenic at 0.01 mg/L and 0.013 mg/L in 2002 and 2005. Two subsequent samples have reported arsenic concentrations at 0.001 mg/L and non-detect. Spoil well WS-128 at the same location has had non-detectable concentrations of arsenic and thus is not a likely source. It is worth noting that WM-188 and WS-187, located north northeast and northeast, respectively, of WM-189, also reported arsenic concentrations at and slightly above the standard during the same time frame. The absence of arsenic exceeding standards since then points to either a synchronous and temporary occurrence of arsenic in the area (August 2002 and September 2005) or a consistent sampling or analytical error. The lack of persistence of arsenic at these locations suggests there is not a problem.

At the Big Sky Mine, 19 samples taken between 1985 and 1987 from Area A wells were reported to have concentrations of arsenic between 0.01 mg/L and 0.054 mg/L, and all but two are less than 0.02 mg/L. The only well with repeated exceedances of arsenic is spoil well ASP22, which had exceedances of 0.018 mg/L to 0.054 mg/L in four consecutive year, 1985 through 1989. The last exceedance was 0.012 mg/L in 1989. This well is in a pre-law mine area that has been released from the Area A permit area.

At Big Sky Mine Area B, arsenic has been among the analytes in the water quality monitoring suite since the middle 1980's. In Area B, 83 samples reported the presence of arsenic, most of them in a single sampling even in 1985, which calls into question the accuracy of either the sampling or analysis. The highest concentration of arsenic reported in the Area B wells was 0.048 mg/L.

The wells with two or more arsenic exceedances include:

- BIN1217 is a historic well that had three exceedances of 0.025 mg/L, 0.012 mg/L, and 0.01 mg/L during 1985 and 1987. The well was removed during mining.
- BIN617 is an active well at the north permit boundary that had three exceedances between 0.01 mg/L and 0.022 mg/L during 1985-1988. Subsequent samples have been mostly non-detect; a few have reported detection below 0.005 mg/L. This well is up gradient of mining.

- BMC1214 is a historic well that reported three exceedances of 0.011 mg/L to 0.027 mg/L during 1985 and 1987, prior to removal by mining.
- BMC314 had four exceedances between 1985 and 1988 ranging from 0.012 mg/L to 0.028 mg/L. All subsequent samples were non-detect. The well was removed in 1994.
- BOV112 had two samples, one each in 1985 and 1990, at 0.021 mg/L and 0.014 mg/L but has reported non-detect or concentrations below 0.005 mg/L since those two samples. This well is up gradient of mining.
- BSM1215 had four samples in the middle 1980's that ranged from 0.01 mg/L to as high as 0.033 mg/L, but has reported only non-detect or concentrations below 0.005 mg/L since.
- BSM315 had four samples between 0.01 mg/L and 0.026 mg/L in the middle to late 1980's, but returned only non-detect concentrations until removal of the well in 1994.
- BSM615 had two samples in the middle to late 1980's of 0.014 mg/L and 0.024 mg/L but has been non-detect in all subsequent samples.
- BSM915 had three samples in 1985 that ranged from 0.012 mg/L to 0.033 mg/L but all subsequent samples returned non-detectable concentrations.

Arsenic occurs naturally at concentrations which can exceed human health standards in aquifers in the Fort Union Formation. Based on the above discussion of samples with arsenic exceedances at Rosebud Mine and Big Sky Mine there is no indication that mining has caused or created a situation that has contributed the occurrence of arsenic inside or outside the mine areas. None of the exceedances reported for arsenic may be attributed to mining operations. Therefore, there is no reason to expect material damage outside the permit boundary due to arsenic.

9.2.6.3 Cadmium

The inclusion of cadmium in water quality analyses has been part of the groundwater monitoring program since sampling began in 1976. In the Rosebud Mine database, cadmium exceeds the human health standard (0.005 mg/L) more often than any other regulated trace metal. However, 92% of the exceedances were from samples taken before 1990, with most occurring in the 1970's and 1980's. Commonly, a single sampling event resulted in widespread exceedances (e.g. July and August 1999). This suggests that a persistent and widespread source of cadmium above human health standards was present during the early days of sampling that is not now present, or there was a long-standing problem with sampling and analysis of this metal that produced spurious results. Water quality samples are currently collected from some of the same wells active in the 1980's in addition to new wells. Only 14 groundwater samples have reported cadmium concentrations above the human health standard since 1990 and only three of those were reported since 2002. None of the exceedances since 1990 are persistent in a given well:

- WR-168 reportedly had a cadmium concentration of 0.24 mg/L in 2010. The analysis reporting 0.24 mg/L is likely a data entry error, as the boron concentration from the sample is also 0.24 mg/L, a typical concentration for boron. Previous samples, when above non-detect, were an order or magnitude below the human health standard.
- WA-172 reportedly had a cadmium concentration of 0.017 mg/L in 2010 but had been at non-detect concentrations before this sample and has remained non-detect. This sample also reported exceedances for arsenic (0.019 mg/L) and lead (0.016 mg/L). Subsequent analyses for this well reported non-detect for all three of these trace metals.

At the Big Sky Mine, Area B, cadmium exceedances were limited to sample events in 1985, 1986, 1987, and one sample in 1990. One hundred and five samples from all monitored hydrostratigraphic units

reportedly had cadmium concentrations between 0.005 mg/L and 0.029 mg/L. Many of these wells are still active and have not had subsequent samples that contained cadmium above the human health limits. Generally, cadmium concentrations do not exceed the detection limit. As in the above discussion of arsenic exceedances, the appearance of cadmium above the standard during this limited timeframe is likely associated with sampling or lab error.

As described above, exceedances the human health standard for cadmium were common prior to 1990, and are attributable to imprecise analytical methods for this trace metal during this time. More recently cadmium exceedances have been rare and are considered anomalous. None of the exceedances for cadmium may be attributed to mining operations. Therefore, there is no reason to expect material damage outside the permit boundary due to cadmium.

9.2.6.4 Copper

There are no exceedances of the copper human health standard (1.3 mg/L) reported from any groundwater samples in the Rosebud Mine or Big Sky Mine. Therefore, there is no reason to expect material damage outside the permit boundary due to copper.

9.2.6.5 Fluoride

There are five reported exceedances of the human health standard for fluoride (4.0 mg/L) in groundwater at the Rosebud Mine. None is from the same well and some of the reported concentrations likely are reporting or data entry errors.

- WA-118 reported the highest concentration at 801 mg/L, which is assumed to be an error in reporting or analysis. This concentration, reported in 2004, is extremely high and exceeds by many orders of magnitude the typical concentration of < 0.05 mg/L at this well.
- WI-102 reported a fluoride concentration of 13 mg/L in 2008. This is most likely a reporting error and should be 0.13 mg/L. All other samples are <0.37 mg/L.
- WA-214 had a reported exceedance of 7.29 mg/L in 2007, although all other samples from this well are <0.34 mg/L. Concentrations of other analytes that appear anomalous, compared to the historic and more recent analyses from the well, call into question the accuracy of the analysis.
- WM-138 reported a concentration of 6.3 mg/L in 2009. All other fluoride concentrations reported from this well are at or below 0.05 mg/L.
- WD-182 is a 500 foot deep underburden well in Area E that has had a persistent high concentration of fluoride since 1985. It had a concentration of 5 mg/L in 1993 and maintains a concentration of 3 mg/L. This well has been monitored since 1984. It has a consistent water quality (TDS = 1,220 mg/L) with an alkaline pH. It shows no water quality evidence of being affected by spoil and depth of this well makes susceptibility to spoil unlikely. Two shallower wells (WI-182, WM-182) at the same location have fluoride concentrations <0.50 mg/L.

No exceedance of fluoride has been reported in samples taken at the Big Sky Mine.

Exceedances of fluoride are uncommon and usually appear to be the result of problems in laboratory analysis or reporting. The exceedance at well WD-182 is likely due to natural causes and not related to mining. None of the exceedance for fluoride may be attributed to mining operations. Therefore, there is no reason to expect material damage outside the permit boundary due to fluoride.

9.2.6.6 Lead

The human health limit for lead is 0.015 mg/L. At the Rosebud Mine, fifteen groundwater samples have exceeded this limit, twelve were from analyses in the 1970's-1980's. The wells that yielded the exceedances do not have recent concentrations that approach the human health limits, suggesting that there is not a persistent problem.

- WA-204 had a concentration of 0.67 mg/L in 2001 in a sample that also has an anomalous iron concentration of 0.67 mg/L, suggesting that there was an error in the analysis or reporting.
- WM-158 had an error similar to the one described above in WA-204, when in 2001, the lead concentration of 0.29 mg/L was reported for both lead and iron.
- WI-162 had a lead exceedance in 2006 with a concentration of 0.37 mg/L, when again, both lead and iron had the same concentration.

At the Big Sky Mine Area A, 113 exceedances for lead have been reported. Most of them were in the 1980's when lab results have been demonstrated to be frequently inaccurate for most metal analyses. A few wells have reported exceedances in the 1990's, but none more recently. Wells with repeated exceedances that include analyses more recent that the 1980's are discussed below:

- AAL14 is an alluvial well down gradient of mining that had four exceedances, most were in the middle 1980's but the most recent was in 1992 at 0.02 mg/L. The shallow depth of this well subjects it to influence from surface water. Surface water often carries sediment that contributes to traces of dissolved metals. This well has also had exceedances of zinc, nitrate, cadmium and arsenic. None of these analytes are persistent and are not interpreted to result from mining impacts.
- AAL51 is an alluvial well in pre-law mining that had four exceedances, including one in 1994. The lack more recent lead exceedances from this well suggest lead is not a problem in this well.
- AMC20 is a McKay coal well that is completed in pre-law mining that has had four exceedances. Three were in the middle 1980's, the latest in 1996.
- AOVM73 has had six exceedances, the most recent in 1996 and the remainder in the middle 1980's. This well is up gradient of mining and therefore represents background water quality.
- ARC30 is a Rosebud well southwest of pre-law mining that has had two exceedances, one in 1984 and one in 1993. Water quality does not show mining related impacts at this well.
- ASSM27 had three exceedances, the most recent in 1992. This is a sub-McKay well located south of the permit boundary that has shown slight increases in TDS but no recent exceedances of lead or other parameters of concern.
- ASMTW4 had two exceedances, the last one in 1992. This is one of the "truck wash" wells located near the pond that received water from the equipment washing facility. Water quality analyses indicate this well has been affected by mine related impacts, but has improved over time, and currently has no parameter concentrations that exceed or are likely to exceed water quality standards.
- ASP40 is a spoil well in pre-law mining that had three exceedances, the most recent in 1992. This well has shown an increase in TDS concentration but currently has no parameter concentrations that exceed or are likely to exceed water quality standards.
- ASPS15 is completed in spoil in pre-law mining and has had six lead exceedances, all but one (1993) in the 1980's. It has water chemistry that suggests it has been affected by mining but currently has no parameter concentrations that exceed or approach water quality standards.
- ASPW1 is a spoil well in pre-law mining that had three exceedances, the most recent in 1996. Other than the two exceedances and one analysis in 1984 of a concentration below the lead standard, lead analyses from this well are non-detect.

At the Big Sky Mine Area B, 66 samples have lead concentrations above the human health limit. The exceedances are from the middle 1980's and the early to middle 1990's. Most of the exceedances are 0.02 mg/L, but they range from 0.015 mg/L to and anomalously high concentration of 0.390 mg/L. Most exceedances are from one sample at a given well. There have been no recent exceedances. Even though lead has remained part of the analytical suite, no subsequent samples have contained lead above the human health limits and most sample concentrations are below detection. The limited timeframe for the exceedances again leads to the likelihood that a problem in sampling or analysis is the reason for the exceedances.

The anomalously high and persistent lead concentrations are discussed below:

- BAL2011, BAL2321, BAL 2521, BAL9011, BAL9031, and BAL9091 are alluvial wells in the north reaches of Lee Coulee that had repeated exceedances (generally in the 0.02 mg/L range) of lead in the early to middle 1990's. Mining was active east of the stream in 1991 and was not active in the uppermost reaches until after 2000. The MPDES discharge point associated with mining on the east side of the stream below the location of most of these wells. The wells were sampled frequently and were non-detect for lead except for the reported exceedances. It seems most likely that the exceedances were spurious.
- BMC714 was located on the south permit boundary and yielded a single sample that reported a lead exceedance of 0.173 mg/L in 1985, prior to mining in Area B. Examination of sample results for other parameters indicates there was a problem with the analysis similar to that observed in BRC413 below.
- BRC413, located southwest of the permit area, had two samples and both had lead exceedances of 0.39 mg/L and 0.24 mg/L in 1985. The initial sample had anomalous analytical results that suggested a problem with the analysis. Calcium and magnesium were exceedingly low (19 mg/l and 14 mg/l), and unusual concentrations of molybdenum (12 mg/L), selenium (0.026 mg/L), aluminum (3.2 mg/L), and exceedances of arsenic (0.02 mg/L) and cadmium (0.029 mg/L) were reported. The latter sample also had unusual results with low calcium and magnesium but most metals other than lead were within normal range. Given its location, this well was outside the influence of mining.

The reports of lead concentrations above the human health limit likely are spurious and likely represent problems with sampling, laboratory analysis, or reporting. None of the lead exceedances are may be attributed to mining operations. Therefore, there is no reason to expect material damage outside the permit boundary due to lead.

9.2.6.7 Nickel

Three groundwater samples reached the human health standard of 0.1 mg/L for nickel at the Rosebud Mine in 1976 and 1977 in wells S-04 and S-05. Subsequent analyses from these wells do not report an exceedance. Nickel does not represent a problem in the Rosebud Mine area.

At the Big Sky Mine two samples in Area A report nickel concentrations above 0.1 mg/L:

- ASP22 had one sample in 1987 that reached the standard. This well commonly reports nickel above the detection limit but has remained an order of magnitude below the standard in all other samples.
- ASPS15 had one sample at 0.1 mg/L in 1990 and commonly has nickel concentrations above the detection limit of 0.010 mg/L, although the last two samples have been non-detect.

In Big Sky Area B, one sample had a nickel concentration above the human health standard. The sample was taken from overburden well BOV1712 in early 1996 and had a concentration of 0.36 mg/L. The well has remained active and has reported subsequent low-level nickel concentrations at least an order of magnitude below the standard. The well is located in an undisturbed area east of the pit and it not likely affected by mining.

Nickel exceedances are rare and appear associated with problems in sampling or laboratory analysis. None of the exceedances reported above for nickel may be attributed to mining operations. Therefore, there is no reason to expect material damage outside the permit boundary due to nickel.

9.2.6.8 Selenium

Eleven groundwater samples from Rosebud Mine reported selenium concentrations above the limit set for human health (0.05 mg/L):

- Two of the samples are from the same well (WO-105); they were taken in 2012 and 2014. This well is located immediately adjacent to the east pit in Area A. Both samples indicate a large increase in TDS (up to 10,000 mg/L) and all major analytes. Field notes indicate this well was damaged and it appeared an animal had fallen into the well. Unusual water quality results confirm there was a problem. Additionally, unusual water quality in the well may be attributable to interception of pit water which had been concentrated by evaporation due to inactivity since 2000. Pit water has been removed from the pit and mining has recently resumed in this part of Area A.
- WA-171 located west of and up gradient of mining in Area B reported a single exceedance of selenium at 0.11 mg/L in 2012. Coincident with this exceedance for selenium, the well experienced a spike in chloride, TDS, calcium, magnesium, nitrite, sodium, and sulfate. This suggests surface influences have affected this alluvial well.
- WA-225 and WO-187 are located far west of Area C in areas undisturbed by mining and thus represent background levels (0.05 mg/L and 0.099 mg/L, respectively).
- WR-126, located at the north edge of Area C central and immediately beyond the margin of mining, had a single selenium exceedance in 2013 of 0.05 mg/L, the standard limit. This well is only 20 feet deep and has water quality that suggests it is affected by surface influences. It has higher than usual boron, chloride, and nitrate, and spikes in calcium and magnesium, likely from road runoff. Selenium is often detected in this well, but the concentrations are usually not close to the human health standard. The water quality changes are not attributed to spoil water as a nearby spoil well (WS-122) contains only four feet of water.

Big Sky Mine Area A had a number of samples that met or exceeded the standard in well

- ASMTW3 had three exceedances, two in the middle 1980's and one in 2000. Most were near the reporting limit (0.05 mg/L), although the first sample in 1984 had 0.17 mg/L.
- ASMTW4 had two exceedances in 1985 near the reporting limit. The ASMTW wells monitored groundwater at the truck wash site and the selenium was likely came from hydrocarbons such as oil and grease. These wells have been part of the monitoring plan for decades and have not had any more recent exceedances than the ones described above.
- Spoil well ASP-22 had one exceedance of selenium in 1984.

There were no samples in Big Sky Area B with exceedances of selenium.

Selenium exceedances are sporadic and often appear associated with a problem in sampling or laboratory analysis. The selenium exceedances in the Big Sky mine truck wash wells were likely caused by the mine, but were within the permit boundary. None of the exceedances reported above for selenium may be attributed to mining operations. Therefore, there is no reason to expect material damage outside the permit boundary due to selenium.

9.2.6.9 Zinc

Sixty-one exceedances for zinc in groundwater are reported in the Rosebud Mine database. Of these, all but three were from samples taken between 1981 and 1989. As most of the wells identified pre-1990 are still active and have no recent exceedances, the appearance of zinc above standards pre-1990 suggests either a temporary, widespread abundance of zinc in groundwater or persistent problems in analytical methods for zinc. As a widespread, temporary source for zinc in groundwater is unidentified and unlikely, the analytical results for zinc, as with other analytes during this period, are suspected to be problematic, indicating there reported exceedances were spurious. Of the samples taken in 1990 and later, there is no indication that there is a cause for concern in the mine areas:

- WA-186 in WFAC had a zinc concentration of 2.09 mg/L in 2000 but had non-detect or low concentrations in samples prior to and after the exceedance.
- WM-181 had an exceedance of 2.71 mg/L in 1990 and an exceedance of 4.67 mg/L in 1988. This McKay well in the west part of Area C was not subject to mining influences at the time of the exceedances, as mining in the west part of Area C did not begin until 2008.
- WS-126 had an exceedance of 3 mg/L in 1999 but analytical results are usually non-detect.

In Big Sky Area A, four wells reported single analyses of zinc above the human health standard of 2 mg/L:

- AAL 14 located south of the permit area reported a zinc concentration of 8.75 mg/L in 2009. This well commonly reports zinc concentrations above detection (0.01 mg/L) but the results of the sample in 2009 is anomalous. No persistent problem with zinc is present in this well.

Three exceedances were reported in spoil wells:

- ASP22 had a single exceedance in 1985 of 4.77 mg/L. Zinc in this well is commonly reported above detection but is generally low and is not perceived to be a problem.
- ASP25R had a single report of zinc at 2.04 mg/L during the same sample event in 2009 that reported zinc above the standard in well AAL14. This well has zinc concentrations above detection on a regular basis but they are orders of magnitude below the human health standard.
- ASP29 had a reported zinc concentration of 37 mg/L in 1997. This is an exceedingly high concentration and is assumed to represent a problem in sampling or analysis. Zinc concentration in this well is generally only slightly above detection or non-detect.

Twenty-six exceedances of zinc were reported from samples taken in Big Sky Area B. Approximately two-thirds of these were reported from two sampling events; one in February 1985 and a second in September 1997. The reported concentrations ranged from 2.38 mg/L to 130 mg/L. The highest concentrations were reported from 15 samples during the September 1997 event, ranging in concentration from 20 mg/L to 130 mg/L. These are extremely high concentrations and likely represent a problem in analysis or reporting. Three wells had two exceedances:

- BRC513 had two exceedances, one each year in 1984 and 1985 of 2.38 mg/L and 8.57 mg/L. The latter sample also was at the standard for lead (0.015 mg/L) and arsenic (0.01 mg/L). This well is north of the permit area and up gradient of mining.
- BSM1015 had exceedances of 3.72 mg/L in 1985 and 40 mg/L in 1997. The remaining analyses are barely above detection (0.01 mg/L).
- BSM1715 had exceedances of 13.1 mg/L and 130 mg/L in 1988 and 1997. More recent analyses are barely above the non-detect limit of 0.01 mg/L.

The exceedances from September 1997 are the last ones reported. A low level of dissolved zinc is generally common in groundwater and a lack of persistent exceedances suggests zinc does not represent a problem in groundwater at Big Sky.

Zinc exceedances are sporadic and appear associated with problems in sampling or laboratory analysis. None of the exceedances reported above for zinc may be attributed to mining operations. Therefore, there is no reason to expect material damage outside the permit boundary due to zinc.

9.2.6.10 Nitrite-Nitrate

Thirty-two samples from the Rosebud Mine have had nitrate concentrations above the human health limit of 10 mg/L. Many represent a single exceedance from a given well that appears to be anomalous when compared to analyses of other samples from the well. No further consideration was given to these wells. Wells that have had persistent exceedances or persistent nitrate near regulatory limits are discussed below.

Three spoil wells have had recent, persistent exceedances of the nitrite-nitrate human health limit:

- Well WS-127 is located in Area D, between the Colstrip power plant and pond 151 and has been monitored for water quality since 1999. This well has high TDS (average 7,882 mg/L), chloride and magnesium concentrations and had nitrate concentrations above the human health standard in five out of six samples collected between 1999 and 2014. The nitrite-nitrate concentration ranged between 7.6 mg/L (Sept. 2011) and 50 mg/L (Sept. 2005) and most recently (2014) was 29.8 mg/L. The well also has an unusually low pH that averages 6.4. The high chloride and magnesium concentrations in this well are most likely related to the application of road stabilization products (magnesium chloride) on the adjacent haul road. A possible source of the persistent nitrite-nitrate concentration in spoil is from blasting agents used during mining. The area is also subject to influences from the power plant and cattle grazing. Groundwater flow in the area is to the southeast. Well WS-126, located southeast of WS-127, serves as a down gradient well to intercept water from WS-127 before it approaches the permit boundary. Nitrate in WS-126 ranges between 0.01 mg/L and 0.06 mg/L, concentrations well below the human health standard. There is no evidence that the proposed expansion of mining in Area B will exacerbate nitrite concentrations in Area E.
- WS-100, located approximately 1,000 feet from the east boundary of permit Area A, has had three samples (2009-2014) that exceed the nitrite-nitrate human health standard of 10 mg/L. The most recent sample (2014) was 24.1 mg/L. Although it is uncertain if the nitrate is associated with mining, agricultural (the reclaimed area is used as grazing pasture) or another unidentified source, ammonium nitrate blasting agents remaining in spoil are a possible source. A stipulation in the approval of AM4 will required expanded monitoring with the expectation that a well will be installed down gradient of WS-100, closer to the permit boundary, to monitor for potential movement of nitrate toward the permit boundary.

- WS-111 is located in the former Pit 6 area. Nitrate concentrations began to rise in 2005 (16 mg/L) and were 12 mg/L in the last two samples (2008 and 2011). Because Pit 6 was a pre-law mine area, it was not subject to current bond release standards, including the requirement to prevent material damage outside the permit area. Pit 6 was released from bond in 2006.

The greatest nitrate exceedance recorded from a monitoring well is 351 mg/L, a highly anomalous value, from WA-113 in 1985. However, this well has a history of elevated concentrations that spans the life of the well. This well is located in a drainage in the town of Colstrip and downstream from a subdivision. Anthropogenic sources such as lawn fertilizer are the most likely source of nitrate in this 15 foot deep well.

A few alluvial wells in the east part of Area B had an exceedance when mining was adjacent to EFAC in the middle 1980's, including well WA-124, and WX-110. Other nearby alluvial wells (e.g. WA-104) showed elevated nitrate below the HHS. The exceedances and persistent elevated nitrate concentrations in alluvial wells from 1982 to 1989 may be attributable to blasting agents used in mining. Use of the stream by cattle is also a potential source of nitrate.

Alluvial well WA-154 was located downstream of Colstrip on EFAC, below the power plant, but showed evidence of elevated nitrate from 1983 until 1995 when monitoring was discontinued. Nitrate here has multiple potential anthropogenic sources other than mining, including the water treatment plant, runoff from the golf course and cattle grazing.

Two Rosebud wells reported nitrate concentrations above the HHS, one (WR-125) in 2000, and another (WR-126) in 2007. WR-125 is up gradient of mining, eliminating mining as the source of the elevated concentrations. WR-126 located along the country road in Area C has shown persistently elevated nitrate since 1987 with one HHS exceedance in 2007. The source is not spoil as water level in the spoil (WS-122) remains 11 feet below the water level in WR-126.

Five samples exceeded the nitrate-nitrate standard in Area A of the Big Sky Mine:

- ASTMW3 and ASTMW4 were the locations of all of the exceedances during the middle 1980's. These wells are known as "truck wash" wells and are located adjacent to the former equipment washing area. The nitrate-nitrogen concentration in four of the samples was over 100 mg/L and ranged as high as 234 mg/L. The source of the nitrate was most likely degreasing and cleaning agents used on equipment at the truck wash.

In Big Sky Mine Area B, fourteen samples had concentrations that ranged from 10.3 mg/L to 54.6 mg/L. The bulk of the samples were from the 1980's and 1990's. Repeated exceedances were from two wells:

- BSM115 (a sub-McKay well) had two exceedances of 11 mg/L and 11.7 mg/L; one in 1998 and one in 2008. This well is located 4,000 feet north and up gradient of mining. Exceedances are due to another land use other than mining.
- BSM2515 (sub-McKay well) is a historic well located below the Rosebud coal crop line in the center of Area B. Both samples with exceedances were 10.3 mg/L and 10.4 mg/L in 1987 and 1995. The reason for the elevated concentration is unclear.

As noted above, elevated nitrate-nitrite have been detected in several locations in both the Rosebud and Big Sky mines. None of these instances are considered material damage because they are either within the permit boundary, or are have a likely source other than coal mining. Because the exceedance at WS-100 is near the permit boundary and could potentially be a result of mining, a stipulation in the

approval of AM4 will require expanded monitoring with the expectation that a well will be installed down gradient of WS-100, closer to the permit boundary, to monitor for potential movement of nitrate toward the permit boundary.

9.2.7 Groundwater Flow Models

The AM4 application included two transient groundwater flow models for permit areas A, B, and C to evaluate potential water level changes caused by mining. The "Rosebud Mine Groundwater Model" evaluates the response of the hydrologic system in and adjacent to the mine area at the end of currently approved mining (Western Energy Co., 2014). The "AM4 Model" evaluates the additional impacts that would result from the mining proposed in application AM4. A flow model was constructed for the Area D permit area in July, 1999 (Western Energy Co., 1999). Mining in Area D concluded in 2012.

Areas A, B, and C
The models simulate flow in all of the shallow aquifers (alluvium, overburden, Rosebud coal, interburden, McKay coal and underburden or sub-McKay) but focus on the Rosebud coal and McKay coal as these are the primary shallow aquifers and the ones most likely to show the greatest effects of mining. Groundwater models are a simplification of the geologic and hydrologic system yet provide reasonable predictions of the local hydrologic function and response to the stresses of mining. After the development of a conceptual groundwater model, a model structure is defined and calibrated. The model is calibrated by comparing model results to measured water levels from monitoring wells and adjusting model parameters to achieve the best simulation of groundwater conditions.

The Rosebud Mine Model simulates drawdown in the Rosebud coal and McKay coal in 2011 (**Figure 9-78** and **Figure 9-79**), and at the end of 2020 (**Figure 9-80** and **Figure 9-81**), the year currently approved mining in Area B is expected to conclude. Drawdown in 2011 was predicted to be greatest in the east part of Area B, with 90 feet of drawdown (including decline in pressure head) in the Rosebud coal and 30 feet in the McKay coal. Because it is confined throughout most of the area, drawdown in the McKay generally extends slightly more than in the Rosebud coal, with the 5-foot drawdown contour reaching slightly less than two miles south of the permit boundary. In 2020, the greatest drawdown in Rosebud coal attributable to currently approved mining is predicted to be 80 feet in the southwest as well as the east half of Area B. In the McKay coal, drawdown in Area B is predicted to be approximately the same as in 2011. In both the Rosebud coal and McKay coal, five feet of drawdown is expected to extend up to two miles outside of the south permit boundary.

Rosebud coal in Area A remains largely unchanged in the amount of drawdown between 2011 and 2020, showing approximately 20 feet of drawdown. Likewise, for the McKay coal, there is approximately 20 feet of drawdown in 2011 and 2020. Area C drawdown is 60 feet in the east part of Area C in 2011, 40 feet in the central part, and 30 feet in the western part. By 2020, drawdown associated with approved mining is 70 feet in the east part, 60 feet in the central part and 30 feet in the west part of Area C. The McKay increases in drawdown by about five feet in 2020 to 30 feet.

The AM4 Model predicts drawdown in areas A, B, and C through 2026 (**Figure 9-82** and **Figure 9-83**), when the additional mining proposed in AM4 is expected to conclude. The largest simulated drawdown at the end of the proposed mining is about 110 feet in the Rosebud coal in the east part of Area B, at the south permit boundary. Five feet of drawdown is projected to extend almost two miles south of the Area B permit boundary. The maximum projected drawdown in the McKay coal is 35 feet in the east half

of Area B. Five feet of drawdown is expected to extend slightly more than two miles south of the Area B permit boundary. In 2026, the increase in drawdown from AM4 mining compared to mining in 2020, at the end of currently approved mining in Area B, is 30 to 40 feet in Area B Rosebud coal and five feet in McKay coal (**Figure 9-84**).

To evaluate the recovery of the system, the AM4 model predicted drawdown remaining in 2076 (**Figure 9-85** and **Figure 9-86**), 50 years after the predicted conclusion of mining in Area B. Fifty years was chosen as the timeframe for insight to the response of the system. For the Rosebud coal, the maximum residual drawdown in 2076 is projected to be about 50 feet in Area B and Area C, and the extent of the five-foot drawdown contour is predicted to be between two and three miles south of the permit boundary. Residual drawdown in the McKay coal is projected to be about 25 feet in the east part of Area B, near the south permit boundary. The five-foot drawdown contour is projected to extend up to two and a half miles south of Area B. The increase in simulated drawdown in 2076 between that expected from currently approved mining and mining proposed in AM4 is as much as 15 feet in Rosebud coal and five feet in McKay coal (**Figure 9-8**7).

Unlike drawdown modeling, there is not a reliable way to calibrate recovery water levels. Modeling the recovery for any period gives a prediction of how the system will respond, but it should be regarded as an estimate. There are limitations to any model based on the input variables used to quantify a hydrologic system. The limitations are even greater in a large area with naturally variable and complex hydrogeology, as found in the Colstrip area. Recovery of the system is not expected to be linear over time. A model for recovery over a determined period, such as 50 years, may be used to extrapolate to a longer time frame, but the results become less reliable with time.

Area D

Application 161 for mining the east part of Area D was approved by DEQ in 2001. The application included a flow model (Western Energy Co., 1999) that predicted water level drawdown and recovery associated with all mining in Area D. The model predicted impacts to the Rosebud coal, interburden and McKay coal. Two scenarios were modeled. Scenario 1 assumed leakance between interburden and McKay coal would increase due to fracturing from blasting, particularly in the south part of the permit area where interburden is thinnest. Scenario 2 assumed no interburden fracturing and thus no increase in leakance. The outcome for both scenarios is similar, with more drawdown to interburden water levels resulting in Scenario 1 along with an increase in water level over beginning levels in the McKay coal. Maximum drawdown for Rosebud coal, interburden and McKay coal at the end of mining was predicted to be about 30 feet, with most of the drawdown to occur in the west-central part of Area D, coincident with a structural depression in the Rosebud coal.

The model assumed Area D mining would be completed in 2011 (**Figure 9-88** and **Figure 9-89**). The modeled Rosebud coal potentiometric surface (Layer 1) closely resembles the Rosebud coal and spoil potentiometric surface developed from current water levels at the end of mining in 2013. However, the McKay coal potentiometric surface measured at the end of mining is 10 feet to 20 feet lower than either one of the model scenarios. The model predicts no drawdown in the McKay coal at the end of mining near the west edge of the permit area. Hydrographs of McKay well WM-110 and the well that replaced it after mining, WM-189, indicate that the current water level closely approximates the water level in 1979 (**Figure 9-50**).

Fifty years after completion of mining, the model predicts between 20 and 25 feet of drawdown in the Rosebud/spoils aquifer in Scenario 1 (**Figure 9-90**). Under this scenario, between 10 and 15 feet of

drawdown will remain in the interburden and up to 10 feet of drawdown will remain in the McKay. A head increase of approximately five feet above the premine potentiometric surface is predicted in the central and southeast permit area. Scenario 2 (**Figure 9-91**) gives similar results after 50 years. Rosebud coal and spoil water levels are predicted to remain 15 feet to 20 feet below starting water levels in the south central part of the permit area. Interburden is predicted to be 10 feet to 20 feet below starting levels, and drawdown in the McKay is predicted to be five feet to 10 feet below starting levels. Drawdown in the sub-McKay units is not expected and was not modeled.

9.2.7.1 Drawdown Impacts to Private Wells

Anticipated drawdown (head decline) in the Rosebud coal and McKay coal in response to current mining and mining proposed in AM4 is discussed in **Section 9.2.7**, Groundwater Models. Numerous private wells outside the permit boundary lie within the area of predicted drawdown in the Rosebud coal , both at the end of currently proposed mining (**Figure 9-94**) and the end of proposed AM4 mining (**Figure 9-95**). The anticipated impact to private wells is included in **Table 6-1** and is based upon the approximate location of the wells as indicated in the GWIC database. Analysis of the potential impact to a given well is based on completion information, where available, static water level provided in the GWIC database and location of the well within the zone of predicted drawdown. Based on reported static water level, wells completed in the Rosebud coal that lie within the area of drawdown generally have adequate head to retain sufficient supply. Wells are not likely to be significantly impacted unless water levels drop below the level required for pumping. Wells with low static water levels that are completed in the Rosebud coal are the wells most likely to be affected. Wells that are impacted by mining are required under ARM 17.24.648 to be replaced by the operator.

The following private wells within the zone of mine related drawdown were initially identified as potentially vulnerable based on their completion depths. Private wells numbered 77 (NE1/4 Section 4, T1N, R39E) and 75 (SE1/4 Section 32, T2N, R39E), are used for stock water and are located west of Area C. Western Energy Company has acquired surface ownership and anticipates abandonment of the wells.

Private wells 82 and 83 are in Section 17 and 18 (T1N, R40E), respectively, and are over a mile from active mining in Rosebud Mine Area B and Area C. Well 82 is completed at 145 feet and has a static water level of 70 feet reported in the GWIC database. Rosebud monitoring well WR-125 (**Figure 7-2**) with a completion depth of 228 feet is less than 600 feet away from well 82. The difference in depth between the two wells suggests that well 82 is completed in the overburden and is not likely to experience drawdown. Drawdown in the overburden is limited due to the typically discontinuous and extremely slow transmissivity of the stratigraphic units that composed the overburden.

Well 83 is completed at 124 feet and reports a static water level of 64 feet. It is located on the 10-foot drawdown contour predicted by the AM4 groundwater model for the year 2026. There is no nearby monitoring well for comparison of water levels or effects of mining to date. It is unlikely to be affected by the predicted 10 feet of drawdown in the Rosebud coal at this location.

Private wells 86, 87 and 89 also lie within or close to the margins of drawdown. Based on predicted drawdown to these wells (five to 10 feet), depth of completion of the wells and the response of monitoring wells that lie even closer to mining, wells 86, 87, and 89 are not anticipated to be significantly affected by drawdown from current or proposed mining operations.

Well 91 located south of the west part of Rosebud Mine Area B (Section 23, T1N, R40E) and northwest of Big Sky Area B, is completed in overburden or Rosebud coal and had a static water level of only 30

feet. It lies near the Rosebud coal 10-foot drawdown contour interval. Rosebud monitoring well BRC1313, located between Rosebud Area B and Big Sky Mine Area B, northeast of well 91, had nine feet of drawdown and now has a stable water level and a head of 110 feet. It is unlikely that well 91 will be vulnerable to drawdown from proposed mining.

None of the potential drawdown impacts described above are considered likely to constitute material damage. Wells located within the expected area of drawdown either have a sufficient water column that predicted drawdown will not affect their use, or are owned by Western Energy Company.

9.2.8 Cumulative Impact of Historic, Current and Proposed Mining

Currently and formerly permitted areas at the Rosebud and Big Sky mines total approximately 53 square miles. Pre-law mining disturbance and approved LOM disturbance is equivalent to approximately 43 square miles (27,305 acres). Rosebud coal has been removed at the Rosebud Mine and Big Sky Mine from easily accessible coal at or near the crop line to interior areas where the depth of overburden cover allows economic extraction of the underlying coal. Mining at Area D and Area E of the Rosebud Mine and Area A and Area B of the Big Sky Mine has been completed and the areas reclaimed. Mining remains active at Rosebud Mine Area A, Area B, and Area C.

Surface disturbance in permit areas established after the enactment of MSUMRA has been reclaimed to the approved postmine topography with equivalent groundwater recharge capacity. Much of the pre-law mining disturbance has been reclaimed to some extent and the remaining unreclaimed topography is not expected to create a barrier to recharge.

Drawdown in water level or declines in pressure head are the most obvious and widespread impact associated with past and present mining in the Colstrip area, with the Rosebud coal aquifer the most widely and severely impacted. Head declines of up to 90 feet in the Rosebud coal from mining at the Rosebud Mine were estimated in a model based on 2011 water levels (**Figure 9-78**) (Western Energy Co., 2014). Based on the model, maximum head decline in Area A has been approximately 20 feet; east central Area B had 90 feet and Area C experienced up to 60 feet. Based on a model of Area D during a proposed expansion in 1999, drawdown (decline in head) was estimated to be between 20 and 30 feet (**Figure 9-88** and **Figure 9-89**)(Western Energy Co., 1999). Part of Area E was mined pre-law and early impacts were not monitored. Based on monitoring in Area E since 1981, Rosebud coal west of the pit has recovered 20 feet since mining concluded in 1986 (Western Energy Co., 2015).

Amount of decline in Rosebud coal in Big Sky Mine Area A is uncertain as initial mining was prior to enactment of statutes regulating coal mining. Monitoring wells initially installed by MBMG in the middle to late 1970's recorded up to 50 feet of head decline in Rosebud coal. Head decline in Rosebud coal at Big Sky Mine Area B has measured as much as 30 feet.

Five feet of head decline in the Rosebud coal currently extends over a mile from the south permit boundary of Rosebud Mine Area B and represents the location of the greatest extent of decline outside the mine permit boundaries. Based on monitoring near the permit boundary and extrapolating from the response of the Rosebud coal aquifer in the Rosebud Mine, the extent of the five-foot head decline west of Big Sky Area B permit boundary is approximately a mile. Head decline in the Rosebud Mine and Big Sky Mine overlaps and coalesces in the area between the two mines. Total extent of drawdown in the Rosebud coal is approximately 8 miles in a north-south direction and 15 miles in an east-west direction.

Mining has also created head decline in aquifers below and adjacent to the Rosebud coal. As overburden removal is preliminary to coal removal, the overburden may experience a drawdown response in areas where it is saturated. However, the discontinuous nature of the fine-grained overburden strata, and thus extent of saturation, causes less of a widespread impact. Head reduction has also been observed locally in the McKay coal. The McKay coal is separated from the overlying Rosebud coal by a few feet to tens of feet of interburden and is not physically disturbed by mining. Some of the reduction in head may be due to unloading of the overlying rock units (overburden and Rosebud coal) or removal of recharge from the Rosebud coal. Steepest head decline in the McKay coal is modeled to be approximately 30 feet in the east part of Rosebud Mine Area B (**Figure 9-79**). Based on monitoring response, head loss in McKay coal in Big Sky Mine Area A is estimated to be between 12 feet and 16 feet and as much as 20 feet to 30 feet in Area B.

Removal of the Rosebud coal has also caused localized declines in the underburden, as observed in Rosebud Mine Area B, Area D and Area E. Recovery of head in unmined Rosebud coal, McKay coal and underburden has occurred relatively quickly in areas where reclamation has been completed, including Area D and Area E of the Rosebud Mine and both areas of the Big Sky Mine. Even where decline has been observed in these units, substantial confined head remains in most of the McKay coal, underburden and unmined Rosebud coal, particularly in areas away from the coal crop line.

Alluvial groundwater in ephemeral drainages is generally unaffected by mining. However, mining has affected alluvium levels as well as water quality in the east part of EFAC and Lee Coulee. Proximity of the Rosebud coal to alluvium in intermittent reaches of EFAC between Rosebud Mine Area A and Area B resulted in drawdown early during Area B mining. Connection of alluvium with Rosebud coal and McKay coal at the east end of the permit areas resulted in recharge to spoil and bedrock units, particularly in Area B. The recharge has been aided by MPDES discharges to EFAC. The increase in water level from MPDES discharges as well as above normal precipitation in recent years has resulted in increases in TDS concentrations in alluvium. MPDES discharge to Lee Coulee (Big Sky Mine Area B) increased alluvial water levels and caused declines in water quality.

Infiltration into backfilled pits is slowly creating a spoil aquifer. The length of time necessary for spoil to recover to premine Rosebud water levels will vary based on hydrologic setting and time of completion of mining and reclamation. Source of recharge to the spoil is mainly from adjacent, unmined Rosebud coal but local surface water contributions from streams, ponds and mine pits may provide additional, recharge. Areas without significant lateral recharge, such as Rosebud Mine Area A, Area D, and the north part of Area C, will take longer to recover than other areas. Spoil currently ranges from dry to thinly saturated in most former pit areas. Recovery is predicted to take many decades after the completion of mining. Fifty years after mining is completed in Area B, including mining the proposed AM4 cuts, depressed heads of up to 50 feet were modeled to remain in Area B and Area C (Western Energy Company, 2015). A stipulation on permit issuance for AM4 will require that the operator eliminate approved and proposed cuts in Section 9 and Section 10 (T1N, R41E) in Area B. This will decrease some of the additional drawdown predicted by AM4 mining.

Spoil water quality is most similar in TDS concentration to overburden water. TDS concentrations from recent spoil water quality samples ranged from 1,830 mg/L to 7,690 mg/L (average = 3,963 mg/L; median = 3,690 mg/L) at the Rosebud Mine and 2,800 mg/L to 5,280 mg/L (average = 3,897 mg/L; median = 3,160 mg/L) at the Big Sky Mine. Water quality in the Rosebud coal up gradient of mining is not affected by spoil water. Except where interburden is thin, the underlying McKay coal is generally not subject to water quality changes from spoil. Due to the low conductivity of underburden rocks, the

underburden remains unaffected by spoil water. Laterally down gradient Rosebud coal has the greatest potential for water quality changes from spoil water, but as pit areas remain largely unsaturated, down gradient coal has remained largely unaffected. At the Rosebud Mine down gradient exposure of Rosebud coal to spoil water is limited by the crop line in Area A, Area D, Area E and part of Area C. Premine Rosebud coal typically became more thinly saturated approaching the crop line and was dry by the time it reached the crop line. This is attributable to the slow movement of groundwater which allows time for evapotranspiration as it approaches the crop line. Given that the transmissivity of spoil is expected to be similar to that of coal, spoil water is expected to behave similarly as it moves toward crop lines. However, where the crop line is intercepted by drainages, the possibility exists for the development of springs, especially where springs existed at the crop line prior to mining.

Spoil water is expected to affect water quality in EFAC (Western Energy Co., 2015). The south margin of the crop line in Area A borders EFAC. Based on comparison of water levels in spoil and alluvium, Area A spoil water is moving toward EFAC alluvium. The contribution of Area A spoil water to the observed increase in TDS in EFAC alluvium currently is approximately three percent. Impacts to EFAC discussed in **Section 9.2.7.1.1** and **Section 9.2.8** indicate that the contribution from Area A spoil to EFAC alluvial water quality is estimated to reach as much as 13 percent. Water quality of the alluvium is expected to meet narrative standards for current and postmine water uses and will not exceed numeric HHS.

A possible connection of the Rosebud coal with alluvium in the southwest part of Area C (as suggested by the response of monitoring well WR-136) suggests EFAC may be subject to spoil water from Area C if there is substantial hydrologic connection with the alluvium. Based on the analysis of contributions from Area A to EFAC alluvium, input from Area C spoil into the stream is expected to be small but may contribute to diminished water quality in EFAC.

Upon saturation, the movement of water from some Area B spoil is anticipated to be to the southeast rather than toward EFAC. This spoil water will be directed to the area between the Rosebud Mine and the Big Sky Mine, and eventually to the Big Sky Mine crop limits. The distance between the Rosebud Mine and Big Sky Mine ranges between approximately a half-mile and two miles. Rosebud coal water quality in the unmined area between the two mines is variable (monitoring wells average between 690 mg/L and 4300 mg/L). Groundwater quality in this area is currently unaffected by spoil. Area B spoil water quality generally exceeds the quality of Rosebud coal between the two mines (see **Section 9.2.5.1.7**). Mixing of spoil with the background Rosebud coal water will take place as spoil moves to the south. An increase in TDS will be due to analytes with narrative standards, mainly sulfate, calcium and magnesium. No analyte with a DEQ-7 numeric limit (e.g. trace metals, nitrate + nitrite) is expected to increase as concentrations of these analytes are generally non-detect in spoil and rarely is there an exceedance. There are no wells identified in the private well inventory that are completed in the Rosebud coal in the area between the Rosebud Mine and Big Sky Mine. No uses of the Rosebud coal water between the two mine areas are expected to be impacted. Due to the variability of water quality in Area B spoils, the unmined coal between Area B and the Big Sky Mine, and Big Sky Area A spoils, and the clinker-enhanced recharge in this area it does not appear that migration of spoil water from Area B will cause a parameter to increase to a level that renders the waters unsuitable for domestic use or livestock and wildlife watering, or harmful, detrimental, or injurious to the beneficial uses listed for Class II and Class III groundwater. If any such harm, detriment, or injury occurs, it will be local and capable of mitigation by providing replacement water.

Observed impacts are used to anticipate the response of the hydrologic system to approved and proposed mining. However, the response of a natural system cannot be predicted with exactness. A

basic understanding of the hydrogeologic system, determined largely by field measurements and observations of the response of the system to date, is used to anticipate future impacts and estimate recovery of the system. Natural systems are dynamic, characterized by special and temporal variability and do not lend themselves to precision, especially when considering large areas and long time frames. Recovery from the extensive mining in the Colstrip area, past and present, is expected to take numerous decades, if not longer. Recovery of water levels and water quality will depend on the response of local hydrogeology, climate, and chemical reactions, all of which individually and in concert are unpredictable and play a part in the outcome. There is no known, generally accepted groundwater model or modeling methodology capable of predicting, with a reasonable probability of certainty, the concentration of inorganic constituents at any time in a hydrologic unit subject to migration of groundwater for an area mined by strip mine methods. Awareness of this inexactness of the prediction of impacts from strip mining is reflected by the statute and rules that require that the "probable hydrologic consequences", rather than the exact hydrologic consequences, of mining be determined.

9.3 NON-MINING IMPACTS

There are numerous sources of impacts to the hydrologic balance in the Colstrip area from sources other than strip mining. Water use and effluent associated with the Colstrip power plant and utilities for the town of Colstrip contribute to impacts to groundwater and surface water.

9.3.1 Colstrip Power Plant

The Colstrip Power Plant is a coal fired plant located east of the Rosebud Mine Area A and west of Area D and Area E (**Figure 1-1**). The Colstrip plant is owned by Talen Energy, Puget Sound Energy, Portland General Electric Company, Northwestern Energy, Avista Corporation, and Pacific Corp.

Operated by Talen Energy, the four-unit coal fired generating power plant can produce 2,200 megawatts. Units 1 and 2 produce 307 megawatts each. These units began producing electricity in 1975 and 1976 and have an average yearly coal consumption of 2.8 million tons. Units 3 and 4 began operation in 1984 and 1986, respectively. Units 3 and 4 average yearly coal consumption is 6.4 million tons and production is 740 megawatts each (PPL, 2011). Sub-bituminous coal is delivered to the power plant from the Rosebud Mine via a four-mile long overland conveyor system. In recent years, coal consumption has declined somewhat due to the combined use of coal and natural gas at the power plant.

The bottom ash from Units 1 and 2 and Units 3 and 4 are hauled to on-site ponds just south and southeast of the plant, respectively. After settling of particulates, the clear water is returned to the plant. Fly ash from Units 1 and 2 is pumped to the Units 1 & 2 ponds, located in a drainage northeast of Rosebud Mine Area A, for final settlement and storage. Fly ash from Units 3 and 4 is pumped via a pipeline to the evaporation holding ponds located approximately 3.5 miles southeast of the plant on a tributary to Cow Creek, outside the Rosebud Mine permit boundary. The evaporation holding pond and clear well have a combined design surface of approximately 324 acres and a usable surface of area of approximately 180 acres (Hydrometrics, 1990).

Failures of the pipeline used to pump slurry to the evaporation holding pond in Cow Creek resulted in five accidental releases of fly ash slurry between 1987 and 1989, with a cumulative volume of more than 280,000 gallons released (DNRC, 1990). Subsequently, more recent leaks have also occurred. Pump-back wells have been installed, and have been partially successful in capturing pond leaks and maintaining or reducing groundwater levels. Water quality and water level data from Rosebud Mine monitoring wells

adjacent to Area D and Area E, suggest that down gradient ground water quality has been impacted by leakage from the pond or releases of slurry.

Leakage of facility ponds at the power plant has been a source of recharge to the groundwater system in the past. The net effect of plant site pond and Castle Rock Lake seepage and Colstrip municipal wastewater effluent discharges, estimated at 390 acre-feet per year in the 1990's, to EFAC was much greater than the estimated 10 acre-feet per year loss in alluvial groundwater due to mining (Montana Department of Environmental Quality, 1998) and represented a more than 50 percent increase to the estimated 730 acre-feet of annual alluvial flow below Colstrip prior to 1970. Rosebud Mine monitoring wells WM-135, WS-116, and WI-116 in Area E, adjacent to ponds at the power plant, indicate that seepage from the ponds caused water levels to rise.

The water quality of influx to EFAC from the above mentioned sources ranges from 200 mg/L to 600 mg/L TDS for Yellowstone River water stored in Castle Rock Lake, to 5,000 to 50,000 mg/L TDS for discharges and seepage from municipal and industrial sources (Montana Department of Environmental Quality, 1998). Most of this influx reaches EFAC downstream of the mine permit area.

Montana DEQ and Talen Energy have entered into an Administrative Order on Consent to address seepage from the on-site ponds. A portion of the seepage from ponds at the plant site, estimated at 130 acre-feet per year in 2014, is currently captured by a system of groundwater interception wells which have lowered water levels under portions of the plant site (Hydrometrics, 2015).The operation of this groundwater interception system has resulted in some improvements in water quality near the plant site, however residual water quality impacts from historic pond seepage are expected to persist for the foreseeable future.

More than 8,000 acre-feet of water per year is pumped from the Yellowstone River via a 29-mile long pipeline to a 2,250 acre-feet storage pond known as Castle Rock Reservoir located on the west side of town, adjacent to Rosebud Mine Area A. Ninety to 95 percent of annual reservoir storage is used by the power plant, with the overwhelming majority of that water lost to evaporation through cooling processes, from pond surfaces and in water used for dust suppression. The remainder is used to supply the town of Colstrip. An estimated 180 acre-feet per year of water leaks from the pond into sub-McKay underburden and EFAC alluvium, increasing the flow in the stream north of the power plant.

9.3.2 Colstrip Municipal Uses

The Colstrip Water Treatment Plant provides potable water from Castle Rock Reservoir. Backwash from the potable water treatment plant is discharged back to the reservoir under MPDES permit MT0030422. Municipal sewage flows via a collection system to the Colstrip Wastewater Treatment Plant which operates at around 200,000 gallons per day, about one third of stated capacity (City of Colstrip, 2014). The City of Colstrip is authorized to discharge from its sewage treatment plant to EFAC pursuant to MPDES discharge permit MT0022373.

The nine-hole public golf course is located adjacent to EFAC approximately a mile downstream of Colstrip. Water used to maintain the greens infiltrates into EFAC, likely causing undefined changes in water level and water quality.

10.0 CONCLUSION

The above sections of this CHIA represent an in depth analysis of impacts to the hydrologic balance from mining that includes an assessment of existing or probable changes to the hydrologic balance inside and outside the permit area and an evaluation of material damage outside the permit area associated with current and proposed mining. The conclusion of the analysis is that no material damage is identified from current or approved mining and that the additional mining proposed under AM4 will not create material damage.

Current water uses include livestock and wildlife drinking water, aquatic life, and domestic uses. Designated uses for the C-3 intermittent and perennial reaches of drainages identified in the cumulative impact area are: bathing, swimming, and recreation, and growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl, and furbearers, and maintenance as marginal for drinking, culinary, and food processing purposes, agriculture, and industrial water supply. *See* ARM 17.24.629(1). Listed beneficial uses for class II groundwater are: 1) public and private water supplies; 2) culinary and food processing purposes; 3) irrigation of some agricultural crops; 4) drinking water for livestock and wildlife; and, 5) most commercial and industrial purposes. *See* ARM 17.30.1006(2)(a). Listed beneficial uses for Class III groundwater are: 1) irrigation of some salt tolerant crops; 2) some commercial and industrial purposes; 3) drinking water for some livestock and wildlife; and, 4) drinking, culinary, and food processing purposes where the specific conductance is less than 7,000 microSiemens/cm at 25ºC. *See* ARM 17.30.1006(3)(a). No changes to water quality attributable to proposed expansion of mining in Area B will render surface or groundwater unsuitable for existing uses. No changes to water quality attributable to mining in Area B will render surface water unsuitable for a listed use or groundwater unsuitable for a current or anticipated use, or harmful, detrimental, or injurious to a listed beneficial use. This conclusion is generally based on the location of proposed expanded mining away from potential impact areas and the range of natural variability of water quality in comparison to potential increases in parameters attributable to proposed expanded mining in Area B. No reductions in water quantity related to mining are expected to impact groundwater uses outside the permit boundary. If unexpected water quantity or quality impacts to groundwater uses were to occur, Western Energy Company has committed to providing replacement water to the affected users by drilling deeper wells.

No numeric DEQ-7 water quality exceedances associated with mining were identified outside the permit boundary. Numeric water quality exceedances inside the permit boundary are uncommon. Persistent nitrate-nitrite nitrogen over the HHS has been identified within the permit boundary at two spoil monitoring wells in the Rosebud Mine. As a stipulation to the permit, additional monitoring wells will be required to monitor potential down gradient movement of the affected water to ensure that it does not leave the permit boundary. Additional monitoring wells are also required inside the south permit boundary of Area B to monitor the quality of spoil water once the backfill becomes saturated and follows the natural flow direction to the southeast. Currently, most of Area B spoil remains unsaturated. Mitigation will be implemented if groundwater concentrations above the HHS appear to be moving close to the permit boundary. A potential rise in parameter concentrations (TDS, calcium, magnesium and sulfate) are not expected to reach concentrations that will render groundwater unsuitable for domestic use or livestock and wildlife watering, or harmful, detrimental or injurious to a listed use for a given groundwater class (ARM 17.30.1006).

Storm-driven runoff and sediment load in the channels downstream of the mine area will be diminished during mining as sediment control ponds capture all runoff within the mine. Consequently, in stream

dams for stock water on ephemeral drainages may see a reduction in water quantity until the sediment control ponds are reclaimed. Once reclamation is complete and the sediment control ponds are removed, a similar quantity of runoff water is anticipated to be delivered from the mine area, and the runoff water is expected to carry less entrained sediment. In reclamation, some sediment ponds will be converted into permanent ponds or small depressions to function as replacement surface water resources.

Intermittent reaches of streams by the mines experienced a reduction in flow during mining as baseflow was reduced through mining the bedrock aquifers. These reaches are expected to reestablish once the spoil and alluvial aquifers recover. For intermittent stream reaches the most sensitive use is aquatic life. Water quality in the stream may change with spoil saturation, but the beneficial uses of the streams, including suitability for aquatic life, are expected to be maintained. Similarly, any springs that have experienced changes in flow due to mining will recover as their source aquifers recharge. Springs that have been destroyed by mining may be replaced by new springs within reclamation. Water quality at springs sourced by spoils is expected to vary over time as spoil water quality changes.

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Table 2-1: Water quality analytes for surface and groundwater and applicable DEQ-7 standards (MDEQ, 2012) and National Secondary Drinking Water Regulations (NSDWRs).[1]

Parameter		DEQ-7 Human Health Standard	DEQ-7 Surface Water Aquatic Life Standard		NSDWR	units
			Acute	Chronic		
Physical Parameters	pH				6.5 - 8.5	s.u.
	Specific Conductance					µS/cm
	Total Dissolved Solids (TDS)				500	mg/L
	Total Suspended Solids (TSS)[2]					mg/L
	Oil & Grease[2]					mg/L
Common Ions	Total Anions					meq/L
	Total Cations					meq/L
	Acidity (total as CaCO3)					mg/L
	Alkalinity (total as CaCO3)					mg/L
	Hardness (total as CaCO3)					mg/L
	Bicarbonate as HCO3					mg/L
	Carbonate as CO3					mg/L
	Cation/anion balance					%
	Calcium					mg/L
	Chloride				250	mg/L
	Fluoride	4			2	mg/L
	Magnesium					mg/L
	Potassium					mg/L
	Sodium Absorption Ratio (SAR)					
	Sodium					mg/L
	Sulfate				250	mg/L
Trace Metals	Aluminum		0.75	0.087	0.05 - 0.2	mg/L
	Arsenic	0.01	0.34	0.15		mg/L
	Boron					mg/L
	Cadmium[3]	0.005	0.0087	0.00076		mg/L
	Copper[3]	1.3	0.052	0.030	1.0	mg/L
	Iron			1	0.3	mg/L
	Lead[3]	0.015	0.48	0.019		mg/L
	Manganese				0.05	mg/L
	Nickel[3]	0.1	1.5	0.17		mg/L
	Selenium	0.05	0.02	0.005		mg/L
	Vanadium					mg/L
	Zinc[3]	2	0.39	0.39	5	mg/L

Table 2-1: Continued.

Parameter		DEQ-7 Human Health Standard	DEQ-7 Surface Water Aquatic Life Standard		NSDWR	units
			Acute	Chronic		
Nutrients	Total Nitrogen					mg/L
	Total Phosphorus					mg/L
	Nitrate-Nitrite	10				mg/L
	Total Ammonia[4]		24.1	3.65		mg/L

[1] *NSDWRs are non-enforceable guidelines for contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.*

[2] *Analyte collected for stream and pond samples only.*

[3] *Aquatic life limits are dependent on hardness. Median hardness of surface water samples from Bull Mountains Mine and nearby drainages is > 400 mg/L so the aquatic standard is shown calculated at a hardness of 400 mg/L.*

[4] *Aquatic standards shown calculated at 22°C, 7.0 pH with early fish life stages present.*

Table 2-2: Guidelines for livestock water quality.			
Analyte	**Threshold limit (mg/L=ppm)**	**Upper limit (mg/L=ppm)**	**Comments**
Alkalinity (total as CaCO3)	Unknown	1000*	
Aluminum	5**	10**	
Arsenic	0.2**	0.2[+]	
Bicarbonate (total as CaCO3)	Unknown**	<1000	
Boron	5**	30**	
Cadmium	0.01**	0.05[+]	
Calcium	100**	150**	
Chloride	100**	300**	
Copper	0.2**	0.5[+]	
Fluoride	2**	2[+]	
Iron	---	----*	Not established, >0.3 may affect taste
Lead	0.05**	0.1[+]	
Magnesium	50**	100**	
Manganese	0.05**	0.5**	
Nickel	0.25**	1[+]	
Nitrate (NO_3 as N)	10**	20**	
Sodium	50**	300**	
Selenium	0.05**	0.10**	
Sulfate	1500*	2500*	Upper limit is upper concentration for “no harmful effects” category
Total Dissolved Solids (TDS)	3000*	4999*	“Should be satisfactory for livestock”
Vanadium	0.05*	0.1[+]	
Zinc	25**	50**/25*	

** Suitability of Water for Livestock Fact Sheet (Sigler and Bauder, 2012)*

*** Beef Briefs (Hutcheson, 2001).*

[+] *Both references have the same limit and use common references*

Table 2-3: Iowa sulfate criteria for surface water to protect macroinvertabrates uses.
Sulfate criteria is based on the concentration of chloride (Cl) and hardness (H) as $CaCO_3$ (Iowa DNR, 2009).

	Cl < 5 mg/L	5 mg/L <= Cl < 25 mg/L	25 <= Cl
H < 100 mg/L	500	500	500
100 mg/L <= H <= 500 mg/L	500	[-57.478 + 5.79*(H) + 54.163*(Cl)]*0.65	[1276.7+5.508*(H)-1.457*(Cl)]*0.65
H > 500 mg/L	500	2000	2000

Table 2-4: Beneficial uses of MT groundwater [ARM 17.30.1006].				
Montana GW Class [ARM 17.30.1006]	**Class I**	**Class II**	**Class III**	**Class IV**
EC @ 25°C (µS/cm)	<= 1000	> 1000; <= 2500	> 2500; <= 15000	> 15000
Suitability Criteria	Suitable	Marginally suitable	Marginally suitable	
Public water	x	x		
Private water	x	x		
Irrigation	x	x	salt tolerant	
Livestock water	x	x	x	
Commercial/ industrial	x	x	x	x
Food Processing	x	x	< 7000µ/cm	
Violation Prohibitions -- DEQ-7 human health standards	x	x	When EC > 7000 µS/cm & K >= 0.1, nitrate nitrogen and nitrate plus nitrite nitrogen must not exceed 50 mg/L	Only carcinogen standards apply. When K >= 0.1, nitrate nitrogen and nitrate plus nitrite nitrogen must not exceed 50 mg/L
Violation Prohibitions -- standards not in DEQ-7	No increase that renders the waters harmful, detrimental, or injurious to beneficial uses			No increase that adversely affects existing beneficial uses

Table 6-1: Private wells and groundwater rights within the groundwater CIA.

MAP ID	GWIC ID	DNRC Water Right	Site Name	Twn	Rng	Sec	Quarter Sec	Total Depth (ft)	SWL (ft below ground)	Yield (gpm)	Test	Date	Use	Potential Impact from Mining
1	94586		Bailey James N*Well 4	01S	42E	7		70	70	8	Pump	1/1/1950	Domestic	None. Completed in Rosebud Ck AL.
1	94587		Bailey James N*Well 2	01S	42E	7		135	35	8	Pump	1/1/1930	Domestic	None. Completed in SM.
1	94588		Bailey James N*Well 3	01S	42E	7		110	35	10	Other	1/1/1924	Domestic	None. Completed in SM.
1	94589		Bailey James N*Well 1	01S	42E	7		260	260	8	Pump	1/1/1924	Domestic	None. Completed in SM.
2	94568		Bailey James	01S	41E	1	DBBA	70	30	20	Other	1/1/1935	Stockwater	Water quality.
3	7024		Bailey J	01S	41E	2	AABB	81	38		Other		Stockwater	Water quality.
4	331		McRae D	01N	41E	12	CBDB	51		2	Other		Stockwater	None. Completed in AL/OB.
5	379		McRae, D.	01N	41E	26	BCAB	195	36	8	Air	9/1/1948	Stockwater	None. Completed in SM.
6	139749		McRae, Doug	01N	41E	34	D	160	120	12	Bailer	8/1/1991	Unknown	None. Completed in SM.
7	332		Hafer C.A.	01N	41E	12	D	65	54		Other		Domestic	Mined out.
8	139748		McRae Doug	01N	41E	20	AB	320			Other	8/1/1991	Unknown	None. Completed in SM.
9	256898		Ellison, Pete	01N	41E	23	A	210	50	20	Bailer	4/12/1976	Stockwater	None. Completed in SM.
10	210087		Harbuck Scott	01N	41E	24	BB	310	120	15	Bailer	12/8/2003	Domestic	None. Completed in SM.
11	165964	C103448	Davis, Boyd	01N	41E	24	BCB	426	220	14	Other	6/16/1997	Domestic	None. Completed in SM.
12	11991		N.P.R.R.	01N	41E	2	DB	141	75	14	Pump	1/1/1956	Stockwater	Mined out.
13	11992		N.P.R.R.	01N	41E	3	BB	55	45	25	Pump	6/12/1958	Stockwater	Mined out.
14	269		Snider J	01N	41E	3	CDDD	86	66	2.5	Other		Stockwater	Mined out.
15	11994		N.P.R.R.	01N	41E	3	DC	100	10	25	Pump	1/1/1925	Stockwater	Mined out.
16	12000		N.P.R.R.	01N	41E	7	DBBA	125	100	5	Other	1/1/1962	Stockwater	None. Completed in SM.
17	12003		Farleys Inc. * 02	01N	41E	8	BBDB	50		20	Other	1/1/1947	Domestic	Water quality.
18	12004		Farleys Inc. * 04	01N	41E	8	BBDD	100		15	Other	1/1/1947	Domestic	None. Completed in SM.
19	12005		Farleys Inc. * 03	01N	41E	8	CBA	50		20	Other	1/1/1947	Domestic	Water quality.
20	12006		Farleys Inc. * 05	01N	41E	8	CBAA	18		5	Other	1/1/1947	Domestic	Water quality.
21	132686	C083584-00	GNP	01N	42E	8	CDB	40		9	Bailer	5/25/1992	Stockwater	None. Completed in AL. (May intercept ash pond water).
22	203836	C30007829	Greenleaf Lands & Livestock	01N	42E	19	BD	50	25	10	Bailer	5/1/2003	Stockwater	None. Completed in AL.
23	12035		Parkins, Charles F. * Well #1	01N	42E	19	CBB	120			Other	1/1/1925	Stockwater	None. Completed in AL/SM.
24	256900		Parkins, Charles F. * Well #2	01N	42E	19	CBB	90				1/1/1925	Stockwater	None. Completed in AL/SM.
25	12036		Greenleaf Land & Livestock Co	01N	42E	19	DBBA	67	20	8	Other	10/1/1958	Stockwater	None. Completed in AL.
26	14236		McDonald, Janet	02N	41E	16	BCC	726	340		Bailer	3/26/1981	Unknown	None. Completed in SM.
27	1075		MacDonald D	02N	41E	17	ADAA			6.7	Other		Other	Completion unknown. Likely AL at mouth of Stocker Ck.
28	14237	C006283-00	Childers, Pat & Mike	02N	41E	21		380	190	10	Bailer	9/6/1981	Unknown	None. Completed in SM.
29	14239		Colstrip Church of Christ	02N	41E	21		810	360	15	Bailer	2/23/1985	Domestic	None. Completed in SM.
30	144690		Pontues, Don	02N	41E	21		415	120	5	Air	8/18/1992	Domestic	None. Completed in SM.
30	199242		Don Pontius Construction Well 1	02N	41E	21		130	34	20	Air	2/22/2002	Domestic	None. Completed in SM.
30	199243		Don Pontius Construction Well 2	02N	41E	21		130	34	20	Air	2/22/2002	Domestic	None. Completed in SM.
31	14240		Penn, Bill	02N	41E	21		800	360	8	Bailer	11/20/1984	Domestic	None. Completed in SM.
32	268380		Burton, Brent	02N	41E	21	BB	100	70	20	Bailer	9/28/2012	Domestic	None. Completed in SM.
33	242581		Burton Brent	02N	41E	21	BD	60	36	30	Air	4/23/2008	Domestic	None. Completed in SM.

Table 6-1: Continued.

MAP ID	GWIC ID	DNRC Water Right	Site Name	Twn	Rng	Sec	Quarter Sec	Total Depth (ft)	SWL (ft below ground)	Yield (gpm)	Test	Date	Use	Potential Impact from Mining
34	14241	C018630-00	Childers, Pat	02N	41E	21	CA	220	50	6	Bailer	4/7/1978	Domestic	None. Completed in SM.
35	203270		Aberle, Joe * PW-709	02N	41E	21	CACD	320	80	25	Other	1/1/1978	Domestic	None. Completed in SM.
36	1077		Seward I.	02N	41E	21	CADA	122	35	20	Other		PWS	
37	14243		MT Dept. of Highway	02N	41E	21	CD	208	50	6	Pump	9/20/1978	Domestic	None. Completed in SM.
38	186072		State of Montana	02N	41E	21	CD	208		6	Pump	9/20/1978	Domestic	None. Completed in SM.
39	154780	C096586-00	Childers, Mike	02N	41E	21	CDA	320	157	10	Air	8/8/1994	Domestic	None. Completed in SM.
40	271909		PPL Services Corp. * PW704	02N	41E	21	CD	194	44			10/15/2012	Domestic	None. Completed in SM.
41	14244		Beck, Allen	02N	41E	21	D	180	70	20	Bailer	3/27/1980	Domestic	None. Completed in SM.
42	14245		Seward, Ivan	02N	41E	21	DBCB	140	70	9	Bailer	11/30/1974	Domestic	None. Completed in SM.
43	122395		B & R Bar	02N	41E	21	DBC	260	120	20	Bailer	9/14/1984	Stockwater	None. Completed in SM.
44	172113	C108793-00	Moose Lodge* PW-717	02N	41E	21	DC	420	45	1	Air	9/29/1998	Domestic	None. Abandoned.
45	14247	C056661-00	Alder, Eugene	02N	41E	21	DCB	180	105	10	Bailer	10/22/1984	Irrigation	None. Completed in SM.
46	14248		Snider, James	02N	41E	22	BAA	68	57	20	Pump	1/1/1929	Stockwater	None. Completed in SM.
47	14249		NPRR	02N	41E	26	AA	135	50	2.5	Pump	1/1/1960	Stockwater	Mined out.
48	14252		MacDonald, Duncan	02N	41E	30	DADD			11	Other	1/1/1959	Stockwater	Completed in AL. Well in permit area. Not in use.
49	1095		MacDonald	02N	41E	30	DDAA			11	Other		Stockwater	Completed in AL. Well in permit area. Not in use.
50	192519		Anderson, Joe and Marlene	02N	41E	31	BB	150	74.3	15	Air	6/5/2001	Domestic	None. Completed in SM.
51	14254	C005632-00	Frontier Village	02N	41E	33	AA	175	40	4	Bailer	11/25/1973	Domestic	None. Completed in SM.
52	182889		BNSF * Colstrip #1	02N	41E	34		1,520		27	Pump	4/1/1926		None. Completed in SM.
53	182891		BNSF * Colstrip #2	02N	41E	34		595.5	203	35	Pump	8/30/1936	PWS	None. Completed in SM.
54	182890		BNSF * Colstrip #3	02N	41E	34		518.5		35	Pump	1/15/1943	PWS	None. Completed in SM.
55	14255	C025025-00	Montana Frontier	02N	41E	33	AA	460	200	20	Other	10/18/1979	Domestic	None. Completed in SM.
56	14218		MacDonald, Lena F	02N	40E	24	C	80		10	Pump	9/10/1947		None. Completed in SM.
57	14219		MacDonald, Lena F	02N	40E	24	D	30	22		Other	1/1/1911	Stockwater	None. Completed in AL. (No AL impact to Stocker Ck.)
58	14220		MacDonald, Lena F	02N	40E	24	D	85	60	15	Other	11/6/1946	Domestic	None. Completed in SM.
59	1063		Lovelace c/o Hendriks	02N	40E	28	AADD	146	75.7	1	Other		Stockwater	None. Completed in SM.
60	205525	C30011414	Salmond Ranch Co	02N	40E	28	AD	293	205	12	Bailer	7/30/2003	Stockwater	None. Completed in SM.
61	1064		Lovelace c/o Hendriks	02N	40E	29	CCDC		-0.78	6	Other		Stockwater	None. Completion unknown. Likely AL/OB or SM.
62	1065		Fulmer, Genie / Dowlin, Mary	02N	40E	30	BAAA	246	49	12	Other	2/28/1956	Stockwater	None. Completed in SM.
63	263490		Western Energy Co.	02N	40E	31	DC	155	105	10	Bailer	10/25/2011	Stockwater	None. Completed in SM.
64	1067		Hinrichs W.	02N	40E	32	BBAB				Other		Domestic	Completion unknown. Well in permit area. Not in use.
65	14225		Round-Up Powder Co	02N	40E	35	CCA	355	315	4	Bailer	5/21/1986	Domestic	None. Completed in SM.
66	1068		Fadhl George	02N	40E	35	DD	252	75	10	Other	1/1/1959	Stockwater	None. Completed in SM.
67	14226		N.P.R.R. & Fadhl G.	02N	40E	35	DDCD	252	146	2	Other	4/12/1959	Stockwater	None. Completed in SM.
68	145092		State Lands	02N	40E	36	CC	100	14	22	Air	11/19/1992	Stockwater	None. Completed in SM.
69	1052		Fulmer, Genie / Dowlin, Mary	02N	39E	23	CC	100	45		Other		Stockwater	None. Completed in SM.
70	14193		Farley Inc.	02N	39E	24	BD	90	50	10	Pump	11/22/1974	Domestic	None. Completed in SM.
71	1053		Fulmer, Genie / Dowlin, Mary	02N	39E	24	CDAB	140	50	15	Other		Stockwater	None. Completed in SM.

Table 6-1: Continued.

MAP ID	GWIC ID	DNRC Water Right	Site Name	Twn	Rng	Sec	Quarter Sec	Total Depth (ft)	SWL (ft below ground)	Yield (gpm)	Test	Date	Use	Potential Impact from Mining
72	14195		Fulmer, Genie / Dowlin, Mary	02N	39E	24	DDC	46	32	15	Other	2/6/1959	Stockwater	None. Completed in AL.
73	1054		Snider D	02N	39E	25	ACDC	136	58	3.5	Other	6/12/1964	Stockwater	None. Completed in SM.
74	14197		Pinkerton, Bill	02N	39E	27		156	89	5	Other	1/1/1967	Stockwater	None. Completed in SM.
75	1056		Sloan Stanley	02N	39E	32	DDDD	136			Other		Stockwater	Drawdown 10’-20’. Abandonment anticipated by WECo.
76	250616		N49.5W 6000	01N	39E	3	AB	320				11/3/1983	Unknown	Completed in SM. Will be removed by mining.
77	11947		Pinkerton, Bill E.	01N	39E	4	AABC	83	60	7	Other	5/1/1957	Stockwater	Drawdown 10’-20’.
78	11979		Farley's Inc.	01N	40E	12	BDB	150	20	20	Other	1/1/1914	Stockwater	None. Completed in SM.
79	204		Farley B	01N	40E	12	CBAA	40	9		Other		Stockwater	Water quality. Completed in AL.
80	11980		Farley's Inc.	01N	40E	12	CBBA	100	20	20	Other	1/1/1950	Stockwater	None. Completed in SM.
81	136771	C085507-00	County of Rosebud	01N	40E	12	DBB	141	70	20	Air	5/14/1993	Domestic	None. Completed in SM.
82	11982		Farleys, Inc.	01N	40E	17	BB	145	70	20	Pump	2/9/1984	Stockwater	Drawdown 20’ if completed in RC.
83	128355	C080635-00	Eernisse, Gary	01N	40E	18		120	64	8	Air	5/14/1992	Domestic	Drawdown 10’-20’ if completed in RC.
84	11983		Farleys Inc.	01N	40E	18	ABBD	20		20	Other	1/1/1930	Domestic	None. Completed in AL.
85	11984		Farleys Inc.	01N	40E	18	ABCD	20		20	Other	1/1/1963	Domestic	None. Completed in AL.
86	11985		Farleys Inc.	01N	40E	18	BAAD	225		80	Other	1/1/1930	Domestic	Drawdown 5’-10’.
87	11986		Farleys Inc.	01N	40E	18	CC	110	60	15	Bailer	2/9/1984	Stockwater	Drawdown 5’-10’.
88	11987	C068082-00	Rhodes, Ronald & Michele	01N	40E	18	DC	300	220	12	Bailer	4/7/1988	Domestic	None. Completed in SM.
89	11988		Farleys Inc.	01N	40E	18	DDCB	225		20	Other	1/1/1963	Domestic	Drawdown 5’-10’.
90	212086		Ashenhurst Ranch Inc.	01N	40E	22	AA	480	340	8	Bailer	5/18/2004	Stockwater	None. Completed in SM.
91	11989		NPRR	01N	40E	23	BD	100	30	6	Other	1/1/1957	Stockwater	None. Completed in OB/AL.
92	212090		Ashenhurst Ranch Inc.	01N	40E	28	AD	65	42	15	Bailer	5/18/2004	Stockwater	None. Completed in OB/AL.
93	229		Farley's Inc.	01N	40E	29	ACBB	232	80	5	Other	1/1/1960	Stockwater	None. Outside drawdown. May be completed in SM.
94	231		L. Farley Sec. 35 Windmill	01N	40E	35	DBBC	30	23.1	3	Other		Stockwater	None. Completed in OB/AL.
95	262532		Fulmer, Genie Philbrick	02N	42E	20	CDB					1/1/1963	Stockwater	None. Outside drawdown. Completed in OB/AL.
96	14223		NPRR	02N	40E	33	AD	140	100	8	Other	1/1/1957	Stockwater	None. Completed in SM.

Blank fields represent lack of information in GWIC.

AL – Alluvium
MK – McKay coal
OB - Overburden
PWS – Public water supply
RC – Rosebud coal
SM – sub-McKay

Table 6-2: Active surface water rights listed with the Montana Department of Natural Resources and Conservation near the Rosebud Mine.
The max flow and max volume in the table refer to the maximum amount of water that can be used by the owner at any one time and in total for the year respectively.

Map ID	Water Right Number	Mine or PPL ID	Purpose	Priority Date	Means of Diversion	Name	Max Flow	Max Vol. (ac-ft)	Site Name / Description	Anticipated Impact from Mining
1	42A 108272 00		Stock	1908	Direct from source	Great Northern Properties Ltd Prtnrshp			Spring, Tributary Of Cow Creek	Quantity may be reduced due to aquifer drawdown from mining. Quality may be impacted if aquifer replaced by spoils.
2	42A 108275 00		Stock	1948	Dam	WPP LLC			Tributary Of Lee Coulee	None. Site is upstream of mine disturbance
3	42A 108297 00		Stock	1968	Dam	Avista Corporation; Northwestern Energy; Pacificorp; Portland General Electric Co; PPL Montana LLC; Puget Sound Energy Inc			Tributary Of Cow Creek	Watershed disrupted by prelaw mining reclamation, roads, and a railroad embankment upstream of dam.
4	42A 108300 00	PO-808	Stock	1939	Dam	Great Northern Properties Ltd Prtnrshp			Tributary Of Spring Creek	Site downstream from Area D mining. May have reduced water quantity until sediment ponds are removed.
5	42A 108302 00	BLDGL	Stock	1948	Dam	WPP LLC			Lee Coulee	Water quantity greatly reduced during mining. May permanently have some reduction in quantity due to flatter topography in watershed.
6	42A 108303 00		Stock	1968	Dam	Great Northern Properties Ltd Prtnrshp			Miller Coulee	Water quantity reduced during mining due to upstream sediment ponds.
7	42A 108308 00	PO-912	Stock	1943	Dam	Avista Corporation; Northwestern Energy; Pacificorp; Portland General Electric Co; PPL Montana Llc; Puget Sound Energy Inc			Cow Creek, South Fork	Watershed disrupted by prelaw mining reclamation and a railroad embankment upstream of dam.
8	42A 141170 00		Irrigation	1959	Pump	Rocker Six Cattle Co	30 gpm		Rosebud Creek	None. Fed by large watershed.
9	42A 145437 00	BUFGL	Stock	1941	Dam	Ashenhurst Gene T; Ashenhurst Ranch Inc			Tributary Of Lee Coulee	None. Site is upstream of mine disturbance
10	42A 145440 00	PO-986	Stock	1942	Dam	Ashenhurst Gene T; Ashenhurst Ranch Inc			Lee Coulee	Small amount of mine disturbance along drainage divide. Impact should be small.
11	42A 171897 00		Stock	1942	Dam	Genie Land Co			Tributary Of Pony Creek	None. No disturbance in watershed
12	42A 171898 00		Irrigation	1885	Headgate	Genie Land Co	10.8 cfs		Rosebud Creek	None. Fed by large watershed.
13	42A 171903 00		Stock	1940	Dam	Garfield Family Lp			Tributary Of West Snider Creek	None. No disturbance in watershed
14	42A 171913 00		Stock	1942	Dam	Garfield Family Lp			Tributary Of West Snider Creek	None. No disturbance in watershed
15	42A 171914 00		Stock	1957	Dam	Garfield Family Lp			Tributary Of Pony Creek	None. No disturbance in watershed
16	42A 171921 00		Stock	1940	Dam	Garfield Family Lp			Tributary Of Pony Creek	None. No disturbance in watershed
17	42A 171922 00		Stock	1940	Dam	Garfield Family Lp			Tributary Of Rosebud Creek	None. No disturbance in watershed
18	42A 171931 00		Stock	1941	Dam	Garfield Family Lp			Tributary Of Pony Creek	None. No disturbance in watershed
19	42A 171937 00		Irrigation	1890	Headgate	Garfield Family Lp	4.13 cfs		Rosebud Creek	None. Fed by large watershed.
20	42A 171938 00		Irrigation	1886	Headgate	Garfield Family Lp	9.65 cfs		Rosebud Creek	None. Fed by large watershed.
21	42A 172075 00		Stock	1930	Dam	Bailey Connie G; Bailey Donald P			Tributary Of Lee Coulee	None. Site is upstream of mine disturbance
22	42A 172076 00		Stock	1940	Dam	Bailey Connie G; Bailey Donald P			Tributary Of Lee Coulee	None. No disturbance in watershed
23	42A 172078 00		Stock	1943	Dam	Bailey Connie G; Bailey Donald P			Lee Coulee	Water quantity reduced during mining due to upstream sediment ponds.
24	42A 172083 00		Irrigation	1910	Pump	Curran Helen E, Curran Joe W	2.95 cfs		Rosebud Creek	None. Fed by large watershed.
25	42A 172087 00		Stock	1896	Direct from source	Curran Helen E, Curran Joe W			Rosebud Creek	None. Fed by large watershed.
26	42A 172093 00	GSP2	Stock	1926	Direct from source	Genie Land Co			Spring, Tributary Of Cow Creek	None. No drawdown expected at this site.
27	42A 172095 00		Stock	1947	Dam	Genie Land Co			Tributary Of Spring Creek	None. No disturbance in watershed

Table 6-2: Continued.

Map ID	Water Right Number	Mine or PPL ID	Purpose	Priority Date	Means of Diversion	Name	Max Flow	Max Vol. (ac-ft)	Site Name / Description	Anticipated Impact from Mining
28	42A 172098 00		Stock	1945	Direct from source	Genie Land Co			Spring, Tributary Of Cow Creek	None. No disturbance in watershed
29	42A 172099 00		Stock	1945	Dam	Genie Land Co			Tributary Of Cow Creek	None. No disturbance in watershed
30	42A 172100 00	GSP1	Stock	1905	Direct from source	Genie Land Co			Spring, Tributary Of Cow Creek	None. No drawdown expected at this site.
31	42A 172107 00		Stock	1942	Dam	Genie Land Co			Tributary Of Pony Creek	None. No disturbance in watershed
32	42A 172109 00		Irrigation	1912	Dam	Garfield Family Lp		75	Pony Creek	Small amount of mine disturbance compared to basin size along drainage divide. Impact should be small.
33	42A 173134 00		Irrigation	1895	Dike	Brawley Loretta J, Rash Dennis		100	Rosebud Creek	None. Fed by large watershed.
34	42A 173135 00		Irrigation	1945	Headgate	Brawley Loretta J, Rash Dennis	386 gpm		Tributary Of Rosebud Creek	None. No disturbance in watershed
35	42A 173230 00		Irrigation	1914	Ditch	Bailey Connie G; Bailey Donald P	1.36 cfs		Lee Coulee	Water quantity reduced during mining due to upstream sediment ponds.
36	42A 173233 00		Lawn and garden	1901	Dike	Bailey Connie G; Bailey Donald P	1.95 gpm	12	Lee Coulee	Water quantity reduced during mining due to upstream sediment ponds.
37	42A 173234 00		Irrigation	1901	Dike	Bailey Connie G; Bailey Donald P		134	Lee Coulee	Water quantity reduced during mining due to upstream sediment ponds.
38	42A 173917 00		Stock	1947	Dam	Rocker Six Cattle Co			Hay Coulee	Small amount of mine disturbance along drainage divide. Impact should be negligible.
39	42A 173929 00		Lawn and garden	1959	Pump	Rocker Six Cattle Co	25 gpm	5	Rosebud Creek	None. Fed by large watershed.
40	42A 173937 00	SP-18	Stock	1932	Direct from source	Avista Corporation; Northwestern Energy; Pacificorp; Portland General Electric Co; PPL Montana LLC; Puget Sound Energy Inc			Spring, Tributary Of Cow Creek	Quantity may be reduced due to aquifer drawdown from mining. Quality may be impacted if aquifer replaced by spoils.
41	42A 173938 00		Stock	1932	Direct from source	Avista Corporation; Colstrip Comm Serv LLC; Northwestern Energy; Pacificorp; Portland General Electric Co; Puget Sound Energy Inc			Spring, Tributary Of Cow Creek	Quantity may be reduced due to aquifer drawdown from mining. Quality may be impacted if aquifer replaced by spoils.
42	42A 173943 00		Stock	1932	Dam	Avista Corporation; Colstrip Comm Serv LLC Northwestern Energy; Pacificorp; Portland General Electric Co; Puget Sound Energy Inc			Tributary Of Cow Creek	Site likely fed by upstream spring. May see reduced water quantity during mining if upstream spring is impacted by drawdown.
43	42A 173944 00	SP-14	Stock	1956	Dam	Avista Corporation; Northwestern Energy; Pacificorp; Portland General Electric Co; PPL Montana LLC; Puget Sound Energy Inc			Tributary Of Cow Creek	None. No disturbance in watershed
44	42A 173945 00	PO-987	Stock	1941	Dam	Avista Corporation; Northwestern Energy; Pacificorp; Portland General Electric Co; PPL Montana LLC; Puget Sound Energy Inc			Tributary Of Cow Creek	None. No disturbance in watershed
45	42A 173946 00	CC-4	Stock	1932	Direct from source	Avista Corporation; Northwestern Energy; Pacificorp; Portland General Electric Co; PPL Montana LLC; Puget Sound Energy Inc			Spring, Tributary Of Cow Creek	Water quantity may be reduced during mining due to upstream sediment ponds.
46	42A 173947 00		Stock	1946	Dam	Avista Corporation; Northwestern Energy; Pacificorp; Portland General Electric Co; PPL Montana LLC Puget Sound Energy Inc			Tributary Of Cow Creek	Water quantity may be reduced during mining due to upstream sediment ponds.
47	42A 173948 00		Irrigation	1957	Dike	Avista Corporation; Northwestern Energy; Pacificorp; Portland General Electric Co; PPL Montana LLC; Puget Sound Energy Inc			Cow Creek	Watershed disrupted by prelaw mining reclamation, roads, and a railroad embankment upstream of dam.
48	42A 174330 00		Stock	1936	Direct from source	Snider James W			Rosebud Creek	None. Fed by large watershed.

Table 6-2: Continued.

Map ID	Water Right Number	Mine or PPL ID	Purpose	Priority Date	Means of Diversion	Name	Max Flow	Max Vol. (ac-ft)	Site Name / Description	Anticipated Impact from Mining
49	42A 174379 00		Irrigation	1917	Dam	Egan Ranch Inc, Snider James W	3.79 cfs		Rosebud Creek	None. Fed by large watershed.
50	42A 182525 00		Irrigation	1906	Headgate	Cornwell Land & Livestock Co	6.82 cfs		Rosebud Creek	None. Fed by large watershed.
51	42A 182536 00		Stock	1965	Dam	Cornwell Land & Livestock Co			Tributary Of Spring Creek	None. No disturbance in watershed
52	42A 182537 00		Stock	1965	Dam	Cornwell Land & Livestock Co			Tributary Of Rosebud Creek	None. No disturbance in watershed
53	42A 182541 00		Stock	1896	Direct from source	Cornwell Land & Livestock Co			Rosebud Creek	None. Fed by large watershed.
54	42A 182542 00		Stock	1944	Dam	Cornwell Land & Livestock Co			Tributary Of Spring Creek	None. No disturbance in watershed
55	42A 19456 00		Stock	1965	Direct from source	Snider James W			Spring, Tributary Of Emile Coulee	Quantity may be reduced due to aquifer drawdown from mining. Quality may be impacted if aquifer replaced by spoils.
56	42A 30017749		Fishery	1978	Instream	Montana, State Of Dept Of Fish Wildlife & Parks		11837	Rosebud Creek	None. Fed by large watershed.
57	42A 3035 00		Stock	1965	Pit	Valdez, Roy & Beverly Trust			Tributary Of Spring Creek	None. No disturbance in watershed
58	42A 34885 00		Stock	1961	Direct from source	Montana, State Of Board Of Land Commissioners			Spring, Tributary Of Cow Creek	Quantity may be reduced due to aquifer drawdown from mining. Quality may be impacted if aquifer replaced by spoils.
59	42A 37960 00		Irrigation	1890	Headgate	Greenleaf Land And Livestock Co	4.2 cfs		Rosebud Creek	None. Fed by large watershed.
60	42A 37962 00		Irrigation	1887	Headgate	Greenleaf Land And Livestock Co	3.94 cfs		Rosebud Creek	None. Fed by large watershed.
61	42A 37970 00		Stock	1948	Dam	Greenleaf Land And Livestock Co			Tributary Of Rosebud Creek	None. No disturbance in watershed
62	42A 37984 00		Stock	1938	Dam	Greenleaf Land And Livestock Co			Tributary Of Rosebud Creek	None. No disturbance in watershed
63	42A 37985 00		Stock	1938	Dam	Greenleaf Land And Livestock Co			Miller Coulee	Water quantity reduced during mining due to upstream sediment ponds.
64	42A 37986 00		Stock	1938	Dam	Greenleaf Land And Livestock Co			Tributary Of Miller Coulee	None. No disturbance in watershed
65	42A 37988 00		Stock	1883	Direct from source	Greenleaf Land And Livestock Co			Miller Coulee	Water quantity reduced during mining due to upstream sediment ponds.
66	42A 37989 00		Stock	1883	Direct from source	Greenleaf Land And Livestock Co			Hay Coulee	Small amount of mine disturbance along drainage divide. Impact should be negligible.
67	42A 37990 00		Stock	1883	Direct from source	Greenleaf Land And Livestock Co			Dobbs Coulee	None. No disturbance in watershed
68	42A 37991 00		Stock	1938	Dam	Greenleaf Land And Livestock Co			Tributary Of Miller Coulee	None. No disturbance in watershed
69	42A 37992 00		Stock	1938	Dam	Greenleaf Land And Livestock Co			Miller Coulee	Water quantity reduced during mining due to upstream sediment ponds.
70	42A 37993 00		Stock	1938	Dam	Greenleaf Land And Livestock Co			Tributary Of Rosebud Creek	None. No disturbance in watershed
71	42A 37994 00		Stock	1938	Dam	Greenleaf Land And Livestock Co			Tributary Of Hay Coulee	Small amount of mine disturbance along drainage divide. Impact should be negligible.
72	42A 37995 00		Stock	1938	Dam	Greenleaf Land And Livestock Co			Tributary Of Miller Coulee	None. No disturbance in watershed
73	42A 37996 00		Stock	1938	Dam	Greenleaf Land And Livestock Co			Tributary Of Hay Coulee	Small amount of mine disturbance along drainage divide. Impact should be negligible.
74, 75	42A 37997 00		Stock	1883	Direct from source	Greenleaf Land And Livestock Co			Rosebud Creek	None. Fed by large watershed.
76	42A 41425 00		Stock	1951	Direct from source	Hanna, Joseph W Trust			Spring, Tributary Of Rosebud Creek	None. No disturbance in watershed
77	42A 41426 00		Irrigation	1958	Pump	Hanna, Joseph W Trust	45 gpm		Rosebud Creek	None. Fed by large watershed.
78	42A 45710 00		Irrigation	1890	Headgate	Greenleaf Land And Livestock Co	1.82 cfs		Rosebud Creek	None. Fed by large watershed.

Table 6-2: Continued.

Map ID	Water Right Number	Mine or PPL ID	Purpose	Priority Date	Means of Diversion	Name	Max Flow	Max Vol. (ac-ft)	Site Name / Description	Anticipated Impact from Mining
79	42A 48018 00		Stock	1940	Dam	Montana, State Of Board Of Land Commissioners			Tributary Of Miller Coulee	None. No disturbance in watershed
80	42A 5964 00	ACG80-1	Stock; flood control	1975	Dam	WPP LLC		32	Emile Coulee	Water quantity reduced during mining due to upstream sediment ponds.
81	42A 5965 00		Stock; flood control	1975	Dam	Glacier Park Co		21	Emile Coulee	Water quantity reduced during mining due to upstream sediment ponds.
82	42A 5966 00		Stock; flood control	1975	Dam	Great Northern Properties Ltd Prtnrshp; WPP LLC		2	Emile Coulee	Water quantity reduced during mining due to upstream sediment ponds.
83	42A 5967 00		Stock; flood control; irrigation	1975	Pit	Great Northern Properties Ltd Prtnrshp; WPP LLC	0.44 cfs	6	Miller Coulee	None. Site upstream of mine disturbance.
84	42A 8206 00		Stock	1940	Direct from source	Montana, State Of Board Of Land Commissioners			Spring, Tributary Of Lee Coulee	None. Spring above coal mine layers that were mined.
85	42A 8207 00	BGDSG	Stock	1940	Dam	Montana, State Of Board Of Land Commissioners			Tributary Of Lee Coulee	None. Site upstream of mine disturbance.
86	42A 8434 00		Stock	1976	Dam	Valdez, Roy & Beverly Trust		7	Tributary Of Spring Creek	None. No disturbance in watershed
87	42KJ 101376 00	SW-73	Irrigation	1997	Headgate	Colstrip Parks And Recreation District		20	Tributary Of Tributary Of EFAC	Water quantity reduced during mining due to upstream sediment ponds.
88	42A 172106 00	SP-25	Stock	1905	Developed Spring	Genie Land Co	7 gpm		Spring, Tributary of Pony Creek	None. No drawdown expected at this site.
89	42A 172103 00		Stock	1905	Developed Spring	Genie Land Co	5 gpm		Spring, Tributary of Pony Creek	None. No drawdown expected at this site.
90	42KJ 106453 00		Stock	1968	Dam	Great Northern Properties Ltd Prtnrshp			Tributary Of Tributary Of WFAC	None. No disturbance in watershed
91	42KJ 106457 00	PO-930	Stock	1944	Dam	Great Northern Properties Ltd Prtnrshp			Tributary Of Stocker Creek	Water quantity reduced during mining due to upstream sediment ponds.
92	42KJ 106459 00	PO-924	Stock	1968	Dam	Great Northern Properties Ltd Prtnrshp			Tributary Of Stocker Creek	Water quantity reduced during mining due to upstream sediment ponds.
93	42KJ 106461 00	PO-925	Stock	1968	Dam	Great Northern Properties Ltd Prtnrshp			Tributary Of Stocker Creek	Water quantity reduced during mining due to upstream sediment ponds.
94	42A 171920 00		Stock	1905	Dam	Garfield Family Lp			West Snider Creek	None. No disturbance in watershed
95	42KJ 108276 00	PO-940	Stock	1968	Dam	WPP LLC			Tributary Of Tributary Of WFAC	Water quantity may be reduced during mining due to upstream sediment ponds.
96	42KJ 108277 00	PO-928	Stock	1968	Dam	Great Northern Properties Ltd Prtnrshp			Tributary Of Stocker Creek	None. No disturbance in watershed
97	42A 172094 00	PO-917	Stock	1905	Dam	Genie Land Co			Pony Creek	Water quantity greatly reduced during mining. May permanently have some reduction in quantity due to flatter topography in watershed.
98	42KJ 108292 00	SP-09	Stock	1908	Direct from source	Great Northern Properties Ltd Prtnrshp			Spring, Tributary Of Stocker Creek	None. No drawdown expected at this site.
99	42KJ 108293 00		Stock	1941	Dam	Great Northern Properties Ltd Prtnrshp			Tributary Of Stocker Creek	None. No disturbance in watershed
100	42KJ 108294 00	PO-989	Stock	1968	Dam	Great Northern Properties Ltd Prtnrshp			Tributary Of Tributary Of EFAC	Water quantity may be reduced during mining due to upstream sediment ponds.
101	42KJ 108351 00	SP-76	Stock	1911	Direct from source	WPP LLC			Spring, Tributary Of Tributary Of WFAC	Quantity may be reduced due to aquifer drawdown from mining. Quality may be impacted if aquifer replaced by spoils.
102	42KJ 108365 00		Stock	1911	Direct from source	Great Northern Properties Ltd Prtnrshp			Spring, Tributary Of Tributary Of WFAC	None. No drawdown expected at this site.

Table 6-2: Continued.

Map ID	Water Right Number	Mine or PPL ID	Purpose	Priority Date	Means of Diversion	Name	Max Flow	Max Vol. (ac-ft)	Site Name / Description	Anticipated Impact from Mining
103	42KJ 108369 00	PO-971	Stock	1968	Dam	Great Northern Properties Ltd Prtnrshp			WFAC	Water quantity may be reduced during mining due to upstream sediment ponds.
104	42KJ 108370 00	PO-947	Stock	1968	Dam	Great Northern Properties Ltd Prtnrshp			Tributary Of Tributary Of WFAC	None. No disturbance in watershed
105	42KJ 108383 00		Stock	1911	Direct from source	WPP LLC			Spring, Tributary Of Black Hank Creek	Quantity may be reduced due to aquifer drawdown from mining. Quality may be impacted if aquifer replaced by spoils.
106	42KJ 108399 00		Stock	1911	Direct from source	Great Northern Properties Ltd Prtnrshp			Spring, Tributary Of Tributary Of WFAC	None. No drawdown expected at this site.
107	42KJ 108401 00		Stock	1968	Dam	WPP LLC			Tributary Of Tributary Of WFAC	Water quantity greatly reduced during mining. May permanently have some reduction in quantity due to flatter topography in watershed.
108	42KJ 111926 00	SP-61	Stock	1908	Direct from source	Howard Family Trust; Howard Richard			Spring, Tributary Of Tributary Of WFAC	None. No drawdown expected at this site.
109	42KJ 129204 00		Stock	1889	Direct from source	Montana, State Of Board Of Land Commissioners			Spring, Tributary Of Stocker Creek	None. No drawdown expected at this site.
110	42KJ 129206 00		Stock	1889	Direct from source	Montana, State Of Board Of Land Commissioners			Spring, Tributary Of Stocker Creek	None. No drawdown expected at this site.
111	42A 108299 00	SP-22	Stock	1908	Direct from source	Great Northern Properties Ltd Prtnrshp			Spring, Tributary of Spring Creek	Quantity may be reduced due to aquifer drawdown from mining. Quality may be impacted if aquifer replaced by spoils.
112	42KJ 135868 00		Stock	1946	Direct from source	Montana, State Of Board Of Land Commissioners			EFAC	Water quantity may be reduced during mining due to upstream sediment ponds.
113	42KJ 142732 00	PO-954	Commercial	1931	Dam	WPP LLC			Tributary Of Tributary Of EFAC	Water quantity may be reduced during mining due to upstream sediment ponds
115	42KJ 162801 00	PO-916	Stock	1935	Dam	Booth Land & Livestock Co			Tributary Of Stocker Creek	Water quantity may be reduced during mining due to upstream sediment ponds
116	42KJ 162803 00		Stock	1920	Direct from source	Booth Land & Livestock Co			Stocker Creek	Water quantity may be reduced during mining due to upstream sediment ponds
117	42KJ 162818 00		Stock	1935	Dam	Booth Land & Livestock Co			Tributary Of Stocker Creek	None. No disturbance in watershed
118	42KJ 162829 00		Stock	1939	Dam	Booth Land & Livestock Co			Tributary Of Stocker Creek	Water quantity may be reduced during mining due to upstream sediment ponds
119	42KJ 162837 00	PO-926	Stock	1942	Dam	Booth Land & Livestock Co			Tributary Of Stocker Creek	None. No disturbance in watershed
120	42KJ 162841 00		Stock	1936	Dam	Booth Land & Livestock Co			Tributary Of Stocker Creek	None. No disturbance in watershed
121	42KJ 162843 00		Stock	1937	Dam	Booth Land & Livestock Co			Tributary Of Stocker Creek	None. No disturbance in watershed
122	42KJ 162847 00	PO-932	Stock	1940	Dam	Great Northern Properties Ltd Prtnrshp			Tributary Of Stocker Creek	None. No disturbance in watershed
138	42KJ 177099 00		Stock	1920	Direct from source	Kl Ranch LLC			Spring, Tributary Of Tributary Of WFAC	Quantity may be reduced due to aquifer drawdown from mining. Quality may be impacted if aquifer replaced by spoils.
139	42KJ 177103 00		Stock	1909	Direct from source	Kl Ranch LLC			Spring, WFAC	None. No drawdown expected at this site.
147	42KJ 182563 00		Stock	1902	Direct from source	Circle R River Ranch LLC			Spring, Tributary Of Tributary Of EFAC	None. Site is upstream of mine disturbance
148	42KJ 183242 00		Stock	1921	Direct from source	Booth Bros Land & Livestock			Spring, Tributary Of Tributary Of WFAC	None. Site is upstream of mine disturbance
149	42KJ 183265 00		Stock	1921	Direct from source	Booth Bros Land & Livestock			Tributary Of Tributary Of EFAC	None. Site is upstream of mine disturbance
150	42KJ 183266 00		Stock	1913	Direct from source	Booth Bros Land & Livestock			Tributary Of Tributary Of EFAC	None. Site is upstream of mine disturbance
151	42KJ 183298 00		Stock	1948	Dam	Booth Bros Land & Livestock			WFAC	None. Site is upstream of mine disturbance

Table 6-2: Continued.

Map ID	Water Right Number	Mine or PPL ID	Purpose	Priority Date	Means of Diversion	Name	Max Flow	Max Vol. (ac-ft)	Site Name / Description	Anticipated Impact from Mining
152	42KJ 183302 00		Stock	1946	Dam	Booth Bros Land & Livestock			EFAC	None. Site is upstream of mine disturbance
153	42KJ 183304 00		Stock	1954	Dam	Booth Bros Land & Livestock			EFAC	None. Site is upstream of mine disturbance
154	42KJ 183305 00	PO-949	Stock	1954	Dam	Booth Bros Land & Livestock			Tributary Of Tributary Of EFAC	None. Site is upstream of mine disturbance
155	42KJ 183313 00		Stock	1952	Dam	Booth Bros Land & Livestock			Tributary Of Tributary Of EFAC	None. Site is upstream of mine disturbance
156	42KJ 183314 00		Stock	1919	Direct from source	Booth Bros Land & Livestock			Spring, Tributary Of Tributary Of EFAC	None. Site is upstream of mine disturbance
157	42KJ 183325 00		Stock	1936	Dam	Booth Bros Land & Livestock			Tributary Of Tributary Of EFAC	Water quantity greatly reduced during mining. May permanently have some reduction in quantity due to flatter topography in watershed.
158	42KJ 183326 00	SW-26; SW-30; EFAC-9	Stock	1918	Direct from source	Booth Land & Livestock Co; Farleys Inc			EFAC	Water quantity may be reduced during mining due to upstream sediment ponds. Postmine baseflow water quality could be impacted by spoil water.
159	42KJ 183335 00		Stock	1940	Dam	Booth Bros Land & Livestock			Tributary Of Tributary Of EFAC	None. Site is upstream of mine disturbance
160	42KJ 183341 00		Stock	1961	Direct from source	Booth Bros Land & Livestock			Spring, Tributary Of Tributary Of EFAC	None. Site is upstream of mine disturbance
161	42KJ 183342 00	PO-937	Stock	1936	Dam	Booth Bros Land & Livestock			EFAC	None. Site is upstream of mine disturbance
162	42KJ 183346 00		Stock	1950	Dam	Booth Bros Land & Livestock			Tributary Of Tributary Of EFAC	None. No disturbance in watershed
163	42KJ 183349 00		Stock	1913	Direct from source	Booth Bros Land & Livestock			Spring, Tributary Of Tributary Of EFAC	None. Site is upstream of mine disturbance
164	42KJ 183474 00		Stock	1956	Dam	Booth Bros Land & Livestock			EFAC	None. Site is upstream of mine disturbance
165	42KJ 183524 00		Stock	1961	Direct from source	Booth Land & Livestock Co			Spring, Tributary Of Tributary Of EFAC	None. Site is upstream of mine disturbance
166	42KJ 183525 00		Stock	1961	Direct from source	Booth Land & Livestock Co			Spring, Tributary Of Tributary Of EFAC	None. Site is upstream of mine disturbance
167	42KJ 183526 00		Stock	1913	Pit	Booth Land & Livestock Co			EFAC	None. Site is upstream of mine disturbance
168	42KJ 183527 00		Stock	1913	Pit	Booth Land & Livestock Co			EFAC	None. Site is upstream of mine disturbance
169	42KJ 183541 00		Irrigation	1947	Dam	Booth Bros Land & Livestock			Tributary Of Tributary Of EFAC	None. Site is upstream of mine disturbance
170	42KJ 183542 00		Irrigation	1916	Dam	Booth Bros Land & Livestock			Tributary Of EFAC	None. No disturbance in watershed
171	42KJ 183543 00		Irrigation	1915	Dike	Booth Bros Land & Livestock			EFAC	Water quantity may be reduced during mining due to upstream sediment ponds.
172	42KJ 183545 00	EFAC-7	Irrigation	1902	Dike	Booth Bros Land & Livestock			EFAC	Water quantity may be reduced during mining due to upstream sediment ponds.
173	42KJ 183553 00		Irrigation	1921	Dike	Booth Bros Land & Livestock			Spring, Tributary Of Armells Creek	None. Site is upstream of mine disturbance
174	42KJ 184507 00		Stock	1958	Direct from source	Bailey Connie G; Bailey Donald P			Spring, Tributary Of Armells Creek	None. Site is upstream of mine disturbance
185	42KJ 47995 00	SP-63	Stock	1950	Direct from source	Montana, State Of Board Of Land Commissioners			Spring, Tributary WFAC	Quantity may be reduced due to aquifer drawdown from mining. Quality may be impacted if aquifer replaced by spoils.
188	42KJ 69974 00	SW-01	Irrigation	1988	Headgate	Colstrip Parks And Recreation District			EFAC	Water quantity may be reduced during mining due to upstream sediment ponds.

Table 6-3: Macroinvertebrate taxa richness.
Unique taxa are defined using the Operational Taxa Units listed in WQPBWQM-009 (2012).
The total taxa per year is a sum of sometimes multiple sampling events and methodologies. Sampling methodologies also may have differed year to year at the same site.

Drainage	Approx. Sampling Location	1976	1977	1978	2015
Cow Crk	PO-905	11	12	14	
Cow Crk	PO-907		3		
Rosebud Crk	Rosebud 4	8			
Rosebud Crk	Rosebud 5	8			
EFAC	SW-09		9	13	
EFAC	SW-03	5	7		
EFAC	SW-21	5			
EFAC	SW-02		19		
EFAC	SW-02A			16	
EFAC	SW-01	6	14	23	
EFAC	SW-01A			20	
EFAC	EFAC-1				14
EFAC	EFAC-2				18

		1985	1989	1990	1991	1992	1993
Lee Coulee	Wet Reach (BBIO 1, 2, 3)	26	20	11	7	8	12

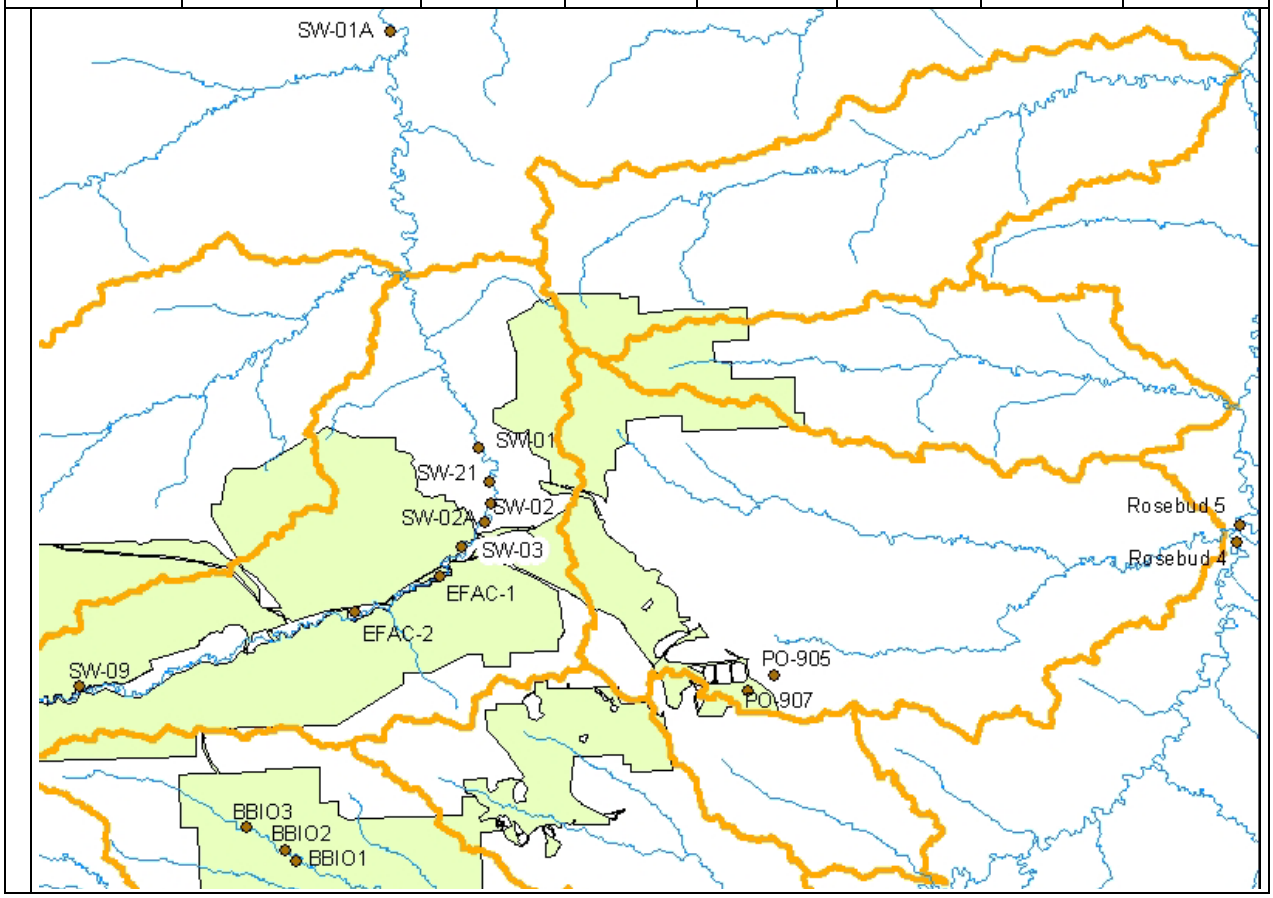

Table 7-1: Water quality monitoring analytical parameters.			
Analyte/Parameter	**Units**	**Reporting Limits**	**Method**
Field Parameters			
pH	s.u.	--	field meter
Conductance	umhos/cm	--	field meter
Temperature	C	--	field meter
Dissolved Oxygen 1	ppm	--	field meter
Laboratory Parameters			
pH	s.u.	0.1	A4500-H B
Specific Conductance @ 25 C	umhos/cm	1	120.1
Alkalinity, Total as CaCO3	mg/L	5	A2320 B
Acidity, Total as CaCO3	mg/L	5	A2310 B
Solids, Total Dissolved TDS @ 180 C	mg/L	10	A2540 C
Solids, Total Suspended TSS @ 105 C [1]	mg/L	10	A2540 D
Potassium	mg/L	1	E200.8
Sodium	mg/L	1	E200.8
Calcium	mg/L	1	E200.8
Magnesium	mg/L	1	E200.8
Sulfate	mg/L	1	E300.0
Chloride	mg/L	1	E300.0
Carbonate as CO3	mg/L	5	A2320 B
Bicarbonate as HCO3	mg/L	5	A2320 B
Orthophosphate as P	mg/L	0.001	A4500-PE
Nitrate+Nitrite as N	mg/L	0.01	E353.2
Fluoride	mg/L	0.1	E300.0
Sodium Adsorption Ratio (SAR)	unitless		Calculation
Boron [2]	mg/L	0.1	E200.8
Iron	mg/L	0.05	E200.8
Lead [2]	mg/L	0.0005	E200.8
Manganese	mg/L	0.005	E200.8
Molybdenum [2]	mg/L	0.005	E200.8
Selenium [2]	mg/L	0.005	E200.8 collision cell

(1) Analyzed for ponds, stream, and spring water only.

(2) Groundwater samples for metals analysis are filtered and metals are reported on a dissolved basis.

Surface water samples for metals are not filtered and metals are reported on a total basis.

Table 7-2: Surface water monitoring plan for Rosebud mine and Big Sky mine.

Site ID	Type	Drainage	Northing NAD83 State Plane (ft)	Easting NAD83 State Plane (ft)	Instrumentation		Measurement Frequency		Purpose
					Flow	Water Quality Sampling	Flow	Water Quality Sampling	
SP-18	Spring	Cow Creek	608,993	2,725,196		Grab	Monthly	Semi-annually	Monitor level and quality
SP-22	Spring	Spring Creek	626,427	2,709,673		Grab	Monthly	Semi-annually	Monitor level and quality
SP-23	Spring	Spring Creek	622,149	2,708,164	Staff	Grab	Monthly	Semi-annually	Monitor level and quality
SP-24	Spring	Pony Creek	618,575	2,716,297			Monthly		Monitor levels
SP-26	Spring	Cow Creek	614,408	2,720,977	Bucket	Grab	Monthly	Semi-annually	Monitor level and quality
SP-27	Spring	Cow Creek	612,219	2,715,682		Grab	Monthly	Semi-annually	Monitor level and quality
SP-34	Spring	WFAC	602,043	2,648,194		Grab	Monthly	Semi-annually	Monitor level and quality
SP-35	Spring	WFAC	602,526	2,649,665		Grab	Monthly	Semi-annually	Monitor level and quality
SP-36	Spring	WFAC	602,765	2,650,980		Grab	Monthly	Semi-annually	Monitor level and quality
SP-37	Spring	WFAC	602,553	2,651,065		Grab	Monthly	Semi-annually	Monitor level and quality
SP-43	Spring	Spring Creek	625,314	2,707,856		Grab	Monthly	Semi-annually	Monitor level and quality
SP-44	Spring	Spring Creek	625,246	2,710,288		Grab	Monthly	Semi-annually	Monitor level and quality
SP-46A	Spring	EFAC	601,382	2,678,951		Grab	Monthly	Semi-annually	Monitor level and quality
SP-63	Spring	WFAC	606,665	2,647,379		Grab	Monthly	Semi-annually	Monitor level and quality
SP-66	Spring	WFAC	598,432	2,643,186		Grab	Monthly	Semi-annually	Monitor level and quality
SP-67	Spring	WFAC	597,893	2,643,008		Grab	Monthly	Semi-annually	Monitor level and quality
SP-76	Spring	WFAC	608,091	2,653,724		Grab	Monthly	Semi-annually	Monitor level and quality
SP-90	Spring	Spring Creek	623,527	2,710,907		Grab	Monthly	Semi-annually	Monitor level and quality
SP-91	Spring	Spring Creek	622,910	2,711,159		Grab	Monthly	Semi-annually	Monitor level and quality
SP-112A	Spring	WFAC	609,266	2,659,108		Grab	Monthly	Semi-annually	Monitor level and quality
CG-03	Stream	Pony Creek	618,621	2,717,584	Crest		Monthly		Monitor stream flow downstream of mine
CG-23	Stream	WFAC	615,396	2,649,401	Crest		Monthly		Monitor stream flow downstream of mine
SW-55	Stream	EFAC	605,432	2,699,425	Flume	Grab; sediment bottle	Continuous	Semi-annually	Monitor stream flow and quality downstream of mine
SW-65	Stream	Stocker Creek	607,994	2,667,479	Flume	Grab; sediment bottle	Continuous	Semi-annually	Monitor stream flow and quality downstream of mine
SW-75	Stream	EFAC	593,889	2,658,236	Flume	Grab; sediment bottle	Continuous	Semi-annually	Monitor baseline stream flow and quality
PO-808	Pond	Spring Creek	626,786	2,709,674			Monthly	Semi-annually	Measure levels and quality of stock pond water
PO-809	Pond	Pony Creek	617,094	2,719,171			Monthly	Semi-annually	Measure levels and quality of stock pond water
PO-917	Pond	Pony Creek	618,700	2,716,476	Staff		Monthly	Semi-annually	Measure levels and quality of stock pond water
PO-921	Pond	Spring Creek	622,563	2,708,216			Monthly	Semi-annually	Measure levels and quality of stock pond water
PO-923	Pond	WFAC	605,374	2,649,324	Staff		Monthly	Semi-annually	Measure levels and quality of stock pond water
PO-970	Pond	WFAC	607,148	2,647,618			Monthly	Semi-annually	Measure levels and quality of stock pond water
PO-978	Pond	WFAC	611,930	2,638,708	Staff		Monthly	Semi-annually	Measure levels and quality of stock pond water
PO-987	Pond	Cow Creek	608,952	2,725,337			Monthly	Semi-annually	Measure levels and quality of stock pond water
AFL50-1	Stream	Pond 20	591,746	2,706,578	Flume	Grab	Continuous	Quarterly; event based	Continuous flow data downstream of reclamation, extension of long term record
ACG80-1	Stream	Emile Coulee	589,296	2,707,329	Crest	Grab; sediment bottle	Summer, Monthly; Winter Quarterly	Quarterly; event based	Downstream peak flow and quality data following sediment pond removal
AMCSW5	Stream	Lower Miller Coulee	584,852	2,703,547	Manual	Grab	Quarterly	Annually	Downstream flow and quality data below pre-1979 reclamation

Table 7-2 continued.

Site ID	Type	Drainage	Northing NAD83 State Plane (ft)	Easting NAD83 State Plane (ft)	Instrumentation		Measurement Frequency		Purpose
					Flow	Water Quality Sampling	Flow	Water Quality Sampling	
BBBW	Stream	Bad Bob Gulch	578,406	2,697,073	Weir		Continuous	Grab; sediment bottle	Downstream continuous flow data following sediment pond reclamation
BPSFL	Stream	Lee Coulee	586,645.3	2,677,705	Flume		Continuous	Grab; sediment bottle	Upstream (background) flow data, extension of long-term record
BMMFL	Stream	Lee Coulee	580,447.3	2,688,638	Flume		Continuous	Grab	Downstream flow data following sediment pond reclamation
BRTFL	Stream	Lee Coulee	583,331.2	2,684,194	Flume		Continuous	Grab; sediment bottle	Mid-channel flow data downstream of reconstructed Lee Coulee
BS33FL	Stream	Lee Coulee	574,866	2,699,420	Flume		Continuous	Grab; sediment bottle	Downstream flow data near permit boundary, extension of long-term record
BLFFL	Stream	Fossil Fork	578,695.9	2,688,739	Flume		Continuous	Grab; sediment bottle	Downstream flow data following sediment pond removal
BSDCG	Stream	Schmidt's Ditch	576,288	2,696,298	Crest		Continuous	Summer, Monthly; Winter, Quarterly	Downstream peak flow data following sediment pond removal
BHWSG	Spring	Lee Coulee	588,932.9	2,690,019	Manual	Grab	Annually	Annually	Background data, extension of long term record
BGDSG	Spring	Lee Coulee	578,560.4	2,683,413	Manual	Grab	Annually	Annually	Background data, extension of long term record
BBIO1	Pond	Lee Coulee	581,670.3	2,686,743		Grab		Semi-annually	Pre-existing pond below reconstructed Lee Coulee, extension of long term quality record
BBIO2	Pond	Lee Coulee	582,284	2,685,434		Grab		Semi-annually	Pre-existing pond below reconstructed Lee Coulee, extension of long term quality record
B3PI	Pond	Lee Coulee	583,824	2,687,187	Staff	Grab		Semi-annually	Approved permanent final cut impoundment
BLCPI	Pond	Lee Coulee	584,394.4	2,681,826	Staff	Grab		Semi-annually	Approved permanent final cut impoundment
B9PI	Pond	Lee Coulee	581,483.3	2,687,884	Staff	Grab		Semi-annually	Approved permanent impoundment

Table 7-3: Rosebud Mine groundwater monitoring analytical parameters.			
Parameters	**Analytical Method**	**Reporting Limit [1]**	**Units**
Conductivity	Field Msmt	1	µS/cm
pH (lab)	SM 4500-H+B	0.1	s.u.
pH (field)	Field Msmt	0.1	s.u.
Specific Conductance	SM 2510B	10.0	µmhos/cm
Total Dissolved Solids (TDS)	SM 2540C	20	mg/L
Temperature (ambient water)	Field Msmt	0.1	C
Total Anions	Calculated, SM1030E		meq/L
Total Cations	Calculated, SM1030E		meq/L
Acidity	SM 2310	5.0	mg/L
Alkalinity (total as CaCO3)	SM 2320B	5.0	mg/L
Total Hardness by 2340B, Dissolved	EPA 200.7	3.3	mg/L
Alkalinity, Bicarbonate (CaCO3)	SM 2320B	5.0	mg/L
Alkalinity, Carbonate (CaCO3)	SM 2320B	5.0	mg/L
Alkalinity, Hydroxide (CaCO3)	SM 2320B	5.0	mg/L
Cation/anion balance %	Calculated, SM1030E		%
Calcium, Dissolved	EPA 200.7	0.50	mg/L
Chloride	EPA 300.0	1.0	mg/L
Fluoride	EPA 300.0	0.10	mg/L
Magnesium, Dissolved	EPA 200.7	0.50	mg/L
Potassium, Dissolved	EPA 200.7	2.5	mg/L
SAR	Calculated	0.24	NA
Sodium, Dissolved	EPA 200.7	2.0	mg/L
Sulfate	ASTM D516-02	2.5	mg/L
Aluminum	EPA 200.8	0.004	mg/L
Arsenic	EPA 200.8	0.0005	mg/L
Boron	EPA 200.8	0.005	mg/L
Cadmium	EPA 200.8	0.00008	mg/L
Copper	EPA 200.8	0.00050	mg/L
Iron	EPA 200.8	0.050	mg/L
Lead	EPA 200.8	0.00010	mg/L
Manganese	EPA 200.8	0.00050	mg/L
Nickel	EPA 200.8	0.00050	mg/L
Selenium	EPA 200.8	0.00050	mg/L
Vanadium	EPA 200.8	0.00010	mg/L
Zinc	EPA 200.8	0.0050	mg/L
Nitrate-Nitrite as N	EPA 353.2	0.010	mg/L
Nitrogen, Ammonia	EPA 350.1	0.050	mg/L
Notes: (1) *The lowest reporting limit provided by the laboratory.*			

Table 7-4: Big Sky groundwater monitoring parameters –suite I.				
Physical Parameters	**Analytical Method**	**Alternate Method**	**Reporting Limit[1]**	**units**
pH (lab)	EPA 150.2		0.1	s.u.
pH (field)	Field Msmt		0.1	s.u.
Specific Conductance	EPA 120.1	A2510-B	1	µS/cm
Total Dissolved Solids (TDS)	EPA 160.1	A2540-C	10000	µg/L
Temperature (ambient water)	Field Msmt		0.1	C
Total Anions	Calculated			meq/L
Total Cations	Calculated			meq/L
Acidity (total as CaCO3)	A2310-B	EPA 130.1	5000	µg/L
Alkalinity (total as CaCO3)	A2320-B	EPA 130.1	5000	µg/L
Hardness (total as CaCO3)	A2340-B		1000	µg/L
Bicarbonate as HCO3	A2320-B	EPA 130.1	5000	µg/L
Carbonate as CO3	A2320-B	EPA 130.1	5000	µg/L
Cation/anion balance %	Calculated			%
Calcium, Dissolved	EPA 200.7	EPA 200.8	1000	µg/L
Chloride	EPA 300.0	A4500-CL B	1000	µg/L
Magnesium, Dissolved	EPA 200.7	EPA 200.8	1000	µg/L
Potassium, Dissolved	EPA 200.7	EPA 200.8	1000	µg/L
SAR	Calculated		100	NA
Sodium, Dissolved	EPA 200.7	EPA 200.8	1000	µg/L
Sulfate	EPA 300.0	ASTM D516	2000	µg/L
Aluminum	EPA 200.7	EPA 200.8	30	µg/L
Arsenic	EPA 200.8		10	µg/L
Boron	EPA 200.7	EPA 200.8	30	µg/L
Cadmium	EPA 200.8		5	µg/L
Copper	EPA 200.8		1300	µg/L
Fluoride	A 45000-F C	EPA 300.0	4000	µg/L
Iron	EPA 200.7	EPA 200.8	50	µg/L
Lead	EPA 200.8		15	µg/L
Manganese	EPA 200.7	EPA 200.8	5	µg/L
Nickel	EPA 200.7	EPA 200.8	100	µg/L
Selenium	EPA 200.8		50	µg/L
Vanadium	EPA 200.8		10	µg/L
Zinc	EPA 200.7	EPA 200.8	2000	µg/L
Nitrate-Nitrite as N	EPA 353.2	A4500-NO3 F	10	µg/L
Total Ammonia as N	EPA 350.1	A4500-NH3 B, C, D, E, or G	50	µg/L
Notes: (1) *The lowest reporting limit provided by the laboratory.*				

Table 7-4A: Big Sky Mine groundwater monitoring parameters – suite ll.				
Parameters	**Analytical Method**	**Alternative Method**	**Reporting Limit[1]**	**Units**
Conductivity	Field Msmt		1	µS/cm
pH (lab)	EPA 150.2		0.1	s.u.
pH (field)	Field Msmt		0.1	s.u.
Specific Conductance	EPA 120.1	A2510-B	1	µS/cm
Total Dissolved Solids (TDS)	EPA 160.1	A2540-C	10000	µg/L
Temperature (ambient water)	Field Msmt		0.1	C
Total Anions	Calculated			meq/L
Total Cations	Calculated			meq/L
Acidity (total as CaCO3)	A2310-B	EPA 130.1	5000	µg/L
Alkalinity (total as CaCO3)	A2320-B	EPA 130.1	5000	µg/L
Hardness (total as CaCO3)	A2340-B		1000	µg/L
Bicarbonate as HCO3	A2320-B	EPA 130.1	5000	µg/L
Carbonate as CO3	A2320-B	EPA 130.1	5000	µg/L
Cation/anion balance %	Calculated			%
Calcium, Dissolved	EPA 200.7	EPA 200.8	1000	µg/L
Chloride	EPA 300.0	A4500-CL B	1000	µg/L
Magnesium, Dissolved	EPA 200.7	EPA 200.8	1000	µg/L
Potassium, Dissolved	EPA 200.7	EPA 200.8	1000	µg/L
SAR	Calculated		100	NA
Sodium, Dissolved	EPA 200.7	EPA 200.8	1000	µg/L
Sulfate	EPA 300.0	ASTM D516	2000	µg/L
Fluoride	A 45000-F C	EPA 300.0	100	µg/L
Iron	EPA 200.7	EPA 200.8	50	µg/L
Manganese	EPA 200.7	EPA 200.8	5	µg/L
Nitrate-Nitrite as N	EPA 353.2	A4500-NO3 F	10	µg/L
Total Ammonia as N	EPA 350.1	A4500-NH3 B, C, D, E, or G	50	µg/L
Notes: (1) *The lowest reporting limit provided by the laboratory.*				

Table 7-5: Rosebud Mine groundwater monitoring plan.

Station	Northing NAD 83 State Plane (ft)	Easting NAD 83 State Plane (ft)	MP Elevation (ft)	Ground Elevation (ft)	Aquifer	Water Level Measured	Water Quality Sampled	Water Quality Suite	Scheduled Rotation [1]	Mine Area	Purpose
P-03	604,897	2,699,096	3260.66	3259.10	Alluvium	Quarterly	Every Third Year	Table 7-3	III	B	Monitor levels and quality in alluvium
P-04	605,093	2,698,940	3254.54	3252.50	Alluvium	Quarterly	Every Third Year	Table 7-3	III	B	Monitor levels and quality in alluvium
P-05	605,276	2,698,791	3255.26	3253.00	Alluvium	Periodic	Every Third Year	Table 7-3	III	B	Monitor levels and quality in alluvium
WA-101	600,876	2,692,530	3310.70	3308.70	Alluvium	Quarterly	Every Third Year	Table 7-3	I	A	Monitor levels and quality in alluvium
WA-104	595,937	2,678,556	3407.50	3405.30	Alluvium	Quarterly	Every Third Year	Table 7-3	II	B	Monitor levels and quality in alluvium
WA-109	617,085	2,680,170	3240.40	3238.50	Alluvium	Quarterly	Every Third Year	Table 7-3	III	North of C	Monitor levels and quality in alluvium
WA-113	608,809	2,697,677	3273.50	3273.50	Alluvium	Quarterly	Every Third Year	Table 7-3	III	East of A	Monitor levels and quality in alluvium
WA-114	599,091	2,688,429	3338.51	3337.51	Alluvium	Quarterly	Every Third Year	Table 7-3	I	B	Monitor levels and quality in alluvium
WA-118	593,761	2,652,614	3659.09	3658.20	Alluvium	Quarterly	Every Third Year	Table 7-3	II	Southwest of C	Monitor levels and quality in alluvium
WA-124	603,215	2,697,763	3265.70	3264.00	Alluvium	Quarterly	Every Third Year	Table 7-3	III	B	Monitor levels and quality in alluvium
WA-126	602,558	2,696,549	3282.37	3280.70	Alluvium	Quarterly	Every Third Year	Table 7-3	II	South of A	Monitor levels and quality in alluvium
WA-128	602,036	2,695,101	3292.02	3290.30	Alluvium	Quarterly	Every Third Year	Table 7-3	I	South of A	Monitor levels and quality in alluvium
WA-131	603,806	2,696,673	3282.99	3280.90	Alluvium	Quarterly	Every Third Year	Table 7-3	I	A	Monitor levels and quality in alluvium
WA-132	608,470	2,721,980	3104.08	3101.90	Alluvium	Quarterly	Every Third Year	Table 7-3	III	South of D	Monitor levels and quality in alluvium
WA-133	607,013	2,720,574	3126.68	3124.63	Alluvium	Quarterly	Every Third Year	Table 7-3	III	East of E	Monitor levels and quality in alluvium
WA-134	608,445	2,715,645	3166.46	3165.00	Alluvium	Quarterly	Every Third Year	Table 7-3	I	South of D	Monitor levels and quality in alluvium
WA-136	597,809	2,723,617	3167.90	3164.90	Alluvium	Quarterly	Every Third Year	Table 7-3	III	East of E	Monitor levels and quality in alluvium
WA-137	597,837	2,720,179	3209.41	3207.70	Alluvium	Quarterly	Every Third Year	Table 7-3	I	East of E	Monitor levels and quality in alluvium
WA-142	605,913	2,715,650	3182.51	3181.20	Alluvium	Quarterly	Every Third Year	Table 7-3	III	East of E	Monitor levels and quality in alluvium
WA-145	605,258	2,714,380	3201.17	3199.20	Alluvium	Quarterly	Every Third Year	Table 7-3	I	East of E	Monitor levels and quality in alluvium
WA-146	609,915	2,721,384	3138.85	3136.80	Alluvium	Quarterly	Every Third Year	Table 7-3	II	South of D	Monitor levels and quality in alluvium
WA-147	609,968	2,721,372	3138.64	3137.00	Alluvium	Quarterly	Every Third Year	Table 7-3	III	South of D	Monitor levels and quality in alluvium
WA-148	611,626	2,716,382	3199.81	3196.51	Alluvium	Quarterly	Every Third Year	Table 7-3	I	South of D	Monitor levels and quality in alluvium
WA-155	625,806	2,691,437	3140.00	3139.70	Alluvium	Quarterly	Every Third Year	Table 7-3	I	North of A	Monitor levels and quality in alluvium
WA-160	620,927	2,686,325	3176.51	3175.80	Alluvium	Quarterly	Every Third Year	Table 7-3	II	North of A	Monitor levels and quality in alluvium
WA-164	614,074	2,672,909	3289.00	3289.00	Alluvium	Quarterly	Every Third Year	Table 7-3	I	North of C	Monitor levels and quality in alluvium
WA-168	611,546	2,671,549	3322.50	3320.00	Alluvium	Quarterly	Every Third Year	Table 7-3	II	North of C	Monitor levels and quality in alluvium
WA-169	606,060	2,666,246	3382.62	3381.60	Alluvium	Quarterly	Every Third Year	Table 7-3	III	North of C	Monitor levels and quality in alluvium
WA-171	593,470	2,662,801	3556.80	3554.70	Alluvium	Quarterly	Every Third Year	Table 7-3	I	B	Monitor levels and quality in alluvium
WA-172	616,790	2,701,089	3227.36	3226.90	Alluvium	Quarterly	Every Third Year	Table 7-3	II	West of D	Monitor levels and quality in alluvium
WA-186	614,895	2,649,274	3238.50	3237.10	Alluvium	Quarterly	Every Third Year	Table 7-3	I	North of C	Monitor levels and quality in alluvium
WA-190	605,799	2,649,070	3383.23	3381.45	Alluvium	Quarterly	Every Third Year	Table 7-3	II	North of C	Monitor levels and quality in alluvium
WA-199	623,936	2,647,883	3142.45	3142.45	Alluvium	Quarterly	Every Third Year	Table 7-3	I	North of C	Monitor levels and quality in alluvium
WA-204	611,005	2,656,907	3338.95	3336.35	Alluvium	Quarterly	Every Third Year	Table 7-3	II	North of C	Monitor levels and quality in alluvium
WA-209	594,559	2,670,892	3469.86	3468.32	Alluvium	Quarterly	Every Third Year	Table 7-3	III	C	Monitor levels and quality in alluvium
WA-214	592,739	2,662,877	3552.61	3550.01	Alluvium	Quarterly	Every Third Year	Table 7-3	II	B	Monitor levels and quality in alluvium
WA-215	593,752	2,660,834	3559.22	3557.65	Alluvium	Quarterly	Every Third Year	Table 7-3	III	West of B	Monitor levels and quality in alluvium
WA-217	604,529	2,660,186	3429.45	3427.15	Alluvium	Quarterly	Every Third Year	Table 7-3	III	C	Monitor levels and quality in alluvium
WA-218	609,104	2,642,995	3362.80	3360.63	Alluvium	Quarterly	Every Third Year	Table 7-3	I	North of C	Monitor levels and quality in alluvium

Table 7-5: Continued.

Station	Northing NAD 83 State Plane (ft)	Easting NAD 83 State Plane (ft)	MP Elevation (ft)	Ground Elevation (ft)	Aquifer	Water Level Measured	Water Quality Sampled	Water Quality Suite	Scheduled Rotation [1]	Mine Area	Purpose
WD-104	598,665	2,721,550	3271.55	3270.25	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	II	E	Monitor levels and quality in sub-McKay
WD-105	614,327	2,720,031	3278.1	3276.50	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	II	D	Monitor levels and quality in sub-McKay
WD-106	608,191	2,710,459	3220.47	3218.30	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	I	South of D	Monitor levels and quality in sub-McKay
WD-107	608,613	2,682,813	3415.26	3413.70	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	II	A	Monitor levels and quality in sub-McKay
WD-109	611,169	2,671,867	3340.47	3337.90	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	I	North of C	Monitor levels and quality in sub-McKay
WD-153	604,337	2,672,305	3466.10	3465.10	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	I	C	Monitor levels and quality in sub-McKay
WD-159	600,921	2,700,394	3379.10	3378.10	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	I	B	Monitor levels and quality in sub-McKay
WD-160	597,183	2,701,030	3436.80	3435.80	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	II	B	Monitor levels and quality in sub-McKay
WD-174	601,191	2,708,106	3467.20	3464.40	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	III	E	Monitor levels and quality in sub-McKay
WD-178	600,714	2,650,088	3610.93	3609.07	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	I	C	Monitor levels and quality in sub-McKay
WD-181	603,033	2,640,145	3620.43	3618.73	Sub-McKay	Annually	Every Third Year	Table 7-3	I	C	Monitor levels and quality in sub-McKay
WD-182	601,290	2,711,475	3318.71	3317.71	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	II	E	Monitor levels and quality in sub-McKay
WD-184	599,733	2,693,111	3347.64	3346.64	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	III	B	Monitor levels and quality in sub-McKay
WD-185	597,542	2,687,145	3371.05	3370.05	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	I	B	Monitor levels and quality in sub-McKay
WD-186	603,981	2,677,013	3484.42	3483.42	Sub-McKay	Semi-annually	Every Third Year	Table 7-3	II	C	Monitor levels and quality in sub-McKay
WD-195	593,462	2,657,776	3614.61	3612.55	Sub-McKay	Quarterly	Every Third Year	Table 7-3	I	West of B	Monitor levels and quality in sub-McKay
WD-196	592,530	2,669,550	3513.14	3511.38	Sub-McKay	Quarterly	Every Third Year	Table 7-3	I	B	Monitor levels and quality in sub-McKay
WD-197	615,650	2,721,874	3346.34	3344.73	Sub-McKay	Quarterly	Every Third Year	Table 7-3	I	D	Monitor levels and quality in sub-McKay
WD-198	606,659	2,657,586	3565.36	3563.53	Sub-McKay	Quarterly	Every Third Year	Table 7-3	III [2]	C	Monitor levels and quality in sub-McKay
WD-199	607,724	2,638,940	3480.12	3478.30	Sub-McKay	Quarterly	Every Third Year	Table 7-3	III [2]	C	Monitor levels and quality in sub-McKay
WD-200	604,288	2,645,757	3497.63	3496.71	Sub-McKay	Quarterly	Every Third Year	Table 7-3	III [2]	C	Monitor levels and quality in sub-McKay
WD-201	601,364	2,660,541	3506.87	3505.73	Sub-McKay	Quarterly	Every Third Year	Table 7-3	III [2]	C	Monitor levels and quality in sub-McKay
WD-202	621,494	2,716,364	3419.40	3418.06	Sub-McKay	Quarterly	Every Third Year	Table 7-3	III [2]	D	Monitor levels and quality in sub-McKay
WI-102	603,094	2,693,382	3307.40	3305.90	Interburden	Semi-annually	Every Third Year	Table 7-3	III	A	Monitor levels and quality in interburden
WI-106	604,844	2,709,829	3288.90	3287.70	Interburden	Semi-annually	Every Third Year	Table 7-3	I	E	Monitor levels and quality in interburden
WI-107	598,677	2,715,484	3271.09	3269.40	Interburden	Semi-annually	Every Third Year	Table 7-3	II	E	Monitor levels and quality in interburden
WI-108	602,386	2,722,752	3285.00	3269.80	Interburden	Semi-annually	Every Third Year	Table 7-3	III	East of E	Monitor levels and quality in interburden
WI-109	604,240	2,717,873	3290.06	3287.90	Interburden	Semi-annually	Every Third Year	Table 7-3	I	East of E	Monitor levels and quality in interburden
WI-110	612,691	2,710,938	3239.17	3239.00	Interburden	Semi-annually	Every Third Year	Table 7-3	II	D	Monitor levels and quality in interburden
WI-111	607,499	2,692,149	3470.57	3468.50	Interburden	Semi-annually	Every Third Year	Table 7-3	III	A	Monitor levels and quality in interburden
WI-116	607,124	2,705,998	3326.50	3325.50	Interburden	Semi-annually	Every Third Year	Table 7-3	I	E	Monitor levels and quality in interburden
WI-117	598,101	2,712,532	3325.14	3324.14	Interburden	Semi-annually	Every Third Year	Table 7-3	II	E	Monitor levels and quality in interburden
WI-153	604,549	2,672,323	3465.90	3464.90	Interburden	Semi-annually	Every Third Year	Table 7-3	I	C	Monitor levels and quality in interburden
WI-157	601,845	2,697,079	3338.50	3337.50	Interburden	Semi-annually	Every Third Year	Table 7-3	II	B	Monitor levels and quality in interburden
WI-159		2,700,381	3379.90	3378.90	Interburden	Semi-annually	Every Third Year	Table 7-3	III	B	Monitor levels and quality in interburden
WI-160	597,171	2,701,011	3436.90	3435.90	Interburden	Semi-annually	Every Third Year	Table 7-3	I	B	Monitor levels and quality in interburden
WI-162	592,268	2,680,417	3530.22	3527.40	Interburden	Semi-annually	Every Third Year	Table 7-3	I	B	Monitor levels and quality in interburden
WI-164	590,111	2,674,466	3522.99	3520.90	Interburden	Semi-annually	Every Third Year	Table 7-3	I	B	Monitor levels and quality in interburden
WI-168	596,872	2,666,244	3571.08	3568.70	Interburden	Semi-annually	Every Third Year	Table 7-3	I	C	Monitor levels and quality in interburden

Table 7-5: Continued.

Station	Northing NAD 83 State Plane (ft)	Easting NAD 83 State Plane (ft)	MP Elevation (ft)	Ground Elevation (ft)	Aquifer	Water Level Measured	Water Quality Sampled	Water Quality Suite	Scheduled Rotation [1]	Mine Area	Purpose
WI-171	593,442	2,657,787	3615.53	3614.00	Interburden	Semi-annually	Every Third Year	Table 7-3	I	West of B	Monitor levels and quality in interburden
WI-172	596,452	2,659,694	3593.44	3592.40	Interburden	Semi-annually	Every Third Year	Table 7-3	II	Southwest of C	Monitor levels and quality in interburden
WI-173	589,689	2,665,491	3647.80	3646.20	Interburden	Semi-annually	Every Third Year	Table 7-3	I	B	Monitor levels and quality in interburden
WI-174	601,172	2,708,085	3467.40	3466.40	Interburden	Semi-annually	Every Third Year	Table 7-3	II	E	Monitor levels and quality in interburden
WI-178	600,728	2,650,098	3610.88	3608.73	Interburden	Semi-annually	Every Third Year	Table 7-3	I	C	Monitor levels and quality in interburden
WI-181	603,024	2,640,156	3621.02	3619.06	Interburden	Annually	Every Third Year	Table 7-3	II	C	Monitor levels and quality in interburden
WI-182	601,298	2,711,486	3318.84	3317.84	Interburden	Semi-annually	Every Third Year	Table 7-3	I	E	Monitor levels and quality in interburden
WI-184	599,734	2,693,129	3347.65	3346.65	Interburden	Semi-annually	Every Third Year	Table 7-3	III	B	Monitor levels and quality in interburden
WI-185	597,533	2,687,161	3770.97	3769.97	Interburden	Semi-annually	Every Third Year	Table 7-3	I	B	Monitor levels and quality in interburden
WI-186	603,979	2,677,028	3484.31	3483.31	Interburden	Semi-annually	Every Third Year	Table 7-3	II	C	Monitor levels and quality in interburden
WM-103	600,855	2,692,536	3310.20	3309.00	McKay Coal	Quarterly	Every Third Year	Table 7-3	II	A	Monitor levels and quality in McKay coal
WM-104	603,657	2,687,180	3448.00	3447.70	McKay Coal	Quarterly	Every Third Year	Table 7-3	III	A	Monitor levels and quality in McKay coal
WM-105	611,315	2,682,672	3449.20	3447.30	McKay Coal	Quarterly	Every Third Year	Table 7-3	I	North of A	Monitor levels and quality in McKay coal
WM-107	596,457	2,659,706	3592.23	3591.10	McKay Coal	Quarterly	Every Third Year	Table 7-3	I	Southwest of C	Monitor levels and quality in McKay coal
WM-120	604,839	2,709,841	3288.79	3287.20	McKay Coal	Semi-annually	Every Third Year	Table 7-3	II	E	Monitor levels and quality in McKay coal
WM-121	595,424	2,714,794	3289.30	3288.30	McKay Coal	Semi-annually	Every Third Year	Table 7-3	I	Southeast of E	Monitor levels and quality in McKay coal
WM-122	594,271	2,717,573	3274.88	3273.50	McKay Coal	Semi-annually	Every Third Year	Table 7-3	I	Southeast of E	Monitor levels and quality in McKay coal
WM-123	593,583	2,723,575	3227.28	3226.38	McKay Coal	Semi-annually	Every Third Year	Table 7-3	II	Southeast of E	Monitor levels and quality in McKay coal
WM-124	602,386	2,722,768	3285.20	3269.80	McKay Coal	Semi-annually	Every Third Year	Table 7-3	III	East of E	Monitor levels and quality in McKay coal
WM-125	614,322	2,720,040	3280.13	3277.67	McKay Coal	Quarterly	Every Third Year	Table 7-3	I	D	Monitor levels and quality in McKay coal
WM-126	604,236	2,717,884	3290.19	3288.30	McKay Coal	Semi-annually	Every Third Year	Table 7-3	II	East of E	Monitor levels and quality in McKay coal
WM-127	600,022	2,716,940	3312.69	3310.50	McKay Coal	Semi-annually	Every Third Year	Table 7-3	I	East of E	Monitor levels and quality in McKay coal
WM-128	612,684	2,710,948	3241.22	3239.10	McKay Coal	Quarterly	Every Third Year	Table 7-3	I	D	Monitor levels and quality in McKay coal
WM-129	607,504	2,692,158	3469.90	3468.90	McKay Coal	Quarterly	Every Third Year	Table 7-3	II	A	Monitor levels and quality in McKay coal
WM-130	603,072	2,693,354	3307.45	3305.90	McKay Coal	Semi-annually	Every Third Year	Table 7-3	III	A	Monitor levels and quality in McKay coal
WM-135	607,115	2,706,001	3330.69	3325.90	McKay Coal	Semi-annually	Every Third Year	Table 7-3	II	E	Monitor levels and quality in McKay coal
WM-136	598,110	2,712,535	3324.85	3323.85	McKay Coal	Quarterly	Every Third Year	Table 7-3	I	E	Monitor levels and quality in McKay coal
WM-138	599,414	2,716,720	3282.76	3280.40	McKay Coal	Semi-annually	Every Third Year	Table 7-3	I	East of E	Monitor levels and quality in McKay coal
WM-139	593,464	2,662,810	3556.71	3554.50	McKay Coal	Quarterly	Every Third Year	Table 7-3	II	B	Monitor levels and quality in McKay coal
WM-153	604,546	2,672,332	3465.90	3464.90	McKay Coal	Semi-annually	Every Third Year	Table 7-3	I	C	Monitor levels and quality in McKay coal
WM-158	602,541	2,698,387	3321.85	3319.00	McKay Coal	Quarterly	Every Third Year	Table 7-3	II	B	Monitor levels and quality in McKay coal
WM-159	600,913	2,700,387	3379.40	3378.40	McKay Coal	Semi-annually	Every Third Year	Table 7-3	III	B	Monitor levels and quality in McKay coal
WM-162	592,275	2,680,410	3529.97	3527.40	McKay Coal	Quarterly	Every Third Year	Table 7-3	II	B	Monitor levels and quality in McKay coal
WM-164	590,100	2,674,468	3522.07	3520.30	McKay Coal	Quarterly	Every Third Year	Table 7-3	I	B	Monitor levels and quality in McKay coal
WM-168	596,864	2,666,254	3570.43	3568.10	McKay Coal	Quarterly	Every Third Year	Table 7-3	III	C	Monitor levels and quality in McKay coal
WM-173	589,689	2,665,499	3647.31	3646.00	McKay Coal	Quarterly	Every Third Year	Table 7-3	III	B	Monitor levels and quality in McKay coal
WM-174	601,181	2,708,091	3466.33	3465.50	McKay Coal	Semi-annually	Every Third Year	Table 7-3	II	E	Monitor levels and quality in McKay coal
WM-178	600,721	2,650,092	3610.72	3609.07	McKay Coal	Quarterly	Every Third Year	Table 7-3	I	C	Monitor levels and quality in McKay coal
WM-181	603,028	2,640,149	3621.02	3618.83	McKay Coal	Annually	Every Third Year	Table 7-3	III	C	Monitor levels and quality in McKay coal

Table 7-5: Continued.

Station	Northing NAD 83 State Plane (ft)	Easting NAD 83 State Plane (ft)	MP Elevation (ft)	Ground Elevation (ft)	Aquifer	Water Level Measured	Water Quality Sampled	Water Quality Suite	Scheduled Rotation [1]	Mine Area	Purpose
WM-182	601,294	2,711,480	3318.84	3317.84	McKay Coal	Semi-annually	Every Third Year	Table 7-3	I	E	Monitor levels and quality in McKay coal
WM-184	599,734	2,693,119	3347.54	3346.54	McKay Coal	Quarterly	Every Third Year	Table 7-3	III	B	Monitor levels and quality in McKay coal
WM-185	597,537	2,687,154	3370.85	3369.85	McKay Coal	Quarterly	Every Third Year	Table 7-3	I	B	Monitor levels and quality in McKay coal
WM-186	603,980	2,677,021	3484.20	3483.20	McKay Coal	Semi-annually	Every Third Year	Table 7-3	II	C	Monitor levels and quality in McKay coal
WM-187	616,577	2,711,107	3424.70	3422.23	McKay Coal	Quarterly	Every Third Year	Table 7-3	III	D	Monitor levels and quality in McKay coal
WM-188	618,193	2,705,338	3402.73	3401.11	McKay Coal	Quarterly	Every Third Year	Table 7-3	III	D	Monitor levels and quality in McKay coal
WM-189	614,501	2,703,634	3305.63	3303.15	McKay Coal	Quarterly	Every Third Year	Table 7-3	III	D	Monitor levels and quality in McKay coal
WM-191	593,459	2,657,802	3614.12	3612.62	McKay Coal	Quarterly	Every Third Year	Table 7-3	II	West of B	Monitor levels and quality in McKay coal
WM-200	606,658	2,657,557	3565.92	3564.00	McKay Coal	Quarterly	Other	Table 7-3	III [2]	C	Monitor levels and quality in McKay coal
WM-201	604,275	2,645,755	3497.86	3496.89	McKay Coal	Quarterly	Other	Table 7-3	III [2]	C	Monitor levels and quality in McKay coal
WO-105	607,548	2,692,244	3469.40	3468.40	Overburden	Semi-annually	Every Third Year	Table 7-3	I	A	Monitor levels and quality in overburden
WO-160	597,155	2,700,997	3437.30	3436.30	Overburden	Semi-annually	Every Third Year	Table 7-3	II	B	Monitor levels and quality in overburden
WO-162	592,255	2,680,434	3531.29	3528.40	Overburden	Semi-annually	Every Third Year	Table 7-3	III	B	Monitor levels and quality in overburden
WO-168	596,884	2,666,227	3571.40	3569.60	Overburden	Semi-annually	Every Third Year	Table 7-3	III	C	Monitor levels and quality in overburden
WO-171	593,440	2,657,776	3616.08	3614.70	Overburden	Semi-annually	Every Third Year	Table 7-3	I	West of B	Monitor levels and quality in overburden
WO-172	596,452	2,659,694	3594.28	3592.40	Overburden	Semi-annually	Every Third Year	Table 7-3	II	Southwest of C	Monitor levels and quality in overburden
WO-173	589,680	2,665,474	3648.82	3647.10	Overburden	Semi-annually	Every Third Year	Table 7-3	II	B	Monitor levels and quality in overburden
WO-174	601,167	2,708,094	3468.70	3467.70	Overburden	Semi-annually	Every Third Year	Table 7-3	I	E	Monitor levels and quality in overburden
WO-178	600,734	2,650,102	3610.84	3608.74	Overburden	Semi-annually	Every Third Year	Table 7-3	I	C	Monitor levels and quality in overburden
WO-181	603,011	2,640,172	3620.55	3618.99	Overburden	Annually	Every Third Year	Table 7-3	II	C	Monitor levels and quality in overburden
WR-103	596,483	2,659,685	3593.30	3592.20	Rosebud Coal	Quarterly	Every Third Year	Table 7-3	II	C	Monitor levels and quality in Rosebud coal
WR-104	603,678	2,687,176	3446.65	3446.20	Rosebud Coal	Quarterly	Every Third Year	Table 7-3	II	A	Monitor levels and quality in Rosebud coal
WR-108	598,204	2,710,460	3416.87	3414.67	Rosebud Coal	Semi-annually	Every Third Year	Table 7-3	II	West of B	Monitor levels and quality in Rosebud coal
WR-121	600,742	2,650,109	3609.70	3607.90	Rosebud Coal	Quarterly	Every Third Year	Table 7-3	I	C	Monitor levels and quality in Rosebud coal
WR-124	593,451	2,662,818	3555.98	3554.50	Rosebud Coal	Quarterly	Every Third Year	Table 7-3	II	B	Monitor levels and quality in Rosebud coal
WR-125	593,439	2,657,798	3614.85	3613.90	Rosebud Coal	Quarterly	Every Third Year	Table 7-3	I		Monitor levels and quality in Rosebud coal
WR-126	604,535	2,672,333	3465.60	3464.60	Rosebud Coal	Semi-annually	Every Third Year	Table 7-3	II	C	Monitor levels and quality in Rosebud coal
WR-127	603,801	2,696,661	3283.26	3281.30	Rosebud Coal	Semi-annually	Every Third Year	Table 7-3	III	A	Monitor levels and quality in Rosebud coal
WR-128	604,245	2,717,863	3289.31	3287.70	Rosebud Coal	Semi-annually	Every Third Year	Table 7-3	I	E	Monitor levels and quality in Rosebud coal
WR-129	600,014	2,716,948	3312.73	3310.30	Rosebud Coal	Semi-annually	Every Third Year	Table 7-3	II	E	Monitor levels and quality in Rosebud coal
WR-130	607,493	2,692,138	3470.30	3468.40	Rosebud Coal	Semi-annually	Every Third Year	Table 7-3	III	A	Monitor levels and quality in Rosebud coal
WR-134	618,257	2,714,629	3289.46	3287.00	Rosebud Coal	Quarterly	Every Third Year	Table 7-3	III	D	Monitor levels and quality in Rosebud coal
WR-136	593,744	2,665,439	3465.60	3528.52	Rosebud Coal	Quarterly	Every Third Year	Table 7-3	II	C	Monitor levels and quality in Rosebud coal
WR-160	597,162	2,701,003	3437.00	3436.00	Rosebud Coal	Semi-annually	Every Third Year	Table 7-3	I	B	Monitor levels and quality in Rosebud coal
WR-162	592,261	2,680,425	3529.23	3528.10	Rosebud Coal	Quarterly	Every Third Year	Table 7-3	I	B	Monitor levels and quality in Rosebud coal
WR-164	590,118	2,674,464	3521.20	3521.10	Rosebud Coal	Quarterly	Every Third Year	Table 7-3	I	B	Monitor levels and quality in Rosebud coal
WR-168	596,880	2,666,234	3571.83	3569.10	Rosebud Coal	Quarterly	Every Third Year	Table 7-3	II	C	Monitor levels and quality in Rosebud coal
WR-173	589,684	2,665,481	3648.27	3646.60	Rosebud Coal	Quarterly	Every Third Year	Table 7-3	II	B	Monitor levels and quality in Rosebud coal
WR-174	601,177	2,708,103	3467.40	3466.40	Rosebud Coal	Semi-annually	Every Third Year	Table 7-3	II	E	Monitor levels and quality in Rosebud coal

Table 7-5: Continued.

Station	Northing NAD 83 State Plane (ft)	Easting NAD 83 State Plane (ft)	MP Elevation (ft)	Ground Elevation (ft)	Aquifer	Water Level Measured	Water Quality Sampled	Water Quality Suite	Scheduled Rotation [1]	Mine Area	Purpose
WR-181	603,015	2,640,166	3621.19	3619.45	Rosebud Coal	Annually	Every Third Year	Table 7-3	I	C	Monitor levels and quality in Rosebud coal
WR-205	600,467	2,693,516	3300.78	3299.78	Rosebud Coal	Quarterly	Every Third Year	Table 7-3	III	B	Monitor levels and quality in Rosebud coal
WS-100	606,553	2,698,261	3270.60	3269.50	Spoils	Semi-annually	Every Third Year	Table 7-3	I	A	Monitor levels and quality in spoils
WS-101	607,655	2,697,942	3318.30	3317.30	Spoils	Semi-annually	Every Third Year	Table 7-3	II	A	Monitor levels and quality in spoils
WS-102	607,560	2,695,653	3358.70	3358.00	Spoils	Semi-annually	Every Third Year	Table 7-3	III	A	Monitor levels and quality in spoils
WS-103	606,878	2,696,660	3353.80	3352.80	Spoils	Semi-annually	Every Third Year	Table 7-3	I	A	Monitor levels and quality in spoils
WS-106	603,082	2,693,368	3308.74	3306.10	Spoils	Semi-annually	Every Third Year	Table 7-3	II	A	Monitor levels and quality in spoils
WS-107	601,798	2,690,251	3370.00	3368.60	Spoils	Semi-annually	Every Third Year	Table 7-3	III	A	Monitor levels and quality in spoils
WS-109	604,848	2,709,814	3289.50	3288.00	Spoils	Semi-annually	Every Third Year	Table 7-3	I	E	Monitor levels and quality in spoils
WS-110	595,435	2,714,801	3289.30	3288.30	Spoils	Semi-annually	Every Third Year	Table 7-3	II	Southeast of E	Monitor levels and quality in spoils
WS-111	594,254	2,717,572	3275.45	3273.50	Spoils	Semi-annually	Every Third Year	Table 7-3	III	Southeast of E	Monitor levels and quality in spoils
WS-112	593,569	2,723,575	3228.06	3226.21	Spoils	Semi-annually	Every Third Year	Table 7-3	I	Southeast of E	Monitor levels and quality in spoils
WS-113	603,933	2,696,079	3272.39	3270.50	Spoils	Semi-annually	Every Third Year	Table 7-3	II	A	Monitor levels and quality in spoils
WS-114	603,473	2,694,890	3288.35	3287.10	Spoils	Semi-annually	Every Third Year	Table 7-3	III	A	Monitor levels and quality in spoils
WS-115	604,823	2,697,343	3271.21	3269.30	Spoils	Semi-annually	Every Third Year	Table 7-3	I	A	Monitor levels and quality in spoils
WS-116	607,136	2,705,995	3326.50	3324.80	Spoils	Semi-annually	Every Third Year	Table 7-3	II	E	Monitor levels and quality in spoils
WS-117	598,091	2,7,12,531	3325.60	3324.60	Spoils	Semi-annually	Every Third Year	Table 7-3	I	E	Monitor levels and quality in spoils
WS-118	601,369	2,696,047	3325.20	3324.20	Spoils	Semi-annually	Every Third Year	Table 7-3	I	B	Monitor levels and quality in spoils
WS-120	604,148	2,679,243	3488.90	3487.90	Spoils	Semi-annually	Every Third Year	Table 7-3	II	C	Monitor levels and quality in spoils
WS-121	599,147	2,676,518	3467.01	3464.91	Spoils	Quarterly	Every Third Year	Table 7-3	II	C	Monitor levels and quality in spoils
WS-122	604,016	2,672,592	3484.42	3482.52	Spoils	Semi-annually	Every Third Year	Table 7-3	II	C	Monitor levels and quality in spoils
WS-123	610,765	2,685,532	3409.65	3407.89	Spoils	Quarterly	Every Third Year	Table 7-3	II	A	Monitor levels and quality in spoils
WS-124	600,843	2,713,699	3308.30	3306.17	Spoils	Semi-annually	Every Third Year	Table 7-3	II	E	Monitor levels and quality in spoils
WS-125	611,992	2,706,471	3266.21	3264.76	Spoils	Semi-annually	Every Third Year	Table 7-3	III	D	Monitor levels and quality in spoils
WS-126	609,223	2,707,905	3284.66	3283.35	Spoils	Semi-annually	Every Third Year	Table 7-3	III	D	Monitor levels and quality in spoils
WS-127	609,717	2,706,349	3295.72	3294.13	Spoils	Semi-annually	Every Third Year	Table 7-3	III	D	Monitor levels and quality in spoils
WS-128	614,517	2,703,628	3305.27	3303.70	Spoils	Semi-annually	Every Third Year	Table 7-3	III	D	Monitor levels and quality in spoils
WS-129	612,745	2,709,110	3268.04	3268.04	Spoils	Quarterly	Every Third Year	Table 7-3	III	D	Monitor levels and quality in spoils
WS-130	604,413	2,706,865	3319.29	3317.08	Spoils	Semi-annually	Every Third Year	Table 7-3	II	E	Monitor levels and quality in spoils
WS-157	601,836	2,697,064	3338.50	3337.50	Spoils	Semi-annually	Every Third Year	Table 7-3	III	B	Monitor levels and quality in spoils
WS-158	602,537	2,698,379	3320.00	3319.00	Spoils	Semi-annually	Every Third Year	Table 7-3	I	B	Monitor levels and quality in spoils
WS-159	600,895	2,700,375	3380.70	3379.70	Spoils	Quarterly	Every Third Year	Table 7-3	II	B	Monitor levels and quality in spoils
WS-184	599,734	2,693,139	3347.66	3346.66	Spoils	Quarterly	Every Third Year	Table 7-3	III	B	Monitor levels and quality in spoils
WS-185	597,531	2,687,168	3370.80	3369.80	Spoils	Quarterly	Every Third Year	Table 7-3	I	B	Monitor levels and quality in spoils
WS-186	603,978	2,677,036	3484.31	3483.31	Spoils	Semi-annually	Every Third Year	Table 7-3	II	C	Monitor levels and quality in spoils
WS-187	616,589	2,711,120	3423.17	3420.67	Spoils	Quarterly	Every Third Year	Table 7-3	III	D	Monitor levels and quality in spoils
WS-188	618,216	2,705,317	3408.65	3406.35	Spoils	Quarterly	Every Third Year	Table 7-3	III	D	Monitor levels and quality in spoils
WS-189	595,863	2,683,702	3411.84	3410.17	Spoils	Quarterly	Every Third Year	Table 7-3	I	B	Monitor levels and quality in spoils
WS-190	594,073	2,678,602	3461.32	3459.65	Spoils	Quarterly	Every Third Year	Table 7-3	I	B	Monitor levels and quality in spoils

Table 7-5: Continued.

Station	Northing NAD 83 State Plane (ft)	Easting NAD 83 State Plane (ft)	MP Elevation (ft)	Ground Elevation (ft)	Aquifer	Water Level Measured	Water Quality Sampled	Water Quality Suite	Scheduled Rotation [1]	Mine Area	Purpose
WS-191	592,522	2,669,532	3513.31	3511.17	Spoils	Quarterly	Every Third Year	Table 7-3	I	B	Monitor levels and quality in spoils
WS-192	616,255	2,717,914	3336.70	3334.78	Spoils	Quarterly	Every Third Year	Table 7-3	I	D	Monitor levels and quality in spoils
WS-193	615,630	2,721,883	3346.70	3344.80	Spoils	Quarterly	Every Third Year	Table 7-3	I	D	Monitor levels and quality in spoils
WS-194	606,658	2,657,572	3565.37	3563.66	Spoils	Quarterly	Other	Table 7-3	III [2]	C	Monitor levels and quality in spoils
WS-195	607,733	2,638,940	3479.87	3478.31	Spoils	Quarterly	Other	Table 7-3	III [2]	C	Monitor levels and quality in spoils
WS-196	604,299	2,645,752	3497.68	3496.23	Spoils	Quarterly	Other	Table 7-3	III [2]	C	Monitor levels and quality in spoils
WS-197	601,377	2,660,537	3506.85	3505.54	Spoils	Quarterly	Other	Table 7-3	III [2]	C	Monitor levels and quality in spoils
WS-198	621,502	2,716,353	3419.62	3418.32	Spoils	Quarterly	Other	Table 7-3	III [2]	D	Monitor levels and quality in spoils

Notes

(1) Scheduled rotation for water quality sampling are as follows:

I = 2012, 2015, 2018…

II = 2013, 2016, 2019…

III = 2014, 2017, 2020…

(2) New wells put in in Water Year 2012, scheduled to be sampled in 2012, 2013, 2014 and then every three years

Table 7-6: Big Sky Mine groundwater monitoring plan.

Station	Northing NAD83 State Plane (ft)	Easting NAD83 State Plane (ft)	Ground Elevation (ft)	Aquifer	Water Level Measured	Water Quality Sampled	Field Parameter Sampled	Water Quality Suite	Mine Area	Purpose
AAL12	587,357	2,712,015	3,155.11	Alluvium	Semi-annually	Not Sampled	----	----	A	Downgradient water levels only, alluvium
AAL14	587,582	2,712,959	3,165.94	Alluvium	Semi-annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, alluvium
AAL51	584,760	2,703,805	3,229.16	Alluvium	Semi-annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, alluvium
AALM70	586,271	2,712,375	3,129.60	Alluvium	Semi-annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, alluvium
ASP22	583,858	2,703,083	3,279.28	Spoils	Annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, spoils
ASP25R	592,043	2,712,331	3,294.73	Spoils	Annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, spoils
ASP40	587,788	2,704,694	3,275.04	Spoils	Annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, spoils
ASPW1	585,770	2,701,631	3,257.50	Spoils	Semi-annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, spoils
ASP49	590,658	2,704,247	3,262.21	Spoils	Semi-annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, spoils
ASPS15	581,851	2,705,003	3,249.81	Spoils	Annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, spoils
ASP61	586,774	2,699,452	3,309.52	Spoils	Annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, spoils
ASP65	586,637	2,701,737	3,279.80	Spoils	Annually	Not Sampled	----	----	A	Downgradient water levels only, spoils
ASPP18	583,836	2,703,065	3,281.51	Spoils	Annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, spoils
ASP68	591,807	2,702,223	3,309.66	Spoils	Annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, spoils
ASP50A	584,997	2,703,068	3,247.25	Spoils	Semi-annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, spoils
AOVM73	593,310	2,701,325	3,432.59	Overburden	Annually	Not Sampled	----	----	A	Upgradient (background) water levels only, overburden
ARC30	581,884	2,702,369	3,357.50	Rosebud Coal	Annually	Annually	Annually	Table 7-4A	A	Upgradient (background) water levels and WQ, Rosebud Coal
ARCM63	591,145	2,701,052	3,409.63	Rosebud Coal	Annually	Not Sampled	----	----	A	Upgradient (background) water levels only, Rosebud Coal
ARCM67	594,308	2,705,293	3,380.07	Rosebud Coal	Annually	Not Sampled	----	----	A	Upgradient (background) water levels only, Rosebud Coal
ARC52	594,021	2,709,537	3,401.31	Rosebud Coal	Annually	Not Sampled	----	----	A	Upgradient (background) water levels only, Rosebud Coal
ARC53	593,103	2,710,645	3,386.18	Rosebud Coal	Annually	Not Sampled	----	----	A	Upgradient (background) water levels only, Rosebud Coal
ARC66	586,990	2,701,458	3,308.50	Rosebud Coal	Annually	Not Sampled	----	----	A	Upgradient (background) water levels only, Rosebud Coal
AMC20	583,793	2,702,825	3,276.50	McKay Coal	Annually	Annually	Annually	Table 7-4A	A	Downgradient water levels and WQ, McKay Coal
ASM2	584,916	2,705,706	3,233.63	Sub-McKay	Annually	Annually	Annually	Table 7-4A	A	Downgradient water levels and WQ, Sub-McKay
ASMS16	584,060	2,704,845	3,223.16	Sub-McKay	Annually	Annually	Annually	Table 7-4A	A	Downgradient water levels and WQ, Sub-McKay
ASMM27	588,790	2,708,147	3,196.76	Sub-McKay	Annually	Annually	Annually	Table 7-4A	A	Downgradient water levels and WQ, Sub-McKay
ASMM32	590,485	2,710,249	3,238.33	Sub-McKay	Annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, Sub-McKay
ASMM69	590,861	2,706,853	3,251.19	Sub-McKay	Annually	Annually	Annually	Table 7-4A	A	Downgradient water levels and WQ, Sub-McKay
ASMTW1	585,395	2,706,117	3,244.88	Sub-McKay	Semi-annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, Sub-McKay
ASMTW2	585,835	2,706,035	3,243.07	Sub-McKay	Semi-annually	Not Sampled	----	----	A	Downgradient water levels only, Sub-McKay
ASMTW3	585,651	2,706,469	3,250.06	Sub-McKay	Semi-annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, Sub-McKay
ASMTW4	585,386	2,706,409	3,256.43	Sub-McKay	Semi-annually	Annually	Annually	Table 7-4	A	Downgradient water levels and WQ, Sub-McKay
BAL2011	586,790	2,677,621	3,392.60	Alluvium	Quarterly	Semi-annually	Semi-annually	Table 7-4	B	Upgradient (background) water levels and WQ, alluvium
BAL2231	578,818	2,688,879	3,262.00	Alluvium	Quarterly	Not Sampled	----	----	B	Downgradient water levels only, alluvium
BAL2321	583,338	2,684,167	3,314.50	Alluvium	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, alluvium
BAL2361	583,278	2,684,115	3,314.60	Alluvium	Quarterly	Not Sampled	----	----	B	Downgradient water levels only, alluvium
BAL2411	580,269	2,688,607	3,252.80	Alluvium	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, alluvium
BAL2441	580,624	2,688,679	3,257.30	Alluvium	Quarterly	Not Sampled	----	----	B	Downgradient water levels only, alluvium

Table 7-6: Continued.

Station	Northing NAD83 State Plane (ft)	Easting NAD83 State Plane (ft)	Ground Elevation (ft)	Aquifer	Water Level Measured	Water Quality Sampled	Field Parameter Sampled	Water Quality Suite	Mine Area	Purpose
BAL2521	574,702	2,699,386	3,150.00	Alluvium	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, alluvium
BAL2551	574,642	2,699,292	3,151.01	Alluvium	Quarterly	Not Sampled	----	----	B	Downgradient water levels only, alluvium
BAL2611	577,280	2,697,037	3,178.90	Alluvium	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, alluvium
BAL2711	573,308	2,702,687	3,116.05	Alluvium	Annually	Annually	Annually	Table 7-4A	B	Downgradient water levels and WQ, alluvium
BAL3111	571,304	2,706,238	3,083.20	Alluvium	Annually	Annually	Annually	Table 7-4A	B	Downgradient water levels and WQ, alluvium
BAL3511	567,895	2,711,008	3,024.22	Alluvium	Quarterly	Semi-annually	Semi-annually	Table 7-4	B	Downgradient water levels and WQ, alluvium
BAL9031	582,052	2,685,786	3,288.50	Alluvium	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, alluvium
BAL9041	581,183	2,687,058	3,269.90	Alluvium	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, alluvium
BAL9051	579,189	2,691,663	3,230.60	Alluvium	Quarterly	Not Sampled	----	----	B	Downgradient water levels only, alluvium
BAL9061	577,753	2,694,172	3,205.30	Alluvium	Quarterly	Not Sampled	----	----	B	Downgradient water levels only, alluvium
BAL9071	576,696	2,696,769	3,179.40	Alluvium	Quarterly	Not Sampled	----	----	B	Downgradient water levels only, alluvium
BAL9081	578,290	2,697,034	3,199.60	Alluvium	Quarterly	Semi-annually	Semi-annually	Table 7-4	B	Downgradient water levels and WQ, alluvium
BIN1017	580,058	2,698,470	3,316.00	Interburden	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, interburden
BIN117	587,000	2,677,970	3,436.10	Interburden	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, interburden
BIN1317	589,473	2,679,752	3,482.50	Interburden	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, interburden
BIN217	581,583	2,677,807	3,435.10	Interburden	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, interburden
BIN417	577,139	2,680,853	3,487.60	Interburden	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, interburden
BIN517	588,054	2,688,698	3,504.70	Interburden	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, interburden
BIN617	584,603	2,690,575	3,407.50	Interburden	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, interburden
BIN717	574,072	2,688,412	3,401.80	Interburden	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, interburden
BMC1014	580,050	2,698,479	3,315.80	McKay Coal	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, McKay Coal
BMC114	587,008	2,677,965	3,435.70	McKay Coal	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, McKay Coal
BMC1314	589,486	2,679,751	3,482.70	McKay Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, McKay Coal
BMC1514	582,831	2,696,180	3,340.30	McKay Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, McKay Coal
BMC1614	577,921	2,706,469	3,294.30	McKay Coal	Semi-annually	Not Sampled	----	----	B	Upgradient (background) water levels only, McKay Coal
BMC214	581,580	2,677,797	3,435.40	McKay Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, McKay Coal
BMC414	577,129	2,680,863	3,488.30	McKay Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, McKay Coal
BMC514	588,049	2,688,709	3,504.20	McKay Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, McKay Coal
BMC614	584,596	2,690,582	3,407.10	McKay Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, McKay Coal
BMC714	574,104	2,688,413	3,400.90	McKay Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, McKay Coal
BMC9154	577,044	2,680,978	3,484.30	McKay Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, McKay Coal
BOV1012	580,072	2,698,458	3,317.20	Overburden	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, overburden
BOV112	586,985	2,677,982	3,436.50	Overburden	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, overburden
BOV1712	581,129	2,697,064	3,352.77	Overburden	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, overburden
BOV212	581,587	2,677,828	3,434.30	Overburden	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, overburden
BOV412	577,156	2,680,826	3,486.90	Overburden	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, overburden
BOV512	588,064	2,688,680	3,505.20	Overburden	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, overburden
BOV612	584,625	2,690,564	3,408.00	Overburden	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, overburden

Table 7-6: Continued.

Station	Northing NAD83 State Plane (ft)	Easting NAD83 State Plane (ft)	Ground Elevation (ft)	Aquifer	Water Level Measured	Water Quality Sampled	Field Parameter Sampled	Water Quality Suite	Mine Area	Purpose
BOV712	574,063	2,688,411	3,401.90	Overburden	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, overburden
BRC1013	580,065	2,698,464	3,316.80	Rosebud Coal	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, Rosebud Coal
BRC113	586,992	2,677,977	3,446.30	Rosebud Coal	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, Rosebud Coal
BRC1313	589,459	2,679,753	3,482.10	Rosebud Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, Rosebud Coal
BRC1513	582,831	2,696,195	3,341.30	Rosebud Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, Rosebud Coal
BRC1713	581,139	2,697,075	3,352.52	Rosebud Coal	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, Rosebud Coal
BRC213	581,585	2,677,818	3,434.80	Rosebud Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, Rosebud Coal
BRC513	588,058	2,688,689	3,504.70	Rosebud Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, Rosebud Coal
BRC613	584,612	2,690,569	3,407.50	Rosebud Coal	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, Rosebud Coal
BRC713	574,084	2,688,413	3,401.30	Rosebud Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, Rosebud Coal
BRC9163	577,030	2,680,990	3,484.50	Rosebud Coal	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, Rosebud Coal
BSM1015	580,043	2,698,487	3,316.10	SubMcKay	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, SubMcKay
BSM115	587,017	2,677,960	3,435.70	SubMcKay	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, SubMcKay
BSM1215R	580,780	2,685,501	3,352.09	SubMcKay	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, SubMcKay
BSM1715	581,120	2,697,053	3,353.06	SubMcKay	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, SubMcKay
BSM215	581,578	2,677,788	3,435.60	SubMcKay	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, SubMcKay
BSM2215	578,726	2,688,893	3,256.90	SubMcKay	Semi-annually	Not Sampled	----	----	B	Downgradient water levels only, SubMcKay
BSM2415	580,386	2,688,630	3,251.10	SubMcKay	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, SubMcKay
BSM2535	574,592	2,699,223	3,153.62	SubMcKay	Semi-annually	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, SubMcKay
BSM2615	577,280	2,697,046	3,179.30	SubMcKay	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, SubMcKay
BSM2715	573,272	2,702,793	3,115.86	SubMcKay	Annually	Annually	Annually	Table 7-4A	B	Downgradient water levels and WQ, SubMcKay
BSM415	577,118	2,680,873	3,488.70	SubMcKay	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, SubMcKay
BSM515	588,044	2,688,718	3,504.50	SubMcKay	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, SubMcKay
BSM615	584,589	2,690,587	3,407.50	SubMcKay	Annually	Annually	Annually	Table 7-4A	B	Upgradient (background) water levels and WQ, SubMcKay
BSM715	574,112	2,688,413	3,400.60	SubMcKay	Annually	Not Sampled	----	----	B	Upgradient (background) water levels only, SubMcKay
BSM815R	581,010	2,694,171	3,316.05	SubMcKay	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, SubMcKay
BSM9035	582,060	2,685,776	3,288.60	SubMcKay	Quarterly	Not Sampled	----	----	B	Downgradient water levels only, SubMcKay
BSM9055	579,178	2,691,675	3,230.40	SubMcKay	Semi-annually	Annually	Annually	Table 7-4A	B	Downgradient water levels and WQ, SubMcKay
BSM9085	578,277	2,697,037	3,199.86	SubMcKay	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, SubMcKay
BSM9095	580,762	2,689,425	3,261.20	SubMcKay	Semi-annually	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, SubMcKay
BSM915R	577,156	2,680,826	3,261.01	SubMcKay	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, SubMcKay
BSM9265	588,064	2,688,680	3,185.55	SubMcKay	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, SubMcKay
BSP1216	584,625	2,690,564	3,353.28	Spoil	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, spoils
BSP1216R	574,063	2,688,411	3,362.80	Spoil	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, spoils
BSP816	580,993	2,694,192	3,315.33	Spoil	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, spoils
BSP916	575,757	2,694,080	3,261.08	Spoil	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, spoils
BSP9916	582,500	2,690,655	3,374.56	Spoil	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, spoils
BSP9926R	582,223	2,694,227	3,294.20	Spoil	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, spoils

Table 7-6: Continued.

Station	Northing NAD83 State Plane (ft)	Easting NAD83 State Plane (ft)	Ground Elevation (ft)	Aquifer	Water Level Measured	Water Quality Sampled	Field Parameter Sampled	Water Quality Suite	Mine Area	Purpose
BSP9936	577,122	2,685,877	3,349.01	Spoil	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, spoils
BSP9946R	576,663	2,688,457	3,297.20	Spoil	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, spoils
BSP9956	577,371	2,688,608	3,297.63	Spoil	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, spoils
BSP9966	582,769	2,686,242	3,323.10	Spoil	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, spoils
BSP9976	581,839	2,681,732	3,354.70	Spoil	Quarterly	Annually	Annually	Table 7-4	B	Downgradient water levels and WQ, spoils

Table 8-1: A comparison of flood-frequency estimates (in cfs).
Peak flows are calculated from a Log Pearson Type 3 fitted curve. Shaded rows indicate stations which have a significantly mine-impacted basin upstream of the station during data collection.
* Sites monitored by Rosebud or Big Sky mines with flows reported as average daily flows. The flood-frequency calculations consequently are maximum average daily flow.
** For the ungauged drainage basins, the 90% prediction interval of peak flows is calculated using the USGS method of estimation given in Parrett and Johnson (2004). Note that these estimates are based only on basin and climate characteristics.

				Return Period (years)											
Drainage	**USGS Number**	**Basin Size (sq. mi.)**	**Years of Record**	**2**		**5**		**10**		**25**		**50**		**100**	
Rosebud Creek	6296003	1302	32	314		665		1072		1936		2972		4518	
Armells Creek	6294995	370	18	134		561		1231		3062		5782		10615	
Headwaters EFAC**		48.2		38	562	150	1340	299	2130	574	3490	830	4900	1110	6770
SW-55 – EFAC*		34	31	0		2		5		16		38		90	
Cow Creek **		31.8		27	396	109	967	219	1550	424	2570	617	3640	833	5050
Stocker Creek **		26.2		23	337	93	830	189	1340	368	2230	537	3160	728	4410
Spring Creek **		22.3		20	295	82	732	167	1180	327	1980	479	2820	650	3940
Lee Coulee**		20.6		19	276	77	688	157	1110	308	1870	452	2660	615	3720
B33FL - Lee Coulee*		16.0	27	1		6		16		55		131		299	
Pony Creek **		14.2		14	202	58	514	119	841	235	1420	346	2040	473	2870
Upper WFAC**		13.7		14	196	56	500	116	818	229	1390	338	1990	462	2800
Miller Coulee**		13.1		13	189	54	483	112	791	221	1340	327	1930	447	2710
East Cabin Creek Tributary	6294600	8.6	40	21		66		125		267		453		753	
SW-75 - Upper EFAC*		7.8	29	0		3		9		33		82		192	
SW-65 - Stocker Creek *		7.2	29	1		7		12		19		25		31	
Hay Coulee**		6.4		7	104	31	276	65	461	131	795	195	1160	270	1650
Sarpy Creek Tributary	6294930	4.4	41	16		46		93		229		443		849	
EFAC Tributary	6294985	1.9	39	40		111		185		326		478		685	

Table 8-2: Summary of transmissivity and hydraulic conductivity values for aquifer test in the Rosebud Mine area (MDSL and OSMRE, 1982; MDSL and OSMRE, 1983).

	TRANSMISSIVITY				HYDRAULIC CONDUCTIVITY			
Aquifer	**Number of Tests**	**Range (gpd/ft)**	**Mean (gpd/ft)**	**Median (gpd/ft)**	**Number of Tests**	**Range (ft/day)**	**Mean (ft/day)**	**Median (ft/day)**
Alluvium EFAC	25	6.0-74,800	12,600	9,900	23	6.4-501.3	119.500	102.5
Alluvium Stocker Ck.	6	2,200-50,000	18,900	5,300	*	*	*	*
Alluvium Cow Ck.	4	190-49,500	(increased	downstream)	4	60-2,800	2,600(mid-reach)	*
Overburden	23	1.0-79,000	8,950	57	12	0.006-3.8	0.468	0.015
Rosebud Coal	35	3-12,700	526	30	35	0.005-68	5.170	0.120
Interburden	8	1.0-210	43	6	8	0.002-0.9	0.150	0.014
McKay Coal	24	1-560	146	104	18	0.002-3.6	0.724	0.150
Sub-McKay	6	90-3,200	860	470	----	----	----	----
Spoil	17	0.24-23,400	2,000	61	17	0.001-65.3	6.020	0.3

*Conductivity values not calculated due to lack of information.
---- No data available

Table 8-3: Summary of transmissivity and hydraulic conductivity values for aquifer tests in the Big Sky Mine area (BSCC, 1988).

	TRANSMISSIVITY				HYDRAULIC CONDUCTIVITY				STORAGE COEFFICIENT			
Aquifer	**No. of Tests**	**Range (ft^2/d)***	**Arithmetic Mean (ft^2/d)***	**Geometric Mean (ft^2/d)***	**No. of Tests**	**Range (ft/d)**	**Arithmetic Mean (ft/d)**	**Geometric Mean (ft/d)**	**No. of Tests**	**Range**	**Arithmetic Mean**	**Geometric Mean**
Alluvium	5	196 – 520	226.2	225.5	5	10.9 – 13.9	12.18	12.13	5	7.2×10^{-4} – 4.92×10^{-3}	1.91×10^{-3}	4.16×10^{-3}
Overburden	3	19.4 – 29.0	23.7	23.4	3	0.73 – 0.97	12.8	12.3	3	6.4×10^{-4}	1.11×10^{-3}	1.04×10^{-3}
Rosebud Coal	4	4.8 – 11.2	7.78	7.44	4	0.20 – 0.42	0.31	0.29	3	9.7×10^{-4} – 7.6×10^{-3}	4.42×10^{-3}	9.22×10^{-5}
Interburden	3	0.50 – 28.0	13.1	5.33	4	0.01	0.301	0.088	2	10^{-5} – 8.5×10^{-4}	$4.3x\ 10^{-4}$	9.22×10^{-5}
McKay Coal	3	1.44 – 1.82	1.69	1.68	3	0.24 – 0.32	0.29	0.28	3	10^{-5}	10^{-5}	10^{-5}
Sub-McKay	3	0.5 – 2.55	1.35	1.08	3	0.015 – 0.085	0.047	0.040	3	10^{-5} – 7.22×10^{-4}	$2.47 \times ^{-4}$	4.16×10^{-5}

*To convert ft^2/day to gpd/ft multiply ft^2/day by 7.481 gallons.

Table 9-1: Alluvial Valley Floor (AVF) determinations at the Rosebud Mine and Big Sky Mine.

AVF Investigation	Decision Date	Mine	Location	Decision Y/N
Coal Bank Coulee [MDSL, 1982 (1)]	October 1982	Big Sky Mine Area A	Big Sky Mine Area A	**N:** Failure to meet geomorphic criteria for a stream channel.
Lee Coulee (MDSL, 1986)	March 1986	Big Sky Mine Area B	Headwaters to confluence with Rosebud Creek.	**N:** Determined to be an upland area based on geologic and hydrologic criteria.
East Fork Armells Creek (MDSL, 1981)	December 1981	Rosebud Mine Area C	Highway 39 crossing (Sec. 3, T1N, R41E) to west end of Area C (Sec. 17, T1N, R40E)	**N:** Insufficient water to support agriculture
East Fork Armells Creek [MDSL, 1984 (2)]	1984	Rosebud Mine Area C	**1)** Highway 39 crossing (Sec. 3, T1N, R41E) north to confluence of Stocker Ck. (Sec. 16, T2N, R41E) **2)** Stocker Ck. (Sec. 16, T2N, R41E) north to confluence of Corral Ck (Sec. 28, T3N, R41E)	**1) N:** Insufficient water to support agriculture **2) Y:** Yes
Portion of Stocker Creek [MDSL, 1982 (2)]	June 1982	Rosebud Mine Area C	Headwaters to corner section of Sec. 23, 24, 26, 26, T2N, R40E	**N:** Insufficient water to support agriculture
Portions of Stocker Creek and East Fork Armells Creek [MDSL, 1984 (1)]	February 1984	Rosebud Mine Area C	Corner section of Sec. 23, 24, 26, 26, T2N, R40E to confluence with East Fork Armells Creek	**N:** Stocker Ck: Insufficient water to support agriculture
Portions of Pony, Spring and Cow Creeks [MDSL, 1984 (3)]	August 1984	Rosebud Mine Area D	Within and adjacent to proposed Area D permit area	Pony Creek: **N:** Insufficient water to support agriculture. Spring Creek: **N:** Insufficient water to support agriculture. Cow Creek: **N:** Headwaters to Section 31. Insufficient water to support agriculture. **Y:** Section 31 to corner of Sections 4, 5, 32, 33, T2N, R42E. Sufficient water to support agriculture.

Table 9-2: Life of mine (LOM) disturbance area and permit area for current and proposed mining activities.
The permit area and disturbance area do not include pre-law mining. Areas are calculated against premine drainage basins, and the calculated acreages for each category may differ from the acreages presented in the permit application due to differences in the delineation of drainage basins. The premine drainage basins used to calculate area are shown in **Figure 9-9**.

Drainage Basin	Pre-mine Drainage Area		Approved LOM Disturbance		App. 184 LOM Disturbance		Total LOM Area		Approved Permit Area		App. 184 Permit Area		Total Permit Area	
	sq. mi.		sq. mi.	% of basin	sq. mi.	% of basin	sq. mi.	% of basin	sq. mi.	% of basin	sq. mi.	% of basin	sq. mi.	% of basin
Armells Creek	371		29	8	0.3	0	29	8	32	9	0.1	0	33	9
East Fork Armells Creek (EFAC)	155		26	17	0.3	0	26	17	29	19	0.1	0	29	19
Stocker Creek	26		8	29	0	0	8	29	9	34	0	0	9	34
Headwaters EFAC	48		18	38	0.3	1	18	38	20	42	0.1	0	20	42
West Fork Armells Creek (WFAC)	216		3	1	0	0	3	1	3	2	0	0	3	2
Upper WFAC	14		3	19	0	0	3	19	3	23	0	0	3	23
Robbie Creek	32		0	0	0	0	0	0	0	0	0	0	0	0
Rosebud Creek	1,307		14	1	0	0	14	1	20	2	0	0	20	2
Spring Creek	22		1	4	0	0	1	4	1	5	0	0	1	5
Pony Creek	14		2	11	0	0	2	11	2	13	0	0	2	13
Cow Creek	32		3	9	0	0	3	9	5	14	0	0	5	14
Hay Coulee	6		0	4	0	0	0	4	0	4	0	0	0	4
Miller Coulee	13		3	19	0	0	3	19	4	28	0	0	4	28
Lee Coulee	21		6	27	0	0	6	27	9	43	0	0	9	43

Table 9-3: Change in drainage basin area from mining at the Rosebud and Big Sky mines.						
Drainage Basin		Premine Drainage Area	Approved Postmine Drainage Area		Approved + Proposed Postmine Drainage Area	
		sq. mi.	sq. mi.	% change	sq. mi.	% change
Armells Creek		370.8	370.9	0.0	370.9	0.0
	EFAC	154.7	154.7	0.1	154.7	0.1
	Stocker Creek	26.2	26.3	0.2	26.3	0.2
	Headwaters EFAC	48.2	48.2	0.1	48.2	0.1
	WFAC + mainstem	216.1	216.1	0.0	216.1	0.0
	Upper WFAC	13.7	13.7	0.0	13.7	0.0
	Robbie Creek	31.6	31.6	0.0	31.6	0.0
Rosebud Creek		1307.0	1306.9	0.0	1306.9	0.0
	Spring Creek	22.3	22.3	0.3	22.3	0.3
	Pony Creek	14.2	14.2	0.0	14.2	0.0
	Cow Creek	31.8	31.6	-0.8	31.6	-0.8
	Hay Coulee	6.4	6.4	0.1	6.4	0.1
	Miller Coulee	13.1	13.1	0.0	13.1	0.0
	Lee Coulee	20.6	20.7	0.5	20.7	0.5

Table 9-4: Estimated maximum discharge and runoff volumes derived from HEC-HMS modeling of NRCS Type II Storms.
The models show only the hydrograph response to changes to stream length, drainage basin size, channel slope, and infiltration rates. Postmine scenarios assume at least 10 years of vegetation (all of the mine meets Phase III bond release requirements and have fully established vegetative communities). See Appendix B for more details on the model.

		East Fork Armells Creek					Stocker Creek			West Fork Armells Creek			Cow Creek			Spring Creek		
	Scenario	Premine	Postmine Approved	Postmine AM 184	% Change Approved	% Change AM 184	Premine	Postmine Approved	% Change	Premine	Postmine Approved	% Change	Premine	Postmine Approved	% Change	Premine	Postmine Approved	% Change
2-yr 24-hr (1.5 in.)	Peak Discharge (cfs)	84	74	74	-13	-12	58	48	-17	6	7	28	88	87	-1	104	103	-1
	Time of Peak (hrs)	26.4	27.8	26.9	5	2	15.1	17.1	14	24.3	24.5	1	19.4	17.8	-8	18.8	19.7	5
	Runoff Vol (ac-ft)	123	102	101	-17	-18	57	53	-7	5	3	-44	104	100	-4	116	113	-2
10-yr 24-hr (2.45 in.)	Peak Discharge (cfs)	581	553	562	-5	-3	510	403	-21	121	146	21	560	555	-1	552	541	-2
	Time of Peak (hrs)	25.8	26.7	25.7	3	0	14.1	16.0	13	16.0	16.0	0	19.6	19.5	-1	18.3	19.3	6
	Runoff Vol (ac-ft)	776	743	740	-4	-5	401	397	-1	99	110	11	572	565	-1	534	525	-2
25-yr 24-hr (3.0 in.)	Peak Discharge (cfs)	1039	998	1014	-4	-2	946	757	-20	299	345	15	1017	1015	0	943	923	-2
	Time of Peak (hrs)	25.7	26.5	25.5	3	-1	14.1	16.1	14	15.5	15.7	1	19.5	19.4	-1	18.2	19.3	6
	Runoff Vol (ac-ft)	1359	1325	1321	-3	-3	715	712	0	207	224	8	980	971	-1	871	858	-1
100-yr 24-hr (3.8 in.)	Peak Discharge (cfs)	1867	1805	1834	-3	-2	1741	1418	-19	697	775	11	1864	1868	0	1631	1598	-2
	Time of Peak (hrs)	25.6	26.3	25.4	3	-1	14.1	16.3	16	15.3	15.5	1	19.5	19.4	0	18.1	19.2	6
	Runoff Vol (ac-ft)	2403	2370	2365	-1	-2	1280	1278	0	420	446	6	1700	1688	-1	1445	1427	-1

Table 9-4 continued.

		Pony Creek			Lee Coulee			Miller Coulee			Hay Coulee		
	Scenario	Premine	Postmine Approved	% Change	Premine	Postmine Approved	% Change	Premine	Postmine Approved	% Change	Premine	Postmine Approved	% Change
2-yr 24-hr (1.5 in.)	Peak Discharge (cfs)	32	32	0	41	37	-11	23	25	6	14	13	0
	Time of Peak (hrs)	14.6	14.6	0	19.9	19.9	0	13.5	13.4	-1	12.8	12.8	0
	Runoff Vol (ac-ft)	34	30	-11	39	35	-11	16	16	2	9	9	0
10-yr 24-hr (2.45 in.)	Peak Discharge (cfs)	291	272	-7	353	369	5	211	208	-1	116	116	0
	Time of Peak (hrs)	16.8	16.2	-4	18.2	17.9	-1	13.2	13.2	0	15.0	14.9	0
	Runoff Vol (ac-ft)	231	218	-6	301	294	-2	151	152	0	82	83	0
25-yr 24-hr (3.0 in.)	Peak Discharge (cfs)	566	534	-6	667	717	7	415	409	-1	251	252	0
	Time of Peak (hrs)	16.6	16.1	-3	17.8	17.5	-2	15.7	15.8	1	14.7	14.7	0
	Runoff Vol (ac-ft)	408	390	-4	543	535	-1	287	287	0	153	153	0
100-yr 24-hr (3.8 in.)	Peak Discharge (cfs)	1087	1035	-5	1267	1387	9	894	879	-2	526	528	0
	Time of Peak (hrs)	16.4	16.1	-2	17.4	17.2	-1	15.6	15.7	1	14.6	14.5	0
	Runoff Vol (ac-ft)	723	698	-4	980	973	-1	540	540	0	282	283	0

Table 9-5: MPDES water quality exceedences since 2010.

MPDES Outfall	Date	Drainage	Analyte in Violation	Measured Concentration	Effluent Limit	DEQ Action
OF-100	7/23/2010	WFAC	Total Settleable Solids (mL/L)	7	0.5	No violation given
OF-100	5/20/2011	WFAC	Total Settleable Solids (mL/L)	175	0.5	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-105	5/20/2011	WFAC	Total Settleable Solids (mL/L)	1.2	0.5	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-095A	5/23/2011	WFAC	Total Boron (mg/L)	0.75	0.6	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-095A	5/23/2011	WFAC	Sulfate (mg/L)	2370	2250	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-63	5/26/2011	EFAC	Total Dissolved Solids (mg/L)	5510	4500	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-095A	6/1/2011	WFAC	Total Boron (mg/L)	0.75	0.6	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-167	6/1/2011	Pony Crk.	Total Dissolved Solids (mg/L)	3990	EC = 500 uS/cm	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-167	6/1/2011	Pony Crk.	Sulfate (mg/L)	2640	2325	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-101	6/1/2011	WFAC	Total Dissolved Solids (mg/L)	4380	3900	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-101	6/1/2011	WFAC	Sulfate (mg/L)	3180	2250	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-59	6/1/2011	EFAC	Sulfate (mg/L)	3320	3075	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-95	6/24/2011	WFAC	Total Boron (mg/L)	1.6	0.6	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-95	6/24/2011	WFAC	Total Dissolved Solids (mg/L)	6580	3900	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-95	6/24/2011	WFAC	Sulfate (mg/L)	4430	2250	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-100	6/24/2011	WFAC	Total Dissolved Solids (mg/L)	4160	3900	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-100	6/24/2011	WFAC	Sulfate (mg/L)	2530	2250	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-70	6/29/2011	Stocker Crk.	Total Boron (mg/L)	2.4	1.5	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-70	10/4/2011	Stocker Crk.	Total Boron (mg/L)	1.9	1.5	During the heavy rains, flooding, and state of emergency declarations in spring/summer 2011, DEQ used enforcement discretion and did not issue violations for effluent limitations exceedences.
OF-032	6/17/2014	Stocker Crk.	Total Suspended Solids (mg/L)	81	70	Violation given
OF-019	4/12/2015	EFAC	Total Suspended Solids (mg/L)	140	70	Violation given

Table 9-6: Fraction of surface water quality samples from ephemeral stream reaches that exceed Human Health Standards of Circular DEQ-7 or guideline livestock thresholds.
Analysis includes spring, pond, and stream data. Exceedences shown as a ratio: # of exceedences / # of samples analyzed
Sites are listed as 'baseline' (sample taken before mining started upstream) or 'mining' (sample taken after mining started upstream).

	Analytes with DEQ-7 Human Health Limit for Surface Water									Analytes with Guideline Livestock Thresholds (no DEQ-7 limit)											
	Total As >= 0.01	Total Cd >= 0.005	Total Cu >= 1.3	F >= 4	Total Pb >= 0.015	Total Ni >= 0.1	NO3+NO2 >= 10	Total Se >= 0.05	Total Zn >= 2	TDS >= 3000	Alk. >= 1000	Diss. Al >= 5	B >= 5	Bicarb. >= 1000	Cl >= 100	Ca >= 100	Mg >= 50	Total Mn >= 0.05	Na >= 50	SO4, Hardness & Cl Limit	Total V >= 0.05
Cow Creek, Baseline	0/0	3/50	0/50	0/60	7/50	0/0	0/62	0/49	0/50	15/61	0/58	0/60	2/61	0/62	0/63	43/63	46/63	8/16	22/63	62/63	3/50
Cow Creek, Mining	0/8	18/166	0/167	0/194	27/167	0/5	3/203	0/169	0/167	51/211	0/195	0/182	0/188	1/207	17/208	124/208	133/208	15/24	77/208	197/208	6/168
EFAC, Baseline	0/4	10/109	0/109	0/114	33/108	0/0	0/116	0/100	0/109	27/117	1/119	2/93	0/109	1/124	1/124	47/124	54/124	4/6	52/124	115/123	9/101
EFAC, Mining	0/18	23/287	0/286	0/318	60/286	0/7	10/320	0/288	1/287	36/373	0/323	0/296	0/359	3/323	21/324	172/324	206/324	30/36	142/324	320/323	17/286
Hay Coulee, Mining	0/1	0/8	0/8	0/8	4/8	0/0	0/10	0/8	0/8	0/12	0/8	0/8	0/10	0/10	0/10	0/10	0/10	0/0	0/10	224/225	0/8
Lee Coulee, Baseline	6/145	17/149	0/149	0/157	0/9	4/145	0/157	0/149	0/147	40/230	1/163	0/157	0/157	3/161	1/160	88/163	116/161	75/143	99/161	149/160	2/149
Lee Coulee, Mining	1/35	0/36	0/36	0/38	0/7	1/36	0/38	0/36	1/34	8/39	0/39	0/38	0/38	0/39	0/39	28/39	27/39	17/36	27/39	37/39	1/36
Miller Coulee, Mining	2/60	6/61	0/44	0/74	3/60	0/60	0/74	0/60	0/60	12/73	0/74	0/63	0/64	0/70	10/74	54/75	53/71	10/44	53/75	70/74	0/60
Pony Creek, Baseline	0/0	4/19	0/19	0/20	2/19	0/0	0/22	0/19	0/18	8/23	0/18	1/20	3/21	0/23	0/23	20/23	19/23	0/0	10/23	23/23	0/19
Pony Creek, Mining	0/2	1/48	0/50	0/51	3/50	0/1	1/50	1/50	0/49	31/49	0/55	1/49	22/55	1/52	1/55	47/55	45/55	9/27	40/55	54/55	6/50
Spring Creek, Baseline	0/0	1/16	0/16	0/16	1/16	0/0	0/16	0/16	0/16	6/18	0/19	0/16	2/17	0/19	0/19	11/19	13/19	7/8	9/19	15/19	2/16
Spring Creek, Mining	0/2	0/48	0/49	0/57	0/49	0/2	14/57	1/54	0/50	26/56	0/57	0/56	9/58	0/54	0/58	50/58	58/58	39/48	31/58	54/58	3/50
Stocker Creek, Baseline	0/0	8/34	0/34	0/39	6/34	0/0	1/44	0/34	0/34	11/46	0/41	0/34	0/41	0/50	2/50	12/50	16/50	0/0	14/50	42/50	3/34
Stocker Creek, Mining	0/2	2/60	0/59	0/67	7/61	0/1	2/67	0/61	0/61	9/121	1/84	2/66	0/128	0/84	1/84	56/85	59/85	5/5	22/84	81/84	3/60
WFAC, Baseline	0/0	2/97	0/97	0/112	6/97	0/0	0/113	0/99	0/97	13/107	0/115	0/112	0/115	3/113	0/116	72/116	109/116	54/78	99/116	108/116	7/97
WFAC, Mining	0/4	1/53	0/53	0/58	1/53	0/2	0/62	0/55	0/53	2/63	0/62	0/58	0/62	0/61	0/66	37/66	57/66	35/47	51/66	62/66	1/53

Table 9-7: Fraction of surface water quality samples from perennial or intermittent stream reaches that exceed Human Health Standards of Circular DEQ-7, Aquatic Life Standards of Circular DEQ-7, or guideline livestock thresholds.
Analysis includes spring, pond, and stream data from in-stream sources. Exceedences shown as a ratio: # of exceedences / # of samples analyzed
For DEQ-7 standards, the smallest limit is used for comparison: chronic aquatic, acute aquatic, or human health.
Sites are listed as 'baseline' (sample taken before mining started upstream) or 'mining' (sample taken after mining started upstream).

	Analytes with DEQ-7 Human Health or Aquatic Life Limit for Surface Water											Analytes with Guideline Livestock Thresholds (no DEQ-7 limit)										
	Diss. Al >= 0.087	Total As >= 0.01	Total Cd, Hardness Limit	Total Cu, Hardness Limit	Total Fe >= 1	F >= 4	Total Pb, Hardness Limit	Total Ni, Hardness Limit	NO3+ NO2 >= 10	Total Se >= 0.005	Total Zn, Hardness Limit	TDS >= 3000	Alk. >= 1000	B >= 5	Bicarb. >= 1000	Cl >= 100	Ca >= 100	Mg >= 50	Total Mn >= 0.05	Na >= 50	SO4, Hardness & Cl Limit	Total V >= 0.05
Rosebud Creek, Baseline	7/144	0/152	44/151	3/152	30/154	0/225	0/9	0/152	0/224	19/154	3/147	2/133	0/223	0/225	0/177	0/225	23/223	223/225	66/154	217/225	1/225	1/131
Rosebud Creek, Mining	4/69	0/66	2/67	0/67	16/68	0/69	0/9	0/67	0/69	0/69	0/65	1/69	0/69	0/69	0/68	0/69	9/69	69/69	31/67	68/69	1/69	1/67
EFAC near SW-55, Baseline	0/0	0/0	0/0	0/0	0/2	0/2	0/0	0/0	0/2	0/0	0/0	0/2	0/2	0/0	0/2	0/2	2/2	2/2	0/0	2/2	0/2	0/0
EFAC near SW-55, Mining	9/30	0/5	4/30	8/30	14/35	0/44	3/30	0/5	0/46	4/30	12/30	9/50	2/48	0/48	0/51	16/51	30/51	33/51	8/8	28/51	6/51	1/30
EFAC through Colstrip, Mining	19/56	0/5	8/59	0/59	28/59	0/61	0/59	0/0	12/61	10/55	3/58	31/61	0/61	2/60	0/61	4/61	59/61	60/61	0/0	60/61	24/61	0/58
Stocker Crk near SW-65, Baseline	4/7	0/0	3/7	0/7	3/7	0/7	1/7	0/0	0/7	1/7	2/7	5/7	0/7	0/7	0/7	0/7	5/7	5/7	0/0	5/7	3/7	0/7
Stocker Crk near SW-65, Mining	8/25	0/0	6/25	10/25	19/38	0/25	7/25	0/0	1/28	7/25	5/25	10/38	1/36	0/36	1/43	0/43	27/43	39/43	12/14	39/43	14/43	6/25
Lee Coulee Wet Reach, Baseline	4/81	3/78	23/78	0/77	4/79	0/81	0/5	0/78	0/81	8/80	0/77	52/155	1/82	0/81	3/82	0/82	58/82	80/82	25/77	78/82	19/82	0/78
Lee Coulee Wet Reach, Mining	0/22	0/22	0/6	0/6	0/6	0/22	0/0	0/6	0/22	0/22	0/4	46/78	0/22	0/22	0/6	0/6	5/22	5/6	2/6	4/6	1/6	0/22

Table 9-8: Surface water station and date of exceedance for samples that exceeded a DEQ-7 Human Health Standard.
Analytes are compared to the limit for total, if available, otherwise dissolved.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Site	Date	0.005	Site	Date	1.3	Site	Date	4	Site	Date	0.015	Site	Date	0.1	Site	Date	0.05	Site	Date	2	Site	Date	10	Site	Date
	0.01	APD7400	Dec-84	0.02	BUSGS-RC	Oct-74	1.75	CG-65	Mar-94	none			0.03	SW-91	Apr-79	0.156	BLFFL	May-87	0.05	SW-65	Jan-99	2.52	PO-010	Jun-87	10.6	PI-02	Mar-73
	0.014	BS33FL	Feb-85	0.067	BUSGS-RC	Aug-76							0.03	SW-26	Mar-80	0.16	BLFFL	Jun-88	0.12	SP-91	Jun-11	420	BLFFL	May-96	38.05	PI-15	Nov-79
	0.011	BBIO1	Jul-85	0.015	SW-91	May-77							0.03	PO-905	Jun-80	0.12	BLFFL	May-96	0.05	PO-917	Nov-11				10.09	SW-01	Sep-80
	0.026	BLFFL	May-87	0.008	SW-91	Aug-78							0.02	SW-09	Jun-80	0.137	BS33FL	May-87							12.38	SP-02	Nov-80
	0.016	BPSFL	May-87	0.007	PO-901	Sep-78							0.02	PI-11	Jan-81	0.116	BS33FL	Jun-88							10	SW-01	Feb-81
	0.025	BS33FL	May-87	0.007	PO-010	Sep-78							0.02	SW-26	Feb-81										10.72	SW-01	Mar-81
	0.013	BRTFL	May-88	0.017	SW-1A	Sep-79							0.03	SW-60	Feb-81										15.29	SW-01	Jul-81
	0.018	BLFFL	Jun-88	0.008	SW-9A	Sep-79							0.04	SW-55	Feb-81										11.32	SW-01	Sep-81
	0.014	BS33FL	Mar-89	0.005	SW-24	Jun-80							0.02	PO-013	Feb-81										51.82	PO-012	Dec-81
	0.011	BRTFL	Oct-93	0.005	PI-11	Jan-81							0.02	PO-909	Feb-81										15.2	SW-01	Dec-81
	0.014	ASW70A	Jan-96	0.005	PO-013	Feb-81							0.02	SP-06	Feb-81										11.18	SW-01	Jun-82
	0.032	BLFFL	May-96	0.005	PO-909	Feb-81							0.03	SW-64	May-81										27.8	PO-010	Jun-82
				0.005	SP-06	Feb-81							0.13	SW-35	May-81										48.43	PO-012	Sep-82
				0.005	SW-64	May-81							0.13	SW-60	May-81										14.08	SW-01	Sep-82
				0.037	PO-011	Jul-81							0.02	PI-13	Jun-81										26.87	PO-012	Jan-83
				0.019	SW-02A	Dec-81							0.02	PO-010	Jun-81										14.58	SW-01	Jan-83
				0.043	PO-014	Feb-82							0.04	PO-009	Jul-81										18.5	SW-01	Apr-83
				0.063	SW-30	Feb-82							0.03	PO-08W	Jul-81										11.3	SW-01	Sep-83
				0.087	BUSGS-RC	Apr-82							0.05	PO-011	Dec-81										12.1	SW-66	Apr-84
				0.005	SW-65	Jun-82							0.02	PO-911	Dec-81										15	PO-016	Feb-85
				0.007	CC-4	Jun-82							0.07	PO-014	Feb-82										32	PO-012	Jan-86
				0.006	SP-17	Jun-82							0.03	PO-009	Feb-82										19.5	PI-14	Jul-86
				0.005	EFAC-8	Jun-82							0.12	PO-004	Mar-82										13.8	PO-022	Sep-86
				0.017	PO-917	Jun-82							0.09	SW-62	May-82										10.8	PO-71C	Apr-89
				0.006	SW-40	Jun-82							0.21	SW-65	Jun-82										11	SW-01	Jan-90
				0.009	SW-1A	Jun-82							0.05	CC-4	Jun-82										11.4	PO-71C	Aug-90
				0.005	PO-005	Jun-82							0.08	SW-68	Jun-82										12.2	PO-027	Aug-90
				0.006	SW-2A	Jun-82							0.05	PO-022	Jun-82										28.9	PO-072	Aug-91
				0.005	SW-40	Aug-82							0.06	SW-60	Jun-82										18.7	SW-65	Jul-07
				0.005	SW-02A	Dec-82							0.03	SW-9A	Jun-82										14.5	PO-917	Nov-11
				0.008	PO-016	Dec-82							0.04	PO-027	Jun-82												
				0.005	SW-65	May-83							0.04	PO-905	Jun-82												
				0.02	PO-013	Sep-83							0.04	SW-1A	Jun-82												
				0.014	SW-81	Jan-84							0.02	PO-002	Jun-82												
				0.012	SW-61	Jan-84							0.02	PO-010	Jun-82												
				0.006	SW-102	Jan-84							0.02	PO-011	Jun-82												
				0.007	SW-112	Jan-84							0.02	PO-014	Jun-82												
				0.006	SW-115	Jan-84							0.13	SW-82	Jul-82												
				0.005	SW-104	Jan-84							0.02	SW-40	Aug-82												
				0.005	SW-105	Jan-84							0.04	PO-012	Sep-82												
				0.005	SW-103	Jan-84							0.03	SW-02A	Dec-82												

Table 9-8: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Site	Date	0.005	Site	Date	1.3	Site	Date	4	Site	Date	0.015	Site	Date	0.1	Site	Date	0.05	Site	Date	2	Site	Date	10	Site	Date
				0.011	SW-106	Jan-84							0.02	PO-010	Jan-83												
				0.007	SW-107	Jan-84							0.04	PO-001	Jan-83												
				0.011	SW-108	Jan-84							0.02	SP-36	May-83												
				0.009	SW-110	Jan-84							0.03	SW-30	May-83												
				0.017	SW-111	Jan-84							0.03	SW-60	May-83												
				0.007	SW-97	Jan-84							0.07	SW-61	May-83												
				0.045	ACG3	May-84							0.02	SW-55	May-83												
				0.045	ASS3-1	May-84							0.04	SW-1A	Jul-83												
				0.005	PO-010	Jun-84							0.02	SW-103	Jan-84												
				0.006	BS33FL	Jun-84							0.03	PO-014	Jan-84												
				0.006	BUDPD	Jun-84							0.03	SW-106	Jan-84												
				0.005	BRTFL	Jun-84							0.07	SW-108	Jan-84												
				0.006	SW-1A	Aug-84							0.03	SW-110	Jan-84												
				0.005	SW-2A	Aug-84							0.09	SW-111	Jan-84												
				0.005	BRTFL	Oct-84							0.06	SW-127	May-84												
				0.007	SP-14	Nov-84							0.08	SW-124	May-84												
				0.005	APD7400	Dec-84							0.02	PO-032	May-84												
				0.007	ADNR2	Dec-84							0.02	PO-033	May-84												
				0.006	PI-08	Jan-85							0.04	SW-128	May-84												
				0.005	PI-19	Jan-85							0.04	PO-046	May-84												
				0.006	PO-914	Jan-85							0.02	APD-L	May-84												
				0.01	BLRCXS	Jan-85							0.19	CC-4	Jun-84												
				0.008	PO-027	Feb-85							0.03	PO-005	Jun-84												
				0.007	PO-905	Feb-85							0.53	SW-131	Jun-84												
				0.006	BLLCXS	Feb-85							0.18	SW-132	Jun-84												
				0.005	SW-147	Mar-85							0.42	SW-64	Jun-84												
				0.007	PO-009	Mar-85							0.08	SW-66	Jun-84												
				0.007	PO-024	Mar-85							0.33	SW-81	Jun-84												
				0.007	PO-04A	Mar-85							0.83	PO-010	Jun-84												
				0.015	CG-08	Mar-85							0.06	SW-84	Jun-84												
				0.011	SW-65	Mar-85							0.67	SW-116	Jun-84												
				0.008	CG-19	Mar-85							0.05	SW-117	Jun-84												
				0.007	SW-152	Mar-85							0.07	SW-118	Jun-84												
				0.007	BPPSG	Apr-85							0.22	PO-001	Jun-84												
				0.011	BRTFL	Apr-85							0.07	SW-60	Jun-84												
				0.014	BLLCXS	Apr-85							0.11	SW-135	Jun-84												
				0.007	BURCXS	Apr-85							0.02	PO-920	Jun-84												
				0.006	BBIO1	Jun-85							1.61	SW-114	Jun-84												
				0.006	BRSG	Jun-85							2.83	SW-136	Jun-84												
				0.007	BGDSG	Jun-85							0.02	BBIO1	Jun-84												
				0.01	ATWPD27	Jul-85							0.016	BRTFL	Jun-84												
				0.013	ATWPD28	Jul-85							0.03	CG-13	Aug-84												

Table 9-8: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Site	Date	0.005	Site	Date	1.3	Site	Date	4	Site	Date	0.015	Site	Date	0.1	Site	Date	0.05	Site	Date	2	Site	Date	10	Site	Date
				0.012	BBIO1	Jul-85							0.02	PO-009	Aug-84												
				0.005	BLRCXS	Jul-85							0.47	PO-010	Aug-84												
				0.011	BURCXS	Jul-85							0.03	PO-012	Aug-84												
				0.006	PO-027	Aug-85							0.02	PO-11A	Aug-84												
				0.006	PO-905	Aug-85							0.06	SW-108	Aug-84												
				0.012	PO-907	Aug-85							0.06	SW-109	Aug-84												
				0.009	SW-1A	Aug-85							0.12	SW-116	Aug-84												
				0.006	SW-2A	Aug-85							0.25	SW-124	Aug-84												
				0.032	PO-032	Aug-85							0.17	SW-1A	Aug-84												
				0.007	BGDSG	Aug-85							0.02	SW-01	Aug-84												
				0.015	BHWSG	Aug-85							0.02	SP-27	Sep-84												
				0.009	BPPSG	Aug-85							1.34	SP-40	Oct-84												
				0.012	BBIO1	Aug-85							0.05	PO-914	Jan-85												
				0.009	BLRCXS	Aug-85							0.2	PO-027	Feb-85												
				0.013	BURCXS	Aug-85							4.92	PO-011	Feb-85												
				0.012	BRSG	Aug-85							0.42	PO-012	Feb-85												
				0.009	BURCXS	Sep-85							0.09	PO-013	Feb-85												
				0.012	BPPSG	Oct-85							0.24	PO-014	Feb-85												
				0.007	BRTFL	Oct-85							0.75	PO-017	Feb-85												
				0.006	BHSFL	Oct-85							1.31	PO-024	Feb-85												
				0.006	BHWSG	Oct-85							1.74	PO-10C	Feb-85												
				0.006	BBIO1	Oct-85							0.21	PO-11A	Feb-85												
				0.009	ADNR3	Oct-85							1.48	PO-14B	Feb-85												
				0.008	BURCXS	Dec-85							0.29	PO-920	Feb-85												
				0.006	PO-027	Jan-86							0.26	SW-144	Feb-85												
				0.006	PO-070	Feb-86							0.15	SW-60	Feb-85												
				0.005	BRTFL	Mar-86							1.32	SW-61	Feb-85												
				0.006	SW-65	Apr-86							0.03	PO-005	Feb-85												
				0.005	SW-166	Apr-86							8.27	PO-905	Feb-85												
				0.005	SW-164	Apr-86							0.09	PO-009	Feb-85												
				0.018	SP-78	May-86							0.04	PO-016	Feb-85												
				0.025	SP-79	May-86							0.06	SW-145	Feb-85												
				0.005	BURCXS	Jun-86							0.17	SW-1A	Feb-85												
				0.005	BURCXS	Aug-86							0.02	SW-01	Feb-85												
				0.007	BUSGS-RC	Aug-86							0.04	SW-2A	Feb-85												
				0.009	SW-163	Aug-86							0.12	PO-001	Feb-85												
				0.008	SP-03	Sep-86							0.12	SW-09	Feb-85												
				0.006	APD7400	Sep-86							0.51	PO-907	Feb-85												
				0.005	PO-006	Sep-86							0.049	BBBFL	Feb-85												
				0.008	BRTFL	Oct-86							0.038	BLDPD	Feb-85												
				0.005	BURCXS	Nov-86							0.018	BLLCXS	Feb-85												
				0.007	BUSGS-RC	Feb-87							0.05	BS33FL	Feb-85												

Table 9-8: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Site	Date	0.005	Site	Date	1.3	Site	Date	4	Site	Date	0.015	Site	Date	0.1	Site	Date	0.05	Site	Date	2	Site	Date	10	Site	Date
				0.005	PO-917	May-87							0.028	BSDCG	Feb-85												
				0.005	PO-027	May-87							0.16	SW-146	Mar-85												
				0.014	BLFFL	May-87							0.27	SW-147	Mar-85												
				0.015	BS33FL	May-87							0.017	BLRCXS	Mar-85												
				0.011	SW-168	Jun-87							0.04	PO-009	Mar-85												
				0.014	SW-169	Jun-87							0.15	PO-012	Mar-85												
				0.011	SW-171	Jun-87							2.71	PO-024	Mar-85												
				0.007	PO-917	Oct-87							5.2	PO-04A	Mar-85												
				0.005	BRTFL	Oct-87							2.59	SW-147	Mar-85												
				0.011	BHSFL	Nov-87							0.22	PO-04A	Mar-85												
				0.009	BRTFL	Nov-87							0.4	PO-011	Mar-85												
				0.007	BHSFL	Dec-87							0.2	SW-150	Mar-85												
				0.006	BRTFL	Dec-87							0.21	PO-017	Mar-85												
				0.006	SW-147	Feb-88							1.18	SW-146	Mar-85												
				0.006	PO-011	Mar-88							0.11	SW-151	Mar-85												
				0.008	PO-013	Mar-88							0.24	SW-60	Mar-85												
				0.006	PO-10C	Mar-88							0.07	CG-08	Mar-85												
				0.005	PO-21C	Mar-88							1.31	SW-148	Mar-85												
				0.006	APD7400	Sep-88							1.11	SW-149	Mar-85												
				0.014	SW-80	Mar-89							0.07	SW-65	Mar-85												
				0.005	SW-83	Jun-89							0.19	CG-19	Mar-85												
				0.01	PO-921	Jun-89							0.08	SW-102	Mar-85												
				0.005	SW-146	Jul-89							0.06	SW-153	Mar-85												
				0.008	PO-13A	Aug-90							1.14	SW-154	Mar-85												
				0.009	PO-71C	Aug-90							0.05	SW-152	Mar-85												
				0.006	PO-027	Aug-90							0.05	ADNR3	Jun-85												
				0.005	PO-71B	Aug-90							0.033	ATWPD27	Jul-85												
				0.005	PO-10C	Aug-90							0.03	PO-037	Jan-86												
				0.008	PO-011	Aug-90							0.09	PO-070	Feb-86												
				0.007	PO-013	Aug-90							0.02	SP-24	Apr-86												
				0.005	PO-46A	Aug-90							0.02	SW-60	May-86												
				0.008	PO-917	Sep-90							0.02	SW-50	May-86												
				0.0068	SW-65	Jul-01							0.05	SP-79	May-86												
													0.03	PO-006	Sep-86												
													0.09	SW-168	Jun-87												
													0.09	SW-169	Jun-87												
													0.03	PO-010	Jun-87												
													0.02	BHSFL	Jan-89												
													0.02	BS33FL	Feb-89												
													0.02	PO-71C	May-89												
													0.05	SW-183	Jun-89												
													0.05	SW-83	Jun-89												

Table 9-8: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Site	Date	0.005	Site	Date	1.3	Site	Date	4	Site	Date	0.015	Site	Date	0.1	Site	Date	0.05	Site	Date	2	Site	Date	10	Site	Date
													0.05	PO-804	Jun-89												
													0.02	PO-921	Jun-89												
													0.09	PO-917	Jun-89												
													0.02	PO-011	Jan-90												
													0.04	PO-917	Sep-90												
													0.02	SP-80	Mar-93												
													0.02	PO-917	Sep-94												
													0.02	SP-24	Sep-94												
													0.02	PO-917	Oct-95												
													0.03	SW-30	Mar-96												
													0.02	SW-45	Mar-96												
													0.02	BURCXS	Jul-96												
													0.02	BUSGS-RC	Dec-96												
													0.06	SW-75	Jun-00												
													0.04	SW-75	Jun-00												
													0.059	SW-75	Jul-01												
													0.18	SW-40	Jul-01												
													0.14	SW-40	Jul-01												
													0.08	SW-65	Jul-01												
													0.18	SW-65	Jul-01												
													0.017	SW-45	May-05												
													0.029	SP-63	Nov-05												
													0.53	SW-65	Apr-07												
													0.017	SW-65	Jul-07												
													0.25	SP-37	Nov-07												

Table 9-9: Rosebud Mine groundwater quality samples with analytes that exceed Human Health Standards of Circular DEQ-7.
Analytes are compared to the limit for dissolved in mg/L.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	**0.01**	**Well**	**Date**	**0.005**	**Well**	**Date**	**1.3**	**Well**	**Date**	**4**	**Well**	**Date**	**0.015**	**Well**	**Date**	**0.1**	**Well**	**Date**	**0.05**	**Well**	**Date**	**2**	**Well**	**Date**	**10**	**Well**	**Date**
	0.011	WA-124	Nov-76	0.014	15-O	Apr-77	none			801	WA-118	Aug-04	0.15	P-05	May-85	0.1	S-05	Nov-76	0.074	S-04	Jun-76	17.2	PW-28	Aug-82	23.35	P-05	Nov-79
	0.012	WA-145	Aug-04	0.009	28-O	Apr-77				13	WI-102	Sep-08	0.28	S-04	Jun-76	0.1	S-05	Jul-77	0.18	WA-119	Jul-95	9.22	PW-72	Aug-84	20.83	P-05	May-80
	0.019	WA-172	Aug-03	0.011	28-R	Apr-77				7.29	WA-214	Sep-07	0.24	S-04	Aug-76	0.1	S-04	Jul-77	0.11	WA-142	Jun-85	2.09	WA-186	Sep-00	29.93	PW-03	Nov-80
	0.014	WA-214	Sep-10	0.011	29-O	Apr-77				6.3	WM-138	Sep-09	0.2	S-04	Oct-76				0.11	WA-171	Sep-12	3.77	WD-150	Feb-87	24.02	PW-03	Jul-82
	0.01	WA-214	Jul-01	0.012	31-O	Apr-77				5	WD-182	Sep-93	0.28	S-04	Mar-78				0.096	WA-212	Aug-93	2.32	WD-174	Aug-89	24.31	PW-107	Jul-82
	0.013	WA-218	Sep-07	0.014	31-R	Apr-77							0.15	S-04	Feb-79				0.05	WA-225	May-13	2.65	WD-175	Oct-82	351	WA-113	Dec-85
	0.015	WD-190	Aug-03	0.01	32-O	Apr-77							0.15	S-05	Oct-76				0.091	WD-178	Aug-92	5.45	WD-179	Dec-84	88.1	WA-113	Nov-91
	0.017	WD-195	Sep-05	0.008	32-R	Apr-77							0.16	S-05	Nov-76				0.052	WO-105	Sep-12	3.62	WD-179	Jul-88	10.5	WA-113	Aug-93
	0.019	WD-195	Sep-09	0.008	34-R	Apr-77							0.16	S-05	Mar-78				0.66	WO-105	Apr-14	2.37	WD-184	Aug-85	19.73	WA-121	Aug-81
	0.013	WD-195	Sep-10	0.012	41-R	Apr-79							0.15	S-10	Mar-78				0.0993	WO-187	May-14	2.94	WI-111	Jul-88	15.4	WA-124	Dec-83
	0.011	WI-114	Sep-11	0.01	4-M	Apr-77							0.67	WA-204	Jul-01				0.05	WR-126	Sep-13	8.61	WI-113	May-87	10.7	WA-154	Jul-95
	0.017	WI-153	Sep-01	0.008	7-M	Apr-77							0.37	WI-162	Aug-06							2.57	WI-114	Dec-85	27.6	WD-180	Jul-89
	0.012	WI-153	Jul-00	0.012	7-R	Apr-77							0.18	WI-166	Sep-85							2.53	WI-117	May-82	21.2	WI-111	Aug-02
	0.016	WI-153	Aug-03	0.007	D-2	Dec-85							0.29	WM-158	Aug-01							5.72	WI-117	Oct-87	13.9	WI-186	Jul-01
	0.018	WI-153	Sep-09	0.009	EX-097	May-85							0.3	WX-229	Jan-83							4.03	WI-117	Sep-89	103	WO-103	Sep-82
	0.1	WM-133	Sep-10	0.01	P-01	Jul-77																2.16	WI-159	Dec-85	34.6	WR-125	Jun-00
	0.01	WM-188	Aug-02	0.006	P-01	Jul-89																3.05	WI-162	Jan-83	16.7	WR-126	Sep-07
	0.013	WM-189	Aug-02	0.008	P-02	Jul-89																3.23	WI-165	Sep-82	10.5	WS-100	Sep-09
	0.01	WM-189	Aug-02	0.01	P-07	Jun-76																2.66	WI-172	Nov-82	34	WS-100	Sep-12
	0.0146	WO-105	Sep-05	0.006	P-08	Aug-84																2.04	WI-172	Sep-88	24.1	WS-100	Apr-14
	0.1	WR-208	Apr-14	0.01	P-09	Nov-76																2.02	WI-174	Dec-85	23.6	WS-107	Dec-85
	0.013	WS-187	Apr-00	0.01	P-11	Nov-76																3.46	WI-178	Jun-88	19	WS-107	Sep-05
	0.01	WS-187	Aug-02	0.012	P-11	Feb-81																3.54	WIN-B	Aug-98	16	WS-111	Sep-05
	0.01	WS-187	Sep-05	0.009	PW-11	Jun-85																8.74	WIN-C	Aug-98	12.2	WS-111	Sep-08
				0.009	PW-169	May-86																3.22	WM-100	Dec-85	12	WS-111	Sep-11
				0.009	PW-170	May-86																2.75	WM-101	Jan-88	39.7	WS-127	Sep-99
				0.005	PW-72	Aug-84																2.21	WM-104	Sep-89	11.6	WS-127	Aug-02
				0.017	PW-86	Jul-83																2.24	WM-112	Jul-89	50	WS-127	Sep-05
				0.02	S-01	Jun-76																2.66	WM-115	May-87	11.8	WS-127	Sep-08
				0.01	S-01	Nov-76																3.52	WM-119	Apr-87	24.1	WS-127	Apr-14
				0.01	S-01	Apr-77																3.34	WM-127	May-81	16.48	WS-157	Aug-82
				0.01	S-02	Jun-76																2.64	WM-127	Aug-81	54	WX-110	Dec-81
				0.01	S-02	Nov-76																2.05	WM-133	May-82			
				0.01	S-02	Apr-77																2.67	WM-133	Dec-85			
				0.02	S-02	Jul-77																2.2	WM-133	Nov-91			
				0.005	S-02	Jun-80																2.53	WM-135	May-82			
				0.01	S-03	Jul-77																2.29	WM-138	Nov-86			
				0.03	S-04	Jun-76																2.69	WM-152	Feb-87			
				0.02	S-04	Nov-76																3.79	WM-168	Dec-87			
				0.01	S-04	Apr-77																4.6	WM-168	Oct-89			
				0.03	S-04	Jul-77																2.31	WM-179	Jun-88			

Table 9-9: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Well	Date	0.005	Well	Date	1.3	Well	Date	4	Well	Date	0.015	Well	Date	0.1	Well	Date	0.05	Well	Date	2	Well	Date	10	Well	Date
				0.02	S-05	Jun-76																4.67	WM-181	Jul-88			
				0.03	S-05	Nov-76																2.71	WM-181	Jul-90			
				0.03	S-05	Jul-77																3.58	WM-185	Feb-87			
				0.006	S-06	Jun-80																5.25	WO-104	Dec-83			
				0.01	S-22	Nov-76																2	WR-103	May-82			
				0.01	S-23	Nov-76																4.36	WR-103	Sep-88			
				0.01	S-24	Nov-76																3.81	WR-104	Sep-89			
				0.008	SP-03	Sep-86																2.57	WR-108	Sep-82			
				0.005	SP-06	Feb-81																8.01	WR-108	May-87			
				0.007	SP-14	Nov-84																3.21	WR-125	Dec-81			
				0.018	SP-78	May-86																3.21	WR-125	Dec-82			
				0.025	SP-79	May-86																3.64	WR-125	Jul-86			
				0.034	WA-104	Nov-84																2.24	WR-125	Oct-87			
				0.01	WA-104	Jan-87																3.21	WR-152	Feb-87			
				0.009	WA-107	May-86																2.52	WR-168	Nov-87			
				0.006	WA-108	Jun-88																2.15	WR-181	Feb-84			
				0.01	WA-111	Jul-89																4.77	WR-181	Jul-88			
				0.005	WA-112	May-82																2.23	WS-105	Oct-89			
				0.013	WA-113	Dec-85																2.61	WS-106	Sep-81			
				0.007	WA-123	Jul-89																3	WS-126	Sep-99			
				0.009	WA-124	Dec-85																					
				0.005	WA-124	Aug-89																					
				0.012	WA-127	Jul-89																					
				0.007	WA-128	Aug-89																					
				0.01	WA-132	Oct-86																					
				0.006	WA-133	Nov-86																					
				0.005	WA-133	Jun-88																					
				0.008	WA-135	Jun-84																					
				0.007	WA-135	Nov-84																					
				0.006	WA-135	Apr-87																					
				0.005	WA-136	Jul-84																					
				0.005	WA-136	Nov-84																					
				0.01	WA-136	Jul-89																					
				0.005	WA-137	Jun-84																					
				0.014	WA-137	Jul-89																					
				0.005	WA-139	Aug-89																					
				0.006	WA-142	Jun-84																					
				0.007	WA-142	Nov-84																					
				0.01	WA-142	Oct-86																					
				0.007	WA-144	Dec-87																					
				0.005	WA-144	Jun-88																					
				0.006	WA-145	Jul-90																					

Table 9-9: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Well	Date	0.005	Well	Date	1.3	Well	Date	4	Well	Date	0.015	Well	Date	0.1	Well	Date	0.05	Well	Date	2	Well	Date	10	Well	Date
				0.005	WA-149	Jul-85																					
				0.008	WA-149	Jul-89																					
				0.006	WA-150	Jul-85																					
				0.005	WA-151	Sep-84																					
				0.007	WA-151	Jun-85																					
				0.005	WA-151	Jul-85																					
				0.012	WA-151	Jul-89																					
				0.009	WA-152	Jun-85																					
				0.007	WA-154	Jul-85																					
				0.007	WA-156	Jul-89																					
				0.013	WA-157	Jul-89																					
				0.005	WA-158	Jul-89																					
				0.008	WA-160	Feb-87																					
				0.007	WA-165	Jul-89																					
				0.005	WA-166	Jul-85																					
				0.015	WA-166	Jul-89																					
				0.008	WA-167	Jul-89																					
				0.008	WA-168	Jul-85																					
				0.006	WA-168	Jul-89																					
				0.005	WA-169	Jun-85																					
				0.005	WA-169	Jul-89																					
				0.009	WA-170	Jun-85																					
				0.013	WA-170	Jul-89																					
				0.01	WA-171	Aug-89																					
				0.005	WA-172	Aug-84																					
				0.017	WA-172	Sep-10																					
				0.005	WA-182	May-86																					
				0.005	WA-183	Dec-85																					
				0.008	WA-183	May-86																					
				0.008	WA-184	May-86																					
				0.007	WA-185	Jul-89																					
				0.008	WA-187	May-86																					
				0.007	WA-188	May-86																					
				0.005	WA-189	May-85																					
				0.006	WA-193	Jun-85																					
				0.006	WA-196	Jun-85																					
				0.006	WA-204	Jun-85																					
				0.007	WA-204	Jul-89																					
				0.006	WA-205	Jul-89																					
				0.006	WA-209	Jul-89																					
				0.015	WA-210	Jul-89																					
				0.006	WA-211	Aug-85																					

Table 9-9: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Well	Date	0.005	Well	Date	1.3	Well	Date	4	Well	Date	0.015	Well	Date	0.1	Well	Date	0.05	Well	Date	2	Well	Date	10	Well	Date
				0.01	WA-211	Jul-89																					
				0.009	WA-213	Jul-89																					
				0.006	WA-215	Aug-85																					
				0.005	WA-215	Jul-89																					
				0.006	WD-150	Feb-87																					
				0.007	WD-174	Aug-89																					
				0.008	WD-174	Nov-91																					
				0.006	WD-179	Jul-88																					
				0.009	WD-180	Jul-89																					
				0.005	WI-102	Dec-83																					
				0.005	WI-110	Feb-87																					
				0.006	WI-111	Jul-88																					
				0.006	WI-175	Sep-84																					
				0.007	WI-180	Jul-89																					
				0.005	WM-106	Jul-89																					
				0.005	WM-126	Jun-84																					
				0.013	WM-126	Nov-84																					
				0.008	WM-127	Jun-84																					
				0.012	WM-127	Nov-84																					
				0.013	WM-127	Nov-86																					
				0.005	WM-127	Jul-92																					
				0.007	WM-132	May-87																					
				0.007	WM-138	Nov-84																					
				0.014	WM-138	Nov-86																					
				0.006	WM-138	Jul-88																					
				0.007	WM-152	Oct-90																					
				0.006	WM-175	Sep-84																					
				0.005	WM-179	Jun-88																					
				0.006	WO-101	Aug-89																					
				0.02	WO-104	Dec-83																					
				0.01	WO-107	Feb-87																					
				0.02	WO-178	Jan-84																					
				0.006	WO-179	Jun-88																					
				0.005	WO-181	Aug-92																					
				0.005	WR-108	Oct-79																					
				0.014	WR-111	Sep-89																					
				0.01	WR-112	Jun-88																					
				0.012	WR-129	Jun-84																					
				0.006	WR-129	Nov-84																					
				0.005	WR-129	Nov-86																					
				0.006	WR-129	Jul-88																					
				0.008	WR-154	Feb-87																					

Table 9-9: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Well	Date	0.005	Well	Date	1.3	Well	Date	4	Well	Date	0.015	Well	Date	0.1	Well	Date	0.05	Well	Date	2	Well	Date	10	Well	Date
				0.005	WR-167	Jul-86																					
				0.24	WR-168	Sep-10																					
				0.005	WR-175	Sep-84																					
				0.007	WR-206	Jul-00																					
				0.007	WR-207	Jul-00																					
				0.005	WS-101	May-87																					
				0.015	WS-106	Sep-83																					
				0.009	WS-108	Feb-87																					
				0.009	WS-113	Jun-88																					
				0.006	WS-114	Jul-99																					
				0.02	WS-115	Aug-97																					
				0.005	WS-158	Dec-91																					
				0.0061	WS-188	Aug-02																					
				0.013	WZ-002	Dec-83																					
				0.008	WZ-014	Aug-90																					

Table 9-10: Big Sky Mine groundwater quality samples with analytes that exceed Human Health Standards of Circular DEQ-7.
Analytes are compared to the limit for dissolved in mg/L.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	**0.01**	**Well**	**Date**	**0.005**	**Well**	**Date**	**1.3**	**Well**	**Date**	**4**	**Well**	**Date**	**0.015**	**Well**	**Date**	**0.1**	**Well**	**Date**	**0.05**	**Well**	**Date**	**2**	**Well**	**Date**	**10**	**Well**	**Date**
	0.012	AAL14	Sep-87	0.006	AAL12	Mar-83	none			none			0.015	AAL12	Apr-84	0.140	ASPS15	Aug-02	0.17	ASMTW3	Oct-84	8.75	AAL14	Sep-09	10.2	AAL12	Sep-82
	0.01	AAL51	Sep-87	0.005	AAL13	Sep-82							0.028	AAL12	Oct-84	0.100	ASP22	Sep-87	0.067	ASMTW3	Jul-85	4.77	ASP22	May-85	10.2	AAL14	Aug-01
	0.011	AALM70	Sep-87	0.005	AAL13	Mar-83							0.025	AAL13	Mar-84	0.360	BOV1712	Apr-96	0.057	ASMTW3	Aug-00	2.04	ASP25R	Sep-09	10.5	AAL14	Aug-00
	0.01	ARC30	Sep-87	0.007	AAL13	Sep-86							0.021	AAL13	Oct-84				0.053	ASMTW4	May-85	37	ASP49	Aug-97	10.6	AALM70	Aug-95
	0.011	ARCM63	Sep-87	0.005	AAL14	Mar-83							0.04	AAL14	Mar-83				0.05	ASMTW4	Jul-85	30	BAL2711	Sep-97	10.8	ASMTW1	Feb-87
	0.014	ASM54	Sep-87	0.006	AAL14	Oct-84							0.03	AAL14	Apr-84				0.072	ASP22	Mar-84	40	BAL3111	Sep-97	11.2	ASMTW3	Aug-02
	0.01	ASMM69	Sep-87	0.006	AAL14	Sep-86							0.052	AAL14	Oct-84							20	BAL3311	Sep-97	11.2	AAL12	Oct-83
	0.011	ASMS16	Sep-87	0.008	AAL51	Sep-82							0.02	AAL14	Sep-92							40	BAL3511	Sep-97	11.34	AAL12	Dec-82
	0.01	ASMTW4	Jul-85	0.007	AAL51	Oct-84							0.02	AAL51	Mar-83							30	BAL9081	Sep-97	12.2	ASPS15	Sep-13
	0.018	ASP22	Oct-85	0.005	AAL51	Sep-87							0.02	AAL51	Mar-84							70	BIN1017	Sep-97	12.4	ASMTW4	Sep-86
	0.012	ASP22	Sep-86	0.007	AALM70	Sep-82							0.024	AAL51	Oct-84							2.48	BIN617	Feb-87	12.9	AALM70	Aug-96
	0.054	ASP22	Sep-87	0.005	AALM70	Dec-82							0.02	AAL51	Sep-94							90	BMC1014	Sep-97	13.2	AAL14	Aug-03
	0.022	ASP22	Sep-88	0.008	AALM70	Mar-83							0.02	AALM70	Mar-83							5.07	BMC614	Feb-85	13.6	ASMTW3	Aug-04
	0.014	ASP22	Sep-89	0.006	AALM70	Oct-83							0.02	AALM70	Apr-84							50	BOV1012	Sep-97	14	AAL12	Oct-84
	0.01	ASP36	Sep-87	0.005	AALM70	Apr-84							0.049	AALM70	Oct-84							90	BOV1712	Sep97	14.2	ASMTW3	Sep-92
	0.012	ASP47	Sep-87	0.008	AALM70	Sep-86							1	AALM70	May-85							2.94	BOV512	Feb-85	14.2	ASMTW1	Mar-86
	0.016	ASP49	Sep-87	0.005	AMC20	Mar-83							0.03	AMC20	Mar-83							70	BRC1013	Sep-97	14.7	AAL12	Mar-83
	0.012	ASPP18	Sep-87	0.011	AMC20	Oct-84							0.03	AMC20	Apr-84							40	BRC1713	Sep-97	14.7	AAL12	Nov-85
	0.011	ASPS15	Sep-87	0.005	AMC20	Sep-86							0.029	AMC20	Oct-84							2.38	BRC513	Dec-84	15.3	AAL14	Aug-02
	0.013	BAL2321	Feb-85	0.006	AMC32	Sep-82							0.02	AMC20	Aug-96							8.57	BRC513	Feb-85	15.4	AAL12	May-10
	0.018	BAL2341	Feb-85	0.007	AMC32	Mar-83							0.03	AMC21	Mar-84							4.75	BRC613	Feb-85	16.5	AAL12	May-85
	0.013	BAL2411	Feb-85	0.005	AMC32	Sep-83							0.02	AMC32	Sep-82							3.72	BSM1015	Feb-85	17.8	AAL12	Aug-02
	0.02	BAL2511	Feb-85	0.005	AMC32	Oct-85							0.03	AMC32	Mar-84							40	BSM1015	Sep-97	19.8	ASMTW1	Sep-86
	0.01	BAL2521	Feb-85	0.009	AMC32	Sep-86							0.015	AMC57	Mar-84							13.1	BSM1715	Mar-88	19.9	ASMTW3	Aug-01
	0.01	BAL2531	Feb-85	0.008	AMC57	Oct-84							0.02	AMC59	Apr-84							130	BSM1715	Sep-97	20	ASMTW3	Mar-86
	0.014	BAL2541	Feb-85	0.007	AMCS25	Mar-83							0.031	AMC59	Oct-84							20	BSM2715	Sep-97	20.2	AAL12	Aug-98
	0.012	BAL2711	Jun-97	0.006	AMCS25	Oct-83							0.02	AMCS25	Sep-82							26	BSM315	Aug-88	21.1	AAL12	Aug-03
	0.011	BAL9011	Feb-85	0.006	AMCS25	Oct-84							0.02	AMCS25	Mar-84							2.74	BSM715	Feb-85	22.7	ASMTW3	Sep-94
	0.017	BAL9031	Feb-85	0.005	AOVM73	Oct-83							0.03	AMCS25	Oct-84							30	BSM9085	Sep-97	26	ASMTW3	Sep-86
	0.02	BAL9041	Feb-85	0.008	AOVM73	Oct-84							0.02	AMCS25	Feb-87							4.12	BSM9135	Oct-91	28	ASMTW3	Aug-95
	0.01	BAL9071	Feb-85	0.006	AOVM73	Oct-85							0.03	AOVM73	Oct-83										30.7	ASMTW3	Jul-93
	0.016	BAL9081	Feb-85	0.009	ARC30	Sep-82							0.02	AOVM73	Mar-84										39.8	ASMTW3	Aug-98
	0.014	BIN1017	Feb-85	0.005	ARC30	Dec-82							0.024	AOVM73	Oct-84										41.6	ASMTW3	Sep-96
	0.011	BIN117	Feb-85	0.005	ARC30	Oct-84							0.437	AOVM73	May-85										43	ASMTW4	Mar-86
	0.025	BIN1217	Feb-85	0.013	ARC30	Oct-85							0.03	AOVM73	Sep-88										45.4	ASMTW3	Aug-99
	0.012	BIN1217	Feb-87	0.019	ARC30	Sep-86							0.02	AOVM73	Aug-96										46.4	ASMTW3	Aug-00
	0.01	BIN1217	Aug-87	0.007	ARC44	Sep-82							0.02	ARC30	Dec-82										56	ASMTW3	Nov-85
	0.023	BIN317	Feb-85	0.006	ARC44	Sep-83							0.03	ARC30	Mar-84										68	ASMTW4	Nov-85
	0.021	BIN417	Feb-85	0.012	ARC44	Oct-84							0.06	ARC30	Aug-93										183	ASMTW4	May-85
	0.012	BIN517	Feb-85	0.009	ARC44	Oct-85							0.02	ARC44	Mar-84										202	ASMTW3	Jul-85
	0.022	BIN617	Feb-85	0.006	ARC44	Sep-87							0.034	ARC52	Oct-84										212	ASMTW3	Oct-84

Table 9-10: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Well	Date	0.005	Well	Date	1.3	Well	Date	4	Well	Date	0.015	Well	Date	0.1	Well	Date	0.05	Well	Date	2	Well	Date	10	Well	Date
	0.012	BIN617	Sep-87	0.016	ARC52	Nov-85							0.025	ARC53	Mar-84										234	ASMTW4	Jul-85
	0.01	BIN617	Aug-88	0.02	ARC52	Sep-86							0.04	ARC53	Oct-84										25.6	BIN1017	Feb-99
	0.028	BIN717	Feb-85	0.005	ARC53	Oct-84							0.025	ARC58	Mar-84										10.4	BIN1317	Aug-03
	0.025	BIN917	Feb-85	0.006	ARC58	Oct-84							0.021	ARC58	May-85										54.6	BMC314	Oct-84
	0.014	BMC1014	Feb-85	0.008	ARC60	Oct-84							0.02	ARC60	Apr-84										13.6	BMC414	May-85
	0.014	BMC114	Feb-85	0.018	ARC66	Sep-86							0.026	ARC60	Oct-84										11.2	BRC1013	Feb-99
	0.027	BMC1214	Feb-85	0.005	ARC66	Sep-87							0.03	ARC66	Sep-88										12	BRC313	Mar-94
	0.013	BMC1214	Feb-87	0.008	ARCM26	Sep-82							0.02	ARCM26	Sep-82										13	BRC613	Feb-02
	0.011	BMC1214	Aug-87	0.005	ARCM26	Dec-82							0.02	ARCM26	Oct-83										15	BRC813	Aug-89
	0.028	BMC314	Feb-85	0.007	ARCM26	Oct-84							0.03	ARCM26	Mar-84										11	BSM115	Aug-98
	0.013	BMC314	Feb-87	0.007	ARCM26	May-85							0.04	ARCM63	Mar-84										11.7	BSM115	Sep-08
	0.013	BMC314	Aug-87	0.005	ARCM26	Sep-86							0.015	ARCM63	Oct-84										10.3	BSM2515	Feb-87
	0.017	BMC314	Feb-88	0.008	ARCM63	Oct-84							0.06	ARCM63	Sep-88										10.4	BSM2515	Mar-95
	0.012	BMC314	Aug-88	0.006	ARCM63	Oct-85							0.023	ASM2	Oct-84										11	BSM615	Aug-85
	0.02	BMC414	Feb-85	0.012	ARCM63	Sep-86							0.03	ASM54	Apr-84										10.9	BSM9265	Apr-89
	0.035	BMC614	Feb-85	0.005	ASM2	Sep-82							0.042	ASM54	Oct-84												
	0.035	BMC714	Feb-85	0.006	ASM2	Mar-83							0.02	ASM54	Sep-88												
	0.015	BMC814	Feb-85	0.006	ASM2	Oct-83							0.053	ASM55	Oct-84												
	0.048	BMC914	Feb-85	0.011	ASM2	Oct-84							0.025	ASM56	Apr-84												
	0.012	BMC9154	Feb-85	0.009	ASM56	Oct-84							0.021	ASM56	Oct-84												
	0.012	BOV1012	Feb-85	0.006	ASMM27	Mar-83							0.021	ASMM27	Oct-84												
	0.021	BOV112	Feb-85	0.01	ASMM27	Oct-84							0.02	ASMM27	Sep-88												
	0.014	BOV112	Aug-90	0.006	ASMM27	May-85							0.02	ASMM27	Aug-92												
	0.016	BOV2012	Feb-85	0.008	ASMM27	Sep-86							0.016	ASMM32	Oct-84												
	0.012	BOV312	Feb-85	0.006	ASMM32	Sep-82							0.04	ASMM69	Sep-83												
	0.013	BOV412	Feb-85	0.005	ASMM32	Dec-82							0.015	ASMM69	Mar-84												
	0.019	BOV812	Feb-85	0.007	ASMM32	Mar-83							0.021	ASMM69	Oct-84												
	0.015	BRC1013	Feb-85	0.005	ASMM32	Mar-84							0.03	ASMS16	Sep-83												
	0.016	BRC1213	Feb-85	0.009	ASMM32	Oct-84							0.03	ASMS16	Mar-84												
	0.02	BRC413	Feb-85	0.007	ASMM32	Nov-85							0.027	ASMS16	Oct-84												
	0.011	BRC513	Feb-85	0.007	ASMM69	Sep-82							0.033	ASMTW1	Oct-84												
	0.022	BRC713	Feb-85	0.005	ASMM69	Dec-82							0.025	ASMTW1	May-85												
	0.012	BRC813	Mar-86	0.008	ASMM69	Nov-85							0.032	ASMTW2	Oct-84												
	0.012	BRC9163	Feb-85	0.005	ASMM69	Sep-86							0.03	ASMTW3	Jul-93												
	0.013	BSM115	Feb-85	0.011	ASMS16	Sep-82							0.02	ASMTW4	Oct-84												
	0.033	BSM1215	Feb-85	0.006	ASMS16	Dec-82							0.02	ASMTW4	Sep-92												
	0.01	BSM1215	Mar-86	0.01	ASMS16	Mar-83							0.02	ASP22	Sep-82												
	0.013	BSM1215	Feb-87	0.005	ASMS16	Mar-84							0.02	ASP22	Mar-83												
	0.013	BSM1215	Aug-87	0.005	ASMS16	May-85							0.03	ASP22	Sep-83												
	0.02	BSM2215	Feb-85	0.007	ASMS16	Oct-85							0.03	ASP22	Mar-84												
	0.015	BSM2415	Feb-85	0.011	ASMS16	Mar-86							0.25	ASP22	Sep-87												
	0.02	BSM2515	Feb-85	0.01	ASMS16	Sep-86							0.02	ASP27	Mar-83												

Table 9-10: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Well	Date	0.005	Well	Date	1.3	Well	Date	4	Well	Date	0.015	Well	Date	0.1	Well	Date	0.05	Well	Date	2	Well	Date	10	Well	Date
	0.026	BSM315	Feb-85	0.01	ASMS16	Mar-88							0.02	ASP27	Sep-83												
	0.012	BSM315	Feb-87	0.006	ASMTW1	Oct-84							0.04	ASP27	Mar-84												
	0.01	BSM315	Aug-87	0.006	ASMTW1	Mar-86							0.038	ASP27	Oct-84												
	0.015	BSM315	Feb-88	0.014	ASMTW1	Sep-86							0.02	ASP35	Sep-82												
	0.012	BSM315	Aug-88	0.005	ASMTW1	Feb-87							0.04	ASP35	Sep-83												
	0.014	BSM415	Feb-85	0.01	ASMTW1	Sep-87							0.023	ASP35	Mar-84												
	0.01	BSM515	Feb-85	0.005	ASMTW1	Sep-88							0.04	ASP35	Oct-84												
	0.024	BSM615	Feb-85	0.006	ASMTW2	May-85							0.016	ASP35	May-85												
	0.014	BSM615	Feb-88	0.007	ASMTW2	Nov-85							0.02	ASP36	Sep-82												
	0.019	BSM715	Feb-85	0.005	ASMTW2	Mar-86							0.04	ASP36	Mar-84												
	0.028	BSM815	Feb-85	0.012	ASMTW2	Sep-86							0.023	ASP36	Oct-84												
	0.033	BSM915	Feb-85	0.009	ASMTW2	Feb-87							0.02	ASP40	Mar-83												
	0.012	BSM915	Jun-85	0.005	ASMTW2	Sep-87							0.03	ASP40	Mar-84												
	0.012	BSM915	Aug-85	0.013	ASMTW3	Oct-84							0.02	ASP40	Sep-92												
	0.014	BSM9255	Mar-88	0.006	ASMTW3	Jul-85							0.05	ASP50	Sep-83												
	0.013	BSM9265	Mar-88	0.011	ASMTW3	Nov-85							0.03	ASP50	Mar-84												
	0.015	BUN9140	Feb-85	0.006	ASMTW3	Mar-86							0.03	ASP50	Oct-84												
	0.017	BUN9230	Jul-85	0.008	ASMTW3	Sep-86							0.02	ASP50A	Jun-90												
				0.008	ASMTW3	Sep-87							0.024	ASP63	Oct-84												
				0.01	ASMTW4	Oct-84							0.022	ASP67	Oct-84												
				0.01	ASMTW4	May-85							0.02	ASP68	Aug-93												
				0.012	ASMTW4	Jul-85							0.02	ASPS15	Sep-82												
				0.018	ASMTW4	Nov-85							0.03	ASPS15	Oct-83												
				0.013	ASMTW4	Mar-86							0.05	ASPS15	Mar-84												
				0.016	ASMTW4	Sep-86							0.037	ASPS15	Oct-84												
				0.008	ASMTW4	Feb-87							0.02	ASPS15	Sep-88												
				0.012	ASMTW4	Sep-87							0.02	ASPS15	Jul-93												
				0.013	ASP22	Sep-82							0.017	ASPW1	Oct-84												
				0.014	ASP22	Dec-82							0.02	ASPW1	Sep-88												
				0.016	ASP22	Mar-83							0.02	ASPW1	Sep-96												
				0.007	ASP22	Sep-83							0.02	BAL2011	Apr-93												
				0.009	ASP22	Mar-84							0.04	BAL2011	Aug-94												
				0.01	ASP22	Oct-84							0.02	BAL2321	Aug-92												
				0.01	ASP22	May-85							0.02	BAL2321	Apr-93												
				0.011	ASP22	Oct-85							0.02	BAL2321	Sep-96												
				0.016	ASP22	Sep-86							0.06	BAL2411	Aug-94												
				0.028	ASP22	Sep-87							0.02	BAL2521	Mar-95												
				0.009	ASP27	Sep-82							0.02	BAL2521	Sep-96												
				0.011	ASP35	Sep-82							0.022	BAL3311	Aug-98												
				0.008	ASP35	Mar-83							0.02	BAL9011	Jun-92												
				0.008	ASP35	Oct-85							0.04	BAL9011	Jul-93												
				0.013	ASP35	Sep-86							0.04	BAL9011	Aug-94												

Table 9-10: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Well	Date	0.005	Well	Date	1.3	Well	Date	4	Well	Date	0.015	Well	Date	0.1	Well	Date	0.05	Well	Date	2	Well	Date	10	Well	Date
				0.009	ASP36	Sep-82							0.02	BAL9011	Sep-96												
				0.017	ASP36	Mar-83							0.02	BAL9031	Aug-92												
				0.009	ASP36	Oct-84							0.02	BAL9031	Jun-93												
				0.009	ASP36	Oct-85							0.026	BAL9031	Feb-96												
				0.014	ASP36	Sep-86							0.02	BAL9031	Oct-96												
				0.005	ASP40	Sep-82							0.02	BAL9041	Jun-92												
				0.011	ASP40	Mar-83							0.02	BAL9041	Sep-96												
				0.008	ASP40	May-85							0.03	BAL9091	May-93												
				0.007	ASP40	Oct-85							0.02	BAL9091	Jun-93												
				0.005	ASP40	Sep-86							0.02	BAL9091	Dec-93												
				0.01	ASP47	Oct-85							0.016	BIN1017	Jun-85												
				0.007	ASP47	Mar-86							0.02	BIN1017	Mar-90												
				0.008	ASP47	Sep-86							0.02	BIN1017	Aug-93												
				0.005	ASP47	Sep-87							0.04	BIN1017	Mar-94												
				0.006	ASP47	Mar-88							0.02	BIN117	Aug-92												
				0.012	ASP49	Oct-85							0.02	BIN317	Aug-90												
				0.011	ASP49	Sep-86							0.02	BIN317	Aug-94												
				0.006	ASP49	Sep-87							0.039	BIN717	Feb-85												
				0.007	ASP50	Sep-82							0.02	BMC1014	Aug-93												
				0.005	ASP50	Oct-84							0.03	BMC1014	Aug-94												
				0.006	ASP50	Oct-85							0.03	BMC1014	Apr-96												
				0.017	ASP50	Sep-86							0.015	BMC114	Feb-85												
				0.007	ASP50	Sep-87							0.03	BMC114	Jul-93												
				0.01	ASP63	Oct-84							0.05	BMC114	Aug-94												
				0.005	ASP65	Sep-86							0.02	BMC314	Aug-94												
				0.013	ASP67	Oct-84							0.173	BMC714	Feb-85												
				0.007	ASP67	Jun-85							0.027	BOV1012	Oct-84												
				0.006	ASPP18	Sep-86							0.04	BOV112	Jul-93												
				0.011	ASPS15	Sep-82							0.02	BOV2012	Aug-94												
				0.007	ASPS15	Dec-82							0.023	BOV412	May-85												
				0.006	ASPS15	Oct-83							0.017	BOV512	Feb-85												
				0.005	ASPS15	Mar-84							0.024	BOV612	Feb-85												
				0.006	ASPS15	Oct-84							0.04	BOV612	Aug-93												
				0.009	ASPS15	Oct-85							0.02	BRC1013	Aug-92												
				0.009	ASPS15	Mar-86							0.015	BRC1413	Aug-85												
				0.012	ASPS15	Sep-86							0.019	BRC1513	Oct-84												
				0.007	ASPS15	Feb-87							0.02	BRC1713	Aug-93												
				0.006	ASPS15	Sep-87							0.39	BRC413	Feb-85												
				0.006	ASPS15	Mar-88							0.024	BRC413	May-85												
				0.01	ASPW1	Oct-84							0.015	BRC513	Feb-85												
				0.005	ASPW1	Oct-85							0.02	BRC613	Feb-85												
				0.005	ASPW1	Sep-86							0.02	BRC613	Aug-89												

Table 9-10: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Well	Date	0.005	Well	Date	1.3	Well	Date	4	Well	Date	0.015	Well	Date	0.1	Well	Date	0.05	Well	Date	2	Well	Date	10	Well	Date
				0.005	ASPW1	Sep-87							0.03	BRC613	Aug-93												
				0.007	BAL2011	Apr-85							0.017	BSM2515	May-85												
				0.005	BAL2321	Apr-85							0.02	BSM2615	Aug-89												
				0.006	BAL2321	Feb-87							0.018	BSM515	Feb-85												
				0.006	BAL2341	Feb-85							0.022	BSM615	Feb-85												
				0.01	BAL2411	Feb-85							0.02	BSM9085	Mar-93												
				0.005	BAL2411	Apr-85							0.015	BSM915	Jun-85												
				0.007	BAL2411	Aug-85							0.02	BSM9255	Mar-91												
				0.006	BAL2411	May-86							0.02	BUN9140	Aug-93												
				0.006	BAL2411	Jun-86							0.03	BUN9210	Aug-93												
				0.005	BAL2411	Aug-86							0.02	BUN9230	Aug-93												
				0.02	BAL2521	Aug-85							0.02	BUN9230	Aug-94												
				0.005	BAL2521	Aug-86																					
				0.005	BAL2521	Aug-87																					
				0.013	BAL2531	Feb-85																					
				0.005	BAL2541	Oct-84																					
				0.005	BAL2611	May-85																					
				0.005	BAL9011	Feb-85																					
				0.007	BAL9021	Mar-85																					
				0.005	BAL9031	Oct-84																					
				0.016	BAL9031	Feb-85																					
				0.006	BAL9081	Jun-86																					
				0.012	BIN1017	Aug-85																					
				0.008	BIN117	Sep-85																					
				0.008	BIN1217	Feb-85																					
				0.006	BIN1317	Nov-85																					
				0.007	BIN1317	Aug-86																					
				0.011	BIN317	Aug-85																					
				0.01	BIN317	Sep-86																					
				0.008	BIN417	Feb-85																					
				0.008	BIN517	Feb-85																					
				0.013	BIN617	Feb-85																					
				0.005	BIN617	Jun-85																					
				0.005	BIN617	Sep-86																					
				0.005	BIN817	Feb-85																					
				0.01	BIN917	Feb-85																					
				0.01	BIN917	Aug-85																					
				0.007	BMC1014	Feb-85																					
				0.013	BMC1014	Aug-85																					
				0.006	BMC114	Sep-85																					
				0.013	BMC1314	Jun-85																					
				0.011	BMC1314	Aug-86																					

Table 9-10: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Well	Date	0.005	Well	Date	1.3	Well	Date	4	Well	Date	0.015	Well	Date	0.1	Well	Date	0.05	Well	Date	2	Well	Date	10	Well	Date
				0.009	BMC1514	Aug-85																					
				0.01	BMC1514	Nov-85																					
				0.006	BMC314	Aug-89																					
				0.009	BMC614	Aug-85																					
				0.006	BMC714	Feb-85																					
				0.008	BMC814	Feb-85																					
				0.005	BMC914	Feb-85																					
				0.011	BMC9154	Dec-85																					
				0.008	BOV1012	Feb-85																					
				0.011	BOV1012	Aug-85																					
				0.011	BOV2012	Feb-85																					
				0.005	BOV2012	Apr-85																					
				0.01	BOV2112	Aug-85																					
				0.005	BOV312	Feb-85																					
				0.005	BOV612	Aug-85																					
				0.005	BOV612	Mar-86																					
				0.005	BOV612	Feb-88																					
				0.008	BOV712	Feb-85																					
				0.005	BOV812	Mar-86																					
				0.006	BRC1013	Feb-85																					
				0.009	BRC1013	Aug-85																					
				0.006	BRC1013	Feb-85																					
				0.009	BRC1013	Aug-85																					
				0.007	BRC1013	Nov-85																					
				0.005	BRC1213	Feb-85																					
				0.006	BRC1313	Aug-86																					
				0.008	BRC1413	Aug-85																					
				0.005	BRC1513	Aug-85																					
				0.008	BRC213	Jun-85																					
				0.008	BRC213	Aug-85																					
				0.007	BRC313	Mar-86																					
				0.029	BRC413	Feb-85																					
				0.009	BRC613	Feb-85																					
				0.006	BRC613	Jun-85																					
				0.005	BRC613	Aug-85																					
				0.007	BRC613	Sep-86																					
				0.022	BRC613	Feb-88																					
				0.01	BRC613	Mar-90																					
				0.008	BRC713	Feb-85																					
				0.009	BRC9163	Feb-85																					
				0.006	BSM1015	Feb-85																					
				0.007	BSM1015	Aug-85																					
				0.011	BSM1215	Feb-85																					
				0.012	BSM1215	Mar-86																					

Table 9-10: Continued.

Analyte	As			Cd			Cu			F			Pb			Ni			Se			Zn			NO2-NO3		
Limit	0.01	Well	Date	0.005	Well	Date	1.3	Well	Date	4	Well	Date	0.015	Well	Date	0.1	Well	Date	0.05	Well	Date	2	Well	Date	10	Well	Date
				0.009	BSM2215	Feb-85																					
				0.008	BSM2215	Apr-85																					
				0.01	BSM2215	Aug-85																					
				0.006	BSM2215	Dec-85																					
				0.007	BSM2415	Apr-85																					
				0.007	BSM2415	Aug-86																					
				0.005	BSM2515	May-85																					
				0.017	BSM2515	Aug-85																					
				0.01	BSM2515	Jun-86																					
				0.009	BSM2615	Feb-85																					
				0.007	BSM2615	May-85																					
				0.012	BSM2615	Aug-85																					
				0.005	BSM2615	Jun-86																					
				0.007	BSM2615	Aug-86																					
				0.01	BSM315	Sep-86																					
				0.01	BSM615	Sep-86																					
				0.005	BSM9095	Mar-86																					
				0.008	BSM9095	Jun-86																					
				0.007	BSM915	Feb-85																					
				0.017	BSM915	Aug-85																					
				0.01	BSM915	Nov-85																					
				0.005	BUN9110	Jul-85																					

13.0 FIGURES

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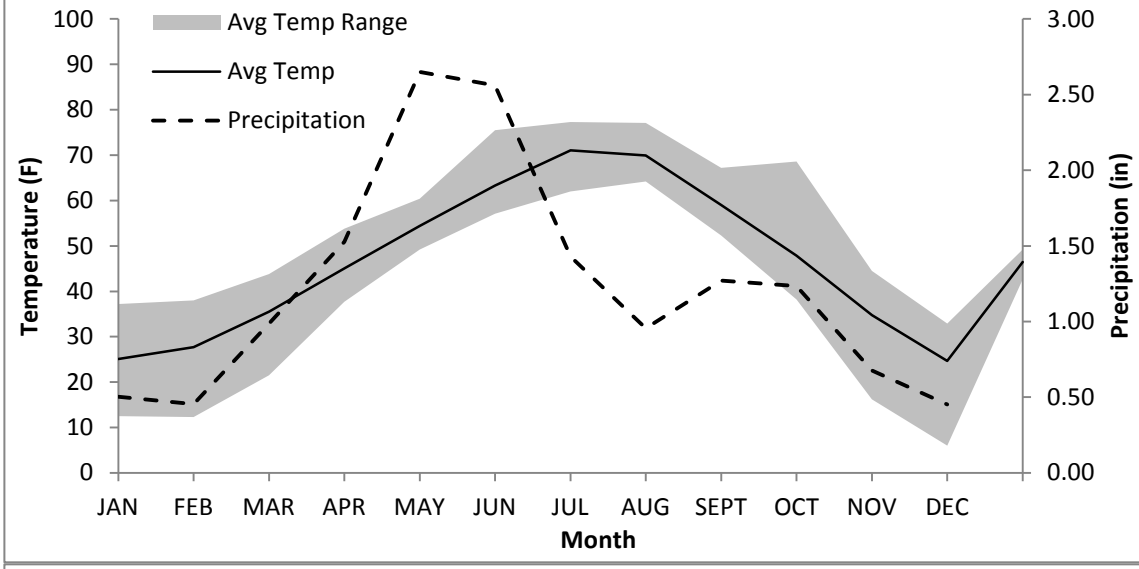
Figure 1-1: Location map of Colstrip, MT area mines.

Figure 3-1: Mine cuts proposed in Rosebud Mine amendment application AM4.

Exhibit 2

Figure 4-1: Location of Powder River Basin, Wyoming and Montana.
(Casper Star Tribune, 2014).



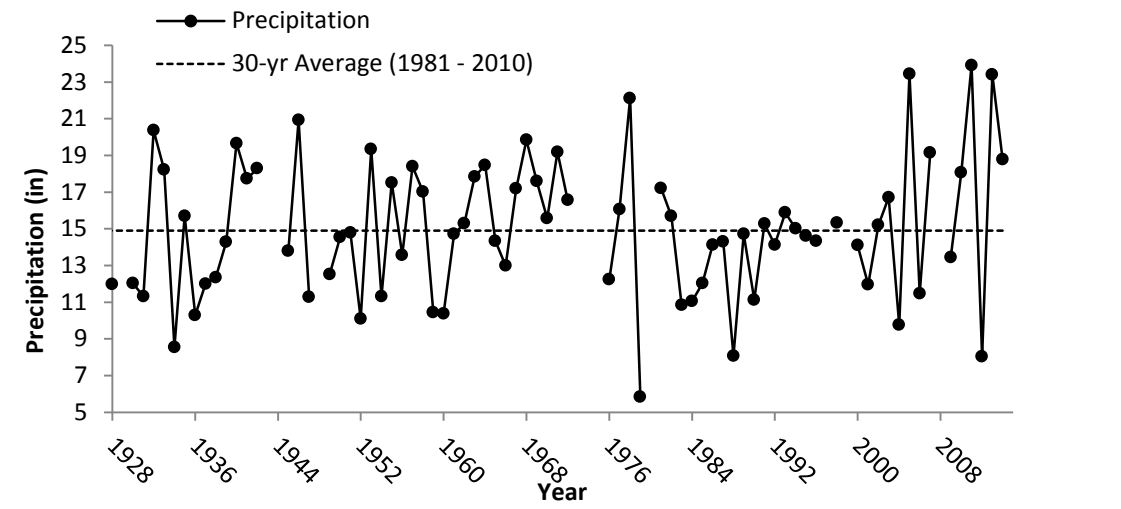


Figure 4-2: Monthly 30-year climate summary for Colstrip, MT from 1981 – 2010 and yearly precipitation totals (WRCC b, 2012).

	Wasatch Formation – Fine to coarse-grained lenticular beds of sandstone and interbedded shale and coal. Locally eroded off in Colstrip area. **Fort Union Formation –** three members **Tongue River Member** – Fine to medium grained thick-bedded to massive and lenticular sandstone and siltstone. Commonly contains shaly siltstone and shale, and numerous coal beds. **Lebo Shale Member**– Predominately dark shale with interbeds of carbonaceous shale, siltstone and local thin coal beds. **Tullock Member –** Interbedded shale, siltstone and sandstone; thin but persistent coal beds grade upward to carbonaceous shale. At the top is a resistant ledge-forming sandstone. Base is marked by predominately massive channel sandstone and dark shale of underlying unit. **Hell Creek Formation –** Shale, siltstone, silty sandstone; locally massive silty sandstone with thin coal beds. **Fox Hills Sandstone** – Near shore sand facies represents uppermost marine deposit. Massive to thin bedded sandstone with sandy shale and siltstone. **Bearpaw Shale –** Marine shaly claystone and shale. Some thin-bedded siltstone, silty sandstone; local thin beds of bentonite.

Figure 4-3: Generalized columnar section of Upper Cretaceous and Cenozoic rocks in northwestern Powder River Basin in the vicinity of Colstrip Montana.
After Lewis and Roberts, 1978.

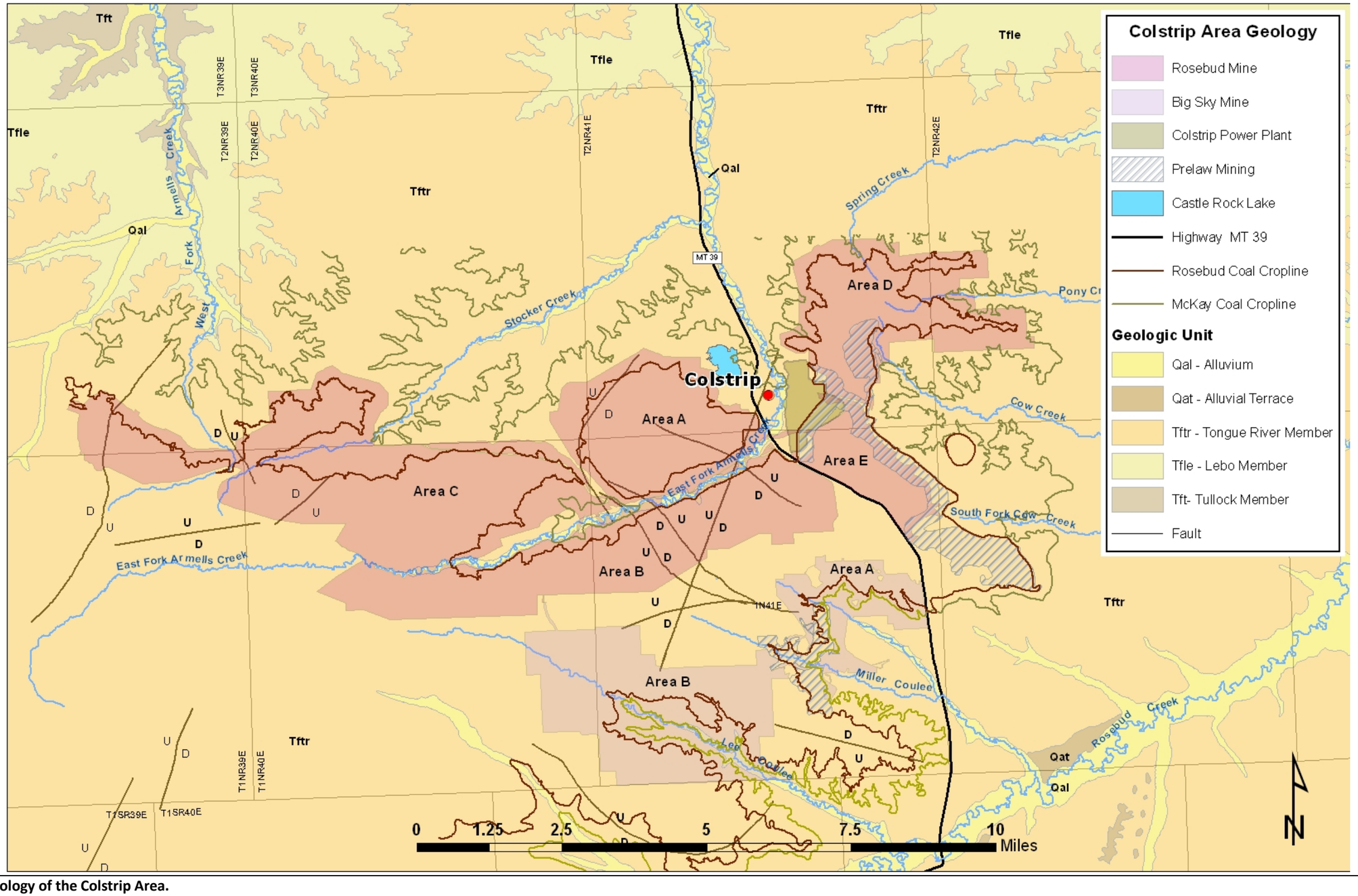


Figure 4-4: Geology of the Colstrip Area.
(Big Sky Coal Company, 1979, 1988; Roberts et al, 1999; Vuke et al., 2001, Western Energy Company, 2000).

Exhibit 2

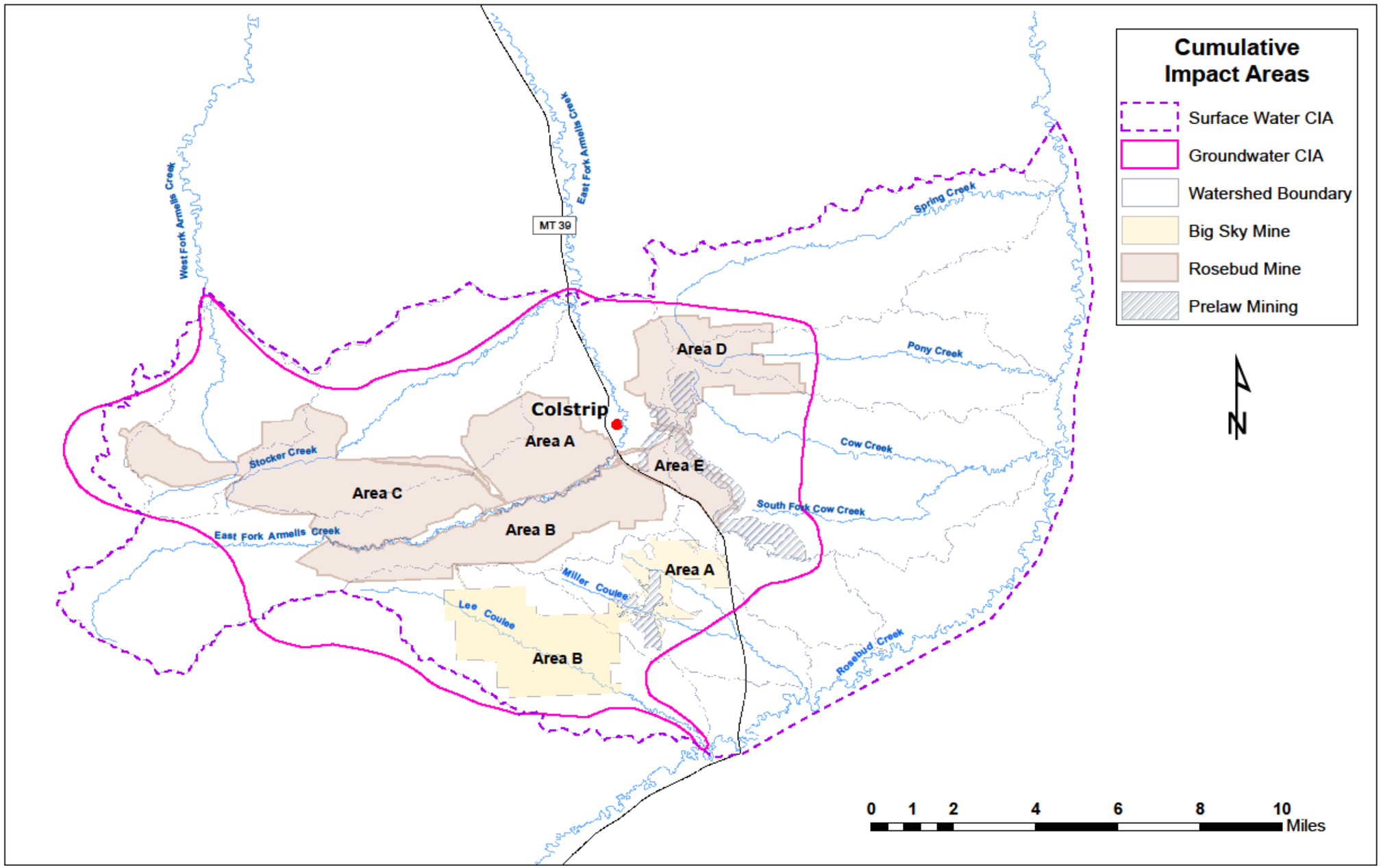


Figure 5-1: Locations and extents of surface water and groundwater cumulative impact boundaries.

Exhibit 2

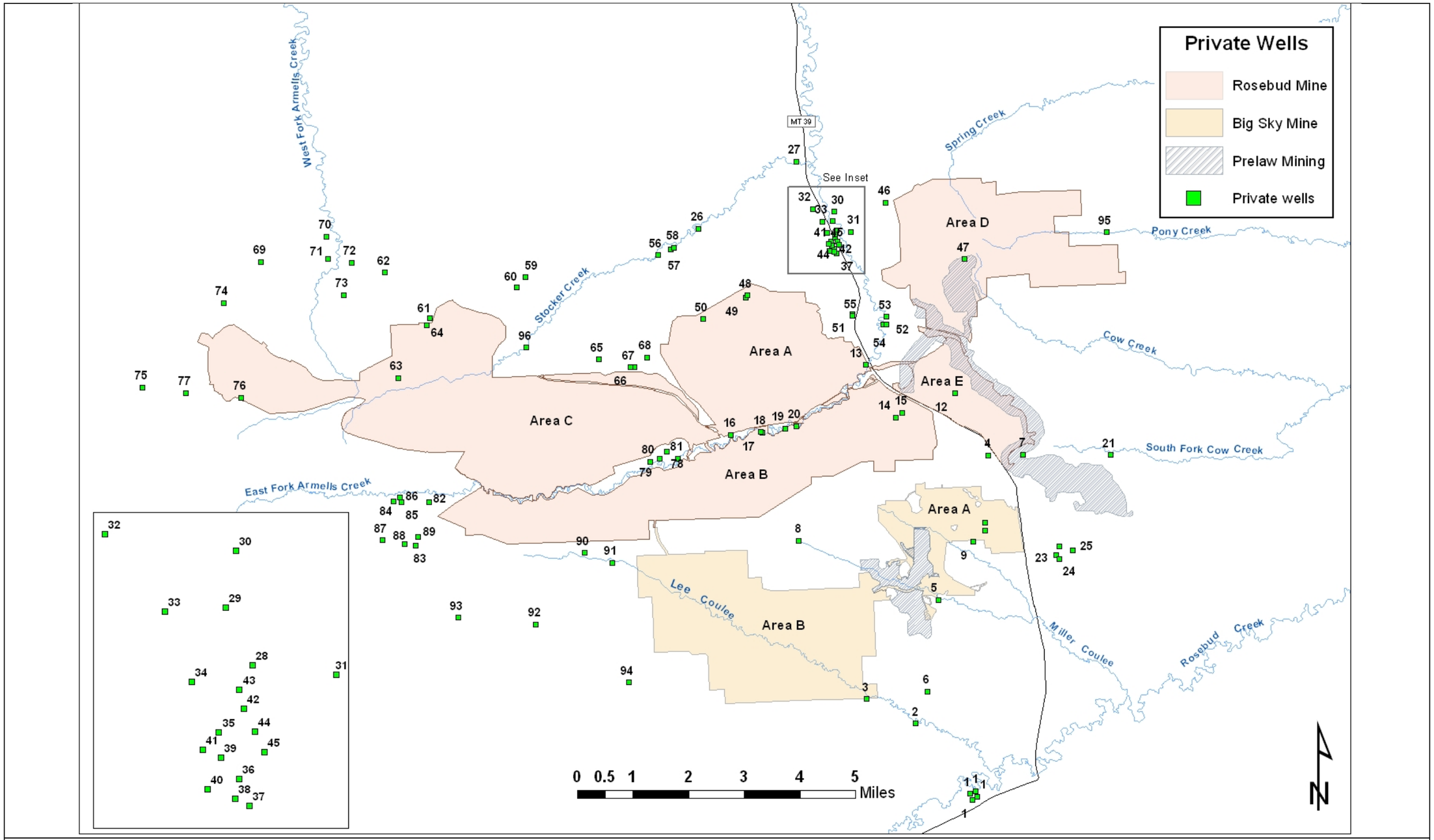


Figure 6-1: Private wells in the groundwater cumulative impact area (CIA).
Well location based on information from GWIC. Numbered wells are listed in Table 6-1. Wells shown do not include monitoring wells, industrial wells or wells owned by the Rosebud or Big Sky mines.

Exhibit 2

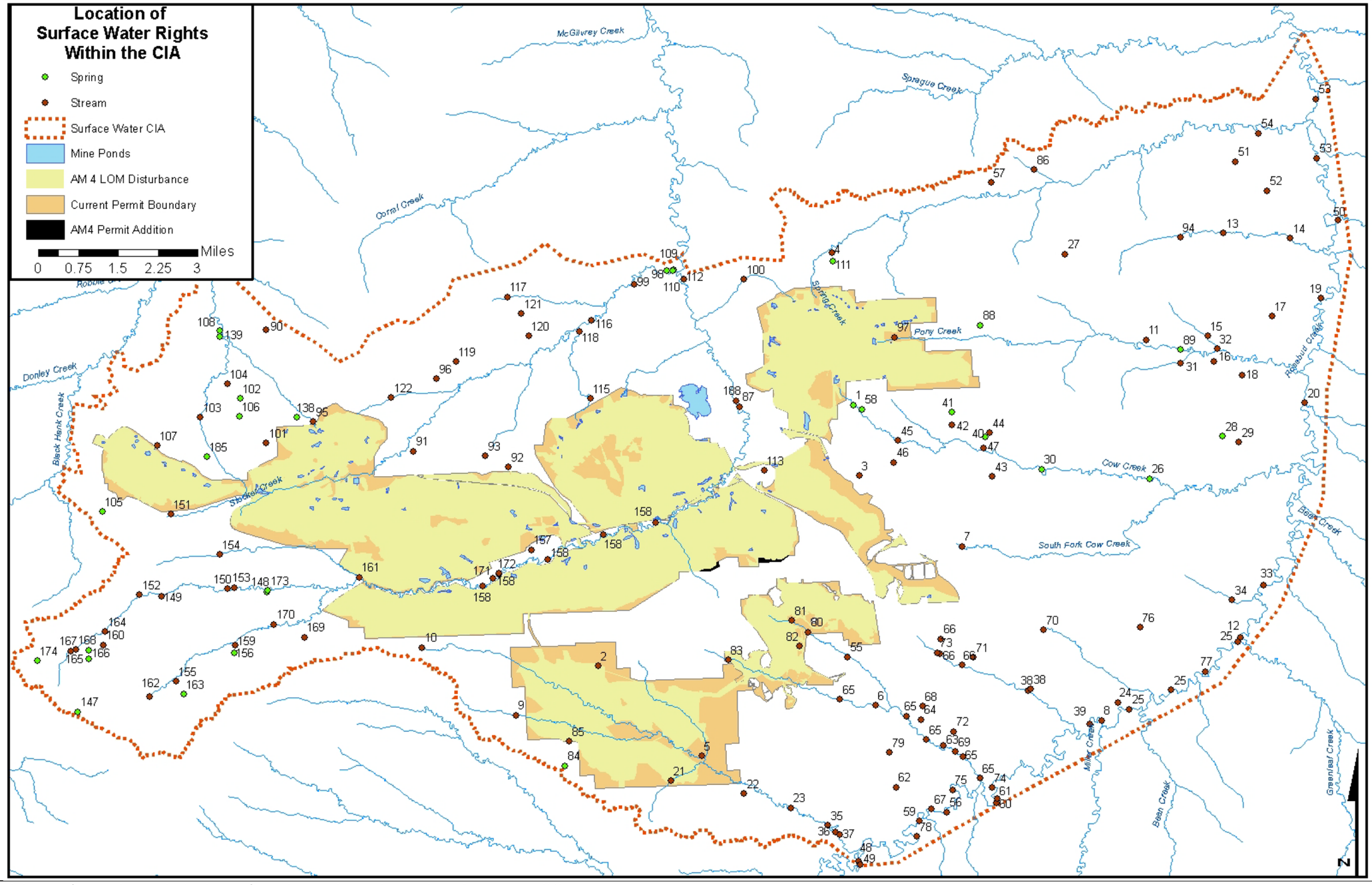


Figure 6-2: Active surface water rights. Further information on the water right is listed in Table 6-2.

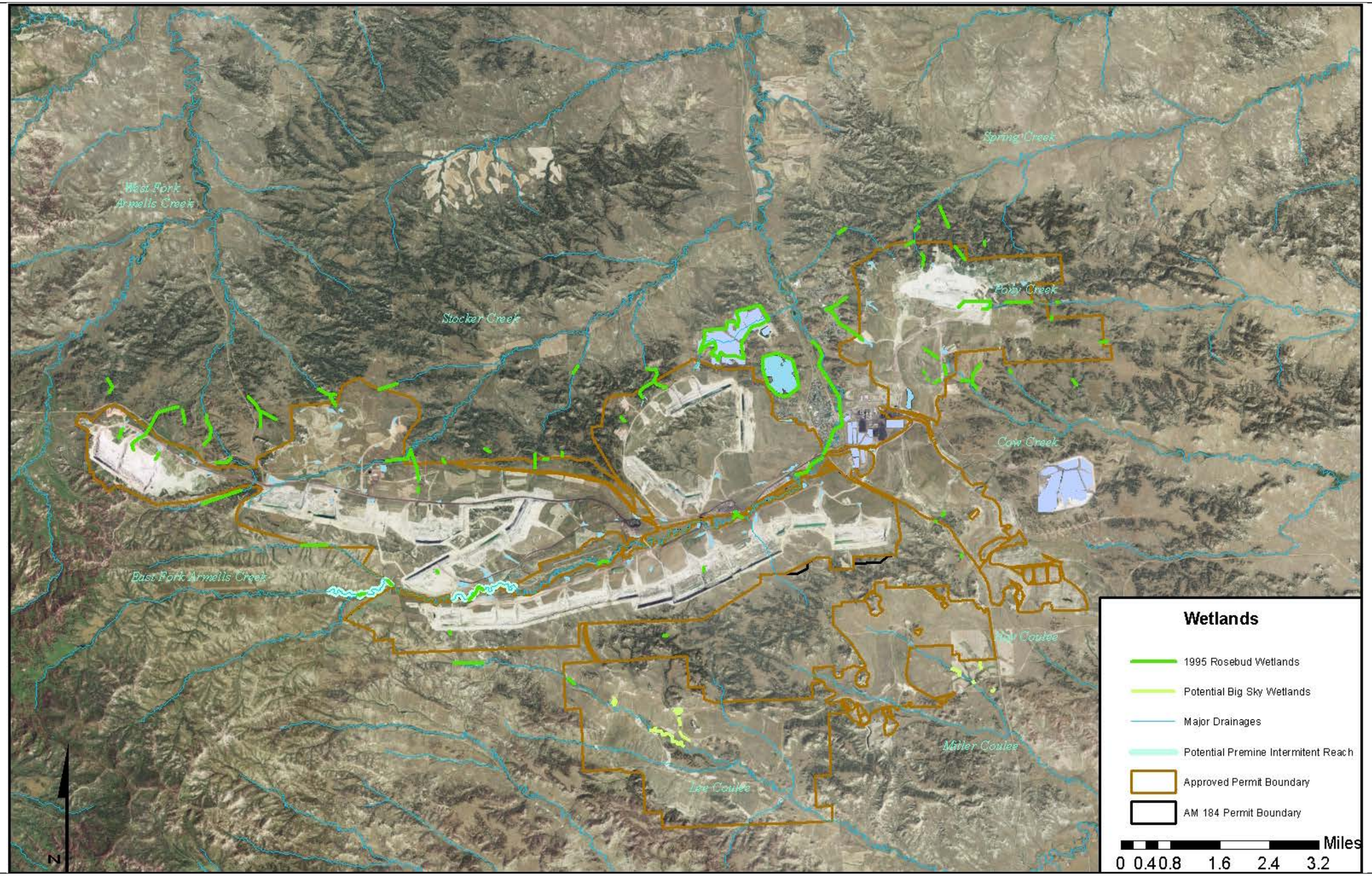


Figure 6-3: Wetlands identified for the Rosebud mine in 1995 and possible wetland reaches for the Big Sky mine identified from 2011 aerial photography.

Exhibit 2

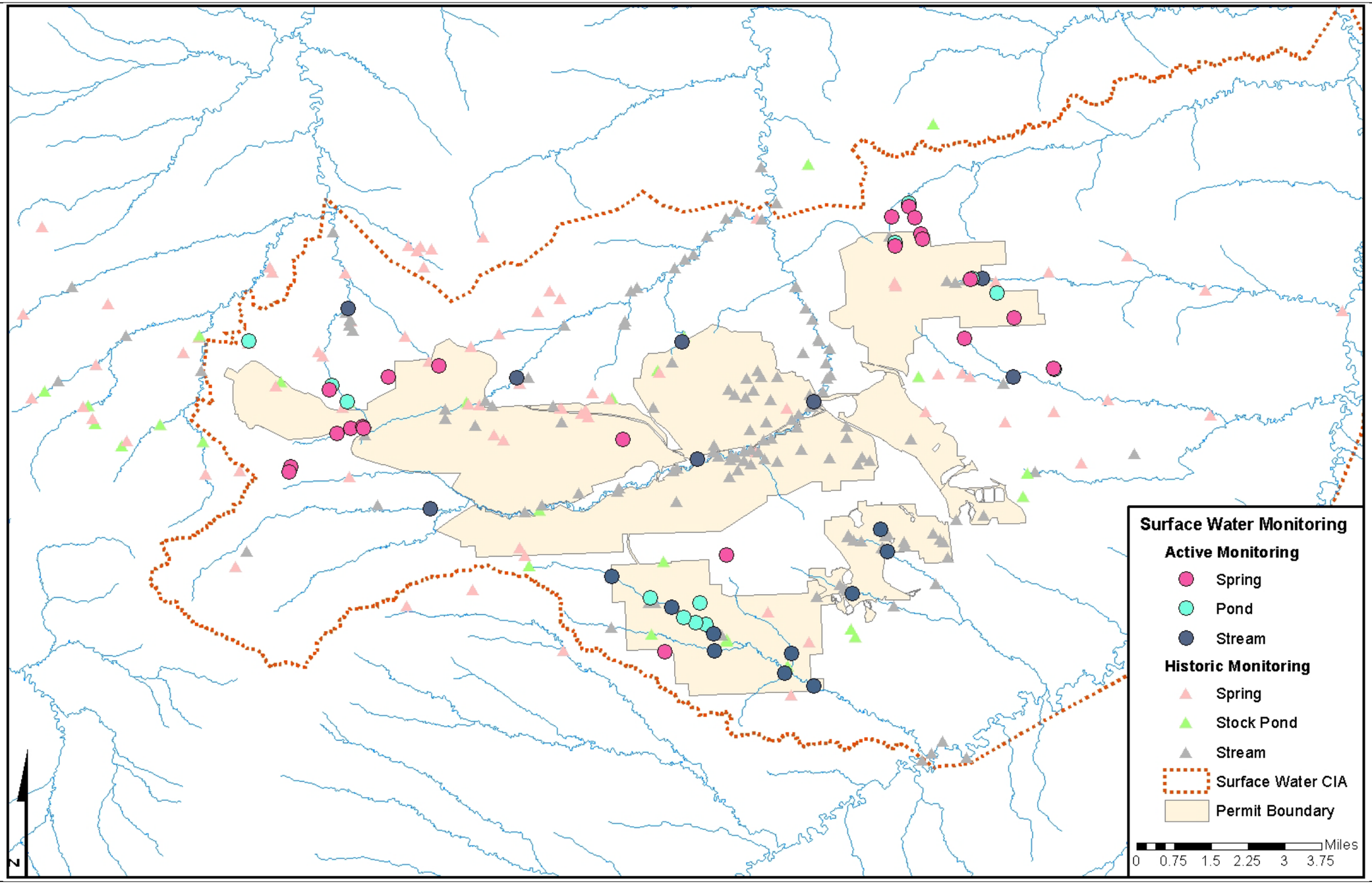


Figure 7-1: Historic and current surface water monitoring locations.

Exhibit 2

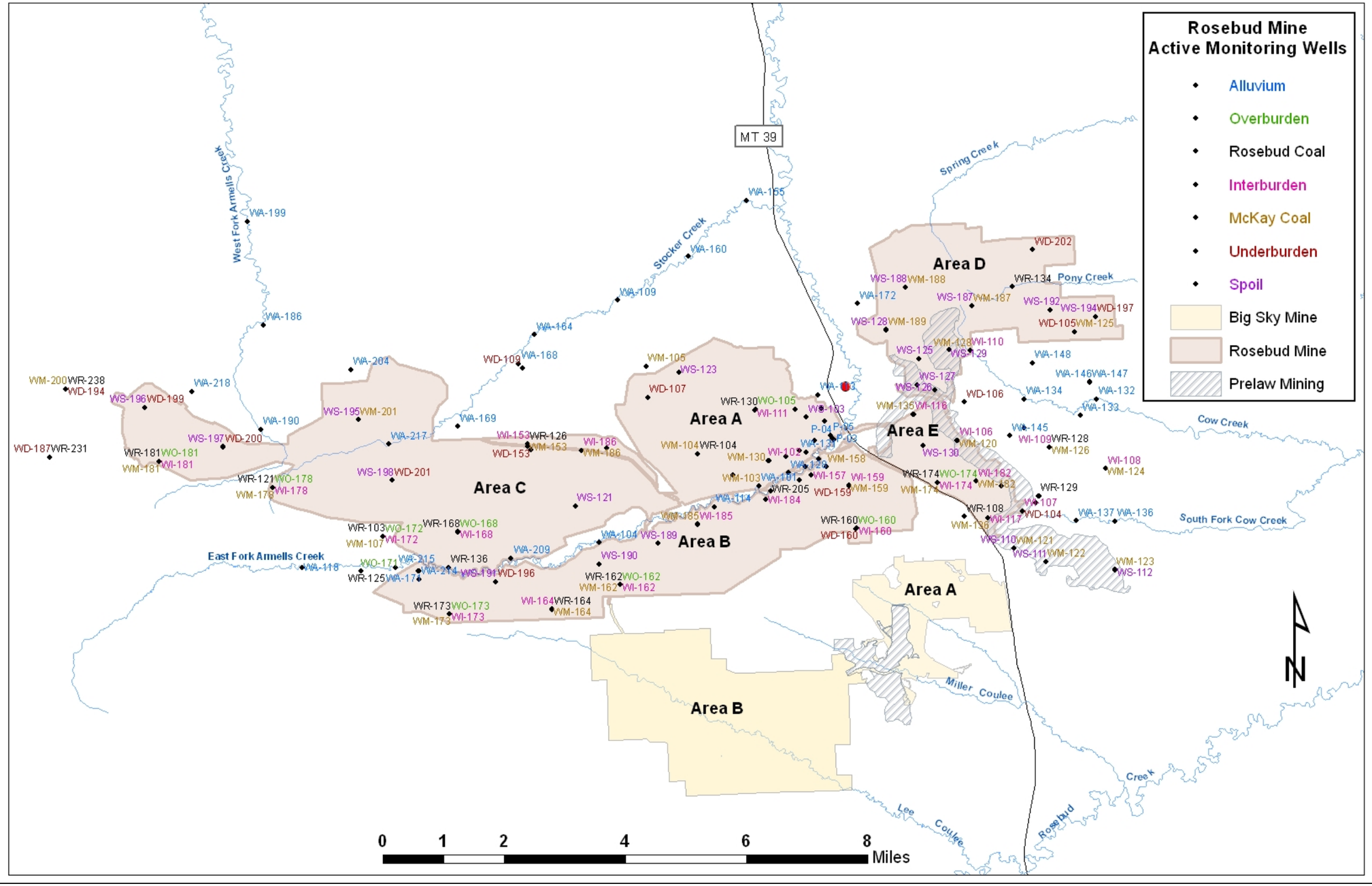


Figure 7-2: Active Rosebud Mine monitoring wells.

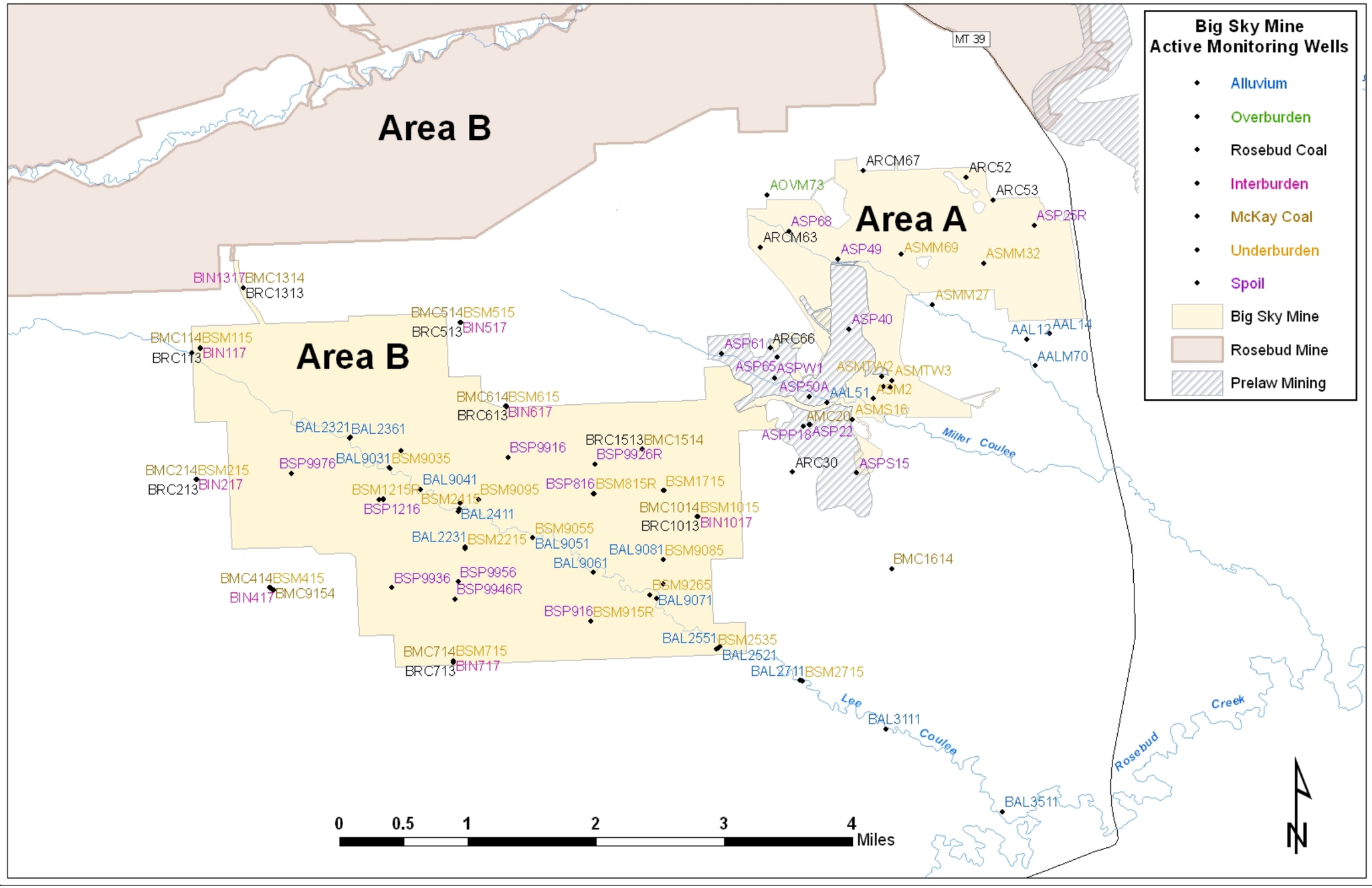


Figure 7-3: Active monitoring wells at the Big Sky Mine.

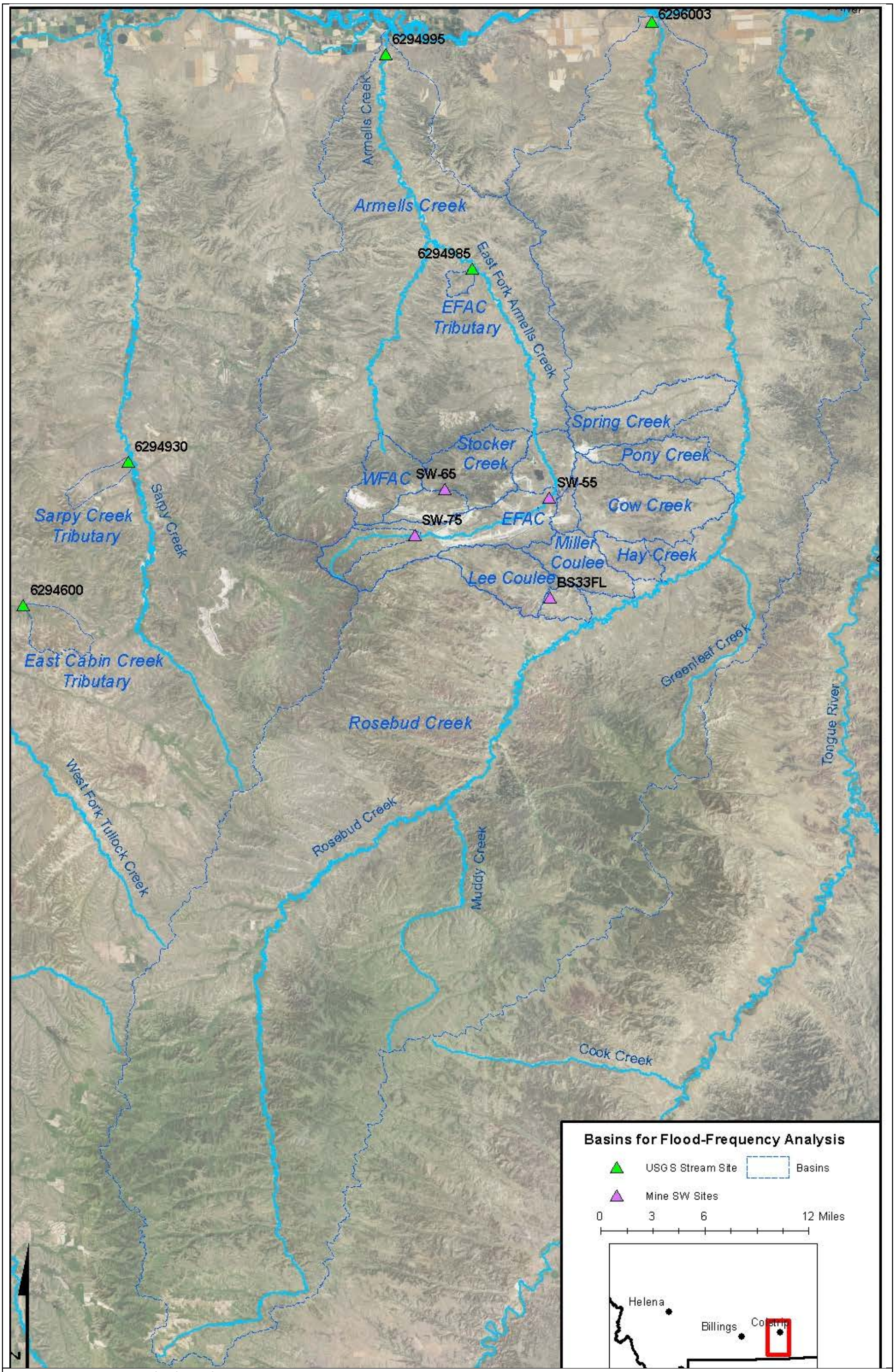


Figure 8-1: Basins used for flood-frequency calculations.

Exhibit 2

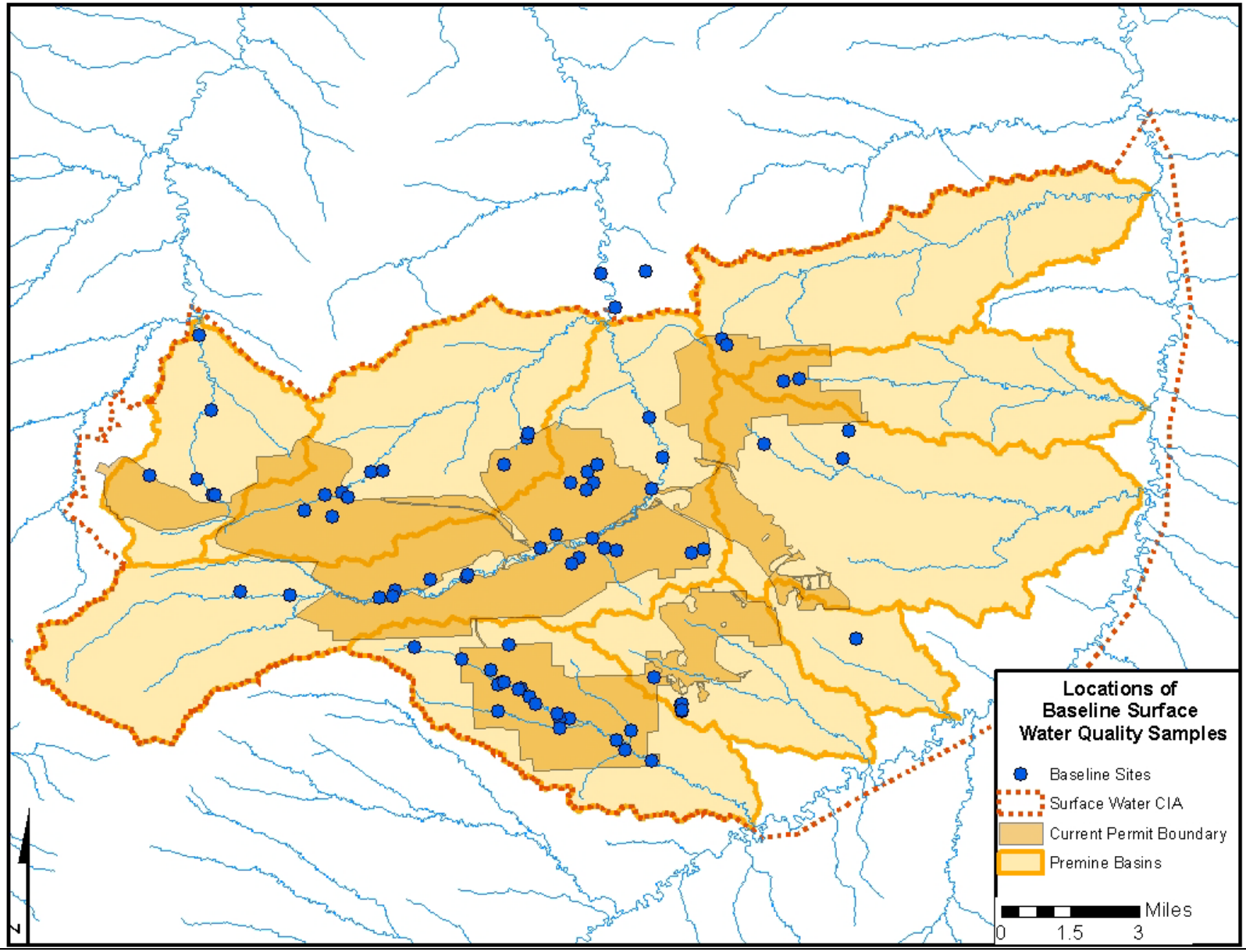


Figure 8-2: Locations of baseline surface (stream and stock pond) water quality samples used in Figure 8-3 and Figure 8-4.

Exhibit 2

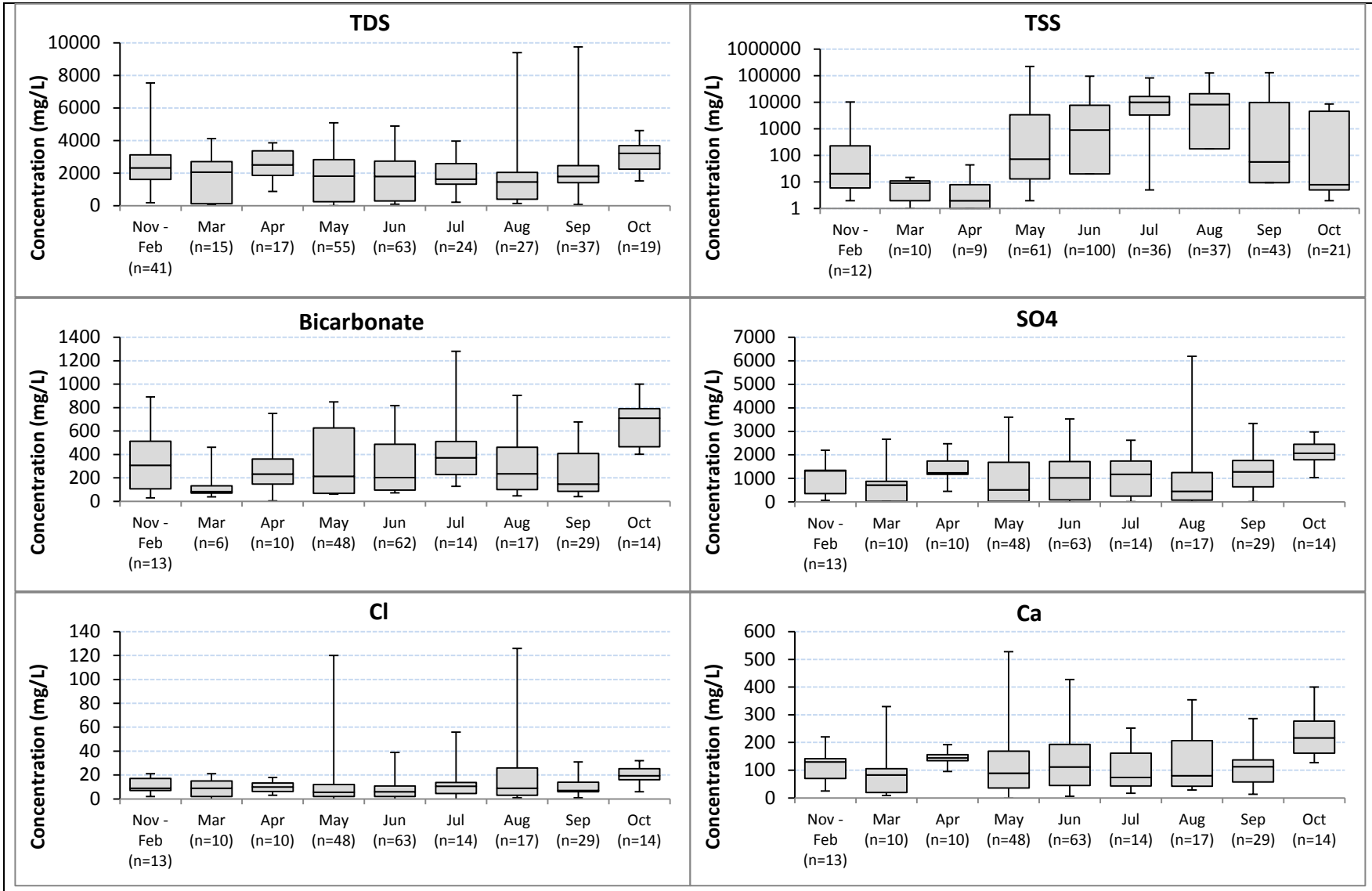
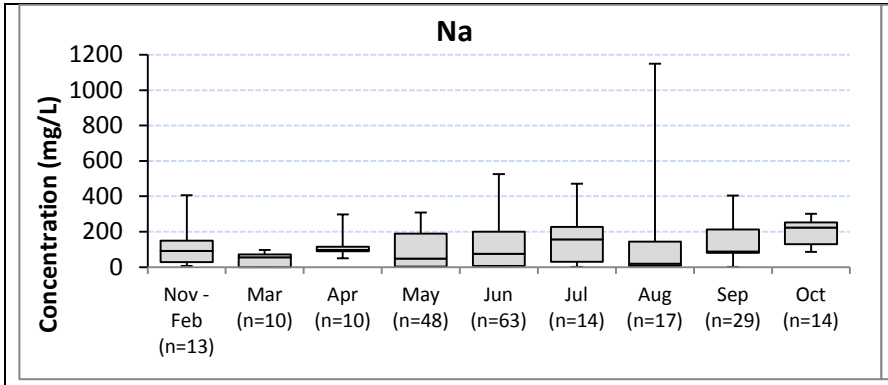


Figure 8-3 a: Baseline stream and stock pond water quality by month.
Baseline samples include all water quality samples collected before mining commenced upstream of a sampling point. The box-and-whisker plots show the 75th percentile, median, and 25th percentile with the min and max shown as error bars.



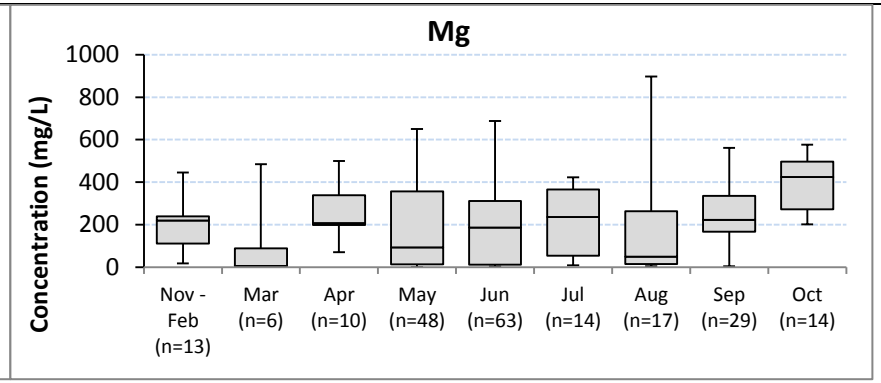
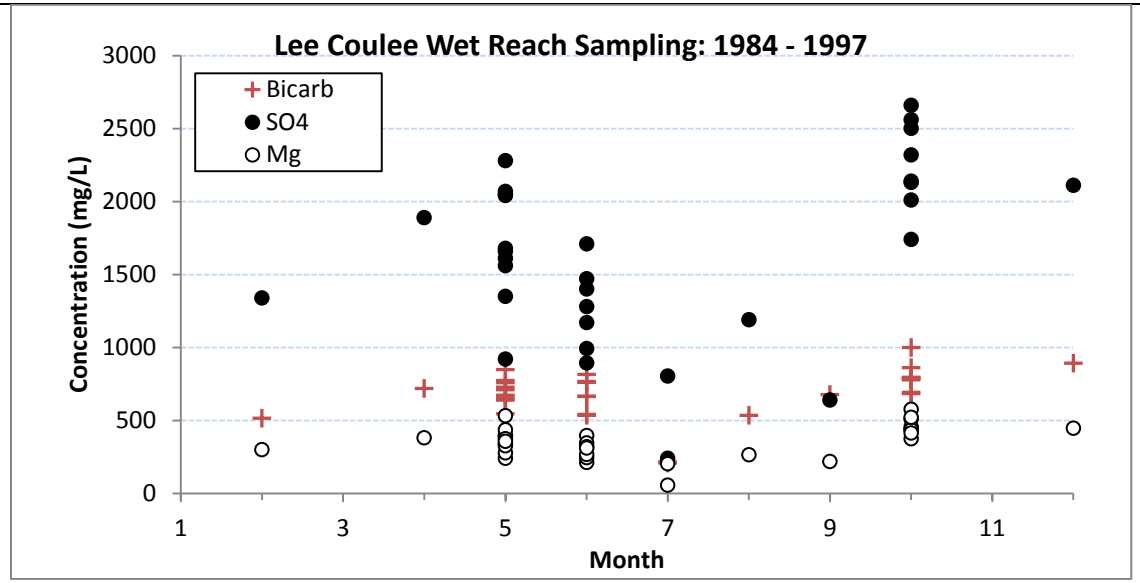


Figure 8-3 a continued.



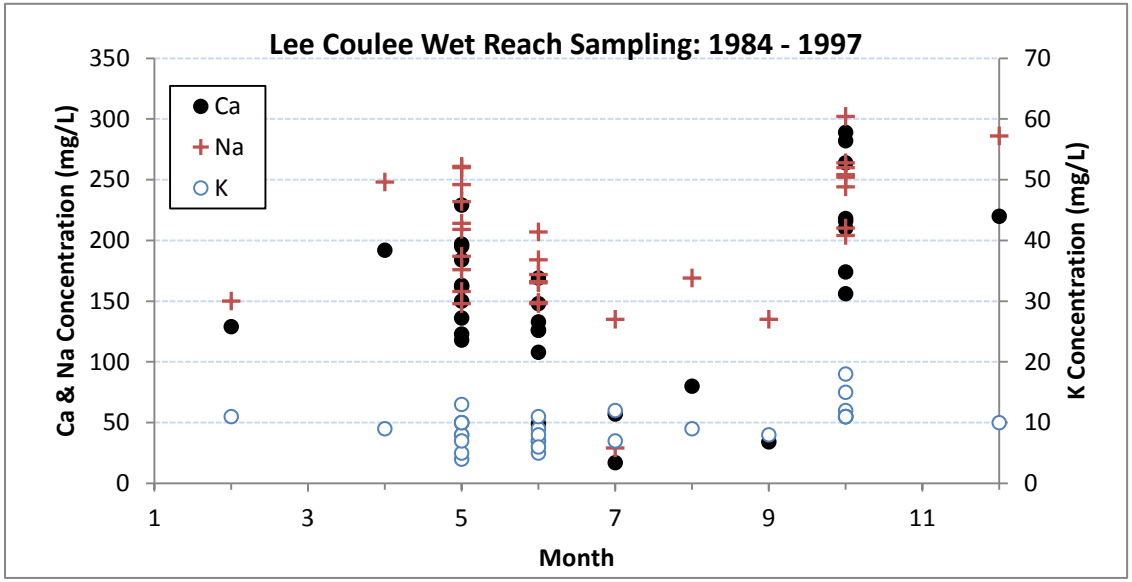


Figure 8-3 b: Lee Coulee wet reach baseline water quality by month.

Exhibit 2

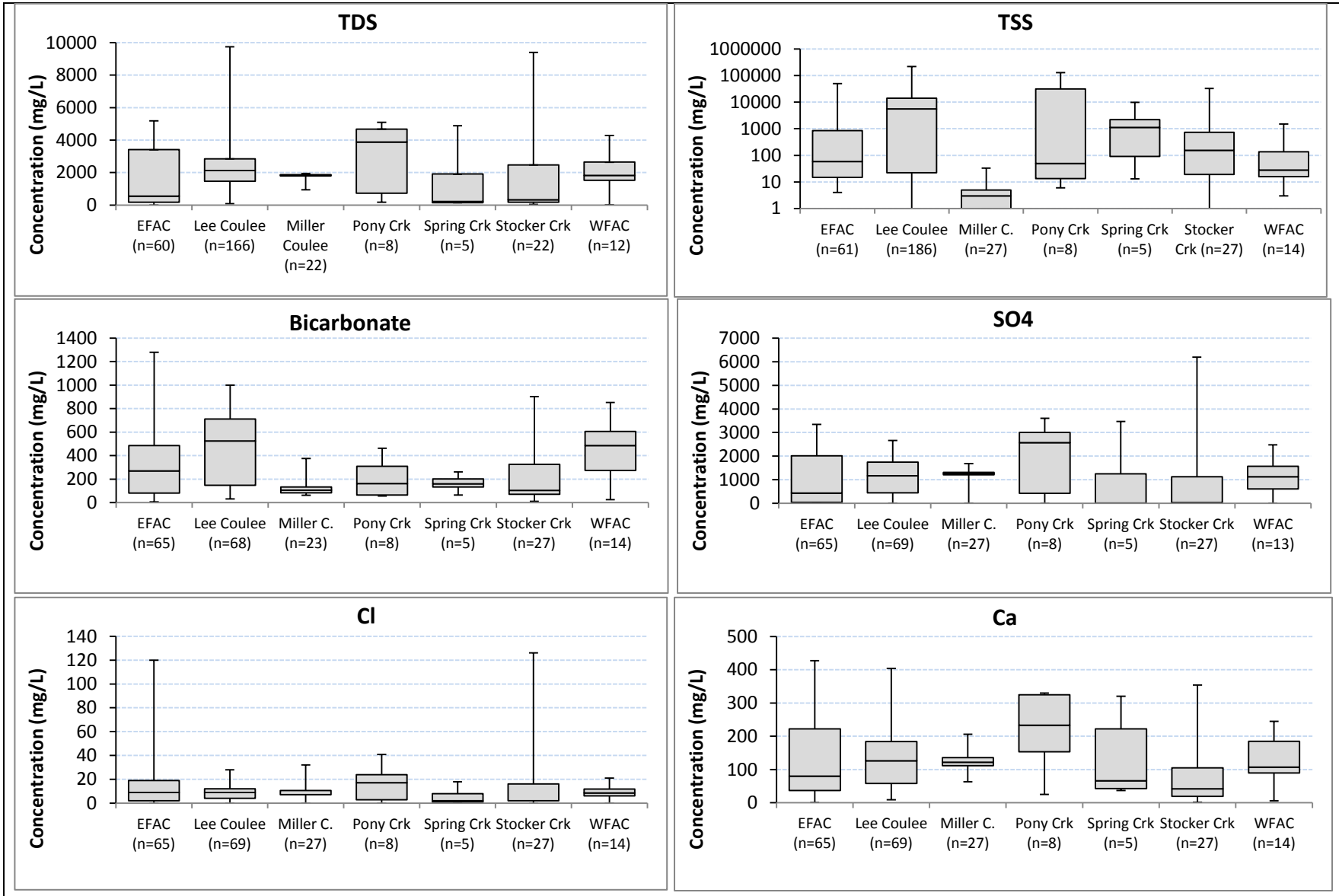
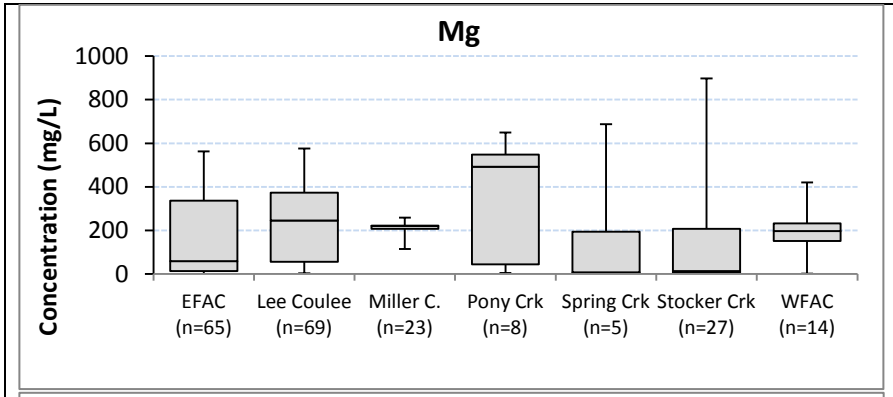
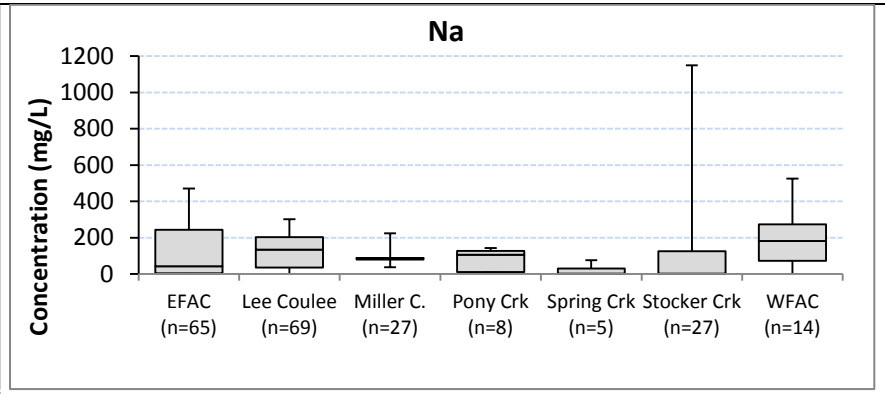


Figure 8-4: Baseline stream and stock pond water quality by drainage.
Baseline samples include all water quality samples collected before mining commenced upstream of a sampling point. The box-and-whisker plots show the 75th percentile, median, and 25th percentile with the min and max shown as error bars.





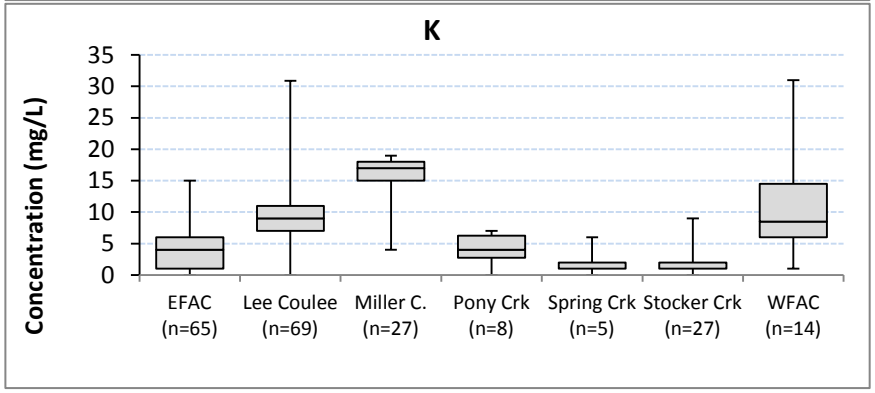


Figure 8-4 continued.

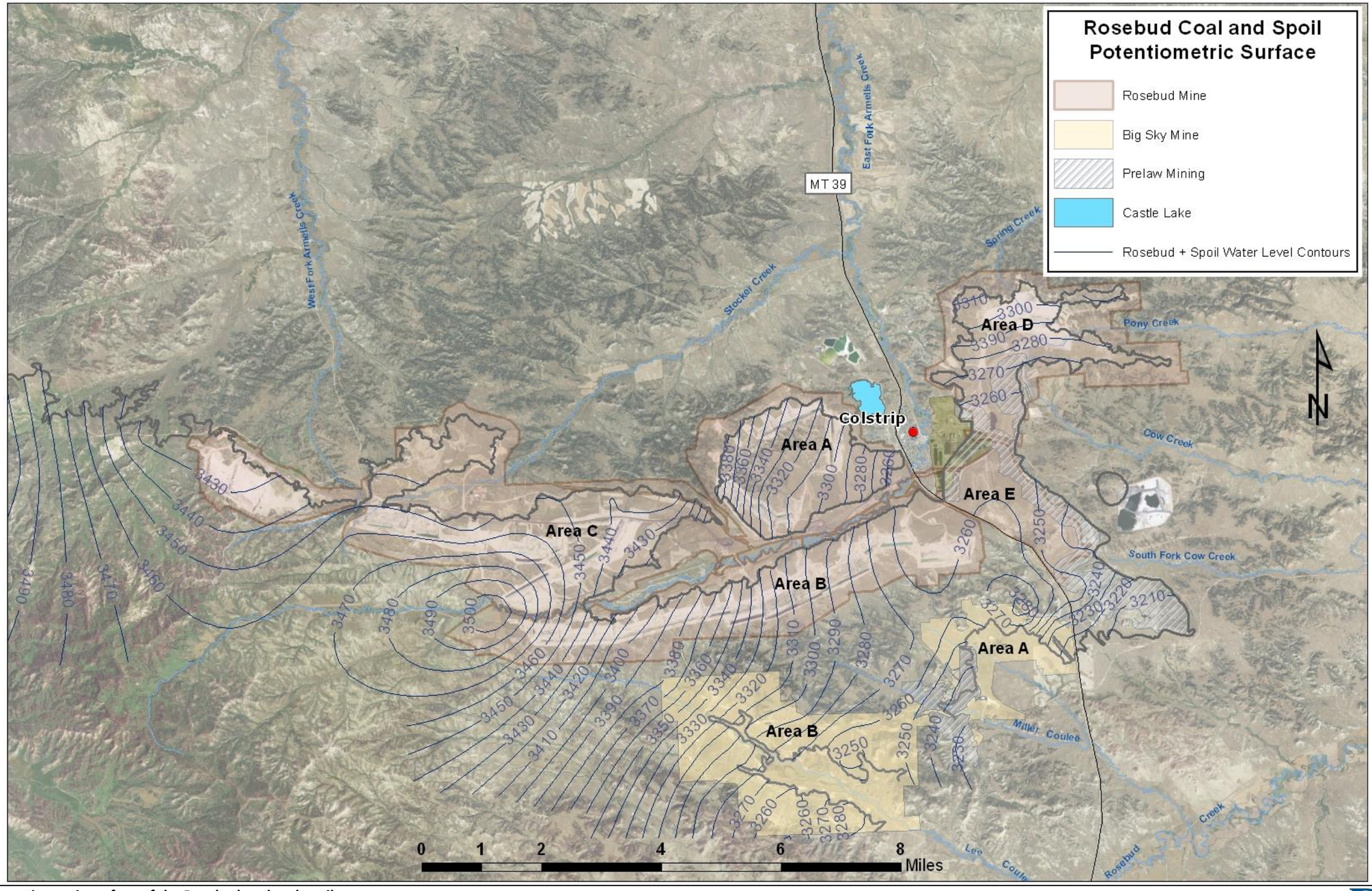


Figure 8-5: Potentiometric surface of the Rosebud coal and spoil.
Plotted from monitoring well water levels at the Rosebud and Big Sky Mines in 2012. (Western Energy Company, 2012; Big Sky Coal Company, 2013).

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Exhibit 2

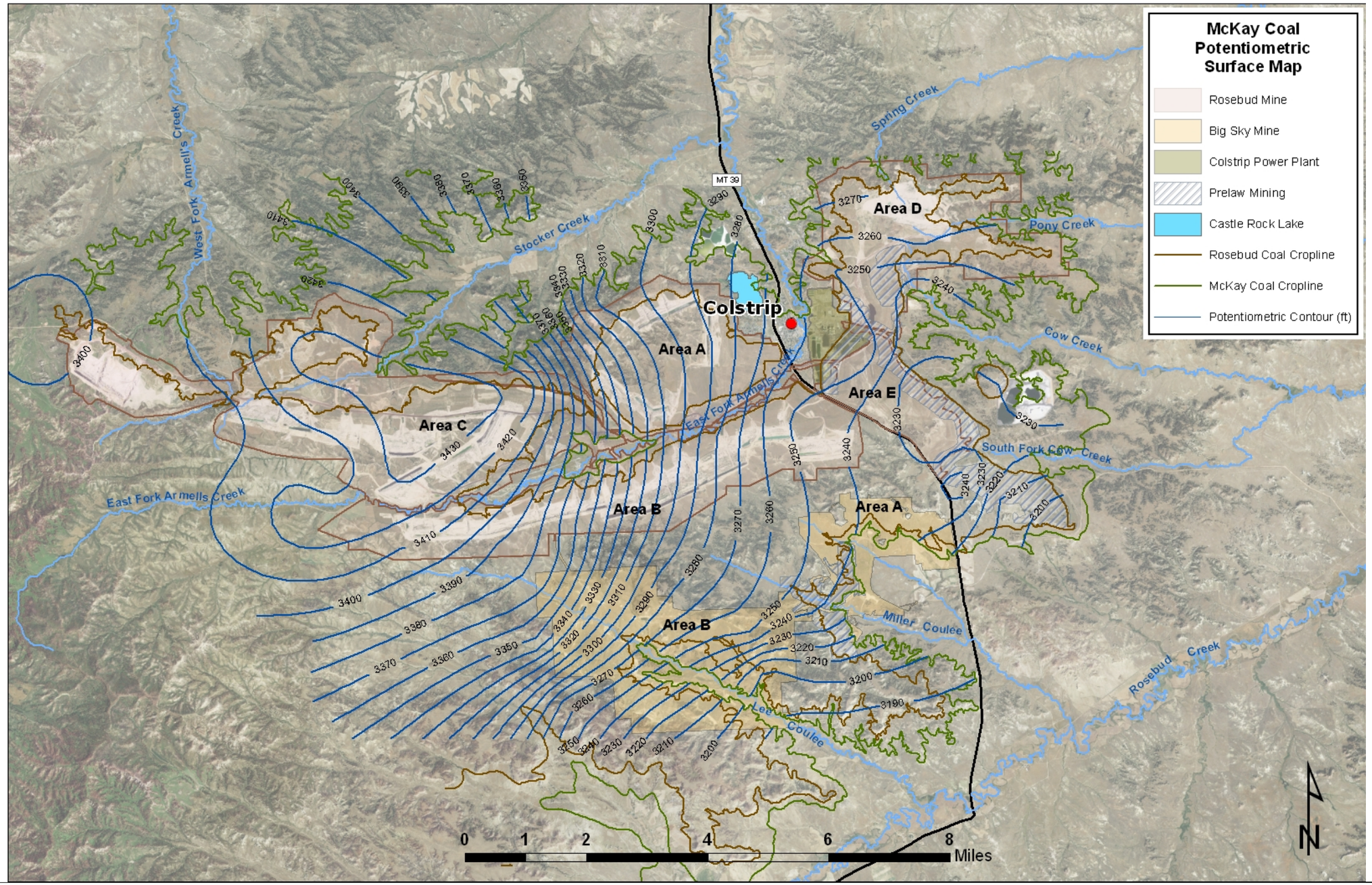


Figure 8-6: Potentiometric surface of the McKay coal.
Plotted from monitoring well water levels at the Rosebud Mine (2012) and Big Sky Mine (2013).

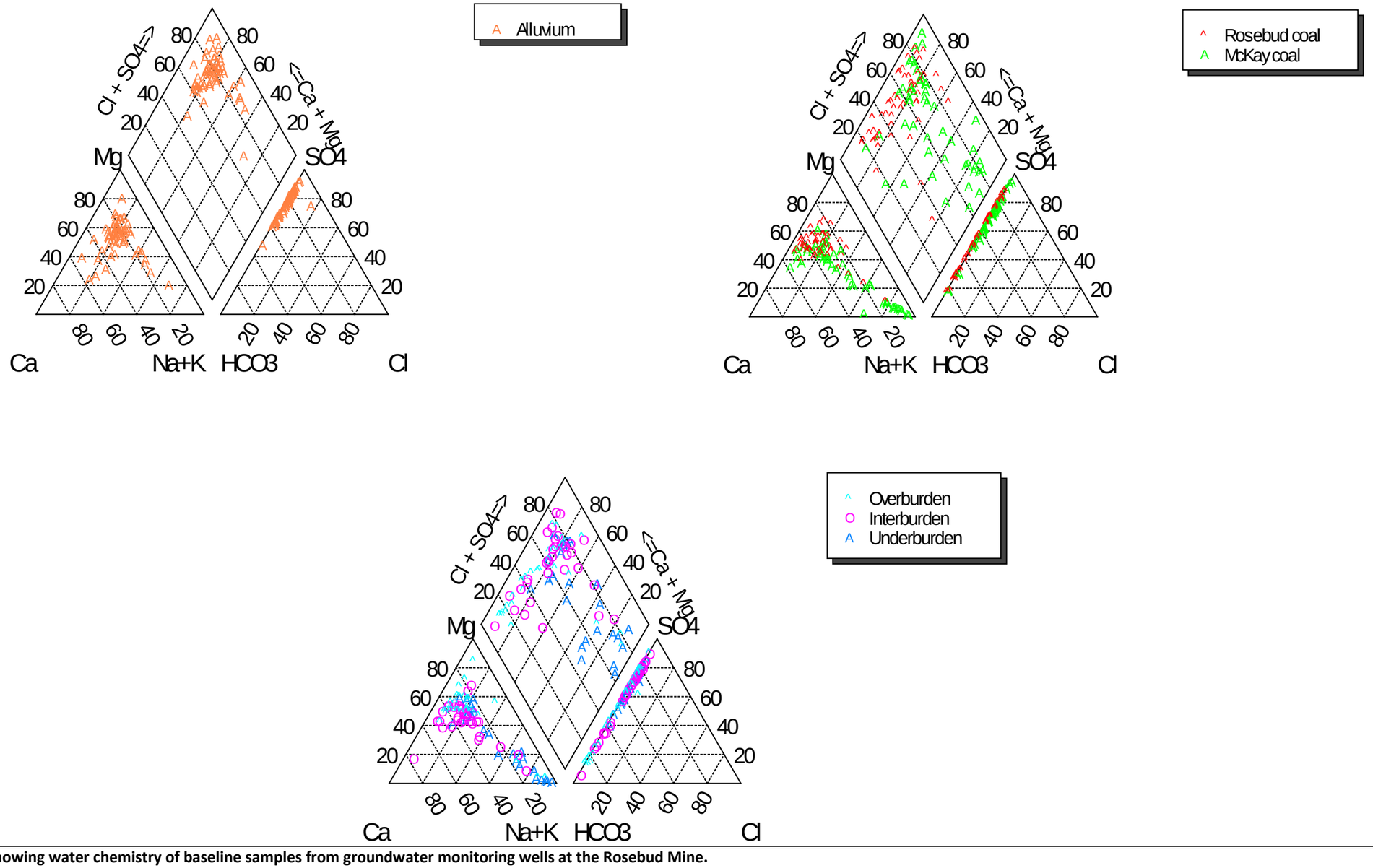


Figure 8-7: Piper plots showing water chemistry of baseline samples from groundwater monitoring wells at the Rosebud Mine.

Figure 8-8: Piper plots showing water chemistry of baseline samples from groundwater monitoring wells in the Big Sky Mine Area B.

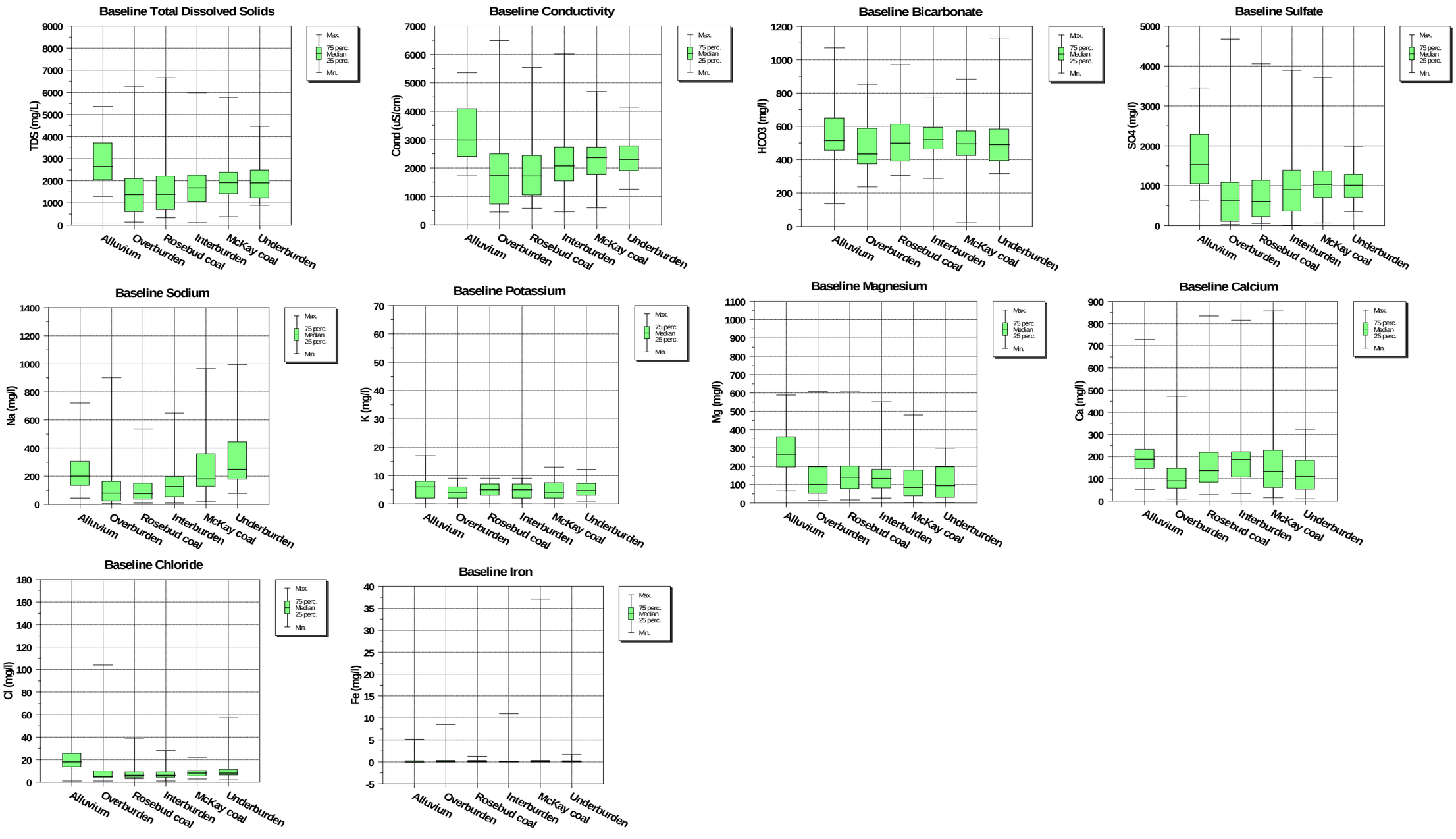
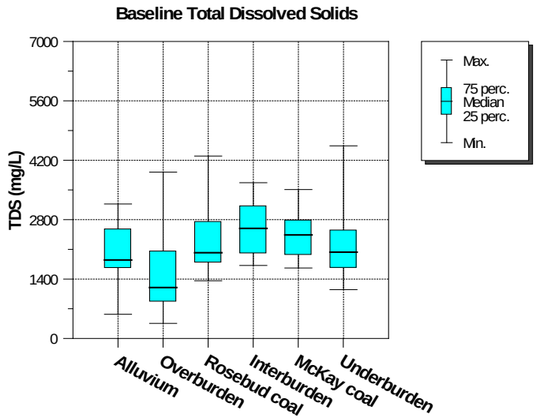
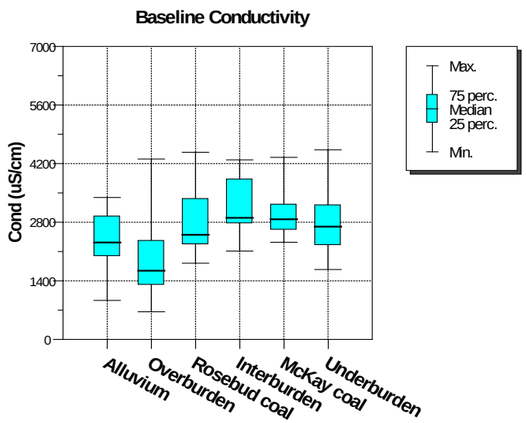
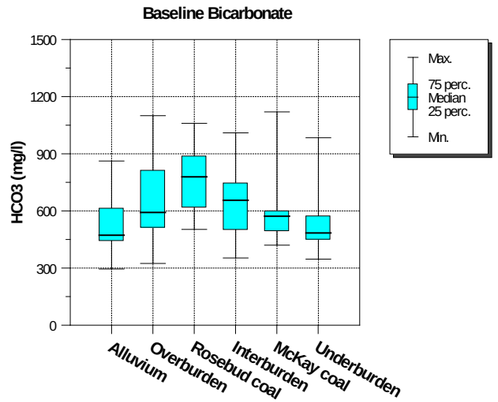
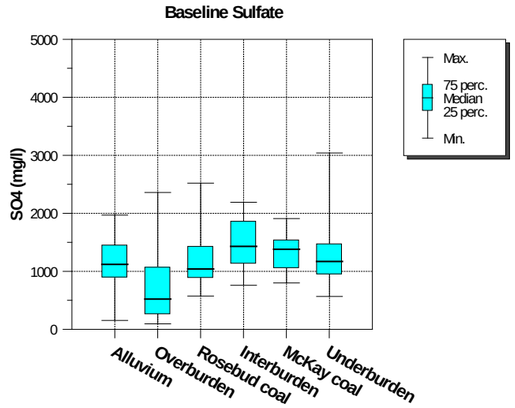


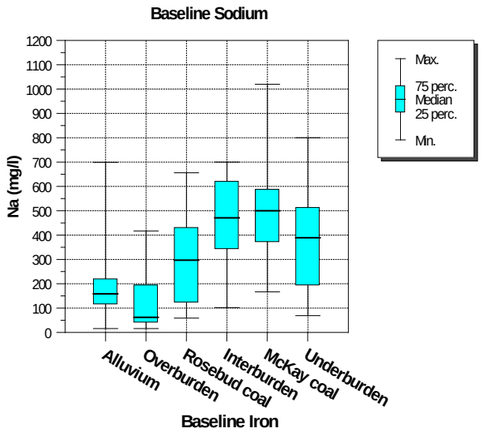
Figure 8-9: Box and whisker plots of baseline analyses from Rosebud Mine monitoring wells.
Total samples= 245; Alluvium=59; Overburden=31; Rosebud=50; Interburden=33; McKay=48; Underburden=24.

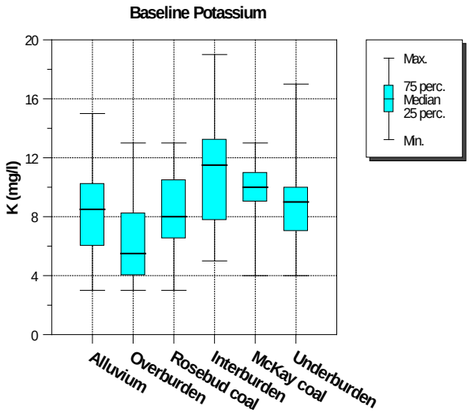


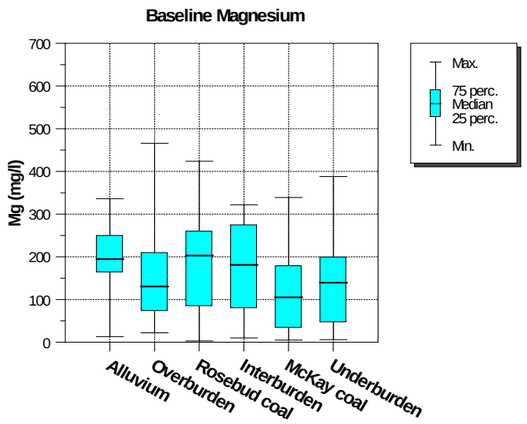


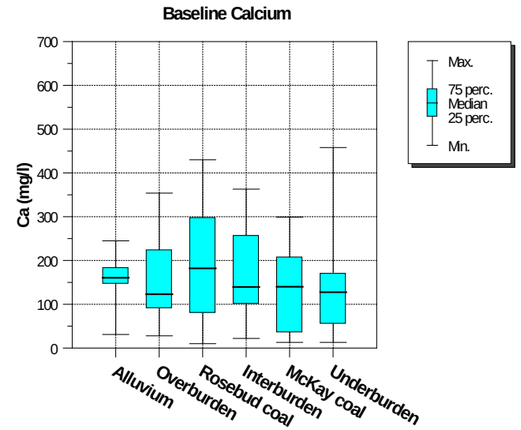


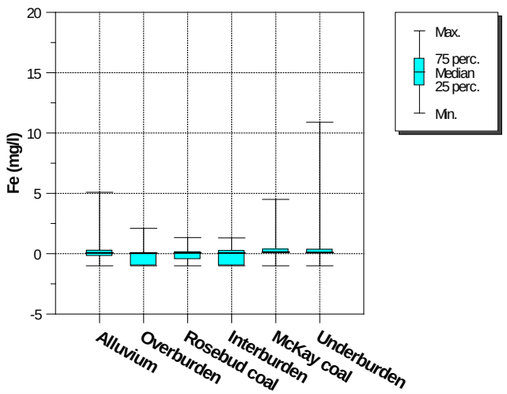












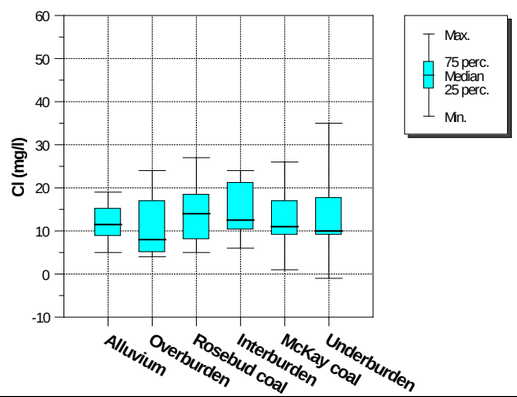


Figure 8-10: Box and whisker plots of baseline analyses from Big Sky Mine Area B monitoring wells.
Total samples=114.

Exhibit 2

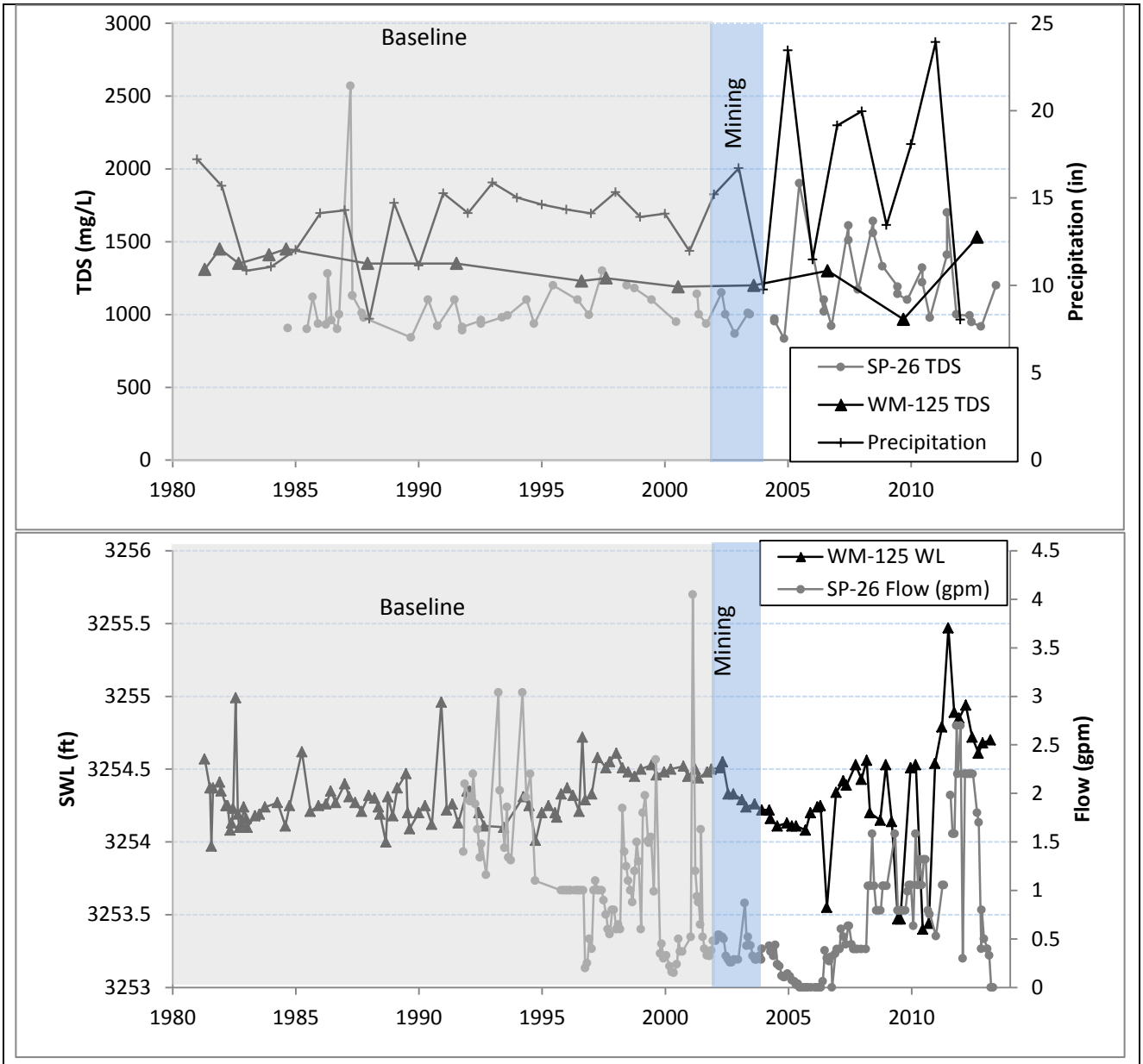
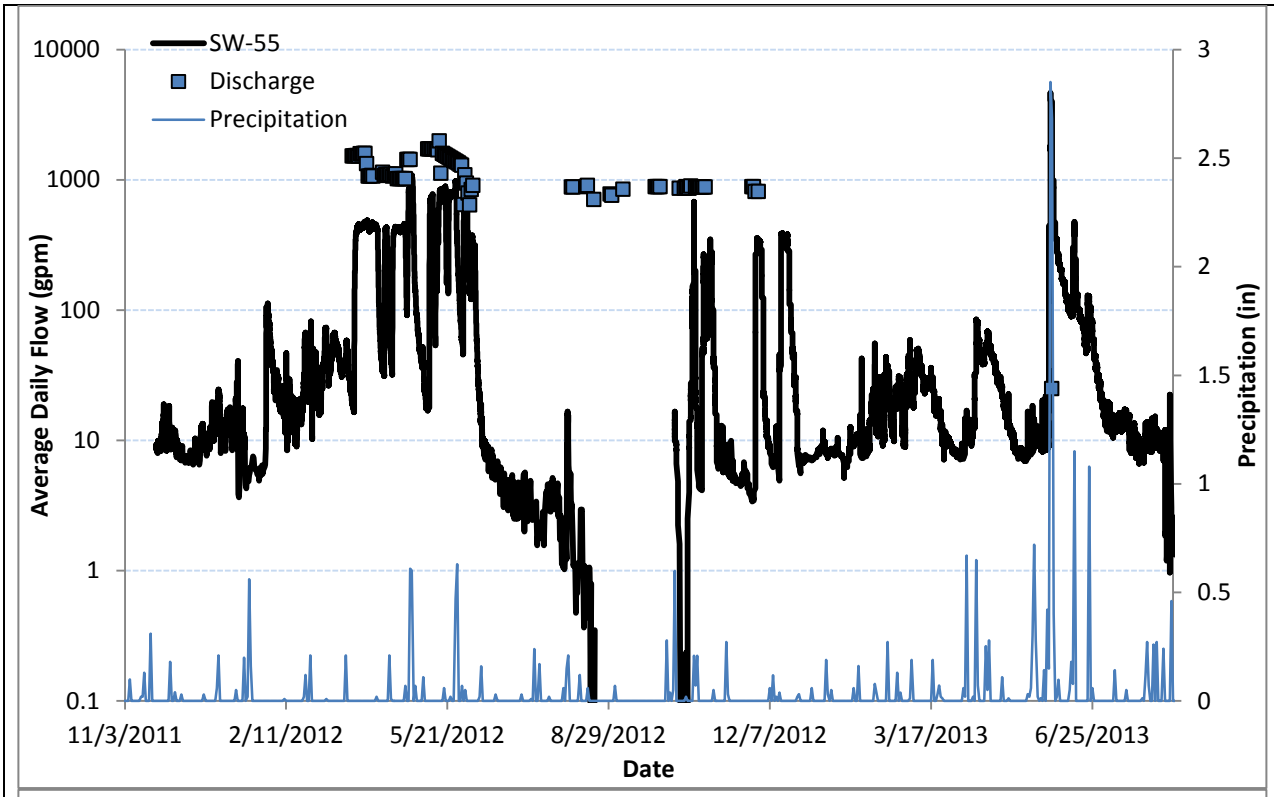


Figure 9-1: Water quality and quantity at Spring SP-26 and nearby McKay well WM-125.

Note that flow measurements at SP-26 include periods when the developed spring was almost frozen. Annual total precipitation (Jan-Dec) is plotted against SP-26 TDS for comparison.



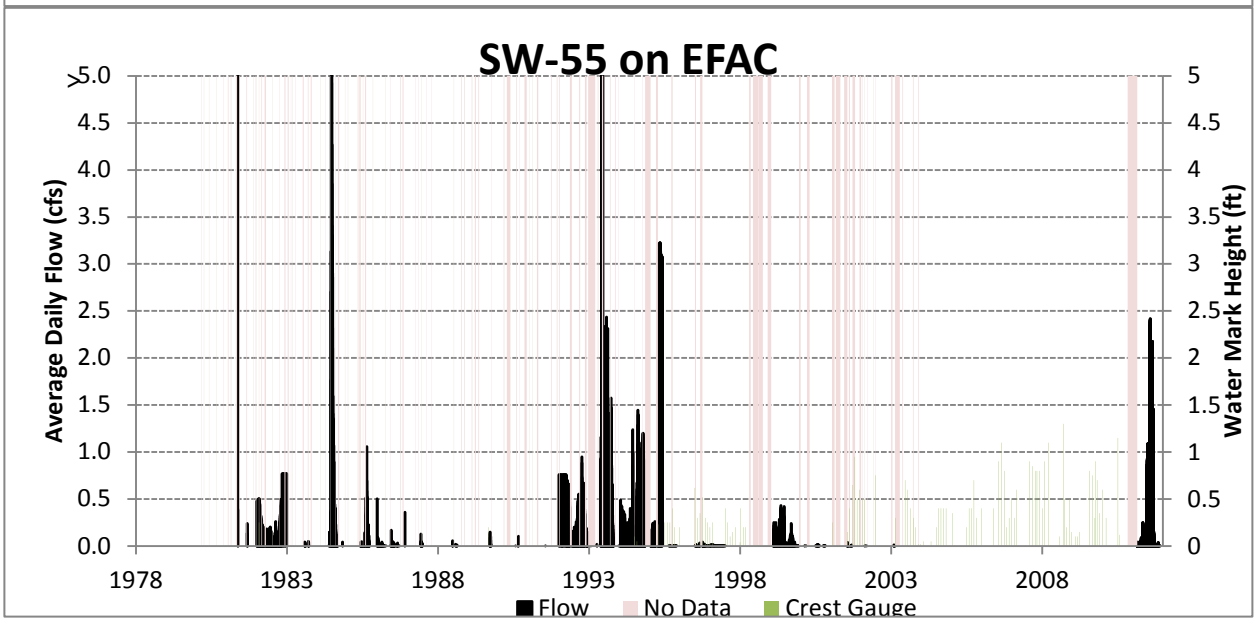
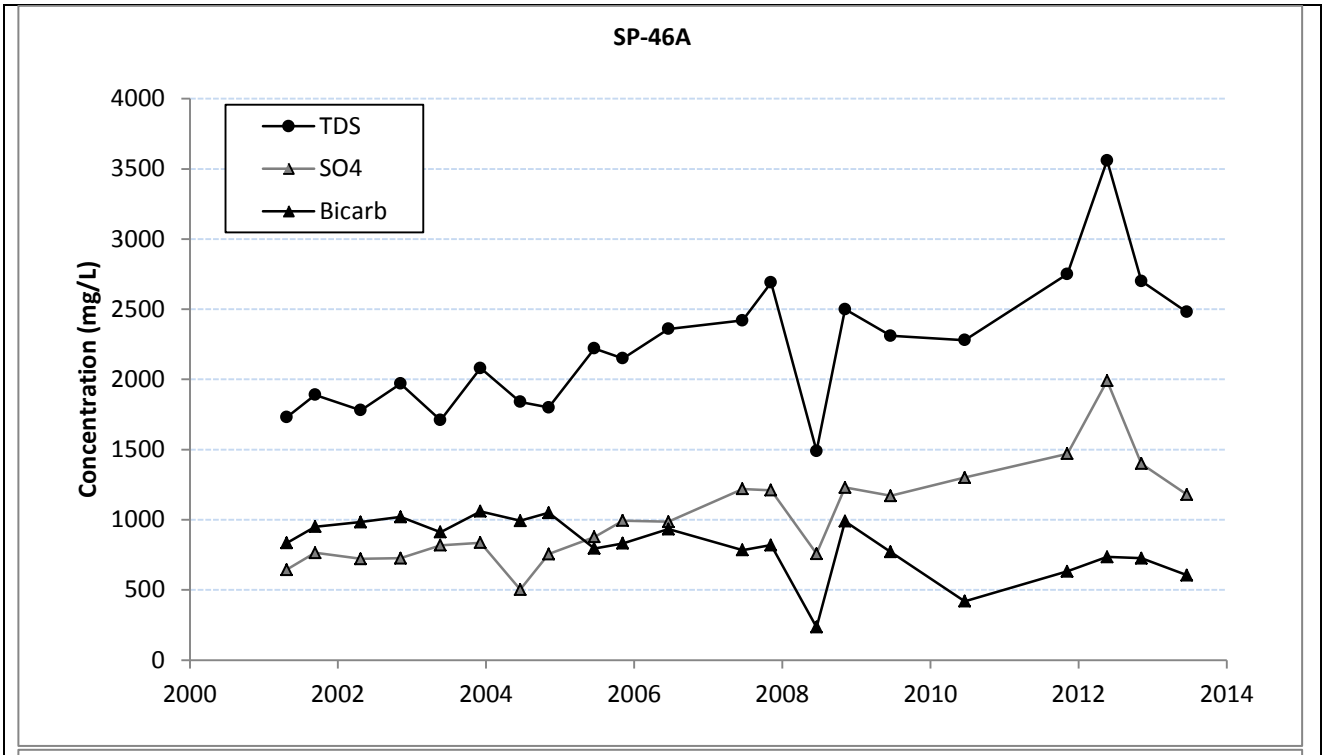


Figure 9-2: Flows measured at SW-55 in East Fork Armells Creek.
In the top graph, flow (in gpm) is compared with MPDES discharge rates of pit water into the creek and precipitation. In the bottom graph, the entire record of flow and crest gauge measurements at SW-55 is shown. The conversion between crest gauge height and instantaneous flow is not known for the site.



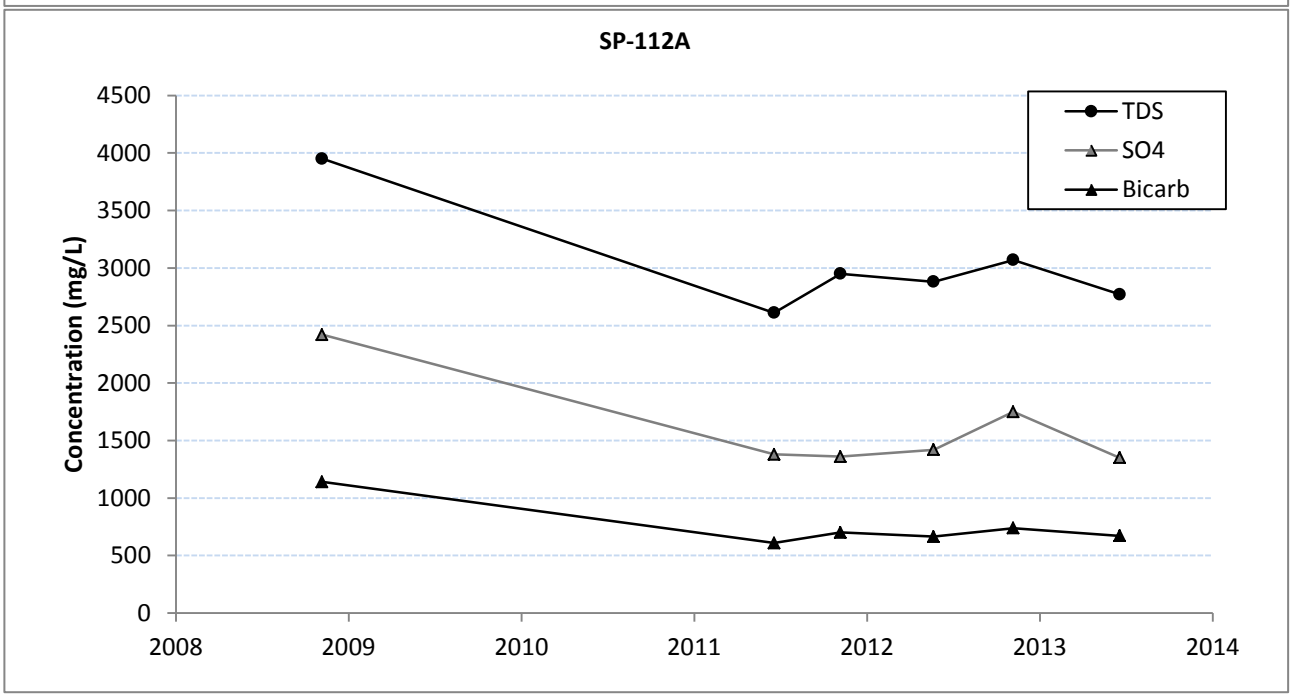


Figure 9-3: Water quality in springs SP-46A and SP-112A.
Both springs are sourced from the spoils aquifer.

Exhibit 2

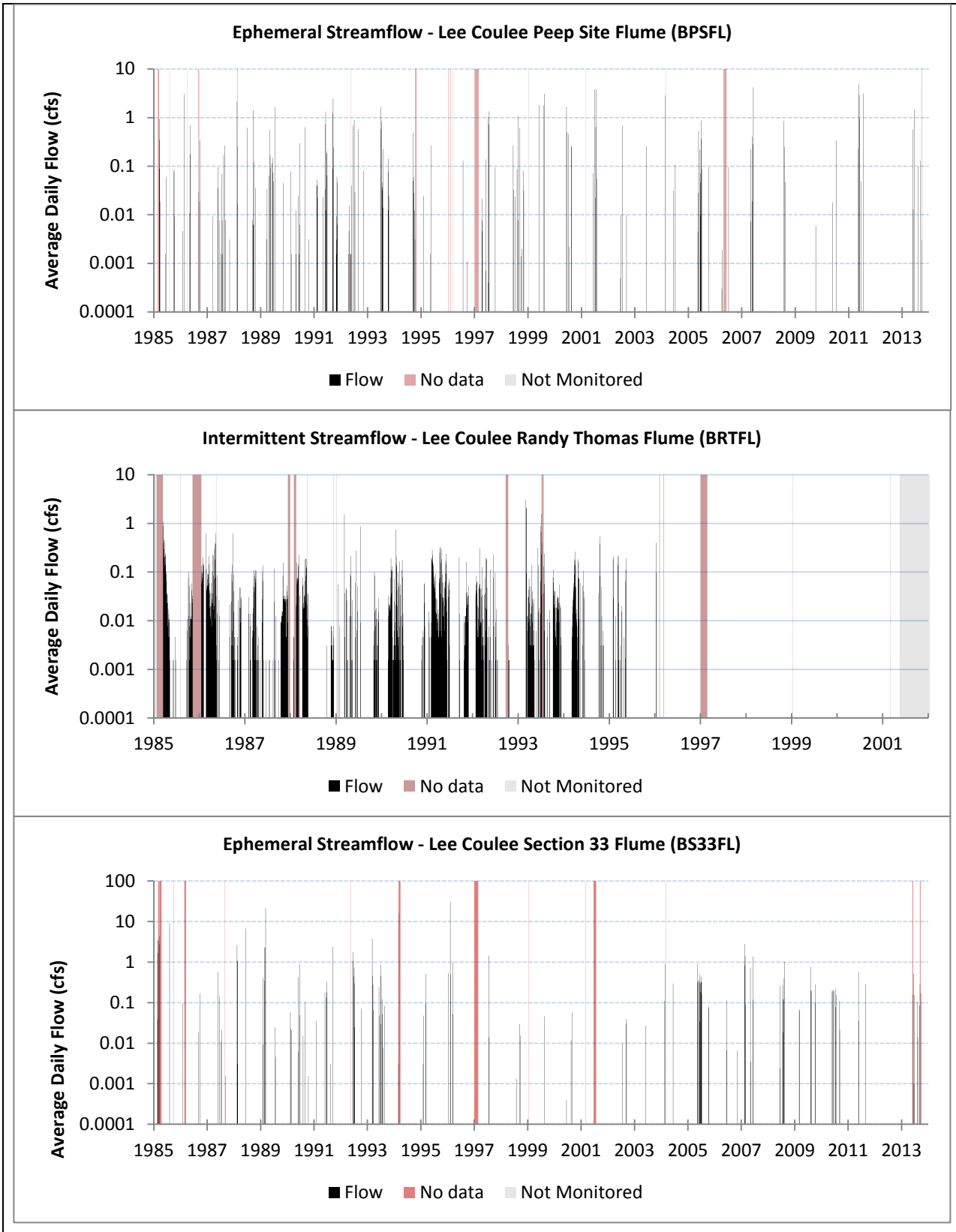
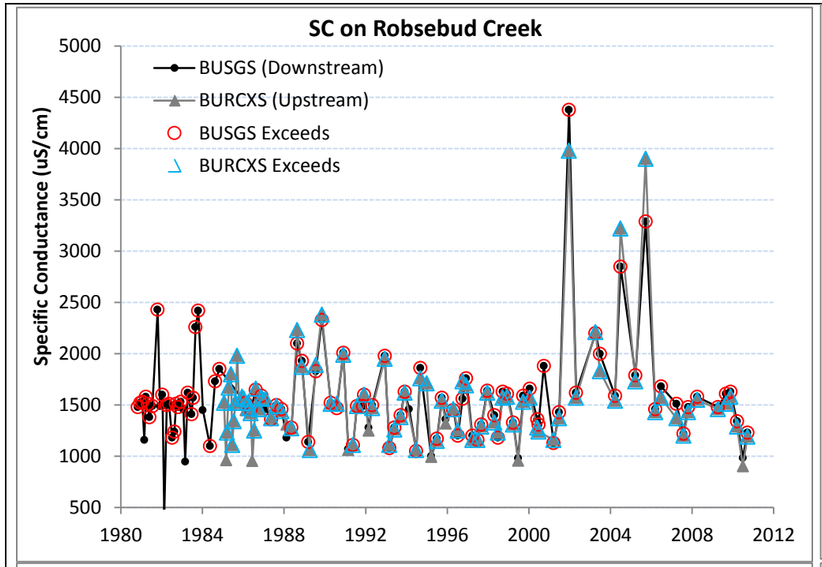
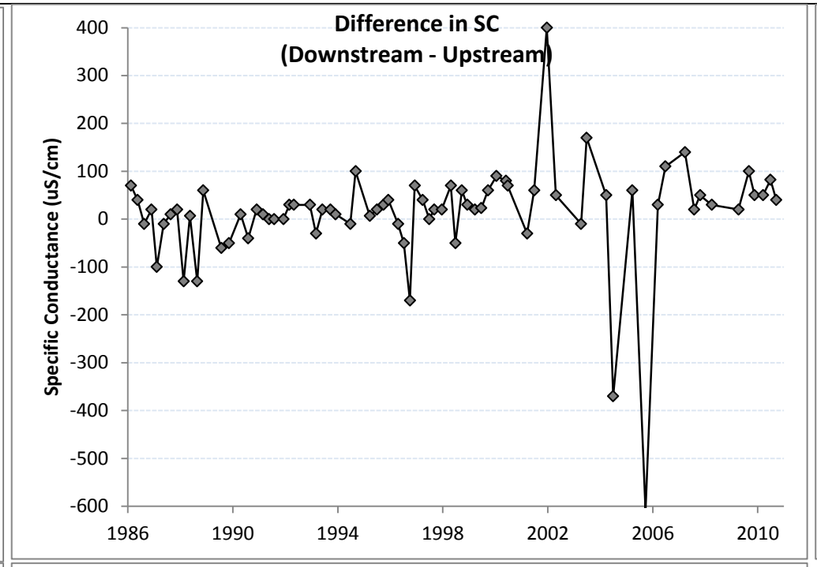
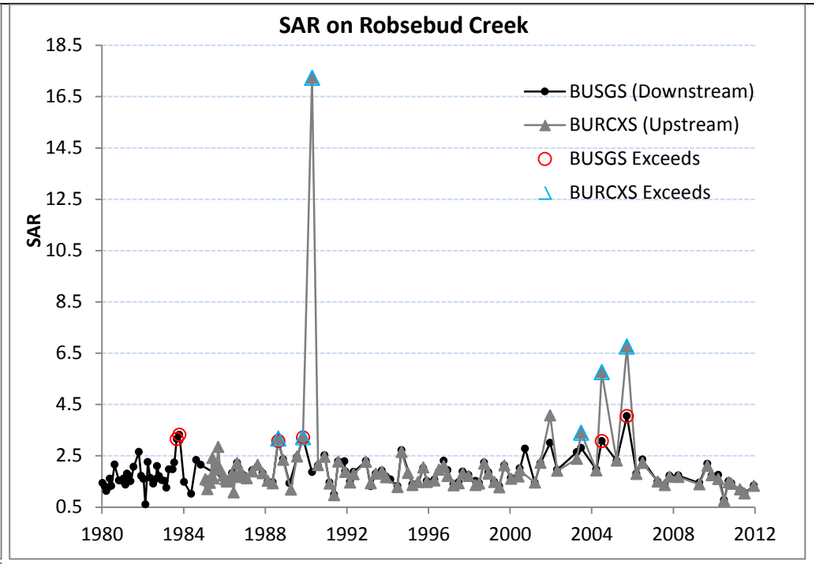
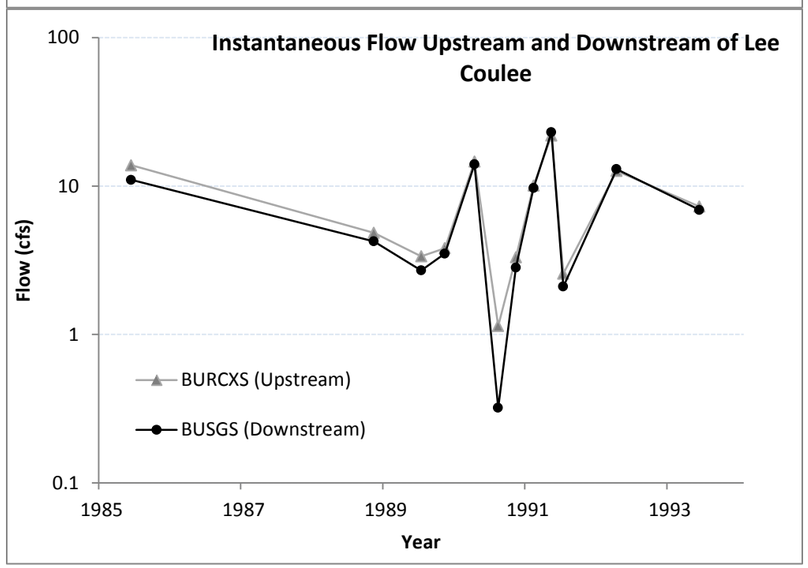


Figure 9-4: Flows measured by flumes on Lee Coulee.









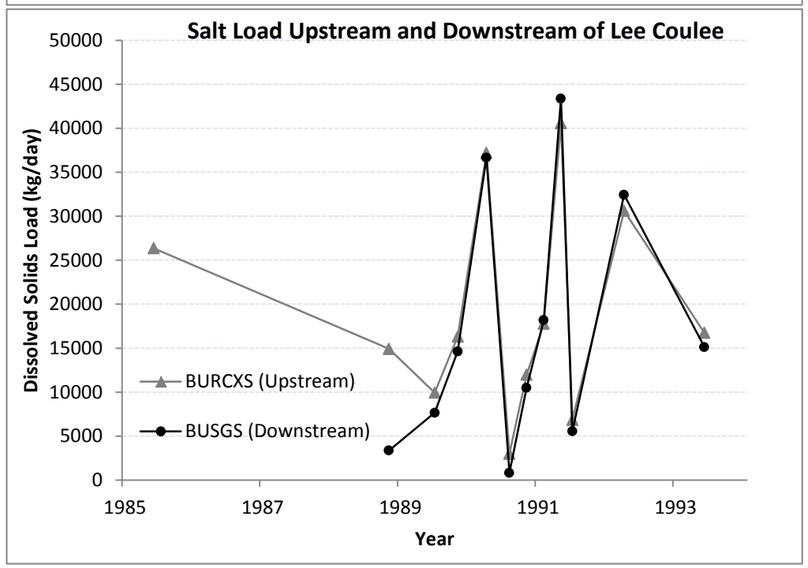
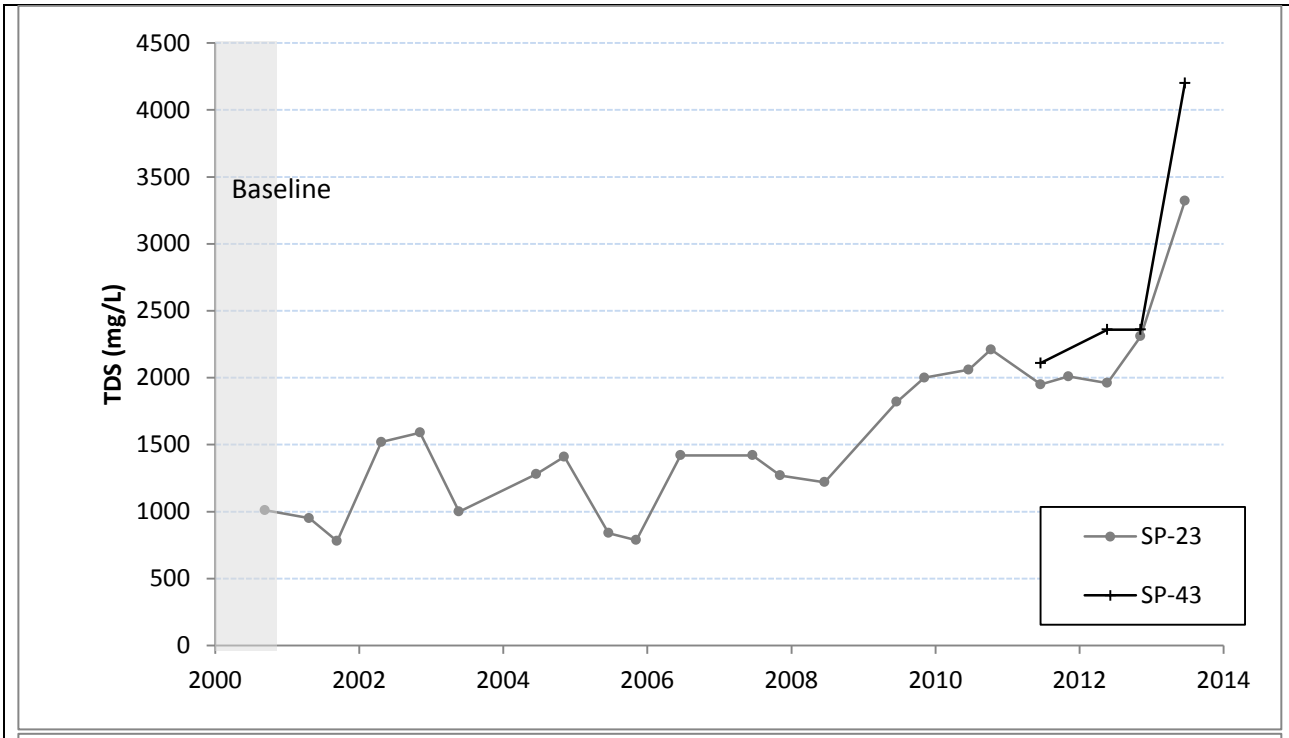


Figure 9-5: SC, TDS, and flow upstream (BURCXS) and downstream (BUSGS) of Lee Coulee on Rosebud Creek and the difference between the two concentrations.
The difference is shown as downstream minus upstream, and consequently positive values indicate that the downstream sample is has a higher Specific Conductance than the upstream sample taken on the same date. Mining started in Lee Coulee in approximately 1989. Exceedances of the monthly average SC (1,500 uS/cm from Nov. through Feb. and 1,000 uS/cm from Mar. through Oct.) and SAR (5 from Nov. through Feb. and 3from Mar. through Oct.) standards are shown in blue and red. Flow measurements taken on the same day indicate that there is a losing reach on Rosebud Creek where Lee Coulee enters.



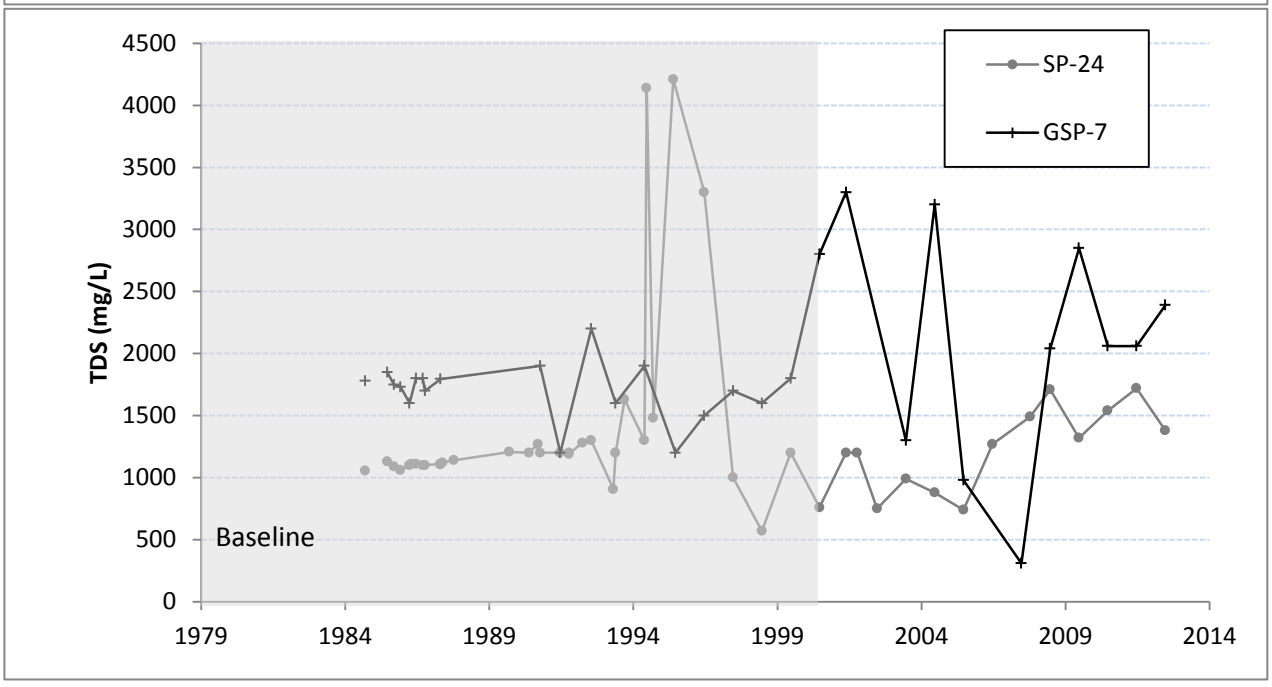


Figure 9-6: TDS changes over time for springs located in Spring Creek (SP-23 and SP-43) and Pony Creek (SP-24 and GSP-7).

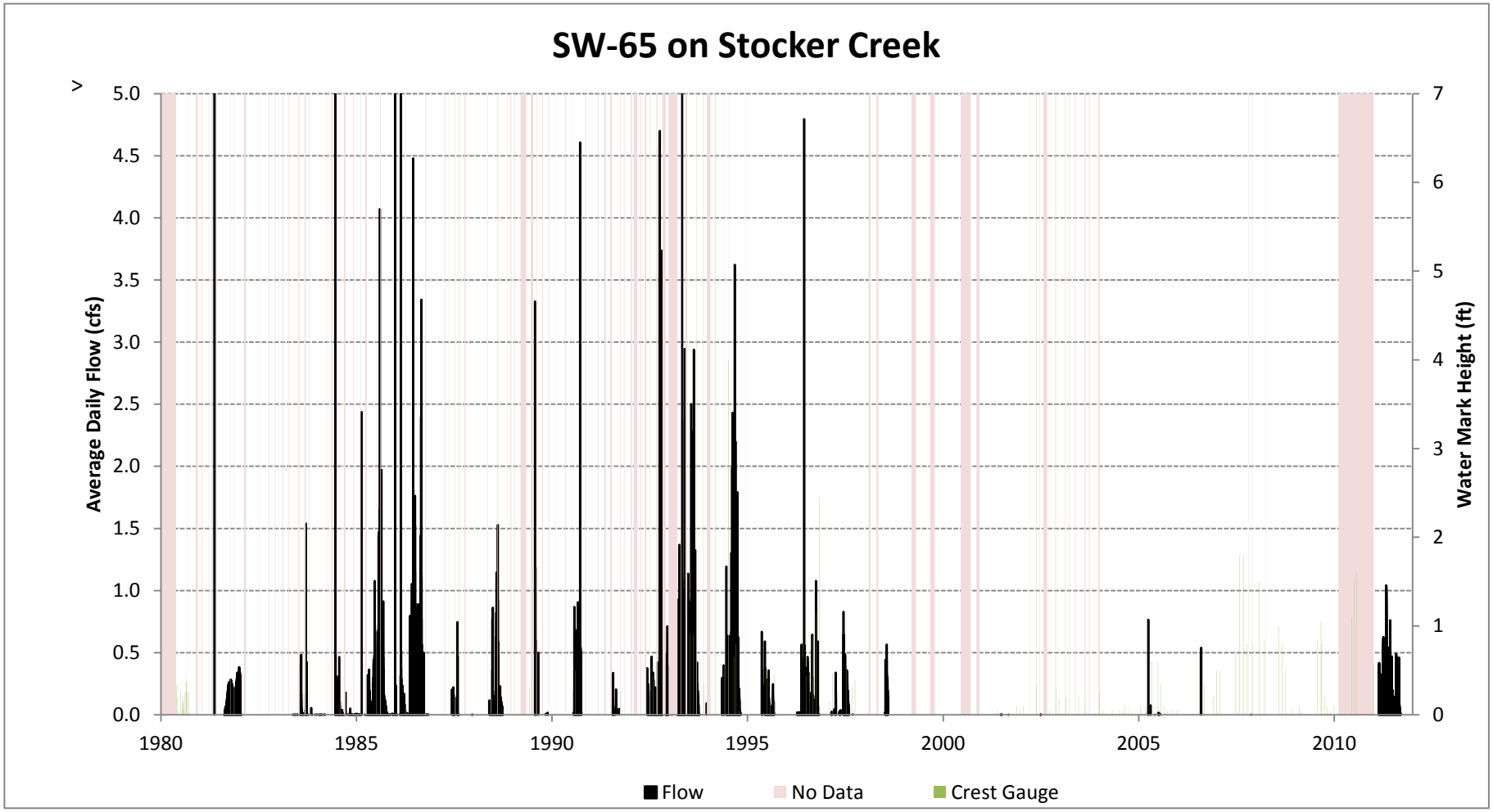
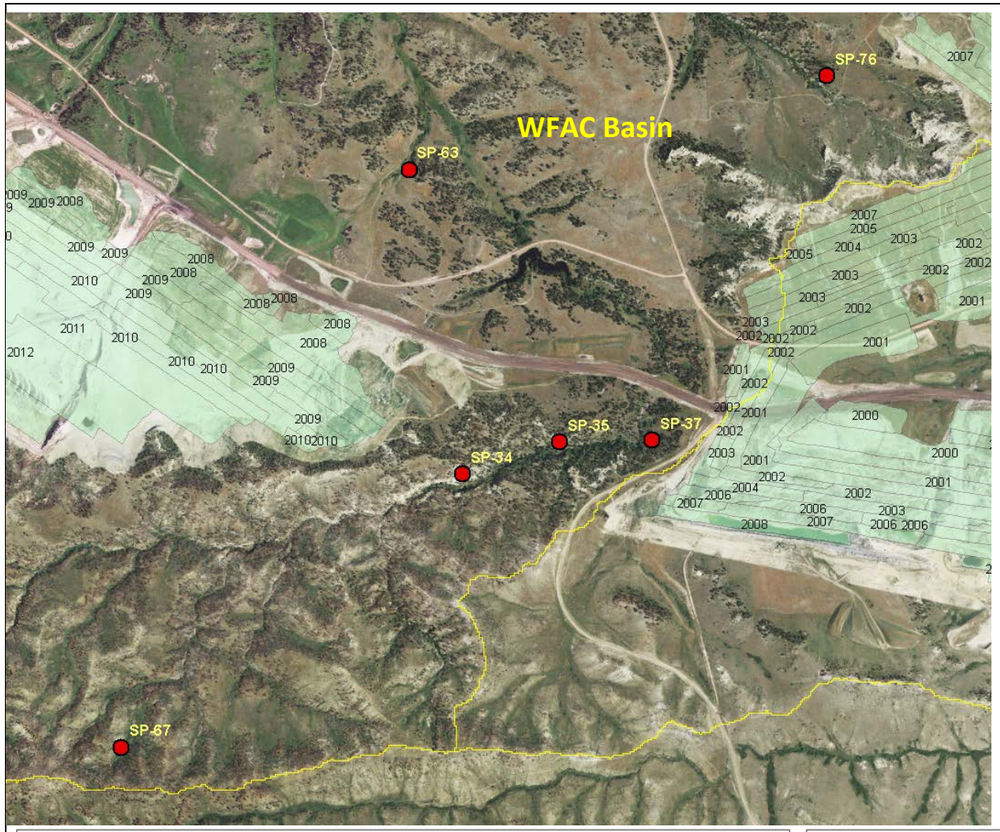
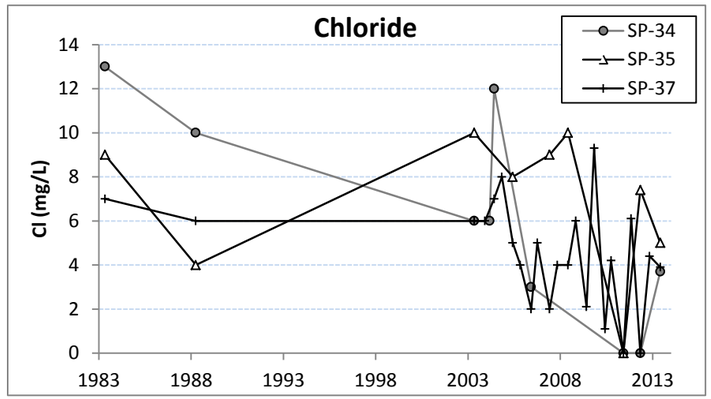
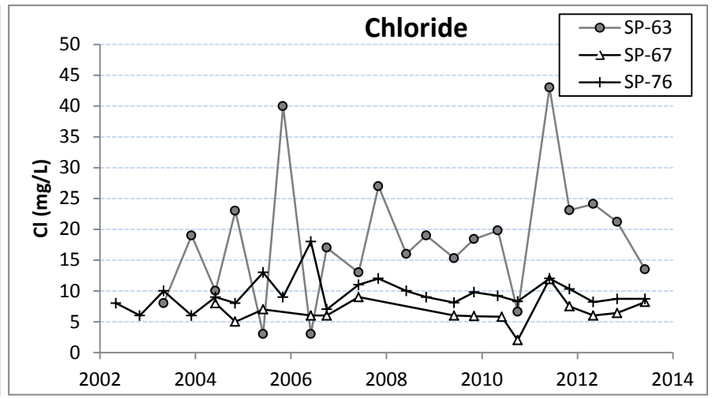


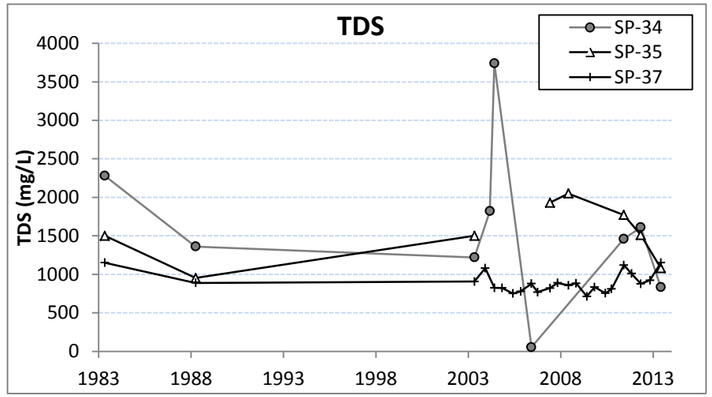
Figure 9-7: Flows recorded at Stocker Creek station SW-65.
Flows greater than 5 cfs are truncated. The conversion between crest gauge height and instantaneous flow is not known for the site.

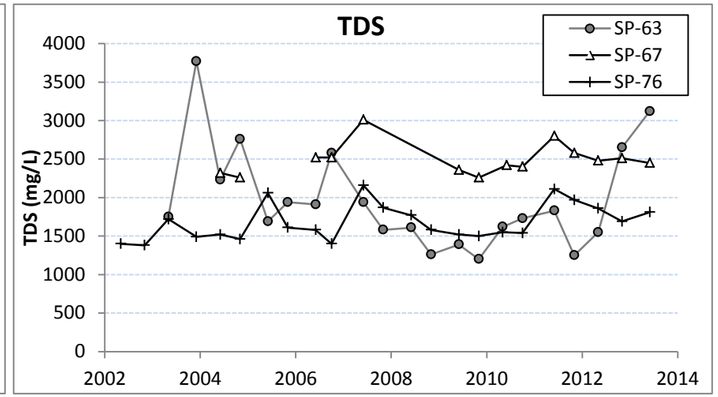
Exhibit 2

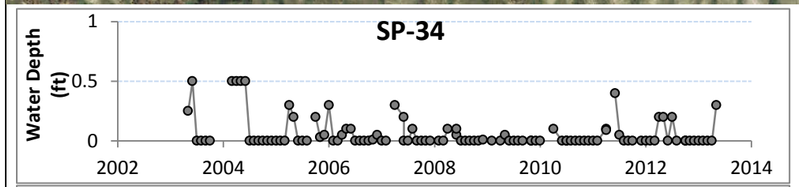


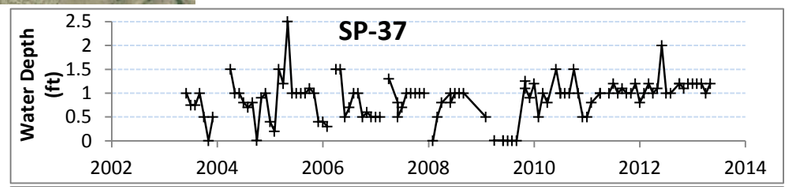


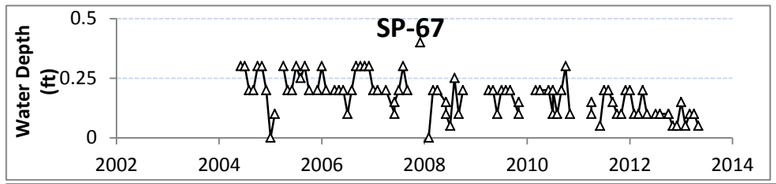


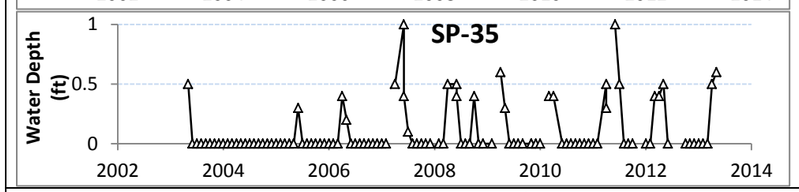


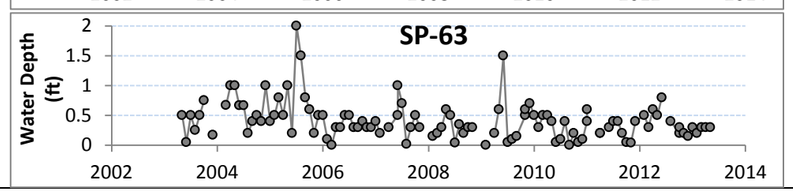












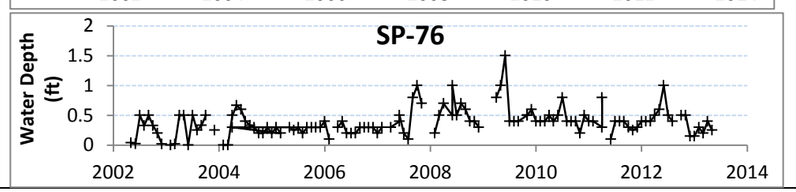


Figure 9-8: TDS, chloride, and ponded water depths from monitored springs in West Fork Armells Creek.
Non-detect chloride concentrations are plotted as 0 mg/L.

Exhibit 2

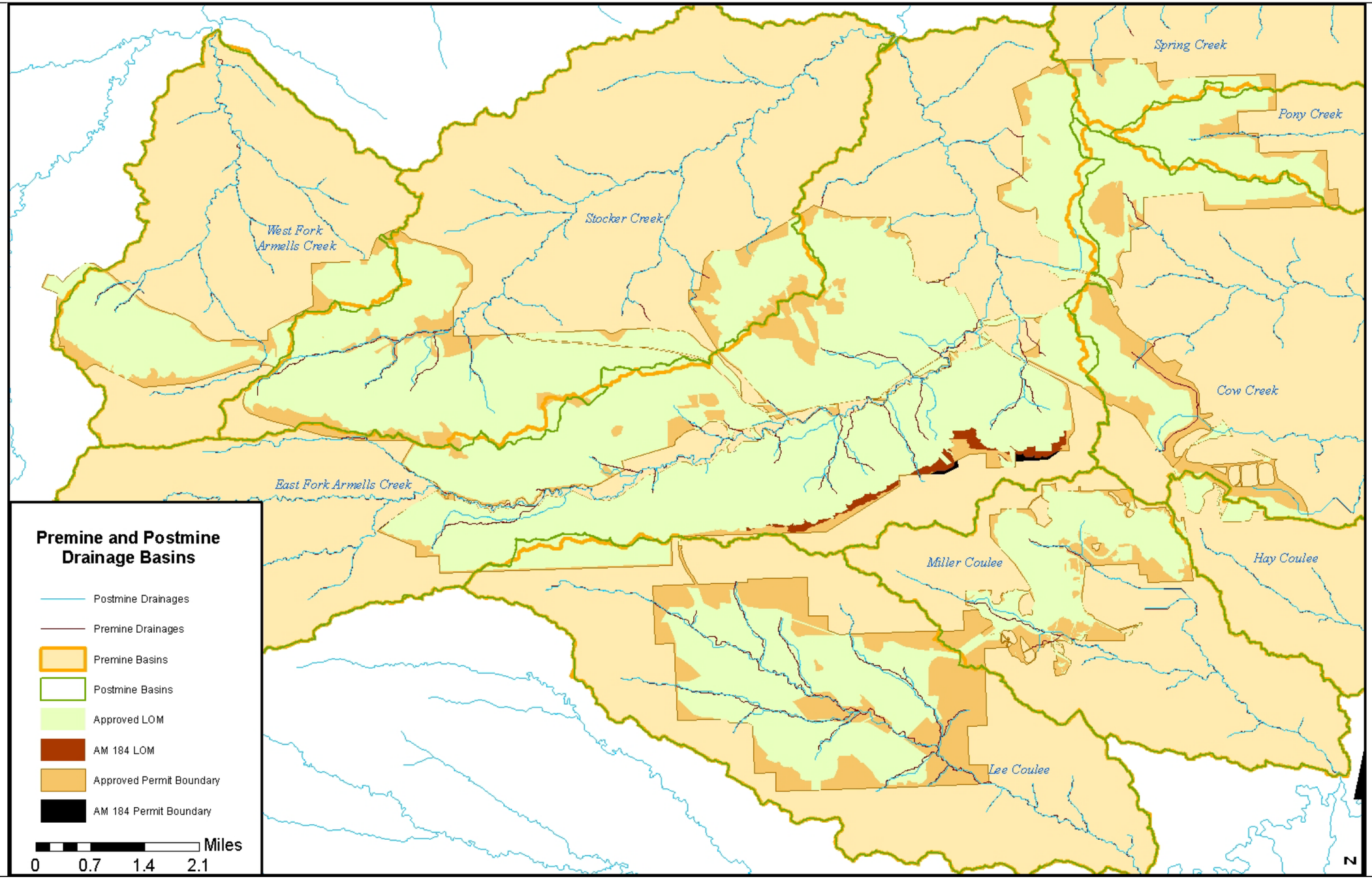
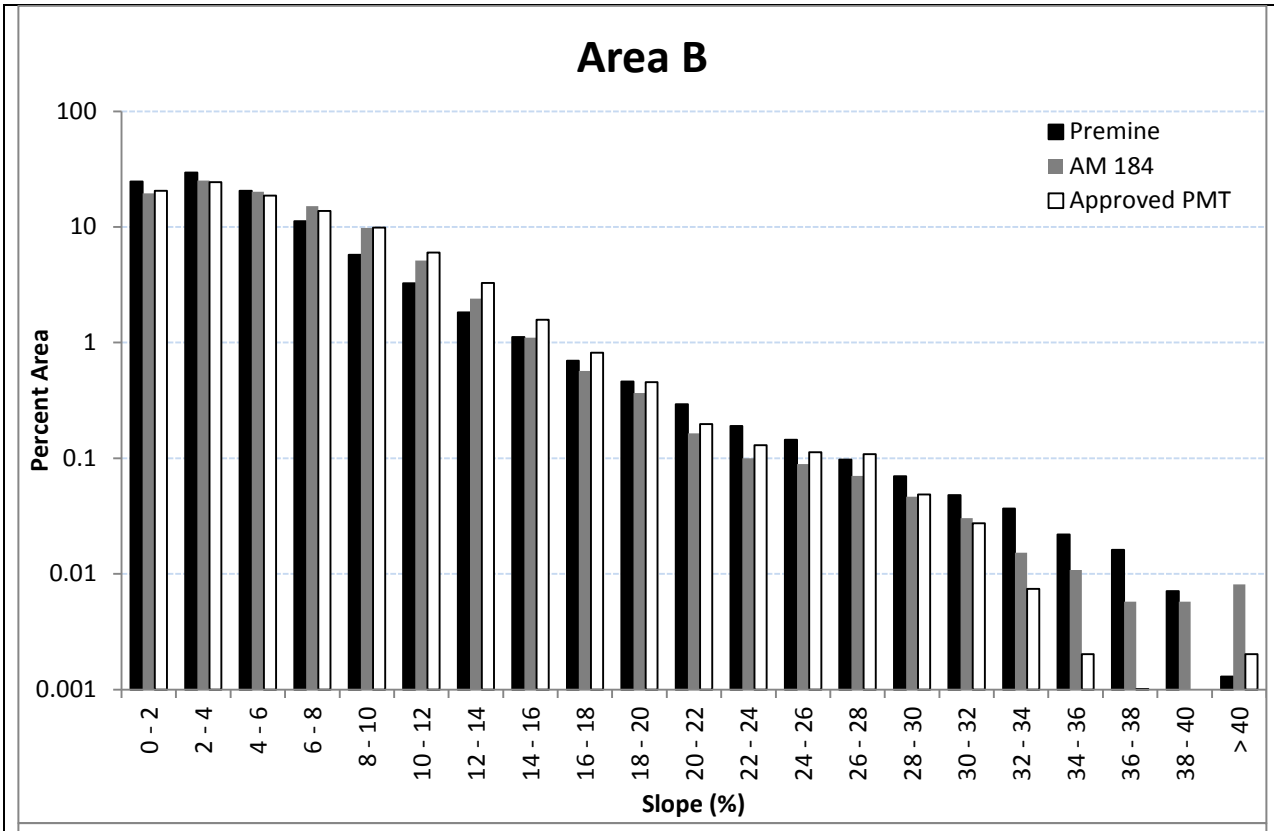


Figure 9-9: Premine and postmine drainage sub-basins and channels derived from premine and postmine topography by HEC-GeoHMS.

Exhibit 2



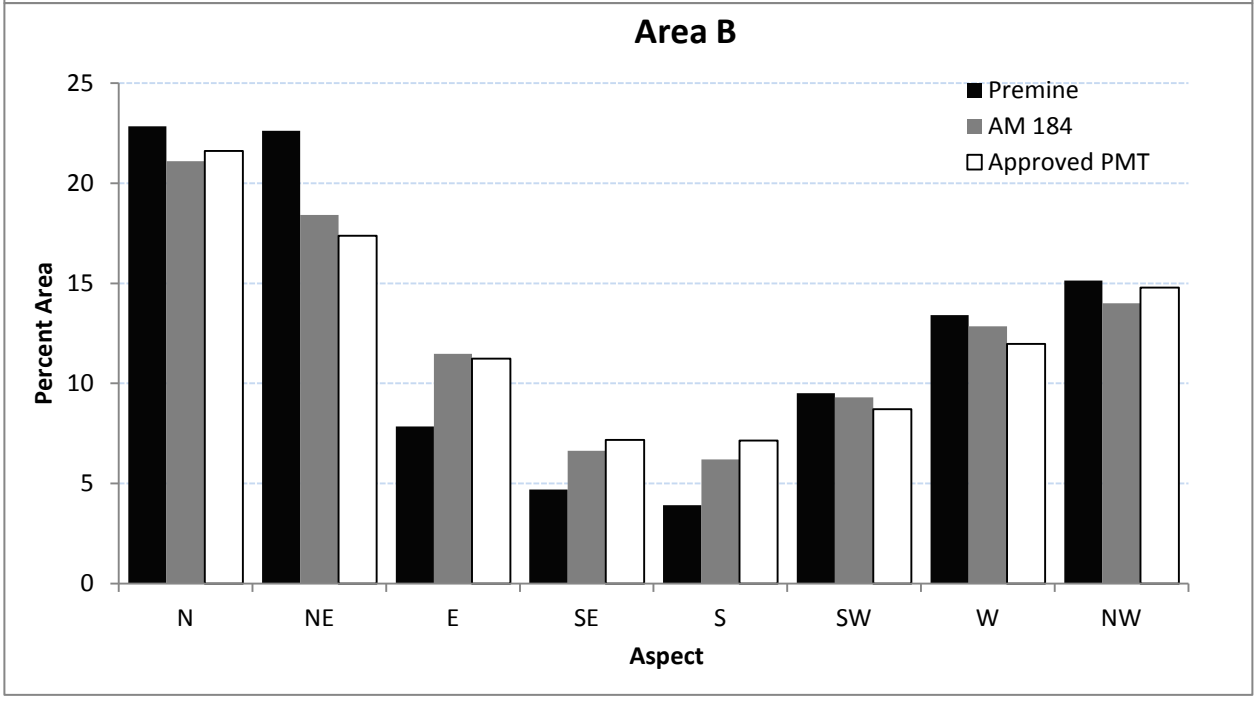


Figure 9-10: The distribution of slope and aspect within the proposed permit.
The distribution is calculated from the premine and proposed postmine topography as well as between the approved postmine topography and the proposed postmine topography using 30-ft resolution digital elevation models.

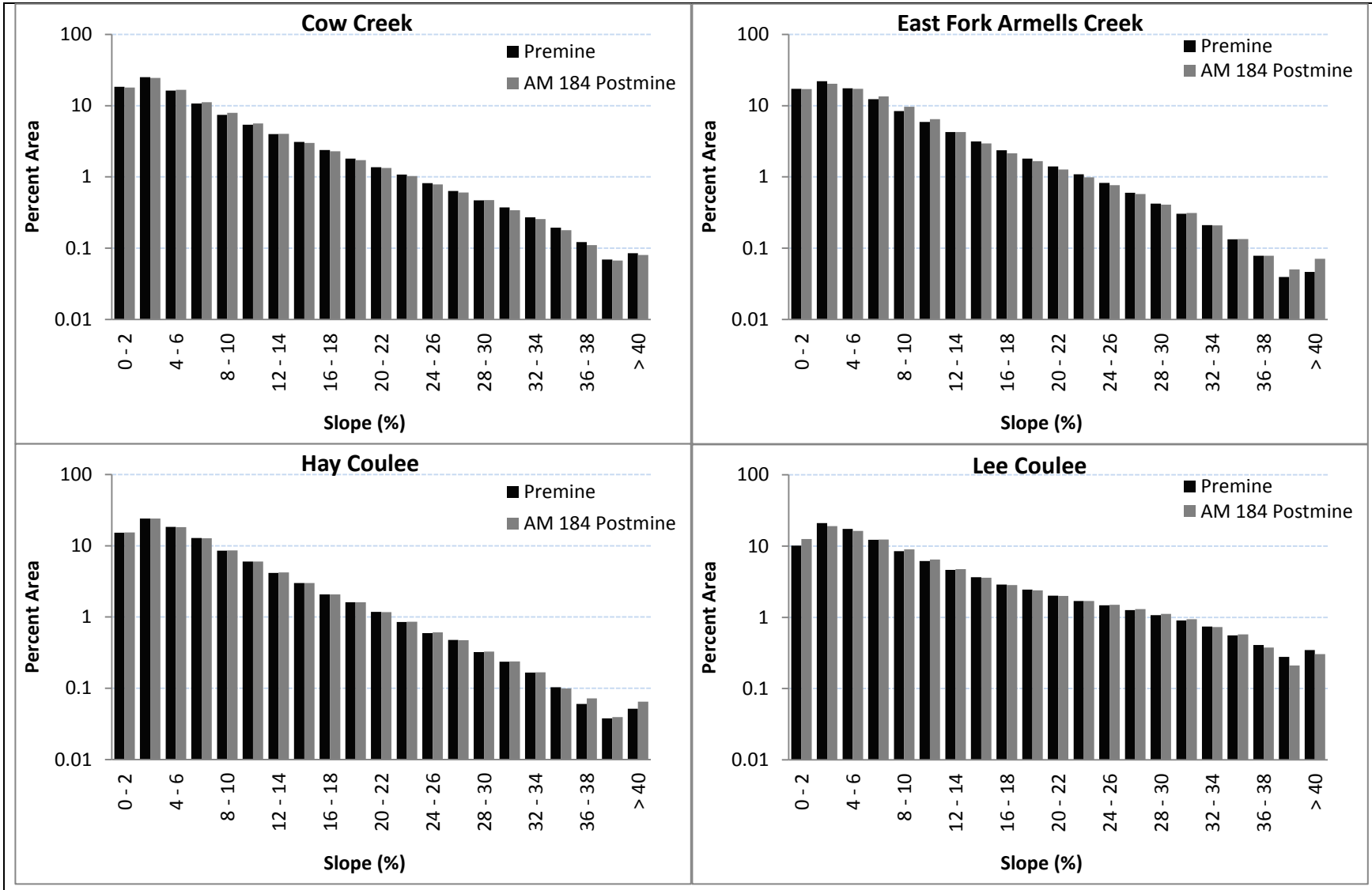


Figure 9-11: Slope distribution per drainage area for premine and postmine topography.

Exhibit 2

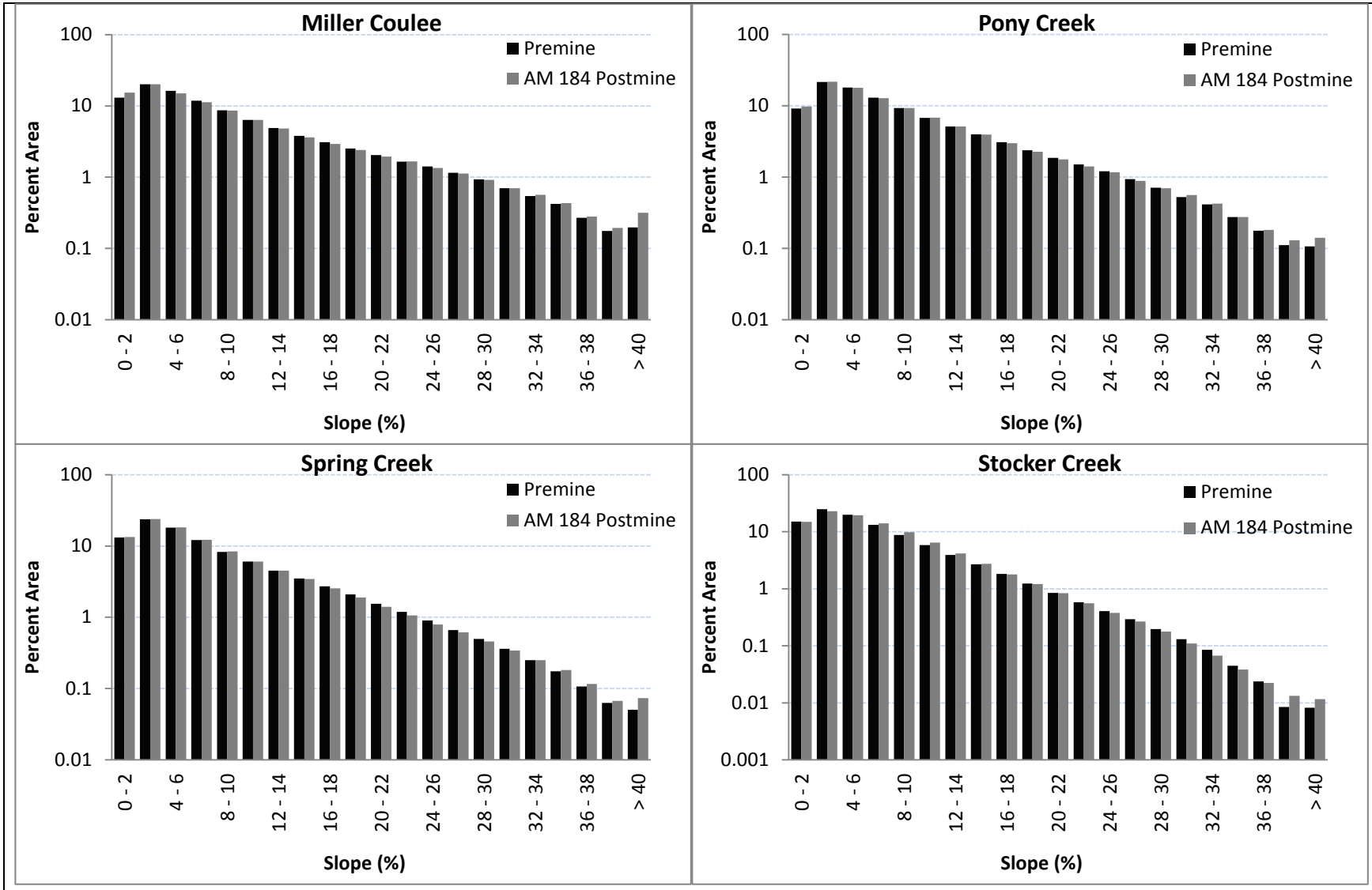


Figure 9-11 continued.

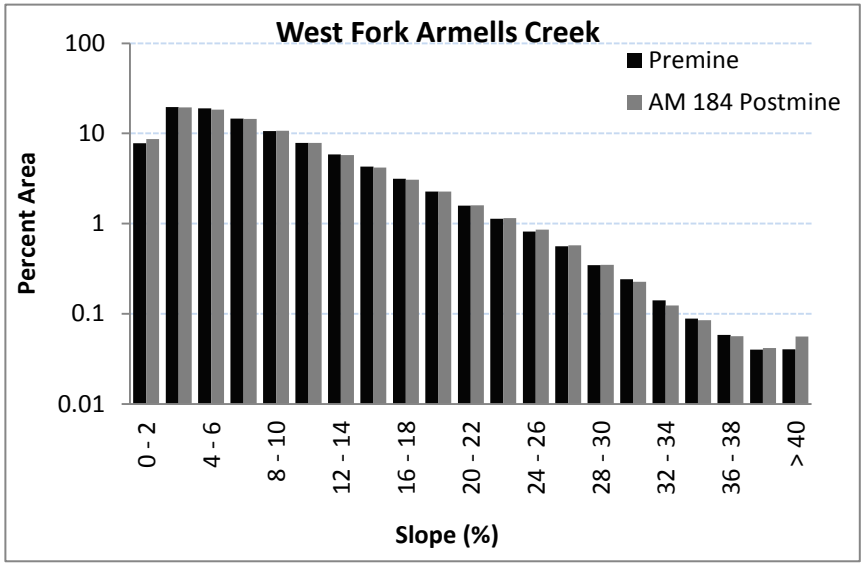


Figure 9-11 continued.

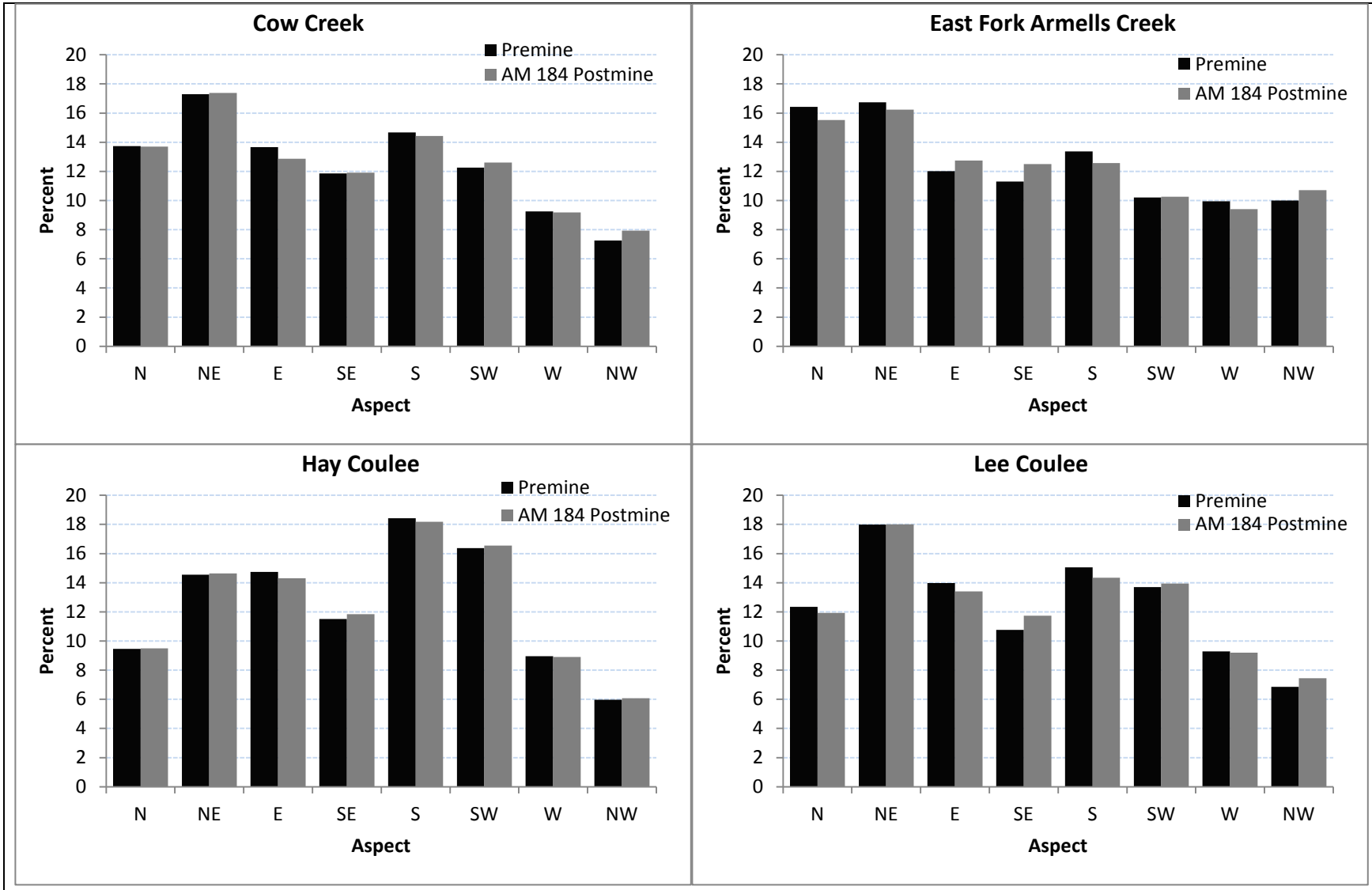


Figure 9-12: Aspect distribution per drainage area for premine and postmine topography.

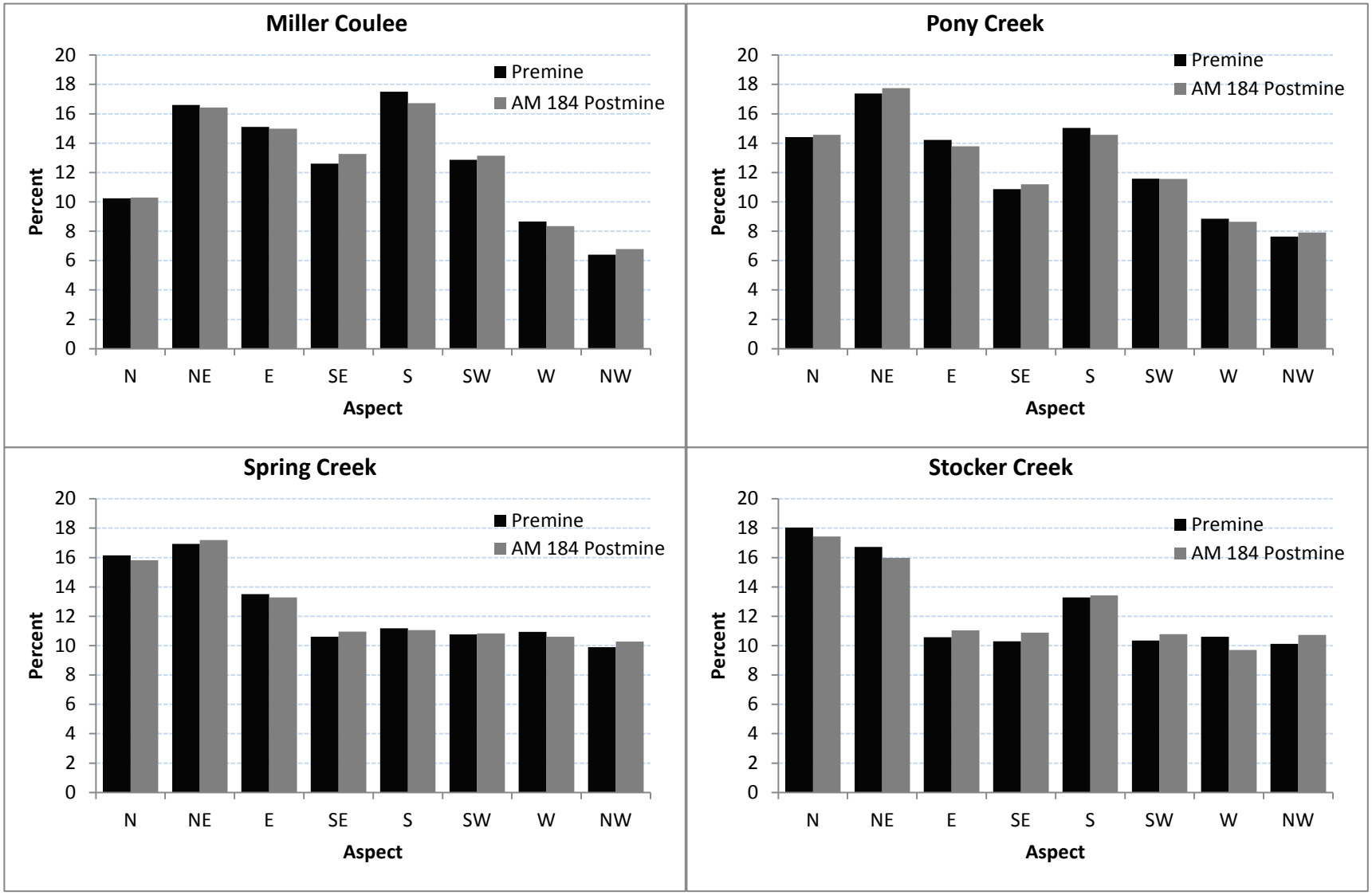


Figure 9-12 continued.

Exhibit 2

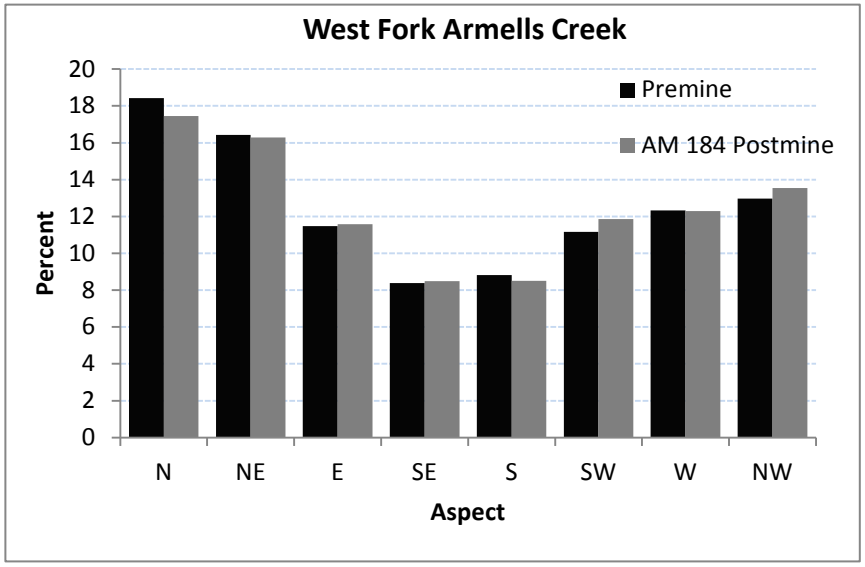


Figure 9-12 continued.

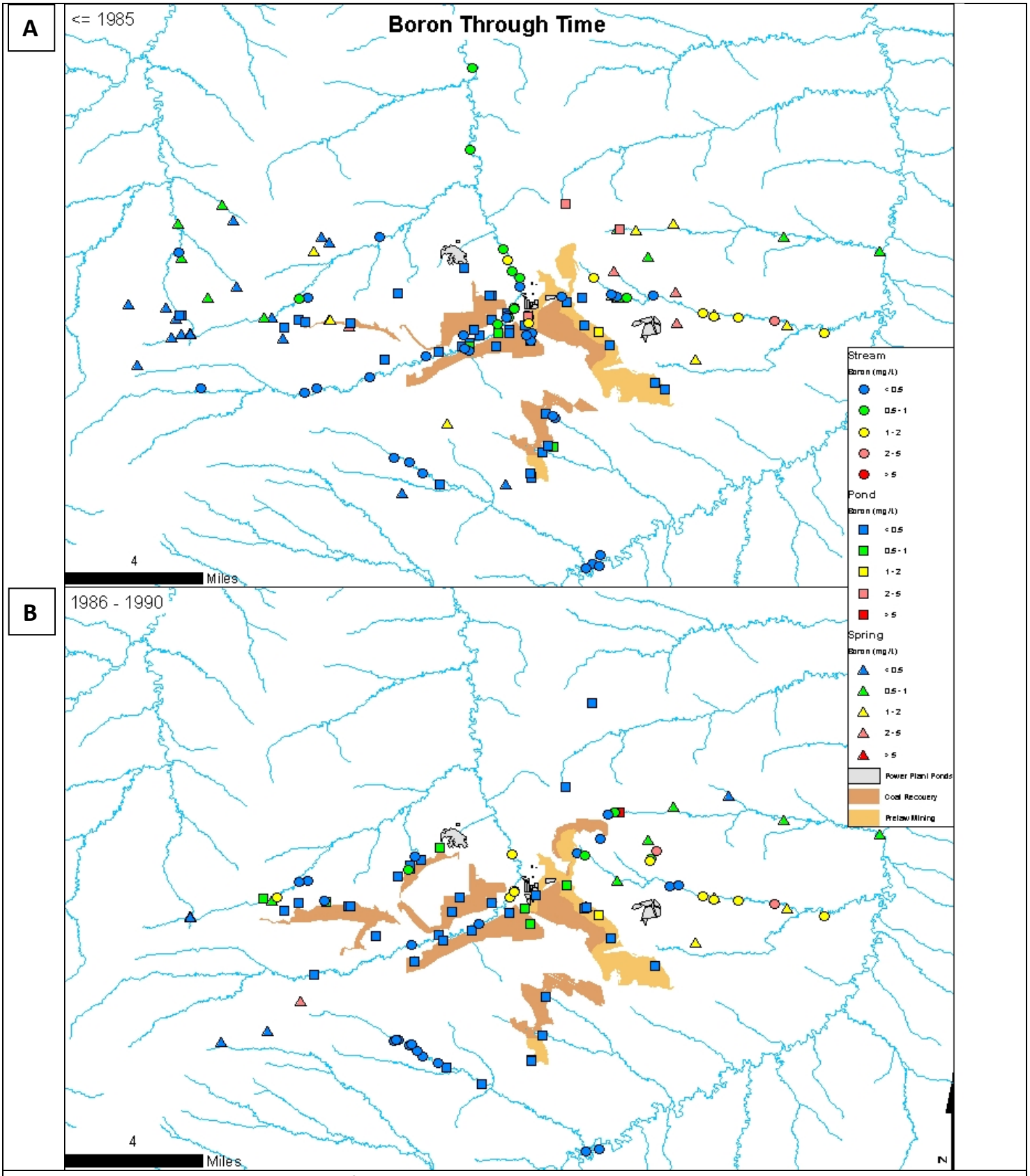


Figure 9-13: Boron concentration in surface water through time.
For locations with multiple water quality samples, the median of the samples is plotted.

Exhibit 2

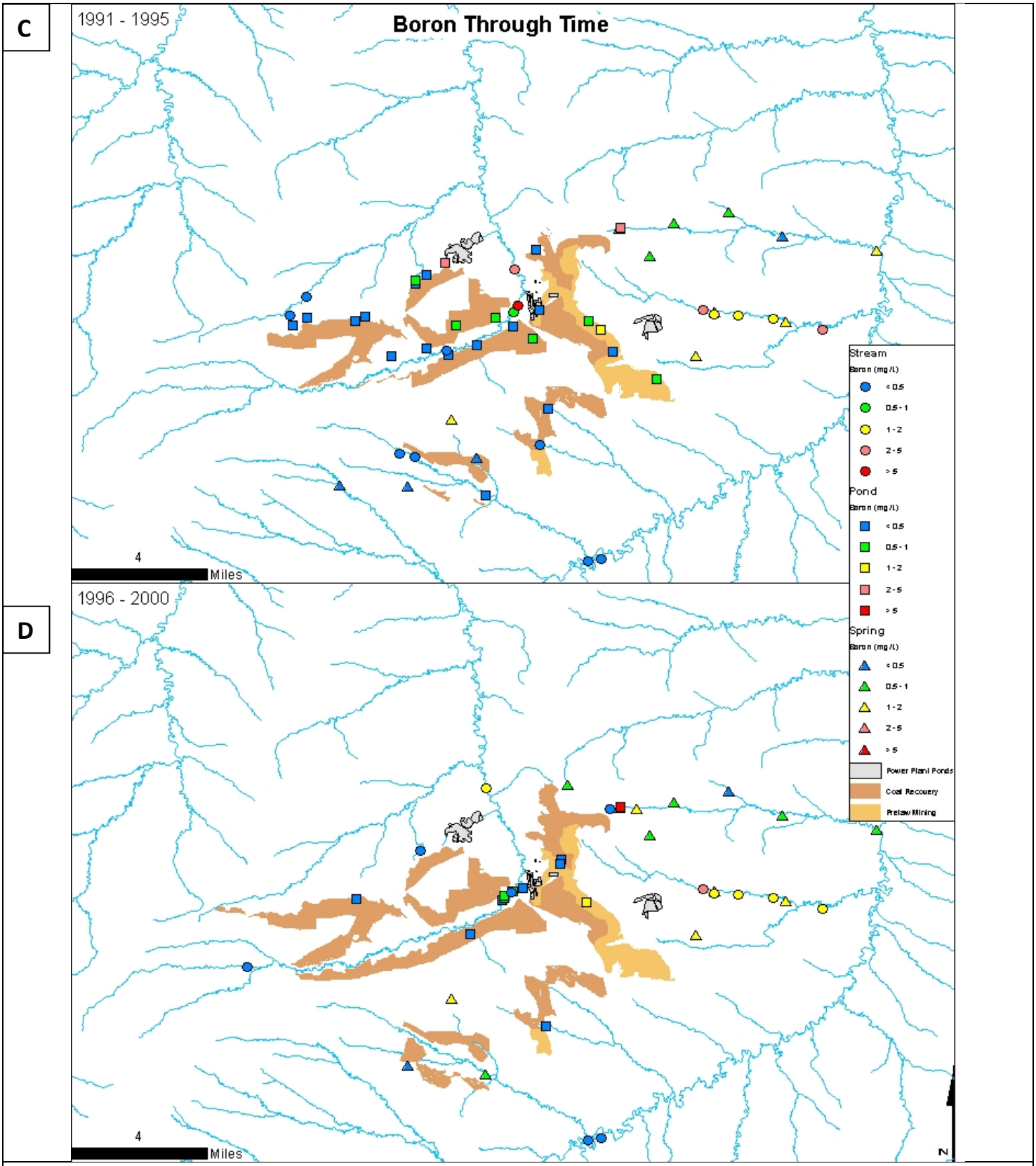


Figure 9-13 continued.

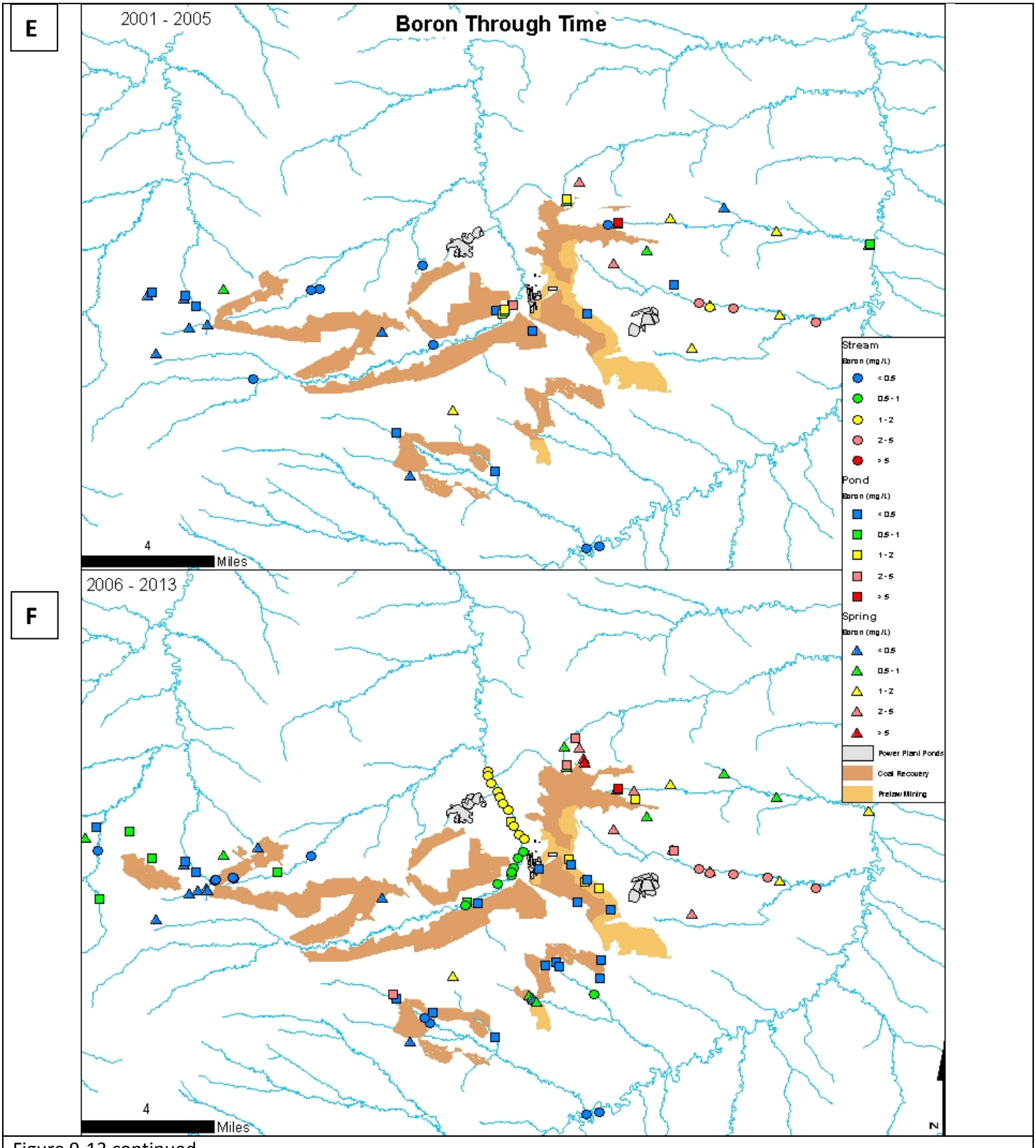


Figure 9-13 continued.

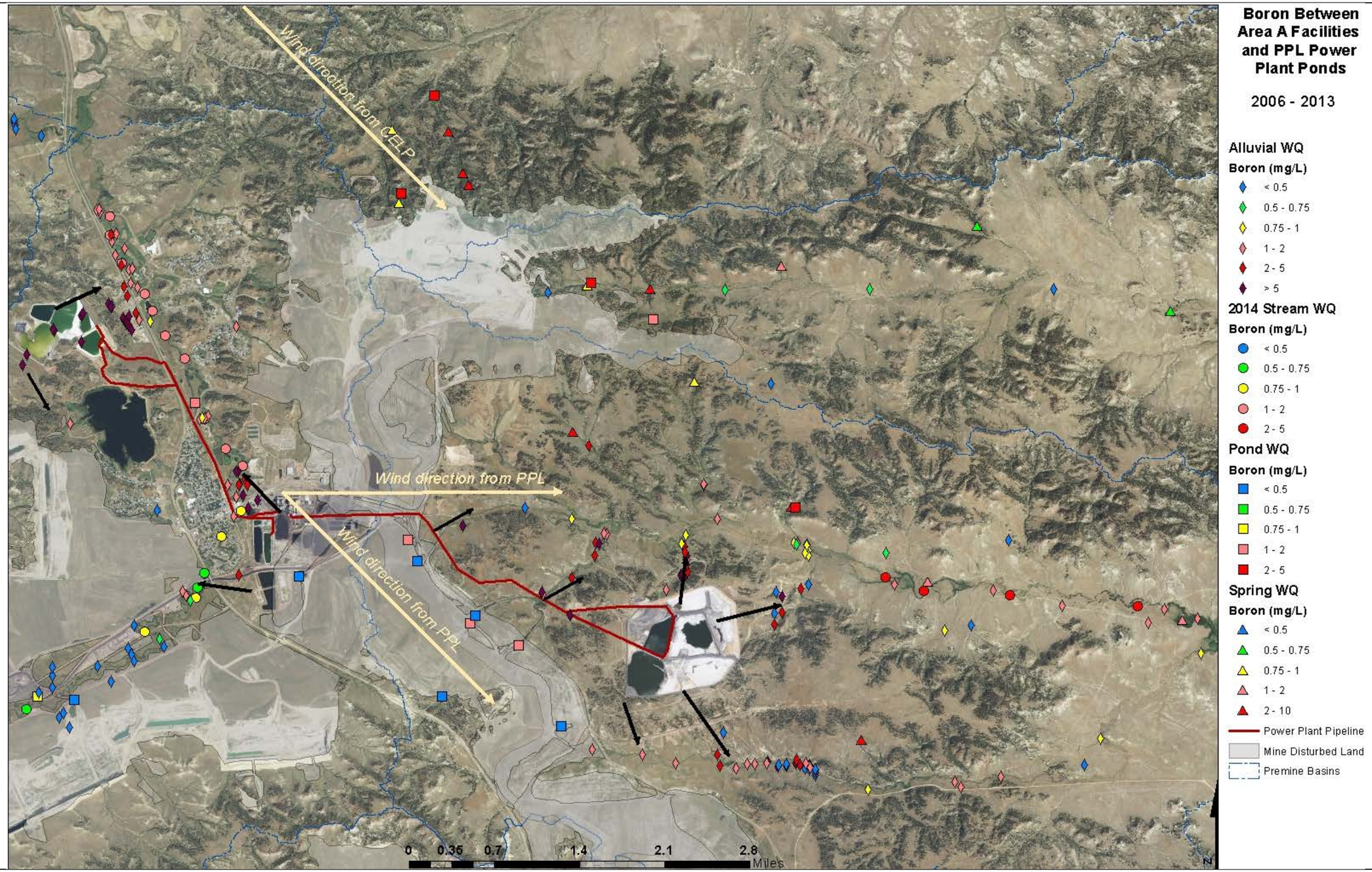


Figure 9-14: Boron concentrations between the Area A facilities and the PPL ash ponds between 2006 and 2013.
For locations with multiple water quality samples between 2006 and 2013, the median of the samples is plotted. Black arrows indicate the general flow direction from possible sources of boron.

Exhibit 2

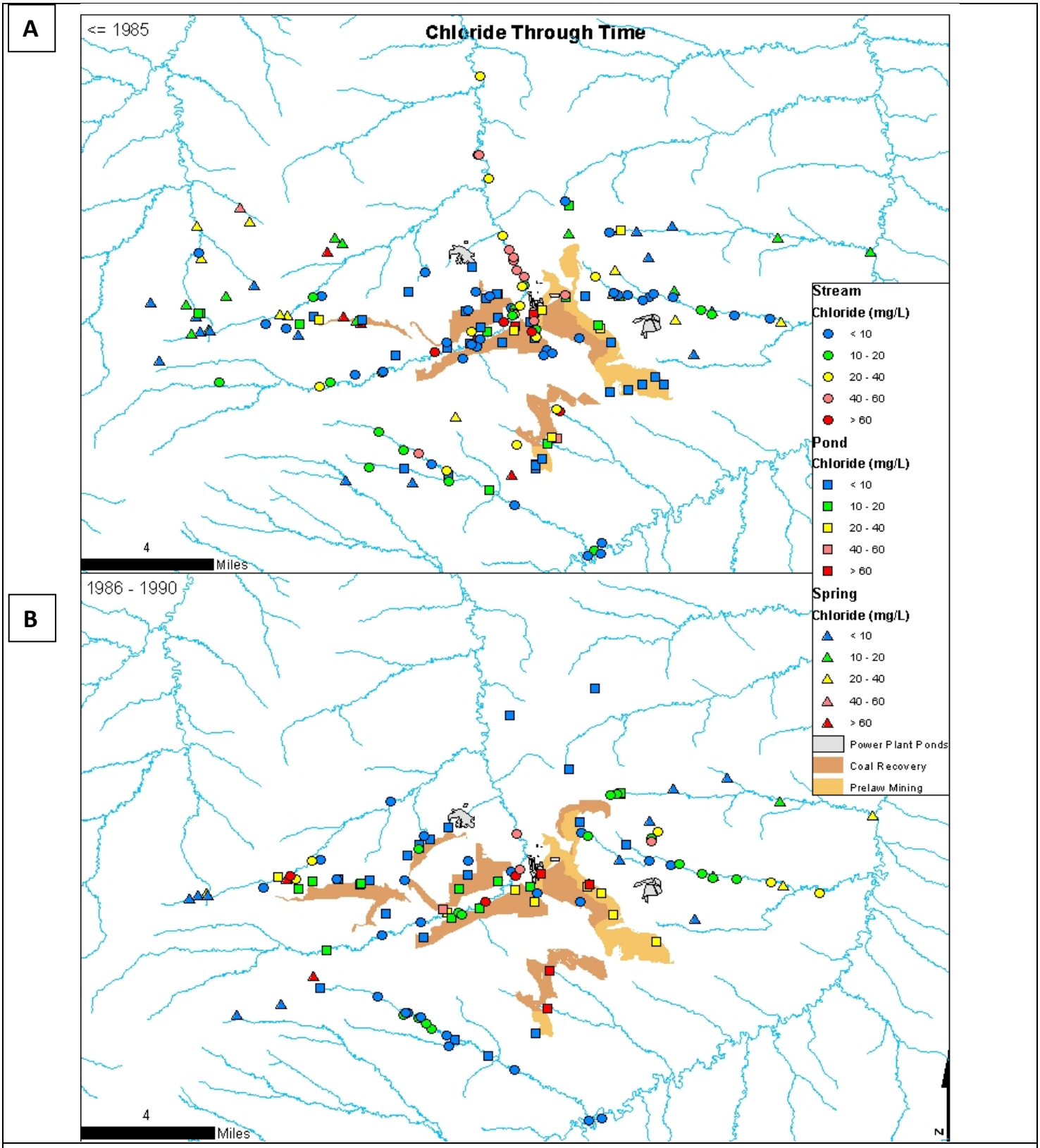


Figure 9-15: Chloride concentration in surface water through time.
For locations with multiple water quality samples, the median of the samples is plotted.

Exhibit 2

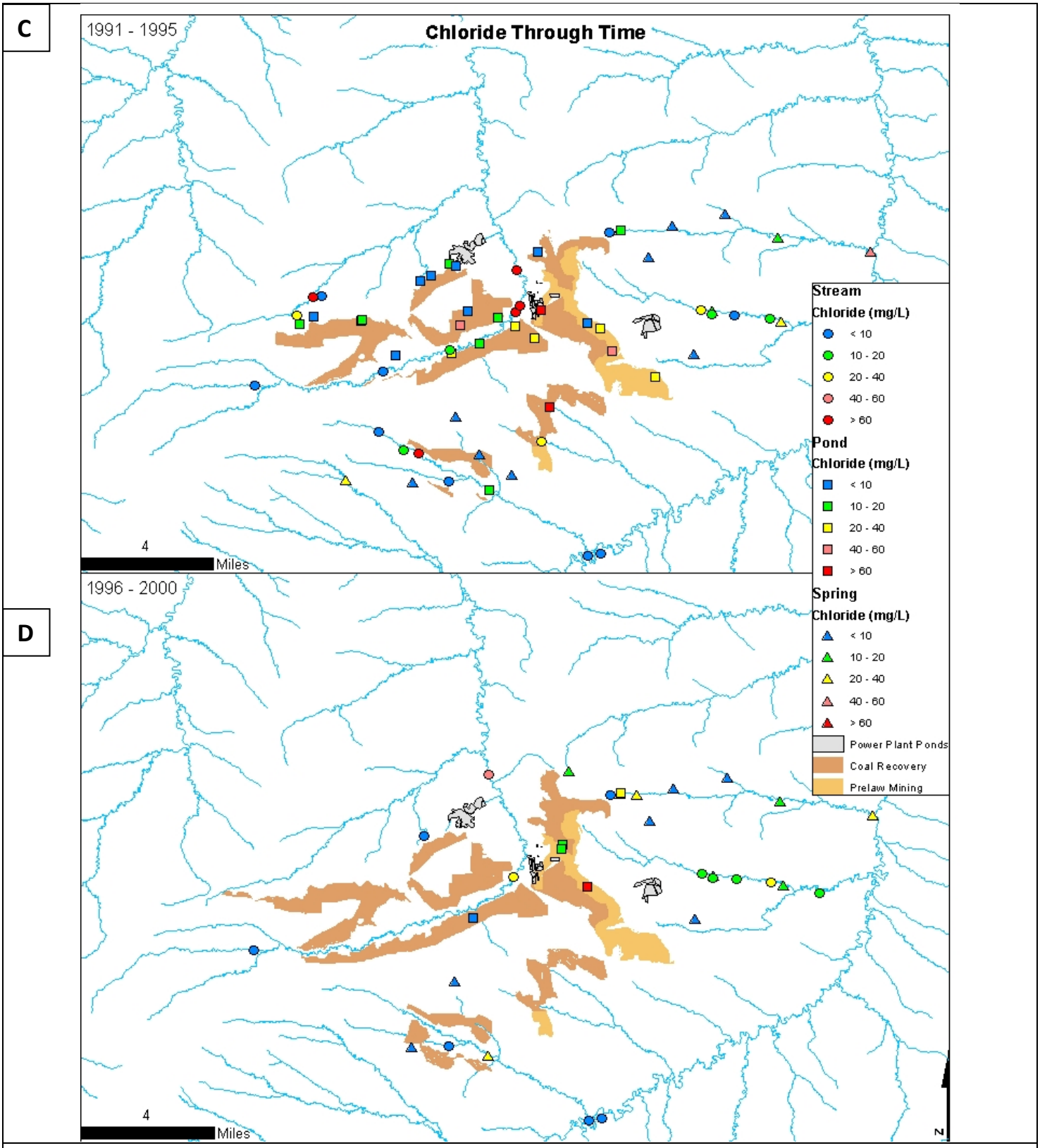


Figure 9-15 continued.

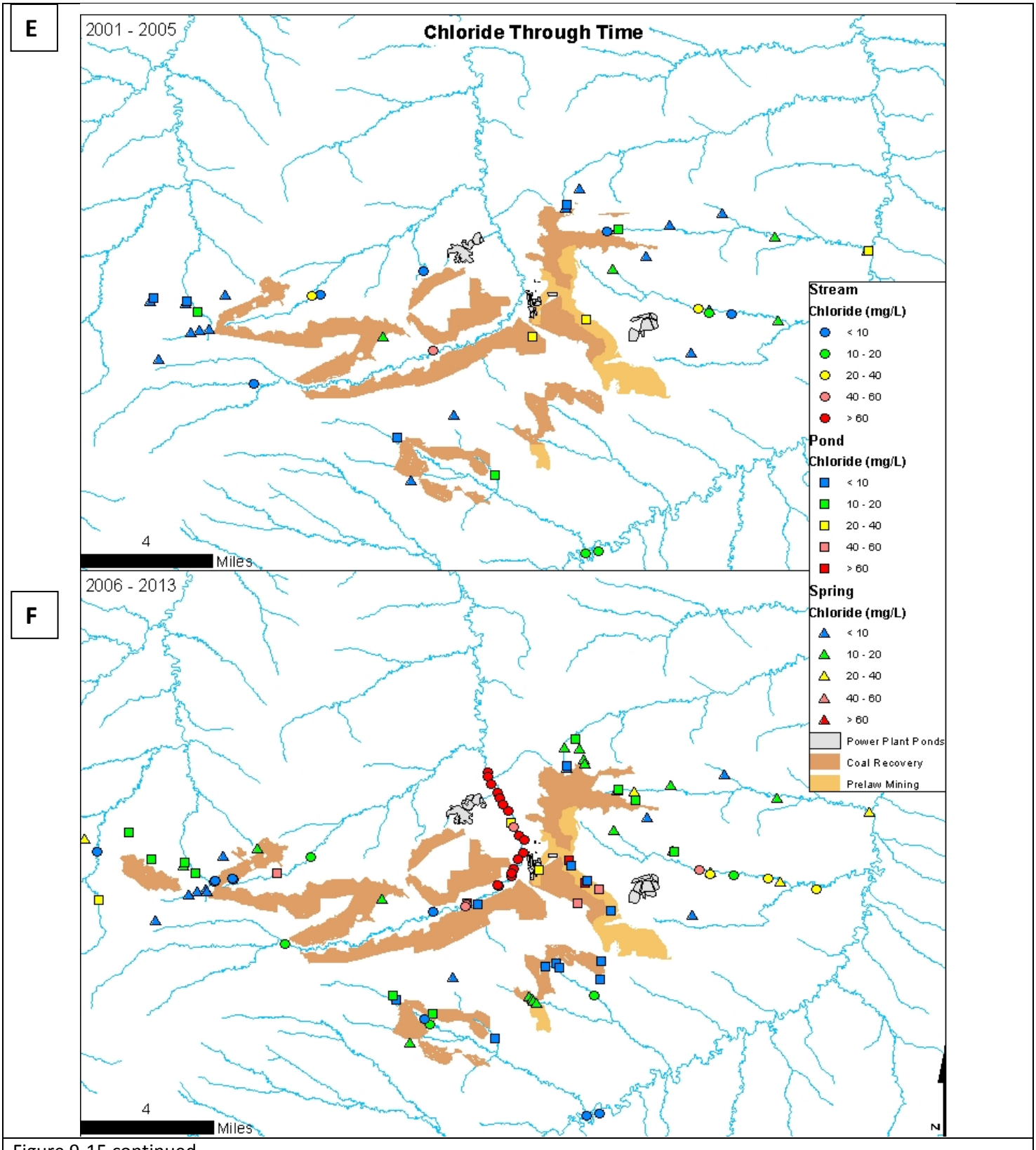


Figure 9-15 continued.

Exhibit 2

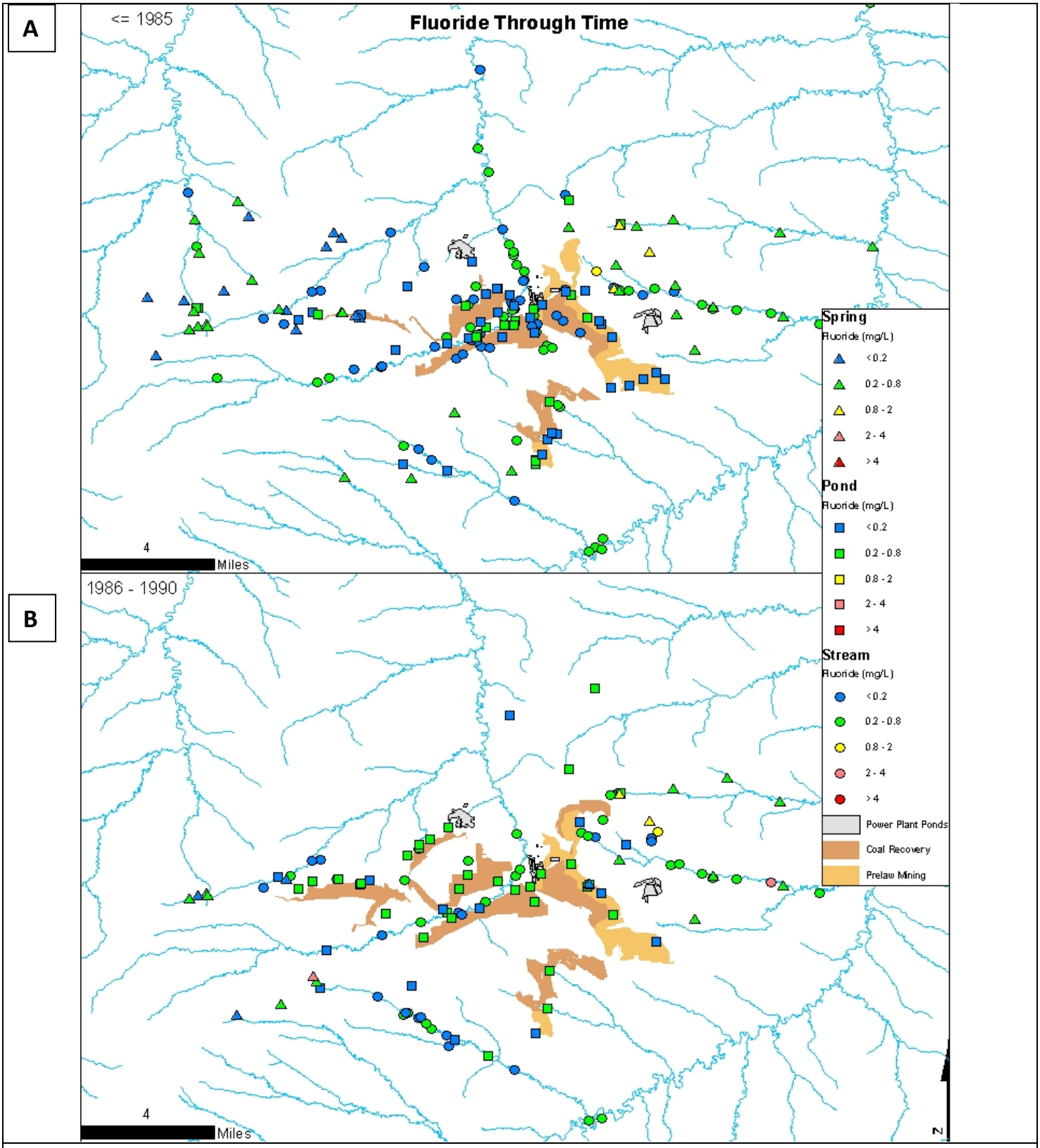


Figure 9-16: Fluoride concentration in surface water through time.
For locations with multiple water quality samples, the median of the samples is plotted.

Exhibit 2

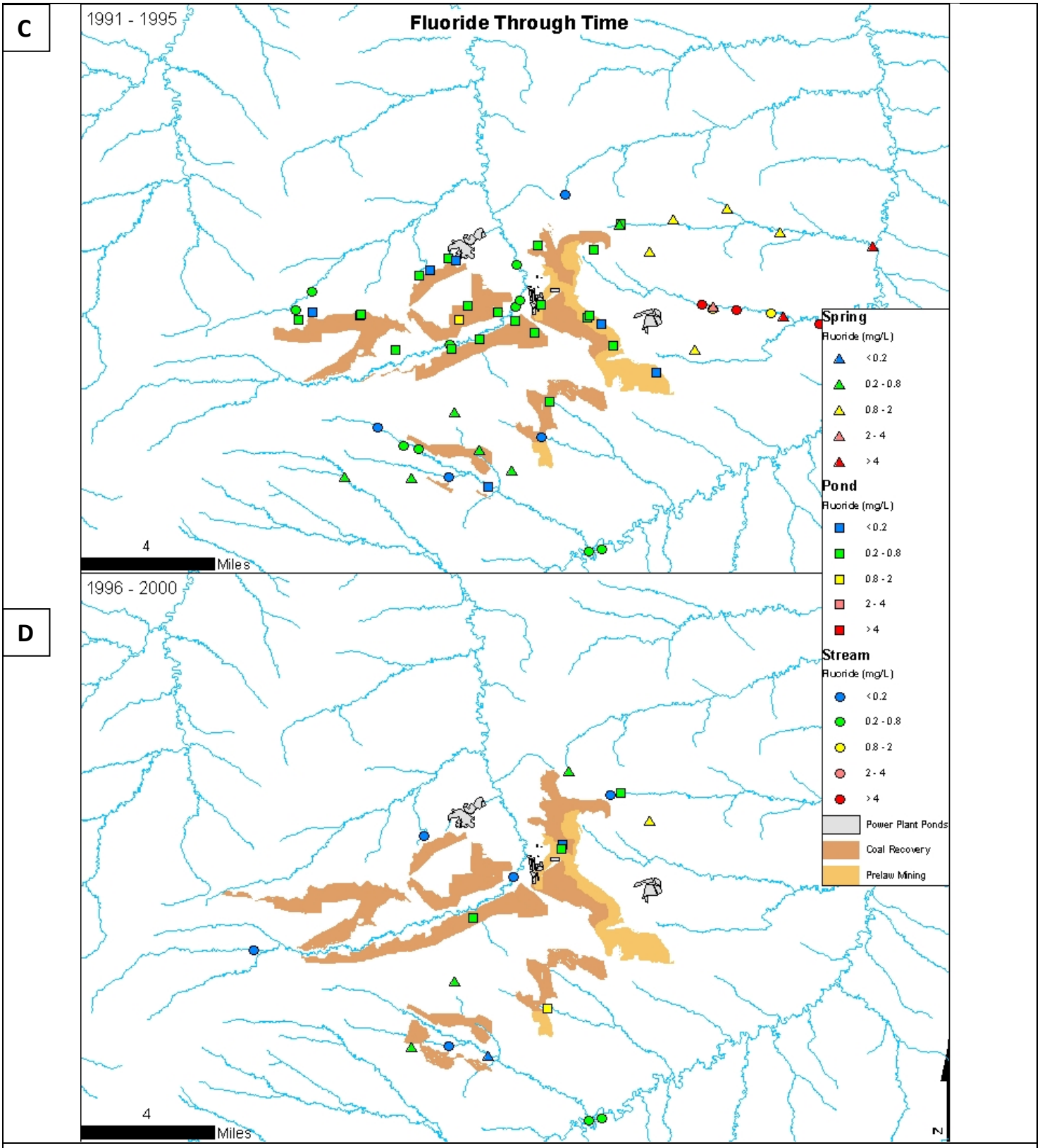


Figure 9-16 continued.

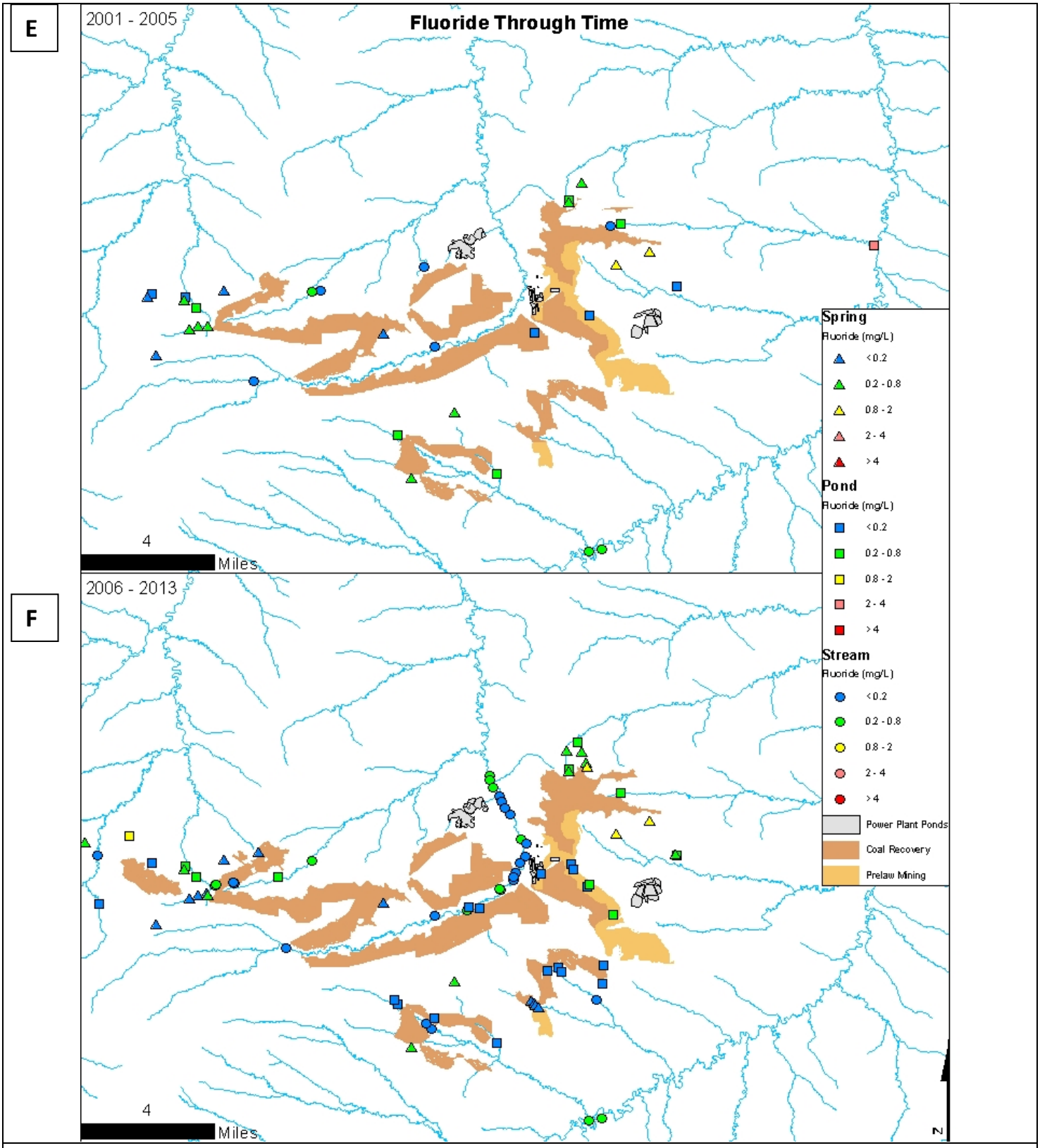


Figure 9-16 continued.

Exhibit 2

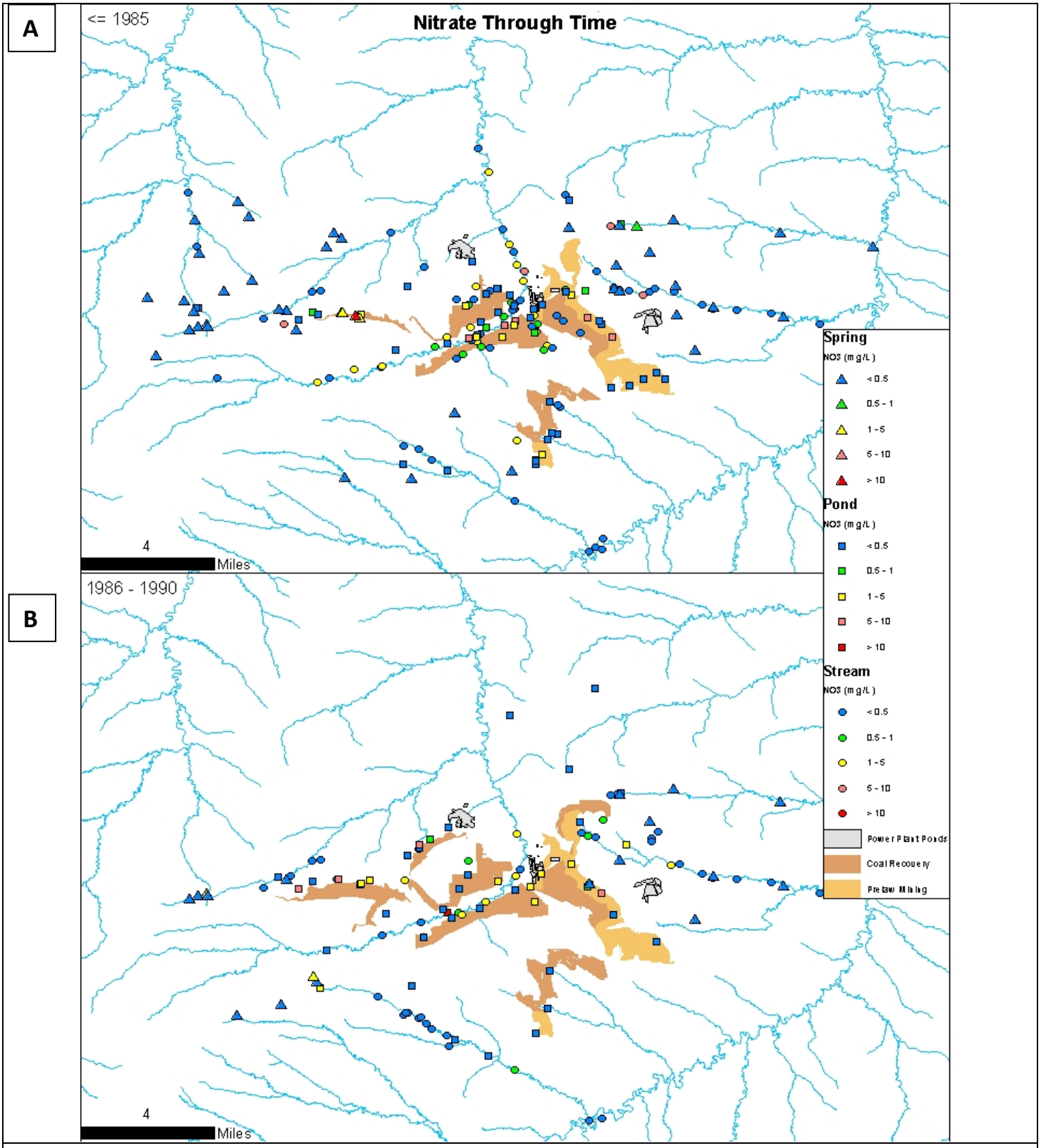
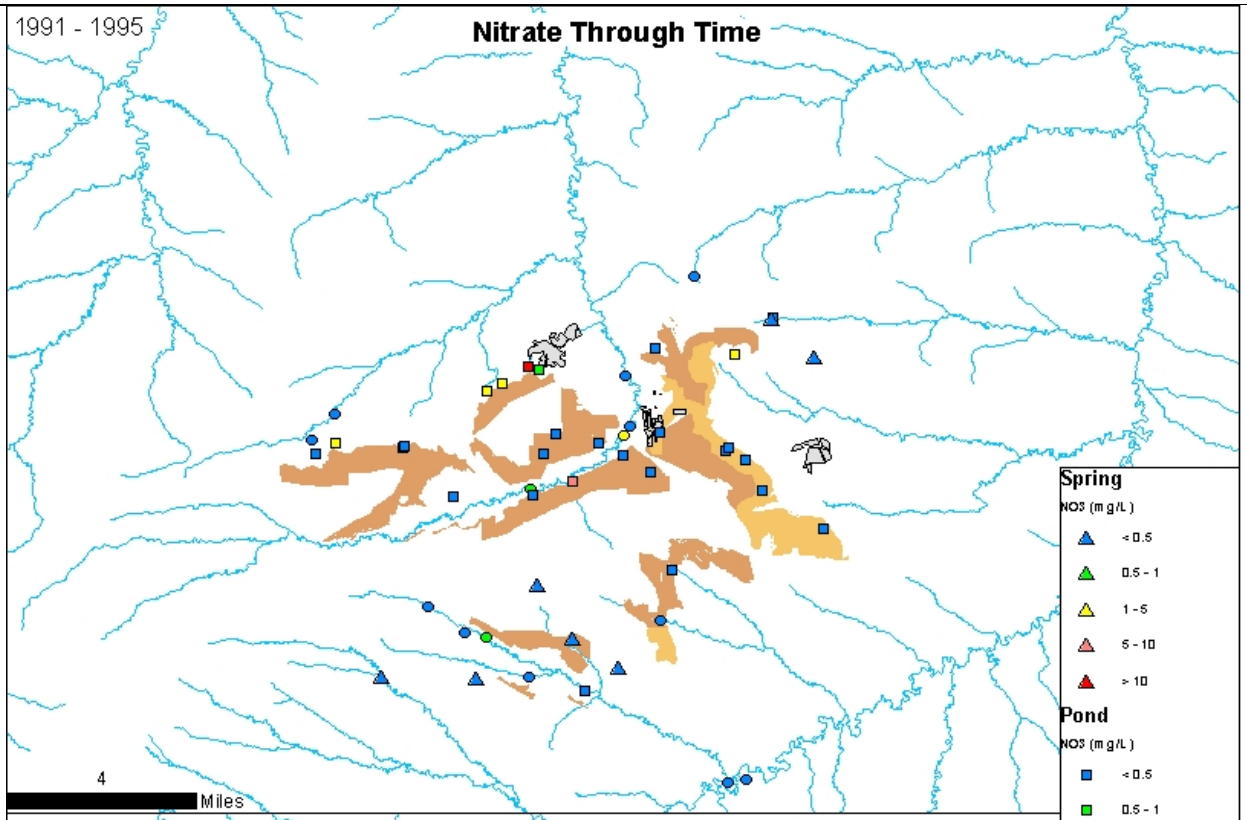


Figure 9-17: Nitrate and Nitrite as Nitrogen concentration in surface water through time.
For locations with multiple water quality samples, the median of the samples is plotted.

Exhibit 2

C



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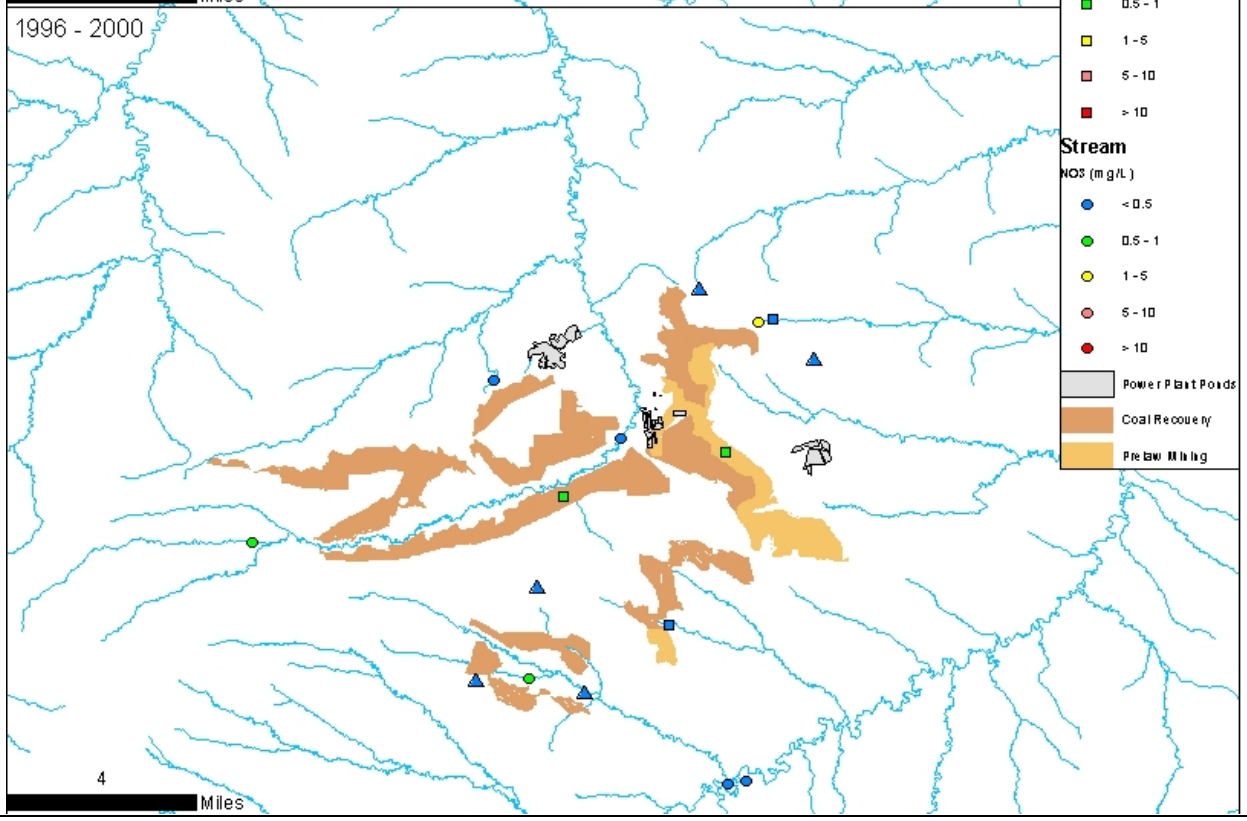


Figure 9-17 continued.

Exhibit 2

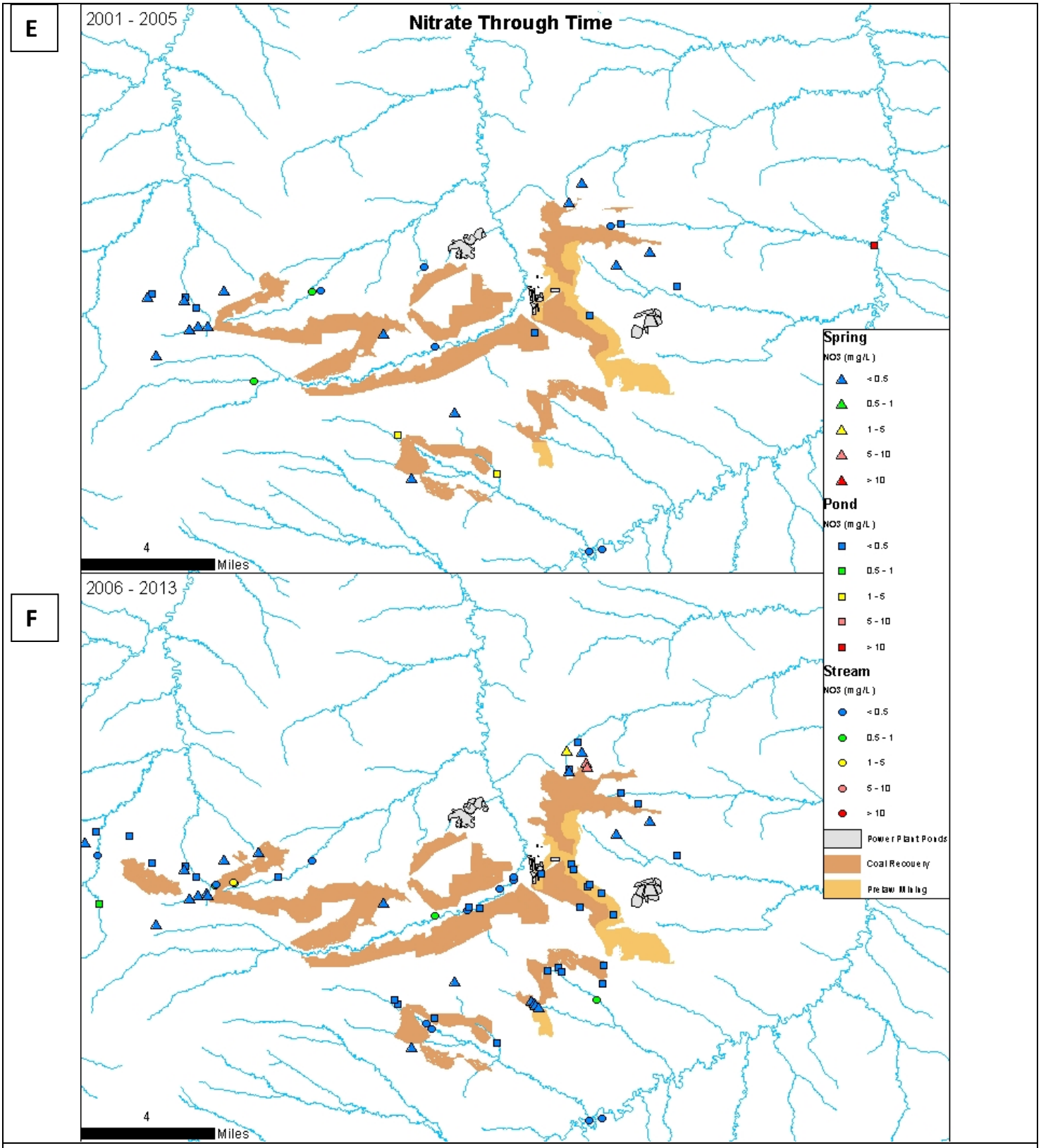


Figure 9-17 continued.

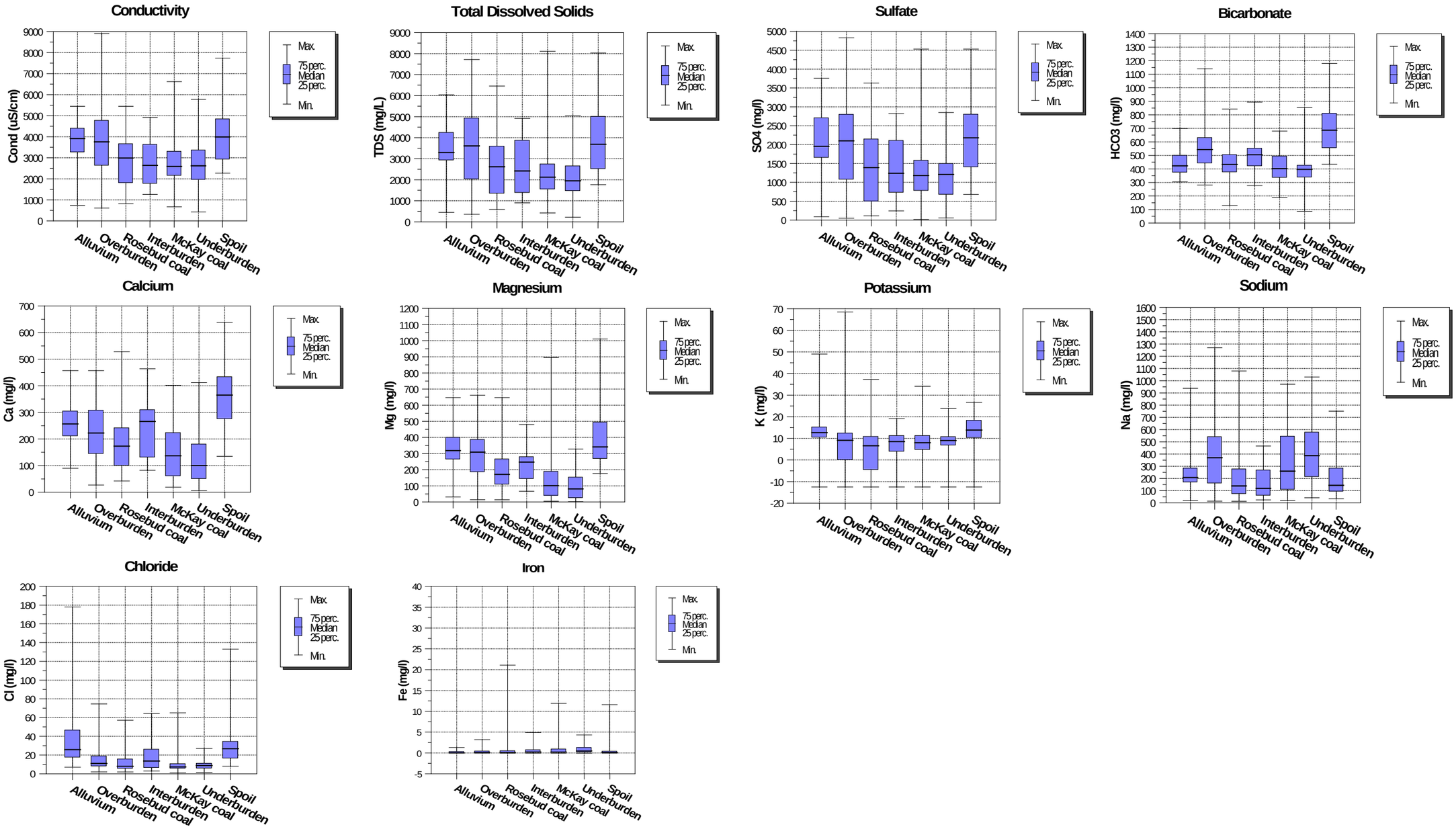


Figure 9-18: Box and whisker plots of recent (2012-2014) analyses from Rosebud Mine monitoring wells.
Total samples=224; Alluvium=42; Overburden= 16; Rosebud=31; Interburden= 25; McKay=51; Underburden=33; Spoil=26.

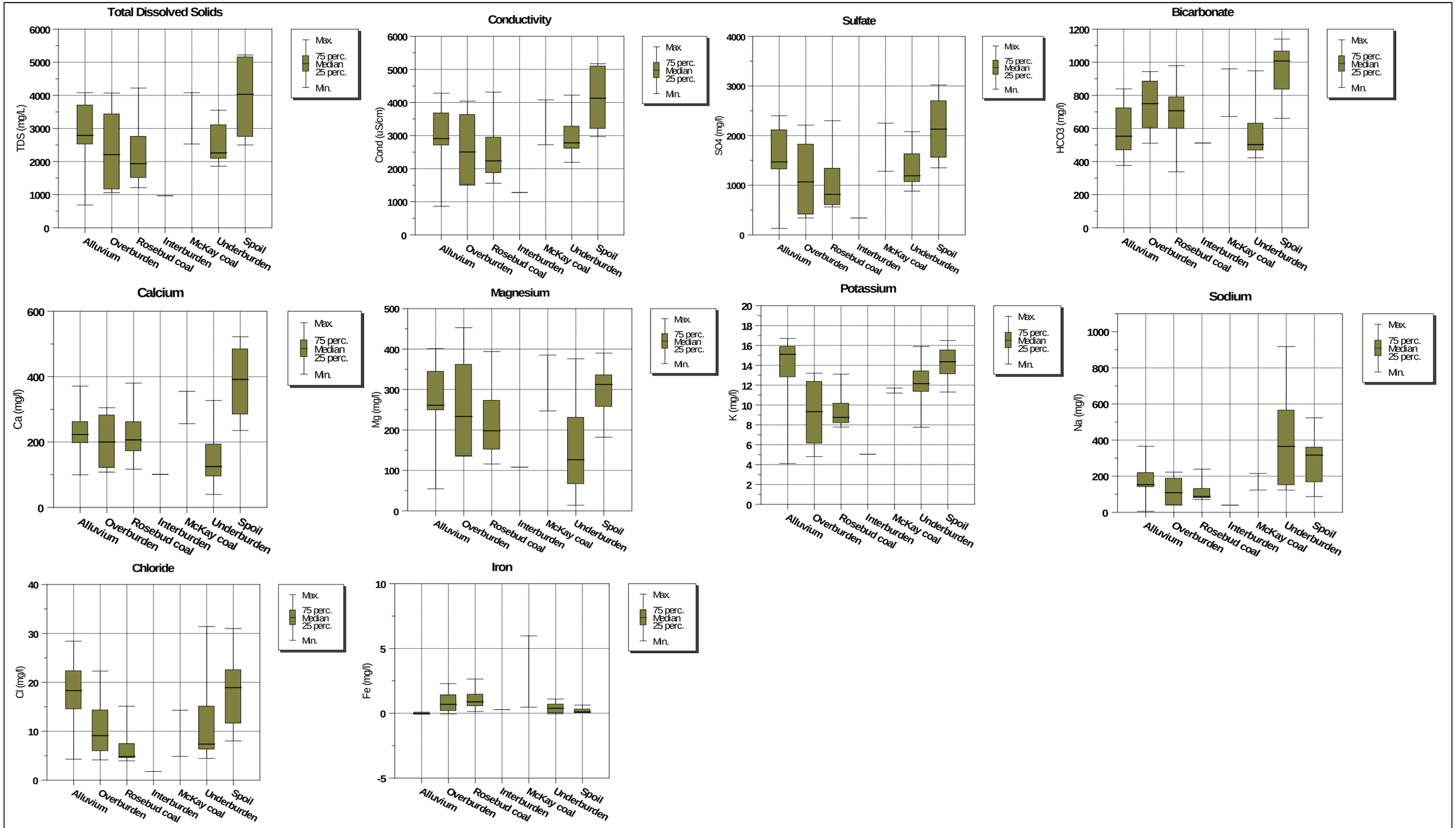


Figure 9-19: Box and whisker plots of current groundwater data at the Big Sky Mine Area B.
Total number of samples=42; alluvium=11; overburden=4; Rosebud coal=4; interburden=1; McKay coal=2; underburden=14; spoil=6.

Figure 9-20: Location of alluvial wells in Rosebud Mine areas A, B, and C, including EFAC, WFAC, and Stocker Creek.

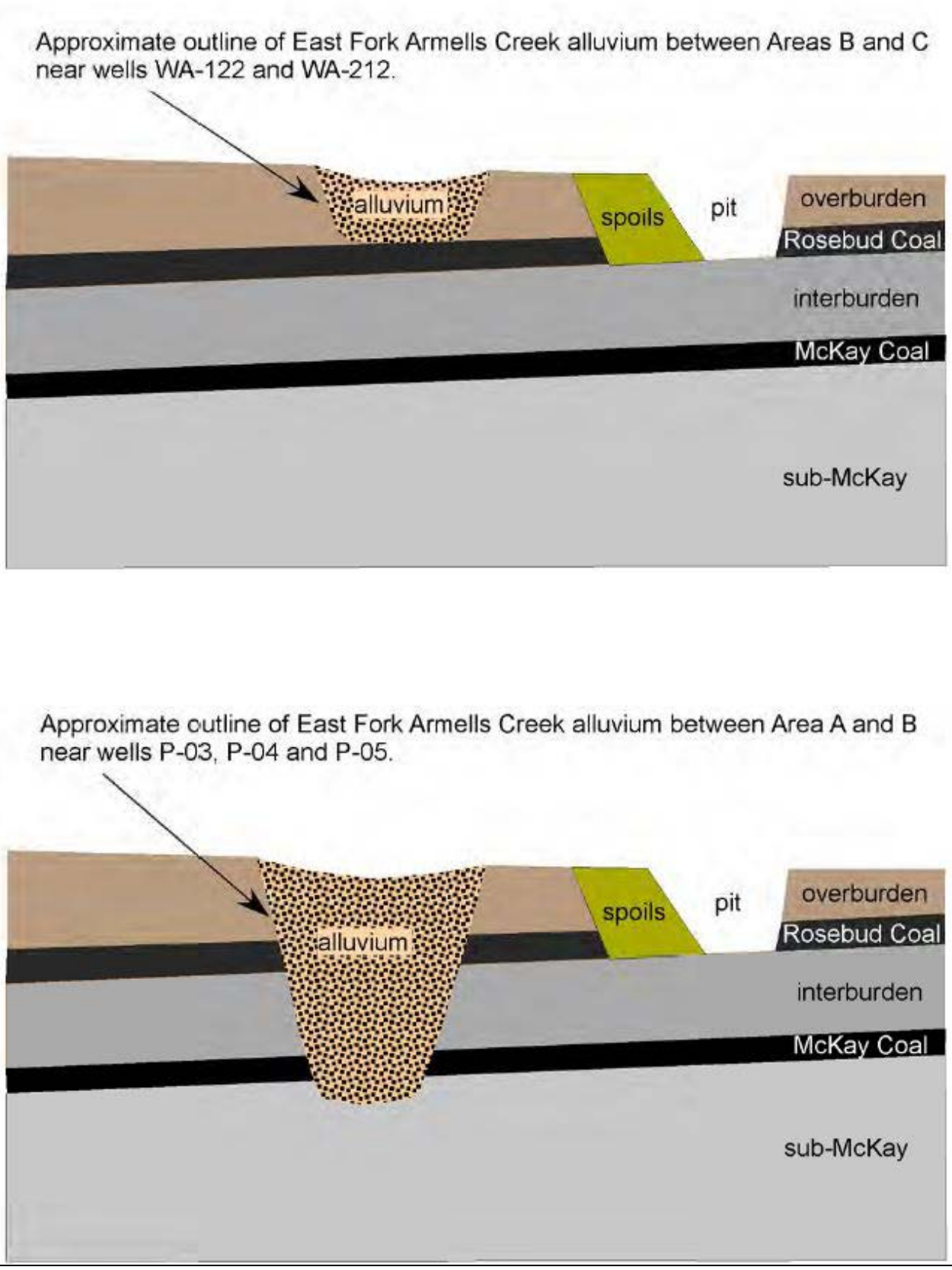
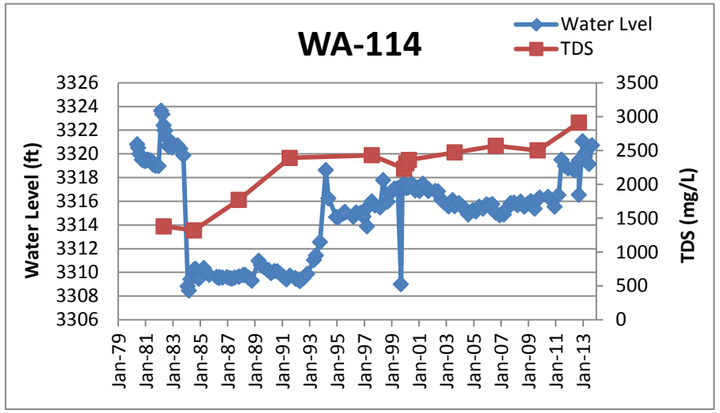
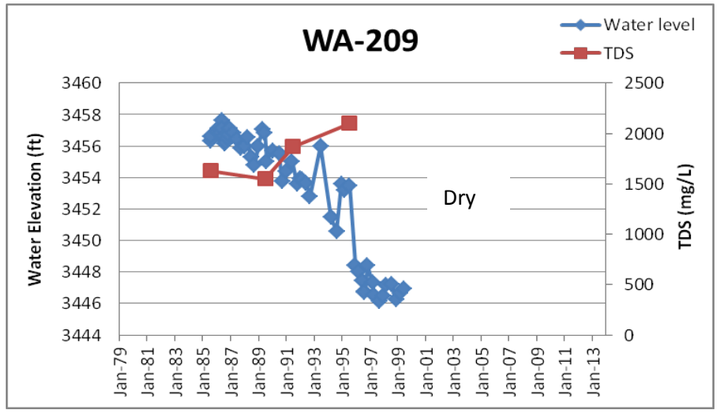
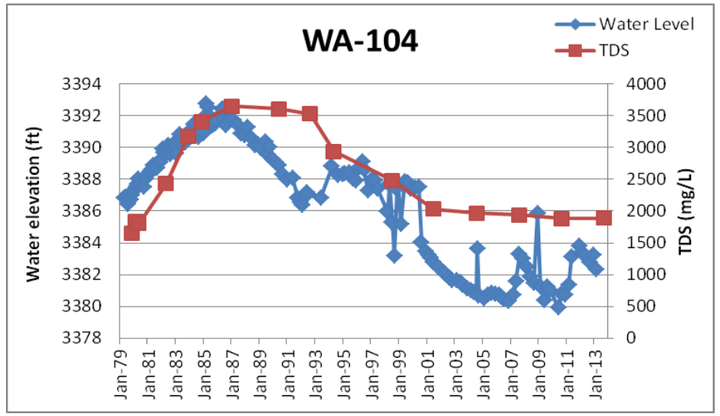


Figure 9-21: Relationship of EFAC alluvium and bedrock geology in Area B.
(After Nicklin in Western Energy Company, 2014).

Figure 9-22: Rosebud Mine down gradient EFAC alluvial well monitoring hydrographs.







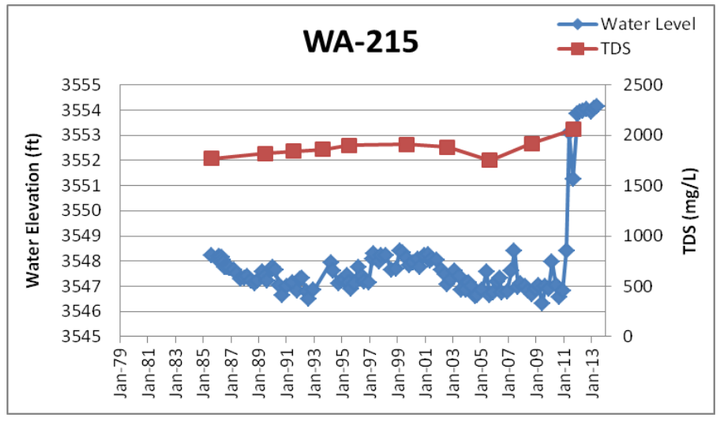


Figure 9-23: Rosebud Mine upgradient EFAC alluvial monitoring well hydrographs.

Figure 9-24: Stocker Creek alluvial monitoring well hydrographs.

Figure 9-25: Upper West Fork Armells Creek alluvial well hydrographs.

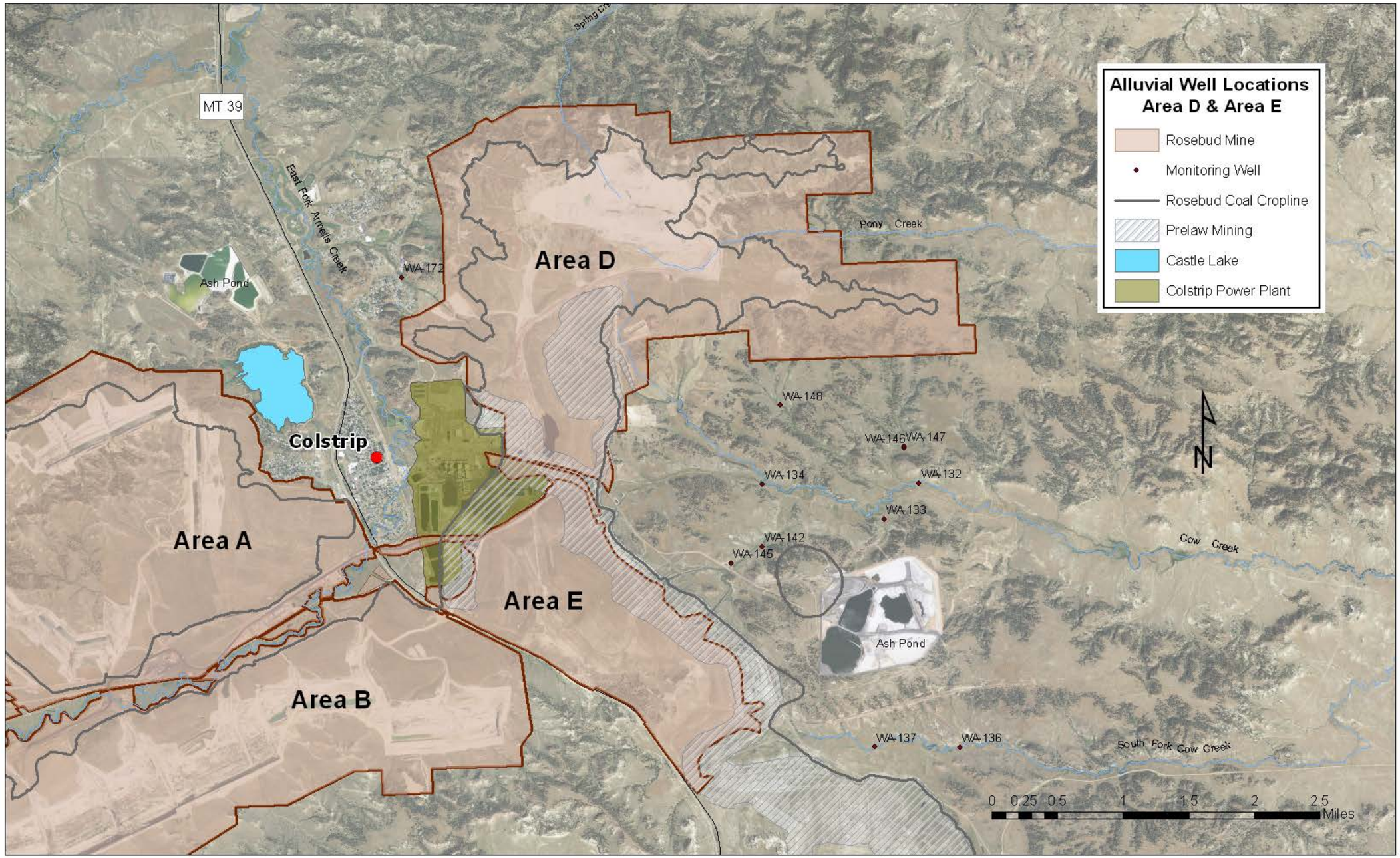


Figure 9-26: Location of alluvial monitoring wells in Rosebud Mine Area D and Area E.

Figure 9-27: Rosebud Mine Cow Creek and South Fork Cow Creek monitoring well hydrographs.

Figure 9-28: Rosebud Mine Area A bedrock and spoil monitoring wells.

Figure 9-29: Rosebud Mine Area A, Area B and Area C overburden well hydrographs.

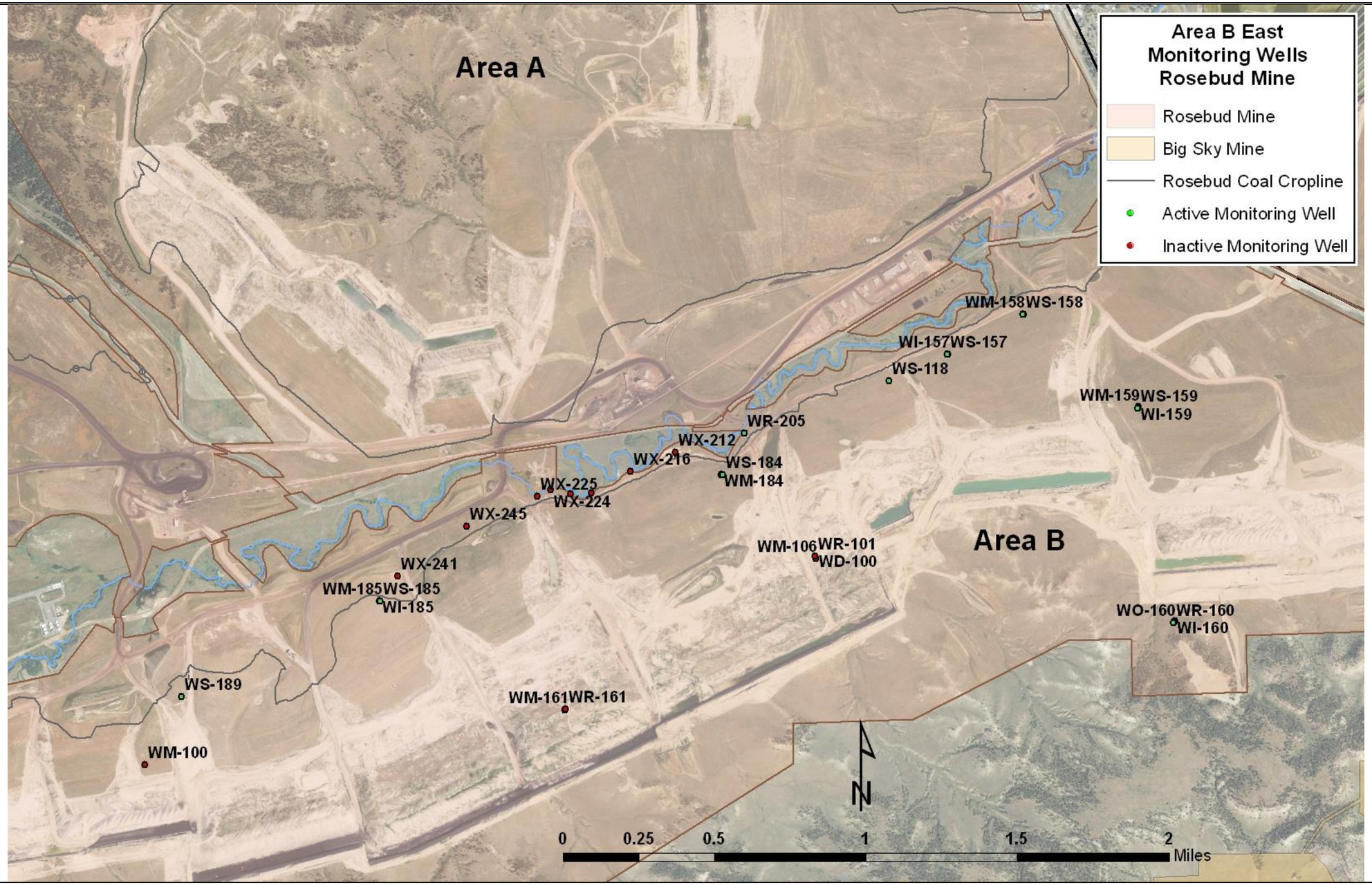


Figure 9-30: Rosebud Mine Area B East bedrock and spoil monitoring wells.

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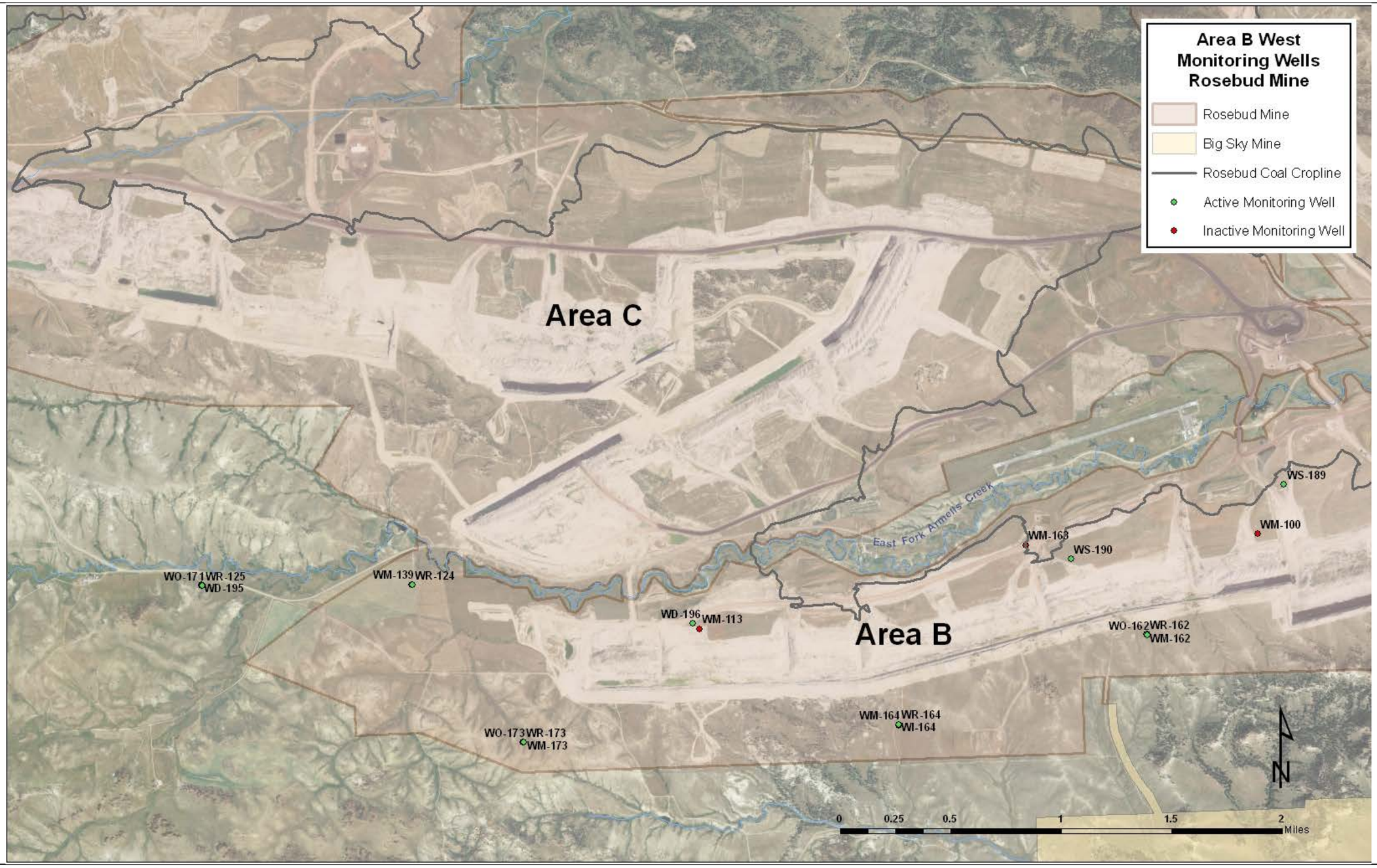

Figure 9-31: Rosebud Mine Area B West bedrock and spoil monitoring wells.

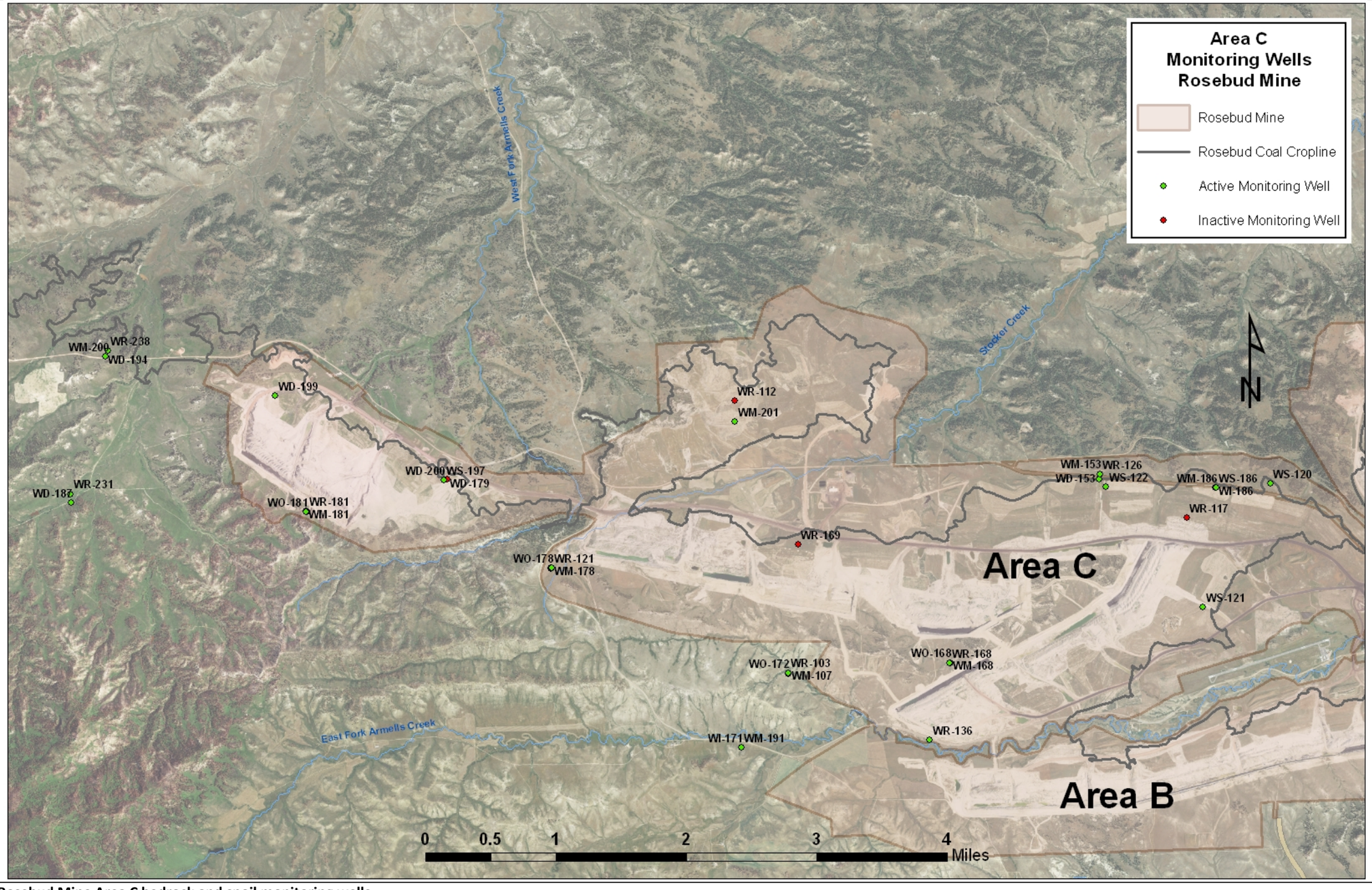

Figure 9-32: Rosebud Mine Area C bedrock and spoil monitoring wells.

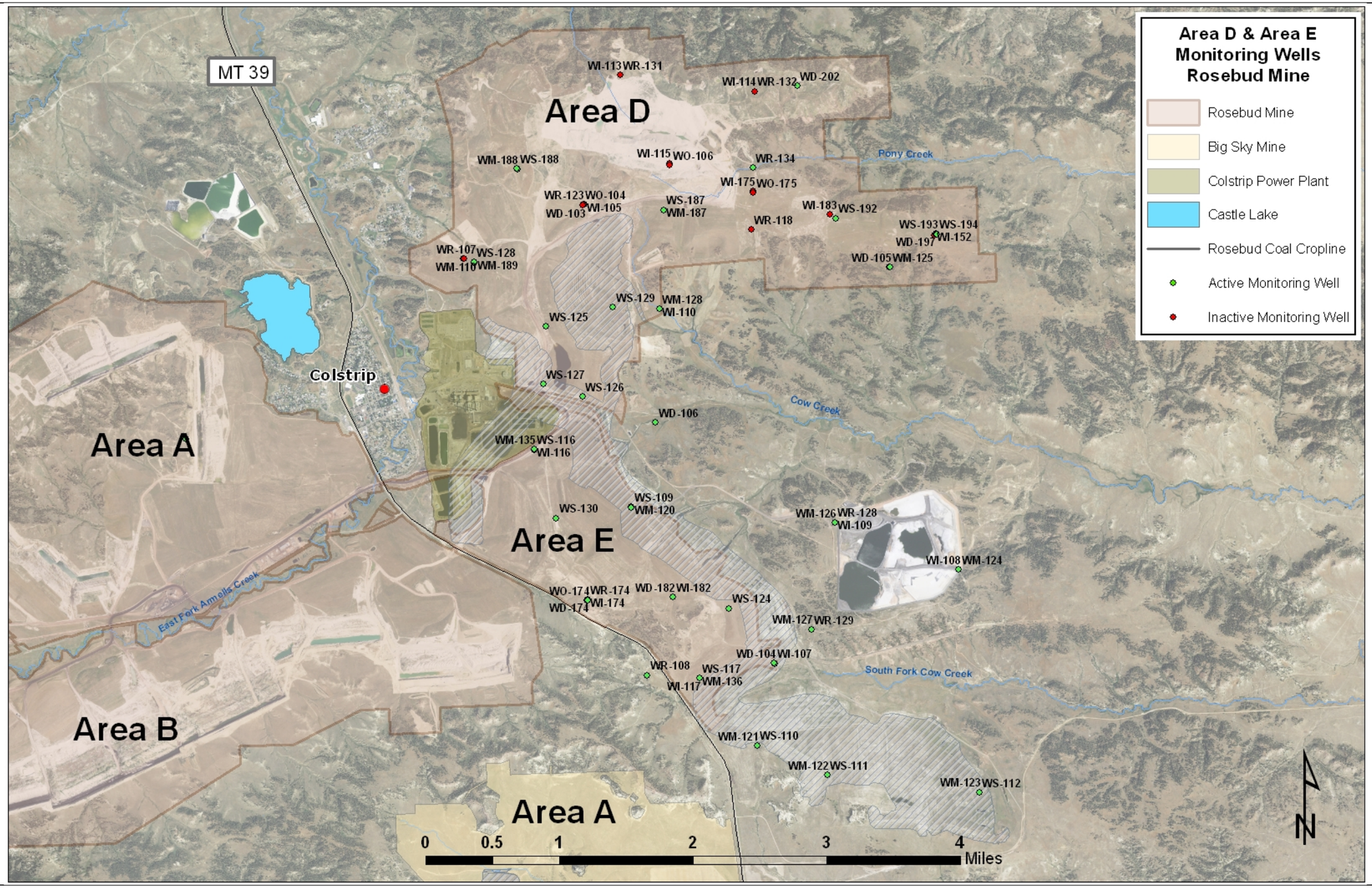

Figure 9-33: Rosebud Mine Area D and Area E bedrock and spoil monitoring wells.

Exhibit 2

Figure 9-34: Rosebud Mine Area D historic overburden wells and Area E active overburden well WO-174.
Shaded hydrographs represents wells that are no longer active.

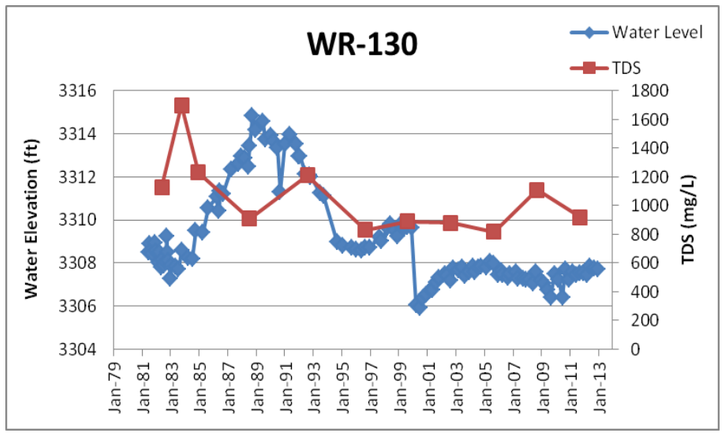

Figure 9-35: Rosebud Mine Area A Rosebud coal monitoring wells.
Shaded wells are not active.

Exhibit 2

Figure 9-36: Rosebud Mine Area B Rosebud coal monitoring well hydrographs.
Shaded graphs are from inactive wells.

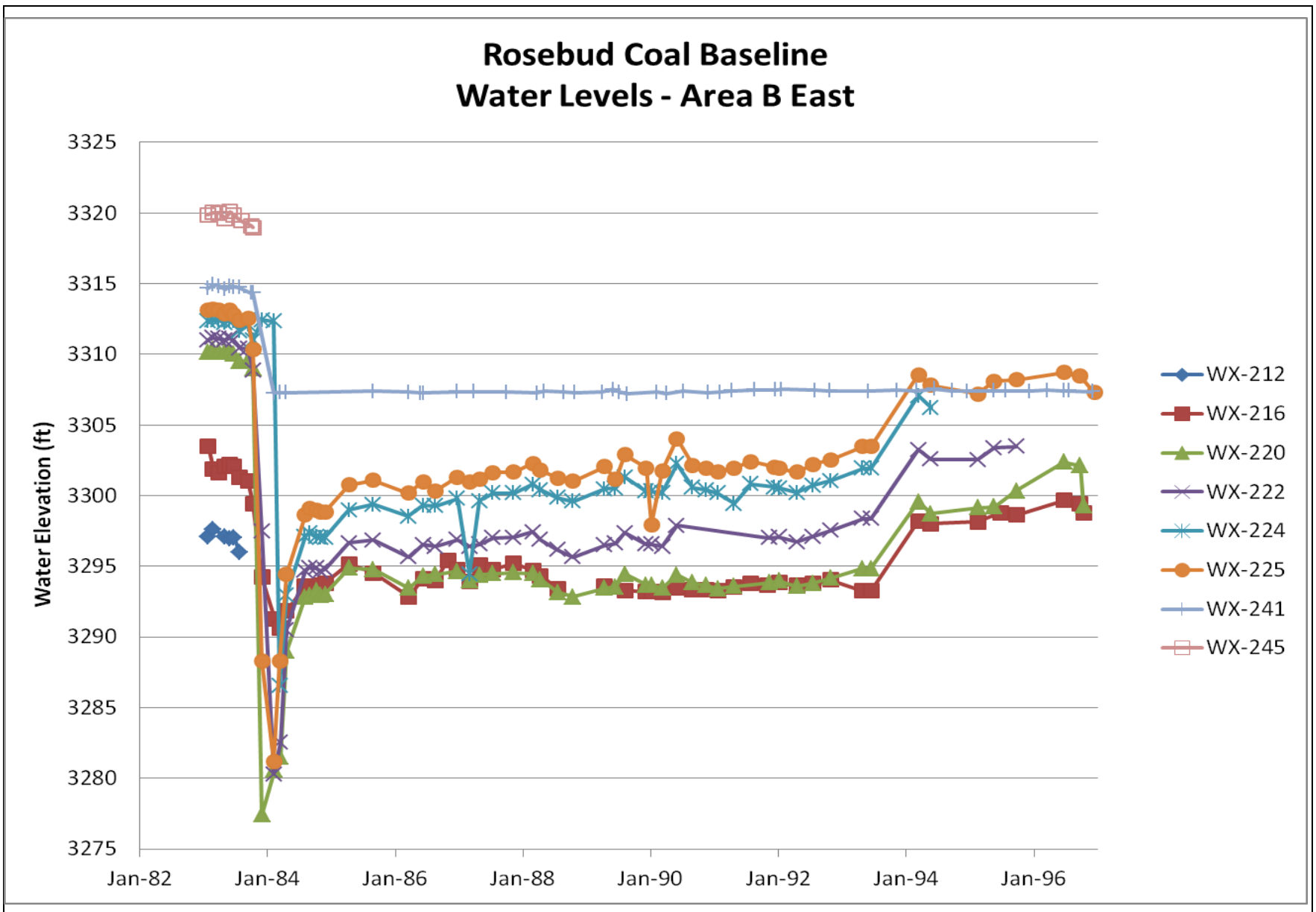

Figure 9-37: Rosebud Mine Area B Rosebud coal and clinker baseline monitoring wells ("WX" wells) that were completed immediately adjacent to the coal cropline at the east end of Area B.

Figure 9-38: Rosebud Mine Area C Rosebud coal monitoring well hydrographs.

Figure 9-39: Rosebud Mine Area D Rosebud coal monitoring well hydrographs.
Shaded graphs represent inactive wells.

Figure 9-40: Rosebud Mine Area E Rosebud coal well hydrographs.

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Figure 9-41: Rosebud Mine Area A interburden monitoring well hydrographs.
Shaded graphs are from inactive wells.

Figure 9-42: Rosebud Mine Area B interburden monitoring well hydrographs.

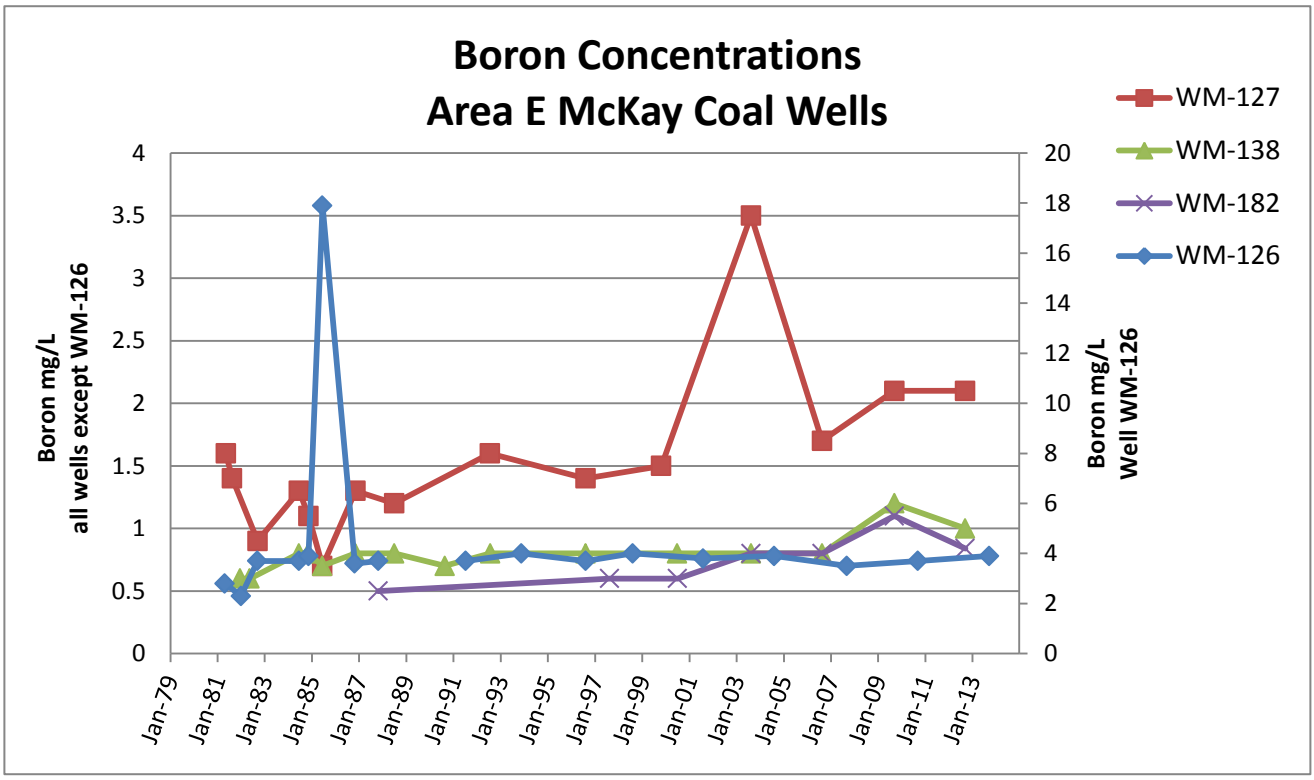
Figure 9-43: Rosebud Mine Area C interburden monitoring well hydrographs.

Figure 9-44: Rosebud Mine Area D interburden monitoring well hydrographs.
Shaded graphs are from inactive wells.

Figure 9-45: Rosebud Mine Area E interburden monitoring well hydrographs.

Figure 9-46: Rosebud Mine Area A McKay monitoring well hydrographs.

Exhibit 2



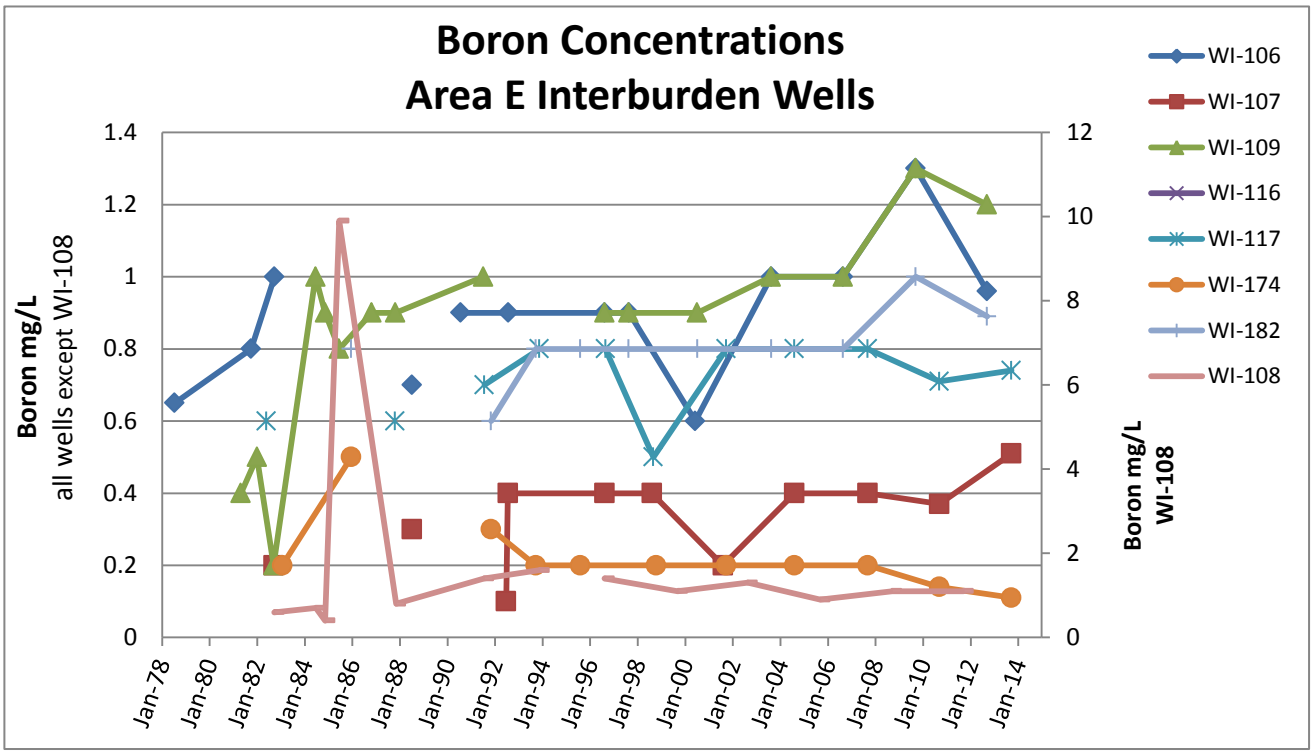


Figure 9-47: Boron concentrations in interburden and McKay coal monitoring wells.
Background concentrations are considered to be 0.5 mg/L or less.

Exhibit 2

Figure 9-48: Rosebud Mine Area B inactive McKay coal monitoring well hydrographs.

Figure 9-49: Rosebud Mine Area B active McKay monitoring wells.

Figure 9-50: Rosebud Mine Area C McKay monitoring well hydrographs.

Figure 9-51: Rosebud Mine Area D McKay coal monitoring well hydrographs.
Shaded graph represents inactive well.

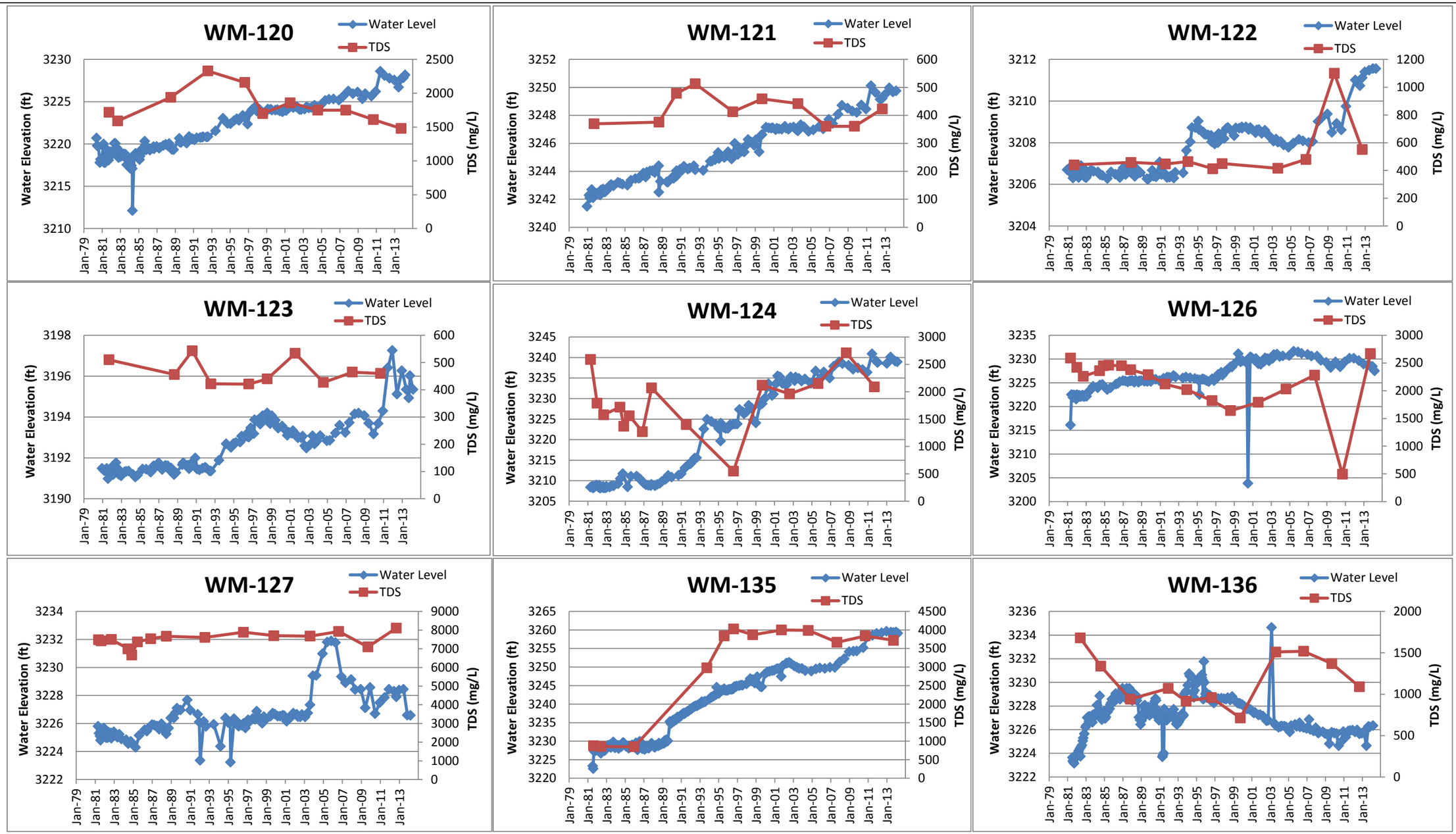


Figure 9-52: Rosebud Mine Area E McKay coal well hydrographs.

Figure 9-52 con't: Rosebud Mine Area E McKay coal well hydrographs.13

Exhibit 2

Figure 9-53: Rosebud Mine Area A and Area B underburden monitoring well hydrographs.
Shaded graph represent inactive well.

Figure 9-54: Rosebud Mine Area C underburden monitoring well hydrographs.

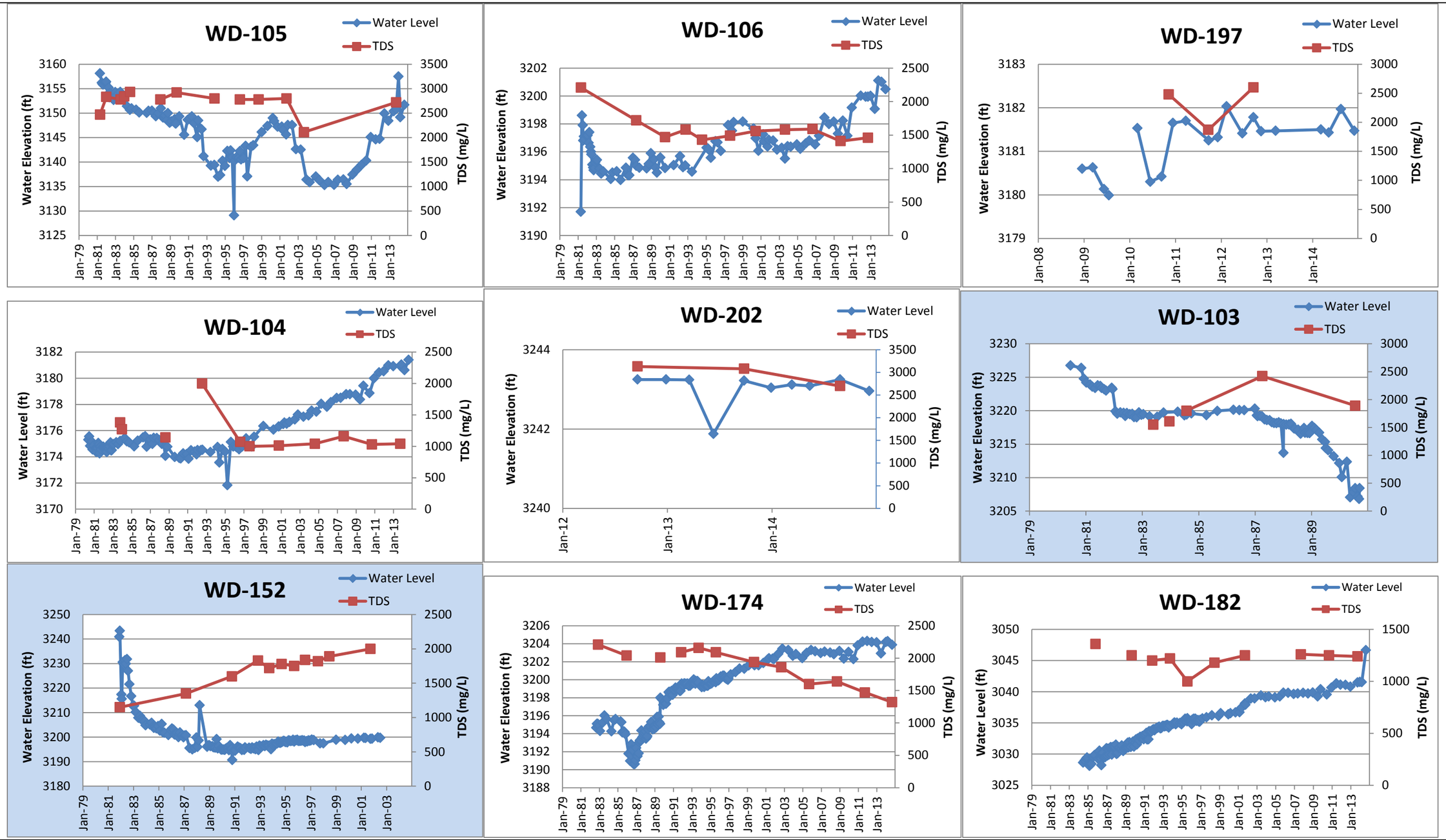
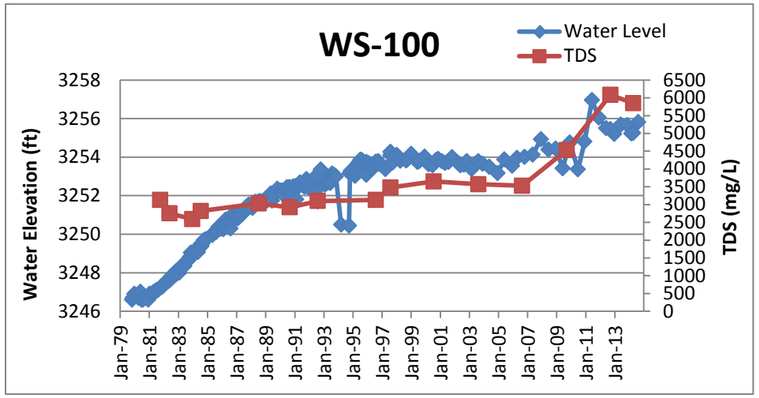
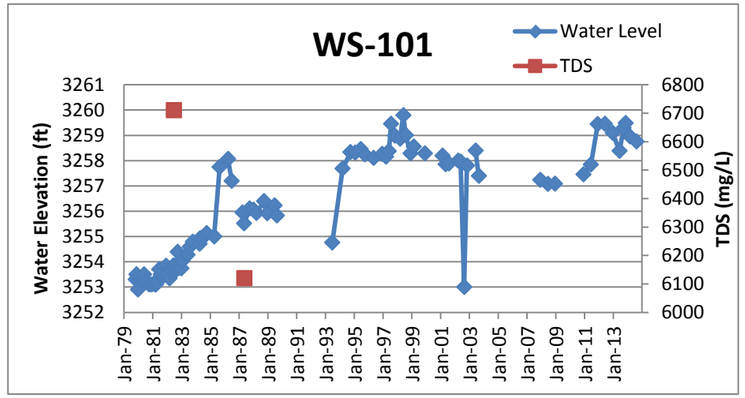
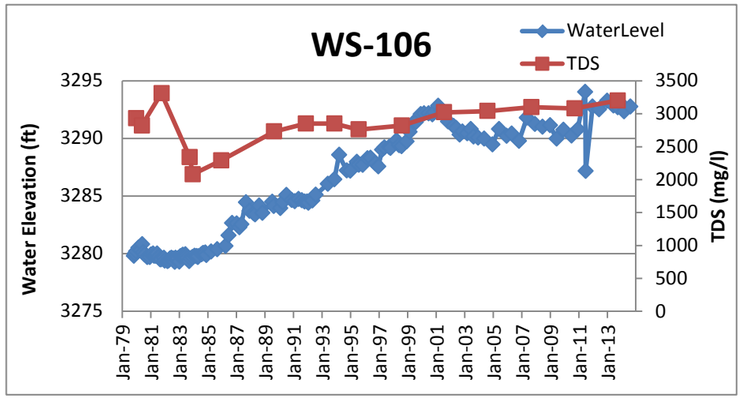


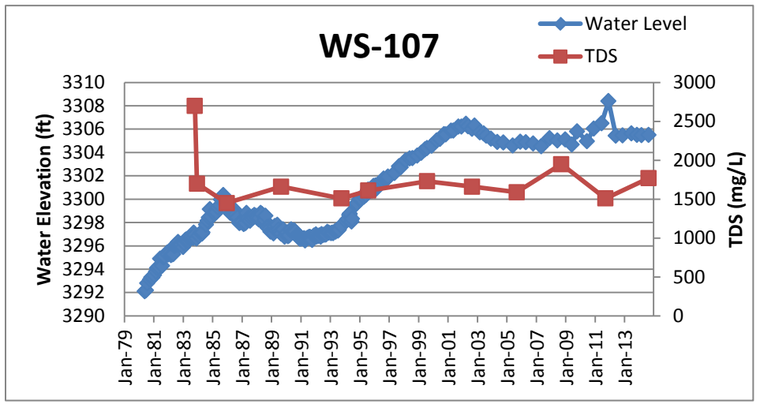
Figure 9-55: Rosebud Mine Area D and Area E underburden monitoring well hydrographs.
Shaded graph represent inactive well.

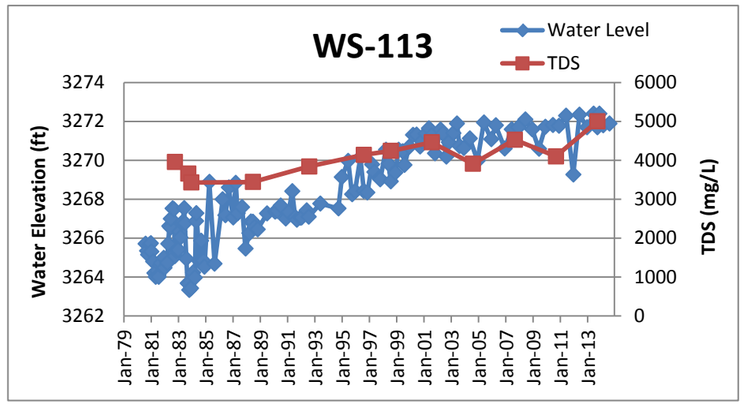
Figure 9-56: History of TDS concentrations from Rosebud Mine spoil wells by permit area.
Analytical results from samples analyzed throughout well life.











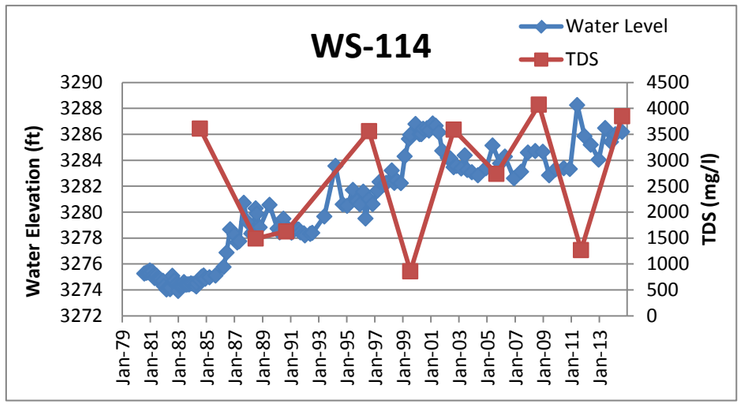
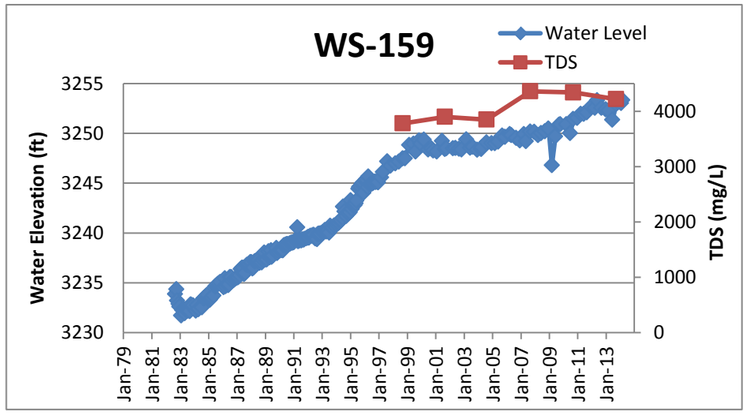
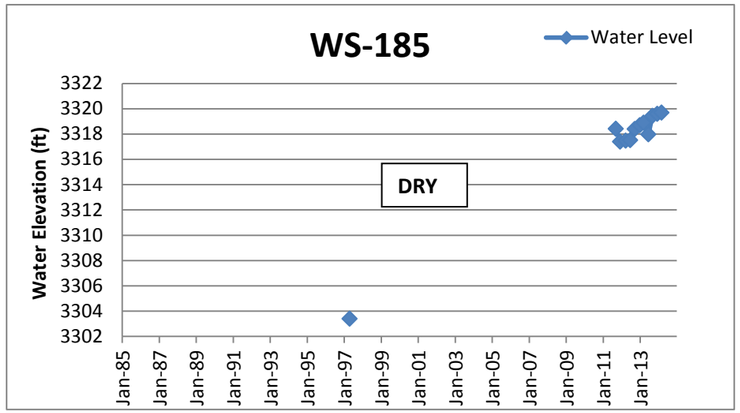
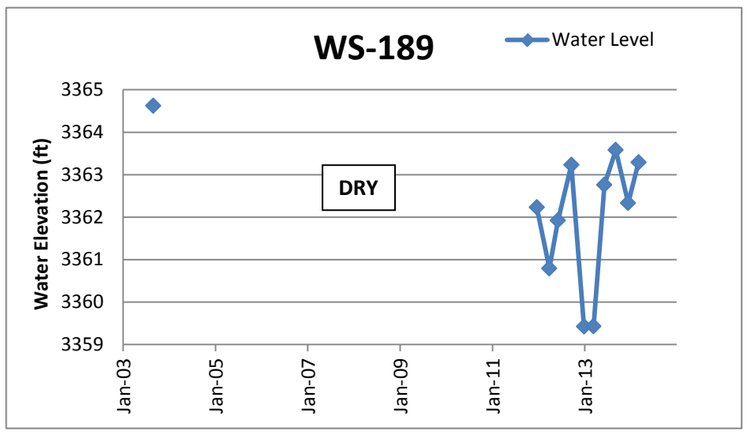


Figure 9-57: Rosebud Mine Area A spoil well hydrographs.







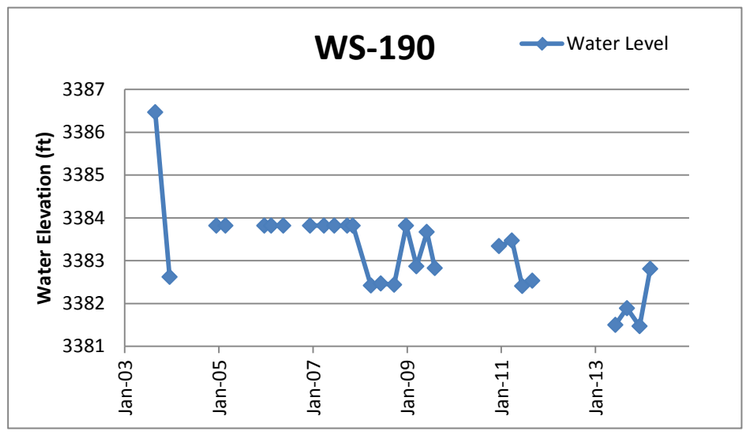


Figure 9-58: Rosebud Mine Area B spoil monitoring well hydrographs.

Figure 9-59: Rosebud Mine Area C spoil monitoring well hydrographs.

Figure 9-60: Rosebud Mine Area D spoil monitoring well hydrographs.

Figure 9-61: Rosebud Mine Area E spoil monitoring wells.

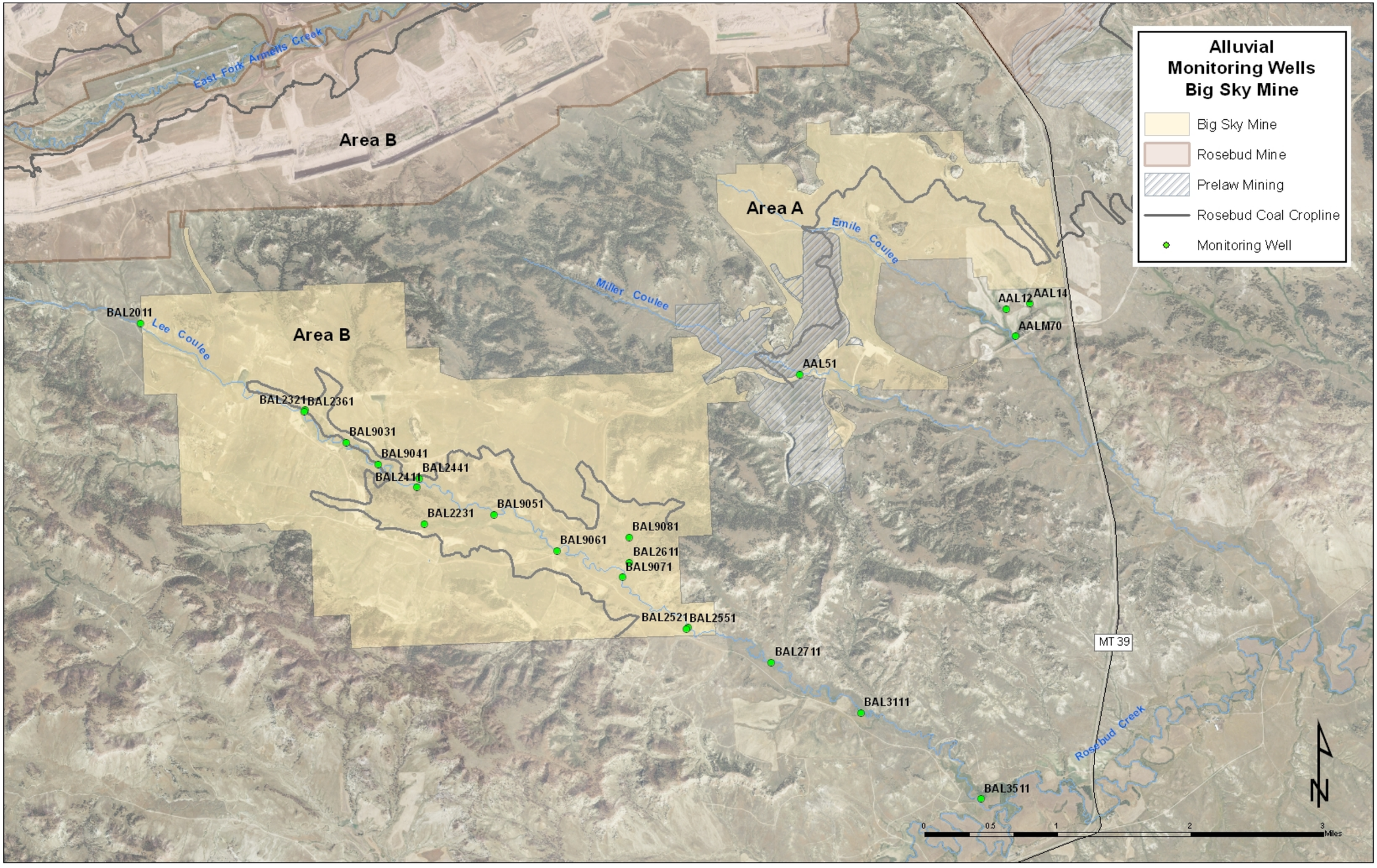


Figure 9-62: Big Sky Mine alluvial monitoring wells.

Figure 9-63: Big Sky Mine Area alluvial monitoring wells.

Figure 9-64: Big Sky Mine Area B alluvial monitoring well hydrographs.

Figure 9-64 continued.

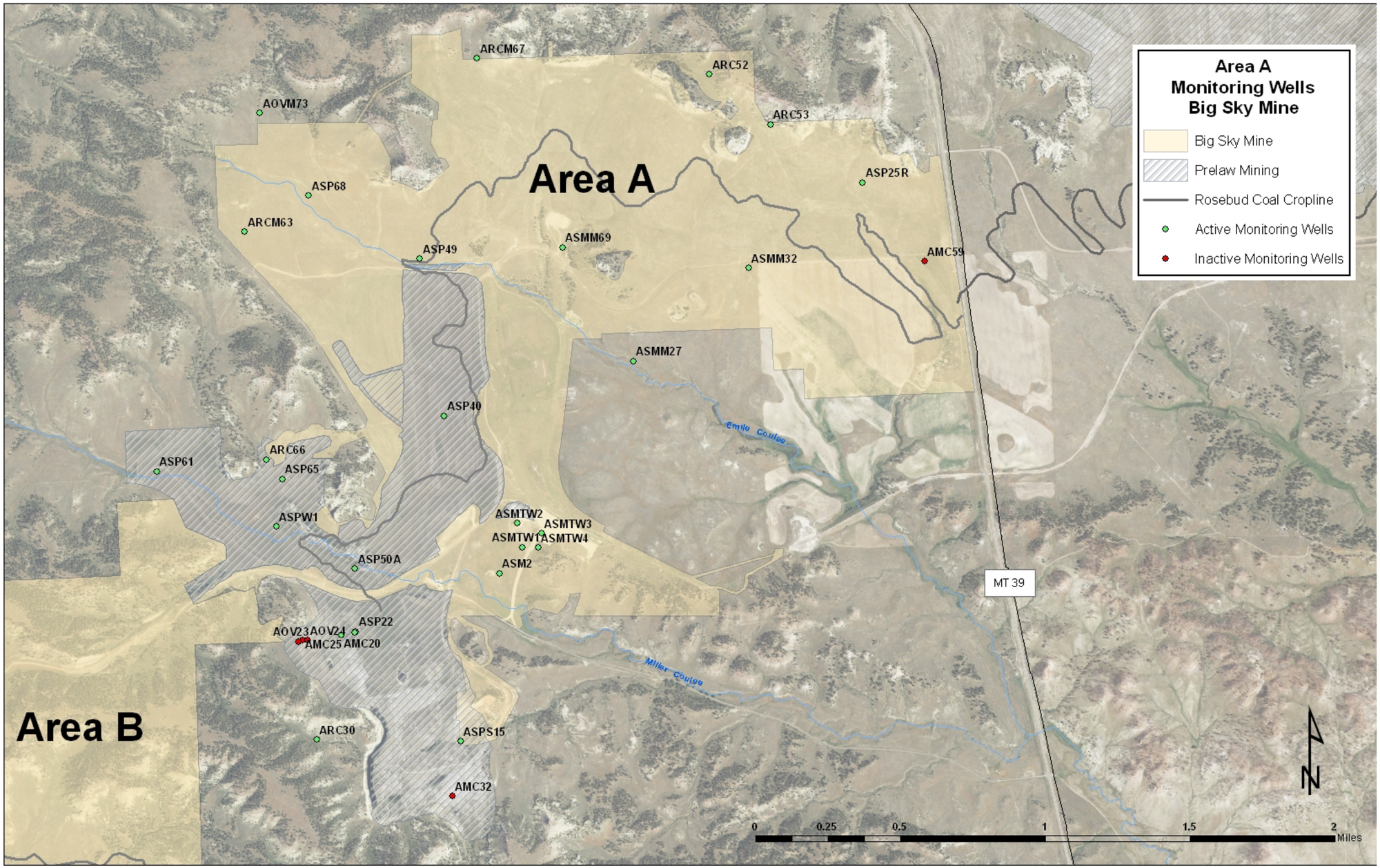


Figure 9-65: Big Sky Area A bedrock and spoil monitoring wells.

Figure 9-66: Big Sky Mine Area A overburden and Rosebud coal monitoring wells.

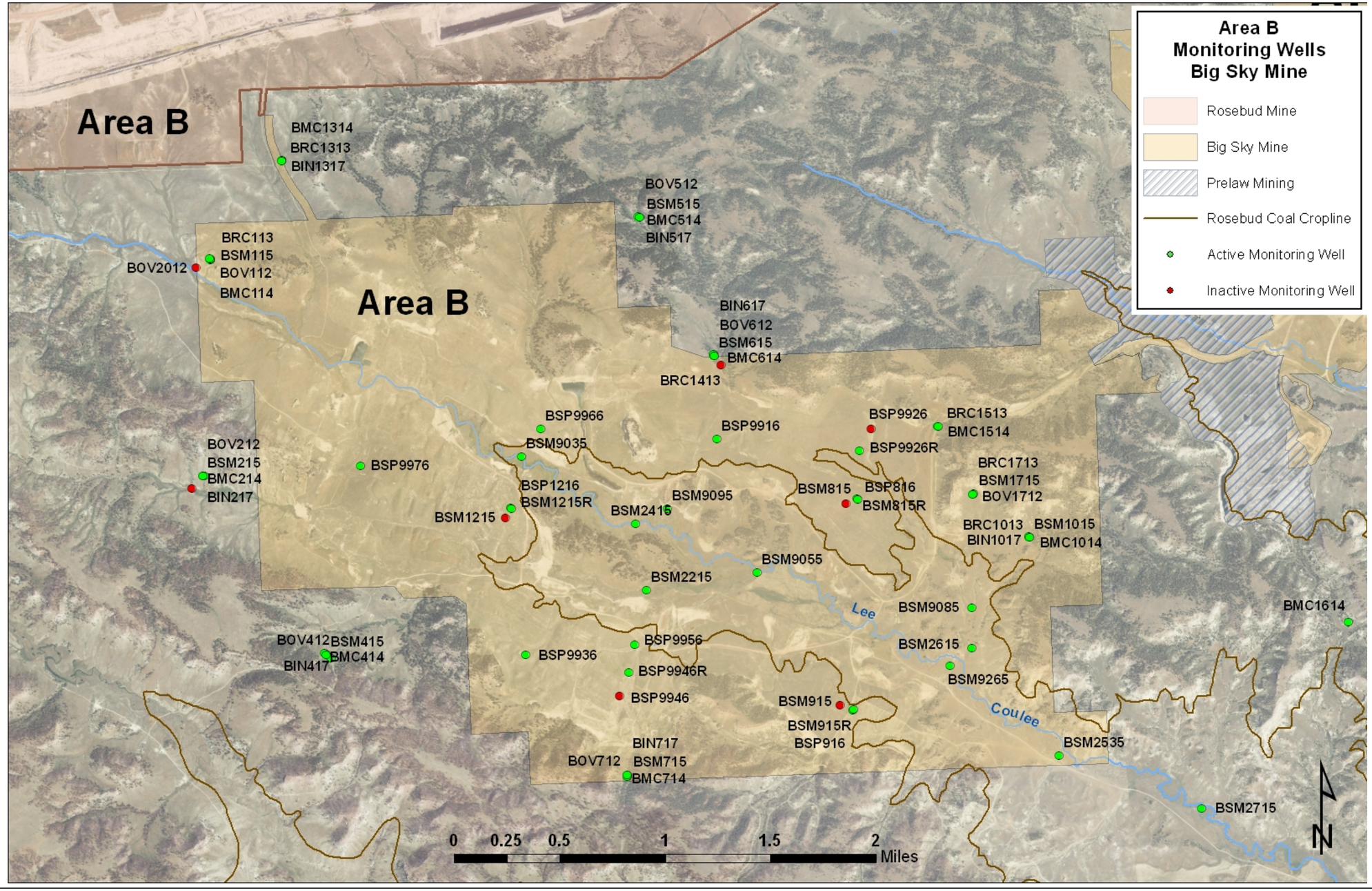


Figure 9-67: Big Sky Area B bedrock and spoil monitoring wells.

Figure 9-68: Big Sky Mine Area B overburden monitoring wells.
Shaded graph indicates that the well BOV2012 is no longer active.

Figure 9-69: Big Sky Mine Area B Rosebud coal monitoring well hydrographs.
Shaded graphs represent inactive wells.

Figure 9-70: Big Sky Mine Area B interburden monitoring well hydrographs.

Figure 9-71: Big Sky Mine Area A McKay coal monitoring wells.
Shaded charts represent wells that are inactive.

Figure 9-72: Big Sky Mine Area B McKay coal monitoring well hydrographs.

Figure 9-73: Big Sky Mine Area A underburden monitoring wells.

Figure 9-74: Big Sky Mine deep underburden monitoring well hydrographs.

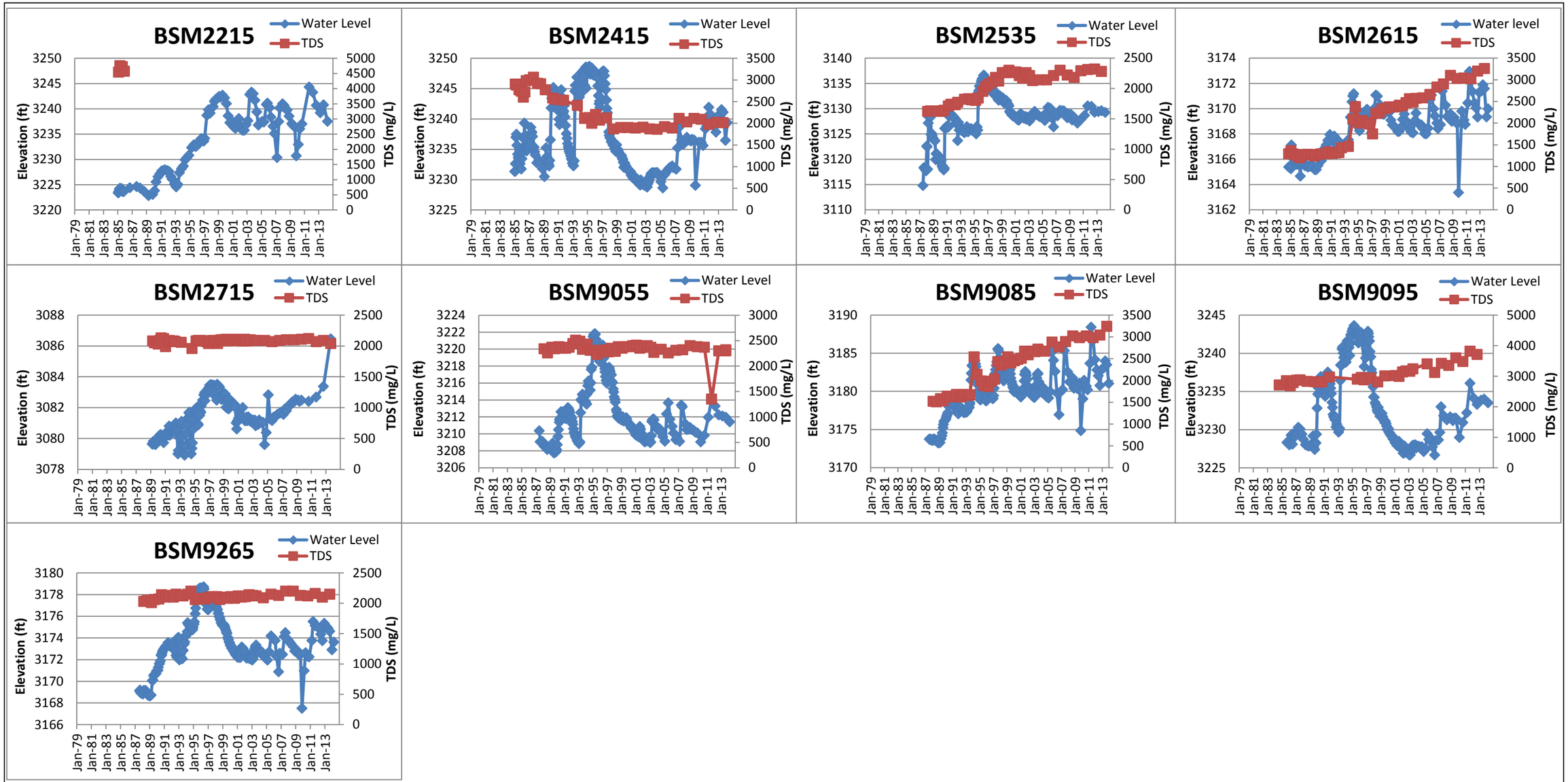


Figure 9-75: Big Sky Mine Area B "shallow" underburden monitoring well hydrographs.
Shaded charts represent wells that are inactive.

Figure 9-76: Big Sky Mine Area A spoil well hydrographs.

Figure 9-77: Big Sky Mine Area B spoil hydrographs.

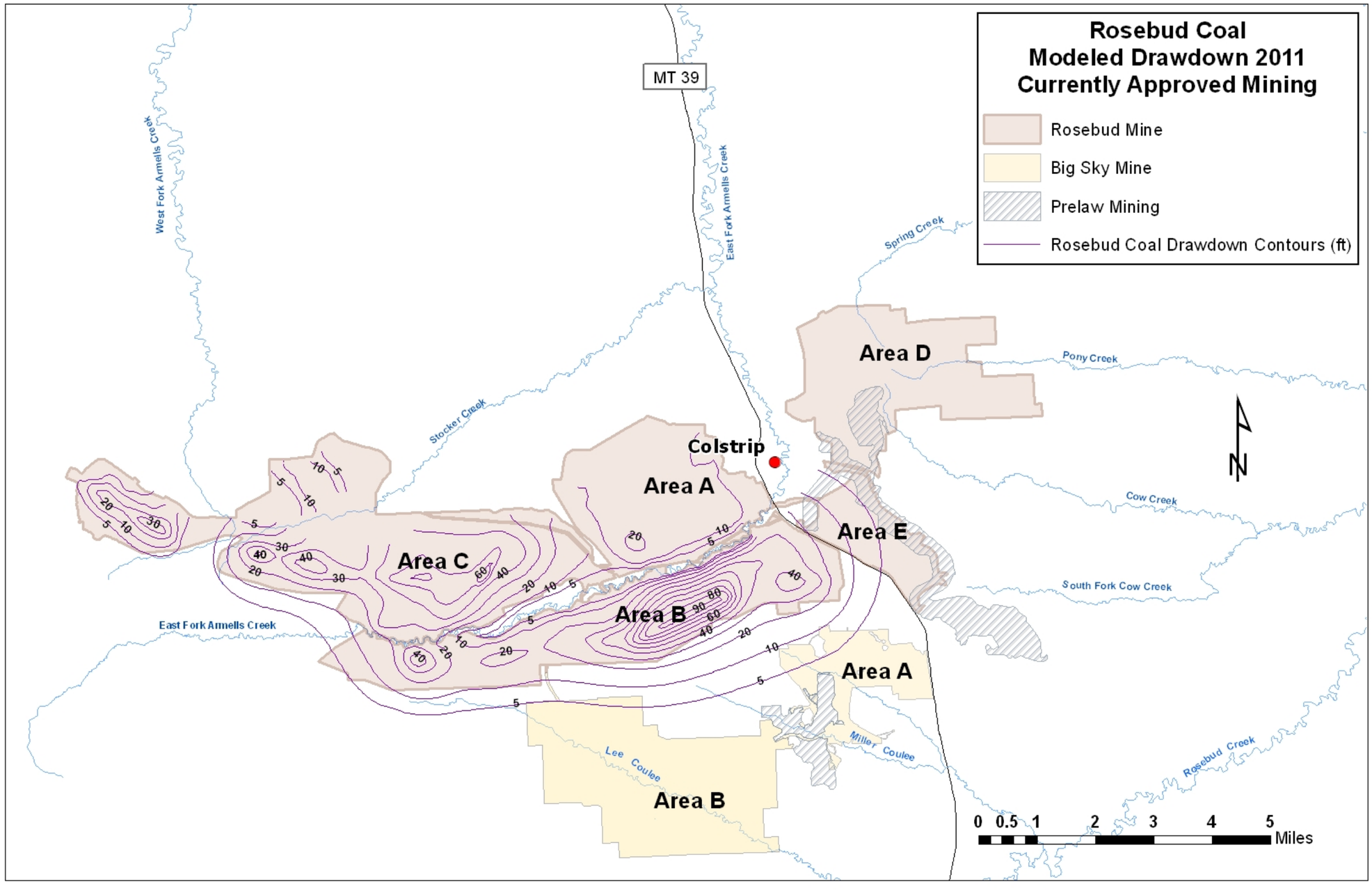


Figure 9-78: Modeled drawdown in Rosebud coal in permit areas A, B, and C of the Rosebud Mine.
Drawdown represents the response to mining through 2011 and approximates current (2014) conditions. Contour interval is 10 feet except for the five foot contour representing the extent of drawdown.

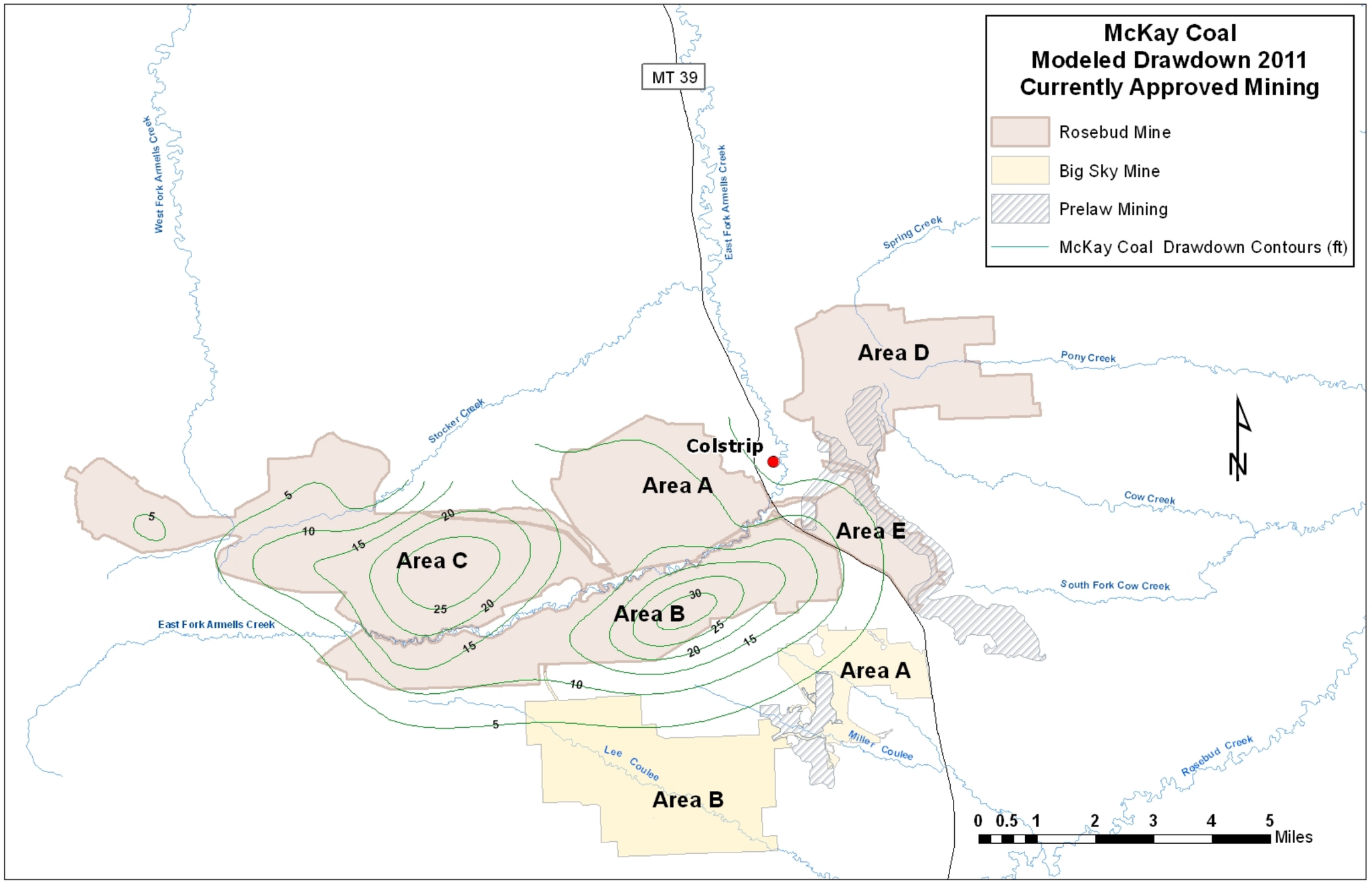


Figure 9-79: Modeled drawdown in McKay coal in permit areas A, B, and C of the Rosebud Mine.
Drawdown represents the response of mining through 2011 and approximates current (2014) conditions. Contour interval is 10 feet except for the five foot contour representing the extent of drawdown.

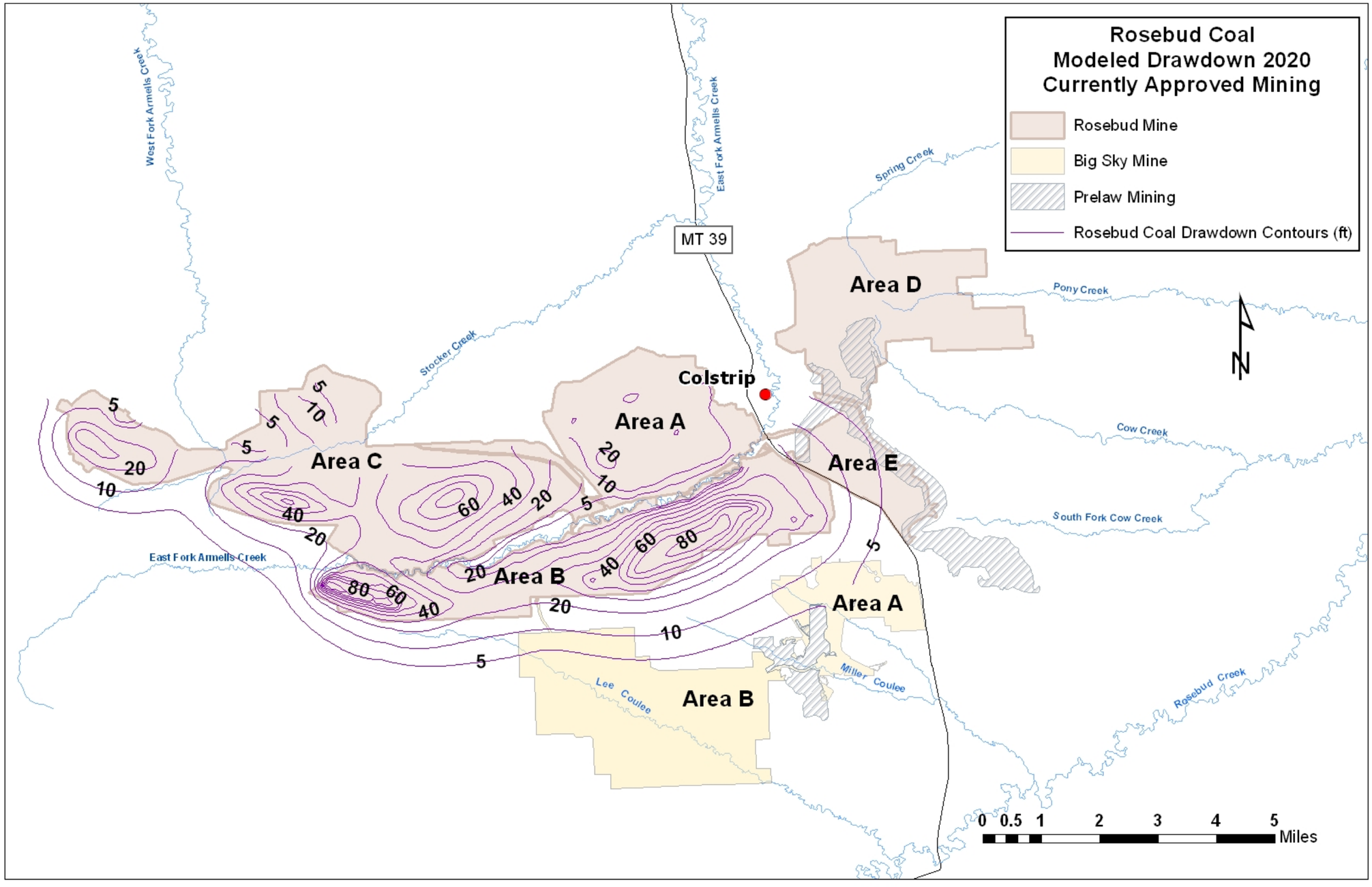


Figure 9-80: Modeled drawdown in Rosebud coal in permit areas A, B, and C of the Rosebud Mine.
Drawdown represents conditions in 2020 at the end of currently approved mining. Contour interval is 10 feet except for the five foot contour representing the extent of drawdown.

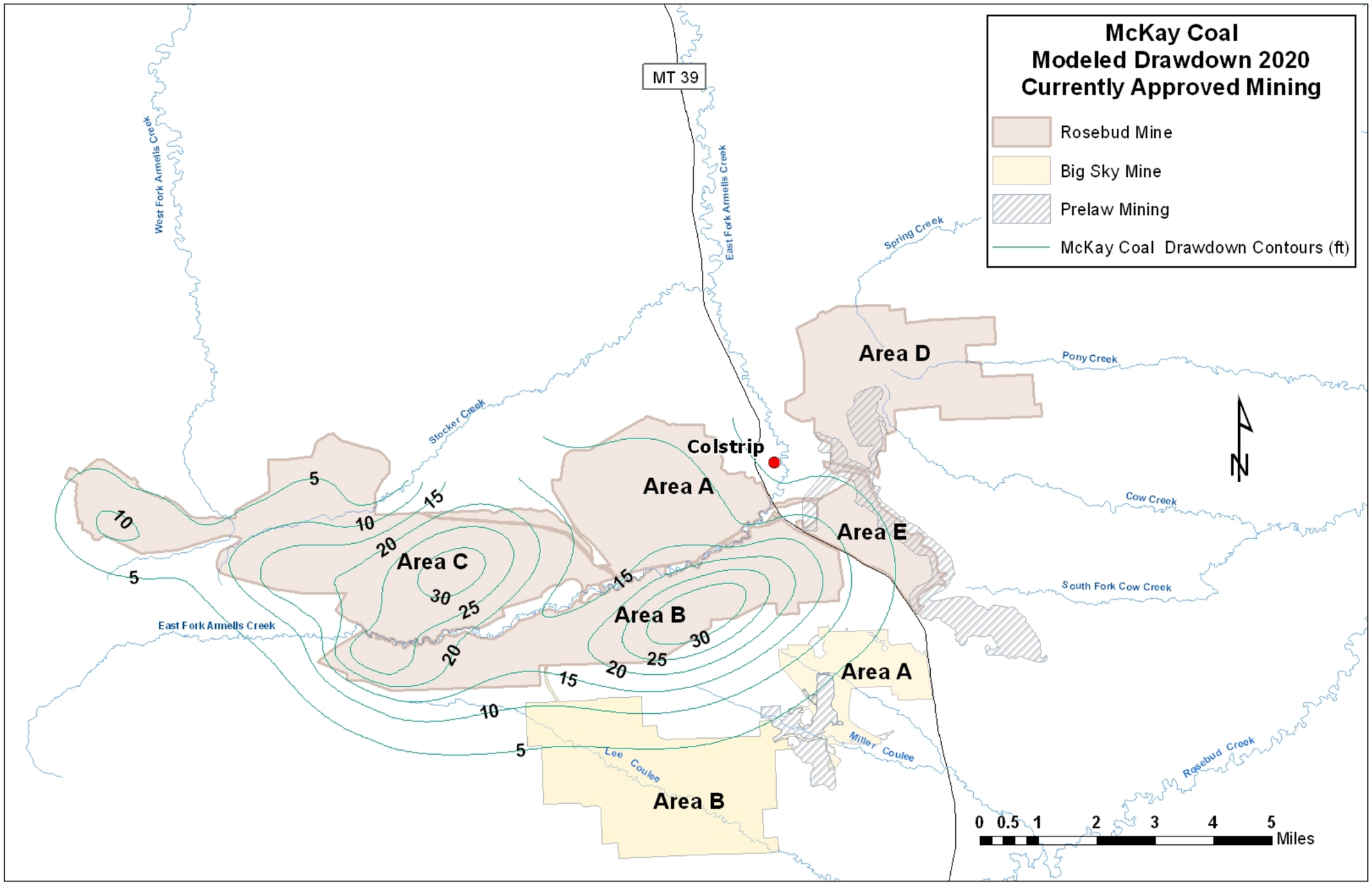


Figure 9-81: Modeled drawdown in McKay coal in permit areas A, B, and C of the Rosebud Mine.
Drawdown represents conditions in 2020 at the end of currently approved mining. Contour interval is 10 feet except for the five foot contour representing the extent of drawdown.

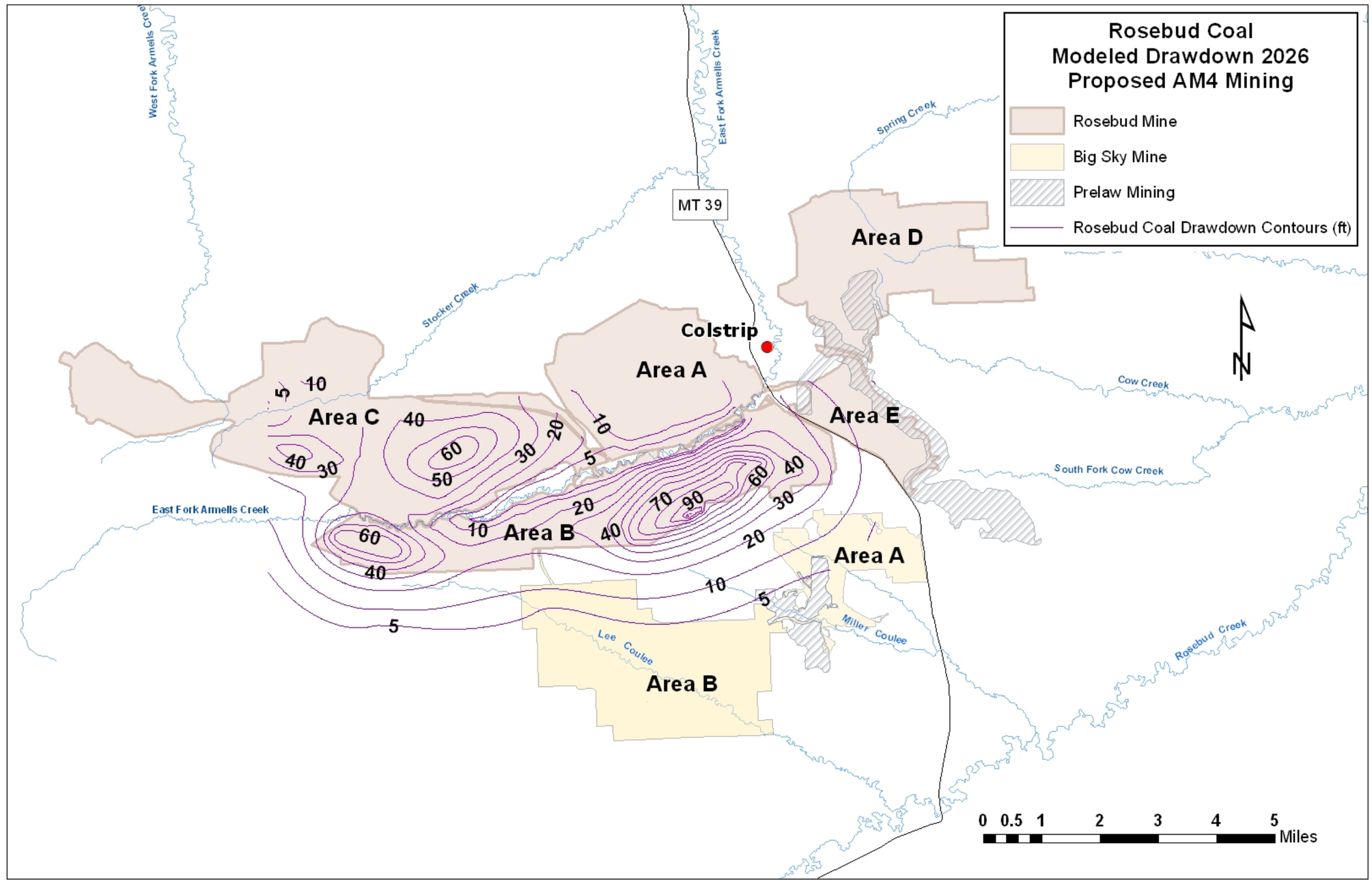


Figure 9-82: Modeled drawdown in Rosebud coal in permit areas A, B, and C of the Rosebud Mine with the addition of mining proposed in AM4.
Drawdown represents conditions at end of mining in 2026. Contour interval is 10 feet except for the five foot contour representing the extent of drawdown.

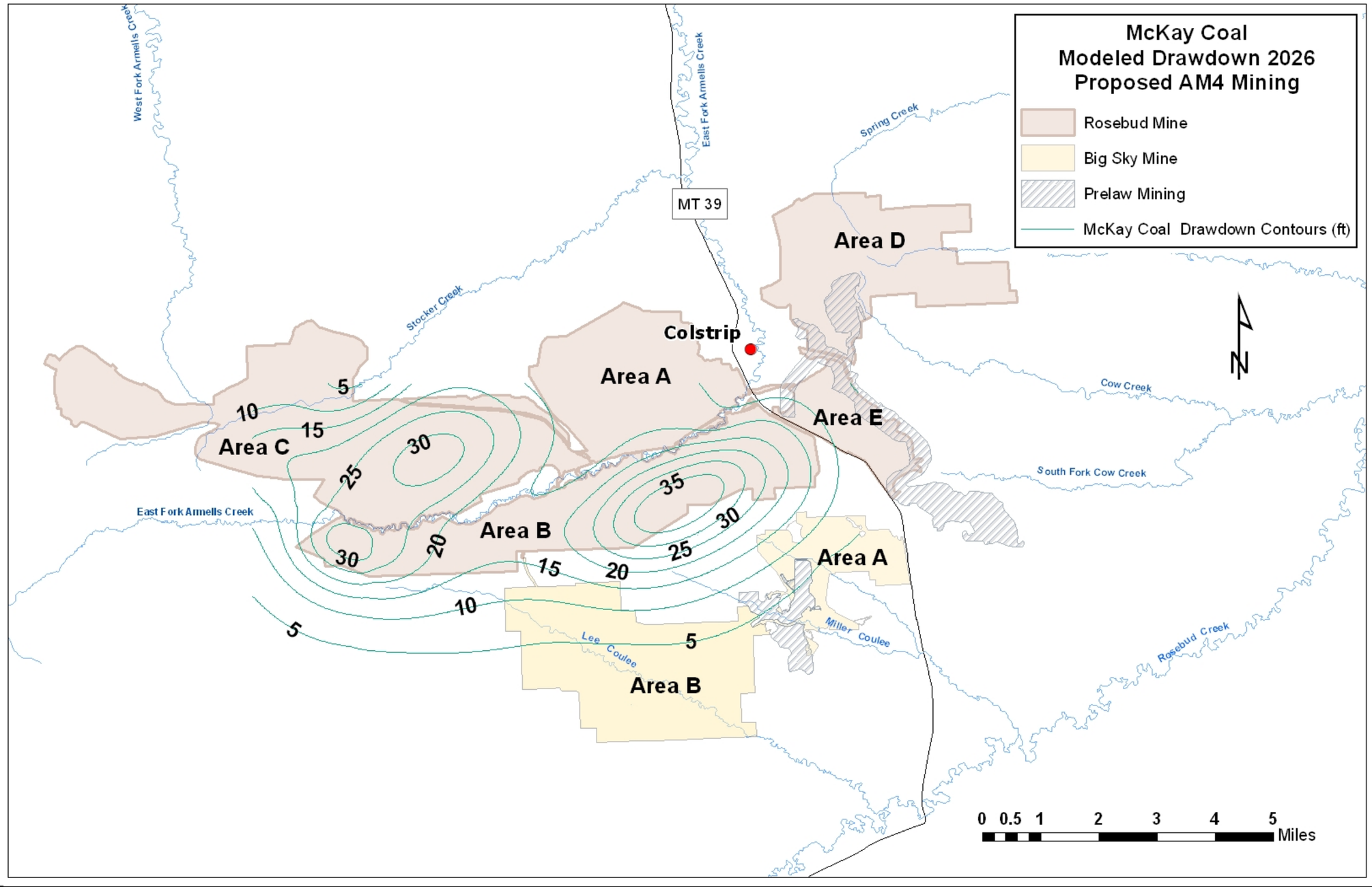


Figure 9-83: Modeled drawdown in McKay coal in permit areas A, B, and C of the Rosebud Mine with the addition of mining proposed in AM4.
Drawdown represents conditions at end of mining in 2026. Contour interval is 10 feet except for the five foot contour representing the extent of drawdown.

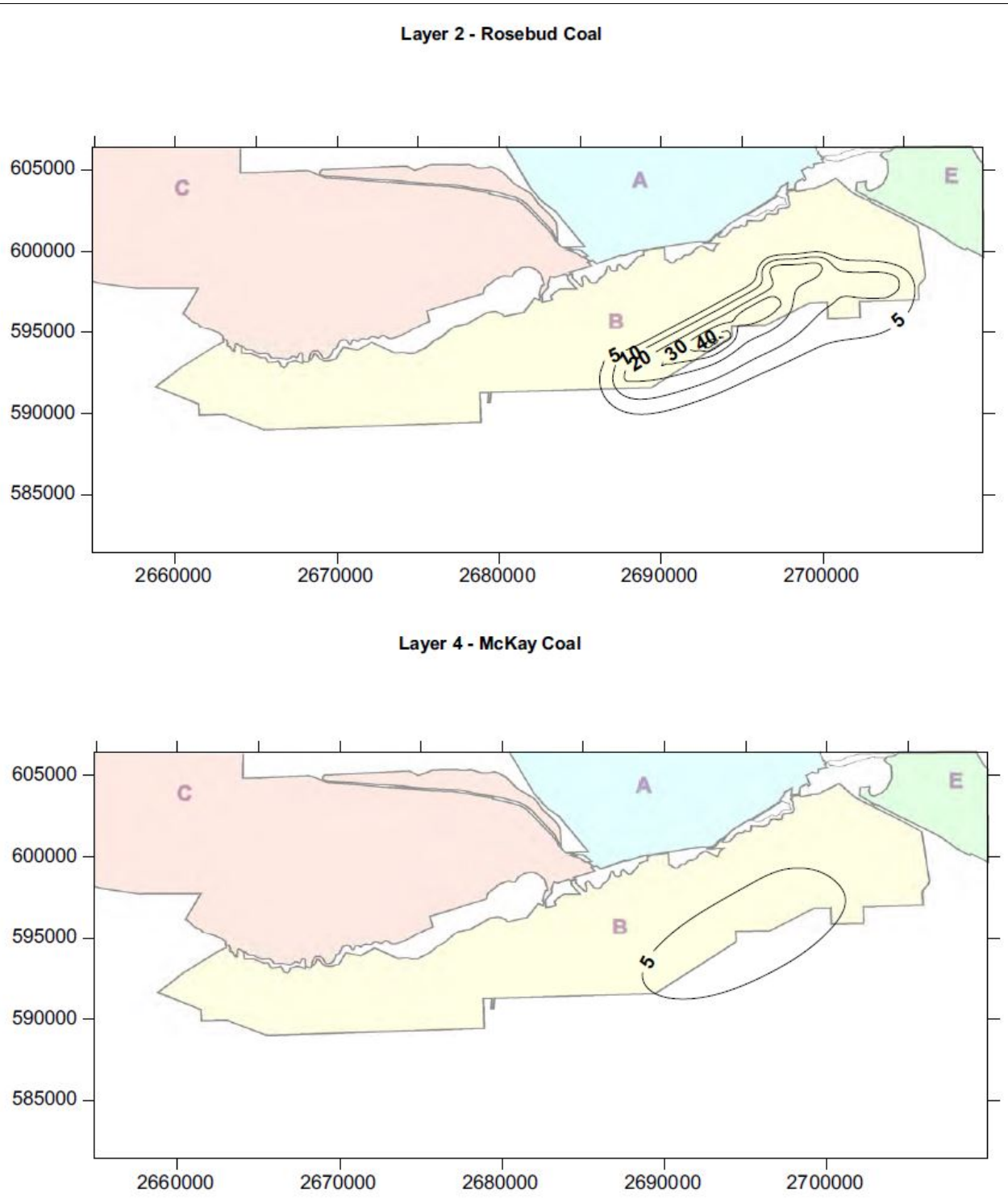


Figure 9-84: Additional drawdown predicted in 2026 in Rosebud coal and McKay coal from mining in AM4 compared to predicted drawdown in 2026 from currently approved mining.
Geographic coordinates in NAD 83 feet. (After Nicklin, 2014).

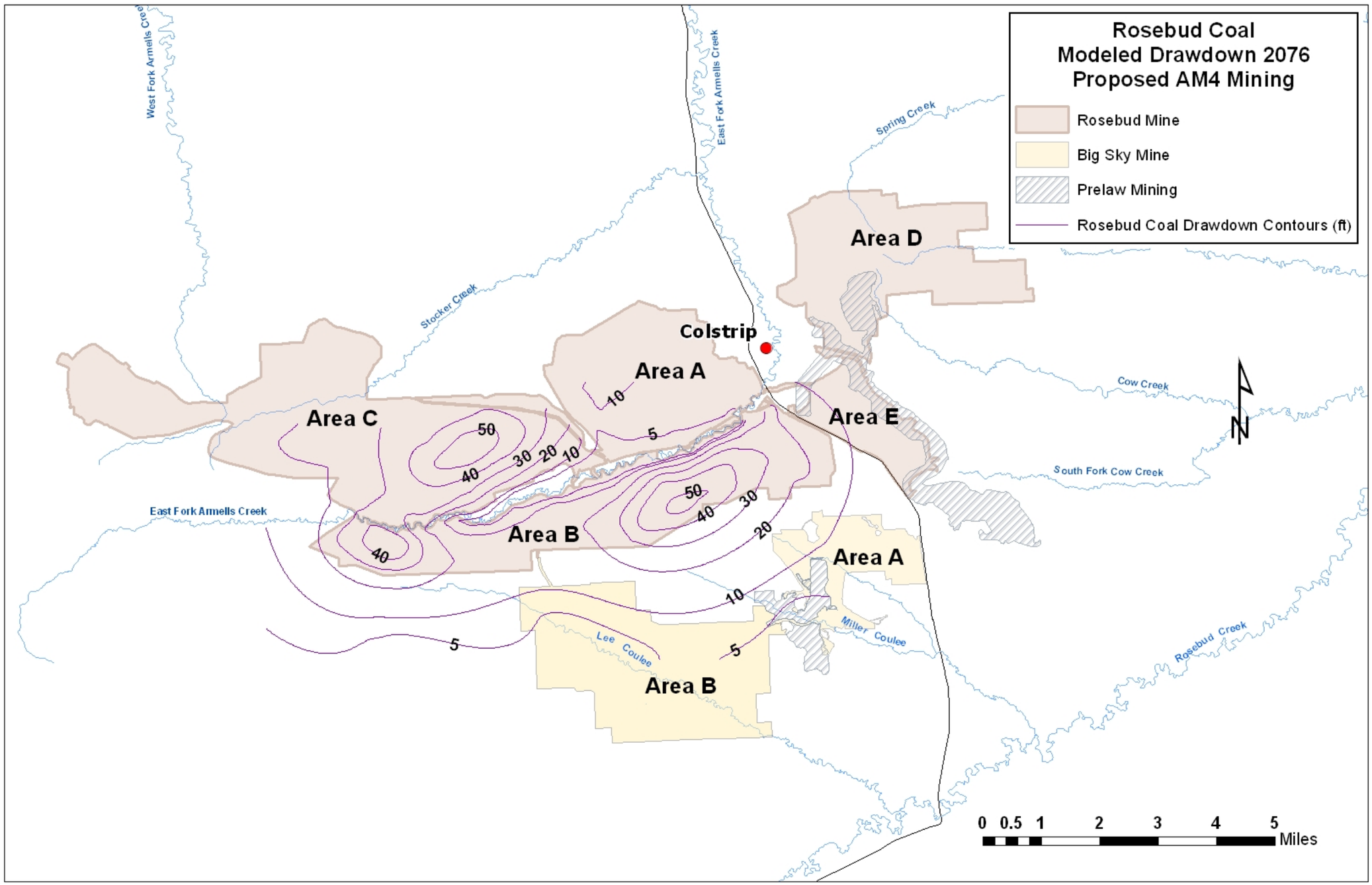


Figure 9-85: Modeled drawdown in Rosebud coal in permit areas A, B, and C of the Rosebud Mine with the addition of mining proposed in AM4.
Drawdown represents conditions in 2076, 50 years after end of mining.

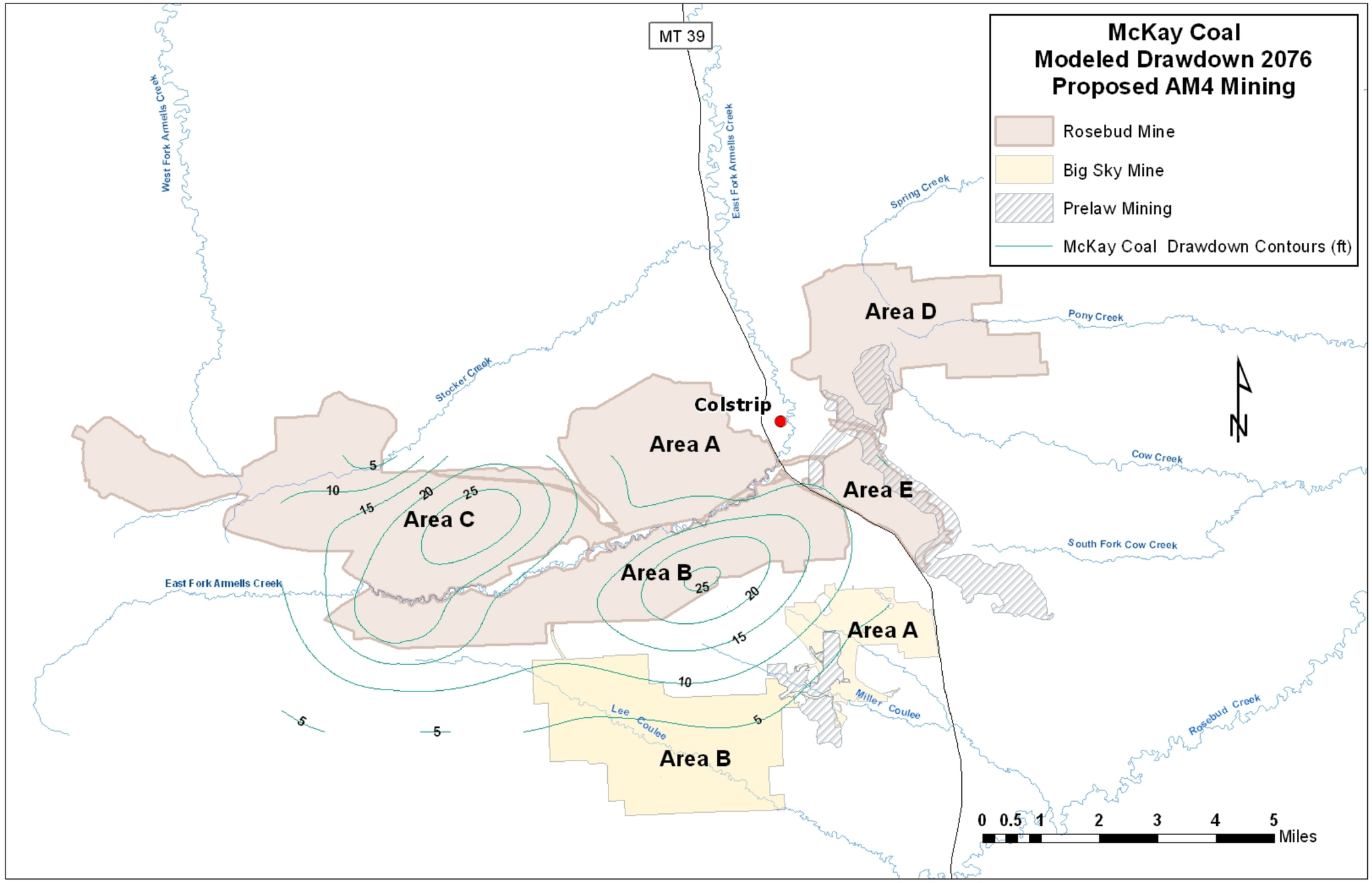


Figure 9-86: Modeled drawdown in McKay coal in permit areas A, B, and C of the Rosebud Mine with the addition of mining proposed in AM4.
Drawdown represents conditions in 2076, 50 years after end of mining.

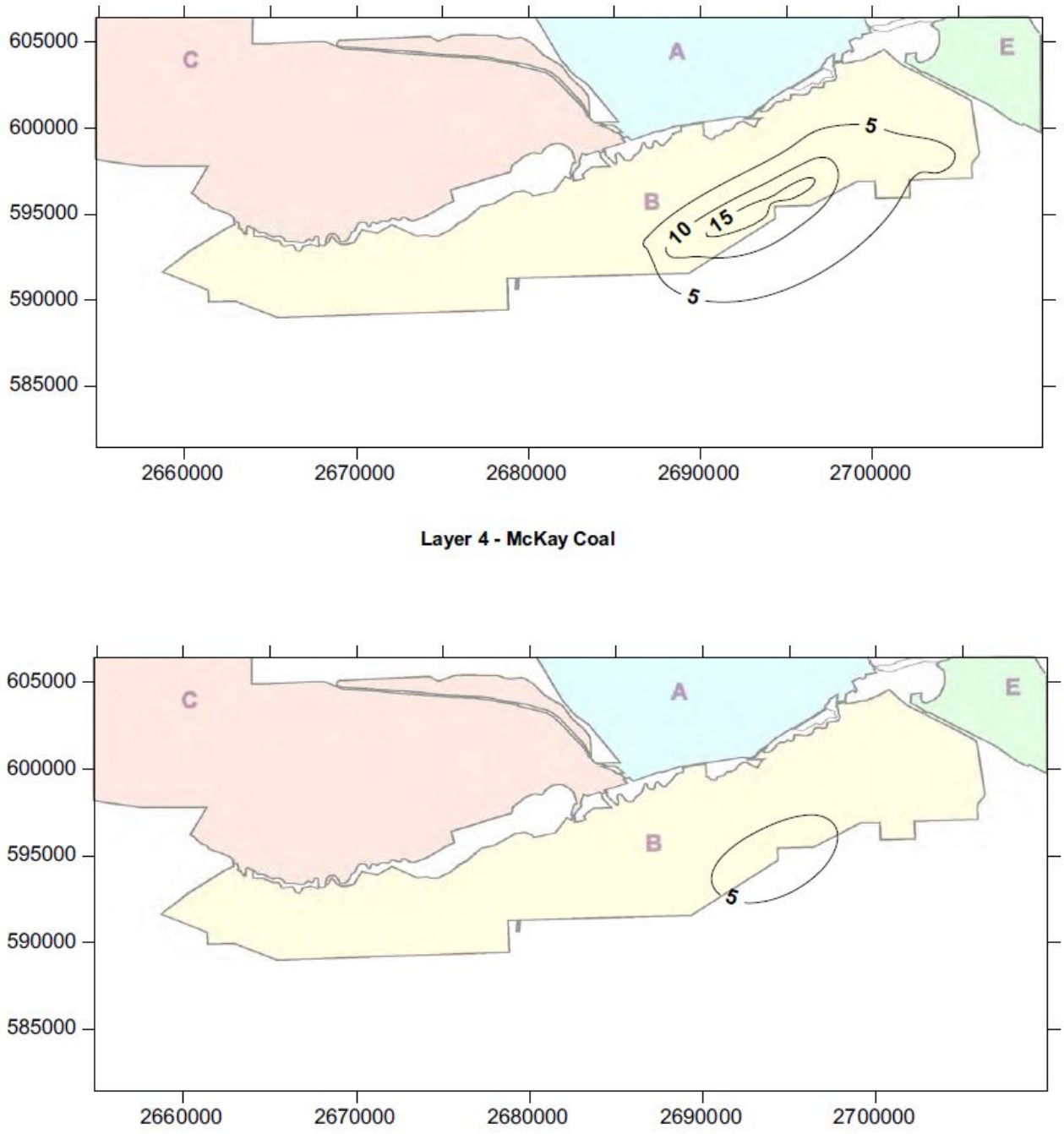


Figure 9-87: Additional drawdown predicted in 2076 in Rosebud coal and McKay coal from mining in AM4 compared to predicted drawdown in 2076 from currently approved mining.
Geographic coordinates in NAD 83 feet. (After Nicklin, 2013).

Figure 9-88: Rosebud Mine Area D groundwater model.
Predicted potentiometric head and drawdown (feet) at end of mining in 2011 under Scenario 1. Layer 1 represents Rosebud Coal; Layer 2 represents interburden; Layer 3 represents McKay coal. (Nicklin, 1999).

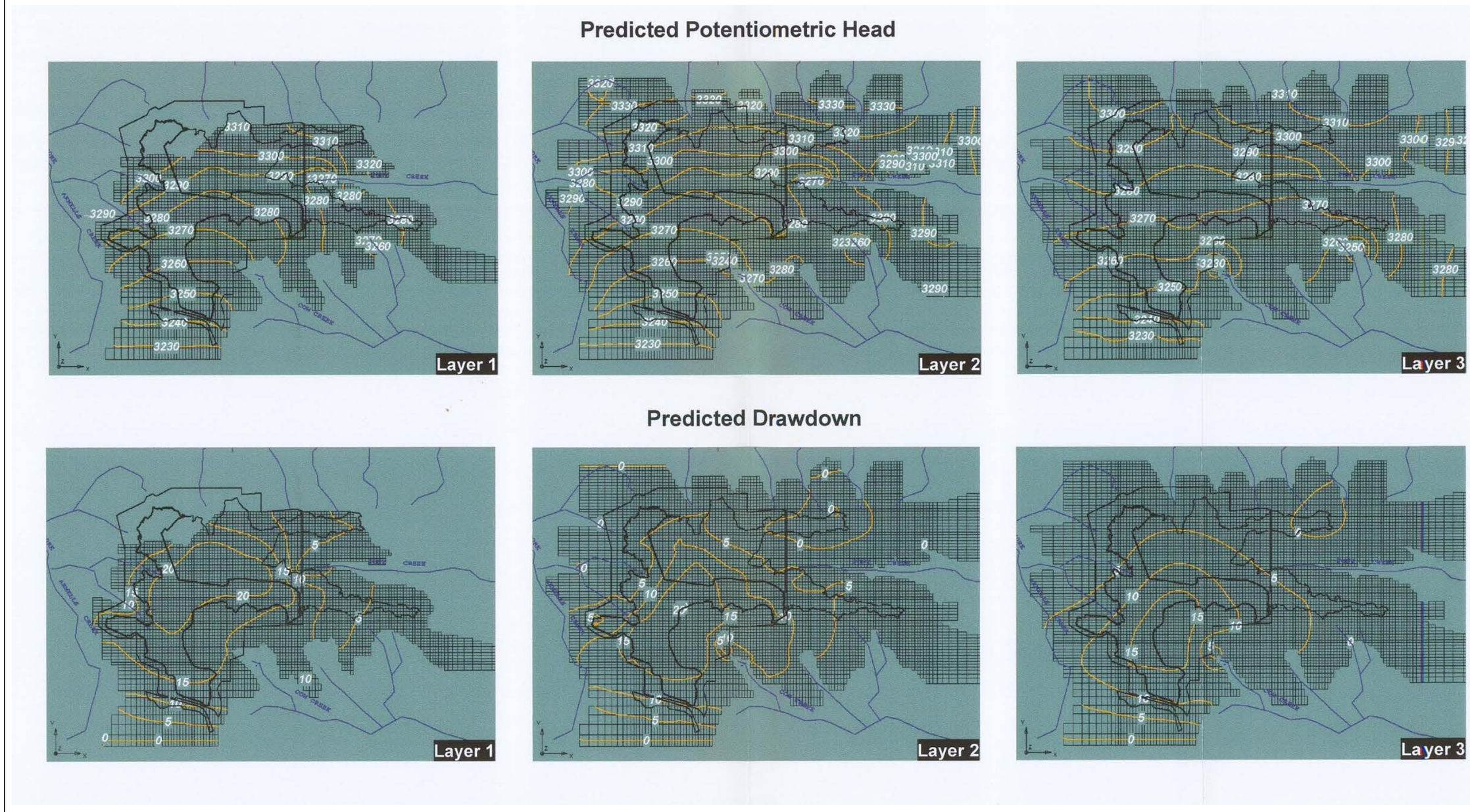
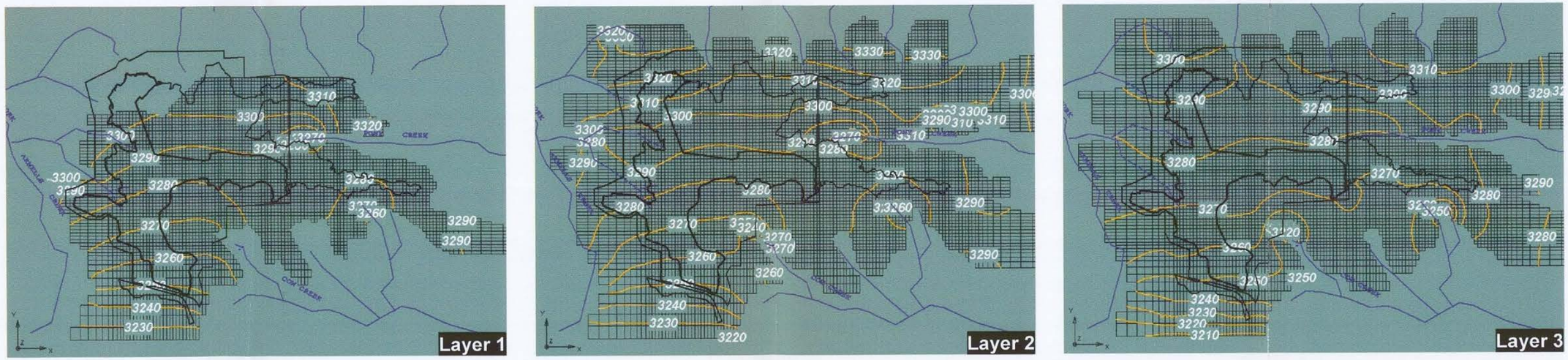


Figure 9-89: Rosebud Mine Area D groundwater model.
Predicted potentiometric head and drawdown (feet) at end of mining in 2011 under Scenario 2. Layer 1 represents Rosebud Coal; Layer 2 represents interburden; Layer 3 represents McKay coal. (Nicklin, 1999).

Figure 9-90: Rosebud Mine Area D groundwater model.
Predicted potentiometric head and drawdown (feet) 50 years after mining (2061) under Scenario 1. Layer 1 represents Rosebud Coal; Layer 2 represents interburden; Layer 3 represents McKay coal. (Nicklin, 1999).

Predicted Potentiometric Head



Predicted Drawdown

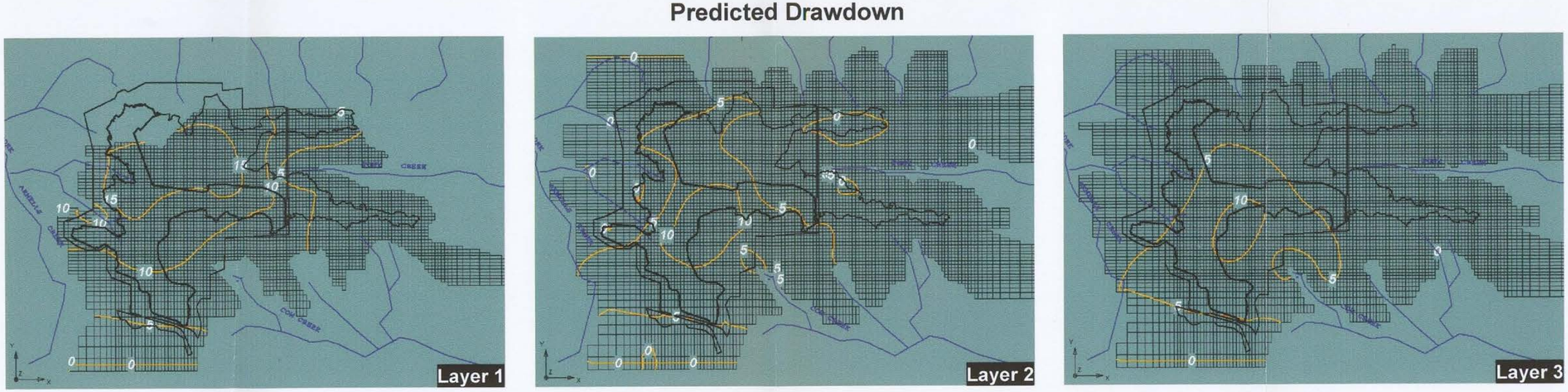
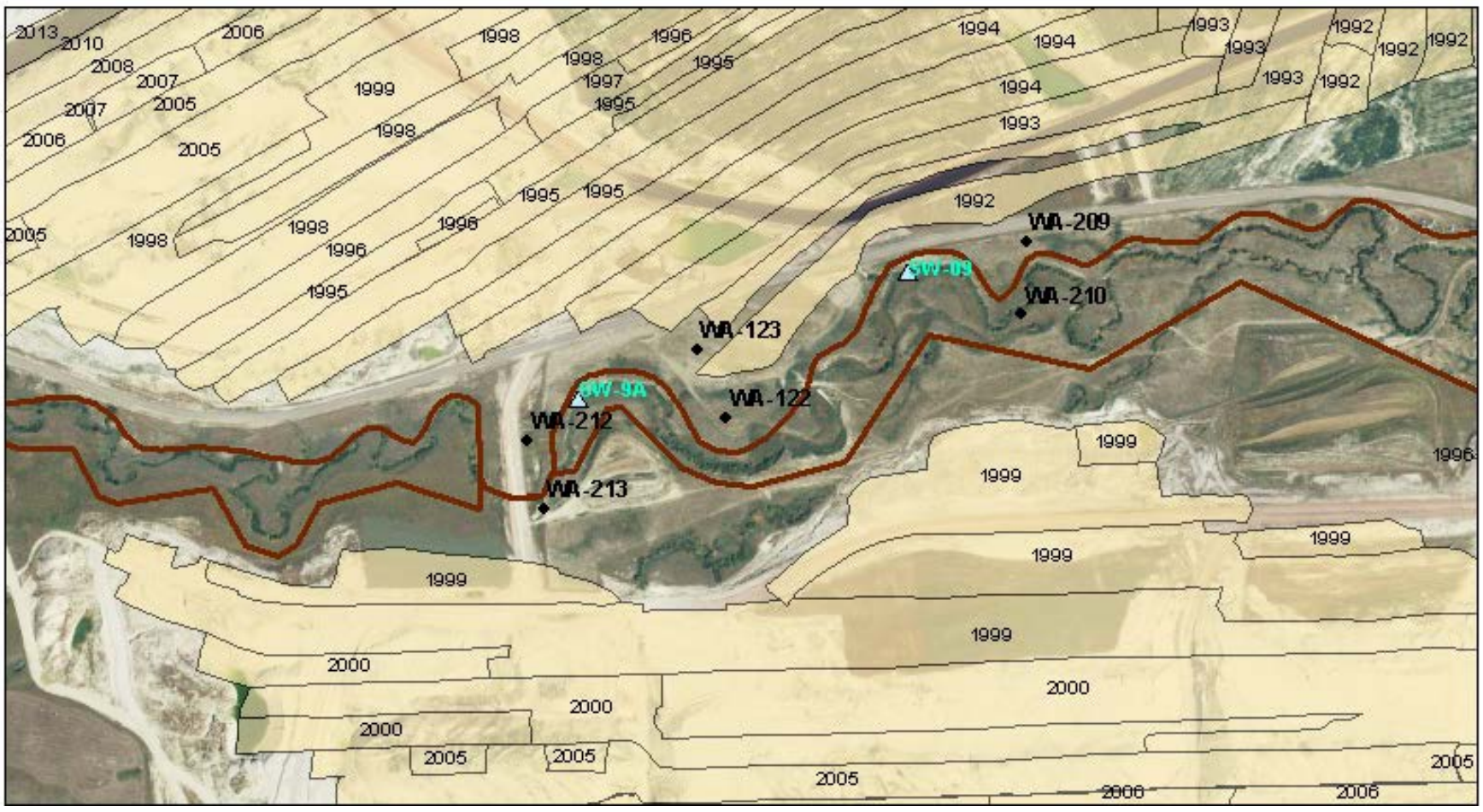
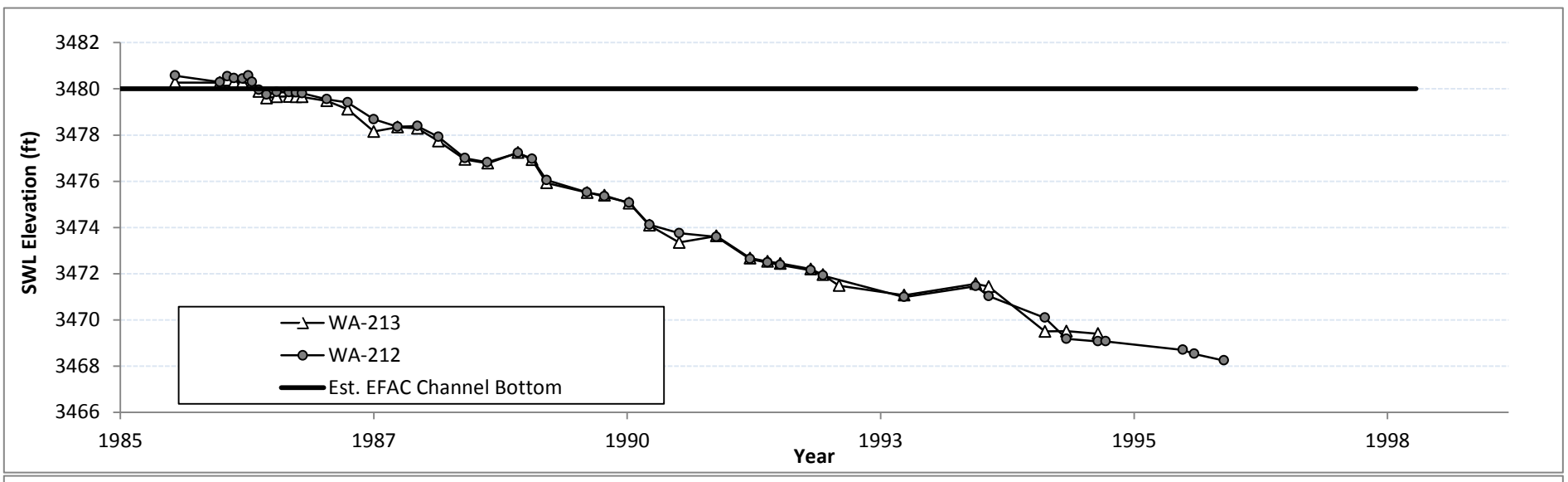
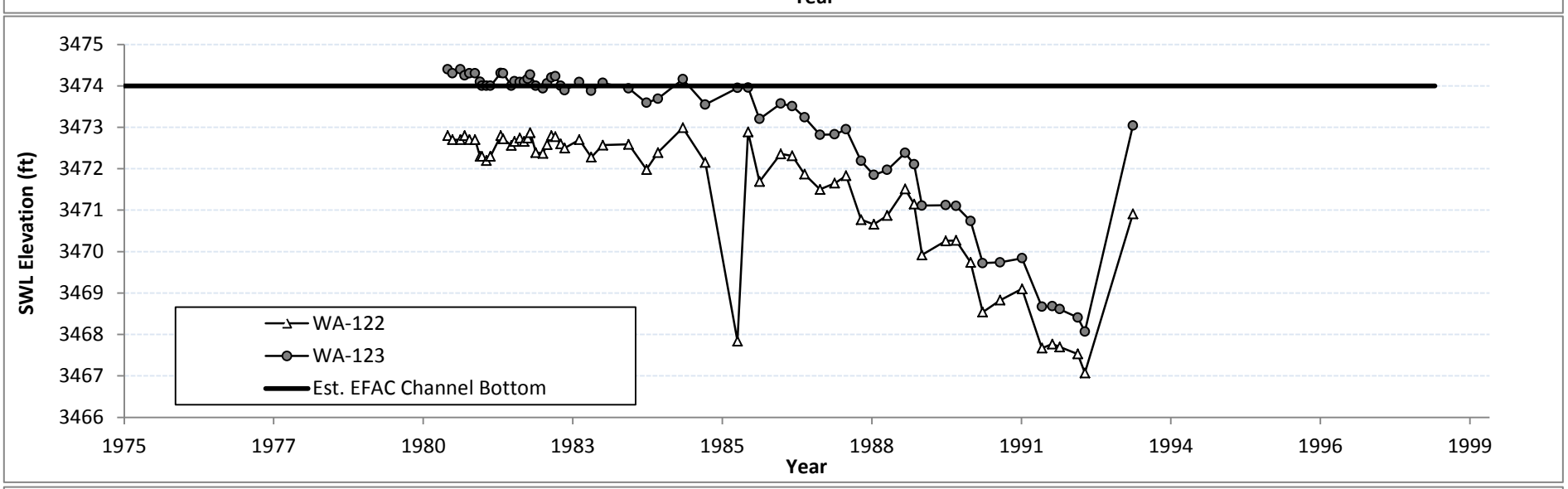


Figure 9-91: Rosebud Mine Area D groundwater model.
Predicted potentiometric head and drawdown (feet) 50 years after mining (2061) under Scenario 2. Layer 1 represents Rosebud Coal; Layer 2 represents interburden; Layer 3 represents McKay coal. (Nicklin, 1999).







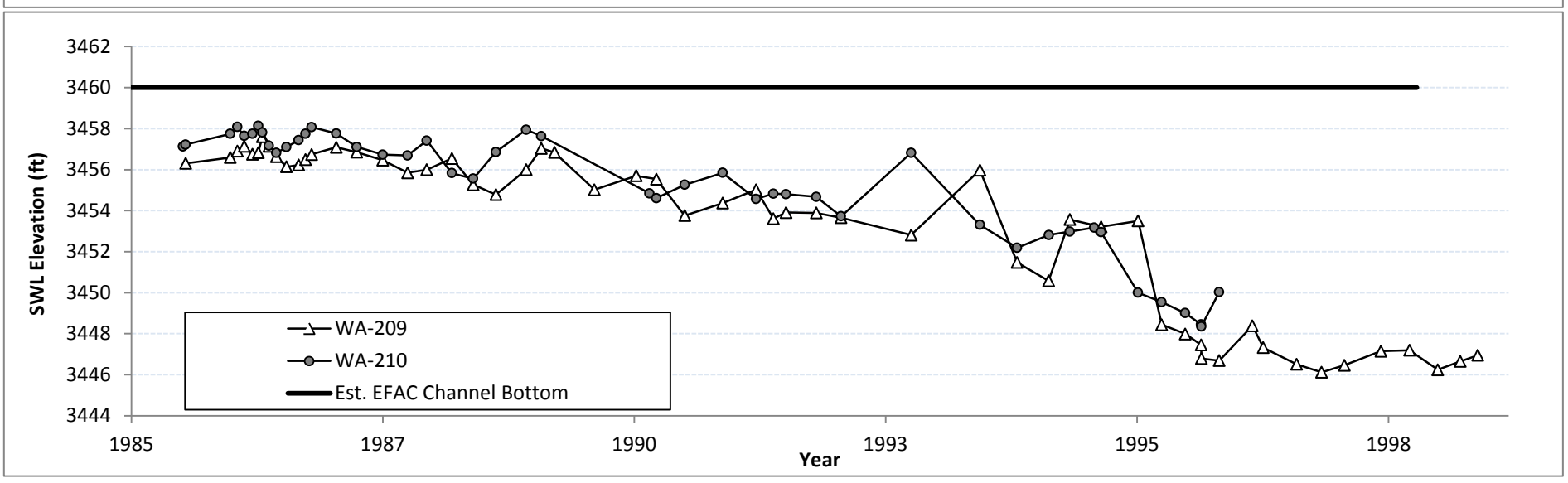
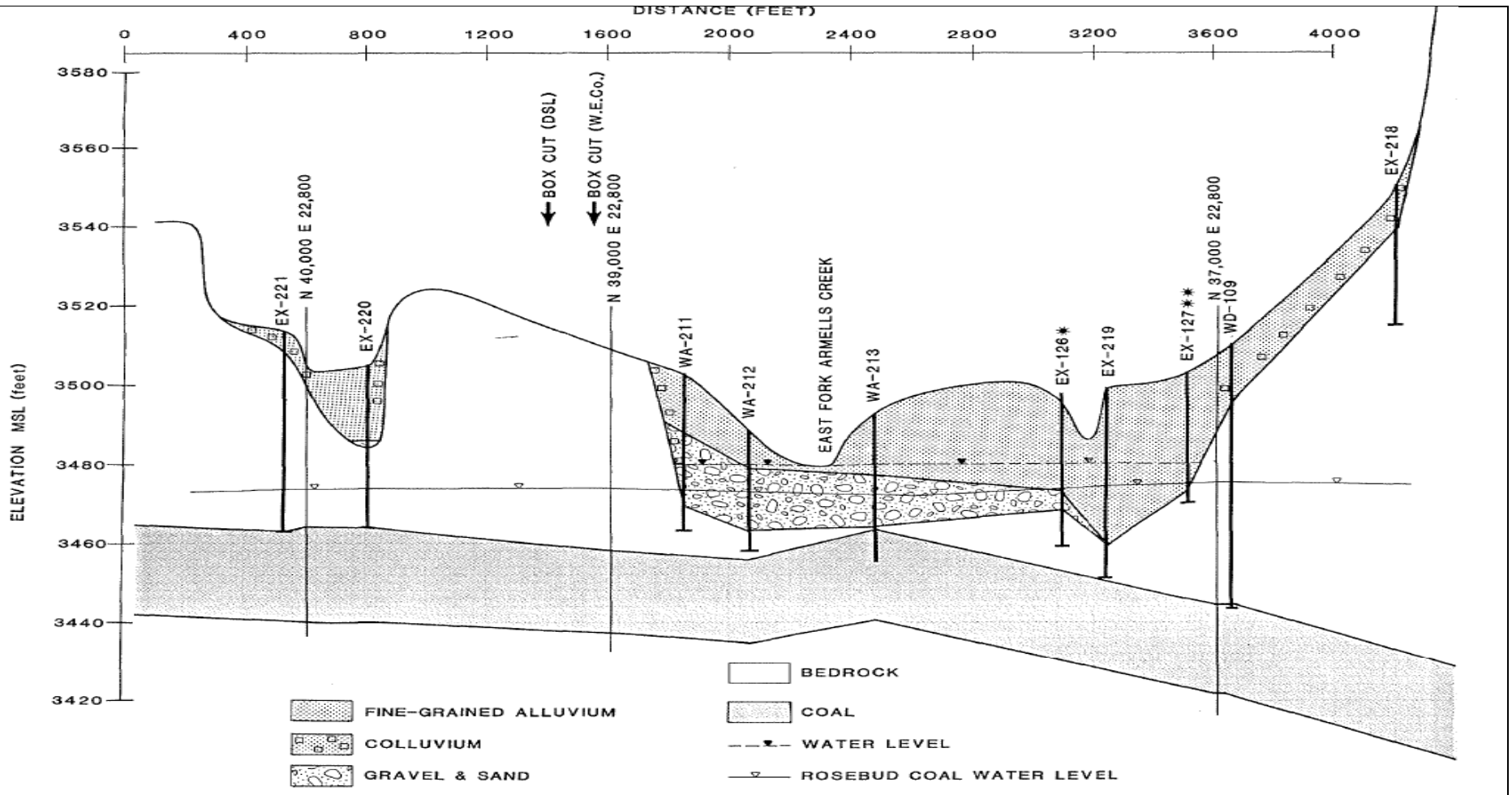
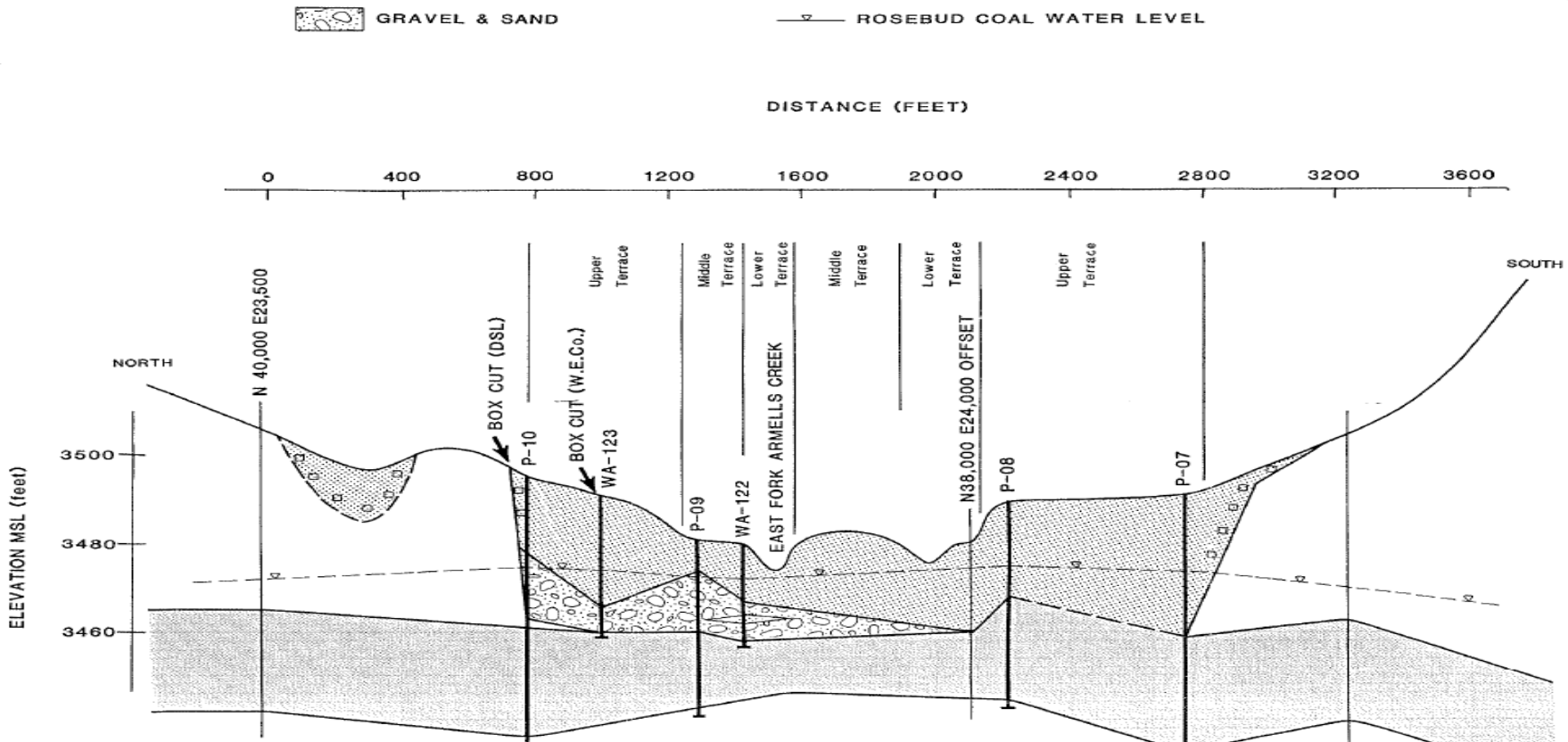


Figure 9-92: Water levels in alluvial wells within the Section 15 reach of EFAC.
The hydrographs show the estimated elevation of the channel bottom taken from the geologic cross sections also shown in this figure. These cross-sections are provided as Appendix F in the Rosebud Mine's Area B permit. The channel bottom elevation is probably accurate to within 1 or 2 feet. Water quality samples were taken in 1973, 1977 – 1983, and 1985 at SW-09 and in 1979 – 1983 in SW-09A.





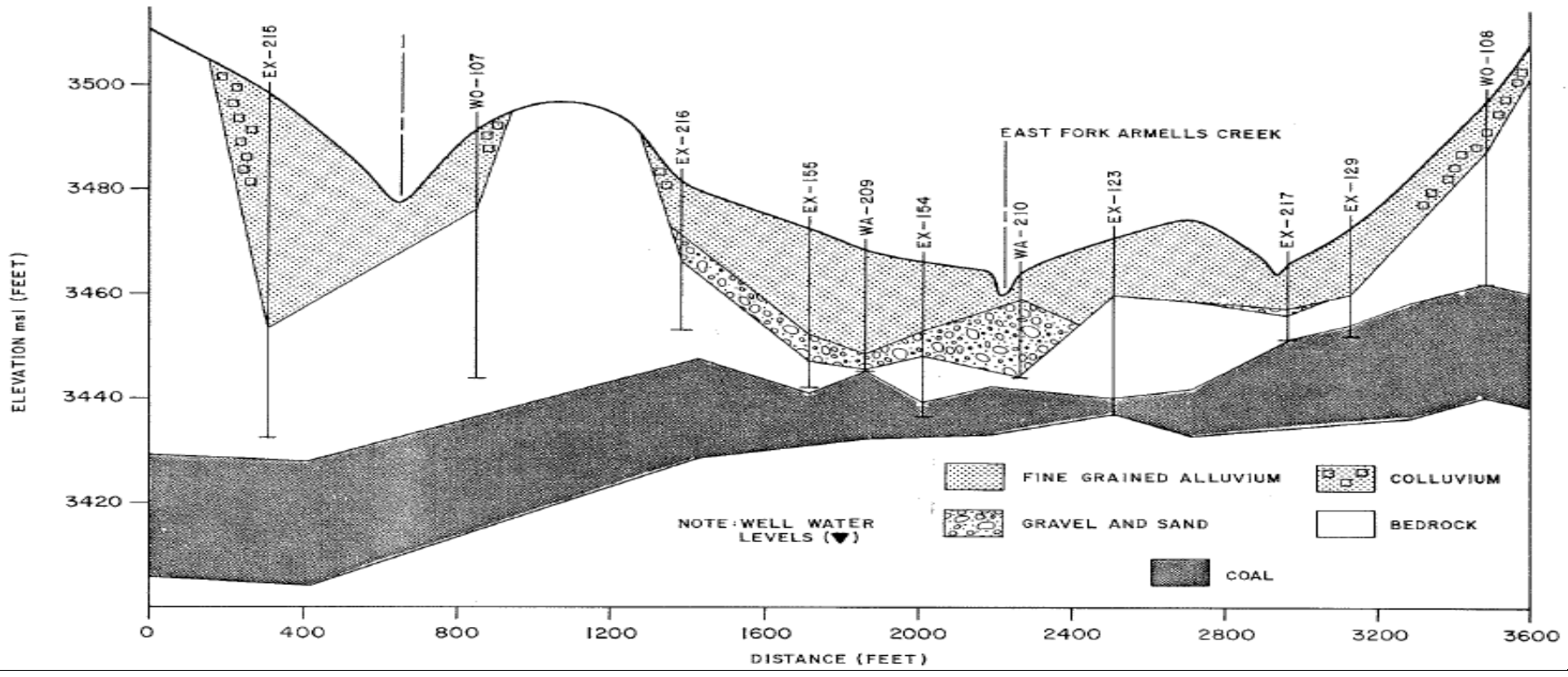


Figure 9-92 continued.

Exhibit 2

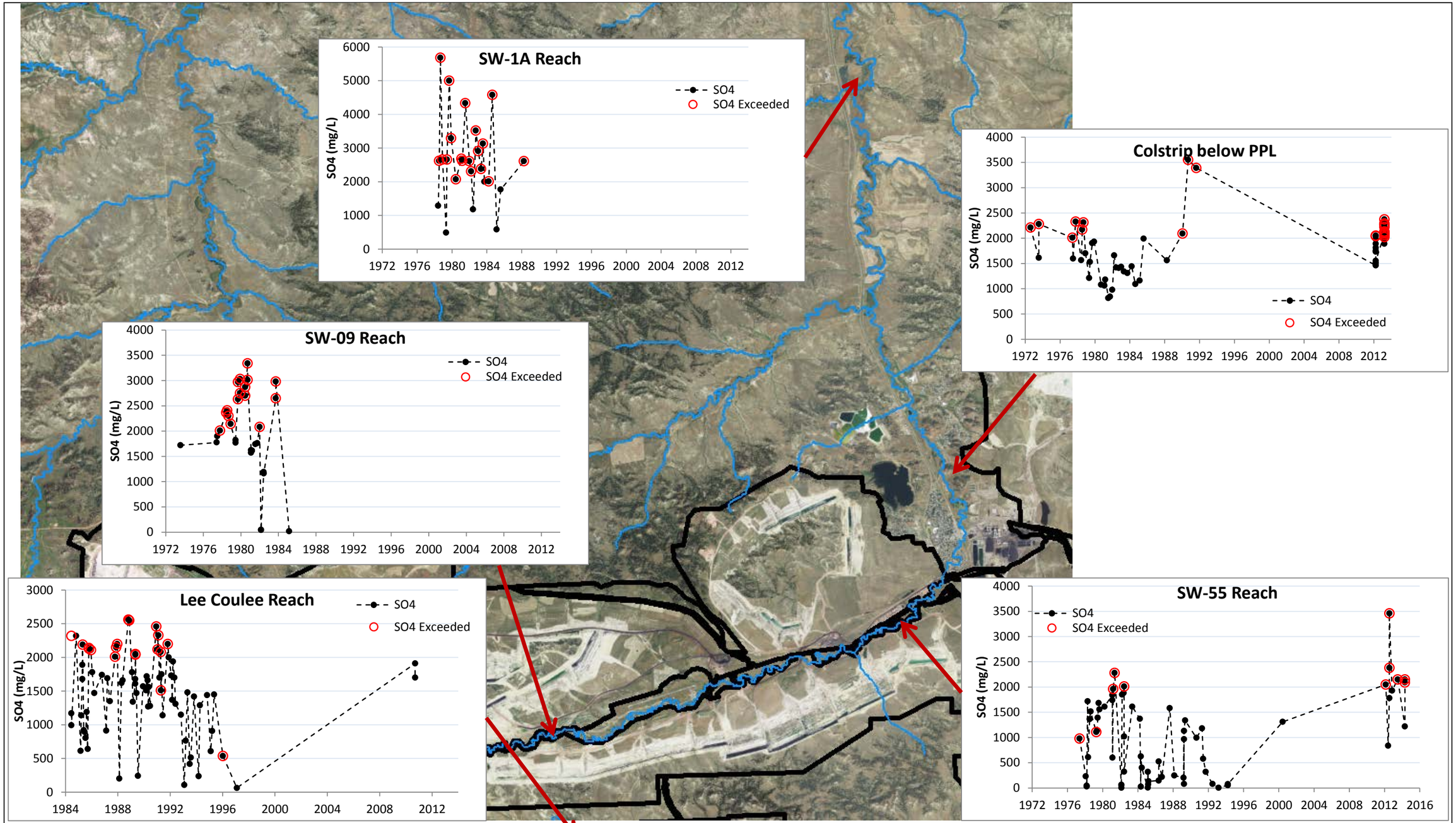


Figure 9-93: Sulfate at intermittent stream reaches along East Fork Armells Creek and Lee Coulee.

Note that the data is a mix of baseflow and runoff domminated events. Low sulfates are indicative of sampling during snow melt events while high sulfates are indicative of sampling during baseflow.

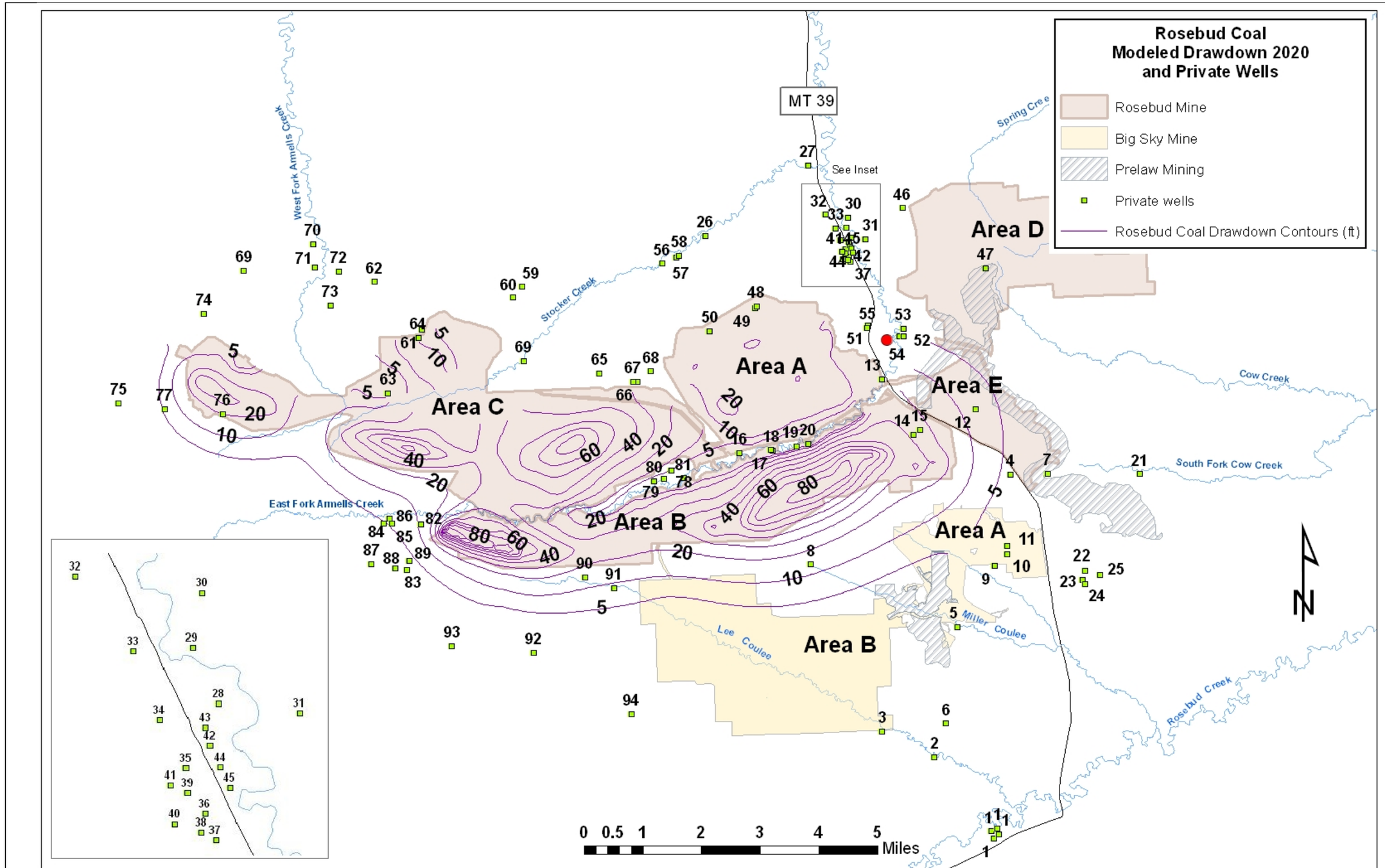


Figure 9-94: Location of private wells within modeled Rosebud Coal drawdown in 2020 at the end of currently permitted mining.

Exhibit 2

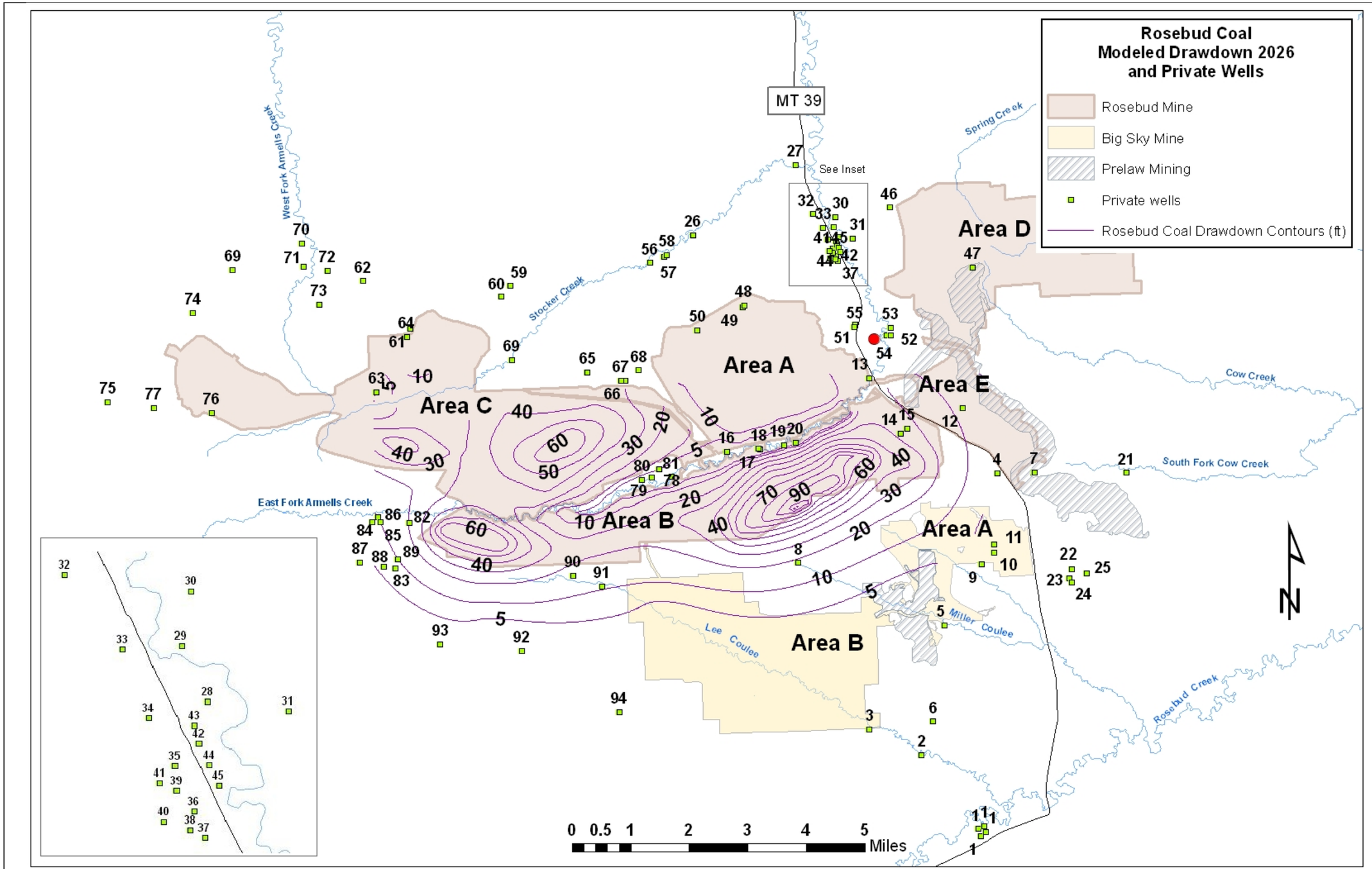


Figure 9-95: Location of private wells within modeled Rosebud Coal drawdown in 2026 at the end of mining in AM4.

Exhibit 2

WRITTEN FINDINGS

Prepared by:

Montana Department of Environmental Quality
Industrial and Energy Minerals Bureau
Coal and Uranium Program

for

AM4 Additional 49 Acres
Western Energy Company, Rosebud Coal Mine Area B

Western Energy Company
Permit No. C1984003B

Rosebud County, Montana

December 4, 2015

Exhibit 1

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ATTACHMENT 2: PRIVATE PROPERTY TAKINGS ASSESSMENT
ATTACHMENT 3: WESTERN ENERGY COMPANY RESPONSE TO OBJECTIONS TO DEQ'S ACCEPTABILITY DETERMINATION FOR ROSEBUD AREA B EXPANSION

INTRODUCTION

1. Western Energy Company's (Western's) Rosebud Mine Area B was originally permitted on January 18, 1978. A total of three amendments to the original permit area have been previously approved. Additionally, the permit area has been adjusted with a couple of incidental boundary changes (surface disturbance only – no additional mining). The amendment area does not include any new federal surface or coal that was not in the existing federal mine plan (Permit Number MT-0002, 12/80).

2. Western applied to the Montana Department of Environmental Quality (DEQ) for the fourth amendment to Area B of the Rosebud Mine (AM4) surface mining permit (the permit) on June 15, 2009. The application was ruled complete on August 7, 2009. After eight rounds of acceptability deficiencies the application was ruled acceptable on July 8, 2015.

3. AM4 proposes the following changes to the permit: a 49 acre increase in the area permitted; a 146 acre increase in the proposed amount of surface disturbance limit (5,531 to 5,677); 8.6% increase in the minable coal reserve (approximately 12.1 million tons); 306 more acres of coal removal or 8.3% increase in the amount of coal aquifer disturbed (3,686 to 3,992); re-calculation of the performance bond to account for current practices and future conditions (increase from $48,403,696 to $73,650,000); and, changes to the postmine topography (PMT). The additional proposed disturbance and mining will be a continuation of existing operations to the south and east.

4. Mining and reclamation operation under AM4 will not deviate substantially from what was previously approved. As coal is removed, the operator will proceed with reclamation according to the requirements of the Reclamation Plan, as described in Section 17.24.313 of the currently approved permit. Topsoil will be removed prior to mining and either direct-hauled to areas graded to the approved PMT or stockpiled. Soil stockpiles will be marked with an identification sign and stockpiles will be protected from erosion. Currently approved permit maps depicting vegetation plans will need to be reviewed and updated as a general course of permit renewal, mid-permit review or an additional minor revision to the permit. Regardless of future permit revisions, the vegetation plan will be monitored over time and adjusted as necessary to achieve successful establishment of plant communities which will support the approved postmine land use.

5. These written findings and permit decision are based on information provided by Western (Amendment application AM4 and existing permit C1984003B), the Checklist Environmental Assessment completed by DEQ dated July 2015 and updated December 2015, and the Cumulative Hydrologic Impact Assessment (CHIA) completed by DEQ dated December 2015.

Exhibit 1

6. Table I - Introductory Table

Applicant	Western Energy Company
Name of Mine	Rosebud Coal Mine Area B
MSHA Number	24-01747
Type of Mine	Strip
Type of Application	Amendment
Area within existing permit boundary (acres)	6,182
Proposed Increase in Permit Area (Acres)	49
Total proposed permit area (acres)	6,231
Anticipated Annual Production	4 million tons

FINDINGS

7. Permit and Review Chronology

December 8, 1980	Surface Mine Permit C1984003B is issued.
June 11, 2009	Various permitting actions December 1980 to June 2009.
June 15, 2009	Application 00184 (AM4), Area B Permit Amendment is submitted to DEQ by Western Energy.
June 25, 2009	Western submits the revised Application Form for the Area B Permit Amendment.
August 7, 2009	DEQ determines that Application #00184 (AM4) is complete and that an environmental impact statement is not necessary.
August 21, 2009	DEQ sends out the notice of application.
September 22, 2009	DEC received the affidavit of publication from Western. The public notice was published on August 27, September 3rd, 10th and 17th, 2009.
December 22, 2009	DEQ sends first round technical comments to Western.
March 18, 2010	DEQ receives Western's response to the first round technical comments for Application 00184 (AM4).
June 1, 2010	DEQ sends the second round deficiency letter to Western.
July 16, 2010	DEQ receives the Area B-East; Hydrological Control Plan and

Exhibit 1

	Associated Ponds.
November 15, 2010	DEQ receives Western's second round deficiency response.
December 8, 2010	DEQ completes a search of the Applicant/Violator System.
January 6, 2011	DEQ requests the CAD versions of the revised exhibits from Western.
January 25, 2011	DEQ receives the CAD for the revised exhibits.
March 14, 2011	DEQ sent Western a third round deficiency letter for Application 00184 (AM4)
January 19, 2012	DEQ receives Western's third round technical deficiency response.
February 29, 2012	DEQ sends Western comments for the Area B PHC via e-mail.
April 4, 2012	DEQ sent Western a request to update the PHC for Rosebud Coal Mine Area B as it had been several years since it was completed.
April 27, 2012	DEQ received information from Western in response to a data request for the amendment.
May 16, 2012	DEQ sent Western a fourth round deficiency letter for Application 00184 (AM4)
March 25, 2013	DEQ received Western's fourth round deficiency response.
April 30, 2013	DEQ sent Western a digital data request to assist in completing the CHIA for amendment.
May 3, 2013	DEQ sent Western a letter detailing a phone conversation describing the requirements of a comprehensive PHC including Areas A, B, and C.
June 13, 2013	DEQ receives the data requested in April 30, 2013 request from Western.
June 16, 2013	DEQ receives the updated PHC from Western.
July 23, 2013	DEQ sent Western a fifth round acceptability deficiency.
November 1, 2013	DEQ receives Western's response to the fifth round

	acceptability deficiency.
January 15, 2014	DEQ sent Western a sixth round acceptability deficiency.
February 3, 2014	DEQ receives Western's response to the sixth round acceptability deficiency.
February 24, 2014	DEQ receives Table 15A for the Area ABC PHC from Western.
June 3, 2014	DEQ sent Western a seventh round acceptability deficiency.
February 2, 2015	DEQ received a response to the seventh round acceptability deficiency.
March 5, 2015	DEQ sent Western an eighth round acceptability deficiency.
March 10, 2015	DEQ received Western's response to the eighth round acceptability deficiency.
May 11, 2015	DEQ received a copy of the Modification of Area B Resource Recovery and Protection Plan (R2P2) for Logical Mining Unit MTM 83589 containing Federal Coal Leases MTM35734, MTM54711 and MTM073109.
June 10, 2015	DEQ received an updated acreage table from Western associated with the Area B permit.
July 8, 2015	DEQ sent Western an acceptability determination letter with a request to verify the acreage for the amendment.
July 8, 2015	DEQ received the acreage table as request in the acceptability determination letter.
July 8, 2015	DEQ sent a Notice of Acceptability to the interested parties as well as having it published in the Billings Gazette which was published on July 17, 2015.
July 8, 2015	DEQ completes and makes available to the public a DRAFT Checklist Environmental Assessment for AM4.
July 22, 2015	DEQ receives a public records request from Western Environmental Law Center
August 3, 2015	DEQ receives public comment from Western Environmental Law Center.

August 24, 2015	DEQ's decision due date is missed due to review of legal counsel requesting changes to the format of the Cumulative Hydrologic Impact Assessment (CHIA).

8. DEQ found that the Rosebud Area B Amendment original application, submitted on June 12, 2009, and revised through March 10, 2015, is complete and accurate, and the applicant has complied with Montana's permanent regulatory program. *See* Administrative Rule of Montana (ARM) 17.24.406(a).

9. The applicant has demonstrated that reclamation, as required by the Montana Strip and Underground Mine Reclamation Act and regulations, can be accomplished under the proposed reclamation plan (*see* ARM) 17.24.406(a).

10. The AM4 amendment area is not located:

a) within an area under study or administrative proceedings under a petition to be designated as unsuitable for strip or underground coal mining operations. *See* (82-4-227(9), MCA;
b) within an area designated unsuitable for strip or underground coal mining operations pursuant to 82-4-227(9), MCA;
c) on any lands within the boundaries of units of the national park system, the national wildlife refuge system, the national wilderness preservation system, the national system of trails, the wild and scenic rivers system, including study rivers designated under section 5(a) of the Wild and Scenic Rivers Act or study rivers or study river corridors established in any guidelines issued under that act, or national recreation areas designated by an act of congress, or on any federal lands within national forests, subject to the exceptions and limitations of 30 CFR 761.11(b) and the procedures of 30 CFR 761.13 (*see*, 82-4-227(13));
d) on any lands upon which mining would adversely impact any publicly owned park or place included in the National Register of Historic Places (*see* ARM 17.24.1131);
e) where the operation will constitute a hazard to a dwelling, public building, school, church, cemetery, commercial or institutional building, public road, stream, lake, or other public property (*see* 82-4-227(7), MCA) except as conditioned below;
f) within 300 feet of any occupied dwelling (*see* 82-4-227(7)(a), MCA);.
g) within 300 feet of any public building, church, school, community or institutional building, or public park ((*see* 82-4-227(7)(b), MCA);
h) within 100 feet of a cemetery (*see* 82-4-227(7)(c), MCA); or
i) within 100 feet of the outside right-of-way line of a public road (*see* 82-4-227(7)(d), MCA).

11. Western has obtained all surface and mineral rights to conduct mining and reclamation operations authorized under AM4.

12. DEQ has made an assessment of the cumulative hydrologic impacts of all anticipated coal mining on the hydrologic balance within the cumulative impact area. See Attachment 1 which is incorporated into these findings by reference. In that

assessment, DEQ has determined that this amendment will not result in material damage to the hydrologic balance outside the permit area.

13. Western has paid all reclamation fees from previous and existing operations as required by 30 CFR Chapter VII, Subchapter R, as verified through the Applicant Violator System (AVS check of 11/25/15).

14. The proposed amendment is not likely to jeopardize the continued existence of threatened or endangered species or result in the destruction or adverse modification of their critical habitats, as determined under the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.) (*see* ARM 17.24.751)(*see* letter of 11/13/01 from USFWS).

15. Western has obtained all required air quality and water quality permits (*see* 82-4-231(2), MCA).

16. There are no pending MSUMRA violations for Western at the Rosebud Coal Mine Area B. No other strip- or underground-coal-mining operation that is owned or controlled by the applicant or by any person who owns or controls the applicant is currently in violation of Public Law 95-87, as amended, any state law required by Public Law 95-87, as amended, or any law, rule, or regulation of the United States or of any department or agency in the United States pertaining to air or water environmental protection, the department may not issue a strip- or underground-coal-mining permit or amendment, other than an incidental boundary revision, until the applicant submits proof that the violation has been corrected or is in the process of being corrected to the satisfaction of the administering agency (82-4-227(11), MCA) (AVS check of 11/25/15).

17. Records of DEQ and OSMRE show that the applicant does not own or control any strip- or underground-coal-mining operation that has demonstrated a pattern of willful violations of Public Law 95-87, as amended, or any state law required by Public Law 95-87, as amended, when the nature and duration of the violations and resulting irreparable damage to the environment indicate an intent not to comply with the provisions of the Montana Strip and Underground Mine Reclamation Act (82-4-227(12), MCA) (AVS check of 11/25/15).

18. Western is in compliance with all applicable federal and state cultural resource requirements, including ARM 17.24.318, 1131 and 1137, and as explained in the conditions listed below.

19. The current bond for the Rosebud Area B permit is $48,403,696. The bond was recalculated as part of the permit renewal application submitted on April 8, 2015. DEQ determined that a bond in the amount of $73,650,000 would be required for both the renewal and AM4 to account for current practices and future conditions. DEQ received adequate bond on December 3, 2015.

PRIVATE PROPERTY TAKINGS

23. The 1995 Montana state legislature passed House Bill (HB) 311, which requires a state agency to prepare an assessment of whether a proposed agency action will result in a taking of private property. DEQ prepared the assessment which concludes that the action approval of AM4 does not result in the taking of private property. The Private Property Takings Assessment is attached to these Written Findings as Attachment 4.

DECISION

20. Based on the information found in Western's Amendment Application 4 and these findings, DEQ hereby approves Amendment Application 04 as revised through March 10, 2015, and DEQ grants the amendment subject to the following conditions:

21. 17.24. 318, 1131[1]: Treatment of cultural resources within SMP C1984003B and the amendment area is covered by a MOA developed under the provisions of Section 106 of the National Historic Preservation Act and pursuant regulations (36 CFR 800). Treatment of all cultural resources, including incidental discoveries during the course of mining, must be handled according to the provisions of this MOA.

22. 17.24.304(1)(e); 17.24.417(1): The stream bottom of all named drainages must be surveyed in a manner acceptable to DEQ. The data must be submitted by the operator via a minor revision for incorporation into the permit by June 30, 2016.

23. 17.24.645(3); 17.24.646(1): Groundwater monitoring must be expanded in order to adequately determine the potential effects of mining to the hydrologic balance outside the permit area. Additional monitoring wells will be required to monitor potential down gradient movement of the affected water to ensure that it does not leave the permit boundary. Additional monitoring wells are also required inside the south permit boundary of Area B to monitor the quality of spoil water once the backfill becomes saturated and follows the natural flow direction to the southeast. This must be accomplished via a minor revision to the MQAP that is approvable by DEQ. The minor revision must be submitted to DEQ for review within 90 days of permit issuance.

24. 17.24.646(1) and (3): Surface water monitoring must be expanded at all streams downstream of mining in order to adequately determine the effects on mining on the hydrologic balance inside and outside the permit area. This must be accomplished via a minor revision to the MQAP that is approvable by DEQ. The minor revision must be submitted to DEQ for review within 90 days of permit issuance.

[1] The number preceding each permit condition is a reference to the provisions of the permit that is the subject of the condition.

257. 17.24.723(1) and (2): Macroinvertebrate monitoring on all intermittent reaches of all streams affected by mining must be performed on a schedule approved by the DEQ (every five years to be submitted with renewal). The proposed monitoring plan must be submitted to DEQ via a minor revision for incorporation into the wildlife monitoring plan.

RESPONSES TO PUBLIC COMMENTS

1. Western Energy is ineligible for a permit because of current violations of environmental laws at the Absaloka Mine.

DEQ Response: See AVS discussion at Written Finding nos. 16 and 17.

2. Western Energy is ineligible for a permit because of current violation of environmental laws at the Rosebud Mine.

DEQ Response: See AVS discussion at Written Finding nos. 16 and 17.

3. According to DEQ's 2014 Final Water Quality Integrated Report, the principal stream impacted by the strip-mining operation, East Fork Armells Creek, is currently not meeting water quality standards…DEQ has determined that the upper portion of the creek is not meeting water quality standards due to "alteration in stream-side or littoral vegetative covers," caused by "surface mining."

DEQ Response: DEQ's Waterbody Assessment Record for East Fork Armells Creek (MT42K002_170.pdf) was conducted in 2006, and no substantive updates have been conducted since this initial assessment. The Assessment Record identifies 'aquatic life' as an unsupported use, with the cause being 'alteration in stream-side or littoral vegetative covers' resultant from surface mining.

Regarding habitat impairments identified in the Assessment Record, the record states that:

a) Grazing is occurring throughout the reach with little impact. The riparian vegetation is mostly grasses and shrubs. Trees are generally missing, but are not required for sustainability.

b) Mining activity has, at a minimum, moderately impaired the habitat in this segment.

c) Because the habitat is impaired, aquatic life is partially supporting, despite the fact the stream is ephemeral.

The Assessment Record makes the claim that 'because the habitat is impaired, aquatic life is partially supporting'. In 2014, Western Energy Company, under the direction of the DEQ, conducted an aquatic survey with the objective of evaluating aquatic life support in upper

EFAC (waterbody segment MT42K002_170). The results of this survey show that the aquatic environments in upper EFAC support a diverse assemblage of aquatic insects, and consist of taxa commonly found in eastern Montana prairie streams. The recent aquatic survey provides empirical evidence that Aquatic Life support is not adversely impacted by mining activity.

4. DEQ has also determined that the lower portion of East Fork Armells Creek is not meeting water quality standards for Nitrate/Nitrite, nitrogen, specific conductance (SC), and total dissolved solids (TDS) and that the cause of these violations of water quality standards includes "coal mining."

DEQ Response: The lower portion of EFAC receives nitrogen-rich effluent from numerous sources including: runoff from the town of Colstrip, the water treatment plant, infiltration and runoff from the golf course (with fertilized and irrigated greens), agriculture, and grazing. The relative contribution from "surface mining" can be evaluated by examining water quality analyses from surface water and alluvial groundwater. Exceedances for nitrate-nitrite nitrogen are discussed in the CHIA (Attachment 1) in Section 9.2.4.4.4 and Section 9.2.6.10. Examination of the Table 9-7 and Table 9-8 in the CHIA (Attachment 1) indicates that the exceedance of nitrate-nitrite nitrogen is uncommon.

The sources listed above as contributors of nitrate-nitrite nitrogen along with leaking power plant ponds, also contribute to SC and TDS in the downstream section of EFAC. Water quality samples taken from EFAC surface and alluvial groundwater below the Highway 39 bridge and the town of Colstrip typically report much higher SC and TDS concentration (as well as nitrate-nitrite) than samples taken upstream of the bridge. Please refer to water quality data in the comprehensive Rosebud Mine database that was previously requested by and submitted to MEIC. The Colstrip power plant also has sampled EFAC south of the Highway 39 bridge and has regularly submitted stream water quality data to the DEQ that is available to the public for review and compare with data from the mine.

5. Indeed, WECo acknowledges that an upper section of the creek in Section 15 was intermittent in 1986 and that recent surveys indicate that it is now dry.[4] "Given the decreased water levels in alluvial wells between Areas B and C, it is possible that the change in flow is a result of mine related dewatering."[5]

DEQ Response: It is unknown whether there was baseflow in the stream section in question, and the premine quantity of water is also unknown. Statements as to the nature of this section premine are anecdotal. Since the nature of this section was not well documented in the 1970's, material damage to this section cannot be determined. While macroinvertebrates were documented using the water in Section 15 in the 1970s, it is unknown if water was present every year or only after wet years when runoff accumulated behind the instream dam, or only after years where the alluvium was saturated to the point of baseflow. Without knowing the true nature of the stream flow and the interaction between groundwater and surface water, a determination of material damage cannot be

made. Refer to page 9-22, 23 of the CHIA (Attachment 1) for a full discussion of the section 15 reach of EFAC.

6. WECo is clearly responsible for all violations of water quality standards in the upper reach of East Fork Armells Creek.

DEQ Response: Please refer to the response to Comment 1, above.

7. WECo also identifies ammonium-nitrate explosives from blasting as a contributor to elevated nitrate plus nitrite nitrogen levels in the East Fork Armells Creek alluvium.

DEQ Response: See the above discussion regarding nitrate-nitrite nitrogen; please refer to the CHIA (Attachment 1) in Section 9.2.6.4 and Section 9.2.8.9. Examination of the Table 9-7 and Table 9-8 in the CHIA (Attachment 1) indicates that the exceedance of nitrate-nitrite nitrogen is uncommon.

8. With respect to groundwater, the PHC recognizes that TDS levels in the spoils will be "two to three times that of the baseline coal groundwater."[10] WECo acknowledges that this will likely result in deterioration of groundwater quality within some areas of the mine backfill to a degree that will require at least temporary reclassification of the groundwater to a lower usage class."

DEQ Response: The comment is mistaken to the extent that it applies the material damage requirement to hydrologic consequences of mining within the permit area. Within the permit area, the Act requires the operator to minimize disturbance to the hydrologic balance. A reduction of water quality in the mining area is expected and is not grounds for denial of a mine permit application as long as reasonable conservation practices are being applied.

9. Further, neither the PHC nor DEQ's draft checklist EA addresses the best science about sulfate impacts to livestock. The PHC states that the sulfate standard for livestock is between 2500 and 3000 mg/L. However, the most recent science shows that sulfate concentrations as low as 1,000 mg/L are harmful to cattle:…

DEQ Response: There is a lack of consensus in the scientific and agricultural communities on the appropriate or acceptable concentrations for livestock drinking water quality. Desirable concentrations or limits on concentrations for livestock generally reflect the regional water quality in combination with feed and exposure, or lack of exposure, to trace elements during foraging. This is especially true for water quality constituents with narrative standards, such as sulfate. The document referenced by WELC as representing the "most recent science" [M.F. Raisbeck, et al. (2008)] has no greater scientific value than the other published water quality criteria for livestock. Indeed, some of the references listed in the document show that livestock growth appeared not to be significantly affected

at higher sulfate concentrations than ones proposed as harmful by the document and WELC.

10. The PHC demonstrates that the strip mine will cause and contribute to ongoing material damage to surface water…The PHC confirms that due to continued operation of the mine, TDS and nitrate/nitrite concentrations will increase in the alluvium of East Fork Armells Creek. PHC Addendum ("Once those water levels fully recover, it is estimated that the increase in TDS in the alluvium will be about 13 percent when compared to baseline conditions."); ("Nitrate plus nitrite nitrogen exceedances were found mostly in alluvium along the EFA and spoils wells…)"

DEQ Response: DEQ does not agree that there is ongoing material damage to surface water in EFAC or that the anticipated increase in TDS concentration in EFAC will create material damage. The standard for determination of material damage is deterioration of the quality or quantity of water outside the permit area to an extent that land uses or beneficial uses are adversely affected or water quality standards are violated. The predicted increase in TDS from mining does not anticipate violation of numeric standards or decline in water quality so that listed beneficial uses as defined by narrative standards are adversely affected. For the most sensitive use of EFAC water, aquatic life, there is no scientific evidence that the 13% increase in TDS will adversely affect macroinvertebrates in EFAC. DEQ will require the operator to monitor aquatic life to determine whether mining activity is materially detrimental to aquatic life in EFAC.

Also, an increase in TDS does not equate with an increase in nitrate-nitrite nitrogen. In their letter, WELC exaggerates the prevalence or extent of nitrate-nitrite nitrogen associated with mining. As discussed in Section 9.2.4.4.4 and Section 9.2.6.10 of the CHIA (Attachment 1), the occurrence of nitrate-nitrite nitrogen that can be clearly associated with mining is relatively rare.

11. Further, WECo's attempts to shirk its responsibility for increased TDS concentrations in alluvial waters are not believable. First, WECo inflates baseline TDS levels in East Fork Armells Creek to 2,299 mg/L.[20] However, the only samples that unquestionably predate mining at Colstrip, which were taken by the U.S. Geological Survey in 1923, had TDS concentrations of 845 and 688. Further, the last time that DEQ appears to have considered the cause of increased TDS concentrations on water quality in East Fork Armells Creek, the agency stated that the baseline average was 2,200 mg/L.

DEQ Response: With the exception of the easternmost part of Area A and Area B where mining was active in the early to mid-1970's, there are numerous monitoring sites with multiple sample analyses that represent premine, baseline conditions in EFAC alluvium. Two water quality samples from a system as dynamic as EFAC alluvium are not an adequate representation of premine baseline. The two samples that WELC refers to "that unquestionably predate mining" were not taken from alluvial water. WELC gleaned the data from MBMG Open-File Report 640 (hereinafter OFR 640), clearly titled Spring and

Stream Water Quality, Powder River Basin, Montana, which did not include alluvial samples. Further, if one examines the 1929 USGS source document (Water Supply Paper 600, hereinafter WSP 600) in which the samples listed in OFR 640 were originally reported, it becomes apparent that the sample location, source, and concentration reported for these samples in OFR 640 are not accurate. The PLSS in the OFR 640 for GWIC ID 201 places the sample more than a mile north of EFAC. WSP 600 indicates that this sample (USGS analysis 122) was collected from a 40 foot deep coal shaft and had a TDS of 1,102 mg/L (p. 138), not 845 mg/L. The sample identified as GWIC ID 309 (USGS analysis 123) was reported in WSP 600 as collected from a "water hole 6 feet deep" in EFAC and had a TDS of 962 mg/L (p. 138), not 688 mg/L.

Please be advised that a difference of 99 mg/L from two baseline averages determined by two different investigators using multiple water quality analyses from numerous wells is not significant and should not warrant concern regarding inconsistency or accuracy.

12. In addition to inflating baseline concentrations, WECo's suggestion that the measured increase in TDS upstream of Colstrip is due to "natural" factors is not credible.[23] First, the increase in alluvial TDS levels is not a recent development but has been documented since the 1990s.[24] DEQ attributed this increase in TDS to mining activity… The only citation that WECo offers for its theory that the increased TDS levels in the alluvium are "natural" is to an "email communication," with no additional explanation.[26]

DEQ Response: WELC refers to a DEQ document (letter to OSM, 1998) as evidence that the increase in TDS is due to mining. The author of the letter (D. Erbes) assumes the increase in TDS is the result of impoundment of surface flow in "upslope ponds". At of the date of these Written Findings, 17 years after the letter was written, subsequent data and more extensive and detailed investigation regarding increasing TDS leads to a different understanding of the source. This is described in detail in the PHC Addendum (Western Energy Company, 2015), a copy of which was obtained by MEIC in a recent information request.

13. The PHC, like DEQ's draft checklist EA, suffers from such generalized vagueness as to be devoid of any informational value to any save industry and agency insiders. For example, the PHC states that TDS concentrations will increase in spoils groundwater "during initial saturation and then decrease to an equilibrium level after one or more pore volumes of water pass through the backfill." There is no indication, however, about the length of time required for multiple "pore volumes" of water to pass through the backfill. … Regarding groundwater quantity, the PHC merely states that "full recovery" "will exceed 50 years in most portions that are mined" and that "[a]lthough it could take considerable time, there is no reason to expect that the regional groundwater flow gradient will not eventually recover because recharge and discharge areas for the principal aquifer will not be affected by mining."

DEQ Response: The comment addresses a lack of specificity in the time horizons for recovery of water quality and water levels that have undergone change due to coal mining. The simple answer is that the response of natural systems cannot be predicted with the exactness desired by WELC. A basic understanding of the hydrogeologic system, determined largely by field measurements, is used to anticipate the response to and recovery from disturbance to the system. Natural systems are dynamic, characterized by spaciotemporal variability and do not lend themselves to precision, especially when considering large areas and long time frames. Recovery of water levels and water quality will depend on the response of local hydrology, climate, chemical reactions, geology, all of which individually and in concert are unpredictable and play a part in the outcome. Awareness of this situation is reflected by statute and rules that require that the probable hydrologic consequences, rather than the exact hydrologic consequences, of mining be determined. Recovery of the hydrologic system will not be linear. Modeling the recovery of a system for the first 50 years gives a prediction of how the system will respond and may be used to extrapolate to a longer time frame, but given the limitations of the variables used in a model, especially for a large and complex area, estimates for time periods beyond fifty years become less reliable and less meaningful.

The DEQ endeavors to anticipate to the extent possible the impacts and outcomes of coal mining, and where more sensitive environmental settings are observed, increased examination is undertaken.

14. In addition to the unlawful vagueness and inconsistency with respect to the time horizons for impacts, the PHC is insufficient because it fails to address the impacts that climate change will have on the hydrologic balance.

DEQ Response: Specific weather changes in a localized area such as Colstrip that may occur over an undetermined period of time as a result of climate change are unknown, and cannot be realistically considered in the probable hydrologic consequences of mining.

15. DEQ's MEPA analysis is insufficient.

DEQ Response: For its response to this comment, DEQ incorporates by reference Environmental Assessment of Application AM4, December 3, 2015.

16. Approval of the proposed mine expansion violates the right to a clean and healthful environment.

DEQ Response: DEQ acknowledges that the Montana Constitution provides a right to clean and healthful environment. Among the inalienable rights declared in the Article II, Section 3 of Montana Constitution is the right to "a clean and healthful environment." The Legislature declared its intent that by enacting the Montana Strip and Underground Mine Reclamation Act ("MSUMRA") it was:

> [M]indful of its constitutional obligations under Article II, section 3, and Article IX of the Montana constitution, has enacted The Montana Strip and Underground Mine Reclamation Act. It is the legislature's intent that the requirements of this part provide adequate remedies for the protection of the environmental life support system from degradation and provide adequate remedies to prevent unreasonable depletion and degradation of natural resources.

Section 82-4-202 (1), MCA. Nevertheless, MSUMRA in pertinent part sets forth the standards and criteria for evaluating whether a proposed coal mine operation protects those constitutional rights. MSUMRA authorizes strip and underground coal mining operations within the state in accordance with its provisions and requirements. The Legislature has authorized DEQ to permit and regulate surface and underground coal mining operations in accordance with MSUMRA and other environmental laws applicable to coal mining operations. By issuing a permit that complies with the requirements of MSUMRA, the Department acts consistently with the declared intent of the Legislature to protect the right of Montanans to a clean and healthy environment.

No provision of MSUMRA authorizes the Department to deny an application to amend a coal mine operating permit based on potential impacts to climate change. To the extent that the comment questions whether MSUMRA in whole or in part is consistent the Montana Constitution or international law, DEQ as a state agency "must faithfully execute the laws of Montana" and questions touching on the constitutionality of MSUMRA lie within the exclusive jurisdiction of the Montana courts. *See Merlin Meyers Revocable Trust v. Yellowstone County*, 2002 MT 201, ¶ 21, 311 Mont. 194, 200, 53 P.3d 1268, 1272.

REFERENCES CITED

Environmental Assessment of Application AM4 (MDEQ, July 2015 updated August 2015)

Western Energy Company Rosebud Coal Mine Area B Surface Mining Permit (SMP C1984003B)

Exhibit 1

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BEFORE THE BOARD OF ENVIRONMENTAL REVIEW
OF THE STATE OF MONTANA

IN THE MATTER OF: **APPEAL AMENDMENT AM4,** **WESTERN ENERGY COMPANY,** **ROSEBUD STRIP MINE AREA B** **PERMIT NO. C198400B**	**CASE NO. BER 2016-03 SM** **AFFIDAVIT OF STEVE GILBERT IN SUPPORT OF PLAINTIFF'S MOTION FOR SUMMARY JUDGMENT**

I, Steve Gilbert, hereby state as follows:

1. My name is Steve Gilbert. I reside in Helena, Montana. I am a citizen of the United States and am over 18 years of age. I am a member of the Montana Environmental Information Center (MEIC).
2. I have been a Montana resident since 1967. For forty-one of these years I have worked as a biological consultant. For twenty-five years I was part-owner and president of an environmental consulting company that specialized in wildlife, aquatics/fisheries, soils, vegetation, forestry, range and hydrology. Separate from my business, I worked in Yellowstone Park on grizzly bears and studied cliff-nesting falcons in Glacier Park. I am an associate with the Montana Peregrine Institute, and have conducted neo-tropical bird and raptor surveys in Montana and other parts of the west nearly every year since 1971.
3. I am a strong environmental advocate and have served for a number of years on the boards of various conservation groups in Montana, including MEIC. I am currently a board member of MEIC. I was chosen to be MEIC Community Activist of the Year in 2003. In 2013, I was awarded the Len and Sandy Sargent award for meritorious award by MEIC. I have testified in the Montana Legislature and the U.S. Senate on water and air quality, soils, aquatics, and wildlife habitat issues relating to irresponsible energy development, coal and hard-rock mines.
4. I was a professional licensed Montana fly fishing guide for 20 years. During those years, I guided on nearly every trout stream of note in Montana. I was

an Orvis endorsed guide for many years and National Guide of the Year in 1990.

5. I have worked and/or played in all 56 Montana counties and every mountain range, wilderness area and national park in the state. I have skied and walked through the Bob Marshall and Scapegoat Wilderness, the Mission Mountain Wilderness, Bitterroot-Selway Wilderness, Absaroka-Beartooth Wilderness, and into every corner of Yellowstone and Glacier Parks. I have paddled thousands of miles of Montana's spectacular canoe waters.
6. I presently do some biological consulting on a pro bono basis. I retired in early 2012 as the state nonmotorized trails specialist for Montana Fish, Wildlife and Parks. As such, I helped administer the federally-funded $1.5 million Recreational Trails Program and inspected trails projects funded by the program, walking many miles a year in the back country. I also worked part-time with the Land and Water Conservation Fund and inspected projects funded by the fund in every county of the state.
7. I am also the father of two adult children. I spend lots of time each fall filling freezers with elk, deer, waterfowl and upland game birds.
8. I have conducted biological research in the Tongue River Valley from 1977 to 1986, and during this time, I spent numerous days in the Colstrip area hunting upland birds, particularly along East Fork Armells Creek, Cow Creek, Green Leaf Creek and Rosebud Creek. In this same period I also wrote the wildlife biology report for the EIS on Area D of the Rosebud Mine and spent time in the field near Colstrip in preparation for writing. While there, I

observed East Fork Armells Creek, Cow Creek, and Rosebud Creek. At first glance, these appear to be pretty southeastern Montana creeks, but they have taken an unnecessary beating from industrial development. It is unfortunate that these creeks have been sacrificed to the degree that they have.

9. During the past ten years, I spent numerous days in and around Colstrip performing Land and Water Conservation Fund inspections on between 15 and 20 projects. Over the past 36 years, I have driven through and around Colstrip at least annually for work, recreation, or as a board member of conservation organizations. I expect to continue to visit the Colstrip area at least on an annual basis in the coming years. As I drive through the area, I will observe the countryside and creeks and streams, including East Fork Armells, Cow Creek, and Rosebud Creek. Most recently, in December of 2016 I hunted sharp tails and pheasants on a private ranch near Colstrip and the Rosebud mine.

10. All of my many experiences with the creeks, streams, and rivers near Colstrip occurred after coal mining had begun. Thus I had low aesthetic expectations, which were all too easily met. I have observed the pits of the Rosebud Mine that swallow the upper reaches of East Fork Armells Creek. I am also familiar with the documentation of the contamination and impairment of East Fork Armells Creek by the Rosebud Mine. In particular, I know that the Montana Department of Environmental Quality has determined that the upper and lower reaches of East Fork Armells Creek are impaired, that the creek does not support healthy assemblages of aquatic life, and that one cause of the

impairment is the strip-mining operation at the Rosebud Mine. I am also aware that the Western Energy Company, which operates the strip-mine, has on multiple occasions violated its pollution discharge limits for boron, iron, sulfates, total suspended solids, and total dissolved solids.

11. Because of my awareness of the pollution from the Rosebud Mine and the Colstrip Power Plant—including specifically water pollution from the mine and the fact that the mine has impaired the downstream receiving waters—it is extremely difficult for me to have positive recreational or aesthetic experiences in the outdoors near Colstrip. While there is some exceptionally beautiful country near Colstrip, my aesthetic experience is always compromised by the industrial development of the Rosebud Mine and Colstrip Power Plant. I love to hunt, fish, and hike in southeast Montana, activities I have done annually since 1977, and I would love to be able to do so in and near Colstrip, and along East Fork Armells Creek, Cow Creek, Rosebud Creek and their tributaries downstream from the Rosebud Mine; however, I am discouraged from doing so because of my concerns about the pollution from the mine and power plant, including specifically water pollution from the Rosebud Mine. The concern about water pollution in these creeks from the Rosebud Mine diminishes my aesthetic enjoyment of the creek and the surrounding area.

12. There is also an ever-present concern that when I drink water in a Colstrip restaurant or in the home of nearby ranchers, I may be drinking water that has been contaminated by mining at the Rosebud Mine or power generation

at the power plant. This concern with groundwater pollution lessens my aesthetic appreciation for the area and discourages me from recreating in the area.

13. While there is some exceptionally beautiful country near Colstrip, my aesthetic experience of East Fork Armells Creek, Cow Creek, Rosebud Creek and the area surrounding Colstrip is always compromised by the industrial development there, including the Rosebud Mine. I have hunted, fished, and hiked in southeast Montana annually since 1977. I have hunted upland birds along East Fork Armells Creek, Rosebud Creek, and Cow Creek five to ten miles downstream from the Rosebud strip-mine in 2014 through 2015. I plan to continue to hunt, fish, and hike in southeast Montana. I also plan to visit people in and around East Fork Armells Creek, Cow Creek, Rosebud Creek, Colstrip, and the Rosebud Mine. I would like to recreate around East Fork Armells Creek, Cow Creek, Rosebud Creek, and the Colstrip area; however, the continued air and water pollution from the mine and power plant will likely continue to impact my recreational interest in and aesthetic appreciation of the area. Because of this, I am less likely to recreate in the area. It is not a positive thing to say that one's low aesthetic expectations are not likely to be met there, but they are. This would be different if it were not for the significant pollution, including water pollution from the mine, in the area.

14. I am also concerned that the Montana Department of Environmental Quality does not always work for the best interests of the people of Montana.

Somehow, it seems DEQ has lost track of its mission to protect and enhance a clean and healthful environment for present and future generations of Montanans. Instead, DEQ seems to think its mission is to make things easier for industry to poison and destroy the air, water, soil, fish and wildlife habitat. Unless there are watchdog organizations, DEQ and the Rosebud Mine will continue to destroy everything they touch.

15. Montana's Constitution recognizes all citizens fundamental civil right to a clean and healthful environment. It is the responsibility of both DEQ and private industry, such as the Western Energy Company, to assure that their actions do not violate or lessen this right. WECo's continued discharge of pollution into the already impaired waters of East Fork Armells Creek and the tributaries of Rosebud Creek, and DEQ's failure to adequately protect the water from this pollution violates my constitutional right to a clean and healthful environment.
16. If DEQ complies with the law prior to issuing a permit to expand to the Rosebud Mine and ensures that no illegal pollution is discharged into East Fork Armells Creek, its tributaries, and the groundwater outside of the permit boundary, my aesthetic and recreational concerns will, to some degree, be reduced. If DEQ complies with the law and imposes lawful restrictions on the mine expansion, the violation of my fundamental civil right to a clean and healthful environment will also be remedied, at least partially.

I declare under penalty of perjury under the laws of the United States that, to the best of my knowledge, the foregoing is true and correct.

Dated this ___ day of June 2016

Steve Gilbert

Subscribed and sworn to me by

D. Eric Fontenot this 14 day of June 2016

Notary Public for the State of Montana

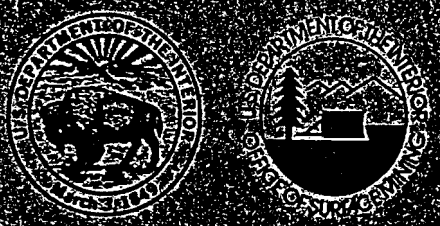
My commission expires: July 31, 2017

D ERIC FONTENOT NOTARIAL SEAL STATE OF MONTANA

D ERIC FONTENOT
NOTARY PUBLIC for the
State of Montana
Residing at Helena, Montana
My Commission Expires
July 31, 2017

DRAFT

Guidelines for Preparation of a Cumulative Hydrologic Impact Assessment (CHIA)



UNITED STATES DEPARTMENT OF THE INTERIOR

Office of Surface Mining Reclamation and Enforcement

December 1985

Exhibit 36

DRAFT

Guidelines for Preparation of a Cumulative Hydrologic Impact Assessment (CHIA)

December 1985

Exhibit 36

PREFACE

This volume is one of three that address the requirements of Public Law 95-87 (the Act) and its promulgated regulations related to the protection of the hydrologic balance on and adjacent to surface coal mines. This volume contains Guidelines for Preparation of a Cumulative Hydrologic Impact Assessment (CHIA). Another volume contains Guidelines for the Preparation of a Probable Hydrologic Consequences Determination (PHC). These guidance documents suggest processes and illustrations that applicants and regulatory authorities may use to prepare the required PHC and CHIA. A third volume contains appendices with supporting information for the PHC and CHIA volumes. In addition to the appendix volume, the PHC and CHIA volumes each include appendices specific to the respective document.

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INTRODUCTION

PURPOSE AND SCOPE

The Surface Mining Control and Reclamation Act of 1977, 30 U.S.C. 1201 et seq. (1982) (SMCRA) requires the regulatory authority, before issuing a permit to conduct surface coal mining and reclamation operations, to make an assessment of the probable cumulative impacts of all anticipated mining in the area to assure that the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area. The Office of Surface Mining (OSM) has termed this assessment a "cumulative hydrologic impact assessment" (CHIA). Although SMCRA is very specific that such an assessment is a necessary part of the permitting process, it provides little in the way of guidance as to how these assessments are to be made. The development of this manual provides this guidance to regulatory authorities in the form of a procedure for making technically sound and legally defensible CHIA's.

This guidance document suggests a thought process which will lead the regulatory authority to recognize and address the critical issues of each assessment. More specifically, this document (1) outlines the statutory basis for developing CHIA's and describes the regulatory requirements for CHIA's, (2) provides a process for the development of an acceptable CHIA, and (3) suggests data sources and proven analytical procedures that may be used in the assessment. These suggestions and procedures should be considered guidelines and not standards. The regulatory authority is not required to use this material. This is an advisory document and should not be construed as being regulatory in any way. There are no limits or conditions specified except those contained in the Act itself and in the promulgated Federal regulations and approved State programs.

The CHIA is an assessment which distinct and separate from the determination of probable hydrologic consequences (PHC), although elements of the PHC can be used to support and develop the CHIA. The CHIA is the responsibility of the regulatory authority, whereas the applicant must provide the PHC determination with the permit application. The PHC determination addresses hydrologic conditions on the permit and adjacent areas; the CHIA considers impacts over the entire cumulative impact area (CIA). This guidance document primarily addresses the CHIA process but may refer to information presented in the PHC determinations of the individual operations. It is assumed that prior to starting the CHIA process, the regulatory authority will have reviewed the hydrologic content of the permit application and will have made a determination that the hydrologic information, the analyses, and the PHC statement in the application provide a complete and adequate evaluation of the hydrologic systems that will be affected by the proposed operation and clearly indicate the magnitude of those effects. If such a determination shows these items to be inadequate or if such a determination has not been made, the CHIA process should not be initiated until these items are provided.

This document is directed primarily to the regulatory authorities, who have the responsibility of completing a CHIA for each permit application. However, coal mine operators and interested members of the public may also find it useful for preparing and understanding permit applications. If each party involved in the permitting process understands what is required of the others, conflicts should

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occur less frequently and be more easily resolved. It is intended that this document provide a common understanding of the CHIA process for all interested parties.

Because this document is intended for nationwide use, the process presented is intentionally nonspecific. It gives the regulatory authorities flexibility to administer the process within regulatory requirements and standards of the individual States. It emphasizes the general elements that should be considered in conducting a CHIA but allows the regulatory authority to choose the specific approaches and methods that will be most appropriate to a given State, region, or cumulative impact area. Therefore, the prudent regulatory authority will develop State-specific CHIA guidelines, using the process presented here as a framework. Such action would allow the regulatory authority to standardize parts of the process, establish appropriate exceptions to the process, and, in general, streamline the whole CHIA process, thus minimizing the total effort required for a given CHIA analysis.

DEFINITIONS

The following definitions will facilitate the understanding of this document. They are provided solely to aid the reader in understanding this guidance document and are not to be construed in any way as official OSM definitions. Other definitions may be found in OSM's Permanent Regulatory Program, 30 CFR 701.5 (appendix A.1).

Baseline hydrologic information.--Information which describes the physical and chemical characteristics of a hydrologic system and the hydrologic balance of an area prior to the imposition of a specific stress, such as a mining operation.

Hydrologically isolated operation.--A surface mining operation where hydrologic impacts are negligible or are dissipated before reaching points in the system where they are additive to hydrologic impacts of other surface mining operations.

Hydrologic concern.--An issue or potential issue relating to some element or aspect of the hydrologic system which may be adversely affected by surface mining activities. Each concern can be described using specific hydrologic parameters and changes in those parameters. Cumulative impact assessments can be focused initially upon hydrologic concerns identified through analysis of baseline information, historical data, etc.

Hydrologic impact.--Any measurable change in hydrologic parameters or conditions associated with a particular hydrologic system caused by surface and underground coal mining activities.

Hydrologic model.--An equation, set of algorithms, or written qualitative description of a phase of the hydrologic cycle. Most often, an equation that results from the use of correlation-regression analysis that relates a hydrologic parameter to physiographic and climatic factors. Also, a computer program that predicts hydrologic parameters as time-series,

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such as streamflow or soil moisture, given meteorologic time-series input. For cumulative impacts of surface mining, the applicable phase of the hydrologic cycle is from precipitation on the land surface or snowmelt to the discharge point at a downstream location or flow in an aquifer.

Hydrologic parameter.--A particular physical or chemical quantity, property, factor, or characteristic used to describe hydrologic conditions.

Material damage to the hydrologic balance means, with respect to CHIA, the changes to the hydrologic balance caused by surface mining and reclamation operations to the extent that these changes would significantly affect present and potential uses as designated by the regulatory authority.

Water availability means that, along with there being a sufficient volume, the water is in an accessible location and it is of acceptable quality for the uses designated by the regulatory authority.

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CHAPTER I

STATUTORY AND REGULATORY REQUIREMENTS FOR CUMULATIVE IMPACT ASSESSMENTS

The statutory requirements for CHIA's are found in Sections 507(b) and 510(b) of SMCRA. These sections which delineate the requirements that the regulatory authority and the permit applicants must meet, state, in pertinent part:

> Section 507(b) "The permit application shall be submitted in a manner satisfactory to the regulatory authority and shall contain, among other things-- * * * (11) a determination of the probable hydrologic consequences of the mining and reclamation operations, both on and off the mine site, with respect to the hydrologic regime, quantity and quality of water in surface and ground water systems including the dissolved and suspended solids under seasonal flow conditions and the collection of sufficient data for the mine site and surrounding areas so that an assessment can be made by the regulatory authority of the probable cumulative impacts of all anticipated mining in the area upon the hydrology of the area and particularly upon water availability: Provided, however, That this determination shall not be required until such time as hydrologic information on the general area prior to mining is made available from an appropriate Federal or State agency: Provided further, That the permit shall not be approved until such information is available and is incorporated into the application" (emphasis in original).
>
> Sections 510(b) "No permit or revision application shall be approved unless the application affirmatively demonstrates and the regulatory authority finds in writing on the basis of the information set forth in the application or from information otherwise available which will be documented in the approval, and made available to the applicant, that * * * (3) the assessment of the probable cumulative impact of all anticipated mining in the area on the hydrologic balance specified in Section 507(b) has been made by the regulatory authority and the proposed operation thereof has been designed to prevent material damage to the hydrologic balance outside the permit area;"

The requirements of Sections 507(b)(11) and 510(b)(3) of the Act have been implemented by the Permanent Regulatory Program at 30 CFR 701.5, 780.21, and 784.14. Section 701.5 defines "cumulative impact area," the name given the area referred to in Section 507(b)(11) as that area which must be included in the assessment of probable cumulative impacts. This definition of the CIA addresses the physical extent of the area and the meaning of the term "all anticipated mining" as used in Section 510(b)(3). According to the preamble, anticipated mining is meant to include "all operations which have a reasonable expectation of receiving regulatory approval to mine and for which there is sufficient mine development information available to allow adequate analyses" (48 Federal Register 43957, September 26, 1983).

Sections 780.21(g) and 784.14(f) of the regulations speak specifically to the scope of the CHIA. Section 780.21 addresses surface mining and 784.14 concerns underground mining. These sections both read as follows:

Cumulative hydrologic impact assessment.

(1) The regulatory authority shall provide an assessment of the probable cumulative hydrologic impacts (CHIA) of the proposed operation and all anticipated mining upon surface- and ground-water systems in the cumulative impact area. The CHIA shall be sufficient to determine, for purposes of permit approval, whether the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area. The regulatory authority may allow the applicant to submit data and analyses relevant to the CHIA with the permit application.

(2) An application for a permit revision shall be reviewed by the regulatory authority to determine whether a new or an updated CHIA shall be required.

Sections 780.21(c) and 784.14(c) discuss the responsibilities of the regulatory authority and the applicant for the collection of hydrologic data needed for the CHIA. These sections provide:

Baseline cumulative impact area information.

(1) Hydrologic and geologic information for the cumulative impact area necessary to assess the probable cumulative hydrologic impacts of the proposed operation and all anticipated mining on surface- and ground-water systems, as required by Paragraph 780.21(g) or 784.14(f), shall be provided to the regulatory authority if available from appropriate Federal or State agencies.

(2) If the information is not available from such agencies, then the applicant may gather and submit this information to the regulatory authority as part of the permit application.

(3) The permit shall not be approved until the necessary hydrologic and geologic information is available to the regulatory authority.

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CHAPTER II

OVERVIEW OF THE CHIA PROCESS

This chapter presents an overview of the CHIA development process, along with the philosophy on which it is based, so that the user can immediately understand its full scope. In addition, brief statements of the functions of each of the process elements are presented. Detailed discussion of the various process elements is presented in later chapters.

PHILOSOPHY OF CHIA

With proper enforcement of surface mining regulations, the hydrologic impacts of individual mining operations will be minimized, though not eliminated entirely. These remaining or residual impacts, however small and individually insignificant, may, with the development of additional mines, accumulate to magnitudes that are significant and potentially damaging to the hydrologic balance. The cumulative hydrologic impact assessment, thus, is necessary to assure that such aggregate impacts will not be overlooked in the routine processing of individual permit applications. In effect, the CHIA is a safety net provision in the Act, and its overall objective is to require routine consideration of the aggregate impacts caused by the disruption of large areas (more than one individual permit area) due to surface mining operations.

The CHIA is a means of keeping the big picture of hydrologic impacts before the regulatory authority at all times, so that if the accumulated impacts reach potentially damaging magnitudes, they can be dealt with in a timely manner. Depending on the hydrologic setting, the potential for damage to the hydrologic system, and the evaluation of the significance of that damage through the application of material damage criteria established by the regulatory authority, the probable cumulative hydrologic impact assessment could result in the denial or delay of a mining permit. The regulatory authority may use the CHIA as a land use planning tool to balance current coal development in a region against probable future development. However, such use is not required (48 Federal Register 43973, September 26, 1983).

Because, through the CHIA process, the regulatory authority is continually reminded of the reality of cumulative impacts, it should not be necessary to completely analyze every facet of the hydrologic system. The process presented in this guidance document is based on the premise that the scope of the analysis can be reduced to those facets of the hydrologic system which are likely to affect the designated uses of water available from that system. At the start of an assessment, its scope should cover all possibilities. Thus, the scope of a CHIA should initially include a complete analysis of the ground- and surface-water systems in the CIA, from the standpoint of water quantity and quality. This initial scope can then be systematically and logically reduced to those concerns considered significant to maintaining the hydrologic balance of the area. The scope reduction procedures, which must be developed by the regulatory authority, are envisioned to often be qualitative in nature.

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The procedures presented here are based on the understanding that hydrologic impact assessment is not a precise process. Because of the many uncertainties associated with hydrologic estimation, the predictions made under the process proposed herein, or under any similar process, must be considered as probable in nature rather than exact. Therefore, the regulatory authority must have the option of using professional judgment to make the final material damage determination. This should not detract from the significance of the process if the determination is based on the facts produced by a comprehensive analysis. Likewise, use of qualitative methods and techniques for the analysis is an acceptable option if the regulatory authority can show them to be adequate for the specific site situation.

OVERVIEW

A CHIA is a permit-specific assessment required by SMCRA and must be an integral part of the permit decision package. The CHIA should be included in the Technical Environmental Analysis (TEA) section of the decision package.

CHIA development is a process which consists of a logically and professionally documented evaluation of a defined set of elements. It basically involves the analysis of critical aspects of the hydrologic system within the cumulative impact area. Emphasis of the analysis is on predicting the type and magnitude of impacts to the hydrologic system attributable to the proposed operation in conjunction with existing operations and anticipated mining. Thus, during the CHIA process, the regulatory authority should (1) define the area to be studied, (2) describe the hydrologic system and determine baseline hydrologic resource values, (3) identify hydrologic resources likely to be affected, (4) develop standards for evaluating the impacts, (5) estimate the impacts of mining on the hydrologic resources, and (6) make a material damage determination and prepare a statement of findings. The regulatory authority should address these elements in a logical sequence based on good hydrologic practice.

Within the constraints of good hydrologic practice and those imposed by statutory and regulatory requirements, the regulatory authority has wide latitude to determine the exact manner in which individual elements will be evaluated. Thus, an assessment based on "professional judgment," or a rigorous analytical assessment may be used, as the situation requires. Also, some of the procedures and hydrologic concerns presented and discussed in this guidance document may not apply to every CHIA. They are offered as examples, and their use is in no way mandatory. The specific concerns, procedures, methods, and data needs may vary with each impact area, and the regulatory authority has complete latitude to use those that best apply to the particular conditions of each site. However, justification for the specific assumptions and decisions made by the professionals conducting the assessment must be included in the findings statement for use in the various review processes (including public review and the program oversight review). The justification of actions and methods should be considered an extremely important aspect of the CHIA process.

Each CHIA should be considered unique to a specific minesite or permit area. However, a totally new analysis is not necessary for each CHIA. It is acceptable to use portions of a previously prepared CHIA for the same area, provided that these portions do, in fact, describe the situation of the newly proposed operation. For

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example, if the proposed permit area was included as a leasehold in a previous CHIA, then that previous CIA delineation may be an appropriate CIA for the CHIA of the newly proposed permit area. In addition, documentation of the procedures used to delineate this CIA should be transferable to the CHIA of the proposed mine with only minor modifications. Likewise, once material damage standards have been established for a specific area, they would be applicable, with little modification, to all future CHIA's in that area. Thus, even though a CHIA should be considered unique to each specific permit application, the actual assessment can draw heavily on the previously prepared CHIA's.

Figure II-1 illustrates the basic CHIA process that may be used by the regulatory authority. The letters in the element boxes are for reference only and do not imply a required process order. The process could be depicted in other, equally acceptable, sequences. The important factor is that the process considers the recommended elements in a logical and workable sequence.

The process illustrated in figure II-1 shows the interrelation of the elements to each other and to the process as a whole. The parallel arrangement of Elements A, B, and C is meant to suggest that these elements are highly interrelated and that their evaluation should take place concurrently and interactively. As a group, these three elements are evaluated first in the process because they provide an information base which forms the basis for selecting techniques and methodologies needed for impact prediction and material damage assessment. The sequential arrangement of Elements D through F indicates that completion of these elements is dependent on the prior evaluation of certain other elements. This should not be construed to mean that one element must be totally completed before the next is started. The feedback arrow suggests that the CIA delineation may need modification after the areal extent of the impacts has been evaluated.

Process Elements

Element A.--Element A addresses the delineation by the regulatory authority of the area for which the CHIA is being prepared. OSM refers to this area as the cumulative impact area (CIA) and defines it in the regulations (30 CFR 701.5) in terms of both a physical area and the type of operations located within the area that must be considered.

The proposed delineation process begins at a point downstream from the most downstream operation in the same river basin where the proposed operation is located. By procedures developed by the regulatory authority, operations spatially and hydrologically distant from the proposed operation are systematically tested to determine the significance of their impacts with respect to the proposed operation. In this way, the CIA is limited to operations whose hydrologic impacts are relevant to the CHIA being developed. The process may be iterative, with some evaluation of the impacts needed before the limits of the CIA can be finally delineated; thus, the feedback loop from Element E to Element A in figure II-1.

Element B.--Element B involves identification by the regulatory authority of hydrologic concerns specific to the CIA. This is a qualitative identification of the aspects of the hydrologic system most likely to be adversely affected by mining activity. By identifying hydrologic concerns peculiar to the CIA, the CHIA process

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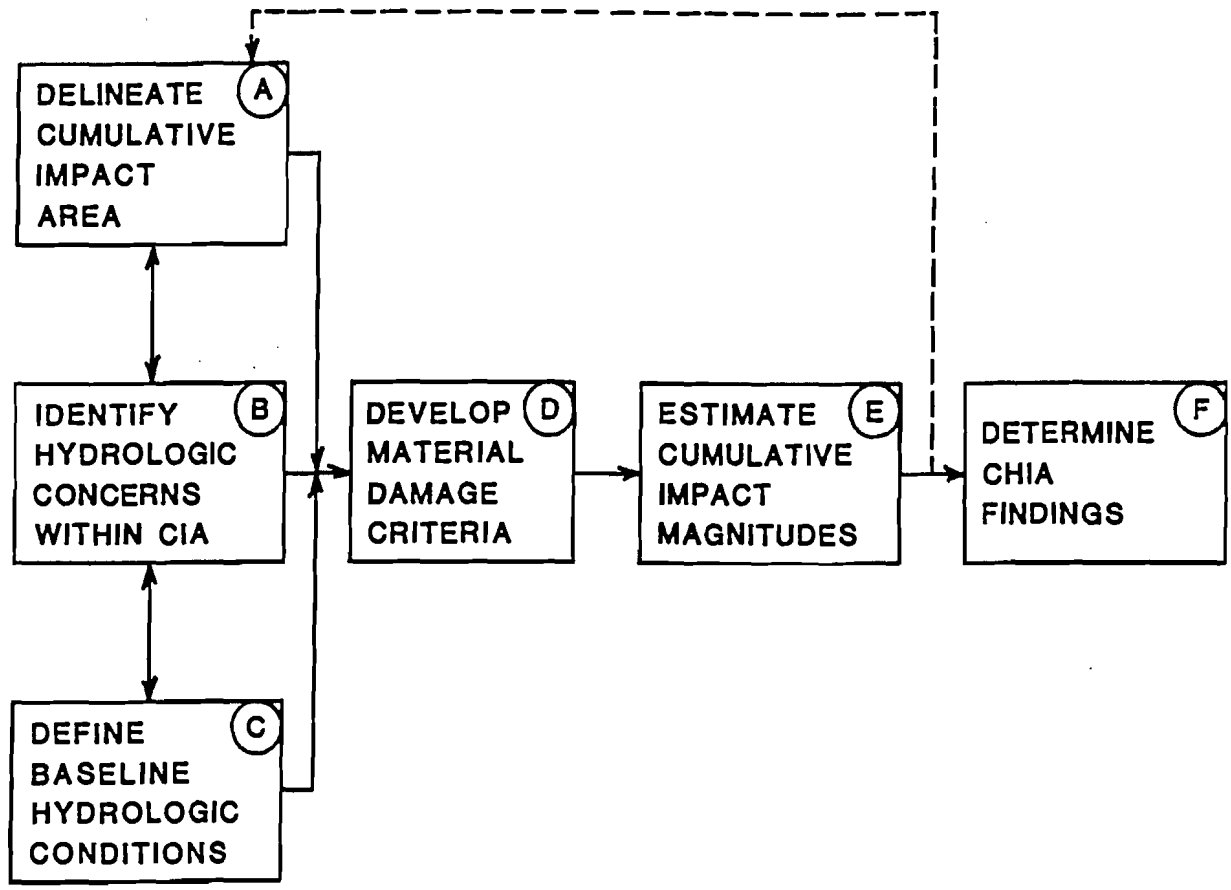

Figure II-1.--Flow diagram of basic CHIA process.

can be focused on these critical segments of the hydrologic system. The concerns can be identified from PHC data, as well as from other baseline data, historical data, or any source that raises valid questions about some aspect of the hydrology of the CIA. The specific parameters to be used to measure and evaluate the concerns, and the sites at which the concerns will be evaluated should also be identified. These parameters will be referred to as "indicator parameters" in the remainder of the guidance document. For example, a common concern associated with mining in the Western United States is increased salt concentration in the postmining ground-water supplies.

Element C.--Element C provides for the determination of baseline hydrologic conditions of the CIA. This determination should result in a description of the hydrologic system and how it functions. It should also provide the normal values of the indicator parameters at the beginning of mining. In effect, baseline conditions are indicators of the state of the hydrologic balance at the time of the analysis, and they provide reference points for evaluating the significance of future impacts (predicted values of indicator parameters) of mining.

Element D.--Under Element D, the regulatory authority establishes for the indicator parameters the threshold values beyond which material damage is likely to occur. It is here that the regulatory authority establishes what constitutes material damage for the CIA. Existing State and Federal water-quality standards should be used where applicable. Where standards are not already available, the regulatory authority will have to develop threshold values. These values normally will be in the form of maxima or minima, but, in some cases, rate-of-change limits (incremental limits) may be necessary. When, with increasing numbers of mines in the CIA, impact levels approach material damage threshold limits, the regulatory authority may wish to establish secondary limits (parameter value less than the material damage thresholds) to indicate when more rigorous and precise analysis procedures should be used.

Element E.--Element E involves estimating values that the indicator parameters are expected to attain as a result of coal mining. First, an analytical approach is adopted. If the combinational approach is used, specific analysis techniques should not be necessary because adequate impact assessments should already exist in the PHC's of the individual anticipated operations. In this case, the regulatory authority needs only to develop procedures by which the results of the individual PHC's can be rationally combined. If PHC's are not available for some of the "anticipated mining" operations, the regulatory authority must first develop PHC's or make equivalent analyses in order to use the combinational approach.

If the independent analysis approach is used, then specific techniques are necessary. Technique selection depends on many factors, but a primary consideration should be that the technique adequately account for the dominant physical conditions that characterize the subject hydrologic system. The selected techniques are applied to the total CIA using data assembled at Element C. The approach and techniques selected are extremely important to the outcome of the CHIA process and should be given careful consideration.

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Element F.--The regulatory authority's final task in the CHIA process (Element F) is to determine whether the hydrologic assessment of the CIA (Elements A through E) indicates that the addition of the impacts of the proposed operation to those of the other anticipated mining may cause material damage to the hydrologic balance outside the permit area and to write a statement of these findings with all supporting evidence and rationale. The determination is the main objective of the whole CHIA process. The supporting evidence and rationale validate the determination.

The determination may be based on quantitative comparisons and/or on qualitative evaluations. Quantitative comparisons should be made whenever possible, but they need not be the sole basis for the determination. The regulatory authority has the flexibility of using qualitative factors along with quantitative comparisons to make final material damage determinations. Regardless of whether the determination is qualitative or quantitative, the rationale for the decisions must always be clearly stated.

The written statement of findings with supporting evidence and rationale should describe the actions taken to complete each of the process elements, with emphasis on justification for these specific actions or decisions. As a matter of expedience, this writing is suggested to be considered a part of each of the other elements, with the appropriate sections being completed as these elements are processed. In this way, the bulk of the writing will be completed when the analysis is completed. Then, in Element F, the statement would require only finalization. A suggested form and content for this document is given in Appendix A.

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CHAPTER III

CHIA CONCEPTS

The CHIA is a novel concept for environmental protection, and all its possibilities should be explored in the process of developing working procedures for its implementation. An important first step toward compliance should be for the regulatory authority to develop a clear understanding of the language and the new terms used in the Act and regulations. This guidance document addresses the terminology in several places. The "Introduction" section defines terms not previously defined in 30 CFR 701.5. This chapter, Chapter III, expands upon, and explores in a broad and conceptual manner, the definitions of the terms "material damage to the hydrologic balance" and "cumulative impact area." These terms are further treated in Chapter IV, which suggests practical, working procedures for implementing the requirements conveyed by the terms. If the reader keeps in mind the differences in the various treatments of this terminology, the appearance of repetition should be minimized.

CONCEPT OF CUMULATIVE HYDROLOGIC IMPACTS AND CUMULATIVE IMPACT AREA

The focus of the CHIA assessments should be on the changes (type and magnitude) and conditions that are the direct result of large areas being mined by more than one operation and the possibility that these changes will result in material damage outside the permit area. In the following discussion of impacts and impact areas, the terms "mine" and "mining" refer to mining operations that are included in the definition of "anticipated mining."

To some users of this guidance document, the term "impact" may connote a severe or adverse condition. As used in this document, however, an impact is "any measurable change * * *." Therefore, a distinction is made between the occurrence of an impact and the severity of the impact. In general usage here, the term "impact" will refer only to the specific changes that are expected to occur and to the geographical area where they are expected to occur. It does not imply that the expected changes (impacts) will be damaging to the hydrologic balance; only that they may occur. Determination of the potential seriousness of the impacts is considered a separate and distinct problem in the CHIA process.

Clarification of the term "impact area" is also needed. A "hydrologic impact" is defined (see "Definitions") as "any measurable change in hydrologic parameters associated with a particular hydrologic system caused by surface and underground coal mining activities." It follows, then, that the impact area of an individual mine is the geographical area over which the mining activities cause measurable changes to the hydrologic system. The changes are expressed in terms of parameters representative of the hydrologic system. The mine's "true" impact area, then, is a composite of the subareas over which each hydrologic parameter is affected.

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The only way to delineate the "true" impact area of a mine is by monitoring the representative parameters at numerous sites over the total time period during which the impacts occur (from before mining until after hydrologic equilibrium is restored after mining). Of course, the impact area would not be known until after the mining and reclamation were completed and, therefore, would not be useful for preparing CHIA's. Therefore, for PHC and CHIA purposes, the size, shape, and position of the impact areas must be estimated. The following discussion of true cumulative hydrologic impacts and cumulative impact area is offered to provide a basis for estimating the practical, "working" impact area.

"Cumulative hydrologic impacts" are the aggregate effects on hydrologic parameter values at a particular location in the hydrologic system, caused by existing and anticipated mining activities. The term is best explained by illustration. Consider the group of mines and leases depicted in figure III-1. Suppose that, at any downstream point, W, in the surface flow system, surface-water quantity and quality parameters could be monitored from a time prior to mining until the system regains equilibrium after the mining. This monitoring would provide a measure of the cumulative effects of the mining on the surface hydrology at point W. Plot A in figure III-2 shows the variation in total salt load over the monitoring period. The difference between the salt load value at any time, t, and the premining value would represent the accumulated change in salt load at time t caused by the mining. This assumes that there are no other types of development activity in the area to affect the system. Since several mines would have contributed dissolved salts into the flow system, this plot depicts the "cumulative" effect of these mines on salt load at point W. Similar measurements and plots at sites X and Y would show the cumulative impacts at those points.

From the preceding illustration, it should be apparent that the true cumulative hydrologic impacts are the net accumulated changes caused by the anticipated mining operations as integrated (combined) by the hydrologic system. The true cumulative impacts are not simple summations of the impacts from a group of individual mines selected according to rigid rules or on some arbitrary basis. Rather, they are the result of stresses on the system and their actual magnitudes can be found only by measurement. The impact values will vary, depending on where in the system and at what point in time they are measured. For CHIA purposes, the maximum expected changes are the relevant values.

As figure III-1 implies, the true impact accumulation area from several mines is not necessarily restricted to the immediate vicinity of the mines. In general, the impacts of concern will affect the quality or quantity of water in the hydrologic system, and most impacts will be transported by, or will in some way be related to, water flow through the system. Therefore, the impacts of a mine can be expected to move mainly downgradient, and the accumulation of impacts of two or more mining operations may occur at locations quite remote from their respective permit areas, or at a time far in the future. Therefore, when impacts of several mines feed into the same flow system as does the proposed mine, and irrespective of the relative locations of the mines within that system, there is theoretically a potential for accumulation of impacts.

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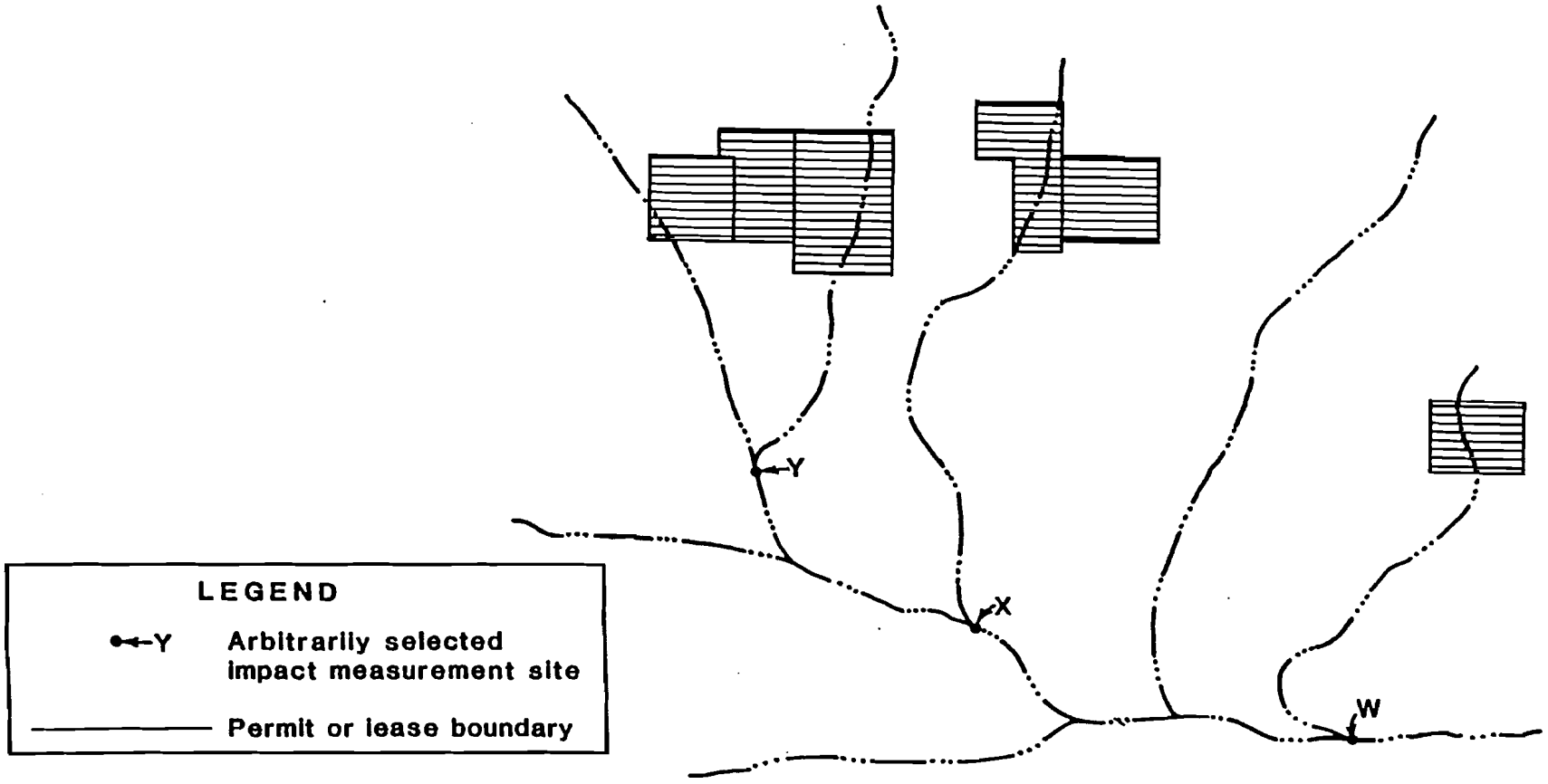

Figure III-1.--Hypothetical sites for measurement of "true" cumulative hydrologic impacts.

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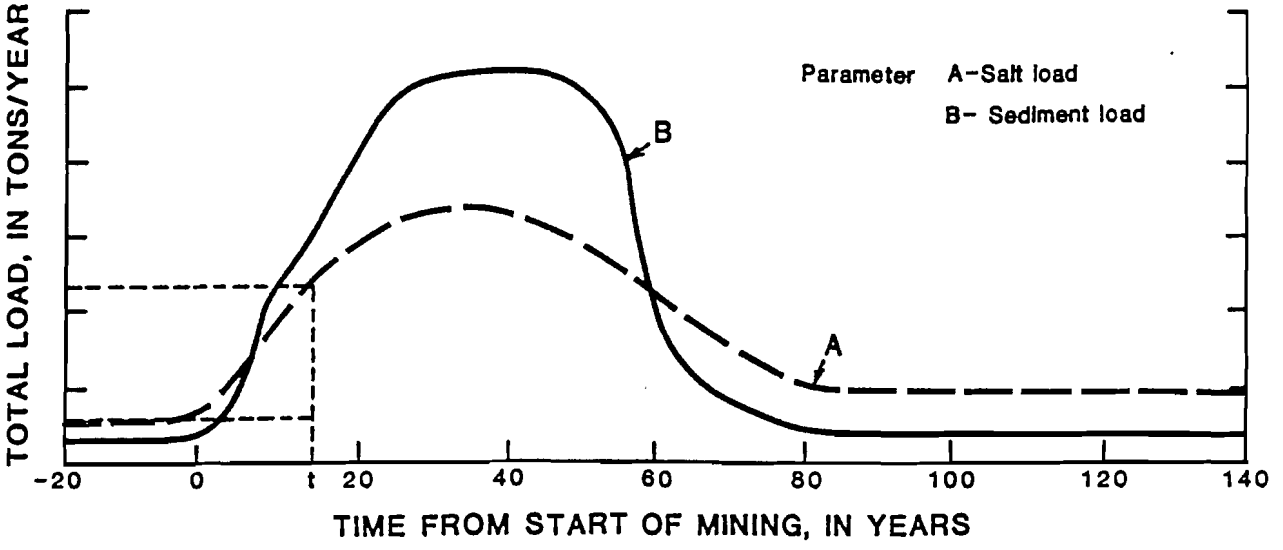

Figure III-2.--Plots of hypothetical cumulative hydrologic impacts measured at point W of figure III-1.

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Following this line of reasoning, all mines within the same river system or ground-water flow system have the potential for impact accumulation with the proposed mine, and it could be argued that the CIA must extend to a point downgradient from the most downgradient mine in the river system. However, it is unlikely that Congress intended a CIA to routinely include whole river systems, as might be required if the preceding rationale were strictly followed. Therefore, the downstream extent of a CIA that is environmentally comprehensive and also satisfies the intent of the Act probably lies somewhere between the downstream boundaries of the proposed permit area and the farthest downstream mine in the river basin. The regulatory authority should develop a rational procedure for identifying this point. Preferably, the procedure would be based on hydrologic and mathematical theory and on professional judgment, rather than on professional judgment alone.

MATERIAL DAMAGE TO THE HYDROLOGIC BALANCE

The term "material damage to the hydrologic balance" may have various interpretations. The following discussion presents a conceptual interpretation of this term. The Permanent Program Regulations do not define "material damage" but do define "hydrologic balance" as "the relationship between the * * * water inflow to, water outflow from, and water storage in a hydrologic unit, such as a drainage basin, aquifer, soil zone, lake, or reservoir" (30 CFR 701.5). According to this definition, the hydrologic balance of a particular unit of the hydrologic system is the relationship of the inputs and outputs of water, and the full range of materials it may contain, to the unit. The specific relationship depends on the physical characteristics of the hydrologic unit and reflects gains and losses of output imposed by those characteristics. The balance of a hydrologic system, such as that within the CIA, can be thought of as the integrated relationship between all water inputs to and outputs from one or more hydrologic units that make up the system. These relationships can be quantified and defined by measuring the outputs and the corresponding inputs. One intended use of baseline hydrologic information is to define the existing preoperation relationships of the hydrologic system. Subsequent changes in system outflow may be considered as a measure of changes in the hydrologic balance, if the inflow is assumed to remain unchanged over the time period evaluated by the CHIA.

The concept that changes in the hydrologic balance are analogous to changes in the outputs of the system is illustrated graphically in figure III-3. Curve A represents a premining state of hydrologic balance between precipitation and runoff from a permit area. An example from the curve shows that 5 units of precipitation will produce approximately 25 units of runoff. When the area is mined, the consequent alteration of physical characteristics will result in some change in the relationship between precipitation and runoff. Curve B represents an estimate of this postmining state of the hydrologic balance. It shows that the area now produces only 15 units of runoff from 5 units of precipitation. The difference in runoff between curves A and B represents the predicted change to the hydrologic balance at a given input level as a result of mining. Quantitatively, the difference represents the change in outputs (runoff, in this case) caused by the altered physical state of the hydrologic system. This concept can be extended to all relationships used in the impact analysis. In developing an actual CHIA, quality as

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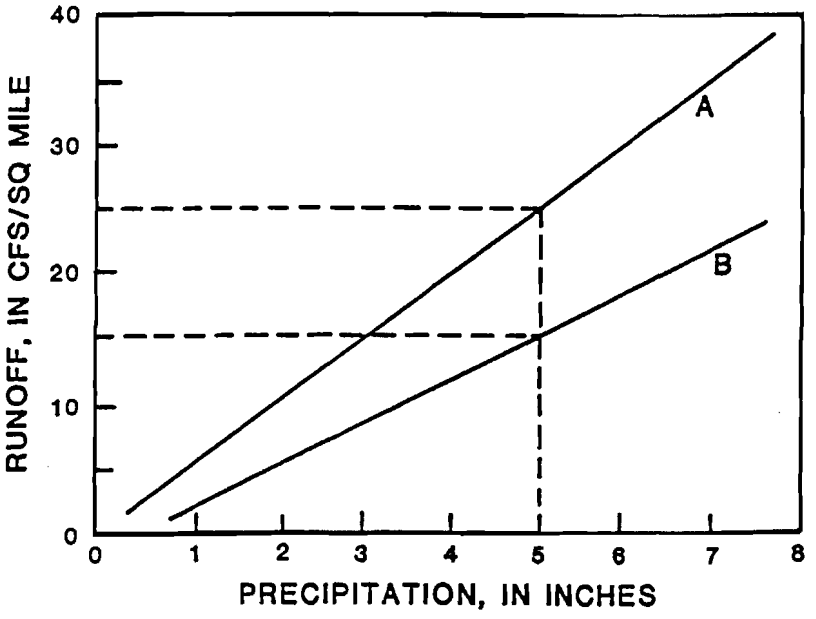

Figure III-3.--Hydrologic balance between runoff and precipitation for (A) premining conditions and (B) postmining conditions.

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well as quantity relationships must be considered. The outputs discussed in the foregoing should be recognized as the parameters identified in Element B as the indices of the hydrologic concerns within the CIA.

Material damage to the hydrologic balance may be characterized by changes to the quality or quantity of surface water or ground water as measured by changes in particular hydrologic parameters or conditions. In terms of the foregoing discussion of hydrologic balance, this means that material damage occurs when postmining outputs exceed defined limits, or when the change in output which occurs in going from the premining relationship (e.g., the state of hydrologic balance) to the postmining relationship exceeds some prescribed amount. The establishment of allowable limits and of allowable increments of change for each parameter identified in Element B is the task to be accomplished in Element D. These limits are referred to in this guidance document as the Material Damage Criteria.

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CHAPTER IV

ELEMENTS OF THE CHIA PROCESS

This chapter describes, in detail, the various elements that constitute the CHIA process.

ELEMENT A. DELINEATION OF CUMULATIVE IMPACT AREA

Element A deals with identification by the regulatory authority of the geographical area that the CHIA is to evaluate. The end product of this element is a delineation of the area within which cumulative hydrologic impacts of the proposed mining are expected to occur. Determination of the cumulative impact area should focus on the identification of the total area that contributes to the magnitude of hydrologic impacts outside the permit areas. Inherent in this identification process is the need to define the specific hydrologic system and to understand how it functions. Such understanding will facilitate CIA delineation, as well as the whole CHIA process, and will result in more rational and complete assessments.

OSM refers to the area which the regulatory authority must evaluate for the required CHIA as the "cumulative impact area" (CIA). The definition of CIA (30 CFR 701.5) provides the regulatory requirements for the delineation of a CIA. These requirements are very specific about the type of operation that must be evaluated but leave unclear the extent of the geographical area required for CHIA consideration. However, the parts are somewhat interdependent in that the CIA must include the impact areas of all "anticipated mining" operations, but "anticipated mining" includes only those operations that lie within the CIA. The preamble to the final rules (48 Federal Register 43956-43959, September 26, 1983) devotes considerable space to discussion of this definition and to comments received from the public relative to the definition. The reader is referred to this material in addition to the following discussion.

All Anticipated Mining Operations

The discussion of cumulative impact area concepts (Chapter III) centers on the geographical area alone. The other part of the CIA delineation process, discussed below, involves identification of the specific operations whose impacts must be included. The definition of CIA specifies the types of operations, which, at a minimum, must be included as "anticipated mining." In addition, "anticipated mining" also includes a time factor; that being, "at a minimum, the entire projected lives through bond releases of:" the above-listed types of operations (30 CFR 701.5, Cumulative Impact Area). This means that the total areas projected to be disturbed by mining and reclamation activities over the entire lives of these operations (not just the 5-year permit areas in effect at the time the CHIA is prepared) must be included in the CIA.

Of the specified types of operations, the proposed operation, existing operations, and operations for which permit applications have been submitted to the regulatory authority are most easily identified. Submitted applications are those which the regulatory authority has in hand, whether or not the application

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has been certified as complete. Existing operations are those for which bond has not been released on the total mine plan area. Unpermitted operations, such as those of less than 2 acres for which a permit may not be required, are considered as existing operations and must be included in the assessment (48 Federal Register 43958, September 26, 1983). Completed operations--those for which total bond has been released prior to submittal of application for the proposed operation--need not be considered. It can be assumed that the CHIA baseline data will reflect any remaining impacts of completed operations.

The definition of Federal coal leases that must be included in the CIA needs amplification. By definition, Federal coal leases required to achieve diligent development need to be considered. More specifically, those Federal leases for which sufficient hydrologic, geologic, and mine development information is available to allow for accurate hydrologic impact assessment (such as planned mining and reclamation techniques, processes, schedules, etc.) must be considered. Federal coal leases exempt from diligence requirements and State and private leases may also be included as "all anticipated mining" if the regulatory authority deems it necessary.

All Federal coal leases and logical mining units (LMU's) issued after August 4, 1976, are required to achieve diligent development (Federal Register 33187, July 30, 1982). Federal coal leases issued prior to August 4, 1976, are required to achieve diligent development upon the effective date of the first lease readjustment after August 4, 1976. Any Federal coal lease included in an LMU is subject to the diligent development requirements imposed on the LMU (Federal Register 33187, July 30, 1982).

In addition, the amended Mineral Leasing Act (1920) requires that the leasee submit a resource recovery protection plan (RRPP) within 3 years of the effective date of a Federal coal lease. The RRPP must contain certain mine development information, as specified in 30 CFR 211.10. Leases obtained prior to August 4, 1976, are exempted from such requirements until the effective date of the first lease readjustment occurring after August 4, 1976. For the purpose of defining "all anticipated mining" in the CIA, it is suggested that the information required in the initial submittal of the RRPP for a Federal lease tract be used to satisfy the "sufficient mining development information" requirement in the definition of "anticipated mining." With this condition, only those Federal leases issued after August 4, 1976, and LMU's approved after that date for which RRPP's have been submitted and approved would have to be included in the cumulative impact area. Leases and LMU's effective before August 4, 1976, would not have to be considered as anticipated mining until they become subject to diligence and RRPP requirements after the first readjustment. Again, the regulatory authority may include, as anticipated mining, other operations, leases, and lands it deems appropriate.

In general, "anticipated mining" includes, as a minimum, all operations which have a reasonable expectation of receiving regulatory authority approval to mine and for which there is sufficient mining development information available to allow an adequate analysis (48 Federal Register 43957, September 26, 1983).

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Delineation of a Working CIA

The need for a defined work area within which to conduct the CHIA is obvious. However, because it is impossible to delineate the "true" cumulative impact area before the impacts occur, the CHIA process must depend on an estimated CIA. (See Chapter III for discussion of true and working CIA's.) A CIA that is not excessively large yet accounts for all operations that may produce cumulative hydrologic impacts must be delineated. The delineation procedure that follows will help to specifically define such an area. This defined area is an estimate of the true CIA and will be called the working CIA.

An outline of the procedure is presented on pages IV-6 and IV-7. It consists of two phases and begins with consideration of a broad-scale CIA, which is subsequently reduced to a practical "working" CIA. Phase I provides for reduction of the broad-scale CIA to an intermediate area within which the working CIA can be delineated. Phase II accomplishes actual delineation of the working CIA. Once Phase I is applied to a region, the results should be generally applicable with little modification to subsequent CHIA's for the same vicinity. Phase II is the heart of the delineation procedure, will require the most effort, and should be applied to each individual CHIA separately. Both phases are necessary for a comprehensive delineation of the CIA.

To this point the CIA has been and will continue to be discussed as a single area unless otherwise stated. However, the surface- and ground-water systems are usually analyzed separately, and the impacted area of the ground-water system may very likely be entirely different in size and shape from the surface-water impacted area. Therefore, it may be advantageous for the regulatory authority to develop separate procedures for delineating surface- and ground-water CIA's. Such procedures must recognize and account for the interrelationships between the surface- and ground-water systems. The composite of these surface- and ground-water CIA's constitutes the working CIA.

Discussion of CIA Delineation Procedure

Phase I

The key to Phase I is development by the regulatory authority of specific criteria with which to test the impact significance of operations or groups of operations that are spatially and hydrologically distant from the proposed operation. These criteria can also serve to identify proposed operations that are "hydrologically isolated"; the CHIA's of such operations can be limited to the impacts of the proposed operation. The criteria should allow a quick evaluation of distant operations, but they should also be indicative of situations that may prove significant under more rigorous analysis. The criteria must not allow exclusion of operations in the immediate vicinity of the proposed operation whose impacts are likely to interact with those of the proposed operation. Once criteria have been developed and applied in a given region, the results should be applicable to subsequent CHIA's with little additional effort.

Possible approaches for developing such criteria follow; others may be equally appropriate. One approach is to compare the accuracy with which impacts can be measured at downstream sites in the surface-water system with the expected magnitudes of the impacts at the mines. By definition, a hydrologic

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impact is a "measurable change." Therefore, impact magnitudes that are less than the inherent error of the measurement technique used could be considered to have insignificant accumulation potential with mines even farther downstream. Criteria based on this approach should specify, at a minimum, the parameters to be evaluated, the measurement methods to be used, and the associated ranges of measurement error.

A similar approach would use the dilution effect in the downstream direction as the basis for exclusion. At the point in the flow system where the pollutant concentrations become diluted to a predetermined level, the concentrations could be considered insignificant in a cumulative sense, and operations farther downstream could be excluded. Criteria based on this approach should specify what parameters to use for determining threshold dilution magnitudes and the threshold dilution levels.

Some States have quality standards for water entering from adjoining States. Where they exist, these standards could be the basis for exclusion criteria. It would be pointless to consider additional downstream mines if water in the system already fails to meet such standards. The regulatory authority might also take the position that if the water does meet these standards, then the State's obligations for cumulative impacts with out-of-State mines have been met. A possible drawback to this reasoning is that incentives to minimize cumulative impacts on a mine-by-mine basis are lacking until impacts have become of such magnitude that the standards are in danger of being exceeded.

Once developed, the criteria can be applied to mark the extremes of the working CIA along receiving streams common to two or more mining operations (these will be referred to as common receiving streams or common streams) in the vicinity of the proposed operation. Several limiting points may be necessary where more than one common stream originate in a probable CIA. When appropriate, upstream as well as downstream points should be located. The criteria can be applied to any logically selected point in the stream system; then to other upstream or downstream points, as the results indicate, until the criteria are satisfied; or, using a more systematic procedure, begin just upstream from the most downstream cluster of mines and proceed upstream to other clusters until the criteria are met. The delineated watershed area between the identified points is the first approximation of the working CIA.

Phase II

In Phase II, the area delineated above is refined and redelineated. The **first step** (see pages IV-6 and IV-7 for outline of procedure steps) of this phase is to identify all "anticipated mining" within the area. The types of operations that must be included have been discussed previously (see pages IV-1 and IV-2) and their identification should be routine. Identification of the downstream limit of the surface-water CIA (Step 2) simply involves locating a point downstream from the confluence of a common receiving stream with any tributary channels whose flows are likely to be affected by mining. Any stream that drains any part of a mine plan area or is close enough to a mine area to be affected by ground-water impacts should be included.

The downgradient limits of the ground-water CIA are defined in Step 3. This involves identification of the areas in which the strata and water levels in the

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strata will be affected by mining or through which affected ground water may flow to reach a discharge point. Identification of strata likely to be affected by the anticipated mining operations and for which there is significant concern, and identification of aquifer recharge and discharge areas are a function of Element B and details of that process are discussed there.

The information necessary for delineation of ground-water drawdown areas and of areas through which plumes of degraded water may migrate should be available for all the anticipated operations which have submitted mine plans (PHC determination sections). For those operations for which PHC's are not available (qualifying leases), the regulatory authority will have to estimate the extent of these areas if this information is needed. Estimates based on information obtained from the PHC's of nearby operations should be adequate for most CIA delineation purposes.

Identifying those stream reaches in which the stream is losing water to the aquifer or gaining water from the aquifer may be more difficult, but this identification is important to understanding how the hydrologic system functions within the CIA. Such reaches are basically aquifer recharge or aquifer discharge (depletion) areas and therefore serve to transmit impacts from the ground to surface systems or vise versa. The PHC determinations in the individual permit applications should identify such reaches, but the regulatory authority should verify that all stream reaches important to the recharge or depletion of aquifers within the CIA have been identified.

Actual delineation of the working CIA is accomplished in Step 4. The procedure provides for separate delineation of surface- and ground-water CIA's; then, an area that encompasses both these CIA's is delineated as the working CIA.

The surface-water CIA boundary can be delineated by beginning at the downstream limits identified in Step 2.A and tracing along the natural drainage divides, or along the boundary delineated in Phase I, so as to completely encompass the impact areas of the operations identified in Step 1. The maximum upstream extent is the watershed boundary or any upstream limit identified in Phase I. It may be permissible to eliminate portions of this area. For example, if all the mining operations are on one side of a river valley, most of the watershed area on the opposite side of the river probably would not have to be included in the CIA because it is not directly impacted. However, the river valley floor and the floors of any common receiving streams must be included because these areas may be directly impacted, either by surface flows or by ground-water flows through the alluvium. The minimum working CIA should include the total watershed areas of all streams that flow across the mine plan areas of the anticipated mining operations and the proposed operation. It should also include all the area between any of the anticipated operations and the area from the operations to and including the valley floors common to receiving streams. Figure IV-1 depicts a surface CIA delineated by this procedure.

A ground-water CIA should be delineated for each impacted aquifer. The area over which a ground-water aquifer is impacted by mining basically extends from the minesites to the aquifer's discharge points. As with the surface CIA, an aquifer CIA should include all the area between the individual anticipated mining operations, as well as between the operations and the aquifer discharge points. In

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addition, areas of projected potentiometric drawdown resulting from pit dewatering and production water withdrawals must be included.

Most aquifers affected by surface mining will somewhere discharge to the surface. At these places, the ground-water impacts become surface-water impacts. These discharge points can often be considered as one boundary of the ground-water CIA. The discharge areas of some regional aquifers may be so far away from the mined area that migration of degraded water to these points will take many years. The CIA boundaries for these aquifers can be taken as the estimated extent of degraded water plumes at a selected point in time after the plumes begin migration from the reclaimed spoils. Rationale for the time period used in these calculations should be discussed in the findings. The boundary of the aquifer CIA should surround the maximum extent of all degraded water plumes and drawdown cones expected to occur in the aquifer, including the areas between individual plumes and cones.

The ground-water CIA is the composite area of the individual aquifer CIA's, and, finally, the working CIA is the composite of the surface- and ground-water CIA's. Figure IV-2 depicts a ground-water CIA delineated by the outlined procedure. The working CIA, composited of the CIA's depicted in figures IV-1 and IV-2, is shown in figure IV-3.

Procedure for Delineating the CIA

(Evaluate interactively with Elements B and C)

Phase I.--Define maximum upstream and downstream extent of CIA.

Step 1. Develop criteria for excluding operations from the CIA that are spatially remote from the proposed operation but that are within the same major surface drainage system.

Step 2. Apply criteria to locate maximum extent of working CIA, both upstream and downstream from the proposed operation.

Step 3. The watershed area between these points is the first approximation of the CIA.

Phase II.--Delineate working CIA within area defined in Phase I.

Step 1. Identify all anticipated mining operations (i.e., life-of-mine areas of proposed operation, existing operations, operations with submitted applications, and Federal leases with diligence requirements) within the area defined in Phase I.

Step 2. Identify the downstream limit of the surface-water CIA.

A. Identify on a receiving stream common to two or more anticipated mining operations a point downstream from all tributary stream

channels whose flows are likely to be affected by the mining. Consider this point as the downstream limit of the surface-water CIA on that stream. Repeat on other receiving streams, as necessary.

Step 3. Identify the downgradient limit of the ground-water CIA.

A. Identify all geologic strata likely to be affected by the anticipated mining operations, including aquifers. Also, identify recharge and discharge areas for the aquifers.

B. Delineate area over which ground-water quantity and quality may be affected by the identified mines.

i. Delineate area of ground-water drawdown caused by each operation in each identified aquifer.

ii. For each identified aquifer, delineate area that ground-water pollution plume from each operation would pass through in moving from the mine to probable discharge points.

iii. Identify probable stream reaches that discharge into or receive discharge from ground-water aquifers affected by the identified mining operations.

Step 4. Delineate working CIA.

A. Surface-water CIA

i. Delineate surface-water CIA boundary along natural drainage boundaries which completely encompass all the impact areas of the operations identified in Step 2.A.

B. Ground-water CIA

i. Delineate ground-water CIA boundary to encompass the maximum extent of pollution plumes and areas of drawdown cones. Include all cones and plumes that affect or discharge to common surface streams or alluvial aquifers, or are contiguous with cone and/or plume of proposed operation.

C. The composite of the surface- and ground-water CIA's is the working CIA for the proposed operation.

The product of this procedure is a working CIA with which to begin CHIA evaluation.

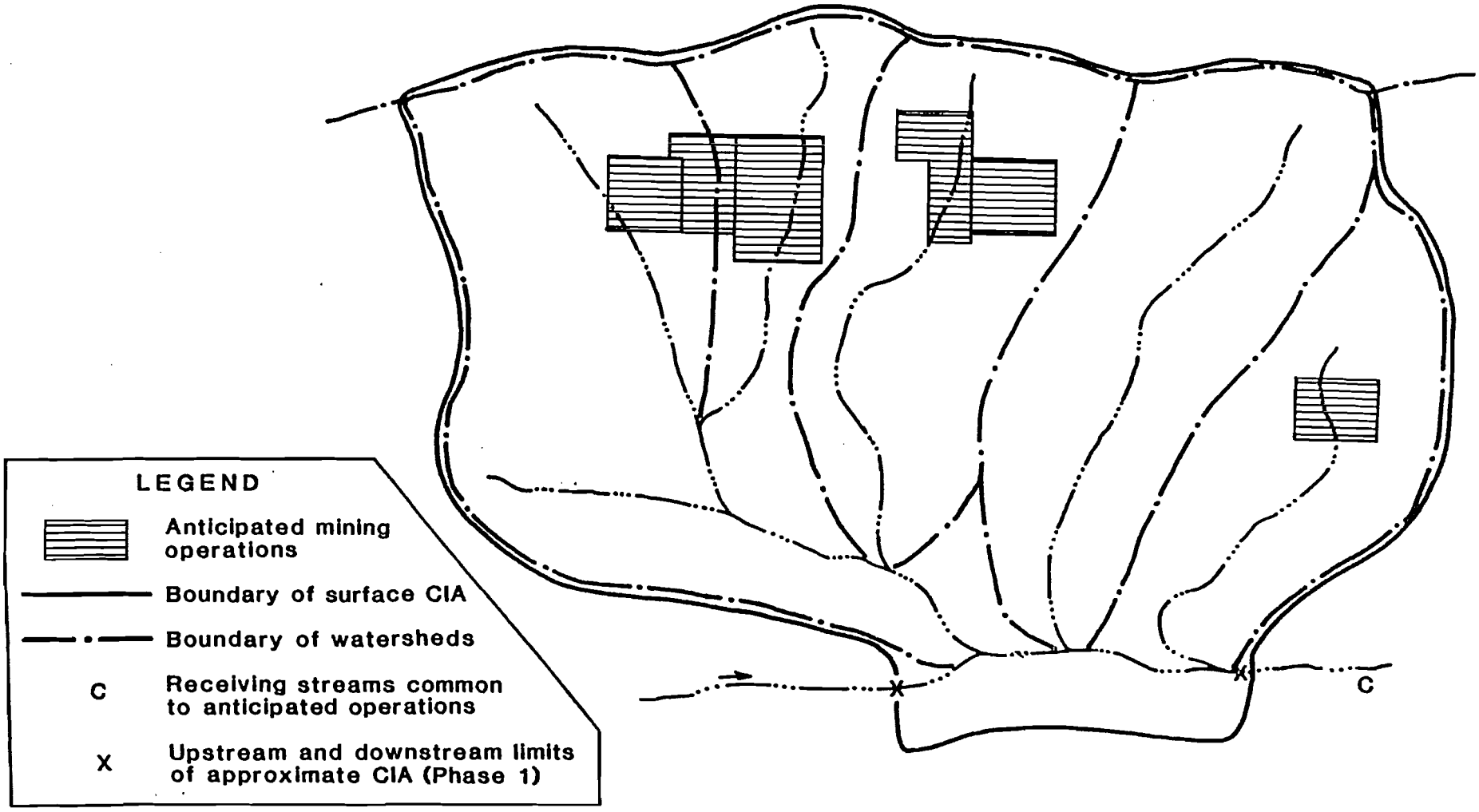

Figure IV-1.--Delineation of surface-water CIA.

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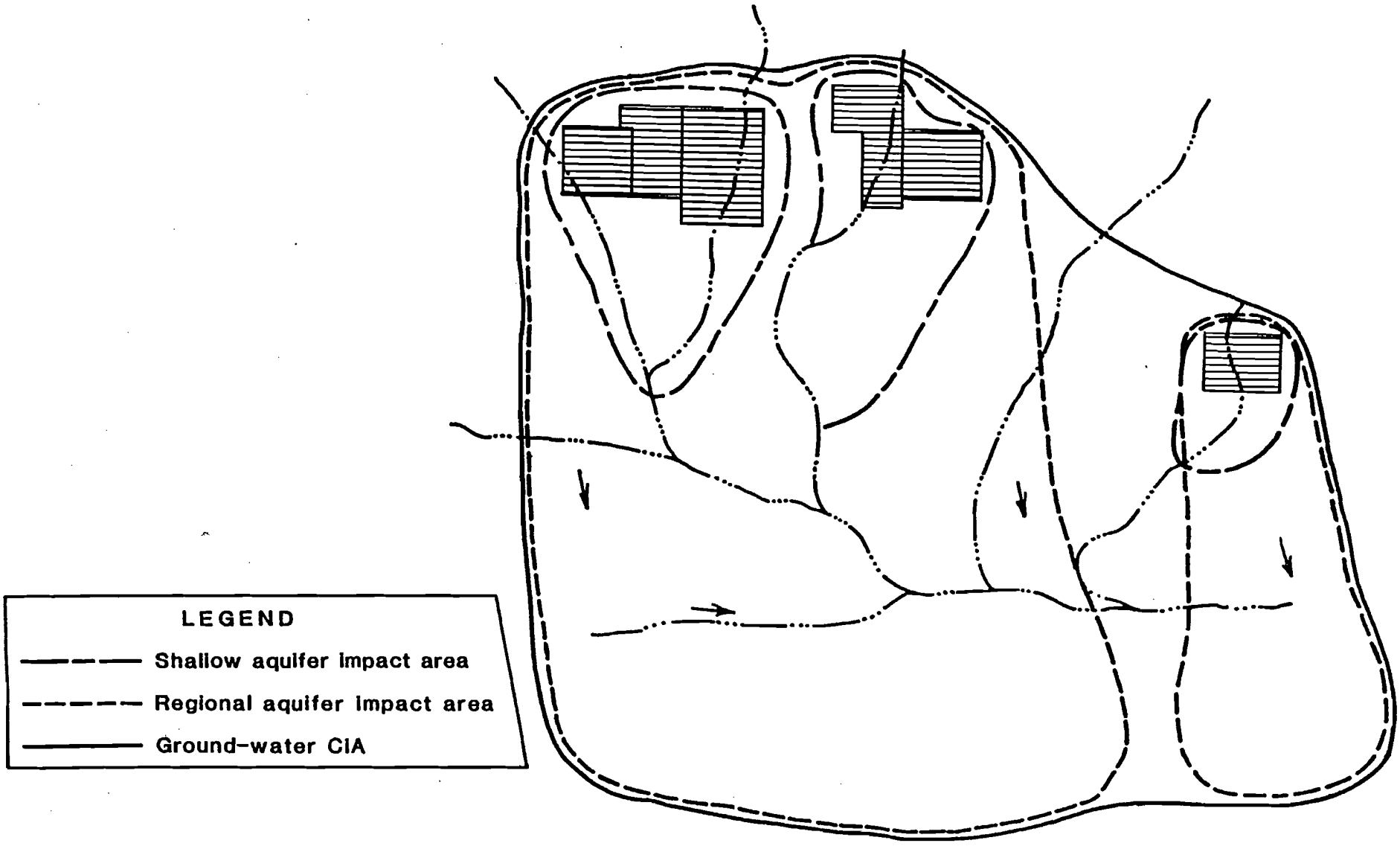

Figure IV-2.--Delineation of ground-water CIA.

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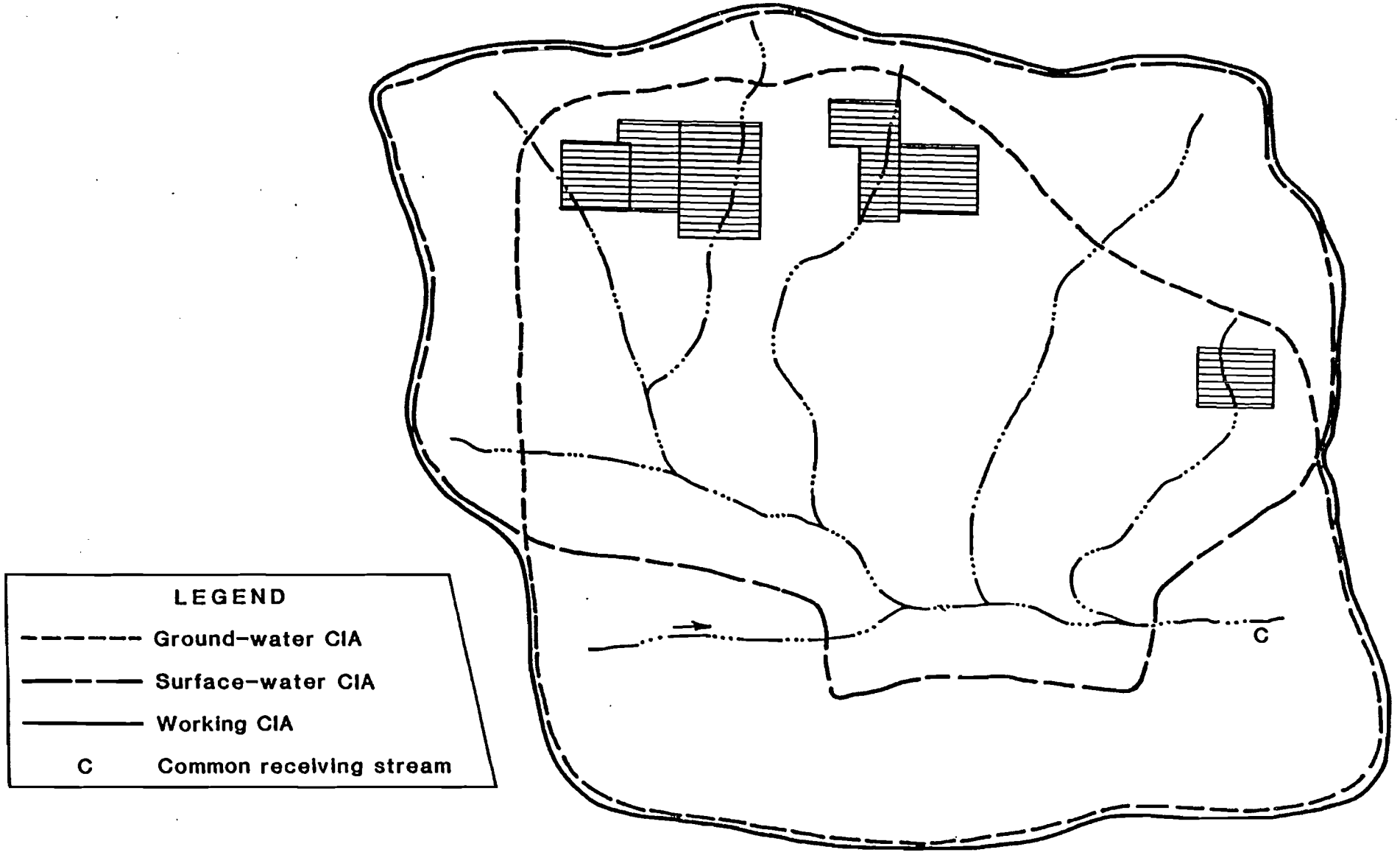

Figure IV-3.--Delineation of working CIA.

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ELEMENT B. HYDROLOGIC CONCERNS

The identification by the regulatory authority of hydrologic concerns (potential problems) related to the hydrologic balance and water uses that may occur or that may be compounded by the cumulative effects of the proposed mining operation and other anticipated mining operations is the function of Element B. The concerns identified in this element must have definable parameters so that material damage criteria may be established (Element D). The determination of hydrologic concerns has great significance to the CHIA process because these factors serve to define the collection requirements for baseline data, the CHIA techniques, and the determination of material damage. It must be remembered that additional or alternate hydrologic concerns may be considered by the regulatory authority to meet area-specific needs.

Baseline data that describe the hydrologic concerns in the permit area should be available in the mine-permit application. The PHC is described in the regulations and expanded in the PHC guidance document. Most concerns will be specified in the permit application, whereas some may be implied from hydrologic characteristics of the permit and adjacent areas. These concerns can be defined from the following information: (1) the location of the source of supply for all surface-water and ground-water uses, (2) the quantity and quality of water required to meet demands related to the different uses, and (3) the geomorphic processes that might be affected by changes in the water regimens. Also, publications of State agencies commonly provide information related to local or regional problems (see appendix B.1 in the appendices volume for sources of State water-quality standards) that may be applicable to specific concerns in the cumulative impact area. A literature search may be necessary to find applicable publications.

Hydrologic concerns are an expression of problems related to water use and the hydrologic balance that may occur as a result of coal mining. In order to determine the potential impact of the problems, it is necessary to select some physical or chemical parameters that are measurable and are representative of the problems.

The interrelationships between water use, hydrologic balance, and geomorphic conditions are shown in figure IV-4. Many of the hydrologic concerns that are identified will relate to more than one of the three listed factors. For example, flow rate can be related to water availability, seasonal variation, and channel erosion. The regulatory authority's objective is to identify quantity and quality parameters that will protect water use and the hydrologic balance and maintain geomorphic stability. Each factor should be considered separately.

Each water use should be identified in the cumulative impact area with the various types being grouped together. For example, irrigation uses will require water at about the same time and of the same quality. The quantity is usually related to flow rate and volume consumed per acre. The quality parameters for irrigation are usually total dissolved solids, sodium-adsorption ratio, and toxic elements, such as boron. The crops that are grown may have to be identified with respect to toxic element sensitivity in the impact area and would, therefore, have an impact on defining the cumulative impact area in Element A. Industrial and domestic water uses are quantified by diversion requirement and quality. Usually, domestic requirements are more restrictive than industrial. Domestic standards

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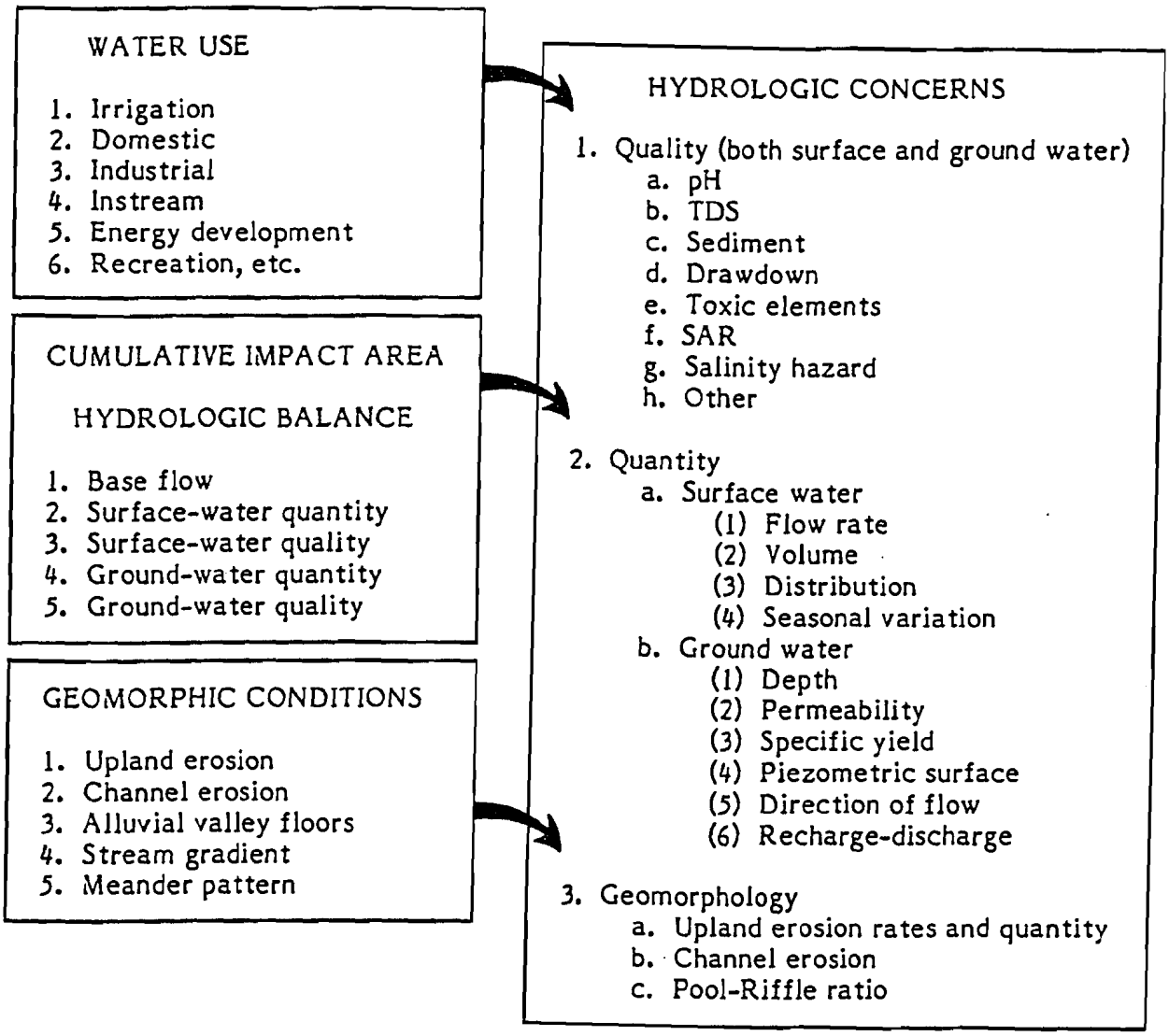

Figure IV-4.--Potential hydrologic concerns as related to cumulative impact area characteristics.

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relate to total dissolved solids, sulfates, nitrites, radioactivity, hardness, sediment, pH, Fe, Mn, and bacterial quality. Usually mining will not impact on the bacterial quality and radioactivity of water. Instream use usually requires a certain minimum flow before adverse impacts occur.

Instream uses, such as fish propagation, may also limit maximum temperature and pH ranges. These values are dependent upon species present. Unique situations may require other considerations, such as have been determined by the U.S. Fish and Wildlife Service for endangered species in the Upper Colorado River basin. They have determined that any withdrawal of water constitutes material damage to the Colorado River squawfish and the humpback chub. They have also specified a way that the impacts can be mitigated at this time to allow continued withdrawals from the streams.

The hydrologic concerns differ greatly in the different coal regions of the United States. This is because the potential impacts of coal mining are dependent on the hydrologic conditions, such as rainfall amounts, temperature, water uses, geomorphic conditions, and geology. For example, typical hydrologic concerns in areas associated with the coal fields of Western United States may include but not be limited to the following:

1. Reductions in the quantity of available surface water and ground water may be critical because existing supplies in the region are relatively scarce and commonly are completely appropriated under State water rights administration. Available supplies may be reduced as a result of changes in surface runoff conditions or lowering of ground-water levels. Beneficial changes can also occur, such as reducing runoff peaks through increased infiltration and increasing base streamflow through increased ground-water discharges.

2. Increases in total dissolved solids (TDS) or sodium-adsorption ratios (SAR) in surface water or ground water may cause critical production losses where supplies are used in irrigation of crops.

3. Increases in the concentration of total suspended solids (TSS) may cause destruction of aquatic habitat or the loss of reservoir storage capacity due to siltation.

4. Changes in flow rates or suspended solids load of a stream can change the erosional balance, which may cause geomorphic instability. The adverse impact may be lowering of ground-water levels because of the downcutting of channels acting as drains which result in the ground-water level being lowered below the plant rooting depths.

5. Changes in water quality may be critical where an increase of one constituent may adversely affect water uses, such as increased concentrations of boron, selenium, iron, or manganese.

Some examples of hydrologic concerns included in the CHIA for areas in Western United States are as follows: (1) Operations of coal mines in Wyoming would lower the ground-water level and reduce the yield from domestic and livestock wells, and (2) mining operations in the Yampa River basin of Colorado would increase the total dissolved solids in streamflow due to the increased

concentrations in surface runoff and in ground water draining from the disturbed areas. These impacts must be assessed, as discussed in Element E, and evaluated for material damage,as discussed in Element F. These are many of the concerns that must be considered by the regulatory authority.

Typical examples of hydrologic concerns in areas associated with coal mining in the Eastern United States may include but are not limited to the following:

1. Changes in the chemical composition of streamflow due to the addition of acid mine drainage (e.g. total iron, total manganese, and pH) may cause deleterious effects in water used for public supplies and maintenance of aquatic organism populations.

2. Increases in the sediment load from the disturbed areas of mines may cause destruction of aquatic habitat in streams and ponds.

3. Changes in conditions affecting surface-water runoff may add to the flood hazard of a watershed.

4. Disturbances of overburden due to mine excavation may increase the availability of some chemical constituents that cause deleterious effects in water (e.g., total iron, manganese, aluminum, total dissolved solids, etc.).

An example of hydrologic concerns included in the CHIA, for mining along the Shavers Fork River in West Virginia, focused on a set of conditions (acidity and iron) that related to probable degradation of the chemical quality of surface water. These parameters were identified as being critical to fish production.

These are typical hydrologic concerns and include only a small number of possibilities. At each specific site and cumulative impact area, the hydrologic concerns must be determined on the basis of water usage in the area, existing water-quality standards, and local hydrologic conditions.

When the hydrologic concerns are being defined for a specific impact area, it is recommended that an inventory be made of all water uses which includes identification of sources, quantity and quality requirements, quality, type of use, and any known or existing water related problems. Water-quality standards and water-quantity requirements associated with the identified water users should also be evaluated. This type of approach provides an effective means of determining the hydrologic concerns that are important in terms of protecting the hydrologic balance and associated water uses. A similar inventory should be made regarding the geomorphic characteristics important to water uses that may be impacted by mining, such as alluvial valley floors, riparian zones, pool-riffle ratio, and sinuosity.

Table IV-1 has been included as a quick check to determine whether proper information has been evaluated to identify hydrologic concerns for the cumulative impact area identified in Element A. If this process is followed by the regulatory authority, it should protect the water resource values with respect to use, as

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affected by water availability and water quality. The information presented in table IV-1, although not an exhaustive list, is an example of some of the steps the regulatory authority should complete in order to identify the hydrologic concerns. It may be expanded or reduced to suit area-specific conditions and considerations.

Table IV-1.--A partial list of types of information to define and evaluate hydrologic concerns

1. Define and quantify existing and projected water uses related to:
   a. Available surface-water supply.
   b. The quality of surface water in the basin.
   c. Available ground-water supply.
   d. The quality of ground water in the basin.

2. Describe existing and potential hydrologic problems related to:
   a. Concerns identified in mine-permit application.
   b. Concerns identified in previous CHIA studies.
   c. Problems identified in regional studies by State agencies.
   d. Water-quality problems that could be created by the chemistry of the overburden.
   e. Changes in runoff characteristics that cause geomorphic instability.

3. Select representative parameters for quantifying hydrologic concerns in order to evaluate changes and assess impacts on the hydrologic balance.

Table IV-2 contains the hydrologic concerns for a hypothetical example for the Black Hole mine. It lists the hydrologic concerns, the physical or chemical characteristics, and the specific parameters to use as a measure of the impact with respect to material damage. Procedures for identifying material damage threshold values are presented in Element D.

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Table IV-2.--Hydrologic concerns for Black Hole example mine CHIA

Concern	Physical-chemical characteristics	Specific parameters
	Surface water	
Damage to fishing stream	Mean flow	Mean monthly discharge.
	Low flows--rate and duration	7-day, 10-year discharge ($7\text{-}Q_{10}$).
	Temperature	Degrees Celsius.
	Alkalinity, acidity, pH	$CaCO_3$ equivalent, pH.
	Suspended solids	Concentration at $7\text{-}Q_{10}$.
	Salts	TDS, sulfate ion.
Reservoir--fishing and irrigation	Stream inflows	Minimum annual volume.
	Alkalinity, acidity, pH	$CaCO_3$ equivalent, pH.
	Sediment	Annual volume.
	Suspended solids	Concentration during storm inflow.
	Ground Water	
Municipal wells	Water level in aquifer A	Percent of baseline saturated thickness.
	Water level in aquifer B	Percent of baseline saturated thickness.
	Salts	TDS.
	Geomorphology	
Potential upland headcutting	Hillslope gradients	Average slope, percent.
	Channel gradients	Maximum slope, percent.

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ELEMENT C. BASELINE HYDROLOGIC INFORMATION

The assembly and evaluation of hydrologic baseline information by the regulatory authority is the function of Element C. The purpose of this information is to characterize the hydrologic system and define imposition of changes by the proposed mine operation. Much of the needed hydrologic and geologic information should be available in the mine-permit applications. Details of collecting and assembling these data are discussed in "Guidelines for a Probable Hydrologic Consequences Determination." Additional baseline data needed for parts of the cumulative impact area outside the permit boundaries must be obtained from other sources, such as the U.S. Geological Survey publications or other Federal and State data collection agencies. With the data presented in the PHC portion of the individual mines and other available data, the regulatory authority must be able to describe the hydrologic system sufficiently to understand the ground-water and surface-water interactions with respect to "anticipated mining" and the hydrologic concerns identified in Element B. The description should at a minimum describe the components of the hydrologic balance that must be protected. The baseline data should provide a basis for assessment of mining impacts with respect to the hydrologic concerns and be used to determine material damage. Establishment of material damage values or thresholds for the hydrologic concerns is covered in Element D.

Appendix C.1 provides potential sources of data from each State that may be useful to the regulatory authority to supplement baseline data contained in the PHC portion of the permit application. Data from outside the permit areas necessary to perform the CHIA must be available to the regulatory authority. For this reason it is essential for each regulatory authority to identify available hydrologic data associated with coal-producing areas of the State. When additional baseline data are required but are not site specific or are not contained in the permit applications, they must be obtained from other available sources, such as Federal and State agencies. The needed baseline data may also be provided by the mining company to expedite permit processing. These data requirements need to be identified as early as possible in the permitting process. It is essential that the information be sufficient to clearly define the hydrologic system, provide required data for analysis of the impacts, and provide a sound basis for assessment of material damage.

Data availability can be a major factor in selecting downstream boundaries of cumulative impact areas. For example, a long-term USGS stream-gaging station that collects both quantitative and qualitative data would provide good baseline data and control for the assessment of impacts. Additionally, the regulatory authority can use future data collected at the station as a check to evaluate the accuracy of the CHIA's and to monitor actual impacts of mining with time. The shorter periods of records collected at the minesites can be correlated with the longer records. These correlations can be used to describe the seasonal variation and to project both high- and low-flow values.

The duration and frequency of sampling required for baseline data should be based on the hydrologic concerns and the variability of the data. For example, streamflow changes rapidly during intense rainfall events. Usually, water-quality parameter values change with the discharge. Hydrologic data covering these situations are important to the understanding of the hydrologic balance of the cumulative impact area for determining the cumulative impacts.

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Baseline data required to define surface-water systems commonly include both quantitative and qualitative information. In order to determine the adequacy of baseline data, it is necessary to describe the hydrologic systems in the cumulative impact area and to describe the type of information needed to define the functions and importance of those systems to the hydrologic balance. Existing baseline data from the permit application should be evaluated with respect to the methods of collection and analysis and the lengths of record. Other sources of hydrologic information also should be investigated, such as the Bureau of Land Management, U.S. Geological Survey, State Engineer, State water-quality agencies, etc. Apparent data deficiencies with respect to coverage, period of record, quality, etc., should be identified. The location and method of data collection for all planned monitoring sites set forth in the permit application should be evaluated with regard to applicability for mining and postmining information. Data related to streams may include quantitative values of average weekly or monthly flows, flow duration, flood-frequency distribution, and low flows. Data related to the quality of water in streams should include concentrations of dissolved constituents (particularly those elements or compounds having health, use, or regulatory limits that are associated with the hydrologic concerns), and the concentration and volume of suspended sediment (annual load or basin yield). Data associated with the use of surface water should include the location and rate of all diversions, the changes in diversion rights during periods of reduced streamflow, the quality standards in relation to the principal users, the rate and volume of use in relation to seasonal requirements, and the quantity of water exported from the basin. These baseline data must reflect the hydrologic concerns identified in Element B with respect to quantity and quality parameters.

Baseline data required to define ground-water systems commonly include a description of the lithologic, structural, and hydrologic characteristics of geologic units within the aquifer and overburden systems, the rate and direction of water movement as defined by the water table or potentiometric surface, the rate and direction of water movement between aquifer units or between the aquifer and associated streams, and the location and rate of recharge or discharge. Some of these baseline data may require measurement and testing, such as determining the aquifer properties of porosity, permeability, hydraulic conductivity, transmissivity, specific yield, and storage coefficient.

Data related to the quality of ground water generally includes the concentration and areal distribution of dissolved constituents, with particular emphasis on those elements or compounds having health, use, or regulatory limits. Additional data may be obtained for determining the quality of water contributed to the aquifer from recharge, the direction and rate of chemical transport, and the associated diffusivity, dispersivity, or geochemical reactions that could occur within the geohydrologic system.

Other data related to the use of ground water include the location and source of supply from all wells and springs, the rates of daily and seasonal withdrawals, and the quality of water in relation to the standards required by the principal users. Additional data should be obtained for determining the return flow to the aquifer or stream and the losses through evaporation and transpiration.

The baseline data should be collected at sites (ground water and surface water) located with respect to the impact areas, the anticipated mining and whether or not they can also be used as impact evaluation sites. It is imperative

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that these sites be near the mining operation to reflect the hydrologic changes. Also, the points must be readily accessible for current and future data collection in order to monitor actual conditions. Data obtained at the evaluation must be reflective of the identified hydrologic concerns and must be quantifiable in terms of the criteria established for material damage. When future monitoring data are available for comparison with estimated values, verification of results can be used to improve the predictive capabilities of the regulatory authority.

Tables IV-3, IV-4, and IV-5 have been included for use to evaluate the adequacy of the baseline data. These tables should not be construed as providing exhaustive or mandatory lists. The regulatory authority should carefully review these tables and modify them to meet site-specific conditions. Table IV-3 covers surface water, table IV-4 covers ground water, and table IV-5 covers the geomorphic conditions that relate to erosion and stream channel stability. Both the upland and channel erosion are of concern and must be considered in the determination of material damage. The regulatory authority must determine how important the geomorphic considerations are with respect to each mining environment.

Table IV-3.--Baseline hydrologic data useful for characterizing the surface-water system

1. Description of drainage basin in relation to runoff.
   a. Total area, topographic relief, basin length, and average basin slope.
   b. Precipitation records that include monthly or seasonal data for snow pack accumulation and rainfall.
   c. Geologic characteristics that affect runoff or streamflow.
   d. Chemical and physical properties of the overburden.
   e. Soil characteristics from soil surveys with respect to infiltration, runoff, and erosion.
   f. Summaries of vegetation types and land use.

2. Description of streamflow characteristics.
   a. Type of streams (perennial, intermittent, or ephemeral).
   b. Streamflow data collected and tabulated to describe mean annual and mean monthly discharges.
   c. Streamflow related to frequency and duration of floods to include:
      (1) Floods of 2-, 10-, 25-, and 100-year recurrence.
      (2) Flows of different frequency and duration for structure design.
   d. Nature of frequency and duration of low flows related to water use:
      (1) Quantitative diversion rights.
      (2) Low-flow water quality related to stream standards and water user needs.
      (3) Annual low flows and period of occurrence.
      (4) Relate low flows to normal base, mean annual, and high flows.
   e. Water quality characteristics with respect to seasonal flow:
      (1) Major ions (Ca, Mg, Na, K, HCO_3, CO_3, Cl, SO_4, TDS).
      (2) Trace elements (Fe, Mn, As, Hg, B, Pb, Zn, Ag, Cu, Cr, Ba, etc.).
      (3) Other (temperature, pH, suspended solids, settleable solids, bacteria)

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Table IV-4.--Baseline hydrologic data useful for characterizing the ground-water system

1. Physical description of aquifer (or aquifers) in relation to the geohydrologic framework of the area.
   a. General description of aquifer units in relation to other stratigraphic units.
   b. Physical description of aquifer and associated confining beds as indicated from test holes, drillers' logs, and geologic maps to include: (1) extent, (2) thickness, (3) lithology, (4) structure, and (5) type of rock.

2. Hydrologic description of aquifers
   a. Description of aquifer in terms of well yields and water use.
   b. Description of confined or unconfined aquifer conditions.
   c. Definition of water table or potentiometric surface as determined from test holes and observation wells.
   d. Delineation of saturated thicknesses, direction of water movement, and areas of recharge and discharge.
   e. Determine gain or loss of base flow in streams in relation to associated ground water.
   f. Water movement between aquifer units and between the aquifer and streams.
   g. Aquifer properties determined by testing that include porosity, permeability, hydraulic conductivity, transmissivity, specific yield, and storage coefficient.

3. Chemical properties of water in the aquifer.
   a. Major ions (including Ca, Mg, Na, K, HCO_3, CO_3, Cl, SO_4, TDS).
   b. Trace elements (including Fe, Mn, As, Hg, B, Pb, Zn, Ag, Cu, Cr, Ba, etc.).
   c. Other (temperature, pH, bacteria).

4. Characteristics of overburden
   a. Physical destruction of resistant rocks into an erodible aggregate.
   b. Potential chemical constituents from the disturbed overburden that may affect the water quality (acidity, alkalinity, salinity, and other toxic elements).

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Table IV-5.--Baseline hydrologic data useful for characterizing the geomorphic stability

1. Basin characteristics related to sediment discharge.
   a. Description of basin in terms of area, length, slope, etc.
   b. Describe geologic characteristics that affect runoff and sediment yield.
   c. Summarize the type and extent of different soils with respect to erodibility.
   d. Summarize the type and extent of vegetation and land use.
   e. Describe channel conditions prior to mining (bedrock bottom, stream bottom, armored, bank conditions, riparian, etc.)

2. Stream characteristics related to sediment discharge.
   a. Type of stream (perennial, intermittent, or ephemeral) in relation to general flow characteristics.
   b. Define nature of flow related to frequency and duration of 2-, 10-, and 25-year floods.
   c. Describe such stream channel characteristics as width, depth, gradient, sinuosity, etc.
   d. Obtain samples of suspended sediment and bed load related to a broad range of stream discharges.
   e. Estimate hydrologic characteristics of ungaged streams on the basis of channel geometry (methods have been described by USGS for most Western coal areas).

3. Erosion and sediment potential in mined areas:
   a. Describe probable effects of erosion and sediment yield during the mining and reclamation phases.
   b. Estimate flow and sediment yield from 2-, 10-, and 25-year floods for design of sediment control structures.
   c. Relate proposed drainage design to geomorphic stability of mined areas after reclamation.

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ELEMENT D. ESTABLISHING CRITERIA FOR DETERMINATION OF MATERIAL DAMAGE

Section 507(b)(11) of the Act requires a determination of probable hydrologic consequences caused by mining and reclamation operations, both on and off the minesite. However, the CHIA process for permit approval or denial under Section 510(b)(3) of the Act requires that these impacts be evaluated to determine whether the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area. Therefore, the regulatory authority must have and must include in the assessment report the criteria by which the potential for material damage can be assessed. These criteria are needed for comparison with the quantitatively or qualitatively predicted impacts of mining that will be obtained through the process outlined in Element E. The product of Element D will be a set of site-specific values for selected parameters used to measure the material damage at each of the predictive points identified in Element B. The criteria should be established prior to completing the projection of impacts in Element E.

There are two bases for the development of these criteria. One is the evaluation of material damage in terms of the effects on the hydrologic system. For instance, a logical extension of the discussion of hydrologic balance concepts (Chapter III) would be to define material damage in terms of the statistics of the premining relationship (A in fig. III-3). For example, if the increment of change from premining to postmining conditions exceeds one standard deviation, the regulatory authority may determine that that change constitutes material damage. The regulatory authority may determine that some other deviation is a more appropriate threshold. Another example would be to express material damage in terms of the proportional disturbance of the cumulative impact area (i.e., material damage will occur if more than a defined percentage of the area is disturbed). Basing material damage criteria on the characteristics of the system is a plausible approach, but it may present difficulties in establishing workable criteria.

The other, more obvious approach is to establish material damage in terms of specified water uses. It is a common regulatory practice to focus on designated uses. However, material damage criteria based on water use should consider both instream and out-of-stream requirements. This means that water-contact recreation, fish habitat, and the needs of aquatic organisms must receive equal consideration with industrial, domestic, and agricultural uses. Although either approach is acceptable, and in some cases the use of both may be desirable, regulatory authorities will probably base material damage criteria on water use considerations.

Discussion of Procedure for Defining Material Damage Criteria

The material damage criteria, of course, cannot require less than the existing laws, standards or regulations. Therefore, the **first step** in developing these criteria is to assemble all existing standards and determine which apply to the cumulative impact area and to the identified hydrologic concerns. Most established standards relate to water quality and its effect on specific uses. Water quantity generally is regulated through water rights laws.

On the Federal level, the Environmental Protection Agency is the major source of standards on water quality. At the State level, several agencies may

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have established standards relating to water quality, rights and use. Appendix B.1 in the appendix volume lists the primary agencies in each State that are possible sources of existing water-quality standards. Counties and cities may also have established standards for water protection and use, especially in metropolitan areas, and should be considered a possible source of existing water standards. It may be expedient to develop an exhaustive listing of standards during the initial cumulative hydrologic impact assessment so that subsequent impact assessments would require only the addition of newly established or modified standards.

After all of the applicable water use standards that apply to the cumulative impact area have been assembled, it should be determined which of the hydrologic concerns and associated parameters identified in Element B are not covered by these standards and which concerns are only partially covered. Also, it may be determined that some of the existing standards are not as stringent as the regulatory authority deems necessary, thus requiring new standards. At this stage, it is assumed that the identified concerns and associated parameters address all the required and desirable aspects to be assessed in the hydrologic system, particularly ground-water and surface-water quality and quantity, and any concerns for the geomorphic stability of the cumulative impact area.

The second step of Element D is the development of criteria for the concerns that are not adequately covered by existing standards. In any given region, standards for an identified concern may be lacking. Concerns that are most likely to lack standards are those relating to ground water and geomorphology. Few States have standards that apply to ground water, and probably none have standards that apply directly to geomorphology. Because entities other than the SMCRA regulatory authority may be trying to resolve many of the same issues (such as agencies that regulate sanitary landfills and toxic waste disposal areas), such agencies should be contacted for suggestions regarding the development of needed criteria. In fact, it would be advisable to develop a statewide policy on protection of hydrologic resources prior to the time specific standards are needed. Then all State-developed standards would have a common basis, which would minimize the possibility of conflict between material damage criteria and the requirements of other regulatory agencies.

One of the more difficult and crucial tasks in the CHIA process is the development of material damage criteria for concerns that have no existing standards, or for which existing standards are not sufficiently comprehensive or stringent. These criteria should be developed cautiously because they may become precedents for establishing the State or areawide standards. Because the criteria must be tailored to regional needs, only general guidance can be provided here.

SMCRA specifically requires the assessment of cumulative impacts "particularly upon water availability * * *" (Section 507(b)(11), and by implication requires that the available water be of adequate quality for the uses designated by the regulatory authority. Development of criteria for limiting changes in surface water discharges commonly will be based on use requirements that are specified by existing water rights. The quantity requirements should consider the probable postmining uses and existing uses, including instream uses and the variation of water quantities used throughout the year. The effects of changed discharge regimes on channel stability also should be considered. Increases in peak discharges may create a flooding potential that could result in channel degradation. On the other hand, a diminished flow regime may cause sediment deposition in

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stream channels, an undesirable condition for most instream water uses. On the assumption that water rights require approximate maintenance of premining water quantities and that increases or decreases in stream discharges may cause changes in channel morphology, material damage criteria should be designed to maintain the flow regime within a small percentage of the baseline quantities.

The major concerns about the cumulative impacts of the mining on ground-water availability tend to focus on the maintenance of streamflows and pumping requirements. The drawdown of the potentiometric surface in the vicinity of the mine is a common impact of mining on the ground-water system. Thus, it is logical to express material damage criteria for ground-water quantity in terms of the potentiometric surfaces affected. Because high water tables also can cause problems in some areas, the criteria may need to address both rises and declines in the potentiometric surface. The development of these criteria then becomes a matter of determining how much change in the potentiometric surface can be sustained without causing material damage to the hydrologic balance of the ground-water system.

Although ground water and surface water are presented as separate entities in this guidance document, it is imperative that the relationship between them be understood and considered in setting limiting criteria. Some items that should be considered are the interrelationships of surface and ground water, long-term rate of recharge to the aquifers, rate of recharge to the reclaimed spoils, rates of recharge relative to rates of use, and the possible impedence of ground-water movement by the reclaimed spoil material.

The increased public concern during the past decade and a half for the quality of the nation's water supplies has led to the establishment of water quality standards by various regulatory agencies. These standards generally are based on the maintenance and protection for specified water uses. Although standards for surface water are most numerous, some States also have established standards for protection of ground water. Material damage criteria for both ground-water and surface-water quality can be developed, in many cases, from existing standards; several sources of information are available to the regulatory authority for guidance. The regulatory authority in nearby States may have established standards for similar concerns. Another source of information is a compilation by McKee and Wolf (1963) regarding the water-quality criteria promulgated by State and interstate agencies as well as legal application of such criteria. Also, EPA (1976) has provided information on the toxic levels of many water polluting substances relative to specific uses. In situations where the aquifer discharges into the surface stream system, the effects of this discharge on the quality of surface flows should be considered in developing ground-water material damage criteria.

Geomorphic concerns probably will focus on channel and hillslope erosion most often. The most likely areas of cumulative concern are increased sediment loads in the streams, the possibility of channel downcutting with its attendant dewatering of alluvial aquifers, and dissection of the land surface with gullies. Criteria for addressing these problems probably should focus on limiting channel and hillslope gradients in the reclamation areas. Hillslope gradients which are within approximate original contour requirements (30 CFR 816.100-106) may not be adequate in terms of erosion potential. In the Western United States, landscapes commonly are carved in layers of erosion-resistant rock that keep stream gradients relatively steep. After the mining process breaks up these

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supporting layers into a variety of smaller fragments, stable gradients for both hillslopes and channels are likely to be different from the premining gradients. The material damage criteria must assure erosively stable slope gradients relative to expected postmining conditions (i.e. vegetative cover, particle-size distribution of reclaimed overburden, etc.).

Step three involves establishment of criteria for any aspects of material damage assessment that have not been categorized. A possible example of this type is the consideration of whether incremental change limits are needed for some parameters.

There is a possibility that the impacts of a single mining operation may "use up" the total allowable change from baseline levels to the maximum allowable limit. To prevent this possibility, it may be necessary to set incremental change limits for some parameters. However, actual changes should already be at a minimum if the permitted operations are, in fact, designed to minimize the impacts to the hydrologic balance, as required by the regulations.

The nature of other hydrologic concerns may dictate that limits be set on the time-rate of change of certain parameter values. For example, some species of aquatic life may be able to survive relatively high water temperatures, but the rate of change of the temperature must be commensurate with the organisms ability to acclimate to temperature changes. The acclimation rate will differ with species and rate-of-change limits may be necessary to assure survival of the specific species. Dissolved oxygen content is another parameter for which rate-of-change limits may sometimes be necessary. The need for both types of incremental limits should be considered in the process of developing material damage criteria.

Step four of Element D suggests that the regulatory authority the design of a specific set of material damage criteria for each evaluation site identified in Element B. Site-specific criteria are necessary because each site could have a different set of conditions to be evaluated. The design of these criteria sets should be a relatively simple part of the process if Steps 1 through 3 have been properly completed. EPA (1983, Chapter 11) has published guidelines for deriving site-specific water quality criteria. The regulatory authority may wish to use these EPA quidelines to develop site-specific material-damage criteria, or to use them as a pattern for its own guidelines. The product of this step and of Element D is a listing of the material damage criteria for each parameter identified at each evaluation site.

Once criteria have been established for the coal-producing areas of a State, they should be applicable to subsequent CHIA's without additional developmental effort. Periodic review and updating should assure that the correct criteria are available at any time.

Procedure For Defining Material Damage Criteria

The following steps are suggested as a process for establishing material damage criteria:

1. Assemble existing State, Federal, and local standards which apply to the expressed hydrologic concerns (product of Element B).

a. Source of standards.

(1) U.S. EPA.

(2) State agencies.

(3) City and county agencies.

b. Identify parameters not adequately addressed by existing standards by comparing existing standards and identified parameters.

2. Develop limiting values for parameters associated with hydrologic concerns not covered by existing standards.

a. Water quantity.

(1) Consider any quantity change defined by applicable water rights.

(2) Consider needs of probable uses.

(3) Consider possible channel stability problems resulting from discharge changes.

b. Water quality.

(1) Consider standards used by surrounding States.

(2) Consider quality requirements for present and potential uses.

(3) See U.S. EPA (1976) and McKee and Wolf (1963) for suggested limits of specific constitutients relative to use.

c. Geomorphology

(1) Consider need for reduced channel and hillslope gradients in the postmining environment.

3. Develop any additional criteria considered necessary for an adequate assessment of material damage.

a. Need for incremental change (or time rate of change) limits.

4. Establish a site-specific set of material damage criteria for each predictive point identified in Element B. These sets of criteria are the product of Element D.

a. Apply appropriate criteria from lists developed in Steps 1 through 3.

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ELEMENT E. ANALYSIS OF CUMULATIVE HYDROLOGIC IMPACTS

Analysis of the hydrologic system with the imposed stress of the anticipated mining to determine its probable impacts and their magnitudes is the goal of Element E. More specifically, the regulatory authority's task involves estimation of the magnitudes of changes that the indicator parameter values can be expected to experience as a result of mining. Accomplishment of this task may best be achieved by first selecting an analytical approach, then selecting the specific techniques and methodology to be used, and, finally, making the analysis.

Two basic analytical approaches have commonly been used to date in the development of CHIA's. One approach is to combine the results (estimated values of indicator parameters) presented in the PHC portions of individual mine plans into composite impact values for the CIA. Use of this approach requires the regulatory authority to develop PHC's for any "anticipated mining" operations for which PHC's are not available (leases, 2-acre exemptions, etc.). The other approach is to make an independent hydrologic analysis of the CIA, using the data provided in the permit application package and in the PHC portions of other applicable mine plans, as well as pertinent data from any other sources. In a given situation, one or the other of these approaches may be appropriately used.

The basic difference between the two approaches is **not** a difference of specific techniques used with each approach; rather, it is one of how selected techniques are applied and by whom. The PHC of each mine operation is normally determined by a different analyst using a different specific set of analytical techniques. Under the combinational approach, the actual combining of these PHC results to obtain the cumulative impacts would involve yet another set of techniques and another analyst (that is, the regulatory authority). Each analyst is likely to make his own assumptions about the hydrologic system. The combination of results obtained from such unrelated bases may invite severe criticism if not rejection. With the independent analytical approach, the same set of techniques would be applied over the whole CIA by the same analyst(s). Therefore, the independent approach could generally be expected to give the most consistent, uniform, and accurate results. From a strictly hydrologic standpoint, the independent analytical approach would be valid in all cases. Use of the combinational approach would be most appropriate early in the development of an area when cumulative impacts could be expected to be small.

Once an analytical approach is adopted, suitable hydrologic estimation techniques can be selected. If the combinational approach is used, specific analytical methods and techniques are not needed because estimates of impacts should already exist in the individual PHC's. However, suitable procedures for combining parameter values are needed because the simple addition of values is not a valid combinational procedure for some hydrologic parameters. For example, flow routing procedures are necessary for combining the peak discharges of two streams, and a discharge-weighted average procedure is needed to determine the concentrations of substances at different locations in the stream system. Therefore, for the combinational approach, the regulatory authority needs to select or develop valid procedures by which results of the individual PHC's can be combined.

If the independent analytical approach is used, then appropriate analytical methods and techniques must be selected. Technique selection depends on many

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factors, but a primary consideration should be that the technique adequately account for the dominant physical processes occurring in the hydrologic system being evaluated. The required degree of accuracy is another important consideration. In some cases, a worst case analysis may be adequate. However, when values of the indicator parameters approach the material-damage threshold levels, more rigorous and accurate techniques may be needed to verify that the material damage thresholds are not violated.

Methods for predicting cumulative impacts may be classified into the following broad categories:

1. Qualitative methods.

2. Empirical equations and statistical correlations.

3. Physical process models of the hydrologic system.

Qualitative methods are those which provide for systematic evaluation of qualitative data inputs and predict a range of output values. They rely heavily on the judgment of the user, who should be a competent hydrologist and highly knowledgeable about the method and the CIA being assessed.

The second category includes a wide range of techniques, equations, and statistical correlations by which values of various hydrologic parameters, under specified conditions, can be calculated. The universal soil loss equation (Wischmeier and Smith, 1965), the Theis equation (Theis, 1935), and the Muskingum flow routing equation (McCarthy, 1938) are examples of techniques in this category. Brief discussions relative to the specific uses of these and other methods in categories 2 and 3 can be found in appendix D.1.

A complete hydrologic analysis would require application of one or more of these techniques in proper order. Thus, the Theis equation would be used to calculate aquifer transmissivity and storage coefficients from pump test data, and these parameters would, in turn, be used to calculate aquifer flow rates and the extent of drawdowns. For CHIA analysis, the appropriate methods would be systematically applied to all mine operations in the CIA, giving appropriate consideration to possible effects of adjoining operations. These calculations can be facilitated by use of programmable hand-held calculators or minicomputers. Programs for many of these methods are generally available (Croley, 1977; OSM, 1981).

The final category of techniques is comprised of hydrologic models which simulate the physical processes in the hydrologic cycle with mathematical equations. In all but the simplest hydrologic systems, the equations governing the system processes are either too numerous or too complicated to be solved by direct mathematics. Therefore, the high speed computational capabilities of digital computers are usually needed to solve the equations.

Models provide the analyst with a means of integrating the responses of interrelated processes of the hydrologic system. In this way, all processes of the system can, in theory, by analyzed with a single procedure. Because all components of the system are automatically and systematically considered, the model and its solutions should more nearly reflect real physical systems than does

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the piecemeal application of individual category 2 techniques. However, the underlying concepts of the individual models and the availability of data are also extremely important to the analysis outcome. In any case where the data base is extensive enough to allow adequate calibration and verification of the models for each set of watershed conditions to be modeled, then physical process models should give excellent results and their use should be strongly considered for that particular CHIA analysis.

Hydrologic models have been designed to accomplish a wide variety of analyses. To date, the need for a single model that analyzes all aspects of the hydrologic cycle has been limited. The complexity of such a model would tax the computational abilities of even today's high-speed computers. Therefore, most physical process models are limited to a particular segment or segments of the hydrologic cycle. Some model the surface-water processes; others, the ground-water system. Still others deal with water pollutants and their transport through the system. A comprehensive surface-water model would include routines for modeling the dilution and transport of water-quality constituents, as well as the generation of upstream and upland runoff volumes and stream discharge rates.

Models also vary in the degree of capability. Some will generate water volume input (surface runoff or aquifer recharge) and route this water into and through the stream channel or aquifer systems. Others only route through the system water quantities calculated by other methods. The same alternatives are available for water quality models.

Another division of model characteristics is between long-term or continuous models and those that only simulate individual storm events. Event models simulate the effects of selected storms on a given set of antecedent conditions. Several simulations using selected antecedent conditions for critical periods of the hydrologic cycle would be necessary for a CHIA analysis. Continuous models account for the cumulative effects of precipitation, evapotranspiration, soil moisture storage, pollution buildup, and so forth; therefore, changes in antecedent conditions are automatically and continuously updated during a simulation run. A CHIA assessment done completely by modeling would require a full range of model capabilities.

Whatever techniques or combinations of techniques are selected, the analytical process must have the capability of predicting water quantity and quality changes (changes in availability) under seasonal conditions. It should also have the capability of determining magnitudes of changes and of routing those changes through the system to the downgradient boundary of the CIA. The time span for the analysis period should cover the mining, reclamation, and postreclamation phases in order to determine maximum impact magnitudes, when the maximums occur, and the rates of recession from the maximum values.

The following is a partial list of considerations that may be useful to the regulatory authority in selecting the appropriate methods and techniques for an independent analysis of cumulative hydrologic impacts:

1. Desired accuracy and precision of results.
2. Available baseline hydrologic data and information.
3. PHC analysis results for anticipated operations,

4. Previous hydrologic studies in the CIA.
5. Identified hydrologic parameters.
6. Time and resources available for the analysis.

Qualitative review of these factors by a hydrologist with experience and knowledge of analytical methods should indicate which general categories of methods are appropriate for the CIA to be assessed. Evaluation of the available hydrologic data is a critical factor, as it affects not only which specific methods can be successfully used but also the accuracy of results that can be achieved with that method. Also, each technique is based on certain assumptions about the conditions of the hydrologic system. Application to systems with conditions significantly different than the assumed conditions can seriously affect the accuracy of the technique, and this factor should be an important consideration in the selection of techniques.

A problem with many of the methods for projecting impacts occurs when the characteristics of the hydrologic system are changed by the mining. Most hydrologic prediction methods must be calibrated and verified if they are to give reliable results. Only with calibration and verification can the accuracy of a method be determined. Calibration involves adjusting fixed-value parameters until predicted outputs closely simulate or "fit" previously measured outputs of the system. Once a "good" fit is obtained, the method is said to be calibrated for the system from which the measured data were obtained. Verification involves using the adjusted parameter values with different input values for the system and comparing the measured outputs with the predicted outputs. However, if the system subsequently is altered, then the method is no longer calibrated and the accuracy of its predictions is unknown. For predicting impacts of coal mining, fixed-value parameters are usually calibrated to premining conditions. After the system is disturbed by mining, accuracy of results are unknown, unless the method has also been calibrated in a similar physiographic and climatic area under similar mining conditions. From calibrations under similar mining conditions, model parameter values can be selected to represent the mining conditions.

Use of physical process models requires sufficient data to calibrate and verify the models for each set of watershed conditions to be modeled. If a model can be satisfactorily calibrated and verified to establish parameters values for the existing and anticipated land use conditions over a physiographic region, coal region, or CIA, then this "precalibrated" model can probably be applied repeatedly within that region for a reasonable cost. However, if the model must be recalibrated for each application, its use may not be cost effective.

After selection of necessary methodology, it is applied according to good hydrologic practice and professional judgment. If results indicate that impacts extend beyond the working CIA boundary, the boundary delineation should be adjusted and the analysis modified accordingly.

Procedure for Analysis of Cumulative Hydrologic Impacts

1. Select analytical approach.
   a. Combinational approach.
   b. Independent analytical approach.
2. Select specific techniques and methodology.

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a. Qualitative methods.
b. Empirical equations and statistical correlations.
c. Physical process models.

3. Analyze CIA for cumulative hydrologic impacts.

ELEMENT F. DETERMINATION AND STATEMENT OF FINDINGS

The final task in the CHIA process (Element F) is to determine whether the hydrologic assessment of the CIA (Elements A-E) indicates that the additional impacts of the proposed operation may cause material damage to the hydrologic balance outside the permit area and, then, to write a statement of these findings, giving all supporting evidence and stating the rationale used. This determination is the main objective of the whole CHIA process. The supporting evidence and rationale validate the determination.

The determination may be based on quantitative comparisons and/or on qualitative evaluations. A quantitative determination is a comparison of analytical estimates for the defined indicator parameters (product of Element E) with the corresponding material damage threshold values for these parameters (product of Element D). A qualitative determination is a judgment determination by the regulatory authority based on all available evidence. For this final determination, the minimum acceptable evidence consists of an adequate PHC evaluation for the proposed operation and for each "anticipated mining" operation within the CIA. Whenever possible, the quantitative approach should be used, but qualitative determinations may also be appropriate. Regardless of whether the determination is qualitative or quantitative, the rationale for the decisions should must always be clearly stated.

Both approaches should probably be used for most determinations. Certainly, quantitative comparisons are most defensible. However, estimating future values of hydrologic parameters is uncertain at best, as is the task of clearly defining what constitutes "material damage" and what does not. For a variety of reasons, one cannot be certain of the correctness of answers provided by hydrologic estimating procedures. Also, different procedures may result in a range of values that straddle critical levels. The natural variability of hydrologic processes may necessitate that damage levels cover ranges rather than single, precise values. To make material damage determinations solely by comparison of estimated values to single-value criterion ignores the fact that natural forces are variable. Quantitative comparisons can be used, but they should not be the sole basis for the material-damage determination. The regulatory authority should use qualitative factors along with quantitative comparisons to make final material-damage determinations.

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The following two-part procedure is suggested for accomplishing Element F:

I. Determine potential for material damage.
   A. Make quantitative comparisons of estimated parameter values with the applicable material-damage criteria assembled in Element D.
   B. Make qualitative comparisons of the parameters for which quantitative evaluation is not appropriate.
   C. Make the final determination of whether impacts from the proposed operation accumulated with the impacts of other anticipated operations may cause material damage to the hydrologic balance outside the permit area.
II. Prepare a statement of CHIA findings.
   A. Introductory information.
   B. Documentation to justify actions.
   C. Statement of findings.

Discussion of Procedure for Determination of Material Damage Potential

Despite the uncertainties of quantitative hydrology, it remains the most defensible means of assessing cumulative hydrologic impacts and should be used at every possible opportunity. The procedure is to compare the predicted magnitudes of the defined indicator parameters (product of Element E) to the corresponding material-damage criteria thresholds for these parameters (product of Element D). This comparison should indicate the potential for material damage to the hydrologic balance outside the permit area. Any necessary conditions for comparison should be spelled out as part of the identification of hydrologic concerns (Element B). For instance, the flow conditions under which total dissolved solids concentrations are to be evaluated should be considered as part of the information needed to characterize the concern for salt loading. The specific wording of these criteria becomes especially important when, with each additional mine, cumulative impact magnitudes approach critical levels. If damage conditions are clearly identified as part of the concern, then the material-damage criteria and the estimated values for the indicator parameters (Element E) can be stated in similar terms and units, and quantitative determinations should be relatively straightforward.

When first estimates indicate that material damage thresholds may be exceeded, the regulatory authority may wish to reevaluate the impact prediction procedures used. Some kinds of modifications to the estimating procedures may be appropriate. For example, worst case conditions are commonly assumed as a means of simplifying the estimation process. It is common CHIA practice to assume that the maximum impacts of all the mining operations within the CIA will occur at the same time. When an analysis based on this assumption indicates potential material damage, a reanalysis using the actual timing sequence of the mining operations may reduce the impact estimates to nondamage levels. Such adjustments are acceptable and proper. However, it would be difficult for the regulatory authority to justify reevaluations in which individual input parameter values are adjusted to obtain favorable output magnitudes.

Qualitative analysis may enter the process at two levels. The first is in determining the magnitudes of the indicator parameters and comparing these

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values to the material damage criteria. The second is in making the final determination of whether impacts of the proposed operation accumulated with the impacts of the other anticipated operations will result in material damage to the hydrologic balance outside the permit area. In the first case (Step I.B of procedure), the analyst applies professional judgment to all available evidence, which may include analytically derived, as well as qualitative, information, to arrive at a material damage determination for each indicator parameter. In the second case (Step I.C), the regulatory authority considers the comparisons made in Steps I.A and I.B, and any other relevant factors to arrive at a CHIA permitting decision. In either case, the rationale used in making the qualitative determination is, in effect, the methodology. Thoroughly document this rationale either directly or by reference, just as analytical methods would be described, as this rationale is the primary defense against potential challenges to qualitative evaluations.

Qualitative estimates allow the regulatory authority to consider all relevant factors in making the final determination. Also, in early development stages of a coal field, while there are few operating mines and minimal impacts, qualitative evaluations may be wholly adequate. However, as the number of operations increases, increased use of quantitative procedures is recommended. But even when the CHIA is mostly quantitative, the regulatory authority should have, when making the final material damage determination, the option to qualitatively consider factors which are not amenable to the more mechanical quantitative comparison approach.

If the determination is negative (material damage to the hydrologic balance is probable), and the regulatory authority determines that no further evaluation of the determination is warranted, the negative finding is reported, granting of a permit is delayed, and the CHIA process is finished for the time being. Mitigating actions by the company to further minimize impacts of the proposed mine would be handled outside the CHIA process as part of the overall permit processing procedure (fig. II-1).

Preparation of Statement of Findings

The second part of Element F involves writing of a statement of findings with supporting evidence and rationale. This statement should describe the actions taken to complete each of the process elements, with emphasis on providing the justification for these specific actions or decisions. It should also document the assessment findings as to whether the addition of the proposed operation to the other anticipated mining will cause material damage to the hydrologic balance outside the permit area. For expediency, preparation of the written statement should be considered a part of each of the other elements, with the appropriate sections being completed as these elements are processed. In this way, the bulk of the writing will be completed when the analysis is completed. Then, at Element F, the statement would only require finalization and the writing of an executive summary. A suggested form and content for the CHIA document is given in Appendix A.

At a minimum, the statement should cover three broad topics. The first is introductory information, which should include why this specific CHIA is necessary (new application, modification, and so forth), and a very brief statement of other mining activity in the immediate area. It should mention any previously prepared CHIA's for the area that are incorporated in the present effort, and it should

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specify any significant difference between approaches used in the present and previous efforts. The statement should also include any information of a general nature that adds to the understanding of the situation and conditions dealt with in this CHIA.

The second is a thorough discussion of actions taken in the evaluation of each element. This discussion will comprise the bulk of the statement and should reflect how the assessment was done and the reasons for specific actions and decisions. The discussion of each element should touch on three basic points:

1. It should document all parts of the analysis that are significant to the outcome of the element product. A partial list of appropriate topics would include the analytical approach used to evaluate the element, the specific methods used, assumptions made, specific parameters used or excluded, appropriate maps and illustrations, description of the portion to the system being analyzed, any exceptions made to the normal procedure, and applicable statutory and regulatory requirements. Any topic necessary to convey what actions were taken in the evaluation of the element and how they were accomplished should be included in this discussion.

2. The discussion of each element should emphasize the justification for each specific decision made during the evaluation of the element. The justification of decisions is an integral facet of the CHIA process. The rationale for using one option over others, and exceptions to normal procedure should be thoroughly documented. Any decision or action may be challenged in the subsequent phases of the permitting process; therefore, the regulatory authority should have legally and scientifically valid reasons for those actions.

3. The discussion of each element should include an illustration or listing of the product resulting from the evaluation of the element. The desired element products have been described in this guidance document in the discussions of the individual elements. For example, a map showing the delineation of the CIA should be a standard illustration for Element A of these statements. The locations of evaluation sites, a partial product of Element B, should also be shown on this map. The listing and discussion of the element products should clearly describe those products and their use to the remainder of the assessment.

The final topic to be addressed in the findings statement is a statement of conclusions and the findings relative to the potential for material damage to the hydrologic balance. This finding is the ultimate objective of the assessment. The discussion should summarize the major reasons for the finding and state any special conditions or stipulations that the finding is contingent upon. Any significant differences from previous CHIA's in the area and the probable reasons for the differences should be noted. Upon completion of the statement, an executive summary should be prepared for general use and for inclusion in the permit application package.

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APPENDIX A

RECOMMENDED CHIA REPORT CONTENT

The final product of the cumulative hydrologic impact assessment is a report that fully documents all aspects of the study and its findings. The report must stand along without the permit application or the permit decision document. The outline that follows suggests a generally acceptable list of contents for a CHIA report. However, it may not include all items that require discussion for a particular study. The exact report contents are site dependent, and, therefore, this outline should be modified as necessary. However, report topics should include all the major steps of the CHIA process. The report should, among other things, thoroughly describe the subject hydrologic system, discuss the adequacy of the data set used, provide the rationale for delineation of the CIA, state hydrologic concerns for the CIA, describe and justify the methods and techniques used, define damage criteria, and generally document and justify each decision made in the course of the study and each conclusion drawn from the study.

REPORT CONTENT

(Note: Materials shown in parentheses indicate the types of items that should be discussed under the indicated topic headings.)

I. Executive summary
II. Introduction
III. Discussion of CHIA process elements
    A. Cumulative impact area
        1. Maximum upstream and downstream extent of CIA
            (a. Discuss criteria used to evaluate significance of spatially remote operations)
            (b. Discuss application of criteria and resulting CIA extremes)
            c. Delineate watershed area between these points on suitable map.
        2. Delineate watershed area between these points on suitable map
            (a. Specify anticipated mining operations and locate on map)
            (b. Discuss process of delineating surface-water CIA)
            (c. Discuss process of delineating ground-water CIA)
            (d. Show working CIA on suitable map.
    B. Hydrologic baseline conditions in the CIA
        1. Adequacy of available hydrologic data
            a. Surface-water data
            b. Ground-water data
        2. Characterize the hydrologic system
            a. General description
            b. Surface-water system
                (i. Describe surface-water system)

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III. Discussion of CHIA process elements--Continued
B. Hydrologic baseline conditions in the CIA--Continued
2. Characterize the hydrologic system--Continued
b. Surface-water system--Continued
(ii. Quantify surface flows)
(iii. Quantify surface-water quality)
(iv. Inventory surface-water usage, location, and quantity)
c. Ground-water system
(i. Describe ground-water system)
(ii. Quantify ground-water flows)
(iii. Quantify ground-water quality)
(iv. Inventory ground-water usage, location, and quantity)
C. Hydrologic concerns and associated indicator parameters
1. Surface-water concerns
a. Identify concerns
(i. Discuss rationale for inclusion of each concern)
b. Indicator parameters used to evaluate surface-water concerns
(i. Discuss reasons for selection of specific parameters)
c. Impact assessment sites
(i. Discuss selection of sites where impacts are to be assessed)
(ii. Locate sites on map of CIA (Use map prepared in step III.A.1.c))
2. Ground-water concerns
a. Identify concerns
(i. Discuss rationale for inclusion of each concern)
b. Indicator parameters used to evaluate ground-water concerns
(i. Discuss reasons for selection of specific parameters)
c. Impact assessment sites
(i. Discuss selection of sites where impacts are to be assessed)
(ii. Locate sites on map of CIA
D. Material damage criteria
1. Existing water-quality standards
2. Existing water-quantity standards
3. Development of limiting parameter values for concerns inadequately covered by existing standards
4. Site-specific material damage criteria
(a. Prepare list of criteria for each parameter at each site)
E. Assessment of cumulative impacts of mining on indicator parameters
1. Mining methods used within the CIA
(a. Describe the mining methods being used)
(b. Discuss effects of various mining methods on hydrology of the CIA)

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III. Discussion of CHIA process elements--Continued
    E. Assessment of cumulative impacts of mining on indicator parameters--Continued
        2. Surface water
            a. Predictive methods used
                (i. Discuss reasons for using these methods)
                (ii. Discuss assumptions of the methods
                (iii. Discuss data requirements of the methods
                (iv. Discuss procedure used to calibrate method)
            b. Projected values of indicator parameters at identified surface-water impact sites--long- and short-term impacts
                (i. Discuss difference in procedure to obtain short-and long-term parameter values)
                (ii. Quantity parameters for each site)
                (iii. Quality parameters for each site)
        3. Ground water
            a. Predictive methods used
                (i. Discuss reasons for using these methods)
                (ii. Discuss assumptions of the methods
                (iii. Discuss data requirements of the methods
                (iv. Discuss procedure used to calibrate method)
            b. Projected values of indicator parameters at identified ground-water impact sites
IV. Determination and statement of findings
    A. Determination of material damage potential
        1. Surface water
            a. Comparison of projected values with material damage criteria
                (i. Discuss comparison procedures used)
            b. Potential for material damage to the surface-water system
        2. Ground water
            a. Comparison of projected values with material damage criteria
                (i. Discuss comparison procedures used)
            b. Potential for material damage to the ground-water system
    B. Statement of findings
        (1. Final findings
        (2. Discuss reasons for these findings
V. References
VI. Appendixes
    A. Baseline hydrologic data

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APPENDIX B

EXAMPLE CHIA FINDINGS REPORT

This example is offerred to show the kinds of information that should be included in a CHIA findings statement. Because examples tend to simplify real conditions, they may not address all topics that should be addressed for a specific real-world site. This example is no exception. Therefore, the specific topics addressed and the specific way they are addressed should not be construed as the only ones that need to be presented, or that this is the "best way" to present them. Especially the results, conclusions, and lines of reasoning leading to the conclusions, as presented here, may not be valid for a specific real situation. Only the actual conditions of the specific CIA should govern how and what should be presented in a findings statement.

CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT FOR THE BLACK HOLE MINE

INTRODUCTION

Coalo Energy Company has submitted an application for a permit to mine its leasehold lying in portions of sections 9, 10, 11, 14, 15, 16, and 17, T. 51 N., R. 71 E., in Anchor County. This is the first permitting application for the mine, which is known as the Black Hole mine. There are two presently active mines in the immediate area (Prairie Chicken and Mud Hen), one recently completed mine (Old Crow), and several lease tracts. A CHIA was prepared approximately 1 year ago for the Prairie Chicken mine, and all applicable information from that document was used in the present effort.

DELINEATION OF THE CUMULATIVE IMPACT AREA

Maximum Possible Extent of CIA

The major river basin (river that discharges into the ocean) associated with the proposed Black Hole mine is that of the Coal River. Within the Coal River basin, coal is being mined in four widely separated areas (fig. B-1). Three of the areas are located on tributaries to the Gold River, which is tributary to the Coal River. The fourth area lies adjacent to the Coal River valley. The mines in these four areas include all operations whose impacts could possibly accumulate with those of the proposed operation.

A CHIA was conducted about 1 year ago for the Prairie Chicken mine, which is located in the same area of development as the proposed mine (Area I, fig. B-1). That assessment determined the maximum downstream extent of the CIA for the mines in Area I to be at the mouth of the Padre River (Point A, fig. B-1). The determination was based on the dilution of estimated total salt load from each of the mines in the Coal River basin. The analysis showed that the increased salt load in the Coal River at Point C would be less than the error inherent in methods available for measuring total salt loads. Therefore, it was concluded that the

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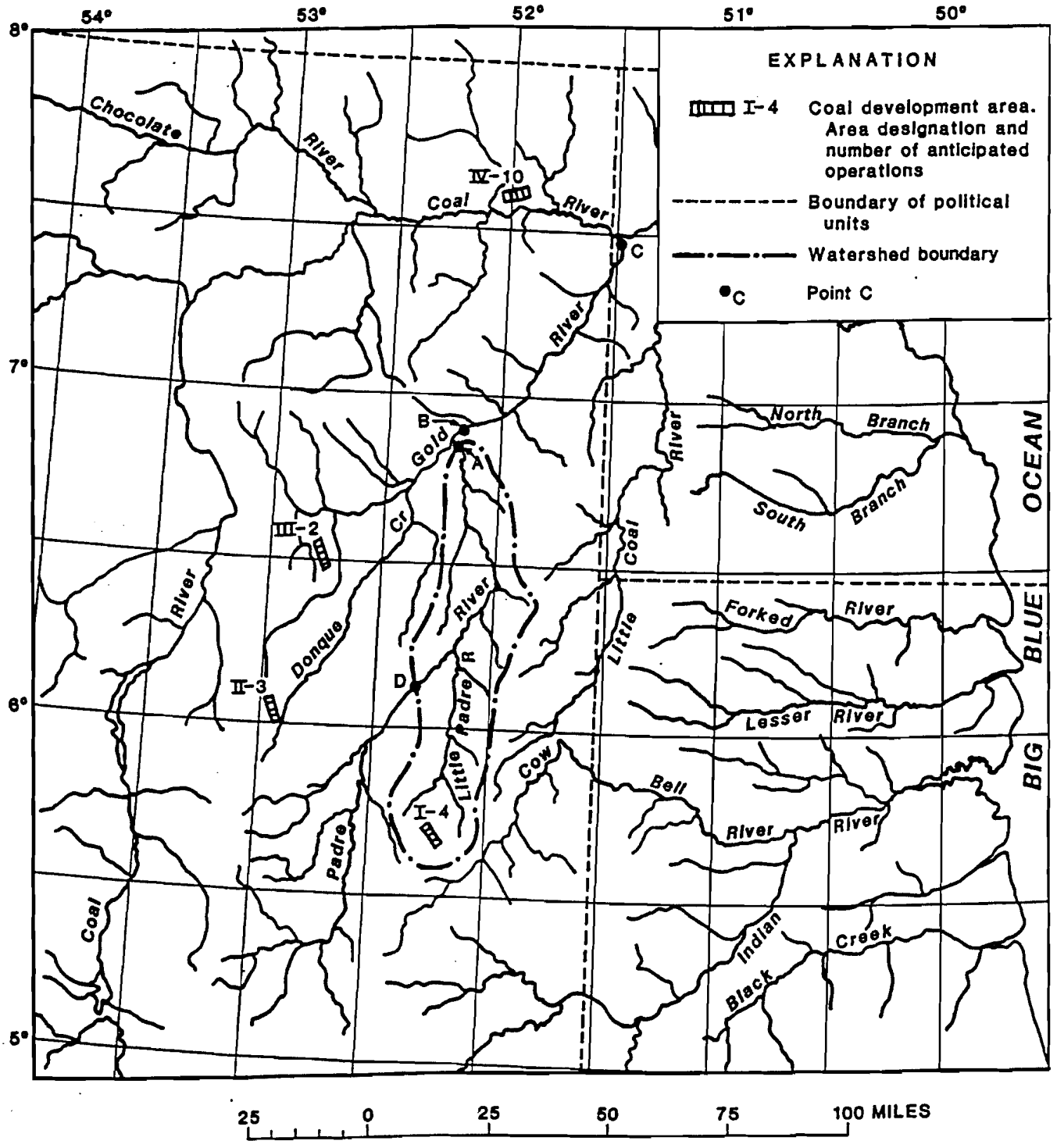

Figure B-1.--Map of the Coal River basin, showing maximum extent of cumulative impact area for the proposed Black Hole mine.

Exhibit 36

increased salt load delivered to the Coal River below Point C and contributed by the mines in the Gold River basin, is not great enough to be considered as an accumulated impact. Calculations support the same conclusion at Point B. (See CHIA for Prairie Chicken mine.) The additional salt load contributed by the proposed mine is not likely to require a different conclusion. Therefore, Point A was considered the maximum possible downstream extent of the surface CIA for this CHIA.

The maximum upstream extent of the surface CIA is marked by the watershed boundaries of East Fork Padre River and the lower Padre River. The upper Padre River basin was excluded because it contains no mines. Any effects of the upper Padre River on the CHIA can be input at the point of truncation (Point D).

Working CIA

All mining operations and leases in Area I, including completed operations, are shown in figure B-2. Operation 4 is the proposed Black Hole mine. Operation 1 was officially completed on November 30, 1979 (date of final bond release), and is no longer considered a mining operation. Operations 2 (Mud Hen mine) and 5 (Prairie Chicken mine) are active mines. Operation 6 is a leased tract for which an approved RRPP is available. Operations 3, 7, 8, and 9 are leases for which RRPP's have not been submitted. By definition, operations 2, 4, 5, and 6 must be considered as "anticipated" mining operations for CHIA purposes.

Pussy Cat Creek is the farthest downstream tributary whose precipitation and snowmelt discharge events are likely to be affected by these operations. Therefore, Point X was considered as the downstream limit of the CIA for surface-water analysis. The watershed above Point X was delineated as shown in figure B-2, and this area was considered to be the surface CIA. Although operations 1, 3, 7, and 8 lie within this CIA, they are not required to be included as "anticipated" mining. The regulatory authority has received no indication that permit applications will be submitted for any of these operations in the near future. Therefore, they were not included as anticipated operations for this CHIA. The areas that these operations occupy were included in the analysis as integral parts of the hydrologic system, but it was assumed that they would not be disturbed by mining and, therefore, would not directly affect the magnitudes of impacts for this particular CHIA.

The geologic strata that could be affected by the anticipated mining are the overburden, Quaternary sediments (valley alluvium), the coal seam, the shale formation under the coal, and a sandstone formation beneath the shale. The regional dip of these strata is 1° to 2° W. The coal outcrops along a line generally trending northwest to southeast.

The overburden is a member of the Wachou Formation and consists of interbedded siltstone and claystone. These materials are generally uniformly textured and moderately to well cemented. Most of the permeability of these materials is due to fracturing. The fractures contain small amounts of water that is sometimes used for domestic livestock. Overburden water is recharged by infiltration in upland areas. It generally moves through the overburden from south to north and discharges into the underlying coal seam and into the alluvium along the stream valleys.

Exhibit 36

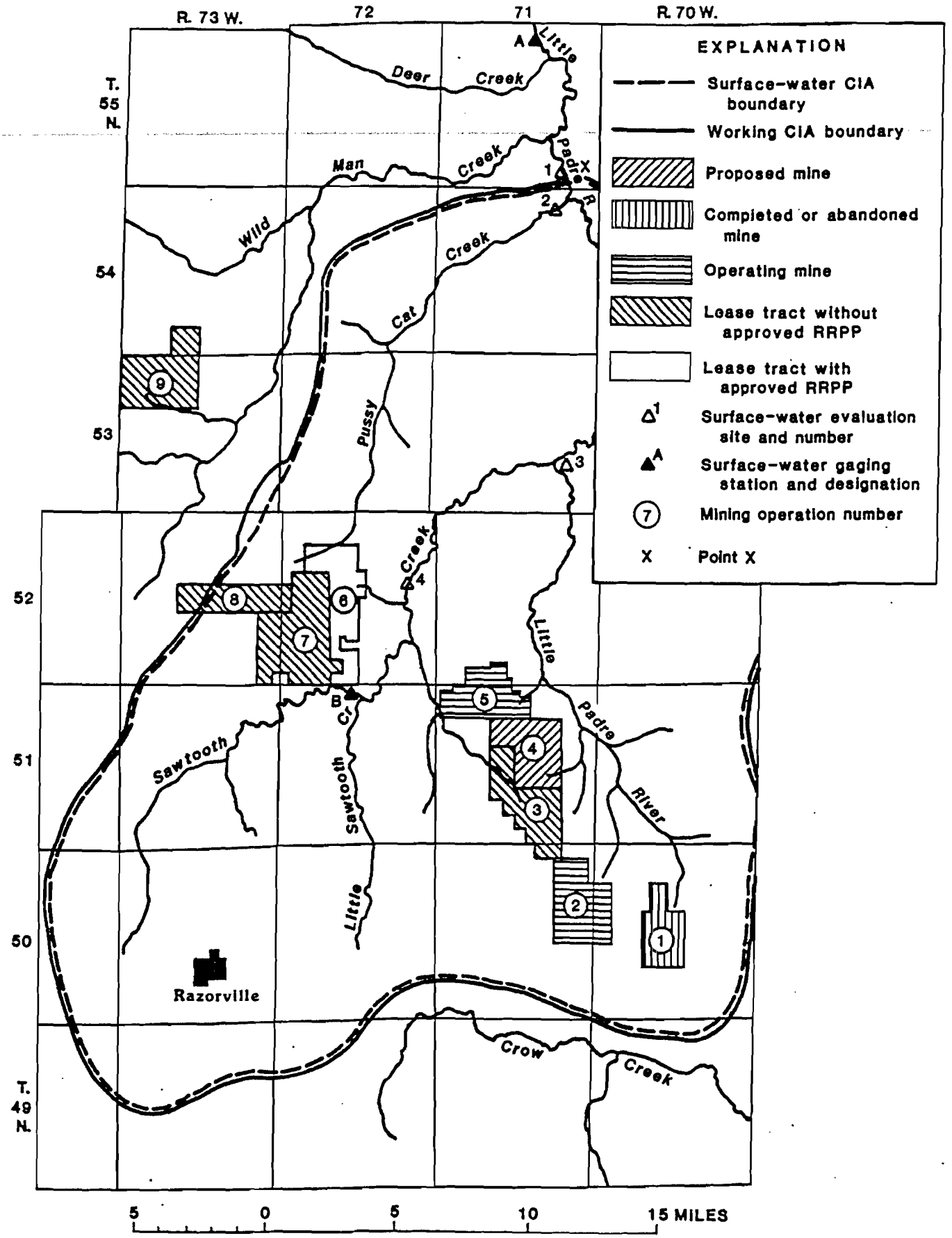

Figure B-2.--Anticipated mining operations associated with the proposed Black Hole mine, and surface-water CIA and ground-water CIA.

Exhibit 36

Quaternary sediment deposits are found along the larger stream valleys in the area. These deposits consist of both streamlaid and colluvial materials and serve as the main discharge area for the coal aquifer. Here, the water is either consumed by evapotranspiration or discharged to the surface farther downstream in the system.

The coal seam averages 80 feet in thickness and contains significant quantities of water. The coal is saturated through its entire thickness and is under artesian pressure. The coal's permeability is due to fracture systems and varies greatly over the area. Yields of wells in the coal vary from 1 to 10 gallons per minute. The coal is recharged along its outcrop and by some leakage through the overburden. It discharges into the Quaternary deposits along the stream valleys.

Immediately beneath the coal is a consistent layer of dense claystone that varies from 2 to 10 feet in thickness. This material (the underclay layer) is an effective barrier to water movement between the coal and the underlying rocks. Other sub-coal rocks are 500 to 700 feet thick and consist mainly of well-cemented shales. There apparently are only a few fracture zones in these rocks. Although these rocks contain some water, yields to wells are generally too small to be useful. For this analysis, these rocks and the underclay layer were considered to be significant aquacludes. The overburden, the coal, and the valley alluvium aquifers are referred to as the near-surface ground-water system. All strata below the coal were considered to be part of the deep ground-water system.

Ample volumes of potable water are available from the Deep Sands aquifer directly beneath the shales. This aquifer is composed of poorly cemented medium sand and is 700-800 feet thick. It crops out 50-60 miles east of the permit area along the eastern edge of the structural basin. The outcrop is the aquifer's main recharge area. The aquifer is confined; its potentiometric surface is approximately at the level of the land surface, and it slopes to the north-northwest at about 0.00009 foot per foot. There are no points within 100 miles of the permit area where this aquifer is known to discharge directly to the surface. However, some upward leakage to the alluvium along the Padre River is probable.

The short-term impacts of the mining on the near-surface ground-water system of this area are dewatering of the coal and overburden in and adjacent to the mine pits. Longer term impacts include the increased mineralization of water in the resaturated spoils and migration of this water off the permit areas and through the system. For the purpose of delineating the working CIA, estimated extent of life-of-mine drawdowns as submitted in the permit applications of operation 2, 4, and 5 were used. For operation 6, the drawdowns in the coal and overburden aquifers were assumed to extend from the permit boundary the same distances as those for operation 2. These drawdown zones are shown in figure B-3 and represent estimated drawdowns of more than 5 feet.

Likewise, paths that the mineralized water will follow in moving from the resaturated spoils to probable discharge points were adopted from the respective permit applications. However, because the aquifer discharge points are so near the permit areas, the pollution paths are all within the coal aquifer drawdown zones and, therefore, were not delineated in figure B-3. The delineation of the ground-water CIA for the overburden and coal aquifers (near-surface system) is shown in figure B-3. A composite of the cumulative impact area for the surface water system and that for the near-surface ground-water system constitutes the working

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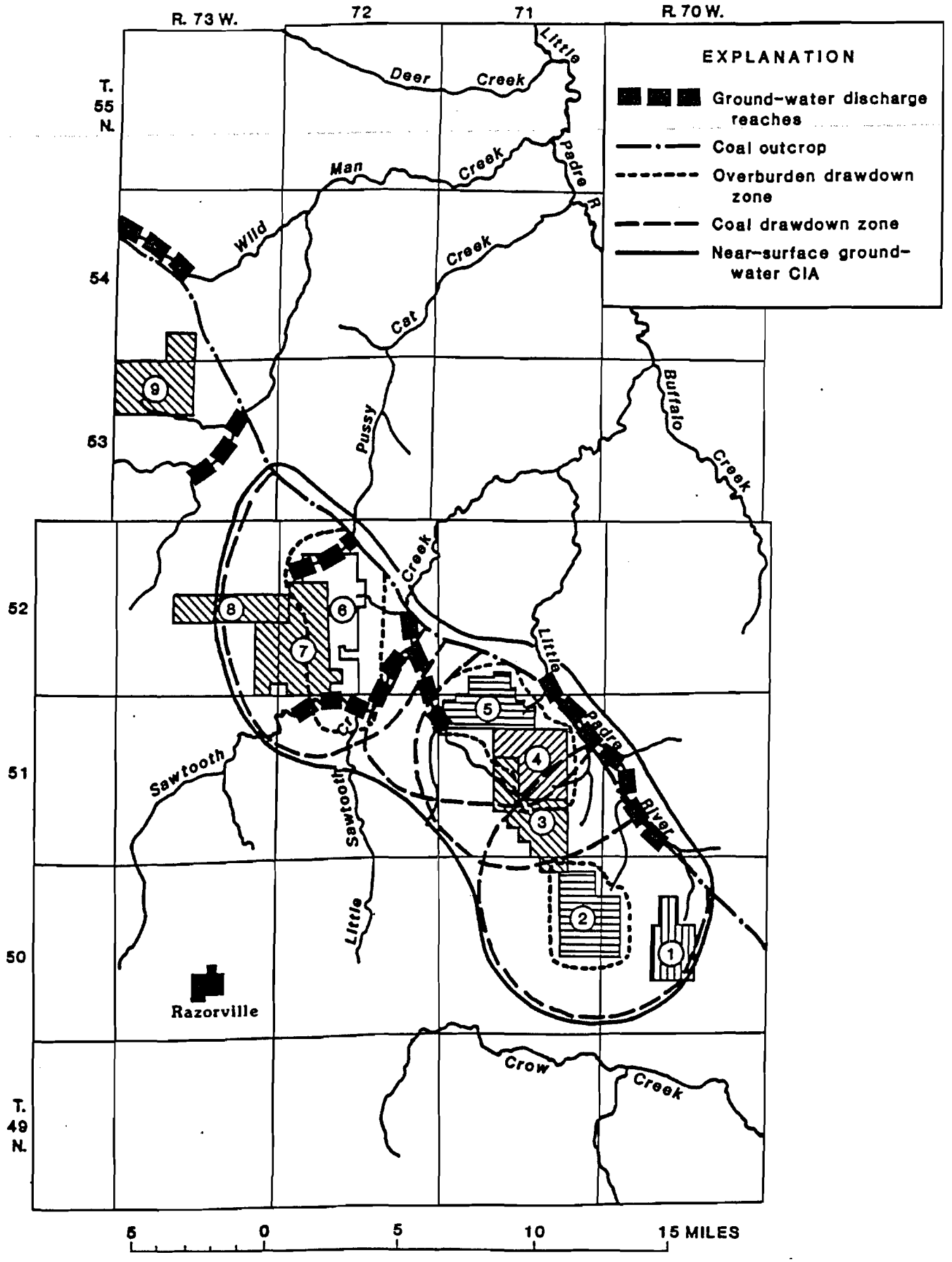

Figure B-3.--Estimated drawdown zones in near-surface aquifers, and near-surface ground-water CIA.

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CIA. The working CIA was delineated by overlaying figures B-2 and B-3 and is shown in figure B-2.

The area of cumulative impacts in the Deep Sands aquifer was delineated and analyzed separately from the above impact area because this aquifer is, to a large degree, isolated from the near-surface hydrologic system by intervening aquacludes. Operations 2, 4, and 5 obtain some water by pumping from this aquifer. However, the permit applications for these operations do not show the extent of anticipated drawdown zones resulting from such pumping. Only the drawdowns expected at the wells are given.

For the purpose of delineating the cumulative impact area of these wells, drawdown zones were estimated with the Theis nonequilibrium formula for a confined aquifer. Transmissivity and storage coefficient values of 2,000 gallons per day per foot and 0.0002, respectively, were used. These values are the maximum values found in the individual permit applications. The wells were assumed to be pumped one-half the time over a 30-year period at a rate of 250 gallons per minute. The resulting composite drawdown zone is shown in figure B-4. This delineation represents drawdowns greater than 20 feet. The travel paths of contaminants through the Deep Sands aquifer are not represented in this delineation because the possibility that the mining operations would degrade this water is highly remote. The introduction of contaminants through the wells penetrating the aquifer is the only way such degradation could occur. If this should occur, immediate heavy pumping at the culprit well should remove the offending contaminant before it could significantly spread through the aquifer.

BASELINE HYDROLOGIC CONDITIONS

Baseline hydrologic information is needed to define the hydrologic system as it exists prior to mining of the proposed operation. This definition provides a base from which to project the probable impacts of the "anticipated mining," including the proposed operation, upon the CIA.

The streams draining the CIA are shown in figure B-2. Two long-term streamflow records are available in this area. Nineteen years of continuous water and sediment discharge records have been collected on the Little Padre River at Station A (fig. B-2). In addition, water temperature, pH, electrical conductivity, total dissolved solids, sulfate ion, total iron and total manganese concentrations have been measured on a monthly basis for the past 5 years. Also, one water sample per year has been analyzed for 17 additional chemical constituents. This record provides good definition of the 2-, 10-, and 25-year peak discharge, low flow characteristics, and the water quality at that site.

Eight years of continuous water discharge records have been collected on Sawtooth Creek at Station B (fig B-2). The same water-quality parameters that have been measured at Station A have been measured at Station B for 2 years. The records at these two sites form the basis for estimation of premining flow characteristics at evaluation sites 1-4.

The streamfow record at Station B was extended in time using the methods suggested by Searcy (1960), and the long-term record at Station A. In addition, a series of discharge measurements have been made at the four evaluation sites over

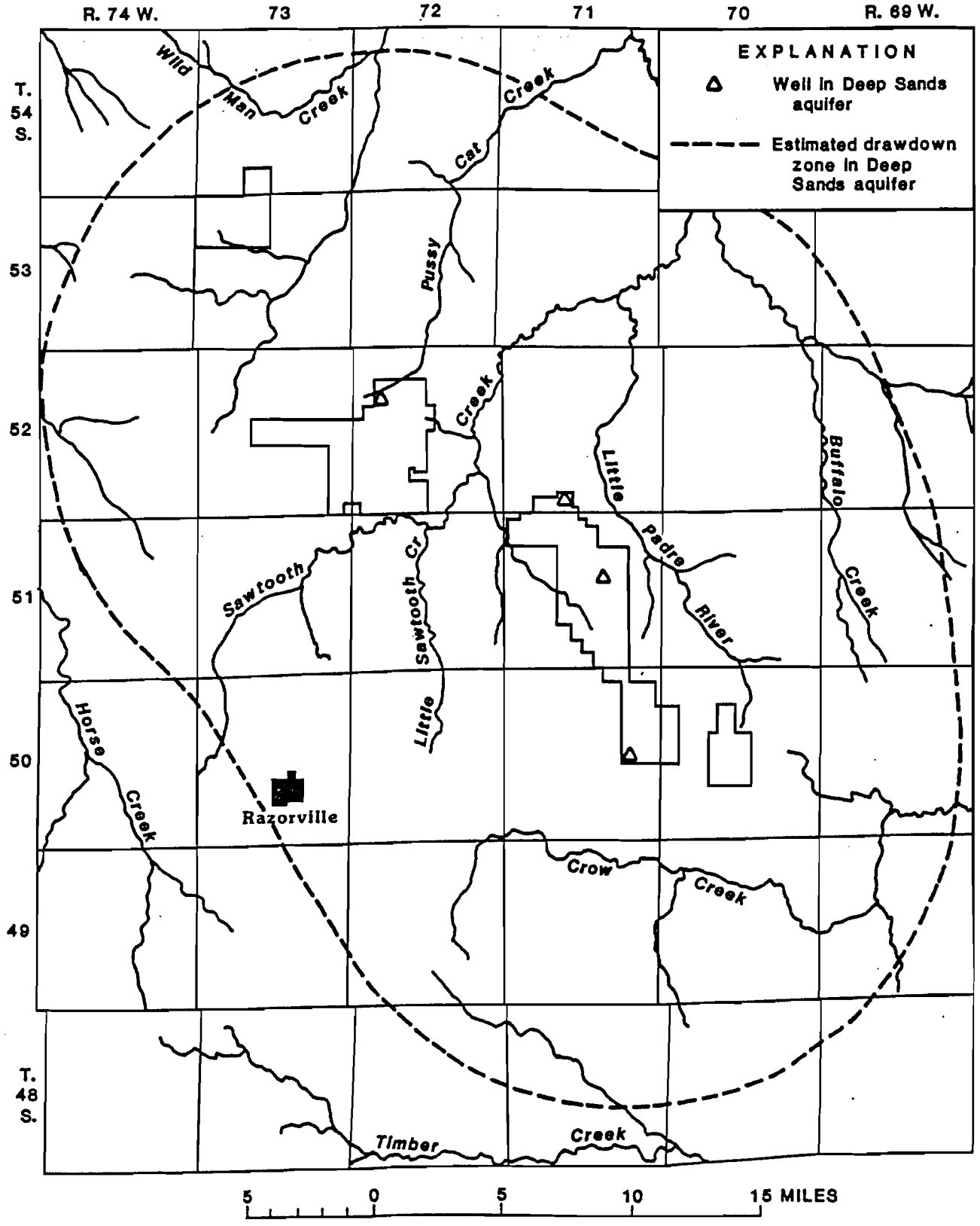

Figure B-4.--Cumulative impact area of Deep Sands aquifer.

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the past 2 years. A regression equation for each evaluation site was developed with these measurements. The measurements at sites 1 and 2 were related to coincident discharges at Station A, whereas the measurements at sites 3 and 4 were related to the extended record at Station B. Using the regression equations, the flow characteristics at the four evaluation sites were estimated. The flow characteristics of these same evaluation sites were first estimated for the Prairie Chicken mine, The values were then established as base values from which to calculate material damage thresholds to be used in all subsequent CHIA's that include these evaluation sites. The base mean monthly discharges (Qmm) and average monthly 7-day low-flow discharges (7Qam) are listed in table B-1.

Table B-1.--Base discharge rates established by regulatory authority for CHIA evaluation sites*

(All values are in cubic feet per second. Qmm = Mean monthly discharge; 7Qam = Average monthly 7-day low-flow discharge)

Month	Evaluation site							
	1		2		3		4	
	Qmm	7Qam	Qmm	7Qam	Qmm	7Qam	Qmm	7Qam
Jan.	2.21	0.35	0.55	0.04	0.66	0.12	1.00	0.14
Feb.	3.70	0.40	0.93	0.40	1.11	0.14	1.66	0.22
Mar.	4.53	2.00	1.13	0.20	1.36	0.72	2.04	1.08
Apr.	6.91	1.80	1.73	0.18	2.07	0.65	3.11	0.97
May	4.03	2.20	1.01	0.22	1.21	0.79	1.81	1.19
June	73.1	2.70	18.3	0.68	21.9	0.81	32.9	1.21
July	26.3	2.00	6.58	0.50	7.89	0.60	11.0	0.90
Aug.	7.14	2.10	1.79	0.52	2.14	0.63	3.21	0.95
Sept.	0.58	0.22	0.15	0.02	0.17	0.08	0.26	0.12
Oct.	0.03	0.00	0.01	0.00	0.01	0.00	0.01	0.00
Nov.	0.07	0.04	0.02	0.00	0.02	0.01	0.03	0.03
Dec.	0.30	0.11	0.10	0.00	0.08	0.04	0.12	0.07

*Baseline discharges for Prairie Chicken mine were basis for these values. Base discharges will be used for all subsequent CHIA's that include these evaluation sites.

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MATERIAL DAMAGE CRITERIA

The criteria for determining material damage potential of surface coal mining has been previously established and justified by the regulatory authority and was used to make such a determination for the Prairie Chicken mine CHIA. The same criteria apply to the Black Hole mine and are restated here.

Except for the area occupied by the city of Razorville, all land within the CIA is used for agricultural purposes, mainly livestock grazing, and this is the most likely postmining land use in the foreseeable future. Therefore, the regulatory authority has determined that the land and waters of the CIA should be restored and maintained to support this use, in particular livestock grazing, and the material damage criteria applied are based on that premise.

The applicable material damage thresholds for all surface hydrology evaluation sites shown in figure B-2 are listed below.

Site	Parameter	Material damage threshold
All	Average monthly 7-day low-flow rate (7Qam).	50% of 7Qam base rate, Mar. 1-Aug. 31.
All	Mean monthly discharge rate (Qmm).	±50% of Qmm base rate, Mar. 1-Aug. 31.
All	Total dissolved solids.	5,000 mg/L.
All	pH	4.5-9.0.
All	Sulfate ion	3,000 mg/L.
1	Manganese	1.0 mg/L.
2,3,4	Manganese	2.0 mg/L - Average of daily values for 30 consecutive days.
All	Total iron (Fe)	6.0 mg/L.

For the months of September through April, streamflows within the CIA are too small for any useful purpose and the regulatory authority has determined that material damage to streamflow quantity cannot occur during that period of the year.

IDENTIFICATION OF HYDROLOGIC CONCERNS

The objective of this CHIA is to determine the probable cumulative hydrologic impacts of the anticipated mine operations within the CIA delineated in the preceding section of this report. Impacts on the quality and quantity of the surface and ground water, with particular emphasis on the availability of water, are addressed as required by SMCRA. The following discussion identifies the critical hydrologic system segments that were analyzed, the specific parameters analyzed, and the points in the systems at which the parameters were evaluated.

The climate of the area is semiarid. Mean annual precipitation is about 16.0 inches. About one-third of this occurs during the months of May and June. Potential evaporation exceeds 50 inches per year and about 15 inches of the annual precipitation is lost to evapotranspiration. Of the remaining inch, about 0.3 inch runs off the surface, and the rest infiltrates.

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The topography of the CIA consists of gently rolling hills of low relief. Topographic features were formed by streams eroding into the nearly flat lying Watchou Formation. The stream channels form dendritic drainage patterns. Upper reaches of most stream channels carry only ephemeral flows. Lower reaches that are eroded into or through the coal may carry intermittent or very small perennial flows derived from the coal aquifer. Between storm- or snowmelt-produced runoff events, this water normally stands or very slowly flows through a series of large pools. Maximum relief between valley floors and adjacent ridges is about 150 feet. Total relief of the CIA is about 500 feet. Premining hillslope gradients range from zero to 40 percent and average 6.5 percent. Eighty percent of the slope gradients are less than 10 percent.

The primary use of water in this area is for livestock and wildlife. Water for this purpose is obtained from wells in the overburden or coal, and by retention of surface runoff in small reservoirs. There have been some attempts at irrigation, but, in general, there is insufficient supply of water from the near-surface system, and it is too poor in quality for successful irrigation. The three available mine plans all indicate grazing as the postmining land use, and it is reasonable to assume that the postmining land use for operation 6 will also be grazing. There has been limited domestic use of ground water from the overburden and coal aquifers, although State and U.S. Public Health standards indicate the water to be unsuitable for human consumption. The best water for human consumption is obtained from the Deep Sands aquifer, which lies 800-1,000 feet below the land surface. The two presently operating mines each have a well tapping this aquifer. The city of Razorville obtains most of its water supply from five wells tapping the Deep Sands aquifer. The wells are located about 25 miles due west of the proposed Black Hole mine.

The concentrations of total dissolved solids in the few samples of surface runoff obtained to date range from 1,060 to 3,200 mg/L. Major constituents are manganese, sodium, calcium, and sulfate. The pH ranged from 7.0 to 9.2. The concentrations of total dissolved solids in ground-water samples range as follows: Overburden, 1,100 to 3,600 mg/L (calcium magnesium sulfate); coal, 800 to 3,800 mg/L (sodium sulfate bicarbonate); Deep Sands, 275 to 1,500 mg/L (sodium calcium bicarbonate sulfate). Concentrations of iron, sulfates, and nitrates in these aquifers frequently exceed drinking water standards.

A direct effect of the anticipated mining is to remove and replace the coal aquifer with fragmented and dewatered overburden material in a broken strip across the CIA. This will cause a redirection toward the reclaimed spoils of the water flow patterns in the coal and overburden adjacent to the reclaimed pits. Until these spoils are resaturated, they constitute a major discontinuity or barrier to the movement of this water toward its present discharge points in the stream valley alluvium.

A subsequent direct effect is that water moving into the reclaimed spoils will become more highly mineralized because of the increased surface area of the fragmented material. Once these spoils are resaturated and flow patterns revert to premining patterns, this highly mineralized water will move into and through the downgradient coal and overburden to the stream valley alluvium and, eventually, into the surface streamflow.

It is obvious from the above physical descriptions of the CIA, of the occurrence of water therein, and of the direct effects of the mining on the hydrology that the major concern relative to the cumulative effects of mining on the hydrology of this area is for the maintenance of already limited amounts of water in the near-surface system available for present uses (i.e., livestock and wildlife watering). This means that the quantity, quality, and distribution of water presently obtained from surface runoff and from the coal and overburden aquifers must be maintained or be made available at present levels. Drawdowns in the coal and overburden aquifers may affect perennial and intermittent streamflows. These drawdowns may also affect some of the wells that now provide water for livestock. An additional concern is that the withdrawal of water from the Deep Sands aquifer for mining-related uses not affect the water supply to the Razorville wells or the cost of pumping that water.

In order to address these concerns, the specific objectives of this CHIA are (1) to determine the change in quantities of water reaching the off-permit stream system, (2) to determine the change in the quality of water that resaturates the reclaimed spoils and eventually reaches the surface-water system and to evaluate the time needed for the spoils to resaturate and for the water to subsequently reach the stream system, (3) to evaluate any change in sediment load to the stream system during and after mining and reclamation, and (4) to determine the effect of the mine wells on the city of Razorville's wells.

The specific parameters used to evaluate each of the stated objectives were as follows:

- Surface-water flow parameters: Mean monthly discharge rate (Qmm) and average monthly 7-day low-flow rate (7Qam).
- Ground-water flow parameter: Drawdown of potentiometric surfaces due to pit seepage.
- Water-quality parameters: Total dissolved solids concentration, sulfate ion concentration, total manganese concentration, total iron (Fe) concentrations, and monthly sediment load.

Surface-water parameters were evaluated at the sites shown in figure B-2. All parameters were evaluated at each site except that low-flow rates were only evaluated at sites with intermittent or perennial flows. Ground-water discharge rates to valley alluvium were evaluated as changes in streamflow rates along the ground-water discharge reaches shown in figure B-3. Water quality parameters were evaluated at all flow evaluation sites and within the projected ground-water drawdown zones.

(READER NOTE: For the sake of brevity, the remainder of this CHIA example will address only the water quantity impacts to the surface hydrology system. However, an actual CHIA **must** address all concerns identified in Element B.)

ANALYSIS OF HYDROLOGIC IMPACTS

The combinational approach was selected for this analysis. The same approach was used for the Prairie Chicken mine CHIA and that assessment showed by wide margins that there was little possibility that the analyzed parameters would exceed material damage thresholds. The only real difference in conditions

for the two assessments is that an additional year of data is now available and a PHC analysis for the Black Hole lease area is available, whereas many estimates were applied to that area in the previous CHIA. The additional data tends to confirm the parameter values estimated for operation 6, and those same values will also be used for this CHIA.

Projected maximum changes in Qmm and 7Qam discharges were obtained from the hydrologic analyses (PHC's) of the individual maine plan applications. These values are listed in tables B-2 and B-3, respectively. Next, these dischargechanges were routed to the four impact evaluation sites. This was done by simple summation at each evaluation site of all nonsummed discharge change values, or of evaluation site sums immediately upstream from the summing site. Thus, the values for site 3 are the sums of discharge change quantities from mine operations 2, 4, and 5 (2-LP, 4-LP, 5-LP, tables B-2, B-3). This routing procedure was considered adequate in this case because discharge changes were routed rather than the total stream discharge, and, therefore, it was not necessary to account for incremental discharge changes (due to nonmining increases or depletions) from within the intervening stream reach. Also, this routing procedure does not account for discharge changes caused by changes in stream channel geometry (width, depth, gradient, roughness) within the stream reach. However, the procedure should give conservative discharge estimates.

Table B-2.--Mean monthly discharge: Projected maximum changes for each mine operation

(All values are in cubic feet per second. 2-LP = Operation number and stream designation: LP, Little Padre River; ST, Sawtooth Creek; PC, Pussy Cat Creek. See figure B-2 for locations of mine operations)

	Operation and receiving stream						
Month	2-LP	4-LP	5-LP	4-ST	5-ST	6-ST	6-PC
January	-0.06	-0.05	-0.04	-0.13	-0.10	-0.09	-0.05
February	-0.10	-0.09	+0.07	-0.22	+0.17	+0.15	+0.08
March	-0.12	-0.11	+0.08	-0.27	-0.20	-0.18	-0.10
April	-0.19	-0.17	-0.12	+0.40	-0.31	-0.28	-0.09
May	+0.11	-0.10	-0.07	-0.24	-0.18	-0.16	-0.16
June	-1.91	-1.81	-1.25	-4.28	-3.29	-2.96	-0.09
July	-0.70	-0.65	+0.47	-1.53	-1.18	-1.06	-1.65
August	-0.19	-0.16	+0.13	-0.42	-0.32	-0.29	-0.59
September	-0.04	-0.03	-0.03	-0.03	-0.01	-0.01	-0.16
October	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
November	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	+0.01
December	-0.02	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01

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Table B-3.--Average monthly 7-day low flows: Projected maximum changes for each mine operation

(All values are in cubic feet per second. 2-LP = Operation number and stream designation: LP, Little Padre River; ST, Sawtooth Creek; PC, Pussy Cat Creek. See figure B-2 for locations of mine operations)

	Operation and receiving stream						
Month	2-LP	4-LP	5-LP	4-ST	5-ST	6-ST	6-PC
January	-0.01	-0.01	-0.01	-0.02	+0.02	-0.02	-0.04
February	-0.01	-0.01	+0.01	-0.03	-0.03	-0.03	-0.04
March	-0.07	-0.06	-0.05	-0.14	-0.11	-0.09	-0.02
April	-0.06	-0.05	-0.04	-0.13	-0.10	-0.09	-0.02
May	-0.08	-0.06	-0.05	-0.18	-0.12	-0.10	-0.02
June	-0.08	-0.06	-0.05	-0.16	-0.12	-0.11	-0.06
July	-0.06	-0.05	-0.04	-0.12	+0.09	-0.08	-0.05
August	-0.06	-0.05	+0.04	-0.12	-0.09	-0.08	-0.05
September	-0.01	-0.01	00.00	-0.01	+0.01	-0.01	-0.01
October	00.00	00.00	00.00	00.00	00.00	00.00	00.00
November	00.00	00.00	00.00	00.00	00.00	00.00	00.00
December	00.00	00.00	00.00	-0.01	-0.01	00.00	00.00

The routed Qmm and 7Qam discharge changes are listed in tables B-4 and B-5, respectively. These are the maximum discharge changes expected at the evaluation as a result of the anticipated mining.

POTENTIAL FOR MATERIAL DAMAGE

The material damage threshold values for surface discharge parameters are calculated from base discharges set by the regulatory authority. The base discharge values are the Qmm and 7Qam discharges determined for each evaluation site at the time that the Prairie Chicken CHIA was prepared.

The material damage criteria set damage thresholds at 50 percent of the base discharge values. Thus, the total allowable discharge change (Qa) from base values is ±50 percent of the base discharge. The base discharge values are listed in table B-1. The Qa values (allowable discharge changes before material damage occurs) are listed in tables B-4 and B-5. The projected changes (Qc) due to anticipated mining are also shown in tables B-4 and B-5. Comparison of the corresponding Qa and Qc values indicates the potential for material damage. In this case, the comparison shows that 40-60 percent of the allowable change values remain, thus indicating no potential damage to surface water quantities due to the anticipated mining.

Exhibit 36

The above-listed Qc values are conservative in that it was initially assumed that the maximum impacts of all the mines would occur at the same time. In reality, the maximum impacts of Operations 2 and 6 will probably occur some years apart, meaning that larger percentages of the allowable changes remain than is indicated by this analysis.

On the basis of the preceding cumulative hydrologic impact analysis, the regulatory authority has determined that the cumulative impacts of the Black Hole mine will not cause material damage to the hydrologic balance that affects surface-water quantities.

Table B-4.--Mean monthly discharges: Estimated maximum changes and allowable changes at evaluation sites

(All values are in cubic feet per second. Qa = Allowable discharge changes before material damage occurs. Qc = Estimated maximum discharge changes. Qc values for Site 1 are sum of values for Sites 2, 3, and 4. Qc values for Site 2 are sum of values 6-PC from table B-2. Qc values for Site 3 are sum of values 2-LP, 4-LP, 5-LP from table B-2. Qc values for Site 4 are sum of values 4-ST, 5-ST, 6-ST from table B-2. NA - Not applicable)

Month	Evaluation site							
	1		2		3		4	
	Qc	Qa	Qc	Qa	Qc	Qa	Qc	Qa
Jan.	-0.52	NA	-0.05	NA	-0.15	NA	-0.32	NA
Feb.	+0.06	NA	+0.08	NA	-0.12	NA	+0.10	NA
Mar.	-0.90	±2.26	-0.10	±0.56	-0.15	±0.68	-0.65	±1.02
Apr.	-0.76	±3.45	-0.09	±0.86	-0.48	±1.04	-0.19	±1.56
May	-0.80	±2.01	-0.16	±0.50	-0.06	±0.60	-0.58	±0.90
June	-15.6	±36.5	-0.09	±9.10	-4.97	±11.0	-10.5	±16.4
July	-6.30	±13.2	-1.65	±3.29	-0.88	±3.97	-3.77	±5.90
Aug.	-1.84	±3.57	-0.59	±0.90	-0.22	±1.07	-1.03	±1.60
Sept.	-0.31	NA	-0.16	NA	-0.10	NA	-0.05	NA
Oct.	-0.07	NA	-0.01	NA	-0.01	NA	-0.03	NA
Nov.	-0.05	NA	+0.01	NA	-0.03	NA	-0.03	NA
Dec.	-0.09	NA	-0.01	NA	-0.04	NA	-0.04	NA

Table B-5.--Average monthly 7-day low flows: Estimated maximum changes and allowable changes at evaluation sites

(All values are in cubic feet per second. Qa = Allowable discharge changes before material damage occurs. Qc = Estimated maximum discharge changes. Qc values for Site 1 are sum of values for Sites 2, 3, and 4. Qc values for Site 2 are sum of values 6-PC from table B-2. Qc values for Site 3 are sum of values 2-LP, 4-LP, 5-LP from table B-2. Qc values for Site 4 are sum of values 4-ST, 5-ST, 6-ST from table B-2. NA - Not applicable)

Month	Evaluation site							
	1		2		3		4	
	Qc	Qa	Qc	Qa	Qc	Qa	Qc	Qa
Jan.	-0.07	NA	-0.04	NA	-0.01	NA	-0.02	NA
Feb.	-0.14	NA	-0.04	NA	-0.01	NA	-0.09	NA
Mar.	-0.54	-1.00	-0.02	-0.10	-0.18	-0.36	-0.34	-0.54
Apr.	-0.49	-0.90	-0.02	-0.09	-0.15	-0.34	-0.32	-0.48
May	-0.61	-1.10	-0.02	-0.11	-0.19	-0.40	-0.40	-0.90
June	-0.84	-1.35	-0.06	-0.34	-0.19	-0.40	-0.39	-0.60
July	-0.49	-1.00	-0.05	-0.25	-0.15	-0.30	-0.29	-0.45
Aug.	-0.49	-1.05	-0.05	-0.26	-0.15	-0.31	-0.29	-0.48
Sept.	-0.06	NA	-0.01	NA	-0.02	NA	-0.03	NA
Oct.	00.00	NA	00.00	NA	00.00	NA	00.00	NA
Nov.	00.00	NA	00.00	NA	00.00	NA	00.00	NA
Dec.	-0.02	NA	00.00	NA	00.00	NA	-0.02	NA

REFERENCE

Searcy, J. K., 1960, Graphical correlation of gaging-atation records: U.S. Geological Survey Water-Supply Paper 1541-C, 23 p.

Exhibit 36

Houle, Hillary

From: Schade, Pete
Sent: Friday, May 16, 2014 1:36 PM
To: Feldman, David
Cc: Hinz, Emily
Subject: FW: Aquatics Spreadsheet
Attachments: SW_macroinvertabrates_Rosebud.xlsx

Dave – it looks like we do have some genus-level data (see attached).

Please take a look when you get the chance and give us your thoughts. Is this data set suitable for calculation a bioassessment score with Plains MMI or RIVPACS?

Thanks

Pete

From: Hinz, Emily
Sent: Friday, May 16, 2014 1:15 PM
To: Schade, Pete
Subject: Aquatics Spreadsheet

This only contains data from the 1978 survey. I've yet to add the 76 and yet to be found 73 survey. Some of the genus names may need to be untangled as these could really be family or group names.

Emily Hinz
Hydrologist
Coal and Uranium Program
Montana Dept. of Environmental Quality
Ph (406) 444-7443

Houle, Hillary

From: Schade, Pete
Sent: Friday, May 16, 2014 4:54 PM
To: Feldman, David
Subject: RE: Aquatics Spreadsheet

No, We're not looking for an impairment call.

What we want to do is compare existing assemblages to these historic assemblages using appropriate metrics.

I understand the assemblages indicate lower water quality. The question is…can a bioassessment score (MMI and/or O/E) be calculated on these assemblages? If no, why not? If yes, let's make it happen.

It appears that what I thought was a simple technical request apparently has implications beyond our need to assess condition.

Thanks. I realize it's out of your hands, but I do appreciate your assistance. I spoke with Eric, and will attempt to follow-up at the mgmt level.

P

From: Feldman, David
Sent: Friday, May 16, 2014 3:21 PM
To: Schade, Pete
Cc: Hinz, Emily
Subject: RE: Aquatics Spreadsheet

Hello!

I've reviewed the data, and here's some thoughts:

I've organized the data by sampling location and date to get an idea of what you're seeing in the macroinvertebrate communities at those locations. The samples are not very diverse, and some samples do not have very many inverts. If we were using these data in any kind of macroinvertebrate indicator of water quality, the samples would all be rated low.

I spoke with Eric Urban about this, and he told me that any kind of impairment determination is beyond the scope of what you need in the Coal Program. He told me the best way I can help you is to describe what taxa are there, and that's it.

I hope this helps!

David Feldman
Biological Water Quality Standards Specialist
Montana Department of Environmental Quality
406-444-6764 (phone)
406-444-6836 (fax)
http://www.deq.mt.gov/wqinfo/standards/default.mcpx

From: Schade, Pete
Sent: Friday, May 16, 2014 1:36 PM
To: Feldman, David
Cc: Hinz, Emily
Subject: FW: Aquatics Spreadsheet

Dave – it looks like we do have some genus-level data (see attached).

Please take a look when you get the chance and give us your thoughts. Is this data set suitable for calculation a bioassessment score with Plains MMI or RIVPACS?

Thanks

Pete

From: Hinz, Emily
Sent: Friday, May 16, 2014 1:15 PM
To: Schade, Pete
Subject: Aquatics Spreadsheet

This only contains data from the 1978 survey. I've yet to add the 76 and yet to be found 73 survey. Some of the genus names may need to be untangled as these could really be family or group names.

Emily Hinz
Hydrologist
Coal and Uranium Program
Montana Dept. of Environmental Quality
Ph (406) 444-7443

Montana Department of Environmental Quality

Sample Collection, Sorting, Taxonomic Identification, and Analysis of Benthic Macroinvertebrate Communities Standard Operating Procedure

March 15, 2012

Approvals:

Dave Feldman, Biocriteria Specialist, Water Quality Standards Date

Robert Bukantis, WQ Standards Supervisor, Water Quality Planning Bureau Date

Mindy McCarthy, QA Officer, Water Quality Planning Bureau Date

Darrin Kron, Monitoring and Assessment Supervisor, Water Quality Planning Bureau Date

REVISION HISTORY

Revision No.	Date	Modified By	Sections Modified	Description of Changes
1	10/21/2004	DF, MB, BB	4,5,7, Appendices, Attachment 1	Quality Assurarnce procedures were added. The taxa list (Appendix 3) was updated The site visit field forms (Attachment 1) were updated.
2	09/08/2006	DF, MB, MS, BB	1,2,5,6,7, Appendices	The Montana Observed/Expected (a.k.a. RIVPACS) Model and Multimetric Indices (MMIs) were added. The Appendices were relabeled by letter instead of number. The taxa list (Appendix A) was updated. The Glossary of metrics was updated for the MMIs. Appendix D was added to the SOP.
3	03/15/2012	DF, MM, KM, BB	All	The scope of the SOP was refined to include which river segments were unwadeable and beyond the scope of the sampling protocols. The justification for the index sampling period was slightly modified. The coldwater O/E model and Bray Curtis (BC) Index were added. The MMIs were removed. The rarefaction instructions to prepare the data for the MMIs in Appendix C were removed and replaced with example outputs from both O/E models. The code to calculate the coldwater O/E model and instructions on how to use it was added as Appendix D. The laboratory subsampling procedures were updated to require that the labs submit their SOPs, and use unbiased subsampling procedures.

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ACRONYMS

Acronym	Definition
CW	Cold Water (fisheries)
DEQ	Department of Environmental Quality (Montana)
EDD	Electronic Data Deliverable
EMAP	Environmental Monitoring and Assessment Protocol
EPA	Environmental Protection Agency (US)
ETOH	95% Ethanol
FFP	Frost-Free Period Point
GIS	Geographic Information System
GPS	Global Positioning System
HBI	Hilsenhoff Biotic Index
ITIS	Integrated Taxonomic Information System
MQO	Measurement Quality Objective
NRCS	National Resources Conservation Service
O/E	Observed/Expected
OTU	Operational Taxonomic Units
PTD	Percent Taxonomic Disagreement
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RPD	Relative Percent Difference
RPDE	Relative Percent Difference in Enumeration
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedure
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
USU	Utah State University
WQX	EPA's Water Quality Exchange System

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1.1 SCOPE AND APPLICABILITY

The methods described herein are used for collecting and analyzing macroinvertebrate data from wadeable streams (1st order or higher) by or for the Montana Department of Environmental Quality (DEQ). Benthic macroinvertebrate data collected on large rivers is beyond the scope of this method. **Table 1-1** lists those large river segments.

Table 1-1. Non-wadeable river segments within the state of Montana

River Name	Segment Description
Big Horn River	Yellowtail Dam to mouth
Clark Fork River	Bitterroot River to state-line
Flathead River	Origin to mouth
Kootenai River	Libby Dam to state-line
Madison River	Ennis Lake to mouth
Missouri River	Origin to state-line
South Fork Flathead River	Hungry Horse Dam to mouth
Yellowstone River	State-line to state-line

1.1 GENERAL CONSIDERATIONS

Prior to conductiong a benthic macroinvertebrate survey, determine the specific data quality objectives (DQOs) and the information sought. DQOs can be qualitative or quantitative statements developed to specify the quality of data needed to support specific decisions and conclusions about the information sought. The DQOs should be documented in a Sampling and Analysis Plan or Quality Assurance Project Plan.

1.1.1 Index Period

The index period is the period of time that samples should be collected to minimize seasonal variation.

- The index period for Montana is generally the summer (June 21 to October 1), following runoff loeb (Richards D.C., 1996; Loeb and Spacie, 1994). Eastern Montana streams may be sampled May 1 to October 1.
- Sampling may occur outside of the index period, however this may reduce certainty that the data are comparable to historical data, reference conditions or indices (see discussion below).

The index period noted above was the temporal basis for reference conditions used in the development of the Observed/Expected (O/E) model. However, even within this index period, extreme runoff or summer drought conditions could affect these periods; professional judgment must be used when considering sampling schedules. Sampling macroinvertebrates during high flows, besides being potentially unsafe, is likely to increase sampling variance due to the difficulties associated with sampling these waters using the methods described herein.

When monitoring for trends at a particular site, minimize seasonal variation by sampling as close as possible to the same date each year.

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1.1.2 Site Selection

Sampling requirements including the total number of sampling sites their location in the study area, and the spatial and temporal independence are outlined in each DEQ pollutant-specific assessment method. Some of the assessment methods do not require any biological samples to be collected for assessment decisions. Refer to the assessment method when determining the sampling design in order to achieve an appropriate assessment of the stream. Always consider potential constraints to collecting representative samples such as site access when selecting sites. Document any necessary changes due to site access restrictions.

The study design should specify requisite site specifications for the study. For example, many study designs use the riffle environment as the specific point of comparison between streams. A *rationale* described in the Sampling and Analysis Plan (SAP) for determining representative riffles for the anticipated stream types would be a *site selection specification*.

Although riffle areas with cobble substrates are generally the most diverse and productive habitat type, these may not be representative of the predominant type of habitat in the stream. If so, the study design should describe the variety of habitats, the rationale for representative sampling, and the various appropriate sampling techniques for the study.

There is ample evidence that the presence of lakes, impoundments, bridges, road crossings, and bedrock or large-boulder dominated substrates affect benthic invertebrate community composition; therefore, sampling sites should be located as far from these as is practical, *unless the objective of the study is to measure their localized influence*.

Always sample sufficiently upstream from the confluence of major tributaries or receiving waterbodies to minimize their influence on study sites. Otherwise, consider the mixing zone of the two waterbodies and select sites downstream of the confluence that are well mixed, and represent both the biological community and water quality conditions.

1.1.3 Sample Collection Methods

DEQ employs a semi-quantitative Environmental Monitoring and Assessment Protocol (EMAP) reach wide sampling technique to collect samples in a known area allowing the estimation of population density, in addition to diversity and abundance.

1.1.4 Checklist of Recommended Field Supplies

- ❑ Field Meter (pH, Spec. Conductance, DO)
- ❑ Macroinvertebrate sample bottles (1 liter wide mouth poly)
- ❑ Lab markers, external labels, clear tape, Parafilm-M
- ❑ Internal labels (paper)
- ❑ Sampler (D-frame net)
- ❑ Field notebook
- ❑ Field data sheets (Site Visit Form, Photo Documentation Form, Site Map Form)
- ❑ Camera
- ❑ GPS unit
- ❑ 95% Ethanol preservative
- ❑ 500 um sieve for washing and sorting out large objects
- ❑ Pencils

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- ❑ Clipboard
- ❑ De-Ionized Water
- ❑ Hip boots or waders
- ❑ Maps
- ❑ Dishwashing brush
- ❑ Hard or soft-sided Coolers to store samples
- ❑ Small soft-sided coolers to transport samples

2.0 SAMPLE COLLECTION PROCEDURES

The following section discusses sample collection procedures used to sample macroinvertebrates in streams and wadeable rivers not listed in **Table 1-1**.

2.1 PRECAUTIONS

Care must be taken when looking for suitable sampling sites not to disturb the substrate or habitat in areas where samples might be collected. A sample collected where the substrate has been disturbed by walking may not be representative of the community.

Be sure to transfer the entire sample to the bottles. Only fill each bottle one-half to three-quarters full with sample to leave room for preservative. Capture all bugs by thoroughly cleaning off all large rocks and sticks. Excluding large rocks prevents grinding damage to bugs during transport. Discard cleaned rocks and sticks.

Pack and store collection bottles carefully and securely in order to protect the sample jars and prevent the loss of contents during transport or shipment.

2.2 SAMPLE LABELING

Accurate labeling of sample bottles is important to preserve critical information. Attach a preprinted label to the jar clearly identifying the sample (location, date, number of bottles, method of collection and sample number). Use pre-printed, fill-in-the-blank labels to help ensure that the sample information is complete.

2.2.1 Sample Containers and Preservation

Collection jars: 1-liter wide-mouth polyethylene bottle. (Note: It may be necessary to use more than one 1-liter polyethylene bottle.)

Use 95% ethanol (ETOH) to preserve the macroinvertebrate samples. . Please remember that ETOH is flammable! The drawback of using ethanol is that the fluid composition of the sample needs to be dominated by ethanol to properly preserve the sample. Because of this, try to keep as much water out of the sample jar as possible, and fill the sample bottle only one half with sample and the remainder with ETOH to fill the bottle completely. Split the sample using an additional bottle(s) if necessary, and be sure to correctly label the bottles using a numeric sequence (i.e. 1 of 3, 2 of 3, 3 of 3).

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2.2.2 Sampling Quality Control

2.2.2.1 Field Replicates

Field replicates are collected to measure total method error and should always be included in the sampling design at a predetermined frequency (usually 10%).

Field replicates are two or more samples, collected side-by-side or consecutively, at the sampling site. Replicate samples should be taken at places that are very similar in terms of depth, substrate, composition, and slope. ***Always collect samples from downstream to upstream to avoid sample contamination***. Replicates are processed in the laboratory as discrete samples. They are compared directly to the original samples. Any difference represents total method error (e.g., heterogeneity of site, reproducibility of sampling technique, sorting error, and identification error).

Relative Percent Difference (RPD) is used to evaluate results differences between two replicate samples.

$$RPD = \frac{(result1 - result2)}{(result1 + result2)/2} \times 100$$

The results of replicated samples (i.e. O/E model results) should be < 20% RPD, however, each project must state its required replicate precision criteria based on project DQO's.

2.2.3 Benthic macroinvertebrate sampling methods and protocols

A variety of other sampling methods are available from EPA, USGS, and other organizations. It is beyond the scope of this SOP to discuss all available sampling methods, or the applicability of sampling design for determining the health of benthic macroinvertebrate communities using the Data Analysis and Interpretation tools presented in Section 5 of this SOP.

When sampling methods other than those listed in this SOP are used for water quality assessments by or for DEQ, the SOP(s) for the alternate methods must be attached or cited in the project's Quality Assurance Project Plan (QAPP) or Sampling and Analysis Plan (SAP). Any known (documented) or assumed comparability to the methods in this SOP should be cited or documented in these Quality Assurance (QA) documents.

2.2.3.1 Environmental Monitoring and Assessment Protocol (EMAP)

Currently, the DEQ Reference Project uses EMAP sampling protocols to identify and assess reference sites (Peck, 2006). These data were included in the compiled reference data collection used for the O/E models. Therefore, EMAP methods are considered valid sampling techniques for use with the tools presented in Section 5 of this SOP.

2.2.3.1.1 Reachwide Sample

The EMAP sampling protocol requires that a kick sample be collected at each of 11 transects (A though K), sampling from downstram to upstream along the reach; these kick samples are composited to obtain a sample that is representative of the entire reach. Collect each kick sample at each transect (A through K) at the assigned sampling point (left, center, or Right). Position a 500um D-frame kick net within a representative portion of the designated channel location and hold the net vertically upright with the base of the frame in contact with the substrate and the open portion of the net facing into the flow. See **Figure 2-1** for a conceptual diagram of the EMAP reach, and where to collect each macroinvertebrate

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kick sample. Note: if a sampling location that is unsafe to wade to is encountered, try to find a safer location either up or downstream approximately 1 meter of that location. Switch to another position (i.e., R.L,C) on the same transect if moving up or downstream to collect the sample isn't possible. Return to the initial sampling pattern at the next transect after the kick is collected. Here are some important points to consider when collecting macroinvertebrate samples:

- *Thoroughly* inspect and clean (with stream water) the net after each sampling event to ensure that all organisms have been removed to prevent contamination between sites. Consider the following procedures to ensure that all organisms are removed from the net and placed in the jars:
  - Rinse large rocks, sticks, and other debris into the net and thoroughly inspect them prior to discarding.
  - Use a small plastic spoon to scoop the sample into the sample jar.
  - Inspect the entire inner surface of the net and use clean forceps to carefully remove any organisms clinging to the net and place them into the sample jar.
  - Dump the contents of the net into a 500 um sieve, rinse stream water through the sieve to clean the sample of fine sediment and transfer the sample into the jar.
  - Elutriate each kick sample to separate the organic and inorganic portions before you transfer it into sample jars; this should help protect the soft-bodied macroinvertebrates from damage caused by inorganic material in the sample jar during sample transport and storage. Elutriate by submerging portions of the sample in a 5 gallon bucket containing some water, vigorously swirl the sample in the water to separate the organic and inorganic portions of the sample, then decant the floating material into the 500 micron sieve and transfer from the sieve into the sample jar. Repeat this process several times until almost the entire organic portion of the sample has been removed. Then transfer the inorganic portion to different sample jars and submit these along with the organic portions to the analytical laboratory.
  - When sampling a pool with little to no flow, follow the same procedure except use your hands or feet to push the sample into the net. If encountering a slackwater area choked with vegetation, sweep the net through the vegetation for 30 seconds over the $0.09m^2$ sampling location.
  - Add enough ETOH to submerge the debris in each sample jar as soon as the material from each kick is added to the jar to prevent damage or loss of some taxa by opportunistic predators.
  - Spray organisms clinging to the net with a dilute (10%) ammonia or (95%) EtOH solution to detach them from the net. Partially immerse the net in the stream to concentrate the detached organisms at the base of the net and/or use forceps to transfer organisms directly into the jar.
  - To collect replicate samples using the reachwide approach, simply collect replicate kicks at each transect at another location on the same transect. For example, if the regular sample is collected following the Right, Left, Center pattern, the replicate sample could either be collected following the Left, Center, Right or Center, Right, Left pattern.
  - Always check all of the sampling gear between sampling events to make certain all organisms were removed. This prevents sample contamination between sites and prevents biased biological assessments

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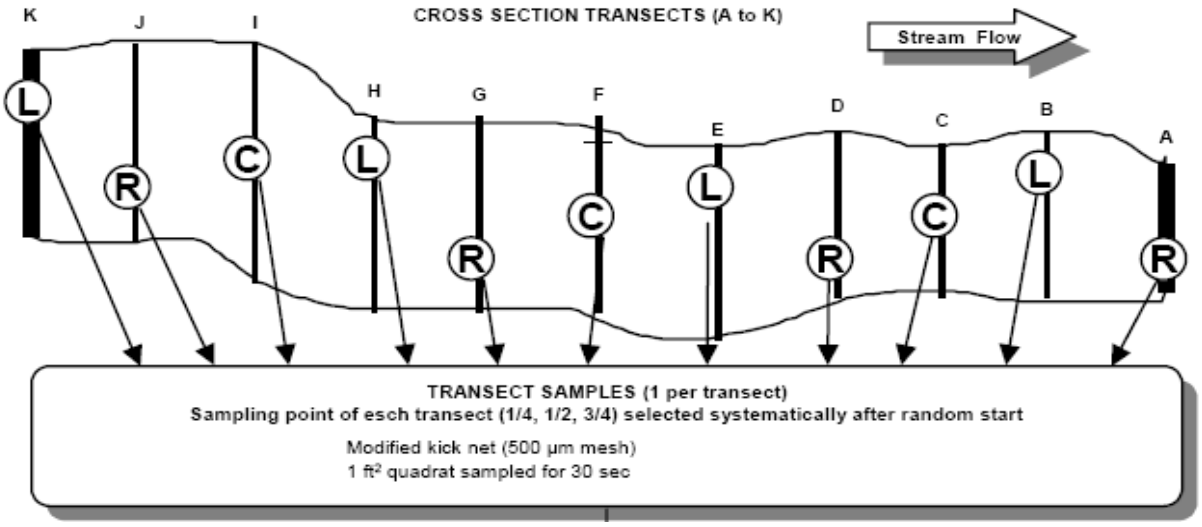

Figure 2-1. Sampling locations for the reachwide benthic macroinvertebrate sample within the sampling reach (adopted from Peck et al. 2006).

2.3 SUPPORTING FIELD DATA

Macroinvertebrate sample sites are described by metadata recorded at the time of sampling as well as any field observations taken at the time of sampling. Use the Site Visit Form (**Attachment 1**) to record metadata (GPS lat/long in decimal degrees, NAD 83) for the sampling site and record sample identifiers.

Digital photographs should be taken of the sampling site (upstream, downstream, and the site itself) and of the substrate sampled. Record metadata for the photos on the Photo Point Form (**Attachment 2**). As a back-up to digital photos, a sketch of the sampling site is recommended, along with an indication where the sample was taken at the site. A Site Sketch Form is included in this SOP (**Attachment 3**).

3.0 SUBSAMPLING & SORTING

Subsampling is using a representative portion of the field-collected sample for analysis. Sorting is the physical separation, counting, and grouping of organisms from the debris collected in the sample. All macroinvertebrate samples collected by and for DEQ should follow an unbiased subsampling procedure to achieve a target subsample count of 500 $\pm$ 10% organisms.

It is important to understand the objectives of the project when selecting subsampling techniques. If the intention of the study is to measure population density (i.e., quantitative sampling), sort the entire sample. Full sample sorts can be used for samples collected by semi-quantitative collection methods if the study requires that all organisms are identified. However, full sample sorts are more time consuming for the taxonomist, adding additional expense to each sample.

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3.1 PRE-SUBSAMPLING METHODS

To get a relatively even distribution of organisms prior to subsampling or sorting, remove large debris from the sample. There are two approaches to this sample clean up. The debris can be removed from the sample (picking) or the sample can be removed from the debris (elutriation).

3.1.1 Picking detritus

Picking the debris from the sample involves rinsing out fine material, removing large rocks, woody debris and setting them aside. Picking and rinsing should be performed in a 500 um sieve with a gentle stream of water to prevent splattering. Large rocks and sticks must be thoroughly scraped, rinsed and examined prior to setting them aside. The remaining sample is placed in an appropriate sized Caton tray for subsampling and sorting.

3.1.1.1 Elutriation

Elutriation is basically an extraction of the organisms from the substrate remaining in the sample. This technique works best when the substrate is inorganic material such as sand, pebbles, and rocks. Samples with a large amount of organic material are not amenable to this extraction. Field elutriations can be performed to reduce the number of jars a field crew transports to the macroinvertebrate laboratory or to separate soft-bodied macroinvertebrates from the course material in a sample.

Dump the sample into a 5-gallon bucket and fill the tray with water. Swish the sample around in the tray to liberate organic material and bugs from the substrate. The organic material and organisms should float in the water. Pour the water and all floating material and organisms into a 500um sieve. Add more water and repeat the process until no more organic material remains in the tray. Note: A 10% magnesium sulfate solution can be used instead of just water to increase the efficiency of the elutriation.

Once the sample is separated, use a magnifying lamp to check the inorganic portion of the sample for snails, clams, stone cased organisms, or any other organism too heavy to have floated. Have a fellow technician take a second look to verify that all organisms were removed. Any organisms found in the inorganic fraction must be added to the organisms in the sieve so they may be included in the sort. If a large number of organisms are found remaining in the inorganic fraction, the elutriation technique is not appropriate and the sample fraction in the sieve must be recombined with the inorganic fraction and sorted as a whole.

3.2 SUB-SAMPLING AND SORTING

The techniques for subsampling and sorting vary slightly between the contractors used by DEQ. Rather than describing (in detail) each contractor's specific method, DEQ requires that each contractor documents their procedure in a SOP, which includes the following components:

- Magnifying glass or microscope used for subsample and sort. (Specify power)
- Standardized sorting bench sheets
- Random selection of cells
- Last cell chosen
- Quality Controls to determine sorting efficiency or precision

SOPs must be submitted to DEQ as part of the contractor qualification process.

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3.2.1 Sorting Quality Control (QC)

3.2.1.1 Relative Percent Difference in Enumeration (RPDE)

DEQ evaluates the precision of sample counts taken for the subsamples by calculating the relative percent difference of enumeration (RPDE). The RPDE is the standard formula used to evaluate how well a laboratory performs by comparing a sample result versus the result generated by a second laboratory evaluating the same sample (American Public Health Association, et al., 1998). Calculate the RPDE by comparing results from two independent laboratories or taxonomists using the formula:

$$\text{RPDE} = \frac{\left| \text{Sample Result}_1 - \text{Sample Result}_2 \right|}{(\text{Sample Result}_1 + \text{Sample Result}_2)/2}$$

where *sample result*$_1$ is the number of organisms in a sample counted by the first laboratory, and *duplicate result*$_2$ is the recount by the second taxonomist or laboratory (adapted from Standard Methods 20th Ed. - 1020 B (American Public Health Association, et al., 1998)). The purpose of this calculation is to highlight those samples where counts differ substantially and to focus attention on obtaining better consistency.

The measurement quality objective (MQO) for RPDE is 10%. Values for individual sample comparisons exceeding the MQO (> 10%) require an examination to determine causes of the difference. Upon completion of this investigation, DEQ will communicate when and if the RPDE exceeds 10% to the taxonomic contractor and QC taxonomist(s). This will occur as a conference call and/or e-mail correspondence with the contractor(s).

4.0 TAXONOMY

4.1 TAXONOMIC IDENTIFICATION

Consistency in macroinvertebrate taxonomy is critical for final site assessments and interpretation. It is the responsibility of the taxonomist to communicate the composition of samples to those personnel performing data entry, and to be able to defend taxonomic results to the ultimate data analysts. DEQ encourages taxonomists to identify specimens to the *lowest practical taxonomic level*. However, DEQ also understands that specimen condition (damage, early instar, poor slide mounts) may force the taxonomist into an unavoidable situation of having to leave identification at more coarse levels (e. g., family instead of genus). With the limitation of organism condition in mind, DEQ will judge consistency of data based on historical hierarchical levels that have been achieved, resulting in the Montana Master Taxa list (**Appendix A**).

Count vs. non-count specimens. In general, all specimens in the subsample should be identified and counted by the taxonomist, including pupae. However, there are several exceptions known as non-counts, which include:

- Empty mollusk shells (lacking soft tissue)
- Worm fragments lacking the anterior (head) end
- Body parts NOT INCLUDING at least the head and thorax
- Surface dwellers such as Collembola, Gerridae, and Veliidae

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- Incidentally-collected terrestrial specimens

Some hierarchical inconsistency in taxonomic data is dealt with during coding and analysis (see **Section 5.2**). During development of the Observed/Expected (O/E) models (**Section 5.5**), operational taxonomic units (OTUs) are specified to reduce the influence of ambiguous taxonomy. The complete Montana taxa list with OTUs and other attributes is available from DEQ as a table within the DEQ macroinvertebrate database and as **Appendix A**. A template for tracking identification and enumerations is provided as **Appendix B**.

4.2 QUALITY CONTROL FOR TAXONOMY

All QC activities, including specification and response to corrective actions, should be completed *prior* to initiation of data reduction (metric calculation and indicator analysis). The aspects relevant to taxonomic data quality are: accuracy and precision (Stribling, et al., 2003).

4.2.1 Accuracy

Accuracy is defined as the nearness of a measurement to a specified analytical truth. For taxonomy, there are several options that can be used as the analytical truth, including:

- Museum-based type material (holotype, paratype, or other; the original specimen or series of specimens on which the original description of a species is based),
- The most current and accepted taxonomic literature (dichotomous keys with illustrated, diagnostic morphological characters), or
- A reference collection, verified by an independent taxonomic specialist.

Type material is usually found in museums, and direct interaction with museum curators is required to use it for comparisons. Thus, it is often not feasible, or even necessary, for routine monitoring and assessment programs or projects (Stribling et al. 2003). Contractors must provide at least one reference collection per year that can be verified by a qualified, independent macroinvertebrate taxonomist. Depending on the magnitude of an individual project, a project-specific reference collection may be requested by DEQ; what the reference collection is intended to represent will be determined by DEQ. Whether the reference collection is annual or project-based, specimens included in it are intended to represent the original taxonomist's concept of the morphological basis of each taxon. Verification of the reference collection, by DEQ staff or independent laboratories or taxonomists, documents the morphological and nomenclatural understanding of the original taxonomist. This will provide DEQ with some assurance of the contract taxonomist's use of up-to-date nomenclature (with the Integrated Taxonomic Information System [ITIS] as the standard), as well as verifying their understanding of the morphological bases of taxonomic groupings.

4.2.2 Precision

Precision is defined as nearness of different measures of the same property. Simply stated, it is a measure of consistency and repeatability; for production taxonomy (Stribling et al. 2003), quantification of taxonomic precision provides the ability to document and communicate the quality of taxonomic data within a project, or within a laboratory over time. Taxonomic precision is evaluated by direct comparison of the results (list of taxa and number of individuals of each) of a randomly-selected sample that is processed by 2 taxonomists or laboratories. Once a sample is identified by the primary taxonomist (T1), it is sent to an outside, independent taxonomist (T2), who re-identifies the entire (sub)sample. The sample should be sent to T2 blind, that is, without any identification labels associated

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with the material. Each taxonomist will be provided with a hierarchical target list (standard level of effort for each taxon) and "counting rules" (need to be included as attachments). The total set of randomly-selected subsamples is a subset of the total number of samples collected for:

- A single project,
- Multiple projects within a sampling year, or
- >1 projects over several sampling years.

If multiple taxonomists within a project or laboratory have each identified enough samples, the subset can be stratified among the taxonomists so that specific checks can be made on individual taxonomists. Generally, and as a rule-of-thumb, the subset of samples can be approximately 10% of the total sample lot. For example, if a project has a total of 30 samples, there should be 3 samples randomly selected that will be re-identified by an outside/independent taxonomist. It is recommended that there be at least 3 samples selected and re-identified for sample lots of ≤ 30. For large programs or projects, say > 500 samples, it may be unnecessary to have 50 samples re-identified, but that decision will be made by DEQ.

Using the final results by the taxonomists, precision is quantified for both specimen enumeration and taxonomic identifications for each of the QC or re-id samples.

4.2.2.1 Percent Taxonomic Disagreement (PTD)

Use the formula below for determining Percent Taxonomic Disagreement (PTD):

$$PTD = \left[1 - \left(\frac{comp_{pos}}{N}\right)\right] \times 100$$

Where: $comp_{pos}$ is the number of agreements, and N is the total number of organisms in the larger of the two counts (Stribling et al. 2003).

Three types of taxonomic errors are illuminated by this comparison process: 1) straight disagreements, 2) hierarchical differences, and 3) missing specimens. Effort will be made during the side by side comparison of individual samples to specify the types of differences that are observed, and which types predominate in each sample. The lower the PTD value, the greater is the overall taxonomic precision, indicating relative consistency in sample treatment. For the 2006 field season and beyond, an MQO for PTD ≤ 15% is established. Values for individual sample comparisons exceeding the MQO (> 15%) will prompt a more detailed examination of those individual samples to determine the cause or causes of the difference in counts. PTD results as well as parsing of the difference types will be used by DEQ to develop corrective actions. Corrective actions related to taxonomic disagreement will be forwarded in writing to the taxonomy laboratory responsible for the primary identifications. The corrective actions will require that the contractor(s) correct the entire sample lot, or only the 10% subset that were the QC samples.

4.2.2.1.1 Bias

Bias is defined as statistical or method error caused by systematically favoring some outcomes over others and can be characterized as the degree of departure from a true value. Taxonomic bias exists if there are consistent misinterpretations of dichotomous keys or morphological features, poor processing of samples (e.g., poor slide-mounting techniques), or inadequate optical equipment. There is no specific

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MQO established for bias but it may be a factor in the review of accuracy, which is described as low bias (directional error) and high precision.

4.2.3 Corrections to database

Any corrections to DEQ databases will be handled by the DEQ QA Officer, who will work directly with the DEQ MT-eWQX Coordinator and the DEQ macroinvertebrate specialist, who are responsible for the MT-eWQX and EDAS databases, respectively.

5.0 DATA ANALYSIS AND INTERPRETATION

Data analysis and assessment of biological integrity should be performed following the six steps listed here and described in **Sections 5.1 – 5.6**.

1. Transfer sample data from laboratory output to a reliable database
2. Reduce sample data
   a) condense to proper OTUs
   b) exclude taxa marked
   c) artificially reduce large samples
3. Compile site information (predictor variables) and identify site classes
4. Calculate the Montana-specific version of the Hilsenhoff Biotic Index (HBI)
5. Calculate a Observed/Expected(O/E) Model Result
6. Assess site biological integrity through interpretation of index results

Most of these steps are considerably simplified by using EDAS (Tetra Tech and Montana Department of Environmental Quality, 2006), which can be obtained from DEQ along with its User's Manual (Tetra Tech, 2006). Compiling site information (step 3), calculating the O/E model (step 4), and the interpreting the results (step 5) are accomplished using other technologies and procedures described below.

5.1 TRANSFER SAMPLE DATA

Benthic macroinvertebrate taxa lists with individual counts should be transferred into EDAS (Tetra Tech 2006a) or another database in which taxa can be associated with the taxonomic attributes used in calculating metrics and predictive models. EDAS includes a function that automates import of taxonomic data after the data are properly formatted in a spreadsheet. With any data transfer procedure, the accuracy of the transfer should be checked to assure 100% accuracy.

5.2 REDUCE SAMPLE DATA

5.2.1 Operational Taxonomic Units (OTUs)

For each taxon in a sample taxa list, the OTU must be determined. OTUs are identified in the Benthic Master Taxa table of EDAS. This is the level of identification at which taxonomic counts are condensed for calculations, for O/E (predictive model) calculations[1]. For instance, midges (Diptera: Chironomidae) have OTUs at the subfamily level because this is the level at which all agencies in Montana reliably

[1] Note: OTUs are not considered taxonomic target levels. Future DEQ macroinvertebrate tools may require different taxonomic requirements. Therefore, macroinvertebrate taxonomy should include identifications at the lowest practical taxonomic level, as stated in **Section 4-1**.

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identify them. Numbers of individuals in multiple taxa identified at a more detailed level are summed within a sample if the OTU is at a more coarse level. OTUs for metric calculations include family and order level identifications. OTUs for predictive models exclude family and more coarse identifications for some taxa groups.

5.2.2 Excluded Taxa

In calculations of metrics that are counts of taxa (richness metrics), only those taxa that are unique within each sample should be counted. Ambiguous taxa are excluded from taxa counts. Such taxa include family level identifications within a sample that also includes genus level identifications from the same family. Likewise, order or coarser identifications may be ambiguously unique and should be excluded. Such exclusions should be made after converting taxa and individual counts at the appropriate OTU level. In EDAS, 'Excluded Taxa' are automatically marked as they are imported. Excluded taxa can also be marked manually. Within each sample, every OTU taxon that defines a group that is also represented by another OTU taxon identified at a more detailed taxonomic level should be marked for exclusion from metrics that count unique taxa.

5.2.3 Re-Sampling

Random re-sampling is the process by which samples larger than the target subsample size are reduced to the exact target subsample size. Random re-sampling generates a list of taxa and their abundances that would occur if the original sample had identified only the target number of individuals. Such a list is necessary for the predictive model, in which presence and absence of taxa for a standard sample size is required. It contrasts from rarefaction, which gives a probability for every taxon, but does not reduce the list of individuals or taxa.

In EDAS, random re-sampling is accomplished by assigning a random number to each individual in an oversized sample, ordering the list by the random numbers, and selecting the top 300 individuals to represent the new sample. By this method, some individuals and perhaps some uncommon taxa are eliminated from the list. Because it uses random number generators in determining the final list of taxa, random re-sampling can result in different taxa lists every time it is executed.

5.3 IDENTIFY SITE CLASSES

5.3.1 Predictor Variables

Site classes for the predictive model (O/E) are not distinct, but are calculated as probabilities within the model. Both indices require predictor variables for site classification (**Table 5-1**). These variables can be derived by associating geographically referenced data with the coordinates and delineated watersheds of each site. While it is possible to derive predictor values through map analysis, watershed delineation and spatial analyses are best performed with a Geographic Information System (GIS), such as ArcGIS 9.x or 10.x. The GIS analysis is outlined in Chinnayakanahalli et al. (2006). The basic GIS analytical procedures include the ***association*** of Station IDs with waterbody names with ***geographic*** coordinates, loading the spatially referenced stations into the GIS program, verifying station locations, delineating catchments using Digital Elevation Models (DEMs), and intersecting station points and catchments with the appropriate predictor data layers.

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Table 5-1. Predictive variables associated with each sampling station.

Variable (EDAS name)	Description	Model	Data Source
Latitude (GIS_LAT)	Latitude (decimal), confirmed during delineation	O/E 2005; 2011	GIS or map
Longitude(GIS_LONG)	Longitude (decimal), confirmed during delineation	O/E 2005	GIS or map
Area (SQ_KM)	Catchment area (km^2)	O/E 2005; 2011	GIS or map
Basin (Columbia River Basin)	Within the Columbia River Basin (1 = yes, 0 = no)	O/E 2005	GIS or map
Air Temperature (TMAX_PT)	Annual mean of daily maximum temperatures at the site between 1971-2000 (C x 10, e.g., 14.4 degrees C = 144)	O/E 2005	PRISM database[a]
Standard Deviation of the elevation within the watershed (ELEVsd_WS)	The standard deviation of the digital elevation model data within the watershed	O/E 2011	GIS
Air Temperature (TMAX_PT_2011)	Annual mean of daily maximum temperatures at the site between 1961-1990 (C x 10, e.g., 14.4 degrees C = 144)	O/E 2011	PRISM database[a]
Julian Day (DAY)	Numeric Day of the year (1-365)	O/E 2011	Calendar
Mountains (Mtn1)	Classified as a coldwater stream (1 = yes, 0 = no)	O/E 2011	ARM[b]

[a]PRISM: Parameter-elevation Regressions on Independent Slopes Model (Daly, et al., 2004), URL: http://www.ocs.orst.edu/prism/
[b]Administrative Rules of Montana

5.4 CALCULATE MACROINVERTEBRATE INDICATOR RESULTS

5.4.1 Calculate the Montana-specific Hilsenhoff Biotic Index (HBI)

The HBI metric represents the relative sensitivity of the sample to nutrient perturbation. It is calculated as the average tolerance value of all individuals in the sample (excluding those without tolerance values). The range of the Biotic Index values is 0-10, 0 being sensitive and 10 being pollution tolerant. The biotic index values are listed in the "TolVal" column in the Master Taxa List in **Appendix A**. The HBI results are calculated using a weighted average:

$$HBI = \sum (ni \; x \; ai)/N$$

Where:
"n" is the number of individuals in a taxon, "i";
"a" is the index value assigned to that taxon;
N is the number of individuals in the sample with a Biotic Index value.

5.4.2 Calculate Observed/Expected

The O/E models are calculated as the ratio of the number of taxa observed (O) in the collected sample to the number expected (E) in that site type (Feldman and Jessup, 2012). The O/E ratio is calculated from sample taxa lists and predictive variables that are either uploaded to a website that runs the model or via the coldwater O/E model built using the R statistical language. The website is maintained by the Utah

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State University's (USU) Western Center for Monitoring and Assessment of Freshwater Ecosystems (http://www.cnr.usu.edu/wmc/). The R code for the coldwater O/E model is detailed in **Appendix D**. Details for generating uploadable files from EDAS and running either of the models are available in the EDAS User's Manual (Tetra Tech 2010) and on the website. An explanation of the theory and processes of the model is included in Feldman and Jessup (2012).

5.5 VALIDATING MODEL OUTPUTS

Output from either O/E model provides information to determine the validity of the values (see **Appendix C**). Validity is dependent on having a minimum sample size after data reduction and, for the O/E, on model recognition of the combination of predictor variables. Sample sizes for the O/E may be different for the same sample because the O/E discounts some coarse taxa identifications (see **Section 5.2**). To determine whether the O/E could recognize the combination of predictor variables, refer to the website results labeled 'outlier'. An outlier O/E test result indicates a site that is outside of the experience of the model and the O/E value may be unreliable.

5.6 INTERPRET THE OBSERVED/EXPECTED INDEX

The interpretation of benthic macroinvertebrate data is a component within the broader Water Quality Assessment Method (Montana Department of Environmental Quality, 2011). Depending on the availability and rigor of other biological data, benthic macroinvertebrate data *may not,* be used exclusively for aquatic life and fisheries beneficial use support determinations. With this in mind, this section of the SOP uses the terms: "pass", or "fail" in relation to the biological model test in the context of the biological component within an established water quality assessment method (**Appendix D**).

The O/E model is used with established assessment methods to determine the integrity of the macroinvertebrate community. The O/E models are used to test how far a given macroinvertebrate community deviates from those sampled at reference sites.

O/E values in **Table 5-4** indicate when a macroinvertebrate sample either passes or fails the biological model test. Note: some DEQ stressor-specific assessment methods apply different O/E thresholds in a different manner than those presented in **Table 5-4** (see Suplee and Sada de Suplee, 2011). Follow the guidelines in those assessment methods when using the biological indicators for stressor-specific assessments. Otherwise use the thresholds in **Table 5-4**.

Table 5-4. Biological test thresholds based on O/E results.

O/E Model	Region (stream setting)	Pass	Fail
2005	Eastern MT (plains)	$\geq$ 0.80	< 0.80
2011	Western MT (mountain/transitional)	$\geq$ 0.90	< 0.90

5.6.1 Bray-Curtis Index

A supplemental measure to the O/E model is the Bray-Curtis Index (BC) (Van Sickle, 2008). The BC index is derived from some of the same information used to calculate the O/E score. It can be a useful tool for discerning counterintuitive O/E results. The BC Index is most helpful whenever a high (i.e. good) O/E score results from a sample collected from a known stressed stream. Occasionally this occurs when certain stressors (e.g. excess nutrients) cause some taxa to be **replaced** by other taxa that are more tolerant of the stressors, resulting in a high O/E score in a stream with high stressors. The BC Index

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shows when new taxa have replaced others taxa above and beyond what the O/E model expected to measure in a given stream.

The formula for the BC Index is the sum of the absolute differences in the number of presence/absence (1,0) of observed taxa (O) minus their associated probabilities of capture (P) divided by the total sum of the O + P values:

$$BC = \frac{\sum|O - P|}{\sum(O + P)}$$

Note that the O is the formula above is not the raw count of individuals from a taxa group (e.g., 15 *Tricorythodes sp.* out of 100 total individual insects counted in a sample). Rather, it is a dummy variable indicating whether or not even a single individual of the taxa in question was observed in the sample (o no, 1 yes). The BC Index is scaled in the opposite direction than the O/E model. The BC scores will range between 0 and 1; a score of 0 means that no taxa replacement has occurred, and 1 means that all of the taxa have been replaced with other taxa**.** Use the BC Index ***only*** to help guideyour assessment decisions when you believe you are getting an incorrect O/E score. It is not meant to trump or replace the O/E score, just to clarify it. Van Sickle (2008) reported that the BC Index was more sensitive to several stressor gradients based upon nationwide datasets. You can use it to show when a community is shifting before the O/E model will react to the stressor.

5.6.1.1 How the BC Index Can Be Helpful

Table 5-6 shows a hypothetical macroinvertebrate sample collected from a stream with a high measured stressor (e.g., a fine sediment source) upstream of the sampling location. For demonstration purposes, this is an extremely small sample (five taxa). Remember that the "E" in the O/E formula is the sum of the probability of capture values for all of the taxa in a sample.

Table 5-6. A hypothetical example that demonstrates the O/E calculation, the absolute difference for the hypothetical observed (O) and expected (P) taxa, and sum of O and P for 5 taxa (adopted from Van Sickle 2008).

Taxon	O	P	|O - P|	(O + P)
1	1	0.1	0.9	1.1
2	1	0.3	0.7	1.3
3	1	0.8	0.2	1.8
4	0	0.9	0.9	0.9
5	0	0.9	0.9	0.9
	O = sum =3	E= sum = 3	Mean = 0.72; sum = 3.6	sum = 6

In this scenario, taxa 4 and 5 were expected by the model to be in the sample (i.e., probability of capture = 0.9; however, they were not collected, therefore O = 0 for both taxa. Taxa 1 and 2 were very unlikely to be collected, yet they were collected (O = 1 for each taxon). The probability of capture rates for taxa 1 and 2 was 0.1 and 0.3, respectively. The O/E score in this scenario = (3/3) = 1, and at first blush, this could be interpreted as a reference quality stream supporting a healthy macroinvertebrate community. In the example, however, recent habitat observations of high fine sediment deposition suggested an impairment really is occurring at the stream but it was not detected by O/E. The BC Index = 0.6 (3.6/6.0). This means that 40% of the taxa in this sample were replaced by rare, potentially tolerant, taxa. With

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this combination of O/E and BC scores, you can say that the macroinvertebrate community was in the process of adjusting to the instream changes in stressor levels.

5.7 REPORTING RESULTS

Reports written for the DEQ following the methods described herein require:

- The EDAS output and a concise one paragraph ecological interpretation. The ecological interpretation includes a description of the invertebrates found in the sample and what their presence represents in terms of water quality.
- Taxonomic lists of macroinvertebrates, including tolerance values and functional feeding group designations used for each taxon. Taxa lists should include class, order, family, genus, and species designations where possible. Taxa lists should follow the taxonomic classification scheme shown in **Appendix A** to facilitate DEQ quality assurance activities.
- Copies of taxonomic bench sheets should be included (Taxa List Template example provided in **Appendix B**.)
- Number pages on all reports, including appendices.
- A clear and concise summary of findings and conclusions.
- Clearly document the dates samples were collected in any written report.
- If an internal reference is developed for the analysis, describe the internal reference used.
- Clear documentation of the proportion of sample subsampled.
- Submit data both in hard copy and in electronic form (EQUiS/WQX Compatible).
- If any further analysis is needed in which the O/E models cannot be used, contact David Feldman; Water Quality Standards Section; Montana Department of Environmental Quality, PO Box 200901, Helena MT 59620- 0901 (406)-444-6764, dfeldman@mt.gov or the current biocriteria specialist for the state of Montana.

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APPENDIX A - MONTANA MACROINVERTEBRATE TAXA LIST

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Phyla	Class	Order	Family	FinalID	TolVal	OTU_2005	OTU_2011
Arthropoda	Insecta	Diptera	Chironomidae	Ablabesmyia	8	Tanypodinae	Ablabesmyia
Arthropoda	Insecta	Diptera	Chironomidae	Acalcarella	8	Chironominae	NA
Arthropoda	Arachnida	Acarina	Acarina	Acarina	5	Acarina	Acari
Arthropoda	Insecta	Ephemeroptera	Baetidae	Acentrella	4	Acentrella	Acentrella
Arthropoda	Insecta	Ephemeroptera	Baetidae	Acentrella insignificans	4	Acentrella	Acentrella
Arthropoda	Insecta	Ephemeroptera	Baetidae	Acentrella turbida	4	Acentrella	Acentrella
Arthropoda	Insecta	Lepidoptera	Pyralidae	Acentria		Lepidoptera	NA
Arthropoda	Insecta	Ephemeroptera	Baetidae	Acerpenna		Acerpenna	NA
Arthropoda	Insecta	Ephemeroptera	Baetidae	Acerpenna pygmaea		Acerpenna	NA
Arthropoda	Insecta	Diptera	Chironomidae	Acricotopus	6	Orthocladiinae	NA
Arthropoda	Insecta	Plecoptera	Perlidae	Acroneuria	0	Acroneuria	Perlidae
Arthropoda	Insecta	Plecoptera	Perlidae	Acroneuria abnormis	2	Acroneuria	Perlidae
Arthropoda	Insecta	Diptera	Culicidae	Aedes	7	Culicidae	NA
Arthropoda	Insecta	Odonata	Aeshnidae	Aeshna		Aeshna	NA
Arthropoda	Insecta	Odonata	Aeshnidae	Aeshnidae	5	Aeshnidae	NA
Arthropoda	Insecta	Coleoptera	Dytiscidae	Agabinus		Agabinus	Dytiscidae
Arthropoda	Insecta	Coleoptera	Dytiscidae	Agabus	5	Agabus	Dytiscidae
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Agapetus	0	Agapetus	Glossosomatidae
Arthropoda	Insecta	Diptera	Blephariceridae	Agathon	0	Blephariceridae	NA
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Agraylea	8	Agraylea	Hydroptilidae
Arthropoda	Insecta	Hemiptera	Naucoridae	Ambrysus	3	Naucoridae	Other_Hemiptera
Arthropoda	Insecta	Hemiptera	Naucoridae	Ambrysus mormon	3	Naucoridae	Other_Hemiptera
Arthropoda	Insecta	Ephemeroptera	Ameletidae	Ameletus	0	Ameletus	Ameletidae
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Ametor		Ametor	Hydrophilidae
Arthropoda	Insecta	Ephemeroptera	Ametropodidae	Ametropus		Ametropus	NA
Arthropoda	Insecta	Trichoptera	Brachycentridae	Amiocentrus	3	Amiocentrus	Amiocentrus
Arthropoda	Insecta	Trichoptera	Brachycentridae	Amiocentrus aspilus	3	Amiocentrus	Amiocentrus
Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae	Amnicola		Hydrobiidae	NA
Arthropoda	Insecta	Odonata	Coenagrionidae	Amphiagrion	7	Amphiagrion	Zygoptera
Arthropoda	Insecta	Trichoptera	Limnephilidae	Amphicosmoecus canax		Amphicosmoecus	Limnephilidae
Arthropoda	Insecta	Plecoptera	Nemouridae	Amphinemura	2	Amphinemura	NA
Arthropoda	Insecta	Plecoptera	Nemouridae	Amphinemura banksi	2	Amphinemura	NA
Crustacea	Malacostraca	Amphipoda	.	Amphipoda		Amphipoda	Amphipoda
Arthropoda	Insecta	Coleoptera	Amphizoidae	Amphizoa		Amphizoa	NA
Arthropoda	Insecta	Trichoptera	Limnephilidae	Anabolia		Anabolia	Limnephilidae

Phyla	Class	Order	Family	FinalID	TolVal	OTU_2005	OTU_2011
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Anacaena	5	ANACAENA	Hydrophilidae
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Anagapetus	0	Anagapetus	Glossosomatidae
Arthropoda	Insecta	Ephemeroptera	Acanthametropodidae	Analetris eximia		Analetris	NA
Arthropoda	Insecta	Odonata	Aeshnidae	Anax	5	Anax	NA
Arthropoda	Insecta	Odonata	Aeshnidae	Anax junius		Anax	NA
Annelida	Annelida	Annelida	Annelida	Annelida		Annelida	NA
Arthropoda	Insecta	Diptera	Culicidae	Anopheles	10	Culicidae	NA
Arthropoda	Insecta	Diptera	Tipulidae	Antocha	3	Antocha	Antocha
Arthropoda	Insecta	Trichoptera	Apataniidae	Apatania	3	Apatania	Apataniidae
Arthropoda	Insecta	Diptera	Chironomidae	Apedilum		Chironominae	NA
Mollusca	Gastropoda	Basommatophora	Physidae	Aplexa		Aplexa	Physidae
Arthropoda	Insecta	Diptera	Chironomidae	Apsectrotanypus	8	Tanypodinae	Macropelopiini
Arthropoda	Insecta	Odonata	Lestidae	Archilestes	9	Archilestes	Zygoptera
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Arctopsyche	2	Arctopsyche	Arctopsyche
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Arctopsyche grandis	2	Arctopsyche	Arctopsyche
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Arctopsychinae		Arctopsychinae	NA
Arthropoda	Insecta	Odonata	Coenagrionidae	Argia	7	Argia	Zygoptera
Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	Asioplax		Asioplax	NA
Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	Asioplax edmundsi		Asioplax	NA
Arthropoda	Insecta	Diptera	Athericidae	Athericidae	2	Atherix	NA
Arthropoda	Insecta	Diptera	Athericidae	Atherix	5	Atherix	NA
Arthropoda	Insecta	Diptera	Athericidae	Atherix pachypus	4	Atherix	NA
Arthropoda	Insecta	Diptera	Ceratopogonidae	Atrichopogon		Forcipomyiinae	Ceratopogonidae
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Attenella	3	Attenella	NA
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Attenella delantala		Attenella	NA
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Attenella margarita	3	Attenella	NA
Annelida	Oligochaeta	Haplotaxida	Tubificidae	Aulodrilus	10	Oligochaeta	Tubificidae
Arthropoda	Insecta	Diptera	Chironomidae	Axarus		Chironominae	NA
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetidae	4	Baetidae	NA
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis	5	Baetis	NA
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis alius	1	Baetis	NA
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis bicaudatus	2	Baetis	Baetis_bicaudatus
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis flavistriga	5	Baetis	Baetis_flavistriga
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis intercalaris		Baetis	NA
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis propinquus	6	Baetis	NA

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Phyla	Class	Order	Family	FinalID	TolVal	OTU_2005	OTU_2011
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis punctiventris		Baetis	NA
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis tricaudatus	4	Baetis	Baetis_tricaudatus
Arthropoda	Insecta	Ephemeroptera	Baetiscidae	Baetisca		Baetisca	NA
Arthropoda	Insecta	Hemiptera	Belostomatidae	Belostomatidae	10	Belostomatidae	Other_Hemiptera
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Berosus	5	Berosus	Hydrophilidae
Arthropoda	Insecta	Diptera	Ceratopogonidae	Bezzia		Ceratopogoninae	Ceratopogonidae
Arthropoda	Insecta	Diptera	Blephariceridae	Bibiocephala	0	Blephariceridae	NA
Arthropoda	Insecta	Diptera	Blephariceridae	Bibiocephala grandis	0	Blephariceridae	NA
Arthropoda	Insecta	Diptera	Blephariceridae	Blephariceridae	0	Blephariceridae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Boreochlus	1	Podonominae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Boreoheptagyia		Diamesinae	NA
Arthropoda	Insecta	Trichoptera	Brachycentridae	Brachycentridae	1	Brachycentridae	NA
Arthropoda	Insecta	Trichoptera	Brachycentridae	Brachycentrus	1	Brachycentrus	Brachycentrus
Arthropoda	Insecta	Trichoptera	Brachycentridae	Brachycentrus americanus	1	Brachycentrus	Brachycentrus
Arthropoda	Insecta	Trichoptera	Brachycentridae	Brachycentrus occidentalis	2	Brachycentrus	Brachycentrus
Arthropoda	Insecta	Ephemeroptera	Caenidae	Brachycercus	3	Brachycercus	Caenidae
Annelida	Hirudinea	Branchiobdellida	.	Branchiobdellida		Branchiobdellida	NA
Arthropoda	Insecta	Diptera	Chironomidae	Brillia	4	Orthocladiinae	Brillia
Arthropoda	Insecta	Diptera	Chironomidae	Brundiniella	3	Tanypodinae	Macropelopiini
Arthropoda	Insecta	Coleoptera	Haliplidae	Brychius	5	Brychius	Haliplidae
Bryozoa	Tubellaria	.	.	Bryozoa		Bryozoa	NA
Arthropoda	Insecta	Hemiptera	Notonectidae	Buenoa		Notonectidae	Other_Hemiptera
Crustacea	Malacostraca	Isopoda	Asellidae	Caecidotea	8	Asellidae	NA
Arthropoda	Insecta	Ephemeroptera	Caenidae	Caenidae	8	Caenidae	Caenidae
Arthropoda	Insecta	Ephemeroptera	Caenidae	Caenis	8	Caenis	Caenidae
Arthropoda	Insecta	Ephemeroptera	Caenidae	Caenis latipennis	7	Caenis	Caenidae
Arthropoda	Insecta	Ephemeroptera	Caenidae	Caenis youngi	8	Caenis	Caenidae
Arthropoda	Copepoda	Calanoida	.	Calanoida		Calanoida	NA
Arthropoda	Insecta	Plecoptera	Perlidae	Calineuria californica	2	Calineuria	Perlidae
Arthropoda	Insecta	Ephemeroptera	Baetidae	Callibaetis	9	Callibaetis	Callibaetis
Arthropoda	Insecta	Hemiptera	Corixidae	Callicorixa		Corixidae	Corixidae
Arthropoda	Insecta	Diptera	Stratiomyidae	Caloparyphus	7	CALOPARYPHUS/EUPARYPHUS	Stratiomyidae
Crustacea	Malacostraca	Decapoda	Cambaridae	Cambaridae		Cambaridae	NA
Arthropoda	Insecta	Ephemeroptera	Baetidae	Camelobaetidius	4	Camelobaetidius	NA
Arthropoda	Insecta	Diptera	Chironomidae	Camptocladius	6	Orthocladiinae	NA

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Phyla	Class	Order	Family	FinalID	TolVal	OTU_2005	OTU_2011
Arthropoda	Insecta	Plecoptera	Capniidae	Capniidae	1	Capniidae	Capniidae
Arthropoda	Insecta	Diptera	Chironomidae	Cardiocladius	5	Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Cardiocladius albiplumus	5	Orthocladiinae	NA
Arthropoda	Insecta	Plecoptera	Perlodidae	Cascadoperla trictura	2	Cascadoperla	Perlodidae
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Caudatella	0	Caudatella	Caudatella
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Caudatella cascadia		Caudatella	Caudatella
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Caudatella edmundsi	0	Caudatella	Caudatella
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Caudatella heterocaudata	0	Caudatella	Caudatella
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Caudatella hystrix	0	Caudatella	Caudatella
Arthropoda	Insecta	Hemiptera	Corixidae	Cenocorixa		Corixidae	Corixidae
Arthropoda	Insecta	Ephemeroptera	Baetidae	Centroptilum	2	Centroptilum	NA
Arthropoda	Insecta	Trichoptera	Leptoceridae	Ceraclea	3	Ceraclea	Leptoceridae
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogonidae	6	Ceratopogonidae	Ceratopogonidae
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	6	Ceratopogoninae	Ceratopogonidae
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Ceratopsyche	5	Hydropsyche_Ceratopsyche	NA
Arthropoda	Insecta	Ephemeroptera	Caenidae	Cercobrachys		Cercobrachys	Caenidae
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Cercyon		Cercyon	Hydrophilidae
Arthropoda	Insecta	Diptera	Chironomidae	Chaetocladius	6	Orthocladiinae	Chaetocladius
Annelida	Oligochaeta	Haplotaxida	Naididae	Chaetogaster		Oligochaeta	Naididae
Annelida	Oligochaeta	Haplotaxida	Naididae	Chaetogaster diaphanus	6	Oligochaeta	Naididae
Annelida	Oligochaeta	Haplotaxida	Naididae	Chaetogaster limnaei	6	Oligochaeta	Naididae
Arthropoda	Insecta	Diptera	Chaoboridae	Chaoboridae	8	Chaoboridae	Chaoboridae
Arthropoda	Insecta	Diptera	Chaoboridae	Chaoborus		Chaoborus	Chaoboridae
Arthropoda	Insecta	Diptera	Empididae	Chelifera	5	Chelifera_Metachela_Neoplasta	Empididae
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Cheumatopsyche	5	Cheumatopsyche	Cheumatopsyche
Arthropoda	Insecta	Trichoptera	Philopotamidae	Chimarra utahensis	4	Chimarra	Philopotamidae
Arthropoda	Insecta	Diptera	Chironomidae	Chironomidae	10	Chironomidae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	7	Chironominae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Chironomini	6	Chironominae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Chironomus	10	Chironominae	Chironomus
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Chloroperlidae	1	Chloroperlidae	NA
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Chloroperlinae		Chloroperlidae	NA
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Choroterpes	2	Choroterpes	Leptophlebiidae
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Choroterpes albiannulata	2	Choroterpes	Leptophlebiidae
Arthropoda	Insecta	Diptera	Tabanidae	Chrysops	10	Tabanidae	Tabanidae

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Phyla	Class	Order	Family	FinalID	TolVal	OTU_2005	OTU_2011
Arthropoda	Insecta	Trichoptera	Limnephilidae	Chyrandra	2	Chyrandra	Limnephilidae
Arthropoda	Insecta	Trichoptera	Limnephilidae	Chyrandra centralis	2	Chyrandra	Limnephilidae
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Cinygma	0	Cinygma	NA
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Cinygmula	0	Cinygmula	Cinygmula
Arthropoda	Insecta	Plecoptera	Perlidae	Claassenia	2	Claassenia sabulosa	Perlidae
Arthropoda	Insecta	Plecoptera	Perlidae	Claassenia sabulosa	3	Claassenia sabulosa	Perlidae
Arthropoda	Branchiopoda	Diplostraca	.	Cladocera		Cladocera	Cladocera
Arthropoda	Insecta	Diptera	Chironomidae	Cladopelma		Chironominae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Cladotanytarsus	7	Chironominae	Cladotanytarsus
Arthropoda	Insecta	Coleoptera	Elmidae	Cleptelmis	4	Cleptelmis	Cleptelmis
Arthropoda	Insecta	Coleoptera	Elmidae	Cleptelmis addenda		Cleptelmis	Cleptelmis
Arthropoda	Insecta	Coleoptera	Elmidae	Cleptelmis ornata	4	Cleptelmis	Cleptelmis
Arthropoda	Insecta	Diptera	Empididae	Clinocera	5	Clinocera	Empididae
Arthropoda	Insecta	Odonata	Coenagrionidae	Coenagrion		Coenagrionidae	Zygoptera
Arthropoda	Insecta	Odonata	Coenagrionidae	Coenagrionidae	7	Coenagrionidae	Zygoptera
Arthropoda	Insecta	Coleoptera	Dytiscidae	Colymbetes		Colymbetes	Dytiscidae
Arthropoda	Insecta	Diptera	Chironomidae	Conchapelopia	6	Tanypodinae	Other_Tanypodinae
Arthropoda	Insecta	Diptera	Chironomidae	Constempellina	8	Chironominae	NA
Arthropoda	Copepoda	Copepoda	Copepoda	Copepoda		Copepoda	Copepoda
Arthropoda	Insecta	Coleoptera	Dytiscidae	Coptotomus	5	Coptotomus	Dytiscidae
Mollusca	Bivalvia	Corbiculacea	Corbiculidae	Corbicula		Corbicula	NA
Arthropoda	Insecta	Odonata	Cordulegastridae	Cordulegaster		Cordulegaster	NA
Arthropoda	Insecta	Odonata	Cordulegastridae	Cordulegastridae		Cordulegastridae	NA
Arthropoda	Insecta	Odonata	Corduliidae	Corduliidae		Corduliidae	NA
Arthropoda	Insecta	Hemiptera	Corixidae	Corisella		Corixidae	Corixidae
Arthropoda	Insecta	Hemiptera	Corixidae	Corisella tarsalis		Corixidae	Corixidae
Arthropoda	Insecta	Hemiptera	Corixidae	Corixidae	9	Corixidae	Corixidae
Arthropoda	Insecta	Diptera	Chironomidae	Corynoneura	7	Orthocladiinae	Corynoneura
Crustacea	Malacostraca	Amphipoda	Crangonyctidae	Crangonyx		Crangonyx	Amphipoda
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus	8	Orthocladiinae	Cricotopus
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus (Cricotopus)	8	Orthocladiinae	Cricotopus
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus (Isocladius)	8	Orthocladiinae	Cricotopus
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus (Nostococladius)	8	Orthocladiinae	Cricotopus
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus bicinctus	9	Orthocladiinae	Cricotopus
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus tremulus	8	Orthocladiinae	Cricotopus

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Phyla	Class	Order	Family	FinalID	TolVal	OTU_2005	OTU_2011
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus trifascia	8	Orthocladiinae	Cricotopus
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus trifasciatus	8	Orthocladiinae	Cricotopus
Arthropoda	Insecta	Trichoptera	Limnephilidae	Cryptochia	3	Cryptochia	Limnephilidae
Arthropoda	Insecta	Diptera	Chironomidae	Cryptochironomus	8	Chironominae	Cryptochironomus
Arthropoda	Insecta	Diptera	Tipulidae	Cryptolabis		Cryptolabis	Other_Tipulidae
Arthropoda	Insecta	Diptera	Chironomidae	Cryptotendipes	6	Chironominae	Cryptotendipes
Arthropoda	Insecta	Diptera	Culicidae	Culex	10	Culicidae	NA
Arthropoda	Insecta	Diptera	Culicidae	Culicidae	10	Culicidae	NA
Arthropoda	Insecta	Diptera	Ceratopogonidae	Culicoides	10	Ceratopogoninae	Ceratopogonidae
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Culoptila	2	Culoptila	Glossosomatidae
Arthropoda	Insecta	Plecoptera	Perlodidae	Cultus	2	Cultus	Perlodidae
Arthropoda	Insecta	Coleoptera	Curculionidae	Curculionidae		Curculionidae	NA
Arthropoda	Copepoda	Cyclopoida	.	Cyclopoida	8	COPEPODA	NA
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	Daphniidae		Cladocera	Cladocera
Crustacea	Malacostraca	Decapoda	.	Decapoda	6	Decapoda	NA
Arthropoda	Insecta	Diptera	Chironomidae	Demicryptochironomus	8	Chironominae	NA
Annelida	Oligochaeta	Haplotaxida	Naididae	Dero digitata		Oligochaeta	Naididae
Arthropoda	Insecta	Coleoptera	Dytiscidae	Deronectes	5	Deronectes	Dytiscidae
Arthropoda	Insecta	Coleoptera	Dytiscidae	Desmopachria		Desmopachria	Dytiscidae
Arthropoda	Insecta	Plecoptera	Leuctridae	Despaxia	2	Leuctridae	Leuctridae
Arthropoda	Insecta	Plecoptera	Leuctridae	Despaxia augusta	2	Leuctridae	Leuctridae
Arthropoda	Insecta	Diptera	Deuterophlebiidae	Deuterophlebia	0	Deuterophlebia	NA
Arthropoda	Insecta	Diptera	Chironomidae	Diamesa	5	Diamesinae	Diamesa
Arthropoda	Insecta	Diptera	Chironomidae	Diamesinae	4	Diamesinae	NA
Arthropoda	Insecta	Trichoptera	Limnephilidae	Dicosmoecus	2	Dicosmoecus	Limnephilidae
Arthropoda	Insecta	Trichoptera	Limnephilidae	Dicosmoecus atripes	2	Dicosmoecus	Limnephilidae
Arthropoda	Insecta	Trichoptera	Limnephilidae	Dicosmoecus gilvipes		Dicosmoecus	Limnephilidae
Arthropoda	Insecta	Diptera	Tipulidae	Dicranota	0	Dicranota	Dicranota
Arthropoda	Insecta	Diptera	Chironomidae	Dicrotendipes	8	Chironominae	Dicrotendipes
Arthropoda	Insecta	Ephemeroptera	Baetidae	Diphetor hageni	5	Diphetor	Diphetor
Arthropoda	Insecta	Diptera	Chironomidae	Diplocladius	5	Orthocladiinae	NA
Arthropoda	Insecta	Diptera	.	Diptera		Diptera	NA
Arthropoda	Insecta	Plecoptera	Perlodidae	Diura	2	Diura	Perlodidae
Arthropoda	Insecta	Plecoptera	Perlodidae	Diura knowltoni	2	Diura	Perlodidae
Arthropoda	Insecta	Diptera	Dixidae	Dixa	4	Dixa	Dixidae

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Arthropoda	Insecta	Diptera	Dixidae	Dixella		Dixella	Dixidae
Arthropoda	Insecta	Diptera	Dixidae	Dixidae	4	Dixidae	Dixidae
Arthropoda	Insecta	Diptera	Dolichopodidae	Dolichopodidae	4	Dolichopodidae	NA
Arthropoda	Insecta	Trichoptera	Philopotamidae	Dolophilodes	0	Dolophilodes	Philopotamidae
Arthropoda	Insecta	Plecoptera	Perlidae	Doroneuria	0	Doroneuria	Perlidae
Arthropoda	Insecta	Plecoptera	Perlidae	Doroneuria theodora	0	Doroneuria	Perlidae
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Drunella	1	Drunella	NA
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Drunella coloradensis	0	Drunella coloradensis/flavilinea	Drunella_coloradensis/ flavilinea
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Drunella doddsi	1	Drunella doddsi	Drunella_doddsi
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Drunella flavilinea	2	Drunella coloradensis/flavilinea	Drunella_coloradensis/ flavilinea
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Drunella grandis	2	Drunella grandis	Drunella_grandis
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Drunella spinifera	0	Drunella spinifera	Drunella_spinifera
Arthropoda	Insecta	Coleoptera	Dryopidae	Dryopidae		Dryopidae	NA
Arthropoda	Insecta	Coleoptera	Elmidae	Dubiraphia	6	Dubiraphia	Dubiraphia
Platyhelminthes	Tubellaria	Tricladida	Planariidae	Dugesia		Turbellaria	Turbellaria
Arthropoda	Insecta	Coleoptera	Dytiscidae	Dytiscidae	5	Dytiscidae	Dytiscidae
Arthropoda	Insecta	Coleoptera	Dytiscidae	Dytiscus	5	Dytiscus	Dytiscidae
Arthropoda	Insecta	Trichoptera	Limnephilidae	Ecclisocosmoecus		Ecclisocosmoecus	Limnephilidae
Arthropoda	Insecta	Trichoptera	Limnephilidae	Ecclisomyia	4	Ecclisomyia	Limnephilidae
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae	Eclipidrilus	4	Oligochaeta	Eclipidrilus
Arthropoda	Insecta	Diptera	Simuliidae	Ectemnia		Simuliidae	Simuliidae
Arthropoda	Insecta	Diptera	Chironomidae	Einfeldia	8	Chironominae	NA
Arthropoda	Insecta	Coleoptera	Elmidae	Elmidae	4	Elmidae	NA
Arthropoda	Insecta	Diptera	Empididae	Empididae	6	Empididae	Empididae
Arthropoda	Insecta	Odonata	Coenagrionidae	Enallagma	7	Coenagrionidae	Zygoptera
Annelida	Oligochaeta	Haplotaxida	Enchytraeidae	Enchytraeidae	4	Oligochaeta	NA
Arthropoda	Insecta	Diptera	Chironomidae	Endochironomus	10	Chironominae	Endochironomus
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Enochrus	5	Enochrus	Hydrophilidae
Arthropoda	Insecta	Trichoptera	Limnephilidae	Eocosmoecus		Eocosmoecus	Limnephilidae
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Epeorus	2	Epeorus	Epeorus
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Epeorus albertae	2	Epeorus	Epeorus
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Epeorus deceptivus	0	Epeorus	Epeorus
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Epeorus grandis	0	Epeorus	Epeorus
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Epeorus longimanus	1	Epeorus	Epeorus
Arthropoda	Insecta	Ephemeroptera	Ephemeridae	Ephemera	2	Ephemera	NA

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Arthropoda	Insecta	Ephemeroptera	Ephemeridae	Ephemera simulans	1	Ephemera	NA
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Ephemerella	2	Ephemerella	Ephemerella
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Ephemerella aurivillii	0	Ephemerella aurivillii	Ephemerella
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Ephemerella inermis	4	Ephemerella	Ephemerella
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Ephemerella infrequens	2	Ephemerella	Ephemerella
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Ephemerellidae	1	Ephemerellidae	NA
Arthropoda	Insecta	Ephemeroptera	Ephemeridae	Ephemeridae	4	Ephemeridae	NA
Arthropoda	Insecta	Ephemeroptera	.	Ephemeroptera		Ephemeroptera	NA
Arthropoda	Insecta	Ephemeroptera	Polymitarcyidae	Ephoron	2	Ephoron	NA
Arthropoda	Insecta	Ephemeroptera	Polymitarcyidae	Ephoron album	2	Ephoron	NA
Arthropoda	Insecta	Diptera	Ephydridae	Ephydridae	6	Ephydridae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Epoicocladius		Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Tipulidae	Erioptera	7	Erioptera	Other_Tipulidae
Arthropoda	Insecta	Odonata	Gomphidae	Erpetogomphus	3	Gomphidae	Gomphidae
Annelida	Hirudinea	Arhynchobdellida	Erpobdellidae	Erpobdella		Erpobdellidae	Hirudinea
Annelida	Hirudinea	Arhynchobdellida	Erpobdellidae	Erpobdellidae	8	Erpobdellidae	Hirudinea
Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella	4	Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella brehmi	2	Orthocladiinae	Eukiefferiella_Brehmi_Gr
Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella claripennis	5	Orthocladiinae	Eukiefferiella_Claripennis_Gr
Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella coerulescens	4	Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella devonica	4	Orthocladiinae	Eukiefferiella_Devonica_Gr
Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella gracei	4	Orthocladiinae	Eukiefferiella_Gracei_Gr
Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella pseudomontana		Orthocladiinae	Eukiefferiella_Pseudomontana_Gr
Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella similis		Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Stratiomyidae	Euparyphus	7	CALOPARYPHUS/EUPARYPHUS	Stratiomyidae
Arthropoda	Insecta	Ephemeroptera	Baetidae	Fallceon quilleri	5	Fallceon	NA
Mollusca	Gastropoda	Basommatophora	Ancylidae	Ferrissia	6	Ferrissia	NA
Mollusca	Gastropoda	Basommatophora	Ancylidae	Ferrissia parallelus	6	Ferrissia	NA
Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae	Fluminicola		Hydrobiidae	NA
Arthropoda	Insecta	Diptera	Ceratopogonidae	Forcipomyiinae	6	Forcipomyiinae	Ceratopogonidae
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	Fossaria	6	Lymnaeidae	Lymnaeidae
Crustacea	Malacostraca	Amphipoda	Gammaridae	Gammaridae	4	Gammaridae	Amphipoda
Crustacea	Malacostraca	Amphipoda	Gammaridae	Gammarus	4	Gammarus	Amphipoda
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	Glossiphonia		Glossiphoniidae	Hirudinea
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	Glossiphonia complanata	9	Glossiphoniidae	Hirudinea

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Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	Glossiphoniidae	9	Glossiphoniidae	Hirudinea
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Glossosoma	0	Glossosoma	Glossosomatidae
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Glossosoma traviatum	0	Glossosoma	Glossosomatidae
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Glossosoma velona	0	Glossosoma	Glossosomatidae
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Glossosomatidae	0	Glossosomatidae	Glossosomatidae
Arthropoda	Insecta	Diptera	Pelecorhynchidae	Glutops	1	Pelecorhynchidae	Glutops
Arthropoda	Insecta	Trichoptera	Limnephilidae	Glyphopsyche	1	Glyphopsyche	Limnephilidae
Arthropoda	Insecta	Diptera	Chironomidae	Glyptotendipes	10	Chironominae	NA
Arthropoda	Insecta	Trichoptera	Goeridae	Goeracea		Goeridae	NA
Arthropoda	Insecta	Odonata	Gomphidae	Gomphidae	2	Gomphidae	Gomphidae
Arthropoda	Insecta	Odonata	Gomphidae	Gomphus		Gomphidae	Gomphidae
Arthropoda	Insecta	Coleoptera	Hydraenidae	Gymnochthebius		Gymnochthebius	NA
Mollusca	Gastropoda	Basommatophora	Planorbidae	Gyraulus	8	Planorbidae	Planorbidae
Arthropoda	Insecta	Coleoptera	Gyrinidae	Gyrinus	5	GYRINUS	NA
Arthropoda	Insecta	Coleoptera	Haliplidae	Haliplidae	8	Haliplidae	Haliplidae
Arthropoda	Insecta	Coleoptera	Haliplidae	Haliplus	8	Haliplus	Haliplidae
Annelida	Oligochaeta	Haplotaxida	Haplotaxidae	Haplotaxidae		Oligochaeta	NA
Annelida	Oligochaeta	Haplotaxida	Haplotaxidae	Haplotaxis		Oligochaeta	NA
Arthropoda	Insecta	Diptera	Chironomidae	Harnischia		Chironominae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Heleniella	6	Orthocladiinae	Heleniella
Arthropoda	Insecta	Coleoptera	Dryopidae	Helichus	5	Helichus	NA
Arthropoda	Insecta	Coleoptera	Dryopidae	Helichus striatus	5	Helichus	NA
Arthropoda	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	3	Helicopsyche	NA
Arthropoda	Insecta	Trichoptera	Helicopsychidae	Helicopsyche borealis	3	Helicopsyche	NA
Arthropoda	Insecta	Trichoptera	Helicopsychidae	Helicopsychidae	3	Helicopsychidae	NA
Mollusca	Gastropoda	Basommatophora	Planorbidae	Helisoma	6	Planorbidae	Planorbidae
Mollusca	Gastropoda	Basommatophora	Planorbidae	Helisoma anceps	7	Planorbidae	Planorbidae
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	Helobdella	10	Glossiphoniidae	Hirudinea
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	Helobdella stagnalis	10	Glossiphoniidae	Hirudinea
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Helophorus	5	Helophorus	NA
Arthropoda	Insecta	Diptera	Empididae	Hemerodromia	6	Hemerodromia	Empididae
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Heptagenia	4	Heptagenia	NA
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Heptageniidae	2	Heptageniidae	NA
Arthropoda	Insecta	Diptera	Tipulidae	Hesperoconopa	1	Hesperoconopa	Other_Tipulidae
Arthropoda	Insecta	Hemiptera	Corixidae	Hesperocorixa		Corixidae	Corixidae

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Arthropoda	Insecta	Hemiptera	Corixidae	Hesperocorixa laevigata	9	Corixidae	Corixidae
Arthropoda	Insecta	Plecoptera	Perlidae	Hesperoperla pacifica	1	Hesperoperla	Perlidae
Arthropoda	Insecta	Trichoptera	Limnephilidae	Hesperophylax	3	Hesperophylax	Limnephilidae
Arthropoda	Insecta	Odonata	Calopterygidae	Hetaerina americana		Calopterygidae	Zygoptera
Arthropoda	Insecta	Coleoptera	Elmidae	Heterlimnius	3	Heterlimnius	Heterlimnius
Arthropoda	Insecta	Coleoptera	Elmidae	Heterlimnius corpulentus	3	Heterlimnius	Heterlimnius
Arthropoda	Insecta	Coleoptera	Heteroceridae	Heteroceridae		Heteroceridae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Heterotrissocladius	0	Orthocladiinae	Heterotrissocladius
Arthropoda	Insecta	Diptera	Chironomidae	Heterotrissocladius marcidus		Orthocladiinae	Heterotrissocladius
Arthropoda	Insecta	Ephemeroptera	Ephemeridae	Hexagenia	6	Hexagenia	NA
Arthropoda	Insecta	Ephemeroptera	Ephemeridae	Hexagenia limbata	6	Hexagenia	NA
Arthropoda	Insecta	Diptera	Tipulidae	Hexatoma	2	Hexatoma	Hexatoma
Annelida	Hirudinea	.	.	Hirudinea	9	Hirudinea	Hirudinea
Arthropoda	Insecta	Trichoptera	Limnephilidae	Homophylax	2	Homophylax	Limnephilidae
Crustacea	Malacostraca	Amphipoda	Talitridae	Hyalella	8	Hyalella	Amphipoda
Crustacea	Malacostraca	Amphipoda	Hyalellidae	Hyalella azteca	8	Hyalella	Amphipoda
Crustacea	Malacostraca	Amphipoda	Hyalellidae	Hyalellidae	8	Hyalellidae	Amphipoda
Coelenterata	Hydrozoa	Hydroida	Hydridae	Hydra	5	Hydridae	NA
Arthropoda	Insecta	Coleoptera	Hydraenidae	Hydraena		Hydraena	NA
Arthropoda	Insecta	Diptera	Chironomidae	Hydrobaenus	8	Orthocladiinae	Hydrobaenus
Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae	Hydrobiidae		Hydrobiidae	NA
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Hydrobius		Hydrobius	Hydrophilidae
Arthropoda	Insecta	Coleoptera	Hydrochidae	Hydrochus	7	Hydrochus	NA
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Hydrophilidae	5	Hydrophilidae	Hydrophilidae
Arthropoda	Insecta	Coleoptera	Dytiscidae	Hydroporus		Hydroporus	Dytiscidae
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche	5	Hydropsyche_Ceratopsyche	Hydropsyche
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche bronta	5	Hydropsyche_Ceratopsyche	Hydropsyche
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche cockerelli	4	Hydropsyche_Ceratopsyche	Hydropsyche
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche morosa	6	Hydropsyche_Ceratopsyche	Hydropsyche
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche occidentalis	5	Hydropsyche_Ceratopsyche	Hydropsyche
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche oslari	4	Hydropsyche_Ceratopsyche	Hydropsyche
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche simulans		Hydropsyche_Ceratopsyche	Hydropsyche
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche slossonae	4	Hydropsyche_Ceratopsyche	Hydropsyche
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsychidae	4	Hydropsychidae	NA
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsychinae		HYDROPSYCHINAE	NA

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Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptila	6	Hydroptila	Hydroptilidae
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilidae	4	Hydroptilidae	Hydroptilidae
Coelenterata	Hydrozoa	.	.	Hydrozoa	5	Hydrozoa	NA
Arthropoda	Insecta	Coleoptera	Dytiscidae	Hygrotus		Hygrotus	Dytiscidae
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Ironodes	0	Ironodes	NA
Arthropoda	Insecta	Odonata	Coenagrionidae	Ischnura	7	Coenagrionidae	Zygoptera
Arthropoda	Insecta	Plecoptera	Perlodidae	Isogenoides	3	Isogenoides	Perlodidae
Arthropoda	Insecta	Plecoptera	Perlodidae	Isogenoides elongatus	3	Isogenoides	Perlodidae
Arthropoda	Insecta	Ephemeroptera	Isonychiidae	Isonychia	2	Isonychia	NA
Arthropoda	Insecta	Plecoptera	Perlodidae	Isoperla	2	Isoperla	Perlodidae
Arthropoda	Insecta	Plecoptera	Perlodidae	Isoperla fulva	3	Isoperla	Perlodidae
Arthropoda	Insecta	Plecoptera	Perlodidae	Isoperla sobria	2	Isoperla	Perlodidae
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Ithytrichia	4	Ithytrichia	Hydroptilidae
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Kathroperla	1	Kathroperla	NA
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Kathroperla perdita	1	Kathroperla	NA
Arthropoda	Insecta	Plecoptera	Perlodidae	Kogotus	1	Kogotus	Perlodidae
Arthropoda	Insecta	Diptera	Chironomidae	Krenosmittia	1	Orthocladiinae	Krenosmittia
Arthropoda	Insecta	Ephemeroptera	Baetidae	Labiobaetis		Labiobaetis	NA
Arthropoda	Insecta	Diptera	Chironomidae	Labrundinia	7	Tanypodinae	Labrundinia
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Laccobius		Laccobius	Hydrophilidae
Arthropoda	Insecta	Coleoptera	Dytiscidae	Laccophilus	5	Laccophilus	Dytiscidae
Arthropoda	Insecta	Ephemeroptera	Oligoneuriidae	Lachlania		Oligoneuriidae	NA
Arthropoda	Insecta	Coleoptera	Lampyridae	Lampyridae		Lampyridae	NA
Arthropoda	Insecta	Coleoptera	Elmidae	Lara	1	Lara	Lara
Arthropoda	Insecta	Coleoptera	Elmidae	Lara avara	1	Lara	Lara
Arthropoda	Insecta	Diptera	Chironomidae	Larsia	6	Tanypodinae	Larsia
Arthropoda	Insecta	Trichoptera	Lepidostomatidae	Lepidostoma	1	Lepidostoma	Lepidostomatidae
Arthropoda	Insecta	Trichoptera	Lepidostomatidae	Lepidostoma cascadense		Lepidostoma	Lepidostomatidae
Arthropoda	Insecta	Trichoptera	Lepidostomatidae	Lepidostoma pluviale		Lepidostoma	Lepidostomatidae
Arthropoda	Insecta	Trichoptera	Lepidostomatidae	Lepidostomatidae	1	Lepidostomatidae	Lepidostomatidae
Arthropoda	Insecta	Trichoptera	Leptoceridae	Leptoceridae	4	Leptoceridae	Leptoceridae
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Leptophlebia	3	Leptophlebia	Leptophlebiidae
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Leptophlebiidae	2	Leptophlebiidae	Leptophlebiidae
Arthropoda	Insecta	Odonata	Lestidae	Lestes	9	Lestes	Zygoptera
Arthropoda	Insecta	Hemiptera	Belostomatidae	Lethocerus	10	Belostomatidae	Other_Hemiptera

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Arthropoda	Insecta	Odonata	Libellulidae	Leucorrhinia		Libellulidae	Libellulidae
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Leucotrichia	2	Leucotrichia	Hydroptilidae
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Leucotrichia pictipes	2	Leucotrichia	Hydroptilidae
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Leucrocuta	1	Leucrocuta	NA
Arthropoda	Insecta	Plecoptera	Leuctridae	Leuctridae	1	Leuctridae	Leuctridae
Arthropoda	Insecta	Odonata	Libellulidae	Libellula	9	Libellulidae	Libellulidae
Arthropoda	Insecta	Odonata	Libellulidae	Libellulidae	9	Libellulidae	Libellulidae
Arthropoda	Insecta	Trichoptera	Limnephilidae	Limnephilidae	3	Limnephilidae	Limnephilidae
Arthropoda	Insecta	Trichoptera	Limnephilidae	Limnephilus	3	Limnephilus	Limnephilidae
Annelida	Oligochaeta	Haplotaxida	Tubificidae	Limnodrilus	10	Oligochaeta	Tubificidae
Annelida	Oligochaeta	Haplotaxida	Tubificidae	Limnodrilus hoffmeisteri	10	Oligochaeta	Tubificidae
Arthropoda	Insecta	Diptera	Tipulidae	Limnophila	3	Limnophila	Limnophila
Arthropoda	Insecta	Diptera	Muscidae	Limnophora	7	Muscidae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Limnophyes	6	Orthocladiinae	Limnophyes
Arthropoda	Insecta	Diptera	Tipulidae	Limonia		Limonia	Other_Tipulidae
Arthropoda	Insecta	Coleoptera	Dytiscidae	Liodessus		Liodessus	Dytiscidae
Arthropoda	Insecta	Diptera	Chironomidae	Lopescladius	2	Orthocladiinae	NA
Annelida	Oligochaeta	Haplotaxida	Lumbricidae	Lumbricidae	4	Oligochaeta	NA
Annelida	Oligochaeta	Haplotaxida	Lumbricidae	Lumbricina	4	Oligochaeta	NA
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae	Lumbriculidae	4	Oligochaeta	NA
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae	Lumbriculus		Oligochaeta	NA
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	Lymnaeidae	6	Lymnaeidae	Lymnaeidae
Arthropoda	Insecta	Diptera	Chironomidae	Macropelopia	6	Tanypodinae	Macropelopiini
Arthropoda	Insecta	Plecoptera	Nemouridae	Malenka	1	Malenka	Malenka
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Mayatrichia	1	Mayatrichia	Hydroptilidae
Arthropoda	Insecta	Plecoptera	Perlodidae	Megarcys	1	Megarcys	Perlodidae
Mollusca	Gastropoda	Basommatophora	Planorbidae	Menetus		Planorbidae	Planorbidae
Arthropoda	Insecta	Diptera	Dixidae	Meringodixa		Meringodixa	Dixidae
Nematoda	Polychaeta	Mermithida	Mermithidae	Mermithidae	5	Nematoda	NA
Arthropoda	Insecta	Diptera	Chironomidae	Mesosmittia		Orthocladiinae	NA
Arthropoda	Insecta	Hemiptera	Mesoveliidae	Mesovelia			Other_Hemiptera
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Metrichia		Metrichia	Hydroptilidae
Arthropoda	Insecta	Diptera	Chironomidae	Metriocnemus		Orthocladiinae	NA
Arthropoda	Insecta	Trichoptera	Brachycentridae	Micrasema	1	Micrasema	Micrasema
Arthropoda	Insecta	Trichoptera	Brachycentridae	Micrasema bactro	1	Micrasema	Micrasema

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Arthropoda	Insecta	Coleoptera	Elmidae	Microcylloepus	5	Microcylloepus	NA
Arthropoda	Insecta	Coleoptera	Elmidae	Microcylloepus pusillus	5	Microcylloepus	NA
Arthropoda	Insecta	Diptera	Chironomidae	Micropsectra	4	Chironominae	Micropsectra
Arthropoda	Insecta	Diptera	Chironomidae	Microtendipes	6	Chironominae	Microtendipes
Arthropoda	Insecta	Trichoptera	Molannidae	Molanna	6	Molanna	NA
Mollusca	Ostracoda	.	.	Mollusca		Mollusca	NA
Arthropoda	Insecta	Diptera	Tipulidae	Molophilus		Molophilus	Other_Tipulidae
Arthropoda	Insecta	Diptera	Chironomidae	Monodiamesa	7	Prodiamesinae	NA
Annelida	Hirudinea	Arhynchobdellida	Erpobdellidae	Mooreobdella	10	Erpobdellidae	Hirudinea
Annelida	Hirudinea	Arhynchobdellida	Erpobdellidae	Mooreobdella melanostoma		Erpobdellidae	Hirudinea
Arthropoda	Insecta	Plecoptera	Leuctridae	Moselia infuscata		Leuctridae	Leuctridae
Arthropoda	Insecta	Diptera	Muscidae	Muscidae	9	Muscidae	NA
Arthropoda	Insecta	Trichoptera	Leptoceridae	Mystacides	4	Mystacides	Leptoceridae
Annelida	Oligochaeta	Haplotaxida	Naididae	Naididae	8	Oligochaeta	Naididae
Annelida	Oligochaeta	Haplotaxida	Naididae	Nais	9	Oligochaeta	Naididae
Annelida	Oligochaeta	Haplotaxida	Naididae	Nais behningi	8	Oligochaeta	Naididae
Annelida	Oligochaeta	Haplotaxida	Naididae	Nais bretscheri		Oligochaeta	Naididae
Annelida	Oligochaeta	Haplotaxida	Naididae	Nais simplex		Oligochaeta	Naididae
Annelida	Oligochaeta	Haplotaxida	Naididae	Nais variabilis	10	Oligochaeta	Naididae
Arthropoda	Insecta	Diptera	Chironomidae	Nanocladius	3	Orthocladiinae	Nanocladius
Arthropoda	Insecta	Coleoptera	Elmidae	Narpus	2	Narpus	Narpus
Arthropoda	Insecta	Coleoptera	Elmidae	Narpus concolor	2	Narpus	Narpus
Arthropoda	Insecta	Diptera	Chironomidae	Natarsia		Tanypodinae	Other_Tanypodinae
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Neaviperla	1	Chloroperlidae	NA
Arthropoda	Insecta	Trichoptera	Leptoceridae	Nectopsyche	2	Nectopsyche	Leptoceridae
Nematoda	Polychaeta	.	.	Nematoda	5	Nematoda	Nematoda
Nematomorpha	Polychaeta	.	.	Nematomorpha		Nematomorpha	NA
Arthropoda	Insecta	Trichoptera	Limnephilidae	Nemotaulius	3	Nemotaulius	Limnephilidae
Arthropoda	Insecta	Diptera	Stratiomyidae	Nemotelus	7	Nemotelus	Stratiomyidae
Arthropoda	Insecta	Plecoptera	Nemouridae	Nemouridae	2	Nemouridae	NA
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Neochoroterpes	2	Neochoroterpes	Leptophlebiidae
Arthropoda	Insecta	Coleoptera	Dytiscidae	Neoclypeodytes		Neoclypeodytes	Dytiscidae
Arthropoda	Insecta	Trichoptera	Uenoidae	Neophylax	3	Neophylax	Uenoidae
Arthropoda	Insecta	Trichoptera	Uenoidae	Neophylax occidentis		Neophylax	Uenoidae
Arthropoda	Insecta	Trichoptera	Uenoidae	Neophylax rickeri	3	Neophylax	Uenoidae

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Arthropoda	Insecta	Trichoptera	Uenoidae	Neophylax splendens		Neophylax	Uenoidae
Arthropoda	Insecta	Diptera	Empididae	Neoplasta	6	Chelifera_Metachela_Neoplasta	Empididae
Arthropoda	Insecta	Hemiptera	Pleidae	Neoplea		Pleidae	Other_Hemiptera
Arthropoda	Insecta	Trichoptera	Uenoidae	Neothremma	1	Neothremma	Uenoidae
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Neotrichia	2	Neotrichia	Hydroptilidae
Annelida	Hirudinea	Arhynchobdellida	Erpobdellidae	Nephelopsis		Erpobdellidae	Hirudinea
Arthropoda	Insecta	Trichoptera	Polycentropodidae	Neureclipsis	6	Polycentropodidae	NA
Arthropoda	Insecta	Odonata	Corduliidae	Neurocordulia		Corduliidae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Nilotanypus	7	Tanypodinae	Other_Tanypodinae
Arthropoda	Insecta	Hemiptera	Notonectidae	Notonecta	5	Notonectidae	Other_Hemiptera
Arthropoda	Insecta	Hemiptera	Notonectidae	Notonectidae	7	Notonectidae	Other_Hemiptera
Arthropoda	Insecta	Trichoptera	Polycentropodidae	Nyctiophylax	5	Polycentropodidae	NA
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Ochrotrichia	4	Ochrotrichia	Hydroptilidae
Arthropoda	Insecta	Coleoptera	Hydraenidae	Ochthebius		Ochthebius	NA
Arthropoda	Insecta	Odonata	Gomphidae	Octogomphus		Gomphidae	Gomphidae
Arthropoda	Insecta	Diptera	Chironomidae	Odontomesa	4	Prodiamesinae	Odontomesa
Arthropoda	Insecta	Diptera	Stratiomyidae	Odontomyia		Hedriodiscus/Odontomyia	Stratiomyidae
Arthropoda	Insecta	Trichoptera	Leptoceridae	Oecetis	8	Oecetis	Leptoceridae
Annelida	Oligochaeta	.	.	Oligochaeta	8	Oligochaeta	NA
Arthropoda	Insecta	Trichoptera	Uenoidae	Oligophlebodes	3	Oligophlebodes	Uenoidae
Arthropoda	Insecta	Trichoptera	Limnephilidae	Onocosmoecus	3	Onocosmoecus	Limnephilidae
Arthropoda	Insecta	Trichoptera	Limnephilidae	Onocosmoecus unicolor	3	Onocosmoecus	Limnephilidae
Annelida	Oligochaeta	Haplotaxida	Naididae	Ophidonais	6	Oligochaeta	Naididae
Annelida	Oligochaeta	Haplotaxida	Naididae	Ophidonais serpentina	6	Oligochaeta	Naididae
Arthropoda	Insecta	Odonata	Gomphidae	Ophiogomphus	5	Gomphidae	Gomphidae
Arthropoda	Insecta	Coleoptera	Elmidae	Optioservus	5	Optioservus	Optioservus
Arthropoda	Insecta	Coleoptera	Elmidae	Optioservus seriatus	4	Optioservus	Optioservus
Crustacea	Malacostraca	Decapoda	Cambaridae	Orconectes		Cambaridae	NA
Arthropoda	Insecta	Coleoptera	Elmidae	Ordobrevia	5	Ordobrevia	NA
Arthropoda	Insecta	Coleoptera	Elmidae	Ordobrevia nubifera	5	Ordobrevia	NA
Arthropoda	Insecta	Coleoptera	Dytiscidae	Oreodytes	5	Oreodytes	Dytiscidae
Arthropoda	Insecta	Diptera	Empididae	Oreogeton	4	Oreogeton	Empididae
Arthropoda	Insecta	Diptera	Tipulidae	Ormosia	6	Ormosia	Other_Tipulidae
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae		Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladius	7	Orthocladiinae	Orthocladius

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Arthropoda	Insecta	Diptera	Chironomidae	Orthocladius annectens		Orthocladiinae	Orthocladius
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladius rivulorum		Orthocladiinae	Orthocladius
Crustacea	Ostracoda	.	.	Ostracoda		Ostracoda	Ostracoda
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Oxyethira	3	Oxyethira	Hydroptilidae
Crustacea	Malacostraca	Decapoda	Astacidae	Pacifastacus	6	Astacidae	NA
Crustacea	Malacostraca	Decapoda	Astacidae	Pacifastacus leniusculus		Astacidae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Pagastia	1	Diamesinae	Pagastia
Arthropoda	Insecta	Hemiptera	Corixidae	Palmacorixa	9	Corixidae	Corixidae
Arthropoda	Insecta	Hemiptera	Corixidae	Palmacorixa buenoi	9	Corixidae	Corixidae
Arthropoda	Insecta	Hemiptera	Corixidae	Palmacorixa gillettei	9	Corixidae	Corixidae
Arthropoda	Insecta	Diptera	Chironomidae	Parachaetocladius		Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Parachironomus	10	Chironominae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Paracladius	8	Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Paracladopelma	7	Chironominae	Paracladopelma
Arthropoda	Insecta	Ephemeroptera	Baetidae	Paracloeodes		Paracloeodes	NA
Arthropoda	Insecta	Diptera	Chironomidae	Paracricotopus		Orthocladiinae	NA
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Paracymus		Paracymus	Hydrophilidae
Arthropoda	Insecta	Diptera	Chironomidae	Parakiefferiella	6	Orthocladiinae	Parakiefferiella
Arthropoda	Insecta	Diptera	Chironomidae	Paralauterborniella	8	Chironominae	Paralauterborniella
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Paraleptophlebia	1	Paraleptophlebia	Leptophlebiidae
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Paraleptophlebia bicornuta	2	Paraleptophlebia	Leptophlebiidae
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Paraleptophlebia debilis	1	Paraleptophlebia	Leptophlebiidae
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Paraleptophlebia heteronea	1	Paraleptophlebia	Leptophlebiidae
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Paraleptophlebia temporalis	1	Paraleptophlebia	Leptophlebiidae
Arthropoda	Insecta	Plecoptera	Leuctridae	Paraleuctra	2	Leuctridae	Leuctridae
Arthropoda	Insecta	Diptera	Chironomidae	Paramerina		Tanypodinae	Paramerina/Zavrelimyia
Arthropoda	Insecta	Diptera	Chironomidae	Parametriocnemus	5	Orthocladiinae	Parametriocnemus
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Paraperla	1	Paraperla	NA
Arthropoda	Insecta	Diptera	Chironomidae	Paraphaenocladius	4	Orthocladiinae	NA
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Parapsyche	0	Parapsyche	Parapsyche
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Parapsyche almota		Parapsyche	Parapsyche
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Parapsyche elsis	1	Parapsyche	Parapsyche
Arthropoda	Insecta	Diptera	Chironomidae	Paratanytarsus	6	Chironominae	Paratanytarsus
Arthropoda	Insecta	Diptera	Chironomidae	Paratendipes	10	Chironominae	Paratendipes
Arthropoda	Insecta	Diptera	Chironomidae	Parochlus	1	Podonominae	NA

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Arthropoda	Insecta	Diptera	Chironomidae	Parorthocladius	6	Orthocladiinae	Parorthocladius
Arthropoda	Insecta	Diptera	Tipulidae	Pedicia	6	Pedicia	Other_Tipulidae
Arthropoda	Insecta	Coleoptera	Haliplidae	Peltodytes	8	Peltodytes	Haliplidae
Arthropoda	Insecta	Diptera	Chironomidae	Pentaneura	6	Tanypodinae	Other_Tanypodinae
Arthropoda	Insecta	Diptera	Chironomidae	Pentaneurini	6	Tanypodinae	Other_Tanypodinae
Arthropoda	Insecta	Diptera	Psychodidae	Pericoma	4	Pericoma/Telmatoscopus	Psychodidae
Arthropoda	Insecta	Odonata	Libellulidae	Perithemis		Libellulidae	Libellulidae
Arthropoda	Insecta	Plecoptera	Perlidae	Perlidae	2	Perlidae	Perlidae
Arthropoda	Insecta	Plecoptera	Perlodidae	Perlinodes	1	Perlinodes	Perlodidae
Arthropoda	Insecta	Plecoptera	Perlodidae	Perlinodes aurea	1	Perlinodes	Perlodidae
Arthropoda	Insecta	Plecoptera	Perlodidae	Perlodidae	2	Perlodidae	Perlodidae
Arthropoda	Insecta	Plecoptera	Leuctridae	Perlomyia		Leuctridae	Leuctridae
Arthropoda	Insecta	Lepidoptera	Pyralidae	Petrophila	5	Lepidoptera	NA
Arthropoda	Insecta	Diptera	Chironomidae	Phaenopsectra	7	Chironominae	Phaenopsectra
Arthropoda	Insecta	Trichoptera	Limnephilidae	Philarctus quaeris		Philarctus	Limnephilidae
Arthropoda	Insecta	Trichoptera	Philopotamidae	Philopotamidae	3	Philopotamidae	Philopotamidae
Arthropoda	Insecta	Diptera	Blephariceridae	Philorus		Blephariceridae	NA
Arthropoda	Insecta	Trichoptera	Phryganeidae	Phryganea		Phryganeidae	NA
Arthropoda	Insecta	Trichoptera	Phryganeidae	Phryganeidae	4	Phryganeidae	NA
Mollusca	Gastropoda	Basommatophora	Physidae	Physa		Physa_Physella	Physidae
Mollusca	Gastropoda	Basommatophora	Physidae	Physella	8	Physa_Physella	Physidae
Mollusca	Gastropoda	Basommatophora	Physidae	Physidae	8	Physidae	Physidae
Arthropoda	Insecta	Diptera	Tipulidae	Pilaria	7	Pilaria	Other_Tipulidae
Annelida	Hirudinea	Rhynchobdellida	Piscicolidae	Piscicolidae		Piscicolidae	Hirudinea
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiidae	8	Pisidiidae	Pisidiidae
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidium	8	Pisidiidae	Pisidiidae
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidium milium	8	Pisidiidae	Pisidiidae
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	Placobdella		Glossiphoniidae	Hirudinea
Platyhelminthes	Tubellaria	Tricladida	Planariidae	Planariidae		Turbellaria	Turbellaria
Mollusca	Gastropoda	Basommatophora	Planorbidae	Planorbella		Planorbidae	Planorbidae
Mollusca	Gastropoda	Basommatophora	Planorbidae	Planorbidae	6	Planorbidae	Planorbidae
Mollusca	Gastropoda	Basommatophora	Planorbidae	Planorbula		Planorbidae	Planorbidae
Arthropoda	Insecta	Ephemeroptera	Baetidae	Plauditus	5	Plauditus	NA
Arthropoda	Insecta	Ephemeroptera	Baetidae	Plauditus punctiventris	5	Plauditus	NA
Arthropoda	Insecta	Plecoptera	Nemouridae	Podmosta	2	Podmosta	NA

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Platyhelminthes	Tubellaria	.	.	Polycelis coronata	4	Turbellaria	Turbellaria
Arthropoda	Insecta	Trichoptera	Polycentropodidae	Polycentropodidae	6	Polycentropodidae	NA
Arthropoda	Insecta	Trichoptera	Polycentropodidae	Polycentropus	6	Polycentropus	NA
Arthropoda	Insecta	Diptera	Chironomidae	Polypedilum	6	Chironominae	Polypedilum
Porifera	Hydrozoa	.	.	Porifera		Porifera	NA
Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae	Potamopyrgus antipodarum		Potamopyrgus	NA
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Potamyia	4	Potamyia	NA
Arthropoda	Insecta	Diptera	Chironomidae	Potthastia	2	Diamesinae	Potthastia
Arthropoda	Insecta	Diptera	Chironomidae	Potthastia gaedii	3	Diamesinae	Potthastia
Arthropoda	Insecta	Diptera	Chironomidae	Potthastia longimana	4	Diamesinae	Potthastia
Annelida	Oligochaeta	Haplotaxida	Naididae	Pristina	10	Oligochaeta	Naididae
Arthropoda	Insecta	Diptera	Chironomidae	Procladius	9	Tanypodinae	Procladius
Arthropoda	Insecta	Ephemeroptera	Baetidae	Procloeon	7	Procloeon	NA
Arthropoda	Insecta	Diptera	Chironomidae	Prodiamesa	3	Prodiamesinae	Prodiamesa
Arthropoda	Insecta	Diptera	Simuliidae	Prosimulium	3	Simuliidae	Simuliidae
Arthropoda	Insecta	Plecoptera	Nemouridae	Prostoia besametsa	3	Prostoia	NA
Nemertea	Enopla	Hoplonemertea	Tetrastemmatidae	Prostoma		Nemertea	NA
Arthropoda	Insecta	Diptera	Tanyderidae	Protanyderus	5	Tanyderidae	NA
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Protoptila	1	Protoptila	Glossosomatidae
Arthropoda	Insecta	Diptera	Chironomidae	Psectrocladius	8	Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Psectrotanypus	10	Tanypodinae	Macropelopiini
Arthropoda	Insecta	Diptera	Chironomidae	Pseudochironomus	5	Chironominae	Pseudochironomus
Arthropoda	Insecta	Ephemeroptera	Baetidae	Pseudocloeon	4	Pseudocloeon	NA
Arthropoda	Insecta	Diptera	Chironomidae	Pseudodiamesa	2	Diamesinae	Pseudodiamesa
Arthropoda	Insecta	Diptera	Chironomidae	Pseudorthocladius	0	Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Pseudosmittia	6	Orthocladiinae	NA
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	Pseudosuccinea		Lymnaeidae	Lymnaeidae
Arthropoda	Insecta	Diptera	Psychodidae	Psychoda	4	Psychoda	Psychodidae
Arthropoda	Insecta	Diptera	Psychodidae	Psychodidae	4	Psychodidae	Psychodidae
Arthropoda	Insecta	Trichoptera	Limnephilidae	Psychoglypha	0	Psychoglypha	Limnephilidae
Arthropoda	Insecta	Trichoptera	Psychomyiidae	Psychomyia	2	Psychomyia	NA
Arthropoda	Insecta	Trichoptera	Psychomyiidae	Psychomyia flavida	2	Psychomyia	NA
Arthropoda	Insecta	Plecoptera	Pteronarcyidae	Pteronarcella	4	Pteronarcella	NA
Arthropoda	Insecta	Plecoptera	Pteronarcyidae	Pteronarcella badia	3	Pteronarcella	NA
Arthropoda	Insecta	Plecoptera	Pteronarcyidae	Pteronarcyidae	2	Pteronarcyidae	NA

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Arthropoda	Insecta	Plecoptera	Pteronarcyidae	Pteronarcys	2	Pteronarcys	NA
Arthropoda	Insecta	Plecoptera	Pteronarcyidae	Pteronarcys californica	2	Pteronarcys	NA
Arthropoda	Insecta	Plecoptera	Pteronarcyidae	Pteronarcys dorsata	2	Pteronarcys	NA
Arthropoda	Insecta	Trichoptera	Phryganeidae	Ptilostomis		Phryganeidae	NA
Arthropoda	Insecta	Diptera	Ptychopteridae	Ptychoptera	7	Ptychopteridae	Ptychopteridae
Arthropoda	Insecta	Trichoptera	Limnephilidae	Pycnopsyche		Pycnopsyche	Limnephilidae
Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae	Pyrgulopsis		Hydrobiidae	NA
Annelida	Oligochaeta	Haplotaxida	Tubificidae	Quistradrilus multisetosus		Oligochaeta	Tubificidae
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	Radix auricularia		Radix auricularia	Lymnaeidae
Arthropoda	Insecta	Hemiptera	Nepidae	Ranatra	7	Ranatra	Other_Hemiptera
Arthropoda	Insecta	Diptera	Tipulidae	Rhabdomastix	1	Rhabdomastix	Rhabdomastix
Arthropoda	Insecta	Coleoptera	Dytiscidae	Rhantus		Rhantus	Dytiscidae
Arthropoda	Insecta	Diptera	Chironomidae	Rheocricotopus	4	Orthocladiinae	Rheocricotopus
Arthropoda	Insecta	Diptera	Chironomidae	Rheosmittia		Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Rheotanytarsus	6	Chironominae	Rheotanytarsus
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Rhithrogena	0	Rhithrogena	Rhithrogena
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Rhithrogena robusta	0	Rhithrogena	Rhithrogena
Annelida	Oligochaeta	Haplotaxida	Tubificidae	Rhyacodrilus		Oligochaeta	Tubificidae
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	1	Rhyacophila	NA
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila alberta	0	Rhyacophila alberta gr.	Rhyacophila_alberta_gr
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila angelita	0	Rhyacophila angelita gr.	Rhyacophila_Angelita_Gr
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila arnaudi		Rhyacophila arnaudi	NA
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila betteni	1	Rhyacophila betteni gr.	Rhyacophila_Betteni_Gr
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila blarina		Rhyacophila sibirica gr.	NA
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila brunnea	0	Rhyacophila brunnea/vemna Gr.s	Rhyacophila_Brunnea_Gr
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila coloradensis	0	Rhyacophila coloradensis gr.	NA
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila hyalinata	1	Rhyacophila hyalinata gr.	Rhyacophila_Hyalinata_Gr
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila iranda		Rhyacophila vofixa gr.	NA
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila narvae	0	Rhyacophila sibirica gr.	Rhyacophila_narvae
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila nevadensis		Rhyacophila nevadensis gr.	NA
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila pellisa	0	Rhyacophila sibirica gr.	Rhyacophila_pellisa/valuma
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila rotunda		Rhyacophila rotunda gr.	NA
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila sibirica		Rhyacophila sibirica gr.	NA
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila vagrita	0	Rhyacophila vagrita gr.	NA
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila verrula	0	Rhyacophila verrula gr.	Rhyacophila_Verrula_Gr

Exhibit 34

Phyla	Class	Order	Family	FinalID	TolVal	OTU_2005	OTU_2011
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila vofixa	0	Rhyacophila vofixa gr.	Rhyacophila_vofixa_Gr
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophilidae	0	Rhyacophilidae	NA
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae	Rhynchelmis		Oligochaeta	Rhynchelmis
Arthropoda	Insecta	Diptera	Chironomidae	Robackia	4	Chironominae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Saetheria	8	Chironominae	NA
Arthropoda	Insecta	Hemiptera	Saldidae	Saldula		Saldula	Other_Hemiptera
Arthropoda	Insecta	Diptera	Sciomyzidae	Sciomyzidae		Sciomyzidae	NA
Arthropoda	Insecta	Trichoptera	Uenoidae	Sericostriata		Sericostriata	Uenoidae
Arthropoda	Insecta	Trichoptera	Uenoidae	Sericostriata surdickae		Sericostriata	Uenoidae
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Serratella	2	Serratella	Serratella
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Serratella micheneri	0	Serratella	Serratella
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Serratella tibialis	2	Serratella	Serratella
Arthropoda	Insecta	Plecoptera	Perlodidae	Setvena	0	Setvena	Perlodidae
Arthropoda	Insecta	Plecoptera	Perlodidae	Setvena bradleyi	0	Setvena	Perlodidae
Arthropoda	Insecta	Hemiptera	Sialidae	Sialis	4	Sialis	Sialis
Arthropoda	Branchiopoda	Diplostraca	Sididae	Sididae		Cladocera	Cladocera
Arthropoda	Insecta	Hemiptera	Corixidae	Sigara	9	Corixidae	Corixidae
Arthropoda	Insecta	Hemiptera	Corixidae	Sigara alternata		Corixidae	Corixidae
Arthropoda	Insecta	Hemiptera	Corixidae	Sigara decorata		Corixidae	Corixidae
Arthropoda	Insecta	Hemiptera	Corixidae	Sigara decoratella		Corixidae	Corixidae
Arthropoda	Insecta	Hemiptera	Corixidae	Sigara grossolineata		Corixidae	Corixidae
Arthropoda	Insecta	Hemiptera	Corixidae	Sigara lineata		Corixidae	Corixidae
Arthropoda	Insecta	Diptera	Simuliidae	Simuliidae	6	Simuliidae	Simuliidae
Arthropoda	Insecta	Diptera	Simuliidae	Simulium	5	Simuliidae	Simuliidae
Arthropoda	Insecta	Ephemeroptera	Siphlonuridae	Siphlonurus	2	Siphlonuridae	NA
Arthropoda	Insecta	Plecoptera	Perlodidae	Skwala	3	Skwala	Perlodidae
Mollusca	Bivalvia	Veneroida	Sphaeriidae	Sphaeriidae	8	Pisidiidae	Pisidiidae
Mollusca	Bivalvia	Veneroida	Pisidiidae	Sphaerium	8	Pisidiidae	Pisidiidae
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	Stagnicola	6	Lymnaeidae	Lymnaeidae
Arthropoda	Insecta	Diptera	Chironomidae	Stempellina	2	Chironominae	Stempellina
Arthropoda	Insecta	Diptera	Chironomidae	Stempellinella	4	Chironominae	Stempellinella
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenacron	4	Stenacron	NA
Arthropoda	Insecta	Coleoptera	Elmidae	Stenelmis	5	Stenelmis	NA
Arthropoda	Insecta	Coleoptera	Elmidae	Stenelmis occidentalis		Stenelmis	NA
Arthropoda	Insecta	Diptera	Chironomidae	Stenochironomus	5	Chironominae	NA

Exhibit 34

Phyla	Class	Order	Family	FinalID	TolVal	OTU_2005	OTU_2011
Arthropoda	Insecta	Diptera	Chironomidae	Stictochironomus	5	Chironominae	Stictochironomus
Arthropoda	Insecta	Coleoptera	Dytiscidae	Stictotarsus		Stictotarsus	Dytiscidae
Arthropoda	Insecta	Diptera	Chironomidae	Stilocladius	6	Orthocladiinae	Stilocladius
Arthropoda	Insecta	Diptera	Stratiomyidae	Stratiomyidae	7	Stratiomyidae	Stratiomyidae
Arthropoda	Insecta	Diptera	Stratiomyidae	Stratiomys		Stratiomys	Stratiomyidae
Arthropoda	Insecta	Odonata	Gomphidae	Stylurus		Gomphidae	Gomphidae
Arthropoda	Insecta	Diptera	Chironomidae	Sublettea	2	Chironominae	NA
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Suwallia	1	Chloroperlidae	Suwallia
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Sweltsa	0	Chloroperlidae	Sweltsa
Arthropoda	Insecta	Odonata	Libellulidae	Sympetrum	9	Libellulidae	Libellulidae
Arthropoda	Insecta	Diptera	Chironomidae	Symposiocladius	6	Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Sympotthastia	2	Diamesinae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Synendotendipes		Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Synorthocladius	2	Orthocladiinae	NA
Arthropoda	Insecta	Diptera	Tabanidae	Tabanidae	10	Tabanidae	Tabanidae
Arthropoda	Insecta	Diptera	Tabanidae	Tabanus	10	Tabanidae	Tabanidae
Arthropoda	Insecta	Plecoptera	Taeniopterygidae	Taenionema	2	Taeniopterygidae	Taeniopterygidae
Arthropoda	Insecta	Plecoptera	Taeniopterygidae	Taeniopterygidae	2	Taeniopterygidae	Taeniopterygidae
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae		Tanypodinae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Tanypus	10	Tanypodinae	Tanypus
Arthropoda	Insecta	Diptera	Chironomidae	Tanytarsini	6	Chironominae	NA
Arthropoda	Insecta	Diptera	Chironomidae	Tanytarsus	6	Chironominae	Tanytarsus
Arthropoda	Insecta	Diptera	Thaumaleidae	Thaumalea		Thaumaleidae	NA
Arthropoda	Insecta	Diptera	Thaumaleidae	Thaumaleidae		Thaumaleidae	NA
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	Theromyzon		Glossiphoniidae	Hirudinea
Arthropoda	Insecta	Diptera	Chironomidae	Thienemanniella	6	Orthocladiinae	Thienemanniella
Arthropoda	Insecta	Diptera	Chironomidae	Thienemannimyia		Tanypodinae	Thienemannimyia_Gr
Arthropoda	Insecta	Diptera	Chironomidae	Thienemanniola		Chironominae	NA
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Timpanoga	2	Timpanoga	NA
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Timpanoga hecuba	2	Timpanoga	NA
Arthropoda	Insecta	Diptera	Tipulidae	Tipula	4	Tipula	Tipula
Arthropoda	Insecta	Diptera	Tipulidae	Tipulidae	3	Tipulidae	Other_Tipulidae
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Traverella	2	Traverella	Leptophlebiidae
Arthropoda	Insecta	Trichoptera	Leptoceridae	Triaenodes	6	Triaenodes	Leptoceridae
Arthropoda	Insecta	Diptera	Chironomidae	Tribelos		Chironominae	NA

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Phyla	Class	Order	Family	FinalID	TolVal	OTU_2005	OTU_2011
Arthropoda	Insecta	Diptera	Empididae	Trichoclinocera		Trichoclinocera	Empididae
Arthropoda	Insecta	Hemiptera	Corixidae	Trichocorixa	9	Corixidae	Corixidae
Arthropoda	Insecta	Hemiptera	Corixidae	Trichocorixa borealis	9	Corixidae	Corixidae
Arthropoda	Insecta	Trichoptera	.	Trichoptera		Trichoptera	NA
Platyhelminthes	Tubellaria	Tricladida	.	Tricladida	4	Turbellaria	Turbellaria
Arthropoda	Insecta	Ephemeroptera	Tricorythidae	Tricorythidae	4	Tricorythidae	NA
Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	4	Tricorythodes	Tricorythodes
Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes minutus	4	Tricorythodes	Tricorythodes
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Triznaka		Chloroperlidae	NA
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Tropisternus		Tropisternus	Hydrophilidae
Annelida	Oligochaeta	Haplotaxida	Tubificidae	Tubifex		Oligochaeta	Tubificidae
Annelida	Oligochaeta	Haplotaxida	Tubificidae	Tubifex tubifex	10	Oligochaeta	Tubificidae
Annelida	Oligochaeta	Haplotaxida	Tubificidae	Tubificidae	10	Oligochaeta	Tubificidae
Platyhelminthes	Tubellaria	.	.	Turbellaria	4	Turbellaria	Turbellaria
Arthropoda	Insecta	Diptera	Chironomidae	Tvetenia	5	Orthocladiinae	Tvetenia
Arthropoda	Insecta	Diptera	Chironomidae	Tvetenia bavarica		Orthocladiinae	Tvetenia
Arthropoda	Insecta	Diptera	Chironomidae	Tvetenia discoloripes		Orthocladiinae	Tvetenia
Arthropoda	Insecta	Diptera	Chironomidae	Tvetenia vitracies		Orthocladiinae	Tvetenia
Arthropoda	Insecta	Diptera	Simuliidae	Twinnia	7	Simuliidae	Simuliidae
Arthropoda	Insecta	Trichoptera	Uenoidae	Uenoidae	2	Uenoidae	Uenoidae
Mollusca	Bivalvia	Unionida	Unionidae	Unionidae		Unionidae	NA
Mollusca	Gastropoda	Heterostropha	Valvatidae	Valvata	3	Valvata	NA
Mollusca	Gastropoda	Heterostropha	Valvatidae	Valvatidae	3	Valvatidae	NA
Arthropoda	Insecta	Plecoptera	Nemouridae	Visoka cataractae	0	Visoka	Visoka
Arthropoda	Insecta	Diptera	Empididae	Wiedemannia		Wiedemannia	Empididae
Arthropoda	Insecta	Trichoptera	Philopotamidae	Wormaldia	0	Wormaldia	Philopotamidae
Arthropoda	Insecta	Diptera	Chironomidae	Xenochironomus	4	Chironominae	NA
Arthropoda	Insecta	Trichoptera	Leptoceridae	Ylodes		Ylodes	Leptoceridae
Arthropoda	Insecta	Plecoptera	Peltoperlidae	Yoraperla	0	Yoraperla	Peltoperlidae
Arthropoda	Insecta	Plecoptera	Peltoperlidae	Yoraperla brevis		Yoraperla	Peltoperlidae
Arthropoda	Insecta	Coleoptera	Elmidae	Zaitzevia	5	Zaitzevia	Zaitzevia
Arthropoda	Insecta	Coleoptera	Elmidae	Zaitzevia parvulus		Zaitzevia	Zaitzevia
Arthropoda	Insecta	Plecoptera	Nemouridae	Zapada	2	Zapada	NA
Arthropoda	Insecta	Plecoptera	Nemouridae	Zapada cinctipes	3	Zapada	Zapada_cinctipes
Arthropoda	Insecta	Plecoptera	Nemouridae	Zapada columbiana	2	Zapada	Zapada_columbiana

Exhibit 34

Phyla	Class	Order	Family	FinalID	TolVal	OTU_2005	OTU_2011
Arthropoda	Insecta	Plecoptera	Nemouridae	Zapada frigida	1	Zapada	NA
Arthropoda	Insecta	Plecoptera	Nemouridae	Zapada Oregonensis		Zapada	Zapada_oregonensis_gr
Arthropoda	Insecta	Diptera	Chironomidae	Zavrelimyia	8	Tanypodinae	Paramerina/Zavrelimyia
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Zumatrichia	3	Zumatrichia	Hydroptilidae
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Zumatrichia notosa	3	Zumatrichia	Hydroptilidae

APPENDIX B - AN EXAMPLE TAXA LIST TEMPLATE

Site ID: Sample Date: Taxonimist(s):	TAXA LIST TEMPLATE

ITIS Code	Class	Order	Family	Genus/Species	Funtional Feeding Group (cite literature)	Count
					Total for this Page:	

Site ID:	**TAXA LIST TEMPLATE**
Sample Date:	
Taxonimist(s):	

ITIS Code	Class	Order	Family	Genus/Species	Funtional Feeding Group (cite literature)	Count
					Total for This Page:	

Page 1 Total:

Page 2 Total:

Total # of Organisms ID'd:

APPENDIX C - EXAMPLE OUTPUT FOR THE OBSERVED/EXPECTED MODELS

The following page shows an example output table from EDAS (Tetra Tech 2006a). These are used to illustrate index results for samples. The EDAS output result comes as a direct output saved as an MS Excel (2003) spreadsheet (**Table C-1**). The spreadsheet contains all of the relevant sampling location information and O/E values. EDAS can also generate Multimetric Index values if a project requires them (not shown in the example).

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Table C-1. EDAS output table example.

Station ID	Waterbody Name	Lat_Dec	Long_Dec	Cld Wrm Type	SiteClass	Four Code HUC	TMDL Planning Area	Reference	ActivityID	CollDate	CollMeth	Ben Samp ID	Rep Num	OE model test	Total OE Bugs	O/E_ 2005	BC_2005	CW_ OE_ 2011	CW_outlier 05_2011	CW_BC_ pc>half_2011
C04FIREC01	Fire Creek	46.8884031	-114.804544	Cold	Mountains	17010204	MIDDLE CLARK FORK	Reference	2523-MAC-R	13-Jun-06	MAC-R-500	17087	0	P	300	0.80	0.62	0.64	1	0.43
C04FIREC01	Fire Creek	46.8884031	-114.804544	Cold	Mountains	17010204	MIDDLE CLARK FORK	Reference	2705-MAC-R	08-Sep-06	MAC-R-500	17089	0	P	300	0.80	0.14	0.94	0	0.25

APPENDIX D - MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY BENTHIC MACROINVERTEBRATE OBSERVED/EXPECTED MANUAL

D1.0 Introduction

D1.1 Background

This manual is intended to guide users in creating and applying predictive models of observed and expected (O/E) benthic macroinvertebrate taxa in samples from streams in Montana. O/E models have been developed in 2005 and 2011 by consultants to the Montana Department of Environmental Quality (DEQ). With this guidance and associated software, development of new models and application of existing models should be possible for DEQ staff.

The O/E model is an assessment tool that can be used to determine the degree to which a sample contains the number and type of taxa expected after considering relevant characteristics of each site's environmental setting. Literature on the O/E predictive models is abundant, and the theories behind the responsiveness of the models to stress can be reviewed in those articles (Clarke et al. 1996, Clarke et al. 2002, Clarke et al. 2003, Hawkins and Carlisle 2001, Hawkins et al. 2000, Hawkins and Norris 2000, Hawkins et al. 2009, Hubler 2008, Van Sickle et al. 2005, Van Sickle et al. 2006, and Van Sickle et al. 2007). The Bray-Curtis (BC) index is used as a secondary indicator and its development and application are also presented in this document. It is developed using theories similar to the O/E index (Van Sickle 2008).

D1.2 Purpose and Goals

This document is intended as a guide for developing, interpreting, and applying O/E and BC indices. It is especially tailored to the needs of DEQ in assessing benthic macroinvertebrate conditions in streams of Montana. Following the steps of this manual should allow DEQ staff to calibrate new predictive models, interpret the model output, and apply developed models for assessment purposes.

D1.3 Data organization and software

Data for analyses must conform to DEQ standards for sample collection for taxa and other data standards for reference designations and predictor data. The necessary information for development and application of the O/E and BC indices include two types: One of taxonomic composition in samples and another of site and sample characteristics (predictors) for the sampling locations. DEQ uses the Ecological Data Analysis System (EDAS) for generating macroinvertebrate indicator of water quality results. EDAS is also used to generate taxonomic and predictor data in formats that can be used for model development and application. Some formats require further manipulation after export from EDAS. In this manual, we assume that the analyst is familiar with EDAS and its functions. Specific format for analyses will be described in following sections.

The instructions include references to existing software. While some details on the use of the software are provided, analysts are expected to have basic knowledge of the software and can investigate software application issues through other manuals specific to those programs. The software referenced most often includes Excel (Microsoft Corporation), PC-ORD (McCune and Mefford 2006), R (http://www.r-project.org), Statistica (StatSoft, Inc.), and "SubSample.exe" (a DOS program). Alternative software could be used for some steps of the analyses.

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D2.0 Applying an Observed/Expected model

Once the O/E and BC models are built on calibration data and saved, they can be applied to test data. Test data are samples from any site that was not used as a reference sample in the model calibration. This could include samples from reference-quality sites sampled in years following the calibration effort or from sites that have some know degree of disturbance.

D2.1 Required files and scripts

The files required to calculate O/E scores from an established model include 2 data files and multiple R scripts. The taxa and predictor matrix should have the same format described for model building. Taxa identifiers should be the 8-character OTUs, predictors must include all predictors used in the models, and records for the taxa and predictor files must have the same sample identifiers in the same order. The same predictor file used for model building can be used for model application, where the 'RefCalVal' field includes 'test' designations. Only the sample identifiers and the model predictors are required in the test predictor file, but the other fields can be included as well.

The model can be applied either at the end of the 'model.build.V4.1.R' script or from the 'model.apply.V4.1.R' script. During its execution, the script calls on other files, including 'model.predict.v4.1.r', 'MyModel.Version1.Rdata', and 'assess.one.sample.4.1.r'. If new data are prepared for calculation of O/E and BC scores, first create the taxon and predictor files as described above. Then run the 'model.apply.V4.1.R' script as described below.

The required fields in the predictor files are as follow. All spellings and cases must be exact.

SampID	Also called BenSamp-Rep (rename to SampID)
RefCalVal	With allowed values 'Calib', 'Valid', or 'test' (case sensitive) (optional field)
ELVsd_WS	Standard deviation of Elevation in the watershed
GIS_LAT	Latitude
JulianDay	Sequential day of the year (cold only)
log_sqkm	logarithm of watershed square kilometers (also called 'log_km2' [rename])
Mtns1	Designation of the mountains ecoregions (1), or not (0)
Tmax_PT	Maximum monthly average temperature at the point (also TMAX_PT_2011)
FFP_PT	Frost-Free Period Point (For Warm-Water model only)
WDmin_PT	Minimum number of wet days (For Warm-Water model only)

There are alternate names for two variables because these were also used in the 2005 O/E model. In the case of Tmax_PT, the value is calculated differently among models, so that in EDAS the value is labeled Tmax_PT_2011, but it is recognized in the model as 'Tmax_PT'.

D2.2 Running model application R code

The model application R code is named 'model.apply.V4.1.R'. The code is run in sections so that errors can be corrected sequentially (and to avoid wasting time running subsequent erred sections). In the next report section, the code for the cold-water model is contained in text boxes. It is recommended that the code be run in the blocks between bullets as shown below. All model development files should be kept

Exhibit 34

in one file folder (or "directory"). Retaining distinct runs in separate directories is a good idea when experimenting and interpreting.

- Introduction and set-up.

```
# R code modified to allow application only (cut out much of the building steps)

# Ben Jessup and Dave Feldman modified original code by John Van Sickle, US Environmental
Protection Agency;
#Version 3: For application of an existing model (established through the model.build.v4.1 script)

##################################################;

## First clear the workspace
rm(list=ls())

#load required packages;
library(gtools); library(MASS);
library(cluster); library(Hmisc);
require(scatterplot3d)
require(maps)

# change directory based on where have script and data files (EWL)
#  but to keep code the same subsititute with "getwd"
# change the working directory to the correct one using "setdir". Notice that the filepath uses "/"
setdir ("C:/working directory")
 myDir <- getwd()
```

- Load the predictor file and display example data, which should be in the same directory as the script.

```
# STEP 1 -- INITIAL SETUP -- Input and organize the bug and predictor data;
# The exact code for this step is very particular for each data set, ;
# but similar operations will need to be done on every data set;
# Data setup below is an example which contains both reference and nonreference sites;

################################;
# Input data are predictor data and a (site x taxa) matrix of abundance for all bugs;
# Predictor data file must include a column to identify the calibration, validation and test sites;

# Step 1a - Read and organize predictor data;
# Input the predictor data, tab delimited. Use the sample/site ID as the row name;

# Import Data
myFile = "data.cold.preds.tst.tab"
predall=read.delim(myFile,row.names=1)

head(predall); #look at 1st 5 rows, all columns;
dim(predall); # number of rows and columns;
```


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- Load the bug file and display dimensions of the file (# rows and # columns)

```
## Step 1b - Input the assemblage data (bug data), as a site-by-taxa matrix;
# The bug matrix is the result of fixed-count subsampling and matrify or cross-tab functions;

bugall<-read.table(paste(myDir,"data.cold.bugs.tst.tab",sep="/"),row.names="SampID",
        header=T,sep="\t");
dim(bugall)
```

- Make sure that the predictor and bug files have records in the same order, with the same identifiers.
- If records are aligned, “true” will appear for every record.

```
## Step 1c - Align bug and predictor data, by site/sample;
#check sample(row) alignment of bug and predictor data;
row.names(bugall)==row.names(predall);
# If samples are not aligned, fix by aligning bugs data to predictor data;
bugall<-bugall[row.names(predall),];
#check alignment again -- alignment OK;
row.names(bugall)==row.names(predall);
```

- Change taxa abundance to presence/absence.

```
#Create a Presence/absence (1/0) matrix (site by taxa) for the bugs;
bugall.pa<-bugall;
bugall.pa[bugall.pa>0]<-1;
```

- The following lines are mostly informative.
- The source and load lines call on scripts and files that should be in the same directory as the script.
- The last line displays taxa names.

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```
# Step 7 (continuation of steps in model.build.v4.1) - Making predictions for new (test) data.
# first, source the prediction script and also load the desired model;
 source("model.predict.v4.1.r");
 load('MyModel.Version1.Rdata');

 # User must supply a sample-by-taxa matrix of taxa abundance or else presence/absence
        #(coded as 1 or 0), for all new samples;
 # User must also supply a corresponding file of predictor data for those same samples;
 # These 2 files should have similar formats as the original taxa and predictor data sets;
 # Notes on file formats --
 #  A) The sample ID column in both files should be read into R as a row name (see Step 1 examples).
 #  B) Predictor data set -- Must include columns with the same names, units, etc.,
 #    as the model's predictor variables. All other columns will be ignored;
 #    Column order does not matter;
 #    Predictions and calculations of O/E will be made only for those samples that have;
 #    complete data for all model predictors.;
 #  C) Sample-by-taxa matrix. Can contain abundance or presence/absence (1 or 0).
 #                Missing or empty cells now allowed;
 #    Sample ID's (row names) must match those of predictor data.
 #    Any names for new taxa (column names) are acceptable, in any order;
 #    HOWEVER - Only those new-data taxa names that match the names in the
 #      calibration data can be used to calculate observed richness;
 #      All other taxa (columns) in the new-data bug matrix are ignored;
 #    To see a list of the calibration-taxa names, do:
    names(bugcal.pa)[colSums(bugcal.pa)>0];
```

- Define subset of data if desired
- Limit analysis to sites with complete data

```
# Example predictions: non-reference sites are labeled "test" (see Step 1);

pred.test<-predall; #predictor data - ALL sites;
bug.test.pa<-bugall.pa; #Bug presence/absence matrix, ALL sites;

#To limit to test sites only, use this code;
#pred.test<-predall[as.character(predall[,'RefCalVal'])=='test',];
#bug.test.pa<-bugall.pa[as.character(predall[,'RefCalVal'])=='test',];

#Drop all samples/sites that do not have complete data for the model predictors;
pred.test<-pred.test[complete.cases(pred.test[,preds.final]),];
bug.test.pa<-bug.test.pa[row.names(pred.test),];
```

- Calculate and display O/E, BC, and outlier status
- Results are not automatically saved and should be copied from the R console

Exhibit 34

- Looking at capture probabilities and predicted group occurrences is optional

```
#makes predictions for test data; *** Check PC at end of line, modify if needed
        #(may want to run BC at PC=1.e-14) **
OE.assess.test<-model.predict.v4.1(bugcal.pa,grps.final,preds.final,
grpmns,covpinv,prednew=pred.test,bugnew=bug.test.pa,Pc=0.5);

# Look at O/E and BC scores of test-data samples;
 OE.assess.test$OE.scores;
##### COPY these from the R console to a spreadsheet

# Look at predicted capture probabilties (1st 5 rows) for all calibration taxa, for test data;
 Head (OE.assess.test$Capture.Probs);
# Look at predicted group occurrence probabilties, for all test samples;
 OE.assess.test$Group.Occurrence.Probs;
```

- Calculate increaser/decreaser statistics
- Results are not automatically saved and should be copied from the R console
- For each of taxon, we list the 'Sensitivity Index'. The index is calculated from the average predicted probability of detection (assuming sites were under reference condition), the number of test sites at which taxa were predicted to occur, the number of test sites at which taxa were observed, and the ratio of observed sites to expected sites for each taxon (the 'Sensitivity Index'). We interpret it as a measure of sensitivity of a taxon to whatever stressors are influencing a taxon within the set of test sites submitted for assessment. A ratio > 1 indicates the taxon was found at more sites than expected and was thus an 'increaser' or tolerant taxon. A ratio < 1 indicates the taxon was found at fewer sites than expected and was thus a 'decreaser' or intolerant taxon.

```
# Increaser/Decreaser taxa
## use the output from this (in test sites) to find increasers and decreasers
## also called the sensitivity index
## Increaser values will be >1 (or >2 for certain increasers)
## Decreaser values will be <1 (or <0.5 for certain decreasers)

# limit above to test sites only
 taxa.pc<-OE.assess.test$Capture.Probs[as.character(predall[,'RefCalVal'])=='test',];
 bug.test.pa<-bugall.pa[as.character(predall[,'RefCalVal'])=='test',]; #Bug presence/absence matrix,
test sites;
# calculate observed occurences in all test sites over predicted occurences in all test sites
 Inc.dec.taxa<-apply(bug.test.pa,2,sum) / apply(taxa.pc,2,sum);
 Inc.dec.taxa
```

- Calculating O/E for an individual sample
- This gives more detailed results than the routine above, especially for individual taxa
- First identify the script and load the data
- Other lines are informative

Exhibit 34

```
## Assessing an individual sample or site;
        source("assess.one.sample.4.1.r")
        bug.test.pa<-bugall.pa
#This function assesses a single site or sample from a new (test) data set to which
# model.predict.v4.1() has already been applied.
# assess.one.sample() compares observed occurrences with the model-predicted
# probabilities of occurrence for all taxa;

# Input parameters are:
# case -- A selected sample ID, for which a prediction has already been made ;
        # The selected case must be among those assessed above;
# result.prd -- Output from O/E calculation above.
# bugnew -- Sample-by-taxa matrix of new samples.
# Pc -- Cutoff for capture probabilties for inclusion of taxa in O/E;
```

- Enter the name of the sample between quotes after *case=*

```
# The function produces a data frame with one row per taxon, and the following columns:
# observed presence(1) or absence(0);
# predicted capture probability;
# Big.diff = "Yes", if there is a big difference (>=0.5) between observed and predicted;
# In.OtoE = "Yes" if the taxon would be included in the O/E calculation for this sample,
        # given the stated value of Pc;

#By default, the function displays the results with its rows (taxa) sorted by
        # the magnitude of (observed-predicted),
        # as suggested in Van Sickle, J. (2008), JNABS 27:227-235;

site1.result<-assess.one.sample.4.1(case="11591_0",result.prd=OE.assess.test, bugnew=bug.test.pa,
Pc=0.5);

# See below for other sorting possibilities;
# Alternative display is to sort the taxa by their predicted occurrence probabilities;
 site1.result[order(site1.result$predicted,decreasing=TRUE),];
# Another alternative is to sort alphabetically by taxon name;
 site1.result[order(row.names(site1.result)),];
```

- End of script

Exhibit 34

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Exhibit 34

Exhibit 34

ATTACHMENT 1 – SITE VISIT FORM

Place Site Visit Label Here

Site Visit Form

(One Station per page)

Project ID:_____

Date: _____ **Time:** _____ **Personnel:** _____

Waterbody: _____ Location: _____

Station ID: _____ Visit #: _____ HUC: _____ County: _____

Latitude: __ __ . __ __ __ __ . Longitude __ __ __ . __ __ __ __. Lat/Long Verified? ☐ By:

Elevation: _____ ft m Geo Method: **GPS** Other: Datum: NAD27 **NAD83** WGS84

Samples Collected:		**Sample ID:**	**Sample Collection Information/Preservation:**
Water	☐		GRAB EWI
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Sediment	☐		SED-1
Analysis:			Preserved: None Other:
Benthic Chl-a	☐		Sample Method: C=Core H=Hoop T=Template N=None
Composite at Lab ☐	Ash-Free Dry Weight ☐		Sample Location: R=Right C=Center L=Left
Transect: A__ - __ B__ - __ C__ - __ D__ - __ E__ - __ F__ - __ G__ - __ H__ - __ I__ - __ J__ - __ K_____ -			
Phytoplankton Chl-a	☐		D1 Filtered:_____mL D2 Filtered:_____mL
Phytoplankton CNP	☐		D1 Filtered:_____mL D2 Filtered:_____mL
Algae	☐		PERI-1-MOD PERI-1 OTHER:
Macroinvertebrates	☐		MAC-R-500 HESS OTHER:
Collection Reach Length (m):			# of Jars: / Mesh Size: 500 OTHER:

Field Measurements:		Time: am pm	**Field Assessments:**
Water Temp: °C °F		Air Temp: °C °F	Field Forms: Fish Cover Form ☐ Photographs ☐
Bar. Pressure: mm/Hg		SC: umho/cm	Aquatic Plant Tracking Form ☐ Rosgen Form ☐
pH:	DO: mg/L	Flow: cfs	NRCS Form ☐ MAP Forms ☐ Summary Form ☐
Flow Comments: Dry Bed ☐	No Measurable Flow ☐		Channel Cross-Section ☐ Other:_____.
Flow Method: Meter ☐ Float ☐ Gage ☐ Visual Est. ☐			Data Loggers: Temperature ☐ YSI ☐ TruTrack ☐
Turbidity: Clear ☐ Slight ☐ Turbid ☐ Opaque ☐			AquaRods ☐ Weather Station ☐ Surveyor ☐

Comments	Only Transect F ☐ Total Site Length____m Average Wetted Width____m Transect Length____m

Chemistry Lab Information:		
Lab Samples Submitted to:	Account #:	Term Contract Number:
Contact Name & Phone:		EDD ☒ Format: MT-eWQX Compatible
1) Relinquished By & Date/Time:	1) Shipped By: Hand ☐ FedEx/UPS ☐ USPS ☐	1) Received By & Date/Time:
2) Relinquished By & Date/Time:	2) Shipped By: Hand ☐ FedEx/UPS ☐ USPS ☐	2) Received By & Date/Time:

Lab Use Only - Delivery Temperature: Wet Ice_____°C Dry Ice_____°C

Rev. 3/18/2011

Exhibit 34

Site Visit Form Instructions

Place a Site Visit Code label in the upper left corner (ONLY 1 SITE VISIT CODE PER FORM).
Place a Trip Label in the upper right corner. (Covering Project ID and Trip ID with label is alright.)

1. **Project ID**: If you do not have a Trip Label, enter the Project ID assigned by Data Management. If Project ID is not assigned, leave blank for Water Quality Database Manager.
2. **Trip ID:** If you do not have a Trip Label, enter the Trip ID assigned by Data Management. If Trip ID is not assigned, leave blank for Water Quality Database Manager.
3. **Date/Time**: Enter the date and time of the station visit.
4. **Personnel**: Enter the first and last name(s) of the personnel conducting field activities.
5. **Waterbody**: Enter the name of the waterbody such as "Missouri River".
6. **Location**: Description of sample location such as "upstream from bridge on Forest Service road 100". For confidentiality please DO NOT use proper names of people in the location field.
7. **Station ID**: If you have a Trip Label, enter the established ID. If there is no ID on the Trip Label, leave the field blank and Data Management will generate a Station ID when the Site Visit Form is submitted.
8. **Visit #**: Enter "1" if this is a new station. Leave blank if visit number is unknown.
9. **HUC**: If you do not have a Trip Label, enter the fourth code (8 digit) HUC the station falls within.
10. **County**: If you do not have a Trip Label, enter the county in which the station falls within.
11. **Lat/Long**: Latitude and Longitudes should be obtained in decimal degrees using a GPS unit reading **NAD83** whenever possible. If a lat/long is obtained by another method, the datum and method must be recorded in the Site Visit Comments.
12. **Lat/Long Verified**: Latitudes and Longitudes should be verified immediately upon return from the field. Verify by plotting on a paper map or using a mapping website. Once the lat/long has been verified check the Verified box and enter initials after "By". Do not make minor adjustments to measured values during verification; they are assumed to be correct within the limitations of the measurement system. Gross errors should be corrected as follows: 1) Draw a single line through the erroneous value(s) and initial. Do not erase the original reading. 2) Write the corrected value in the comment field along with the method and datum used to derive the corrected value.
13. **Elevation:** Record elevation collected by GPS and circle the GPS datum used. If elevation is obtained by another method, the datum and method must be recorded in the Site Visit Comments.
14. **Samples Collected**: Check the box next to each activity that is collected during the station visit.
15. **Sample ID**: Write the Sample ID (Site Visit Code-sample identifier) for all of the samples collected.
16. **Sample Collection Procedure**: Circle the appropriate Sample Collection Procedure ID.
    For each Chlorophyll-*a* transect, record the sample collection method in the first space provided and the sample location in the second space provided (example: A: T - R).
    For Phytoplankton, record the volume filtered for each sample collected.
17. **Analysis Requested**: Record the requested laboratory analysis for each chemistry sample and circle the preservative used.
18. **Field Measurements**: Record your field measurements in the spaces provided.
19. **Field Assessments**: Check the boxes next to each type of field assessment completed.
20. **Site Visit Comments**: Record general comments about the station visit, samples, and field measurements.
21. **Chemistry Lab Information**: If chemistry lab samples were taken, complete this section.
    Lab Samples Submitted to: Enter name of laboratory where samples will be sent.
    Account #: Enter account number at laboratory where samples will be sent.
    Date Submitted: Record date the samples were received by the laboratory.
    Sign and date the form each time the samples change possession.

Exhibit 34

Exhibit 34

ATTACHMENT 2 – PHOTOGRAPH LOCATIONS AND DESCRIPTIONS OF REACH AND/OR SITES

Exhibit 34

PHOTOGRAPH LOCATIONS AND DESCRIPTIONS OF REACH AND/OR SITES

Date:		**Site Visit Code(s):**	

Photo No: _____ **Lat** _____ **Long** _____
Description:

Photo No: _____ **Lat** _____ **Long** _____
Description:

Photo No: _____ **Lat** _____ **Long** _____
Description:

Photo No: _____ **Lat** _____ **Long** _____
Description:

Photo No: ___ **Lat** _____ **Long** ___
Description:

PHOTOGRAPH LOCATIONS AND DESCRIPTIONS-CONTINUED

Photo No:		**Lat**		**Long**	
Description:					
Photo No:		**Lat**		**Long**	
Description:					
Photo No:		**Lat**		**Long**	
Description:					
Photo No:		**Lat**		**Long**	
Description:					
Photo No:		**Lat**		**Long**	
Photo No:		**Lat**		**Long**	
Description:					

Exhibit 34

Exhibit 34

ATTACHMENT 3 – SITE SKETCH FORM

Date:_____ **Site Visit Code:**_____

Waterbody: _____

Personnel: _____

Exhibit 34

Appendix O
Probable Hydrologic Consequences
Area F
Western Energy Rosebud Mine
Permit ID: C2011003F

Prepared for

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A Subsidiary of WESTMORELAND COAL COMPANY
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February 2016

Exhibit 33

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Appendix O
Probable Hydrologic Consequences
Area F
Western Energy Rosebud Mine

1.0 INTRODUCTION

Western Energy has operated the Rosebud Mine located near Colstrip Montana in Rosebud and Treasure Counties since 1975 (See Figure O-1). The mine is operating under Montana Department of Environmental (DEQ) permits C1986003A, C1984003B, C1985003C, C1986003D, and C1981003E.

Western Energy submitted a permit application (C2011003F) for new Mine Area F in October 2011. The Rosebud Mine Site Map is shown as Figure O-2.

This report provides the identification and evaluation of probable hydrologic consequences (PHC) to support the Area F permit application in accordance with the requirements of ARM 17.24.314(3).

1.1 Background

There have been many previous investigations and evaluations conducted in the vicinity of and at the Rosebud Mine. Background reports considered in this PHC include:

- Area F Permit Application, Western Energy Company, October, 2011.
- Comprehensive Evaluation of Probable Hydrologic Consequences, Areas A, B and C, Western Energy Rosebud Mine, Nicklin Earth & Water, September 2013.
- Hydrology of Area 49, Northern Great Plains and Rocky Mountain Coal Provinces, Montana and Wyoming, Slagle et al, United States Geological Survey, January 1983.
- Hydrogeologic Conditions and Projections Related to Mining Near Colstrip, Southeastern Montana, Van Voast, Hedges, and McDermott, Montana Bureau of Mines and Geology, 1977.

- Hydrogeologic Responses: Twenty Years of Surface Coal Mining in Southeastern Montana, Van Voast and Reiten, Montana Bureau of Mines and Geology, 1988.

- Final Environmental Impact Statement, Western Energy Company's Rosebud Mine, Area C, Block 1, Montana Department of State Lands, US Office of Surface Mining, 1982.

Relevant Rosebud Mine monitoring reports include baseline and investigation reports, mining permit applications, and annual monitoring reports.

1.2 Approach

Baseline hydrologic data have been collected at Area F (Refer to Appendix B) and numerous previous investigations and hydrologic monitoring activities have been performed at the Rosebud Mine resulting in a very large amount of hydrologic data. Compilation, presentation, and evaluation of the available hydrologic data collected over the many years of operation of the Rosebud Mine allows for the identification and evaluation of probable hydrologic consequences beyond those developed based on baseline data. This information is provided in 17.24.304 and specifically in Appendix B of the permit application.

The key time-frames of interest include:

- Baseline (premine)

- Short-term (during mining and reclamation)

- Long-term (post mine and bond release)

1.3 Mining Progression

1.3.1 Past Mining

Mining has occurred at the Rosebud Mine since 1975 in Areas A, B, C, D and E. Figure O-3 shows the mining progression that has occurred at the mine over time and planned mining in the future.

1.3.2 Present Mining Situation

Active mining at Rosebud Mine is presently occurring in Areas A, B and C. Mining at Rosebud consists of a combination of topsoil removal, overburden removal, and coal removal. Topsoil is salvaged with appropriate mining equipment prior to overburden removal and stockpiled as necessary or hauled directly to regraded areas. Overburden is moved by the dragline and the coal is removed by means of a truck and shovel operation.

1.3.3 Future Mining

Figure O-4 depicts the planned mining progression at Area F. The present mine plan anticipates mining to occur from 2015 to 2034.

2.0 HYDROLOGIC SETTING SUMMARY

2.1 Climate

The climate of eastern Montana is classified as semiarid continental and is characterized by hot moderately dry summers, cool dry falls, cold dry winters and cool moist springs. Winter cold spells are often interrupted by periods of warmer weather. The passage of mid-latitude storm systems is typical of the climate of this area; day-to-day weather changes can be quite extreme because of the migrating systems.

At the mine, precipitation occurs predominantly as snow from about November to April. About one-third of the total annual precipitation is in the form of snow. Due to the prevailing westerly wind, the snow typically accumulates on the leeward slopes of drainage.

Refer to Appendix C for additional data and discussion of climate and weather at and in the vicinity of Area F.

2.1.1 Temperature

The average maximum and average minimum daily temperatures as measured at Colstrip are 88.1^{o} F in July and 9.6^{o} F in January respectively. The maximum and minimum temperatures ever recorded at Colstrip are 111° F (August 6, 1961) and -50° F (February 15, 1936).

2.1.2 Precipitation

The average annual precipitation at Colstrip is 15.1 inches. Monthly precipitation varies with higher average monthly precipitation in the spring (May and June). Snowfall and snow accumulation is usually highest in December and January. Total average snowfall is 41.6 inches.

2.1.3 Long-Term Precipitation

The long-term precipitation trends are discussed in Appendix C in terms of precipitation departure from average (DFA) plots. The DFA plot provides a graphical representation

of precipitation trends. Periods with negative values are indicative of lower than average precipitation (drought) and periods with positive values represent wetter than normal precipitation.

2.2 Water Availability

Generally, both surface water and groundwater are scarce at the Area F vicinity. The water supply is sufficient for domestic and livestock watering uses but not for irrigated agriculture. As typical of the semi-arid west, potential evapotranspiration exceeds average precipitation during the growing season.

2.3 Surface Water

The land surface at Rosebud Mine can be characterized by gentle slopes and subdued drainage divides. There are steeper slopes and narrow ridges present in the western portions of the area.

Ephemeral drainages at Area F include Trail, McClure, Robbie, Donley and Black Hank Creeks. McClure is tributary to Trail Creek which is tributary to the West Fork Armells Creek. Black Hank and Donley are tributary to Robbie Creek which is tributary to the West Fork Armells Creek. Armells Creek is tributary to the Yellowstone River.

Flow in these ephemeral drainages typically occurs only during periods of snowmelt and/or after periods of significant rainfall. When rainfall or snowmelt exceeds the infiltration rate of soils and vegetation evapotranspiration, water flows overland and then to drainage channels. Lesser amounts of runoff in drainage channels tend to be captured in stock ponds and/or infiltrate to the subsurface. Channelized runoff quantities tend to vary as they are dependent on precipitation patterns (e.g., wet versus dry climate periods), the nature (intensity and duration) of precipitation and snow accumulation and snow melt, soil conditions (dry, wet, frozen, etc.), vegetative cover, slopes and natural storage.

The proposed mine plan (Area F Permit Application Exhibit A) does not physically disturb the main Robbie, Donley and Black Hank Creek channels except where the haul road passes over these channels. Therefore, ephemeral discharges originating up-gradient of Area F pass through unimpeded.

As discussed in Appendix B (Hydrology), springs, ponds and wetlands are present within the main drainage channels found in and adjacent to Area F. Pond leakage and spring discharges have led to formation of wetlands down-gradient of the source of water. The function of springs, ponds and wetlands is also directly related to surface and groundwater hydrology.

2.3.1 Surface Water Quality

The surface water quality at Area F reflects runoff conditions and is variable. Baseline monitoring indicates that surface water has about two to three times higher specific conductivity when compared to the Rosebud Mine in general. Similarly, average TDS and major ion concentrations are higher in Area F surface water samples when compared to other Rosebud Mine drainages. Trace metals in Area F surface water are comparable to baseline data for Armells Creek and East Fork Armells Creek. One Area F surface water sample had lead concentration in excess of DEQ-7 numeric standards. There were no other exceedances of DEQ-7 standards in any other of the Area F surface water samples.

2.3.2 Surface Water Uses

Historically, the only known use of surface water at and in the vicinity of Area F is for wildlife and livestock watering direct from the source and from stock ponds. Wildlife and livestock also use water from springs. Stock ponds are constructed impoundments, typically in drainage bottoms, that store surface water flows resulting from precipitation events or snowmelt runoff. Some stockponds are sourced by springs. At areas adjacent to Area F, livestock water use will continue. During mining, surface water will be used for industrial purposes related to mining including road watering for dust control.

2.4 Groundwater

Groundwater at the Rosebud Mine occurs in shallow alluvial and colluvial deposits found in drainage bottoms and in Fort Union Formation consolidated deposits, including the Rosebud and McKay coal seams. At Area F, alluvial groundwater is limited and is hydraulically connected to the adjacent overburden in the upper portions of the Area F drainages. At these locations, the channel base of the alluvium is hydraulically isolated from the Rosebud coal. Progressing down-gradient along the drainages, the alluvium is

likely hydraulically connected to the Rosebud coal seam (see also Appendix I, Part A).

The overburden, Rosebud coal, interburden, McKay coal, and sub-McKay are all strata from the Tongue River Member of the Fort Union Formation. The Tongue River Member can be as thick as 540 feet. These units yield low quantities of water but at sufficient rates to provide domestic and stock watering supplies. Low yield springs also occur at outcrops from these deposits and they are frequently used for stockwater.

The groundwater flow direction in the coal seams is generally consistent with topography to the northeast.

Refer to Appendix I (Area F Groundwater Model Report) for a detailed characterization and discussion of groundwater and groundwater hydraulic properties at and in the vicinity of Area F.

2.4.1 Groundwater Quality

The groundwater quality at Area F varies significantly based on geologic stratum. The highest average TDS concentrations are observed in the overburden (average of 4,098 mg/L), followed by the alluvium (3,203 mg/L), Rosebud coal (2,101 mg/L), sub-McKay (1,961 mg/L) and McKay coal (1,819 mg/L). Generally, TDS concentrations are higher when compared to regional baseline data (Slagle et al, 1983). Sulfate is the dominant major ion with average concentrations of: 2,400 (overburden), 1,948 (alluvium), 1,065 (Rosebud), 1,052 (sub-McKay) and 979 (McKay) mg/L. DEQ-7 human health standards for one or more of the following analytes were exceeded in six groundwater samples: arsenic, fluoride, lead and selenium.

The overall groundwater quality at Area F is generally similar to the Rosebud Mine except that the overburden groundwater is characterized by higher concentrations of most major ions.

2.4.2 Groundwater Use

Premine groundwater use at and in the vicinity of Area F is mainly for livestock watering with a few domestic wells. The main source of water is wells developed in coal and sub-McKay deposits.

2.5 Springs, Ponds and Wetlands

2.5.1 Springs

Springs and seeps at Area F generally occur due to the surfacing of shallow, sometimes perched, groundwater that accumulates at the transition from more to less permeable strata. This tends to occur where erosional processes at drainages expose perched groundwater. Typically, the perched groundwater lies on low permeability mudstones. This groundwater may discharge as seeps or springs when these contacts are exposed to the surface. The flow from seeps and springs typically results in the presence of a down-gradient wetland. These surface expressions typically flow or “ooze” down the drainage for a limited stretch before being evapotranspired or absorbed into the soil. Of the springs monitored since 2011, only Spring 4 generally exhibits flows exceeding one gpm. Spring water quality is highly variable.

Springs and seeps are sources of water for wildlife and livestock in the vicinity of Area F. Springs are sometimes developed (e.g., excavated or impounded) to maximize the availability of water for livestock. These wet areas are often trampled by wildlife (e.g., elk) and livestock use and surrounding vegetation and water quality are impacted by this use. Monitored springs are characterized in detail in Attachment B-J of Appendix B (Hydrology).

2.5.2 Ponds

The ponds in the vicinity of Area F were constructed to store water for livestock use. Typically, a berm or dam is constructed across the channel to impound runoff flows. Some ponds are constructed down-gradient of a spring. Additionally, road and two track road construction can create ponding conditions. Detailed characterization of ponds at Area F is provided in Attachment B-L of Appendix B (Hydrology).

2.5.3 Wetlands

The identification, characterization and delineation of Area F wetlands are described in the report, “The Rosebud Mine Wetlands Delineation Report, Area F” (Cedar Creek Associates, 2013) (Appendix E). The Army Corps of Engineers determined that these

wetlands are isolated and not jurisdictional (See Appendix E). These wetlands are sourced by springs and seeps or seepage from pond embankments. The vegetative assemblies associated with wetlands are described in the wetland delineation report.

2.5.4 Aquatic Life

The aquatic life survey (ALS) (ERM, 2015)(See Appendix B) reports the results of the aquatic benthic community survey. Ten wetland areas within Area F were surveyed.

3.0 PROBABLE HYDROLOGIC CONSEQUENCES

3.1 Surface Water Probable Hydrologic Consequences

Due to mining operations, the surface water system will be impacted. Consequences to the surface water quantity, surface water quality, topography and erosional stability are discussed below.

Mining will alter the existing premine topography. For reclamation, the post mine topography (PMT) was designed to be as similar as possible to premine topography, given the constraints of earthmoving equipment, economics, contemporaneous reclamation, and stripping ratio. During reclamation, smooth transitions will be constructed between undisturbed and reclaimed land to re-establish surface drainage patterns.

During mining, the reclamation will be performed following the mining advance, causing temporary changes to the drainage system. As the post mine topography is developed, the drainage system will start to function similarly to the premine drainage system. The PMT was designed to meet the regulatory definition for approximate original contours. The final surface configuration resembles the premine configuration and blends into and complements the drainage pattern of the surrounding terrain. By developing a PMT that closely resembles the premine topography, Western Energy is ensuring that the post mine drainage system performs in a manner that meets the needs of the post mine land uses.

3.1.1 Surface Water Quantity – PHCs

3.1.1.1 Short Term Impacts – During Mining

Generally, surface water flows at Area F are ephemeral and dominated by short term/episodic precipitation and snowmelt runoff events. During mining, the surface water quantity will be impacted. Tributary drainages will be mined out and surface runoff from disturbed areas will be impounded in mine pits and/or sediment control structures in accordance with the mine's hydrologic control plan. The detention and controlled release of surface runoff will result in reduced peak flows to the Armells Creek drainage.

Generally, the nature of climate and weather at Area F dominates the water supply. Overall surface water supply is scarce and its use is opportunistic based on the capture of runoff from the infrequent flow events. Based on 20 years of discharge data collected by USGS at the Armells Creek gaging station (06294995), the average contribution to Armells Creek surface flows from Area F is 117 acre-feet per year. This represents the maximum impact if all of the runoff in the entire Area F were to be detained. However, surface flows will be augmented by discharges from sediment ponds (e.g., MPDES discharges). As the sediment ponds are designed to retain up to the volume of runoff produced by the theoretical 10-year 24-hour storm event, runoff from larger events will discharge to the main channels.

It is anticipated that the quantities of surface runoff, soil moisture storage, and infiltration to underlying groundwater will increase during mining due to the impacts of disturbed ground when compared to premine vegetated conditions. This increased runoff is then detained in mine pits and sediment ponds. Impounded water will be utilized (e.g., road dust control), evaporate, and infiltrate to the subsurface contributing to the recharge of underlying hydrostratigraphic units.

At times, impounded water will be discharged from sediment ponds to surface water drainages. Planned and unplanned discharges will occur in conformance with mine MPDES discharge permit requirements. Locations of all potential discharges to Trail Creek, McClure Creek, Robbie Creek, Donley Creek, and Black Hank Creek from disturbed lands which will be detained in sedimentation ponds are shown in Exhibit D of the permit application. Discharges from the permit area are described in more detail in Permit Sections 17.24.633, 17.24.639, and 17.24.313.

Based on the USGS flow data from Armells Creek, the average annual contribution to surface flows from runoff originating up-gradient of Area F is projected to be 149 acre-feet. As the main channels (Robbie, Donley and Blank Hank) are not mined out, up-gradient ephemeral discharges will flow through Area F unimpeded. Similarly, non-impacted runoff originating down-gradient of Area F will discharge to main channels, providing water supply to existing users.

Surface water (when present) is also connected to the underlying alluvium (where present). Smaller surface flows tend to rapidly infiltrate to the subsurface. If the alluvium becomes fully saturated, groundwater can surface to the channels. This has been observed at Robbie Creek in the vicinity of the county road, during the recent wet

climatic conditions. It also occurs downstream from Area F as discharges from groundwater cause intermittent and perennial flow conditions lower in the Armells Creek drainage. This water supply becomes available to downstream users.

Alternate water supplies (e.g., wells supplied by coal aquifers and sub-McKay sands) are available if adjacent surface water users are impacted by mining operations.

3.1.1.2 Long Term Impacts – After Mining

As reclamation proceeds, the drainage system will be restored. All disturbed drainages and stream channels will be constructed to approximate original drainage configurations. A tributary system will be designed and constructed to restore the premine system of incised drainages that collected runoff and sediment from the uplands and convey them to the main drainage channels. The post mine channels and floodplains are designed to mimic the premine channels' response to rainfall events. This is achieved by providing channel geometry (length, slope, longitudinal profile, cross-section, and bedform) that gives velocities, flow areas, and other hydraulic properties that are similar to premine properties for the same discharge events. As the mine area is reclaimed, long term effects on the drainage system are expected to be minimal.

Evaluation of available stream flow data collected at the Rosebud Mine confirms that flows are infrequent, ephemeral and occur in response to precipitation events and snowmelt. The key factor is precipitation. More specifically, the ephemeral flows reflect the nature of the snow accumulation and melt and higher intensity precipitation events. These factors are mostly independent of mining activities and post mine surface water flows should be essentially the same as premine upon completion of reclamation.

As surface flows are highly variable and event based, premine and post mine comparisons should be based on the evaluation of hydraulic function and quantifications from surface modeling of a set precipitation event such as a 10-year, 24-hour storm (e.g., SedCad™ modeling).

The evaluation of pre and post mine geomorphology, drainage basin characteristics and runoff presented in Tables J-1 through J-4 of Appendix J (Protection of the Hydrologic Balance) demonstrates that post mine surface water flows will be essentially the same when compared to premine as the reclamation will result in similar geomorphic and hydraulic characteristics.

Surface water losses (recharge) to the alluvial groundwater system should also return to premine conditions as natural surface water flows are reestablished and groundwater levels recover following mining.

3.1.2 Surface Water Quality - PHCs

As discussed above, tributary drainages will be mined out and runoff from disturbed areas will be contained. Sediment control structures will prevent the discharge of water with elevated suspended solids and sediment to receiving drainages for precipitation events up to the design event (10-year, 24-hour). The result is a net improvement of downstream water quality during mining.

For significant spring and summer-time runoff events (greater than 10-year, 24-hour), receiving drainages would likely have naturally occurring elevated suspended solids and sediment levels. The quality of receiving water during winter events would likely be variable, depending on the conditions. For example, melt water flowing over frozen land would likely be low in suspended solids, however significant flows in drainage channels would tend to transport suspended solids and sediment depending if the bottom of the channels are frozen.

As discussed above, the mine will at times discharge treated water in accordance with its MPDES permit. Under typical conditions, discharged water will infiltrate to the subsurface of the main undisturbed drainage channels. At times, when receiving drainages are flowing due to significant precipitation and/or snow melt events, the discharged water will likely be of similar quality to the receiving water.

The surface water quality at the mine is continually monitored to ensure that the surface water is protected. By continuing to monitor the surface water and enforcing and adapting the mine's hydrologic control plan (Exhibit D), current and future impacts to the surface water will be minimized.

Over the long term, implementation of the reclamation plan will establish topography, vegetation and drainage channels that approximate premine conditions. Tributary drainages will be restored during reclamation and flow patterns reestablished, including incised drainages that collect runoff and sediment from uplands and transport these to the primary drainages. Reclamation vegetation will mimic premine conditions and provide for similar surface runoff rates and volumes.

The comparison of premine to post mine geomorphology, drainage basins, and runoff provided in Appendix J (Tables J-1 through J-4) shows that the post mine hydrology is essentially the same as premine. When combined with reclamation vegetation, the post mine water quality will be similar to premine.

Generally, the quality of the surface water at the mine is highly variable, due to the nature of the flows. As such, statistically significant correlations of changes in surface water quality to mining have not been observed to-date. It should be noted that continued monitoring, data collection and evaluation may allow identification of trends should they occur.

Presently, the alluvial groundwater quality in East Fork Armells Creek is affected by a variety of factors. A relatively high proportion of the change is related to above average rainfall and recharge. The main transition that can be attributed to mining activity is the increase in chloride concentrations in eastern portions of this creek between Areas A and B. Otherwise, mining impacts to date are very limited primarily because presently groundwater in Area B spoils is not flowing toward the alluvium. Eventually, it is predicted there will be some increase (estimated at about 13 percent) in TDS concentrations in the alluvium as groundwater levels recover in Area B.

Similarly, post mine sediment yields should be comparable to premine. Generally, significant sediment transport and deposition are associated with high intensity, low frequency events (e.g., 10-year and greater). The impacts from these events overwhelm any minor differences in premine to post mine land cover, topography, and geomorphology.

Following reclamation regrading and approval of the Western Alkaline sediment control plan, sediment ponds will be removed and replaced by approved BMPs. The sediment control plan will demonstrate that modeled post mine sediment yields will be less than premine yields.

3.1.3 Surface Water Use - PHCs

At and adjacent to Area F, wildlife and livestock water use will continue. During mining at Area F, detained surface water will be used for industrial purposes related to mining including road watering for dust control. As noted previously, runoff from disturbed areas will be detained as required during mining. This reduces the quantity of water

available to down-stream wildlife and livestock use. Generally, stock water use at and immediately adjacent to Area F is opportunistic based on the storage of ephemeral flows in stock ponds as well as utilization of discharges from springs. Some stock ponds impound spring discharges.

On average, the net surface water availability will be slightly reduced during mining due to the detainment of runoff and potential impacts to springs from mine dewatering. This impact is the most pronounced immediately down-gradient of Area F and decreases with distance from the mine. Sufficient water supplies are expected during wet periods. Typically, the water supply from runoff is scarce during dry and average conditions.

Table O-1 presents an impact evaluation for all inventoried surface water rights in the vicinity of Area F (see Appendix B – Table B-18). Three types of surface water users are included in this table: springs, ponds and uses direct from source. A more detailed impact assessment of springs and ponds is presented in Sections 3.3.1 and 3.3.2, respectively. Table O-1 includes six surface water uses directly from the source. During mining, impacts to surface water users can be mitigated, most likely by the installation of water supply wells sourced by coal and/or sub-McKay aquifers.

Following mining, the water supply will be similar to premine conditions resulting from the restoration of premine hydrologic function. Western Energy will propose enhancements to the post mine topography (PMT) that will include features to capture surface water when available for livestock and wildlife watering.

3.2 Groundwater Probable Hydrologic Consequences

Mining will cause impacts to both the quantity and the quality of the groundwater in the mine area. Impacts result from the following mining activities as discussed below.

The subsurface is dewatered at active mine pits to about the level of the bottom of the Rosebud coal. This groundwater is typically routed to adjacent pits and/or sediment control ponds and used for road dust control.

Disturbance of the land surface alters the infiltration rate from the surface to groundwater. At premine conditions, the majority of precipitation evaporates, sublimates (from snow), or is lost as evapotranspiration by natural vegetation. If the quantity of precipitation is large enough, surface runoff occurs. A small portion of the remaining water infiltrates through the soil profile, some is held in the soil profile (field

capacity) and a small amount percolates to underlying groundwater. The amount of groundwater recharge from precipitation is relatively small. The groundwater model (Appendix I) utilizes general recharge rates of about 0.09 inches per year. Higher recharge rates (from 0.8 to 2.5 inches per year) are expected at clinker and alluvial deposits (drainage channels). During mining, higher than normal recharge is anticipated from water management structures such as sediment ponds.

Mining will remove the Rosebud coal and replace it with spoils. During mining, the dragline removes overburden material by pulling the bucket upward from near the base of the cut toward the top. This material is then "cast" into spoil ridges in the preceding cut. As the stripped overburden material is cast, it is spread over a relatively large area. During this process, the materials are thoroughly mixed, and blocks of geologic materials tumble down steep spoil pile slopes and form a "rubble layer" at the base of the replaced spoil. Moran et al. (1979) conclude that the rubble zone is probably thin but has a substantially higher permeability than the original materials. Backfilled spoils have a higher porosity than the original strata and these spoils probably have a higher vertical percolation rate since the materials when backfilled are more isotropic. Most sedimentary materials exhibit a strong preferential horizontal permeability.

Mining impacts of hydrological importance that can occur are the destruction of horizontal continuity in the overburden strata and the mixture of the overburden strata in the backfilled pits creating a more isotropic media. During this process, some geological materials that were previously saturated are intermixed with materials that were unsaturated. In addition, a variety of lithologies are mixed including siltstones, sandstones and shales. The mining process substantially increases the surface area of excavated materials exposed to air and water. During the mining process, soil structure is altered, vegetation is removed, and the replaced subsoil and topsoil probably has a slightly increased bulk density.

The Area F Groundwater Model (See Appendix I) has been developed to predict the quantity and duration of the impacts to groundwater associated with mining. Many years of groundwater quality data from the Rosebud Mine have been evaluated to assess potential impacts to groundwater quality from mining.

3.2.1 Groundwater Quantity - PHCs

Mining will remove the Rosebud coal aquifer and cause diminished water levels in this

aquifer in the mine vicinity for the duration of mining. Drawdown commonly extends laterally into unmined coal adjacent to mine pits. The degree of drawdown in unmined coal diminishes with distance from the mine pits, with the most extensive depression of the groundwater surface occurring down-gradient of the mine passes.

The Area F groundwater model report (Appendix I-B) simulates and predicts water level drawdowns over time during and after mining. Based on the results of the groundwater model, the drawdown (Rosebud and McKay coal) within a one mile radius of the Area F permit boundary is predicted to be less than five feet during the mine phase.

Following mining, backfill water levels are expected to return to premine coal-seam water levels. Post-mine model simulations were run to predict groundwater levels in the Rosebud Mine and its vicinity every five years after the cessation of mining at Area F, up to 50 years after mining. See discussion in Appendix I-B (Section 2.2) regarding the rationale behind the selection of the 50 year simulation horizon. The simulation results predict that following mining, water levels will gradually recover. However, the post mine model predicts that the five foot drawdown contour south of the eastern portion of Area F, in both the Rosebud coal and McKay coal will move further away from the permit boundary. The maximum distance between the permit boundary and the five foot drawdown contour is approximately 1.3 to 1.4 miles for both strata. The model predicts that 50 years after mining, the residual drawdown to the south and west of Area F will be less than 10 feet in the Rosebud coal and less than five feet in the McKay coal. Although it will take considerable time, it is expected that the regional groundwater flow gradient will eventually recover to near premine conditions because recharge and discharge areas for the principal aquifers will not be substantially altered by mining. The hydraulic characteristics of the spoils will facilitate storage and transmission of groundwater between the undisturbed up-gradient and down-gradient coal aquifer restoring the essential function of conveying groundwater from recharge to discharge areas. The key recharge areas at Area F which are associated with clinker and drainage channel bottoms are not excavated during mining. Upon the reestablishment of comparable topography, soils, and vegetation groundwater recharge rates in spoils areas will likely be slightly higher than in previously unmined terrain.

Mining near the alluvium may reduce the groundwater flow from bedrock units to the alluvium, which may result in lower alluvial groundwater levels. The ephemeral drainage channels dissect the overburden in areas south and west of the Rosebud coal

outcrop (see Figure O-5). In more southern portions of the mine permit area, there tends to be a dearth of alluvium or it is absent. The thickness and lateral extent of the alluvium tends to increase moving northward where it sequentially progressively truncates through the overburden, the Rosebud coal, the interburden, the McKay coal and then the sub-McKay.

Analysis of available groundwater level data (e.g., at alluvial well WA-223) in Appendix B shows that alluvium in the upstream (most southerly portions of the drainages) is likely unsaturated. Unsaturated alluvium up-gradient of the mine cannot be impacted by Area F mining.

The effects of mining to groundwater levels in the overburden are projected to be limited to the immediate vicinity of mining or mine passes. This is inferred from analysis set forth in Appendix I-A that demonstrated that overburden wells generally don't respond to mining unless that overburden is in close proximity to mine passes. For areas where the saturated or partially saturated overburden, and saturated or partially saturated Rosebud coal is mined out in the proximity of the alluvium, some limited reduction in flow to the alluvium from the overburden is anticipated. Figure O-5 shows areas where this is most likely to occur.

Table O-2 tabulates the simulated flow to the alluvium from bounding strata within the Area F boundary (see Appendix I-B). Within the Area F permit boundary, lateral contributions of flow from bedrock strata to the alluvium at the end of mining are simulated to be 32 percent lower than during premine conditions. Simulation results predict that it could take more than fifty years for flows from bedrock strata to alluvium to reach premine conditions. For instance, the results in Table O-2 show that within Area F the simulated flow from the bedrock strata to the alluvium fifty years post mining is about 10 percent lower than simulated premine flow. However, such an estimate is considered conservative as modeling does not take into account the effects of temporal increases of recharge to the alluvium that are likely to occur with MPDES discharges of stormwater runoff and/or pit water accumulations that may occur during mining in Area F. The detailed evaluation of the hydrologic response to mining of the East Fork Armells Creek (ABC PHC Addendum – Attachment 1, NE&W 2015) demonstrated, that MPDES discharges can lead to accelerated or rapid recovery of alluvial water levels.

Climatological factors (e.g. the amount of precipitation in any given year), are also highly influential in determining water levels in the alluvium. For example large amounts

of precipitation during a wet year may significantly accelerate the recovery of water levels in the alluvium. As the frequency and size of MPDES discharges as well as climatological factors cannot be predicted, it is not feasible to predict the time frame of recovery for water levels in the alluvium.

3.2.2 Groundwater Quality – PHCs

Groundwater quality within the permit area will be impacted. This has been the subject of considerable study throughout the Powder River Basin and elsewhere (Van Voast and others 1977 and 1988). TDS concentrations in spoils groundwater are generally higher when compared to the groundwater in the coal they replaced. Re-saturation of backfill, primarily by lateral groundwater flow from the undisturbed coal aquifers, can be expected to result in increases in TDS concentrations as a result of elevated levels of most soluble salts, (primarily sulfate and magnesium) leached from the overburden. According to Van Voast and Reiten (1988), average TDS concentrations of groundwater in mine spoils in southeastern Montana mines are 50 to 200 percent higher than the average concentrations in the undisturbed aquifers. Similar geochemical conditions have also been simulated in the laboratory with bench scale column-leach and paste-extract leaching techniques using overburden materials representative of those to be disturbed by mining at specific mines (Van Voast and Reiten, 1988).

Based upon the bench scale tests, it is projected that the total dissolved solids concentrations in the backfill water will reach a maximum during initial saturation and then decrease to an equilibrium level after one or more pore volumes of water pass through the backfill. As re-saturation of the backfill continues, salt concentrations are expected to be extremely variable and peak at concentrations potentially two to three times that of the baseline coal groundwater quality and then decline to some equilibrium value after being flushed by one or more pore volumes of groundwater.

Therefore, spoils groundwater near areas receiving relatively higher amounts of recharge (e.g. near clinker areas or alluvium) may establish geochemical equilibrium more quickly than in other areas. Similarly, spoils groundwater at the up-gradient edge of the spoils is expected to establish a relative equilibrium more quickly than at the down gradient edge.

The detailed evaluation (Appendix B [Hydrology]) of Rosebud Mine groundwater quality data indicates that the TDS concentrations in spoils will be higher than the

concentrations in premine overburden groundwater. In areas where spoils groundwater flows into adjoining strata, it can lead to increased TDS concentrations in those strata. TDS data from Areas A, B and C wells show that this has likely occurred at the Rosebud Mine. Furthermore, analysis of TDS concentrations in Areas A, B and C wells shows that the changes in water level associated with nearby dewatering activities may result in variable TDS concentrations in those wells.

Table O-3 presents a summary of water quality data in Areas A, B and C spoils and baseline overburden groundwater. The TDS concentration in spoils groundwater is highly variable with concentrations ranging from 860 to 8,750 mg/L. Appendix B Tables B-26A, B-26B, and B-26C present spoils and overburden groundwater quality data for Areas A, B and C, respectively. These tables show that the average TDS concentration in Area C overburden groundwater is higher than in Areas A and B. Likewise, the average TDS concentration in Area C spoils is higher than in Areas A and B. The maximum TDS concentration in spoils groundwater in Areas A, B and C is 6,710, 8,750 and 7,360 mg/L, respectively. These data indicate that higher average TDS concentrations in overburden may result in higher TDS concentrations in spoils groundwater.

Table O-3 shows that in Areas A, B and C the average spoils TDS concentration is 73 percent higher than the average overburden TDS concentration. This falls within the 50 to 200 percent range reported by Van Voast and Reiten (1988). Similarly, in Rosebud Mine Areas A, B and C, the average major ion concentrations in spoils groundwater are 34 percent to 167 percent higher than in overburden groundwater, whereas the average pH of spoils groundwater appears slightly lower than in overburden groundwater.

For comparison purposes, Table O-3 presents water quality statistics of the Area F overburden groundwater. It is characterized by higher concentrations of most major ions when comparing it to overburden groundwater in other mine areas. Therefore, it is reasonable to assume that the average TDS concentration in Area F spoils groundwater may be higher than observed in mine Areas A, B and C. If assuming that the average TDS concentration in Area F will increase proportionally to the overall increase observed in Areas A, B and C (73 percent), an average TDS concentration in Area F spoils of 7,089 mg/L can be projected. As stated earlier, data from Areas A, B and C show comparable maximum TDS concentrations in spoils groundwater, even though average baseline overburden TDS concentrations were variable. The maximum TDS concentration in spoils groundwater is governed by the complex geochemistry of

groundwater and geochemical equilibria limit the degree of mineralization of spoils groundwater.

The specific conductivity in groundwater at Area F ranges from 585 to 7,310 umhos/cm. The Area F groundwater classifications (ARM 17.30.1006) range from Class I (up to 1,000) and Class II (1,000 to 2,500) to Class III (2,500 to 15,000). The maximum classification for 24 out of 36 Area F monitoring wells is Class III. Alluvial groundwater is generally Class III, with only one out of 57 samples exhibiting Class II groundwater. Similarly, all Area F overburden groundwater samples were Class III. Based on the quality of groundwater samples from the Rosebud coal, McKay Coal and sub-McKay wells throughout Area F, it is clear that the only groundwater from these strata near the Rosebud coal outcrop produces Class I or II groundwater. This is primarily because of its near-surface proximity to recharge sources. In other portions of Area F, groundwater from these strata can generally be classified as Class III.

The maximum SC measured in spoils groundwater at Rosebud mine during the 1973 through 2013 period was 8,420 umhos/cm (see Table O-3). This value is well below the 15,000 umhos/cm cutoff for Class III groundwater. Based on these historical data, it is reasonable to assume that spoils groundwater at Area F will not exceed Class III in the future. As a result, the classification of alluvial and overburden groundwater in Area F is expected to remain the same. Similarly, the classification of Rosebud coal, McKay coal and sub-McKay groundwater in areas away from the Rosebud coal outcrop is expected to remain the same. However, a classification change of the Rosebud coal near the Rosebud coal outcrop is more likely. Note that if these changes do occur, they would be well within the permit since nearly all outcrops are well within the permit boundary. No transitions are likely to occur outside the permit boundary. The following factors are influential for assessing the potential for a classification change of the groundwater in this area:

- The stratum. The groundwater quality of the Rosebud coal adjacent to and downgradient of mine spoil is more likely to change since the Rosebud coal will either be replaced with spoils materials in areas that are mined out. The McKay coal is separated from the Rosebud coal or spoils by the interburden. The ABC PHC found that if the thickness of the interburden was less than 40 feet, there were more likely to be changes in water quality in the McKay coal and to a lesser degree the sub-McKay. According to geologic cross-sections provided in the permit (Appendix Q), the interburden is typically about 100 feet thick. Well logs

from four observation wells indicate thicknesses ranging from 41 to 64 feet. The preponderance of the data provided via a combination of the geologic exploration wells penetrating both the Rosebud and McKay coals, coupled with the observation wells indicate that thicknesses tend to be far over the 40 foot criterion seen in the cases discussed in the ABC PHC. Therefore, it is projected that any transitions in water quality for adjacent underlying strata would be limited to upper portions of the interburden. Changes in water quality for the McKay coal and subMcKay are considered unlikely because of the thickness of the interburden.

- Location with respect to mining. Groundwater in the strata below the immediate mining footprint is more likely to change classification simply because mine spoil will replace the Rosebud coal. Outside of the mining footprint, an increased down gradient distance from mining is expected to decrease the likelihood of a classification change. Hence, any transitions that do occur are projected to remain well within the permit boundary.

- Proximity to outcrop. In addition to the above, the Rosebud coal near its outcrop in some portions of Area F is bounded by clinker. Depending upon the proximity of the mining to that clinker, it is possible that quality of adjacent clinker (and immediately underlying interburden) would see an increase in TDS as a result of up-gradient mining. However, at the same time, clinker is known to receive much more recharge than the consolidated strata. Thus, it is anticipated that the impact of any lateral flux from mine spoil, through the residual/oxidized coal, and into the clinker will be diluted accordingly and progressively with distance from the mined areas. If significant transitions in water quality do occur, they are projected to remain very near the mine footprint because of the effects of recharge and dilution.

In summary, if transitions in classification do occur in the Area F permit, they are projected to be primarily beneath and just downgradient of the mining footprint.

3.2.3 Groundwater Use - PHCs

Several existing wells will be eliminated by mining. Several of these wells comprise the mine's groundwater monitoring network. Some of these wells were used in the past for stock watering purposes. Groundwater model simulations (Appendix I) indicate that

water levels in domestic, stock, and monitoring wells in the mine vicinity are likely to exhibit reduced water levels.

The potential hydrological impact from mining in Area F on the private wells and water supply wells within one mile surrounding and three miles down-gradient of the permit boundary is determined by the location of the well with respect to mining, the stratum in which it is completed, and the available water column in the well.

Groundwater level drawdowns at and adjacent to Area F are depicted in drawdown figures provided in the Area F Groundwater Model Report (Appendix I-B). A well would become impacted if the water column is reduced to the level limiting pump performance. The required minimum water column is well-specific. Wells that become impacted can be replaced with deeper or replacement wells as needed.

Figure O-6A shows the maximum simulated Rosebud coal groundwater drawdown contour and identified groundwater users (e.g., wells). Generally, the simulated affect is about five to twenty feet of drawdown or less in wells to the west and south of Area F. Wells located to the northeast of the mine permit boundary are not predicted to be impacted as the strata of interest (impacted strata) outcrop at the northern portion of Area F. Figure O-6B shows simulated Rosebud coal groundwater drawdown contours and identified groundwater users at 50 years following the completion of mining at Area F. At 50 years following mining, groundwater levels are predicted to have significantly recovered with limited potential impacts outside of the proposed Area F permit boundary.

Table O-4 presents an impact evaluation for the groundwater users listed in the inventory included in Appendix B (Hydrology), Table B-29. Note that the groundwater use inventory represents information from databases (GWIC, NHD, NRIS and Western Energy) that may be duplicative.

3.3 Springs, Ponds and Wetlands Probable Hydrologic Consequences

3.3.1 Springs - PHCs

A spring would be impacted by mining if it is physically disturbed (e.g., mined out) or if its water source or water quality is affected by mining drawdown. Springs located within, or near, the footprint of mining are more likely to be affected than the other springs. Figure O-7 shows the location of monitored springs.

Factors considered relevant for evaluating the potential significance of mining to springs include:

- Proximity to mining
- Strata or deposits sourcing the spring
- The observations to date for monitored springs in Rosebud Mine Areas A, B and C.

Evaluation of the spring water quality data from Rosebud mine Areas A, B and C does not identify changes in water quality associated with mining in those areas to date. Continued monitoring will allow ongoing evaluation of spring water quality.

Table O-5 presents an impact evaluation for the springs listed in the inventory included in Appendix B (Hydrology), Table B-31. Note that the spring use inventory represents information from databases (NHD, NRIS and Western Energy) that may be duplicative.

Springs 7, 10 and 11 are located at or near the edge of mine passes, and are likely sourced by overburden/Rosebud coal or Rosebud coal/clinker. There is significant potential for mining effects these springs as water bearing overburden and Rosebud coal near the springs will be mined.

Monitored Springs 3, 8 and 9 will potentially be affected by mining as they are located near mining passes within the disturbance boundary. The most likely water sources for these springs are either overburden sandstones or Rosebud coal and associated clinker (see Appendix B).

The remaining monitored springs are located outside of the Area F disturbance area and are unlikely to be affected by mining.

Springs 2 and 12 are located approximately 0.3 miles north of projected mine passes and about 0.2 miles north of the Rosebud coal outcrop. The source of these springs is unknown, however because of the distance from mining both laterally and vertically it is deemed unlikely that they would be impacted by mining.

Spring 13 is associated with Wetland D and is likely sourced by McKay coal. Spring 14 is a sub-McKay spring located approximately 0.9 miles east of projected mine passes. Given that the seepage in this spring is from strata beneath the Rosebud coal, the potential for impacts due to mining is limited, both from a water quantity and water quality perspective.

Monitored Springs 1, 4, 5 and 6 are overburden springs located 0.6 to 1 mile up-gradient from projected mine passes. These springs will not be impacted by mining as they are sourced from overburden strata well above the Rosebud coal. It is highly probable that they are sourced by perched groundwater in that overburden.

In addition to potential impacts to springs due to mining, some springs in Area F and its vicinity may be impacted by the relocation of the county road and the construction of the haul road. Figure O-8 shows the projected location of the roads with respect to the Area F springs and wetlands. From this figure it is apparent that Spring 11 is likely to be impacted by the haul road construction. Spring 8 and 13 are located less than 300 feet from the haul road. The haul road construction is projected to disturb the ground surface near Spring 8 and a spring mitigation plan is being developed by WECo. Similarly, Spring 13 could be impacted by haul road construction. Finally, Spring 2 and 12 are located 340 and 150 feet from the relocated county road. There is limited potential for the flow from these springs to be impacted by road construction, as the source of spring flow is not likely to be disturbed by construction. The water quality of springs in the vicinity of mining disturbance will be protected by implementation of the Area F Hydrologic Control Plan.

Mitigation plans will be developed and implemented for all springs that are impacted by mining related activities.

3.3.2 Ponds - PHCs

Area F ponds are shown on Figure O-7. No ponds will be mined out. The quantity of water and use of the down gradient ponds (Pond 4) will be impacted during mining due to reduced water supply resulting from the impoundment of tributary runoff. Table O-6 presents an impact evaluation for the ponds listed in the inventory included in Appendix B, Table B-40. Note that the pond inventory represents information from databases (NHD, NRIS and Western Energy) that may be duplicative.

Following mining, impacted ponds can be reestablished or mitigated as necessary to support wildlife and livestock use with the same function as premine.

3.3.3 Wetlands - PHCs

A wetland would be impacted by mining if it is mined out or if the water source to the wetland is affected by mine dewatering. All of the identified wetlands, except for Wetland B, are located along the main drainage channels, which are not mined out. Wetland B is located in the upper reach of Trail Creek, but is located away from planned mine passes.

Impacts to springs are discussed in Section 4.1.

Figure O-7 shows the locations of Area F wetlands with respect to projected mining and Figure O-8 shows the locations of wetlands with respect to Area F roads. Figure O-5 shows that impacts to the alluvium are limited to areas located adjacent to mine passes. Identified impacts to wetlands include:

- The upstream portion of Wetland C, which is associated with Spring 10, will be mined out. Depending upon if the water source of that wetland recovers following mining, it is possible that the downstream section of this wetland may be affected. In addition a portion of the wetland will be disturbed by haul road construction.

- Wetland D is associated with Spring 13. Both the spring and wetland may be impacted by the construction of the haul road.

- Wetland E and F-081 are associated with Springs 12 and 2, respectively. These springs may experience limited impacts as a result of adjacent road

construction and could potentially be impacted.

- Wetland B is associated with Spring 7 which has significant potential to exhibit altered flow as a result of mining.
- Wetland F028 is associated with Spring 11, which has potential to be impacted by reduced flow as a result of mining and haul road construction.
- Wetland F is associated with overburden Spring 9. Model simulations predicted that flows from the overburden toward the stream channel are likely to be reduced in this area.

Following mining, the source of water supply to wetlands from springs not physically disturbed may be reestablished as groundwater levels recover. The remaining wetlands in Area F are not likely to be impacted by mining activities.

3.3.4 Aquatic Life

As described in the Area F Aquatic Live Survey (ERM 2015)(See Appendix B), the aquatic organisms found at Area F wetlands are indicative of fairly poor to very poor water quality. This may be due to the heavy impact of cattle which was observed in most of the wetlands visited, but may also be influenced by the seasonal or intermittent conditions that are likely present at these locations. Such conditions are expected to result in the presence of species that are tolerant of variable water quality conditions. Therefore, limited changes in TDS concentrations in the spring water sourcing these wetlands are not expected to significantly change the presence and composition of aquatic life at these locations. As such, aquatic life is expected to reestablish in wet areas in the PMT similar to the emergence of aquatic life in the vicinity of the mine when previously dry areas become wet due to climate variations.

4.0 ALLUVIAL VALLEY FLOOR PROBABLE HYDROLOGIC CONSEQUENCES

PENDING DEQ DETERMINATION

5.0 MITIGATION OF MINE IMPACTS

Some mine-related hydrologic impacts can be mitigated. For example, a well that is adversely affected by mining can be replaced with a well that provides an equivalent amount of water of comparable quality. Both the Rosebud coal and sub-McKay sands yield sufficient water for livestock and domestic use.

Streamflow is generally a result of snowmelt runoff or intense thunderstorms, and the resulting discharge events typically have short durations. To mitigate the general lack of water, although this lack of water is not primarily a consequence of mining, the mine will propose enhancement features within the post mine topography to capture water when available and use it to enhance habitat for wildlife and livestock and to establish wetlands. These features will be in the form of small impoundments which will store water following runoff events, providing water sources and promoting establishment of wetland species which will diversify the post mine habitat types within the permit area. These small impoundments will also help to retain sediment within the permit area.

Western Energy is committed to the restoration of the hydrologic balance and the approved post mine land usage, which consists of wildlife habitat and grazing by both livestock and wildlife. The post mine landscape will be restored to the approximate original contour. The post mine channels will be designed to convey peak flows at velocities and depths similar to the premine channels for corresponding rainfall-runoff events to restore the hydrologic function of the premine drainage system. Impacted springs, ponds and wetlands will be reestablished or mitigated as part of reclamation.

Some of the hydrologic consequences of mining cannot be mitigated despite the best efforts of the mining company and regulatory performance standards. For example, the Rosebud coal aquifer will be removed by mining within much of the permit area.

The spoils which replace the mined coal will contain groundwater and should provide sufficient water to support a limited number of livestock wells. The post mine groundwater flow patterns, from west to east through the replaced backfill, will be similar to premine flow patterns. However, it may take some years for the post mine equilibrium to establish, and the interim groundwater quality and quantity within the permit area will be somewhat impaired when compared to premine conditions during the interim.

6.0 HYDROLOGIC MONITORING

Water resources at Area F will be monitored for quantity and quality at sites such as wells, surface water sites, springs and ponds. The proposed monitoring plan is provided in Appendix P. Monitoring data and interpretations are reported in Annual Hydrologic Reports (AHR). This on-going monitoring will provide information to adjust the mining and reclamations plans, if needed, to protect the hydrologic systems.

7.0 SUMMARY OF PROBABLE HYDROLOGIC CONNSEQUENCES

The key impacts to the hydrologic systems resulting from mining can be summarized as:

1) Interception of tributary surface flows during mining.
2) Diminished alluvial aquifer recharge from reduced surface flows during mining.
3) Groundwater level drawdowns resulting from mine dewatering during mining.
4) Changes in groundwater quality as the mined coal is backfilled with spoils.
5) Changes in groundwater quality in alluvial aquifers due to the migration of spoils impacted groundwater. The classification of alluvial groundwater within Area F and down gradient from Area F is not expected to change.

Following mining and reclamation, surface water flows and quality should return to premine conditions. Groundwater levels will recover over many years. It is anticipated that groundwater quality will reestablish geochemical equilibrium over time. Temporal changes in groundwater quality are not expected to negatively affect existing uses. There is potential for impacts to surface water use (livestock watering) and to private wells (livestock watering and domestic) located near the mine until groundwater levels recover. These impacts can be mitigated. Wells located at distance from the mine should not be impacted. Future monitoring should focus on spoils water quality and the potential for impacts to the alluvial aquifer.

8.0 REFERENCES

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Tables

Table O-1
Area F Surface Water Users - Impact Assessment

Water Right ID	Means of Diversion	Source Name	User	Easting	Northing	Potentially impacted ?	Reasoning
42KJ 108264 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF BLACK HANK CREEK	WPP LLC	2631184	607480	yes	see Table O-5
42KJ 108351 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF UNNAMED TRIBUTARY OF WEST FORK ARMELLS CREEK	WPP LLC	2653483	608231	no	see Table O-5
42KJ 108365 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF UNNAMED TRIBUTARY OF WEST FORK ARMELLS CREEK	GREAT NORTHERN PROPERTIES LTD PRTNRSHP	2650822	612798	no	see Table O-5
42KJ 108369 00	DAM	ARMELLS CREEK. WEST FORK	GREAT NORTHERN PROPERTIES LTD PRTNRSHP	2646923	610680	no	see PO-971 in Table O-6
42KJ 108370 00	DAM	UNNAMED TRIBUTARY OF UNNAMED TRIBUTARY OF WEST FORK ARMELLS CREEK	GREAT NORTHERN PROPERTIES LTD PRTNRSHP	2649451	614068	no	see Table O-6
42KJ 108371 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF TRAIL CREEK	GREAT NORTHERN PROPERTIES LTD PRTNRSHP	2615857	631858	no	see Table O-5
42KJ 108383 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF BLACK HANK CREEK	WPP LLC	2637231	601432	no	see Table O-5
42KJ 108385 00	DAM	UNNAMED TRIBUTARY OF TRAIL CREEK	GREAT NORTHERN PROPERTIES LTD PRTNRSHP	2616517	631881	no	see Table O-6
42KJ 108386 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF TRAIL CREEK	GREAT NORTHERN PROPERTIES LTD PRTNRSHP	2615198	631836	no	see Table O-5
42KJ 108387 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF TRAIL CREEK	GREAT NORTHERN PROPERTIES LTD PRTNRSHP	2615881	631199	no	see Table O-5
42KJ 108393 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF ROBBIE CREEK	WPP LLC	2615026	617325	yes	see Table O-5
42KJ 108394 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF MCCLURE CREEK	WPP LLC	2616258	620006	yes	see Spring 10 in Table O-5
42KJ 108395 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF ROBBIE CREEK	WPP LLC	2618319	617440	no	see Spring 13 in Table O-5
42KJ 108396 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF MCCLURE CREEK	WPP LLC	2616194	621981	yes	see Table O-5
42KJ 108397 00	DAM	DONLEY CREEK	WPP LLC	2617340	606845	no	see Pond 5 in Table O-6
42KJ 108399 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF UNNAMED TRIBUTARY OF WEST FORK ARMELLS CREEK	GREAT NORTHERN PROPERTIES LTD PRTNRSHP	2650874	610820	no	see Table O-5

Table O-1
Area F Surface Water Users - Impact Assessment

Water Right ID	Means of Diversion	Source Name	User	Easting	Northing	Potentially impacted ?	Reasoning
42KJ 108401 00	DAM	UNNAMED TRIBUTARY OF UNNAMED TRIBUTARY OF WEST FORK ARMELLS CREEK	WPP LLC	2642393	607879	no	see PO-976 in Table O-6
42KJ 108407 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF UNNAMED TRIBUTARY OF WEST FORK ARMELLS CREEK	WPP LLC	2641800	605875	no	see Table O-5
42KJ 108673 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF MCCLURE CREEK	WPP LLC	2618191	621393	yes	see Spring 11 in Table O-5
42KJ 111926 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF UNNAMED TRIBUTARY OF WEST FORK ARMELLS CREEK	HOWARD RICHARD	2648616	619338	no	see SP-62 in Table O-5
42KJ 145448 00	DAM	UNNAMED TRIBUTARY OF TRAIL CREEK	SALMOND RANCH CO	2625700	633697	no	see Table O-6
42KJ 162796 00	DAM	UNNAMED TRIBUTARY OF DONLEY CREEK	BOOTH LAND & LIVESTOCK CO	2622057	603877	no	see Table O-6
42KJ 162812 00	DEVELOPED SPRING	SPRING. UNNAMED TRIBUTARY OF DONLEY CREEK	WESTERN ENERGY CO	2638984	611056	yes	see Table O-5
42KJ 162813 00	DAM	UNNAMED TRIBUTARY OF DONLEY CREEK	BOOTH LAND & LIVESTOCK CO	2621356	605175	no	see Pond 7 in Table O-6
42KJ 162815 00	DAM	UNNAMED TRIBUTARY OF BLACK HANK CREEK	WESTERN ENERGY CO	2633936	601322	no	see Pond 1 in Table O-6
42KJ 162816 00	DAM	UNNAMED TRIBUTARY OF BLACK HANK CREEK	BOOTH LAND & LIVESTOCK CO	2632025	599274	no	see Table O-6
42KJ 162823 00	DAM	UNNAMED TRIBUTARY OF BLACK HANK CREEK	BOOTH LAND & LIVESTOCK CO	2625399	600358	no	see Pond 3 in Table O-6
42KJ 162825 00	DAM	BLACK HANK CREEK	BOOTH LAND & LIVESTOCK CO	2629246	603375	no	see Pond 2 in Table O-6
42KJ 162828 00	DAM	UNNAMED TRIBUTARY OF DONLEY CREEK	WESTERN ENERGY CO	2638962	611716	yes	see PO-978 in Table O-6
42KJ 162844 00	DEVELOPED SPRING	SPRING. UNNAMED TRIBUTARY OF UNNAMED TRIBUTARY OF WEST FORK ARMELLS CREEK	WESTERN ENERGY CO	2646264	610657	no	see SP-65 in Table O-5
42KJ 162852 00	DEVELOPED SPRING	SPRING. UNNAMED TRIBUTARY OF DONLEY CREEK	WESTERN ENERGY CO	2638984	611056	yes	see 42KJ 162812 00 in Table O-5
42KJ 162853 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF DONLEY CREEK	BOOTH LAND & LIVESTOCK CO	2622057	603877	no	see Spring 6 in Table O-5
42KJ 162857 00	DEVELOPED SPRING	SPRING. UNNAMED TRIBUTARY OF BLACK HANK CREEK	BOOTH LAND & LIVESTOCK CO	2625373	601018	no	see Spring 1 in Table O-5
42KJ 162858 00	DAM	UNNAMED TRIBUTARY OF DONLEY CREEK	BOOTH LAND & LIVESTOCK CO	2621991	603131	no	see Pond 6 in Table O-6

Table O-1
Area F Surface Water Users - Impact Assessment

Water Right ID	Means of Diversion	Source Name	User	Easting	Northing	Potentially impacted ?	Reasoning
42KJ 162860 00	DEVELOPED SPRING	SPRING. UNNAMED TRIBUTARY OF DONLEY CREEK	BOOTH LAND & LIVESTOCK CO	2622711	601585	no	see Table O-5
42KJ 177102 00	LIVESTOCK DIRECT FROM SOURCE	DONLEY CREEK	KL RANCH LLC	2644805	624818	yes	Water at this location may be surfacing alluvial groundwater, model predicts a temporary decrease in alluvial groundwater flow at the Area F permit boundary. However, impacts at this location are likely to be mimimal, given the 3 mile distance from permit boundary.
42KJ 177102 00	LIVESTOCK DIRECT FROM SOURCE	DONLEY CREEK	KL RANCH LLC	2641615	621392	yes	Water at this location may be surfacing alluvial groundwater, model predicts a temporary decrease in alluvial groundwater flow at the Area F permit boundary. Impacts at this location are likely to be mimimal, given the 1.9 mile distance from permit boundary.
42KJ 177102 00	LIVESTOCK DIRECT FROM SOURCE	DONLEY CREEK	KL RANCH LLC	2641551	623371	yes	Water at this location may be surfacing alluvial groundwater, model predicts a temporary decrease in alluvial groundwater flow at the Area F permit boundary. Impacts at this location are likely to be mimimal, given the 2.2 mile distance from permit boundary.

Table O-1
Area F Surface Water Users - Impact Assessment

Water Right ID	Means of Diversion	Source Name	User	Easting	Northing	Potentially impacted ?	Reasoning
42KJ 177102 00	LIVESTOCK DIRECT FROM SOURCE	DONLEY CREEK	KL RANCH LLC	2642167	624716	yes	Water at this location may be surfacing alluvial groundwater, model predicts a temporary decrease in alluvial groundwater flow at the Area F permit boundary. Impacts at this location are likely to be mimimal, given the 2.5 mile distance from permit boundary.
42KJ 177108 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF UNNAMED TRIBUTARY OF WEST FORK ARMELLS CREEK	KL RANCH LLC	2648638	618677	no	see SP-61 in Table O-5
42KJ 183221 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF UNNAMED TRIBUTARY OF NORTH FORK TRAIL CREEK	BOOTH BROS LAND & LIVESTOCK	2617791	633246	no	see Table O-5
42KJ 183227 00	PIT	SPRING. UNNAMED TRIBUTARY OF TRAIL CREEK	BOOTH LAND & LIVESTOCK CO	2614658	628516	no	see Table O-5
42KJ 183228 00	PIT	SPRING. UNNAMED TRIBUTARY OF TRAIL CREEK	BOOTH LAND & LIVESTOCK CO	2615292	629199	no	see Table O-5
42KJ 183229 00	PIT	SPRING. UNNAMED TRIBUTARY OF TRAIL CREEK	BOOTH LAND & LIVESTOCK CO	2614538	631813	no	see Table O-5
42KJ 183230 00	PIT	SPRING. UNNAMED TRIBUTARY OF TRAIL CREEK	BOOTH LAND & LIVESTOCK CO	2618540	630632	no	see Table O-5
42KJ 183231 00	DAM	UNNAMED TRIBUTARY OF TRAIL CREEK	BOOTH LAND & LIVESTOCK CO	2615857	631858	no	see 42KJ 108385 00 in Table O-6
42KJ 183236 00	DAM	HORSE CREEK	BOOTH BROS LAND & LIVESTOCK	2609640	620441	no	see Table O-6
42KJ 183297 00	DAM	UNNAMED TRIBUTARY OF BLACK HANK CREEK	BOOTH BROS LAND & LIVESTOCK	2634047	598022	no	see PO-980 in Table O-6
42KJ 183299 00	DAM	UNNAMED TRIBUTARY OF UNNAMED TRIBUTARY OF WEST FORK ARMELLS CREEK	BOOTH BROS LAND & LIVESTOCK	2642436	603831	no	see Table O-6
42KJ 183339 00	SPRING BOX	SPRING. UNNAMED TRIBUTARY OF MCCLURE CREEK	BOOTH BROS LAND & LIVESTOCK	2623390	623722	no	see Table O-5
42KJ 183348 00	DAM	UNNAMED TRIBUTARY OF HORSE CREEK	BOOTH BROS LAND & LIVESTOCK	2608490	615134	no	see Table O-6
42KJ 183350 00	SPRING BOX	SPRING. UNNAMED TRIBUTARY OF ROBBIE CREEK	BOOTH BROS LAND & LIVESTOCK	2613768	615304	yes	see Table O-5

Table O-1
Area F Surface Water Users - Impact Assessment

Water Right ID	Means of Diversion	Source Name	User	Easting	Northing	Potentially impacted ?	Reasoning
42KJ 183351 00	DAM	ROBBIE CREEK	BOOTH BROS LAND & LIVESTOCK	2611255	611265	no	see Table O-6
42KJ 183353 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF ROBBIE CREEK	BOOTH BROS LAND & LIVESTOCK	2618341	616780	no	see Spring 13 in Table O-5
42KJ 183492 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF ROBBIE CREEK	BOOTH BROS LAND & LIVESTOCK	2615047	616666	yes	see Table O-5
42KJ 183497 00	DAM	TRAIL CREEK	BOOTH BROS LAND & LIVESTOCK	2625218	628402	no	see Table O-6
42KJ 183498 00	SPRING BOX	SPRING. UNNAMED TRIBUTARY OF MCCLURE CREEK	BOOTH BROS LAND & LIVESTOCK	2625919	627105	no	see Table O-5
42KJ 183500 00	LIVESTOCK DIRECT FROM SOURCE	UNNAMED TRIBUTARY OF TRAIL CREEK	BOOTH BROS LAND & LIVESTOCK	2621282	627609	yes	water at this location may be the result of leakage from pond 42 KJ 183501 00. As this pond is potentially impacted during mining, this surface water use may be impacted during mining.
42KJ 183501 00	DAM	TRAIL CREEK	BOOTH BROS LAND & LIVESTOCK	2621282	627609	yes	see Table O-6
42KJ 183502 00	DAM	UNNAMED TRIBUTARY OF TRAIL CREEK	BOOTH BROS LAND & LIVESTOCK	2624382	633653	no	see Table O-6
42KJ 183503 00	DAM	UNNAMED TRIBUTARY OF TRAIL CREEK	BOOTH BROS LAND & LIVESTOCK	2619765	633490	no	see Table O-6
42KJ 183508 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF BLACK HANK CREEK	BOOTH BROS LAND & LIVESTOCK	2629227	606755	yes	see Table O-5
42KJ 183510 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF DONLEY CREEK	BOOTH BROS LAND & LIVESTOCK	2623821	610537	yes	see Table O-5
42KJ 183512 00	DAM	BLACK HANK CREEK	BOOTH BROS LAND & LIVESTOCK	2633645	612844	yes	see Pond 4 in Table O-6
42KJ 183513 00	DAM	DONLEY CREEK	BOOTH BROS LAND & LIVESTOCK	2630966	614073	no	see Table O-6

Table O-1
Area F Surface Water Users - Impact Assessment

Water Right ID	Means of Diversion	Source Name	User	Easting	Northing	Potentially impacted ?	Reasoning
42KJ 183532 00	LIVESTOCK DIRECT FROM SOURCE	ROBBIE CREEK	BOOTH BROS LAND & LIVESTOCK	2627771	620897		Water at this location may be surfacing alluvial groundwater, model predicts a temporary decrease in alluvial groundwater flow at the Area F permit boundary. Impacts at this location are likely to be mimimal, given the distance of 1.3 miles from permit boundary.
42KJ 183534 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF BLACK HANK CREEK	BOOTH BROS LAND & LIVESTOCK	2637998	598154	no	see SP-72 in Table O-5
42KJ 25022 00	DAM	TRAIL CREEK	MONTANA. STATE OF BOARD OF LAND COMMISSIONERS	2615384	626564	yes	see Pond 9 in Table O-6
42KJ 44613 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF TRAIL CREEK	BOOTH BROS LAND & LIVESTOCK	2616765	624638	yes	see Spring 7 in Table O-5
42KJ 44616 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF TRAIL CREEK	BOOTH BROS LAND & LIVESTOCK	2614132	624543	yes	see Table O-5
42KJ 44618 00	DAM	UNNAMED TRIBUTARY OF TRAIL CREEK	BOOTH BROS LAND & LIVESTOCK	2613386	627151	no	see Table O-6
42KJ 44628 00	DAM	ROBBIE CREEK	BOOTH BROS LAND & LIVESTOCK	2611255	611265	no	see 42KJ 183351 00 in Table O-6
42KJ 47995 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF ARMELLS CREEK. WEST FORK	MONTANA STATE OF BOARD OF LAND COMMISSIONERS	2647715	606743	no	see SP-63 in Table O-5
42KJ 8211 00	DAM	MCCLURE CREEK	MONTANA STATE OF BOARD OF LAND COMMISSIONERS	2620798	622320	yes	see Pond 8 in Table O-6
42KJ 8260 00	DAM	UNNAMED TRIBUTARY OF TRAIL CREEK. MIDDLE FORK	MONTANA STATE OF BOARD OF LAND COMMISSIONERS	2615704	636477	no	see Table O-6
42KJ 8261 00	LIVESTOCK DIRECT FROM SOURCE	SPRING. UNNAMED TRIBUTARY OF TRAIL CREEK. MIDDLE FORK	MONTANA STATE OF BOARD OF LAND COMMISSIONERS	2614492	633136	no	see Table O-5

Notes
(a) Surface Water Rights inventory (NRIS), see Appendix B. This list includes use from springs, ponds, and direct from source.

Table O-2
Simulated Flow to the Alluvium (acre-feet/year)
Rosebud Mine, MT

Pre-Mine	2015	2020	2025	2030	2034 (End of Mining)	2044	2054	2064	2074	2084
Simulated Flow from all Model Layers into Alluvial Drains Within Area F										
266	257	227	217	207	181	195	209	222	231	239

Notes

Flows shown do not include other contributions or losses from the alluvial drainages associated with surface recharge and lateral underflow.

Table O-3
Overburden and Spoils Groundwater Quality Comparison

Parameter	Statistics	ABC Spoils (a,b)	ABC Overburden Baseline (b)	Percentage Change	Area F Baseline Overburden (c)
Total Dissolved Solids (m/L)	Average	3404	1963	73%	4098
	Median	3020	1590		3985
	Minimum	860	136		2900
	Maximum	8750	6280		8210
	Standard Dev.	1730	1453		1173
	No of samples	135	103		78
Specific Conductivity (umhos/cm)	Average	3553	2267	57%	4330
	Median	3190	2010		4395
	Minimum	1170	424		2850
	Maximum	8420	6490		7310
	Standard Dev.	1487	1384		983
	No of samples	136	103		78
pH (s.u.)	Average	7.0	7.5	-7%	7.2
	Median	7.0	7.5		7.2
	Minimum	5.6	6.5		6.6
	Maximum	8.0	8.5		8.1
	Standard Dev.	0.4	0.4		0.4
	No of samples	137	102		78
Sulfate (mg/L)	Average	1898	1088	74%	2400
	Median	1575	810		2165
	Minimum	*368*	18		1400
	Maximum	5440	4680		4830
	Standard Dev.	1099	979		804
	No of samples	136	103		78
Bicarbonate (mg CaCO3/L)	Average	740	527	40%	620
	Median	661	510		614
	Minimum	262	44		331
	Maximum	1648	907		1880
	Standard Dev.	278	174		235
	No of samples	136	103		78
Chloride (mg/L)	Average	36	14	167%	14
	Median	27	7		9
	Minimum	4	1		5
	Maximum	200	481		26
	Standard Dev.	34	47		12
	No of samples	136	103		78
Calcium (mg/L)	Average	354	156	127%	265
	Median	330	118		267
	Minimum	94	13		165
	Maximum	3821	472		419
	Standard Dev.	347	107		61
	No of samples	137	103		78

Table O-3
Overburden and Spoils Groundwater Quality Comparison

Parameter	Statistics	ABC Spoils (a,b)	ABC Overburden Baseline (b)	Percentage Change	Area F Baseline Overburden (c)
Magnesium (mg/L)	Average	333	200	66%	371
	Median	295	163		352
	Minimum	69	0.1		238
	Maximum	1070	609		667
	Standard Dev.	184	147		98
	No of samples	137	103		78
Sodium (mg/L)	Average	215	161	34%	386
	Median	141	108		402
	Minimum	42	6		159
	Maximum	858	901		775
	Standard Dev.	178	178		153
	No of samples	137	103		78
Potassium (mg/L)	Average	9	6	49%	12
	Median	9	7		11
	Minimum	1	1		<12.5
	Maximum	21	13		19
	Standard Dev.	5	3		2
	No of samples	130	90		78

Notes
(a) Samples obtained from spoils wells in Area A (8 wells), B (5 wells) and C (2 wells)
(b) Data through September 2013.
(c) Data through December 2014.

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
GWIC	192	unknown - (MBMG - TRM)	domestic/stock	Sloan, Stanley	300	-	-	yes	5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	possibly same as NDH 139627487, 139627503, WR 42KJ 162821 00, 42KJ 162822 00
GWIC	1043	Overburden or alluvium	stock	MT Power Co - 2 M N Sarpy School	17	17	0	no		no	Well outside 5 foot drawdown contours and well located up-gradient from Area F permit boundary.	
GWIC	1044	SubMcKay (MBMG - Tullock)	stock	Ashenhurst - 20 mi NW Colstrip	57	-	-	no		no	Well screened below Tongue River Member.	
GWIC	1045	Alluvium	stock	Ashenhurst - 18 mi NW Colstrip	16	15	1	no		no	Alluvial well > 2 miles from Area F mining.	possibly same as NHD 00813514
GWIC	1046	SubMcKay (MBMG - Tullock)	stock	Robinson Maude - 20 mi NW Colstrip	202	-	-	no		no	Well screened below Tongue River Member.	
GWIC	1047	SubMcKay (Tullock - MBMG)	domestic	Robinson Maude * 20 mi NW Colstrip	340	-	-	no		no	Well screened below Tongue River Member.	
GWIC	1050	SubMcKay (Tullock - MBMG)	domestic	Dowlin - 12 mi NW Colstrip	555	-	-	no		no	Well screened below Tongue River Member.	possibly same as WR 42KJ 177111 00, 42KJ 177112 00, 42KJ 45735 00
GWIC	1051	unknown (MBMG - TRM)	stock	Farley B.N. * 13 mi E McCrae	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	possibly same as NHD 00813295, WR 42KJ 183514 00
GWIC	1052	unknown - (MBMG - TRM)	stock	Fulmer, Genie / Dowlin, Mary Genie - 12 mi NW Colstrip	100	45	55	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	well over one mile from mine
GWIC	1053	SubMcKay	stock	Fulmer, Genie / Dowlin, Mary Genie - 11 mi NW Colstrip	140	50	90	no		no	Well outside 5 foot drawdown contours and not an alluvial well < 2 miles downgradient from Area F permit boundary.	Possibly same as PW-10

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
GWIC	1056	Rosebud Coal	stock	Sloan Stanley - FU-067	136	-	-	yes	10-20	unknown	Possible Rosebud coal well. Possible water quantity impact. No water level data available.	possibly same as WR 42KJ 162850 00
GWIC	1057	unknown (MBMG - TRM)	domestic	Pinkerton Bill * 12 mi NW Colstrip	60	27	33	yes	10-20	no	Well located in Area C West disturbance area, likely outside Area F influence.	In disturbed Area C West, possibly same as PW-13
GWIC	1058	unknown (MBMG - TRM)	stock	Pinkerton Bill * 12 mi NW Colstrip	80	26	55	yes	10-20	no	Located in mined out Area C west.	in mined out area C West, possibly same as PW-14, WR 42KJ 46520 00
GWIC	11949	unknown	stock	Sloan, Stanley	150	150	0	yes	5-10	no	Static water level indicates dry well. Unknown stratum.	
GWIC	11950	Overburden	domestic/stock	Sloan, Stanley	70	-	-	yes	10-20	no	Overburden well about 0.4 miles up-gradient from Area F mining footprint.	possibly same as WR 42KJ 162850 00
GWIC	11951	unknown	domestic/stock	Sloan, Stanley	-	-	-	yes	5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	possibly same as NDH 139627487, 139627503, WR 42KJ 162821 00, 42KJ 162822 00
GWIC	11952	unknown (MBMG - TRM)	domestic/stock	Sloan, Stanley	275	-	-	yes	5-10	unknown	Deep well screened in unknown stratum, > 1 mile from mining. Unknown static water level. Could be impacted only if limited water column.	possibly same as NDH 139627487, 139627503, WR 42KJ 162821 00, 42KJ 162822 00
GWIC	11953	unknown	stock	Ashland Lumber Co		245		yes	5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	possibly same as PW-153, WR 42KJ 183295 00
GWIC	14176	unknown	stock	Sloan, Stanley #1	150	150	0	no		no	Well outside 5 foot drawdown contours and not a down gradient alluvial well.	
GWIC	14177	unknown	stock	Sloan, Stanley #2	60	60	0	no		no	Well outside 5 foot drawdown contours and not a down gradient alluvial well.	
GWIC	14180	SubMcKay (MBMG - Tullock)	stock	Ashenhurst Ranch Inc	97	-	-	no		no	Well screened below Tongue River Member.	

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
GWIC	14186	SubMcKay (MBMG - Tullock), 'sandrock'	irrigation/stock	Fulmer Genie / Dowlin Mary Genie	71	35	36	no		no	Well screened below Tongue River Member.	possibly same as WR 42KJ 177111 00, 42KJ 177112 00, 42KJ 45735 00
GWIC	14188	SubMcKay	domestic/stock	Fulmer Genie / Dowlin Mary Genie	176	30	146	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
GWIC	14189	SubMcKay	stock	Northern Pacific Railway Co	74	50	24	no		no	Well outside 5 foot drawdown contours and > 2 miles from mining.	
GWIC	14190	SubMcKay	stock	Fulmer Genie / Dowlin Mary Genie	100	35	65	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
GWIC	14193	unknown	domestic/stock	Farley Inc.	90	50	40	no		no	Well outside 5 foot drawdown contours and screened below Tongue River Member.	location suspect
GWIC	14195	SubMcKay (Sandstone)	stock	Fulmer Genie / Dowlin Mary Genie	46	32	14	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
GWIC	14199	unknown (MBMG - TRM)	domestic/stock	Hays, Winford	200	100	100	yes	10-20	yes	Located in Area F mining footprint	in Area F
GWIC	14201	Rosebud Coal	stock	Sloan, Stanley Well # 1	150	150	0	yes	20-30	yes	Possible Rosebud coal well. Possible water quantity impact. However static water level indicates dry well.	
GWIC	14202	(MBMG - TRM), overburden or Rosebud coal	stock	Sloan, Stanley Well # 2	150	150	0	yes	5-10	no	Static water level indicates dry well.	
GWIC	14203	unknown (MBMG - TRM)	domestic/stock	Pinkerton, Bill	120	40	80	yes	10-20	no	Located in mined out Area C west.	in mined out area C West, possibly same as PW-13, WR 42KJ 162814 00 or 42KJ 177607 00

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
GWIC	15341	SubMcKay (MBMG - Tullock)	stock	Northern Pacific Railway Company	175	50	125	no		no	Well outside 5 foot drawdown contours and screened below Tongue River Member.	possibly same as WR 42KJ 108363 00, 42KJ 183223 00
GWIC	122393	Interburden	stock	Farleys Inc	100	73	27	yes		no	Located in mined out Area C west.	in mined out Area C West
GWIC	205523	SubMcKay	stock	Salmond Ranch Co	160	100	60	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
GWIC	234997	SubMcKay (Sandstone)	domestic	Booth Land and Livestock	380	260	120	yes	10-20	yes	Located in Area F mining footprint	in Area F, possibly same as NHD 139628112, WR 42KJ 44622 00
GWIC	246645	Overburden, Rosebud Coal, Interburden	stock	Booth Land and Livestock	375	265	110	yes	10-20	no	Impact not likely due to water column (110 feet).	Possibly same as WZ-025
GWIC	250616	unknown	unknown	N49.5W 6000	320	-	-	yes	10-20	unknown	Deep well screened in unknown stratum, > 1 mile from mining. Unknown static water level. Could be impacted only if limited water column.	
GWIC	257166	Overburden	stock	Kluver Kirby	75	43	32	yes	50-60	yes	Located within Area F mining footprint.	
GWIC	705179	unknown	stock	BN Railroad	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
GWIC	705180	unknown	stock	BN Railroad	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
GWIC	705191	unknown	stock	Hays Wilson	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
GWIC	705192	unknown	stock	Hays Wilson	-	-	-	yes	5-10	unknown	Unknown strata, unknown static water level.	
GWIC	705193	unknown	stock	Hays Wilson	-	-	-	yes	10-20	unknown	Very shallow well half a mile up-gradient from mining. Rosebud coal is 100-150 feet deep at this location.	

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
GWIC	705194	unknown	stock	Hays Wilson	-	-	-	yes	10-20	unknown	Unknown strata, unknown static water level.	
GWIC	705195	unknown	stock	Hays Wilson	-	-	-	yes	30-40	yes	Located within Area F disturbance boundary.	
GWIC	705196	unknown	stock	Farley	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	possibly same as WR 42KJ 183237 00, NHD 00813370
GWIC	705209	unknown	domestic	Farley, Inc	-	-	-	yes	10-20	unknown	Unknown strata, unknown static water level. Impact likely if shallow well, due to close proximity to mining.	possibly same as WR 42KJ 183352 00
GWIC	705210	unknown	stock	Sloan S	-	-	-	no		no	Well outside 5 foot drawdown contours and not a down gradient alluvial well.	possibly same as WR 42KJ 106490 00
GWIC	705211	SubMcKay	stock	Hays W.	266	-	-	yes	5-10	unknown	Deep SubMcKay well in close proximity to mining. Unknown static water level. Could be impacted if limited water column.	
GWIC	705224	unknown (MBMG - TRM)	stock	Sloan S	-	-	-	no		no	Well outside 5 foot drawdown contours and not a down gradient alluvial well.	
NHD	00813017	unknown			-	-	-	yes	5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	possibly same as 42KJ 162797 00
NHD	00813059	unknown			-	-	-	yes	20	unknown	Unknown strata, unknown static water level.	in area F, possibly same as WR 42KJ 162798 00
NHD	00813190	unknown			-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	possibly same as WR 42KJ 108360 00 or 42KJ 108368 00
NHD	00813191	unknown			-	-	-	no		yes	Located within Area F disturbance boundary.	possibly same as WR 42KJ 108400 00
NHD	00813194	unknown			-	-	-	yes	5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	possibly same as WR 42KJ 44608 00 or GWIC 705211

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
NHD	00813291	unknown			-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	possibly same as WR 42KJ 108381 00
NHD	00813295	unknown			-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	possibly same as GWIC 1051, WR 42KJ 183514 00
NHD	00813370	unknown			-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well .	possibly same as WR 42KJ 183237 00, GWIC 705196
NHD	00813514	SubMcKay			-	-	-	no		no	Well outside 5 foot drawdown contours and > 2 miles from Area F permit boundary.	possibly same as GWIC 1045
NHD	00813572	SubMcKay			-	-	-	no		no	Well outside 5 foot drawdown contours and not a downgradient alluvial well.	possibly same as GWIC 1044, WR 42KJ 30011417
NHD	139627487	unknown			-	-	-	yes	5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	possibly same as GWIC 192, 11951, 11952, WR 42KJ 162821 00, 42KJ 162822 00
NHD	139627503	unknown			-	-	-	yes	5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	possibly same as GWIC 192, 11951, 11952, WR 42KJ 162821 00, 42KJ 162822 00
NHD	139627524	SubMcKay			-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well down gradient from Area F.	Possibly same as PW-11, WR 42KJ 177109 00
NHD	139627561	unknown			-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	possibly same as WR 42KJ 183486 00
NHD	139627654	unknown			-	-	-	yes	30-40	no	Located in mined out Area C west.	In mined out Area C West, possibly same as PW-150, WR 42KJ 183300 00

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
NHD	139628112	unknown			-	-	-	yes	10-20	yes	Located in Area F mining footprint	in Area F, possibly same as WR 42KJ 44622 00, GWIC 234997
NRIS	42KJ 106490 00	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not a down gradient alluvial well.	possibly same as GWIC 705210
NRIS	42KJ 108360 00	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well down gradient from Area F.	possibly same as NHD 139627543
NRIS	42KJ 108363 00	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not a down gradient alluvial well.	possibly same as WR 42KJ 183223 00
NRIS	42KJ 108508 00	unknown	stock	Unknown	-	-	-	yes	10-20	unknown	Unknown strata, unknown static water level.	possibly same as PW-151
NRIS	42KJ 108513 00	SubMcKay or alluvium	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and if alluvial well, > 3 miles downgradient from Area F permit boundary.	possibly same as WR 42KJ 42798 00
NRIS	42KJ 162797 00	unknown	stock	Unknown	-	-	-	yes	5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	possibly same as NHD 00813017
NRIS	42KJ 162814 00	Unknown	stock	Unknown	120	-	-	yes	10-20	unknown	Well located in Area C West disturbance area, likely outside Area F influence.	in disturbance area C West, possibly same as PW-13, WR 42KJ 177607 00
NRIS	42KJ 162821 00	unknown	stock	Unknown	-	-	-	yes	5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	possibly same as GWIC 192, 11951, 11952, NDH 139627487, 139627503
NRIS	42KJ 162822 00	unknown	stock	Unknown	-	-	-	yes	5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	possibly same as GWIC 192, 11951, 11952, NDH 139627487, 139627503

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
NRIS	42KJ 16285000	unknown	stock	Unknown	-	-	-	yes	10-20	unknown	Unknown strata, unknown static water level.	possibly same as GWIC 1056
NRIS	42KJ 17710700	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well down gradient from Area F.	
NRIS	42KJ 17710900	SubMcKay	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well down gradient from Area F.	Possibly same as PW-11, NHD 139627524
NRIS	42KJ 17711000	unknown	stock	Unknown	-	-	-	no		unknown	Possible water quality impact if this alluvial well < 1 mile downgradient from Area F permit boundary.	
NRIS	42KJ 17711100	SubMcKay	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and if alluvial well, > 3 miles downgradient from Area F permit boundary.	Possibly same as PW-08, GWIC 1050, 14186
NRIS	42KJ 17711200	SubMcKay	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and if alluvial well, > 3 miles downgradient from Area F permit boundary.	Possibly same as PW-08, GWIC 1050, 14186
NRIS	42KJ 17760600	unknown	domestic	Unknown	-	-	-	no		no	Possible alluvial well based on location, but < 1 mile downgradient from Area C, not likely impacted by Area F mining.	
NRIS	42KJ 17760700	Unknown	domestic	Unknown	120	-	-	yes	10-20	no	Well located in Area C West disturbance area, likely outside Area F influence.	in mined out area C West, possibly same as PW-13, WR 42KJ 162814 00
NRIS	42KJ 18322300	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not a down gradient alluvial well.	possibly same as WR 42KJ 108363 00
NRIS	42KJ 18323700	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	possibly same as GWIC 705196, NHD 00813370

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
NRIS	42KJ 18329500	unknown	stock	Unknown	-	-	-	yes	5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	possibly same as PW-153, GWIC 11953
NRIS	42KJ 18330000	Unknown	stock	Unknown	150	-	-	yes	20	no	Located in mined out Area C west.	In mined out Area C West, possibly same as PW-150, NHD 139627654
NRIS	42KJ 18333300	SubMcKay	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not a down gradient alluvial well.	
NRIS	42KJ 18333400	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
NRIS	42KJ 18333800	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours. Could be an alluvial well based on location, but 1.5 miles downgradient from Area F permit boundary.	
NRIS	42KJ 18335200	unknown	stock	Unknown	-	-	-	yes	20-30	unknown	Unknown strata, unknown static water level. Water quantity likely impacted if this is a shallow well, due to proximity to mining	possibly same as GWIC 705209
NRIS	42KJ 18347300	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not a down gradient alluvial well.	possibly same as NHD 00813190
NRIS	42KJ 18348500	SubMcKay	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not a down gradient alluvial well.	possibly same as WR 42KJ 108406 00
NRIS	42KJ 18348600	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not a down gradient alluvial well.	possibly same as NHD 139627561
NRIS	42KJ 18349900	SubMcKay	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours. Could be an alluvial well based on location, but 1 mile downgradient from Area F permit boundary.	

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
NRIS	42KJ 18350900	unknown	stock	Unknown	-	-	-	yes	40-50	yes	Located in Area F mining footprint	
NRIS	42KJ 18351100	unknown	stock	Unknown	-	-	-	no		unknown	Unknown strata but north of Rosebud coal outcrop, unknown static water level. Impact likely only if limited water column.	
NRIS	42KJ 18351400	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	possibly same as WR 42KJ 183514 00
NRIS	42KJ 30011413	SubMcKay	stock	Unknown	160	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
NRIS	42KJ 35412 00	unknown	domestic	Unknown	-	-	-	yes	5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	
NRIS	42KJ 42782 00	SubMcKay or alluvium	domestic	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours. Could be an alluvial well based on location, but > 2 miles downgradient from Area F permit boundary.	
NRIS	42KJ 42797 00	unknown	stock	Unknown	-	-	-	yes	10-20	unknown	Unknown strata, unknown static water level.	possibly same as PW-151
NRIS	42KJ 42798 00	SubMcKay	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours. Could be an alluvial well based on location, but > 3 miles downgradient from Area F permit boundary.	possibly same as WR 42KJ 108513 00
NRIS	42KJ 44621 00	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
NRIS	42KJ 44622 00	unknown	stock	Unknown	-	-	-	yes	10-20	yes	Located in Area F mining footprint	in Area F, possibly same as NHD 139628112, GWIC 234997

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
NRIS	42KJ 45734 00	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
NRIS	42KJ 45735 00	SubMcKay	domestic	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	Possibly same as PW-08, GWIC 1050, 14186
NRIS	42KJ 46520 00	unknown	stock	Unknown	-	-	-	yes	10-20	no	Located in mined out Area C west.	in mined out area C West, possibly same as PW-14, GWIC 1058
NRIS	42KJ 56479 00	SubMcKay	stock	Unknown	80	-	-	no		no	Well outside 5 foot drawdown contours.	
NRIS	42KJ 8262 00	unknown	stock	Unknown	-	-	-	no		no	Well outside 5 foot drawdown contours and not a down gradient alluvial well.	
NRIS, GWIC	42KJ 108368 00	SuMcKay	stock	Northern Pacific Railroad Company, Snider D FU-069	136	58	78	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	same as GWIC 1054, possibly same as NHD 139627543
NRIS, GWIC	42KJ 108381 00	subMcKay	stock	Northern Pacific Railway Co	235	35	200	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	same as GWIC 14191, possibly same as 00813291
NRIS, GWIC	42KJ 108400 00	SubMcKay	stock	Northern Pacific Railway Co	110	50	60	no		yes	Well located within Area F disturbance boundary.	same as GWIC 14198, possibly same as NHD 00813191
NRIS, GWIC	42KJ 108406 00	SubMcKay (MBMG - Tullock)	stock	Northern Pacific Railway Company	145	50	95	no		no	Weel outside 5 foot drawdown contour and screened below Tongue River Member.	same as GWIC 15360, possibly same as WR 42KJ 183485 00
NRIS, GWIC	42KJ 162798 00	interburden or SubMcKay	stock	Western Energy Co.	220	140	80	yes	20-30	no	Impact not likely due to water column (80 feet), screened in stratum below Rosebud coal.	same as GWIC 14200, possibly same as NHD 00813059
NRIS, GWIC	42KJ 162845 00	Alluvium	stock	Pinkerton, Bill E	14	6	8	no		no	Alluvial well > 2 miles down gradient from Area F mining.	same as GWIC 14181, possibly same as NHD 00813572

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
NRIS, GWIC	42KJ 177113 00	SubMcKay	stock	Fulmer Genie / Dowlin Mary Genie	130	75	55	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	same as GWIC 14182, possibly same as GWIC 14182
NRIS, GWIC	42KJ 19562 00	SubMcKay ('sand')	stock	Dowlin Fullmer Ranch	180	60	120	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	same as GWIC 14187
NRIS, GWIC	42KJ 28394 00	Overburden ('sand')	stock	Unknown	40	20	20	yes	20-30	yes	Overburden well in close proximity to mining. Possible water quantity impact.	same as GWIC 226077
NRIS, GWIC	42KJ 30011417	SubMcKay (MBMG - Tullock)	stock	Salmond Ranch Co	100	40	60	no		no	Weel outside 5 foot drawdown contour and screened below Tongue River Member.	same as GWIC 205522
NRIS, GWIC	42KJ 44608 00	unknown	stock	Keefer, Bob	225	200	25	yes	5-10	yes	Possible impact on water quantity, due to limited water column.	same as GWIC 14170
NRIS, GWIC, WECo	PW-154	Overburden (sandstone)	stock	Pinkerton, Bill E.	83	60	23	yes	20-30	yes	Overburden well in close proximity to mining. Possible water quantity impact.	same as GWIC 11947, WR 42KJ 162827 00
NRIS, GWIC, WECo	PW-155	Overburden (sandstone)	stock	Sloan, Stanley	115 or 98	84	31	yes	10-20	no	Overburden well 0.75 miles up-gradient from mining,	same as GWIC 11948, 42KJ 162836 00
NRIS, GWIC, WECo	PW-164	SubMcKay	stock	Pinkerton, Bill	156	89	67	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	same as 42KJ 162799 00, GWIC 14197
NRIS, WECo	42KJ 4389 00	Interburden (sandstone)	stock/domestic	Unknown	90	-	-	yes	5-10	yes	Located in Area F mining footprint	Will be mined out.
WECo	250613	Interburden ('sand')		N49E1	200	-	-		5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	
WECo	42KJ 175134 00	unknown	Western Energy Company		-	-	-			unknown	not on map, no water rights exist in NRIS database with this number	These were in permit tables, but are not on map
WECo	42KJ 175135 00	unknown	Western Energy Company		-	-	-			unknown	not on map, no water rights exist in NRIS database with this number	These were in permit tables, but are not on map

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
WECo	42KJ 183262 00	unknown		Booth Land and Livestock	-	-	-			unknown	not on map, no water rights exist in NRIS database with this number	These were in permit tables, but are not on map
WECo	42KJ 42813 00	unknown	WPP LLC		-	-	-			unknown	not on map, no water rights exist in NRIS database with this number	These were in permit tables, but are not on map
WECo	42KJ 46519 00	unknown	stock	Unknown	-	-	-	no	5-21	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	Possibly same as PW-159
WECo	PW-08	Alluvium (SubMcKay)			15	-	-	no		no	Well outside 5 foot drawdown contours, alluvial well > 3 miles down gradient from Area F.	Possibly same as WR 42KJ 177111 00, 42KJ 177112 00, 42KJ 45735 00, GWIC 1050, 14186
WECo	PW-09	unknown			-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
WECo	PW-10	SubMcKay			-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well down gradient from Area F.	Possibly same as GWIC 1053
WECo	PW-11	SubMcKay			46	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well down gradient from Area F.	Possibly same as WR 42KJ 177109 00, NHD 139627524
WECo	PW-13	Unknown			15	-	-	yes	10-20	no	Shallow well in Area C disturbance area, not likely impacted by Area F mining.	In disturbed Area C west, possibly same as WR 42KJ 162814 00, 42KJ 177607 00, GWIC 1057
WECo	PW-131	unknown (MBMG - TRM)	stock	Northern Pacific Railway Company	84	30	-		5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	In disturbed Area C West

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
WECo	PW-14	Unknown			15	-	-	yes	10-20	no	Located in mined out Area C west.	in mined out area C West, possibly same as WR 42KJ 46520 00, GWIC 1058
WECo	PW-147	unknown			-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well down gradient from Area F.	
WECo	PW-150	Unknown			125	-	-	yes	30-40	no	Located in mined out Area C west.	in mined out area C West, possibly same as WR 42KJ 183300 00, NHD 139627654
WECo	PW-151	Unknown			123	-	-	yes	10-20	unknown	Unknown strata, unknown static water level.	Possibly same as WR 42KJ 108508 00 or 42KJ 42797 00
WECo	PW-152	SubMcKay			100	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
WECo	PW-153	unknown			-	-	-	yes	5-10	unknown	Unknown strata, unknown static water level. Impact likely only if limited water column.	possibly same as WR 42KJ 183295 00, GWIC 11953
WECo	PW-159	unknown			-	-	-	no		yes	Well located within Area F disturbance boundary.	Possibly same as WR 42KJ 46519 00
WECo	PW-163	unknown			-	-	-	no		no	Possible alluvial well based on location, but < 1 mile downgradient from Area C, not likely impacted by Area F mining.	
WECo	PW-165	unknown			-	-	-	no		no	Well outside 5 foot drawdown contours and not an alluvial well.	
WECo	PW-29	Alluvium or Overburden			15	-	-	yes	10-20	no	Very shallow well half a mile up-gradient from mining. Rosebud coal is 100-150 feet deep at this location.	

Table O-4
Groundwater Users - Impact Assessment

Data Source (a)	ID (a)	Stratum (a)	Purpose (a)	Owner	Well Depth (ft)	Static Water Level (ft)	Water Column (ft)	Within Influence Boundary? (b)	Simulated Max. Drawdown (ft) (c)	Potentially Impacted ? (d)	Reasoning	Comments
WECo	WZ-025	unknown			-	-	-	yes	10-20	no	Unknown strata, unknown static water level. Well south of Area C west, not likely impacted by Area F mining.	Possibly same as GWIC 246645

Notes

(a) For more information refer to Appendix B - Hydrology.

(b) Is well located within the simulated maximum extent of the 5 foot Rosebud coal drawdown contour and is the well located south of Rosebud coal outcrop?

(d) This is simulated maximum drawdown as a result of both Area C and Area F mining.

(d) Only impact due to Area F mining was evaluated. Wells impacted by Area C mining, but not likely impacted by Area F mining were labeled not likely impacted.

Table O-5
Springs - Impact Assessment

Type	Source (a)	ID (a)	Purpose	Source Name	alternate IDs	Comments	Potentially Impacted?	Reasoning
Spring	NHD	00812928					no	Spring outside 5 foot drawdown contours, up-gradient from mining.
Spring	NHD	***139627490***					no	Spring sourced by stratum below Tongue River Member
Spring	NHD	***139627729***					no	Spring sourced by stratum below McKay coal, approximately one mile from mining.
Spring	NHD	***139628177***					no	Spring outside 5 foot drawdown contours, up-gradient from mining.
Spring	NRIS	42KJ 108264 00	stock	Spring, unnamed tributary of Black Hank Creek		livestock direct from source	yes	Spring within mining footprint. However, no evidence was found that it exists at this location.
Spring	NRIS, NHD, WECo	42KJ 108351 00	stock	Spring, unnamed tributary of unnamed tributary of West Fork Armells Creek		livestock direct from source	no	Spring sourced by stratum below Rosebud coal, close to Area C north, not likely to be influenced by Area F mining.
Spring	NRIS	42KJ 108365 00	stock	Spring, unnamed tributary of unnamed tributary of West Fork Armells Creek		livestock direct from source	no	Spring sourced by stratum below Rosebud coal, north of Area C north, not likely to be influenced by Area F mining.
Spring	NRIS	42KJ 108371 00	stock	Spring, unnamed tributary of Trail Creek		livestock direct from source	no	Spring outside 5 foot drawdown contours, > 1 mile and cross gradient from mining.
Spring	NRIS	42KJ 108383 00	stock	Spring, unnamed tributary of Black Hank Creek		livestock direct from source	no	Overburden spring up-gradient from mining.
Spring	NRIS	42KJ 108386 00	stock	Spring, unnamed tributary of Trail Creek		livestock direct from source	no	Spring outside 5 foot drawdown contours, > 1 mile and cross gradient from mining.
Spring	NRIS	42KJ 108387 00	stock	Spring, unnamed tributary of Trail Creek		livestock direct from source	no	Spring outside 5 foot drawdown contours, > 1 mile and cross gradient from mining.
Spring	NRIS	42KJ 108393 00	stock	Spring, unnamed tributary of Robbie Creek		livestock direct from source	yes	Spring within mining footprint. However, no evidence was found that it exists at this location.
Spring	NRIS	42KJ 108396 00	stock	Spring, unnamed tributary of McClure Creek		lievstock directly from source, possibly associated with Spring 11	yes	This water right may be associated with Spring 11. PHCs are discussed in Section 4.1.

Table O-5
Springs - Impact Assessment

Type	Source (a)	ID (a)	Purpose	Source Name	alternate IDs	Comments	Potentially Impacted?	Reasoning
Spring	NRIS	42KJ 108399 00	stock	Spring, unnamed tributary of unnamed tributary of West Fork Armells Creek		livestock direct from source	no	Spring sourced by stratum below Rosebud coal, north of Area C, not likely to be influenced by Area F mining.
Spring	NRIS	42KJ 108407 00	stock	Spring, unnamed tributary of unnamed tributary of West Fork Armells Creek		in mined out area C West, livestock directly from source	no	Spring located in Area C mining footprint. Not likely to be affected by Area F mining.
Spring	NRIS	42KJ 162812 00	stock	Spring, unnamed tributary of Donley Creek	WR 42KJ 162852 00	possibly same as SP-71, developed spring	yes	This may be a coal/clinker sourced spring, model predicts some drawdown at this location due to mining in Area C. No impacts to date from Area C mining have occurred. Hence impacts from Area F are unconsidered unlikely.
Spring	NRIS	42KJ 162860 00	stock	Spring, unnamed tributary of Donley Creek		developed spring	no	Overburden spring outside 5 foot drawdown contours, up-gradient from mining.
Spring	NRIS, NHD	42KJ 183221 00	stock	Spring, unnamed tributary of unnamed tributary of North Fork Trail Creek	***NHD 139628261***	livestock direct from source	no	Spring outside 5 foot drawdown contours, > 1 mile and cross gradient from mining.
Spring	NRIS	42KJ 183227 00	stock	Spring, unnamed tributary of Trail Creek		pit	no	Spring outside 5 foot drawdown contours and cross gradient from mining.
Spring	NRIS	42KJ 183228 00	stock	Spring, unnamed tributary of Trail Creek		pit	no	Spring outside 5 foot drawdown contours and cross gradient from mining.
Spring	NRIS	42KJ 183229 00	stock	Spring, unnamed tributary of Trail Creek		pit	no	Spring outside 5 foot drawdown contours, > 1 mile and cross gradient from mining.
Spring	NRIS	42KJ 183230 00	stock	Spring, unnamed tributary of Trail Creek		pit	no	Spring outside 5 foot drawdown contours, > 1 mile and cross gradient from mining.
Spring	NRIS, NHD	42KJ 183339 00	stock	Spring, unnamed tributary of McClure Creek	***NHD 139627830***	spring box	no	Spring outside 5 foot drawdown contours, sourced by stratum below the McKay coal.
Spring	NRIS	42KJ 183350 00	stock	Spring, unnamed tributary of Robbie Creek		likely same as Spring 3, spring box	yes	This water right may be associated with Spring 3. PHCs are discussed in Section 4.1.

Table O-5
Springs - Impact Assessment

Type	Source (a)	ID (a)	Purpose	Source Name	alternate IDs	Comments	Potentially Impacted?	Reasoning
Spring	NRIS	42KJ 183492 00	stock	Spring, unnamed tributary of Robbie Creek		livestock direct from source	yes	Spring within mining footprint. However, no evidence was found that it exists at this location.
Spring	NRIS, NHD	42KJ 183498 00	stock	Spring, unnamed tributary of McClure Creek	***NHD 139627770***	spring box	no	Spring sourced by stratum below McKay Coal
Spring	NRIS	42KJ 183508 00	stock	Spring, unnamed tributary of Black Hank Creek		livestock direct from source	yes	Spring is located 300 feet from mining footprint. However, no evidence was found that it exists at this location.
Spring	NRIS	42KJ 183510 00	stock	Spring, unnamed tributary of Donley Creek		possibly same as Spring 9, livestock direct from source	yes	This water right may be associated with Spring 9. PHCs are discussed in Section 4.1.
Spring	NRIS, NHD	42KJ 44616 00	stock	Spring, unnamed tributary of Trail Creek	NHD 00813442	livestock direct from source, spring associated with Wetland A (Area F Wetlands Delineation)	yes	Potential impact to this spring is likely limited, as it is likely sourced by groundwater flowing in from the drainage divide to the southwest.
Spring	NRIS	42KJ 8261 00	stock	Spring, unnamed tributary of Trail Creek, Middle Fork		livestock direct from source	no	Spring outside 5 foot drawdown contours, > 1 mile and cross gradient from mining.
Spring	WECo	SP-33					no	Spring sourced by stratum below Rosebud coal, north of Area C west, not likely to be influenced by Area F mining.
Spring	NRIS, NHD, WECo	SP-61	stock	Spring, unnamed tributary of unnamed tributary of West Fork Armells Creek	WR 42KJ 111926 00, WR 42KJ 177108 00	livestock direct from source	no	Spring sourced by stratum below McKay coal, >2.5 miles from Area F.
Spring	NRIS, NHD, WECo	SP-63	stock	Spring, unnamed tributary of Armells Creek, West Fork	WR 42KJ 47995 00, NHD ***139627567, NHD 139627560***	livestock direct from source	no	Spring sourced by stratum below Rosebud coal, north of Area C west, not likely to be influenced by Area F mining.
Spring	WECo	SP-64					no	Spring sourced by stratum below Rosebud coal, north of Area C west, not likely to be influenced by Area F mining.
Spring	NRIS, NHD, WECo	SP-65	stock	Spring, unnamed tributary of unnamed tributary of West Fork Armells Creek	WR 42KJ 162844 00, NHD ***139627587***	developed spring	no	Spring sourced by stratum below McKay coal, >2 miles from Area F.

Table O-5
Springs - Impact Assessment

Type	Source (a)	ID (a)	Purpose	Source Name	alternate IDs	Comments	Potentially Impacted?	Reasoning
Spring	WECo	SP-69					no	Spring sourced by stratum below Tongue River Member
Spring	WECo	SP-70					no	Spring sourced by stratum below Tongue River Member
Spring	NRIS, NHD, WECo	SP-72	stock	Spring, unnamed tributary of Black Hank Creek	WR 42KJ 183534 00, NHD ***139627497***	livestock direct from source	no	Overburden spring located up-gradient from mining.
Spring	NRIS	SP-74				associated with PO-980	no	Overburden spring located up-gradient from mining.
Spring	NRIS, NHD, WECo	Spring 1	stock	Spring, unnamed tributary of Black Hank Creek	WR 42KJ 162857 00, NHD ***139628418***	developed spring	no	Monitored spring, PHCs are discussed in Section 4.1.
Spring	NHD, WECo	Spring 2			***NHD 139627884***	spring associated with Wetland 081	no (b)	Monitored spring, PHCs are discussed in Section 4.1.
Spring	WECo	Spring 3				possibly same as 42KJ 183350 00	yes	Monitored spring, PHCs are discussed in Section 4.1.
Spring	NHD, WECo	Spring 4			NHD 00813021	spring associated with Wetland F058	no	Monitored spring, PHCs are discussed in Section 4.1.
Spring	NHD, WECo	Spring 5			***NHD 139628403***	digitized coordinates	no	Monitored spring, PHCs are discussed in Section 4.1.
Spring	NRIS, NHD, WECo	Spring 6	stock	Spring, unnamed tributary of Donley Creek	WR 42KJ 162853 00, NHD ***139628085, NHD 139628298***	livestock direct from source, digitized coordinates	no	Monitored spring, PHCs are discussed in Section 4.1.
Spring	NRIS, NHD, WECo	Spring 7	stock	Spring, unnamed tributary of Trail Creek	WR 42KJ 44613 00, NHD ***139628337***	livestock direct from source, spring associated with Wetland B	yes	Monitored spring, PHCs are discussed in Section 4.1.
Spring	WECo	Spring 8					yes	Monitored spring, PHCs are discussed in Section 4.1.
Spring	WECo	Spring 9				possibly same as 42KJ 183510 00, spring associated with Wetland F	yes	Monitored spring, PHCs are discussed in Section 4.1.
Spring	NRIS, WECo	Spring 10	stock	Spring, unnamed tributary of McClure Creek	WR 42KJ 108394 00	livestock direct from source, spring associated with Wetland C	yes	Monitored spring, PHCs are discussed in Section 4.1.

Table O-5
Springs - Impact Assessment

Type	Source (a)	ID (a)	Purpose	Source Name	alternate IDs	Comments	Potentially Impacted?	Reasoning
Spring	NRIS, WECo	Spring 11	stock	Spring, unnamed tributary of McClure Creek	WR 42KJ 108673 00	livestock direct from source, seeps in two tributaries (coordinates of NW tributary shown), associated with Wetland F028	yes	Monitored spring, PHCs are discussed in Section 4.1.
Spring	WECo	Spring 12				spring associated with Wetland E	no (b)	Monitored spring, PHCs are discussed in Section 4.1.
Spring	NRIS, WECo	Spring 13	stock	Spring, unnamed tributary of Robbie Creek	WR 42KJ 183353 00 and WR 42KJ 108395 00	livestock direct from source, two seeps associated with Wetland D	no (b)	Monitored spring, PHCs are discussed in Section 4.1.
Spring	WECo	Spring 14				spring associated with Pond 8	no	Monitored spring, PHCs are discussed in Section 4.1.

Notes

(a) For more information refer to Appendix B - Hydrology.

(b) Spring not likely to be impacted by mining, but may be influenced by nearby road construction.

Table O-6
Ponds - Impact Assessment

Source (a)	ID (a)	Purpose	Source Name	alternate IDs	Downstream from Area F Disturbance ?	Potentially Impacted ?	Reasoning
NHD	10100001022387				no	no	no upstream disturbance
NHD	10100001022413				no	no	no upstream disturbance
NHD	10100001022414				no	no	no upstream disturbance
NHD	10100001022421				no	no	no upstream disturbance
NHD	10100001022426				no	no	no upstream disturbance
NHD	10100001022459				no	no	no upstream disturbance
NHD	10100001022462				no	no	no upstream disturbance
NRIS, NHD	42KJ 108370 00	stock	unnamed tributary of unnamed tributary of West Fork Armells Creek	NHD 10100001022435	no	no	no upstream disturbance
NRIS, NHD	42KJ 108385 00	stock	unnamed tributary of Trail Creek	WR 42KJ 183231 00, NHD 10100001022367	no	no	no upstream disturbance
NRIS, NHD	42KJ 145448 00	stock	unnamed tributary of Trail Creek	NHD 10100001022364	no	no	no upstream disturbance
NRIS, NHD	42KJ 162796 00	stock	unnamed tributary of Donley Creek	NHD 10100001022456	no	no	no upstream disturbance
NRIS, NHD	42KJ 162816 00	stock	unnamed tributary of Black Hank Creek	NHD 10100001022475	no	no	no upstream disturbance
NRIS	42KJ 183236 00	stock	Horse Creek		yes	no	upstream disturbed area is very small compared to total area draining to pond.
NRIS, NHD	42KJ 183299 00	stock	unnamed tributary of unnamed tributary of West Fork Armells Creek	NHD 10100001022465	no	no	no upstream disturbance
NRIS	42KJ 183348 00	stock	unnamed tributary of Horse Creek		no	no	no upstream disturbance
NRIS, NHD	42KJ 183351 00	stock	Robbie Creek	WR 42KJ 44628 00, NHD 10100001022425	no	no	no upstream disturbance
NRIS, NHD	42KJ 183497 00	stock	Trail Creek	NHD 10100001022381	yes	no	pond is downstream from another stock pond, the area draining only to this pond will not disturbed by mining
NRIS, NHD	42KJ 183501 00	stock	Trail Creek	NHD 10100001022382	yes	yes	some of the runoff received by the pond will be temporarily retained during mining

Table O-6
Ponds - Impact Assessment

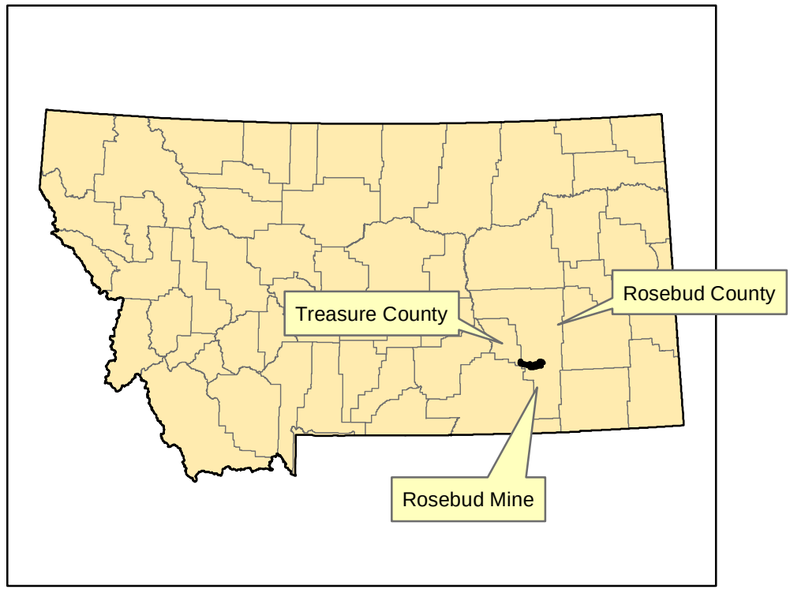
Source (a)	ID (a)	Purpose	Source Name	alternate IDs	Downstream from Area F Disturbance ?	Potentially Impacted ?	Reasoning
NRIS	42KJ 183502 00	stock	unnamed tributary of Trail Creek		no	no	no upstream disturbance
NRIS, NHD	42KJ 183503 00	stock	unnamed tributary of Trail Creek	NHD 10100001022363	no	no	no upstream disturbance
NRIS	42KJ 183513 00	stock	Donley Creek		yes	no	dam is breached
NRIS, NHD	42KJ 44618 00	stock	unnamed tributary of Trail Creek	NHD 10100001022380	no	no	no upstream disturbance
NRIS, NHD	42KJ 8260 00	stock	unnamed tributary of Trail Creek, Middle Fork	NHD 10100001022357	no	no	no upstream disturbance
WECo	PO-922				no	no	no upstream disturbance
WECo	PO-923				no	no	no upstream disturbance
WECo	PO-948				no	no	
NHD, WECo	PO-970			NHD 10100001022457	no	no	no upstream disturbance
NRIS, NHD, WECo	PO-971	stock	Armells Creek, West Fork	WR 42KJ 108369 00, NHD 10100001022450	no	no	no upstream disturbance
WECo	PO-972				no	no	no upstream disturbance
WECo	PO-975				no	no	no upstream disturbance
NRIS, NHD, WECo	PO-976	stock	unnamed tributary of unnamed tributary of West Fork Armells Creek	WR 42KJ 108401 00, NHD 10100001022455	no	no	no upstream disturbance
WECo	PO-977				no	no	no upstream disturbance
NRIS, NHD, WECo	PO-978	stock	unnamed tributary of Donley Creek	WR 42KJ 162828 00, NHD 10100001022440	yes	yes	upstream disturbed area is very small compared to total area draining to pond, however spring draining to pond may be impacted.
NRIS, NHD, WECo	PO-980	stock	unnamed tributary of Black Hank Creek	NHD 10100001022488, WR 42KJ 183297 00	no	no	no upstream disturbance
NRIS, NHD, WECo	Pond 1	stock	unnamed tributary of Black Hank Creek	WR 42KJ 162815 00, NHD 10100001022470	no	no	no upstream disturbance
NRIS, NHD, WECo	Pond 2	stock	Black Hank Creek	WR 42KJ 162825 00, NHD 10100001022461	no	no	no upstream disturbance

Table O-6
Ponds - Impact Assessment

Source (a)	ID (a)	Purpose	Source Name	alternate IDs	Downstream from Area F Disturbance ?	Potentially Impacted ?	Reasoning
NRIS, NHD, WECo	Pond 3	stock	unnamed tributary of Black Hank Creek	WR 42KJ 162823 00, NHD 10100001022468	no	no	no upstream disturbance
NRIS, NHD, WECo	Pond 4, PO-979	stock	Black Hank Creek	WR 42KJ 183512 00, NHD 10100001022430	yes	yes	pond is immediately downstream from mining, a significant portion of the runoff received by the pond will be temporarily retained during mining
NRIS, NHD, WECo	Pond 5	stock	Donley Creek	WR 42KJ 108397 00, NHD 10100001022449	no	no	no upstream disturbance
NRIS, NHD, WECo	Pond 6	stock	unnamed tributary of Donley Creek	WR 42KJ 162858 00, NHD 10100001022458	no	no	no upstream disturbance
NRIS, NHD, WECo	Pond 7	stock	unnamed tributary of Donley Creek	WR 42KJ 162813 00, NHD 10100001022452	no	no	no upstream disturbance
NRIS, WECo	Pond 8	stock	McClure Creek	WR 42KJ 8211 00	yes	yes	pond is downstream from mining, some of the runoff received by the pond will be temporarily retained during mining
NRIS, NHD, WECo	Pond 9	stock	Trail Creek	WR 42KJ 25022 00, NHD 10100001022384	yes	yes	upstream disturbed area is very small compared to total area draining to pond, however the pond receives spring water from a spring that may be impacted by mining

Notes
(a) For more information refer to Appendix B - Hydrology.

Figures



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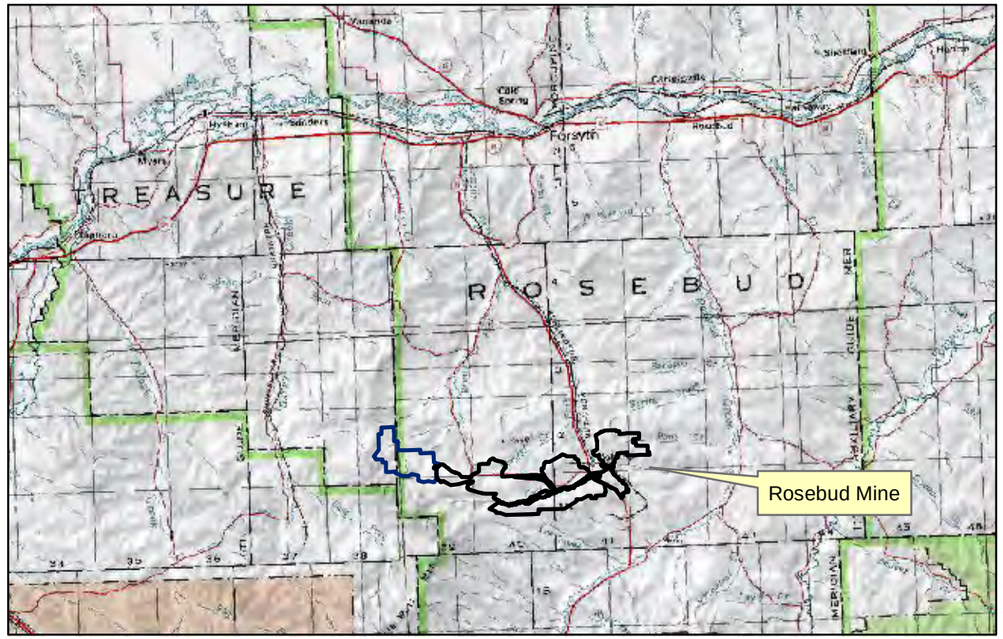

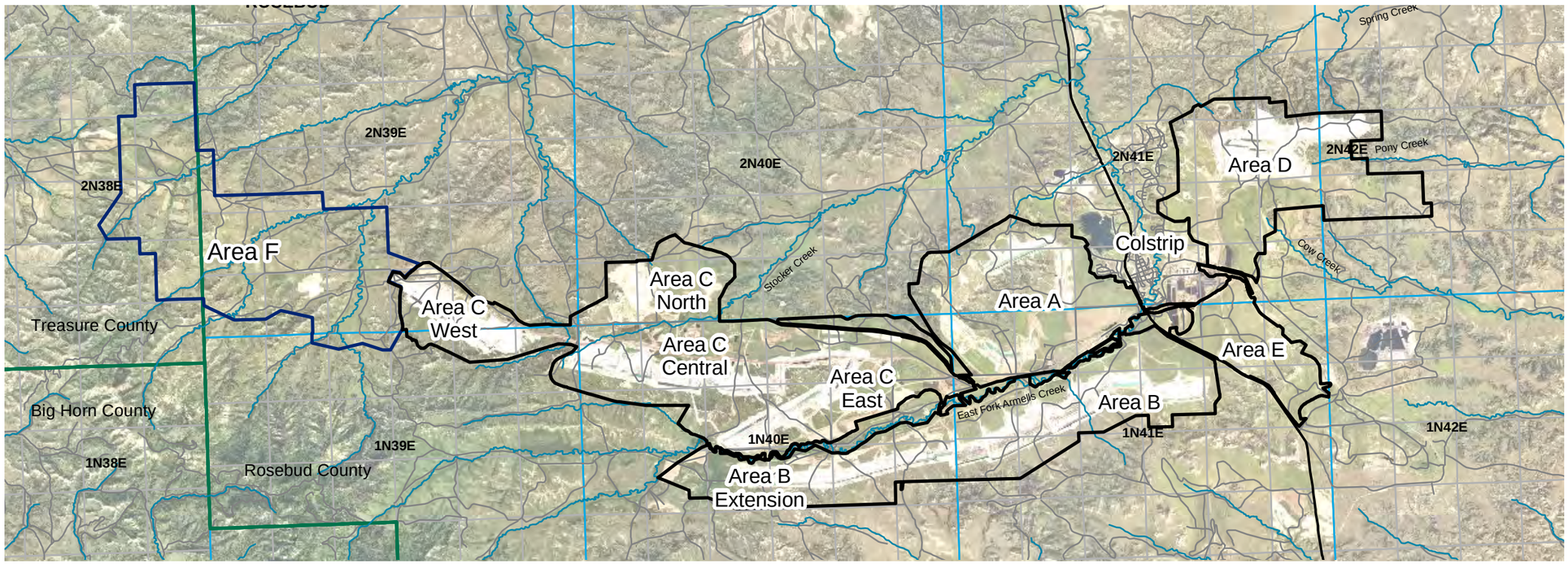

NICKLIN EARTH & WATER, INC.

Notes:
1) Aerial Photographs: 2011 NAIP

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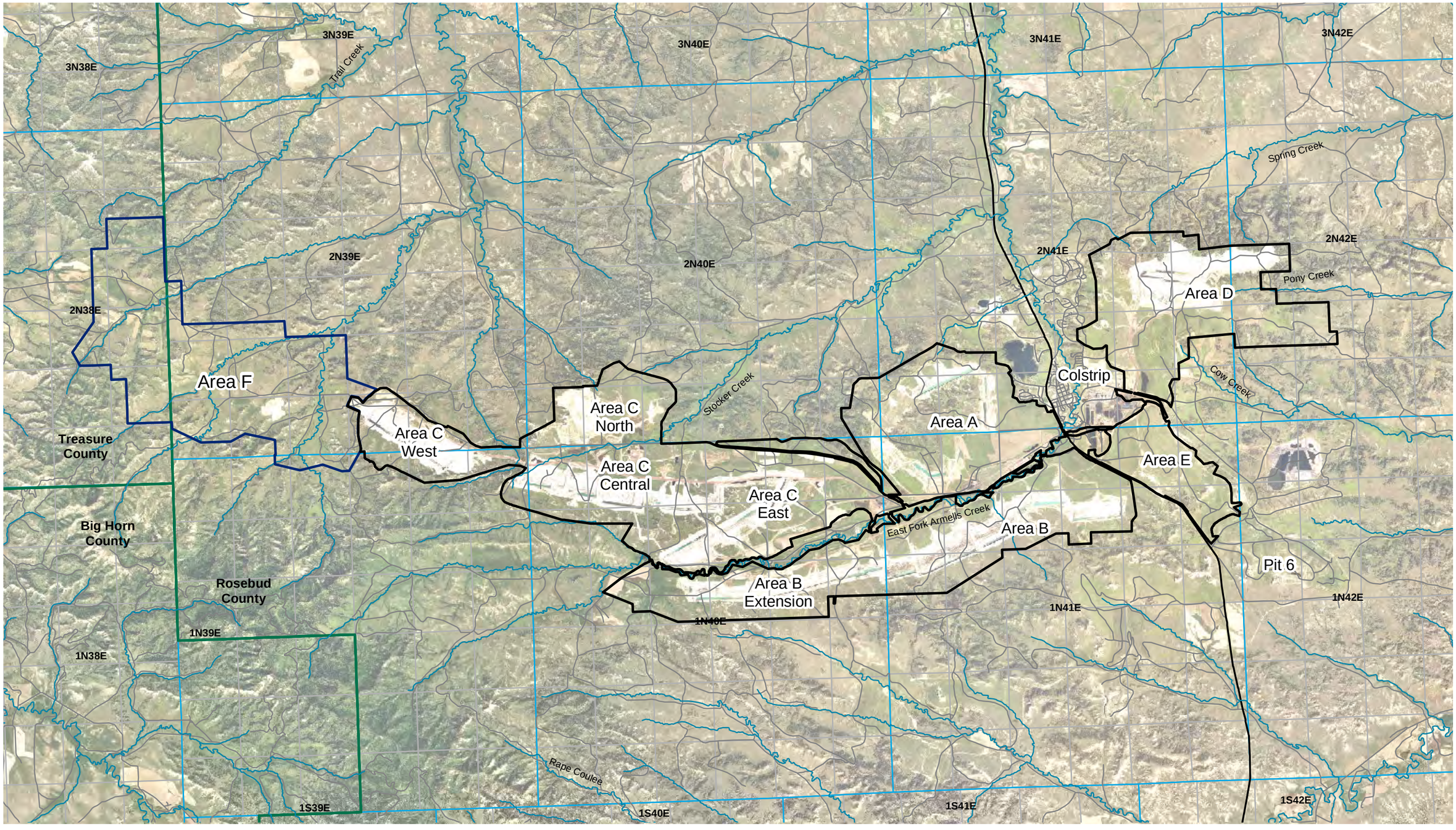
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure O-1
Location Map
Appendix O PHC

Exhibit 33

Date: 12/2/2013 File: O-1 Project Location



NICKLIN EARTH & WATER, INC.

0 5,000 10,000 Feet

N

Date: 12/2/2013 File: O-2 Site Map

Notes:
Aerial Photo: 2011 NAIP

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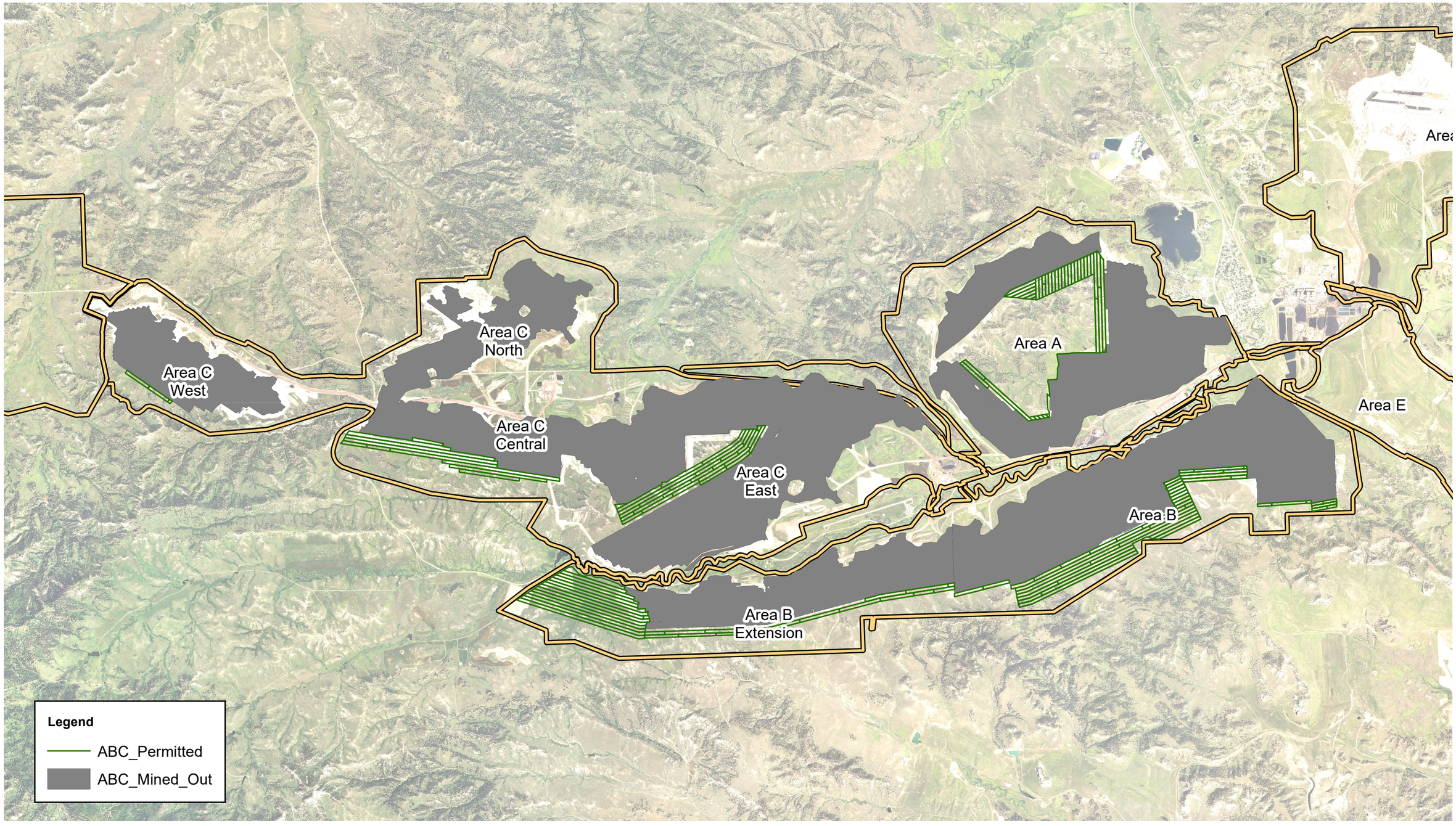
Figure O-2
Site Map
Appendix O PHC

Exhibit 33



NICKLIN EARTH & WATER, INC.

0 2,500 5,000 Feet

N

Notes:
1) Aerial Photograph: 2011 NAIP
2) Mining Progression as of 9/30/2015

Date: 1/26/2016 File: O-3 Mining Progression

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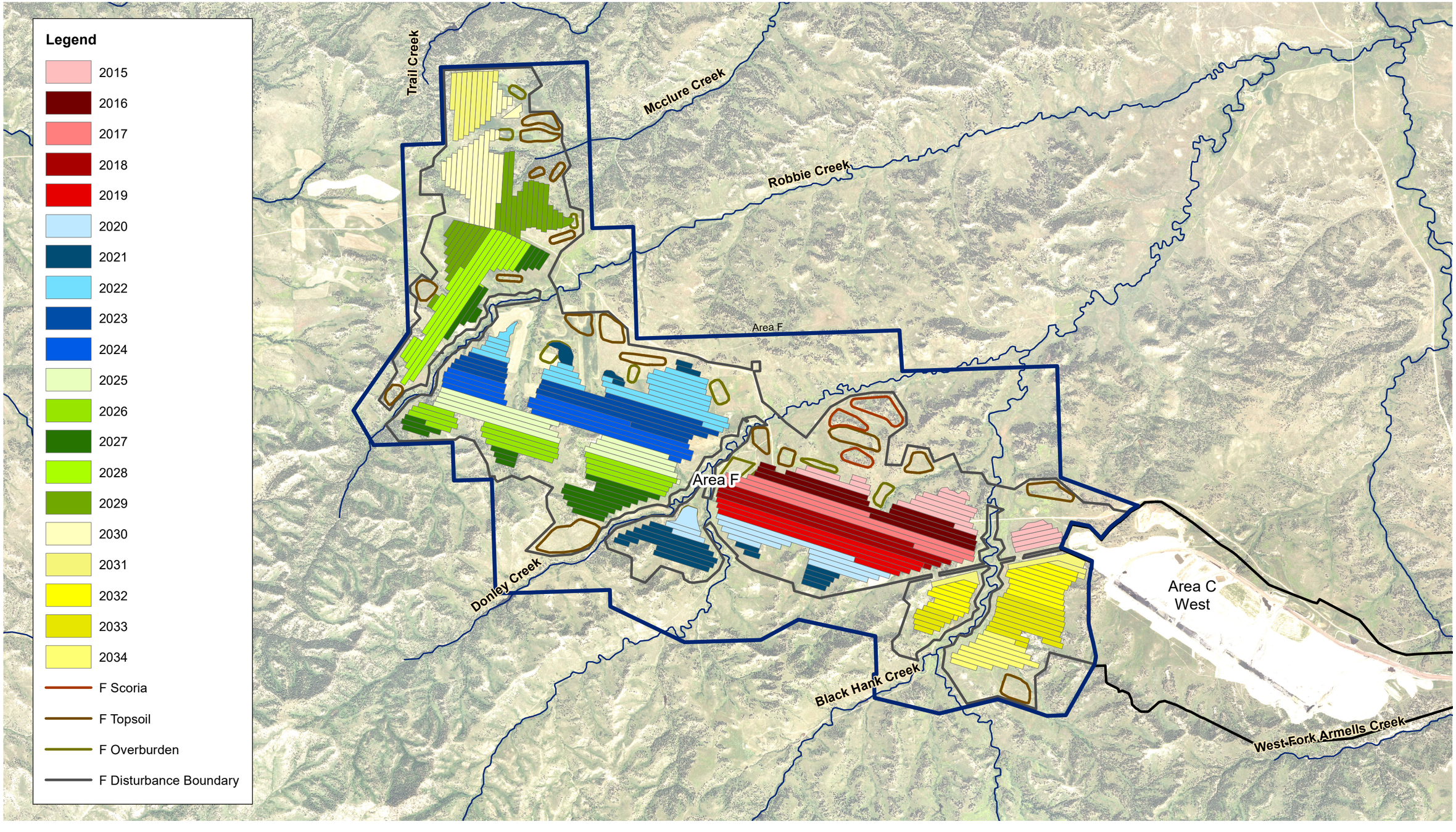
Figure O-3
Mining Progression
Appendix O PHC

Exhibit 33



NICKLIN EARTH & WATER, INC.

Feet
0 1,500 3,000

N

Notes:
1) Aerial Photograph: 2011 NAIP

Date: 1/25/2016 File: O-4 F Mine Plan

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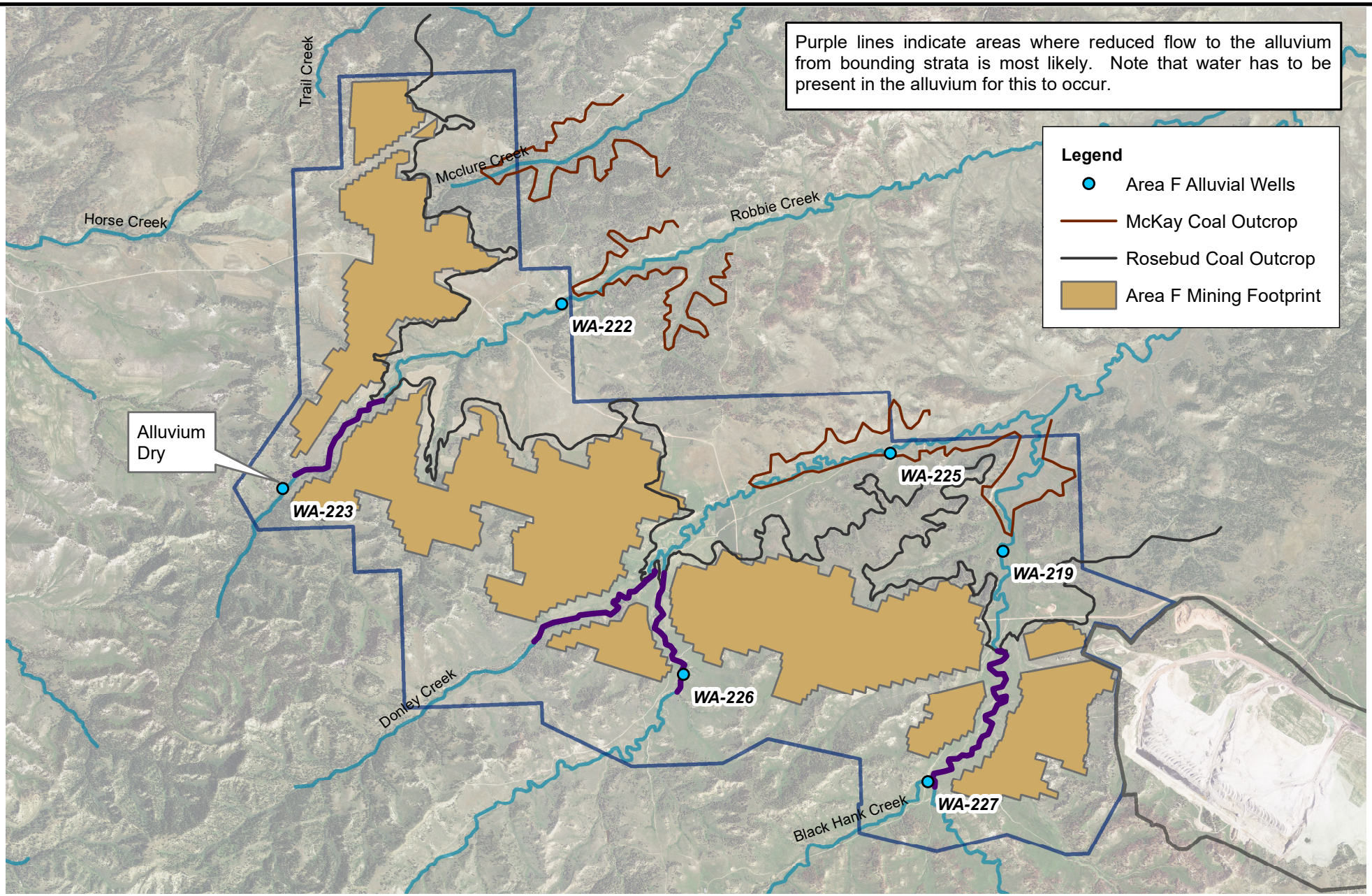
Figure O-4
Area F Mine Plan
Appendix O PHC

Exhibit 33



NICKLIN EARTH & WATER, INC.

Miles
0 0.25 0.5

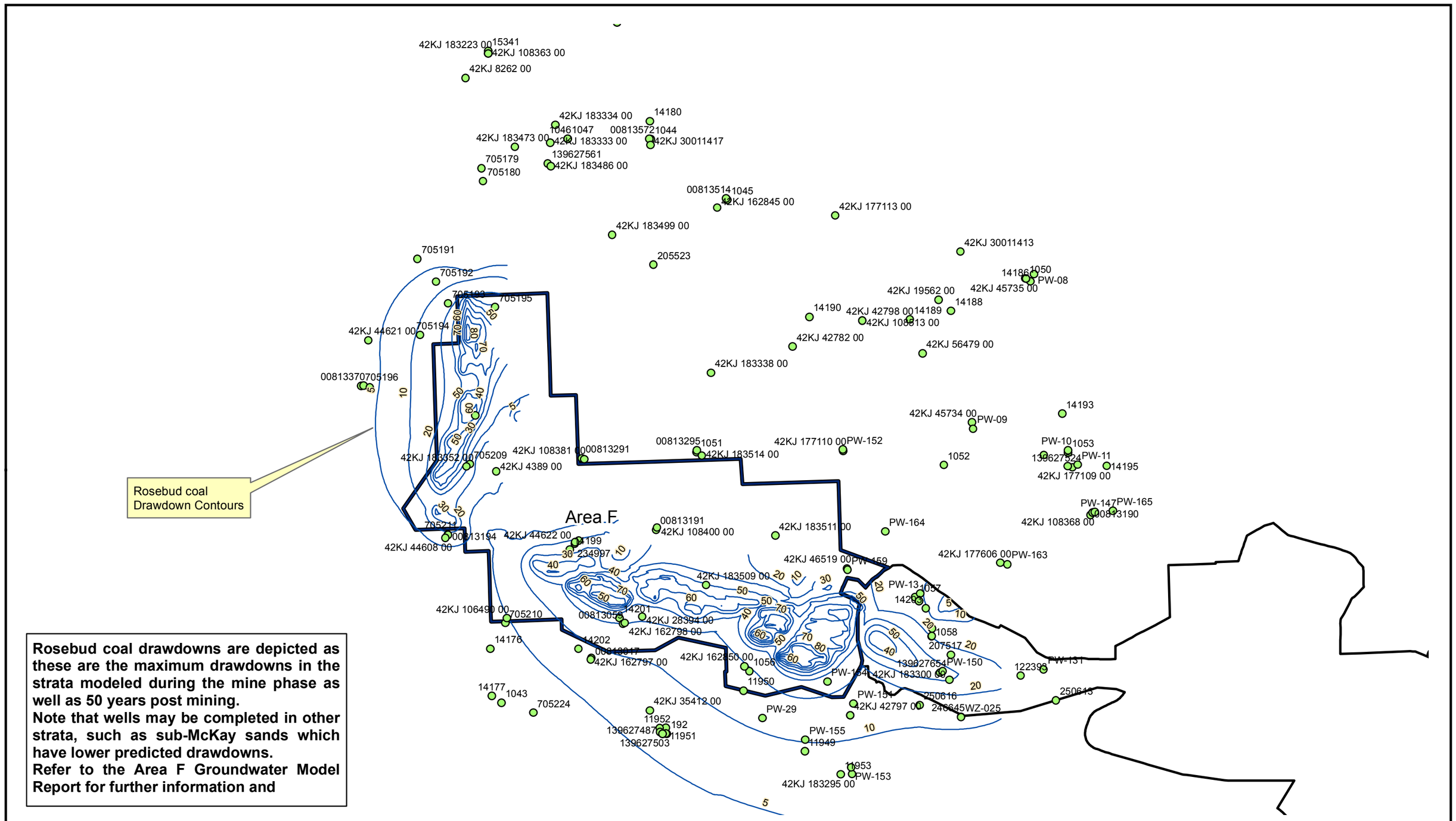
N

Notes:
1) Aerial Photographs: 2013 NAIP

Date: 2/17/2016 Name: O-5 Alluvium reduced flow areas

Figure O-5
Alluvium Areas Potentially Impacted
Appendix O - PHC

Exhibit 33



Rosebud coal drawdowns are depicted as these are the maximum drawdowns in the strata modeled during the mine phase as well as 50 years post mining.
Note that wells may be completed in other strata, such as sub-McKay sands which have lower predicted drawdowns.
Refer to the Area F Groundwater Model Report for further information and

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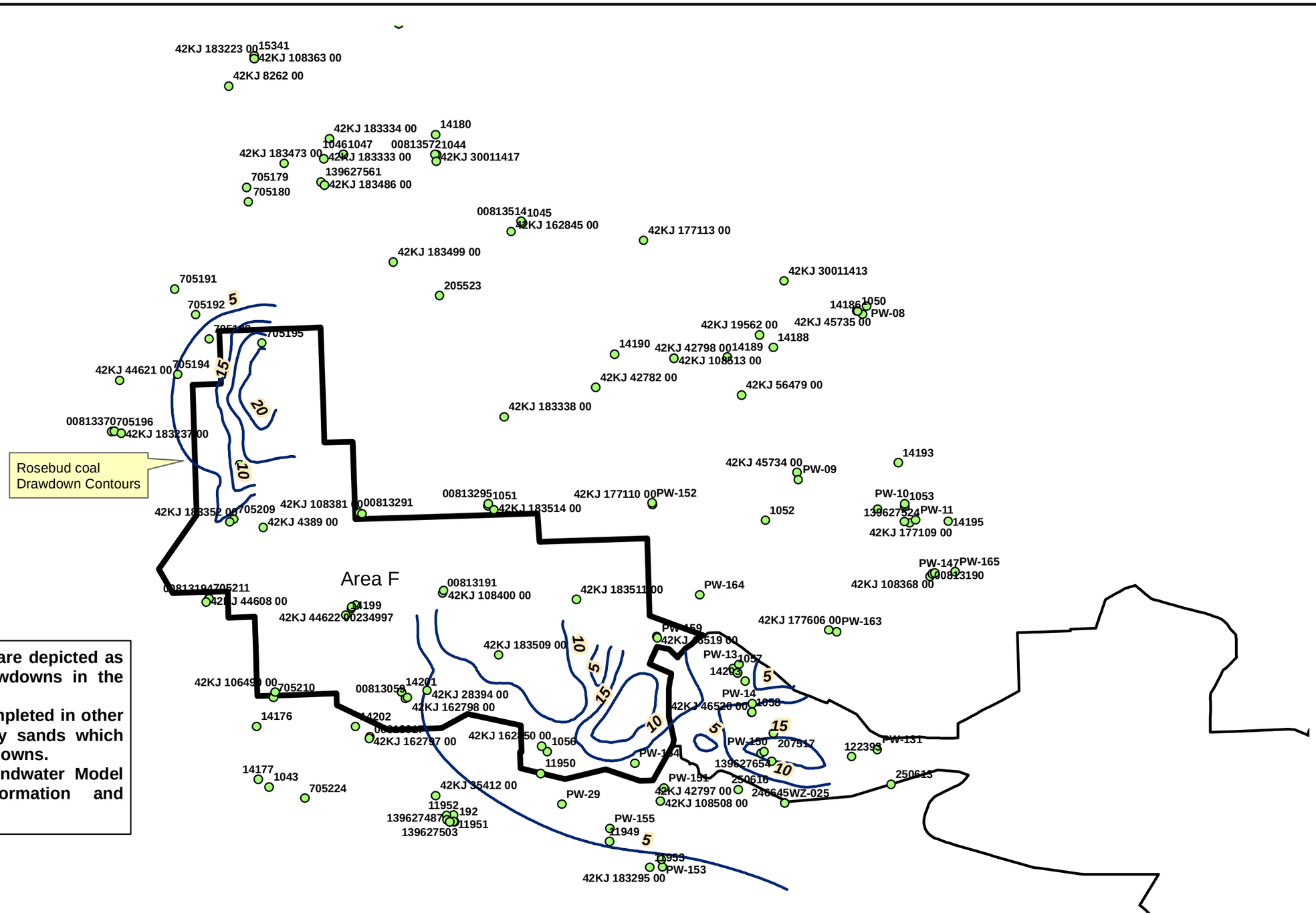
Figure O-6A
Maximum Groundwater Drawdowns and Use
Appendix O - PHC

Exhibit 33



Rosebud coal drawdowns are depicted as these are the largest drawdowns in the strata modeled.
Note that wells may be completed in other strata, such as sub-McKay sands which have lower predicted drawdowns.
Refer to the Area F Groundwater Model Report for further information and discussion.

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0 0.5 1 Miles

N

Notes:
Water use inventory based on information from Western Energy, NRIS (water rights), and GWIC (wells).

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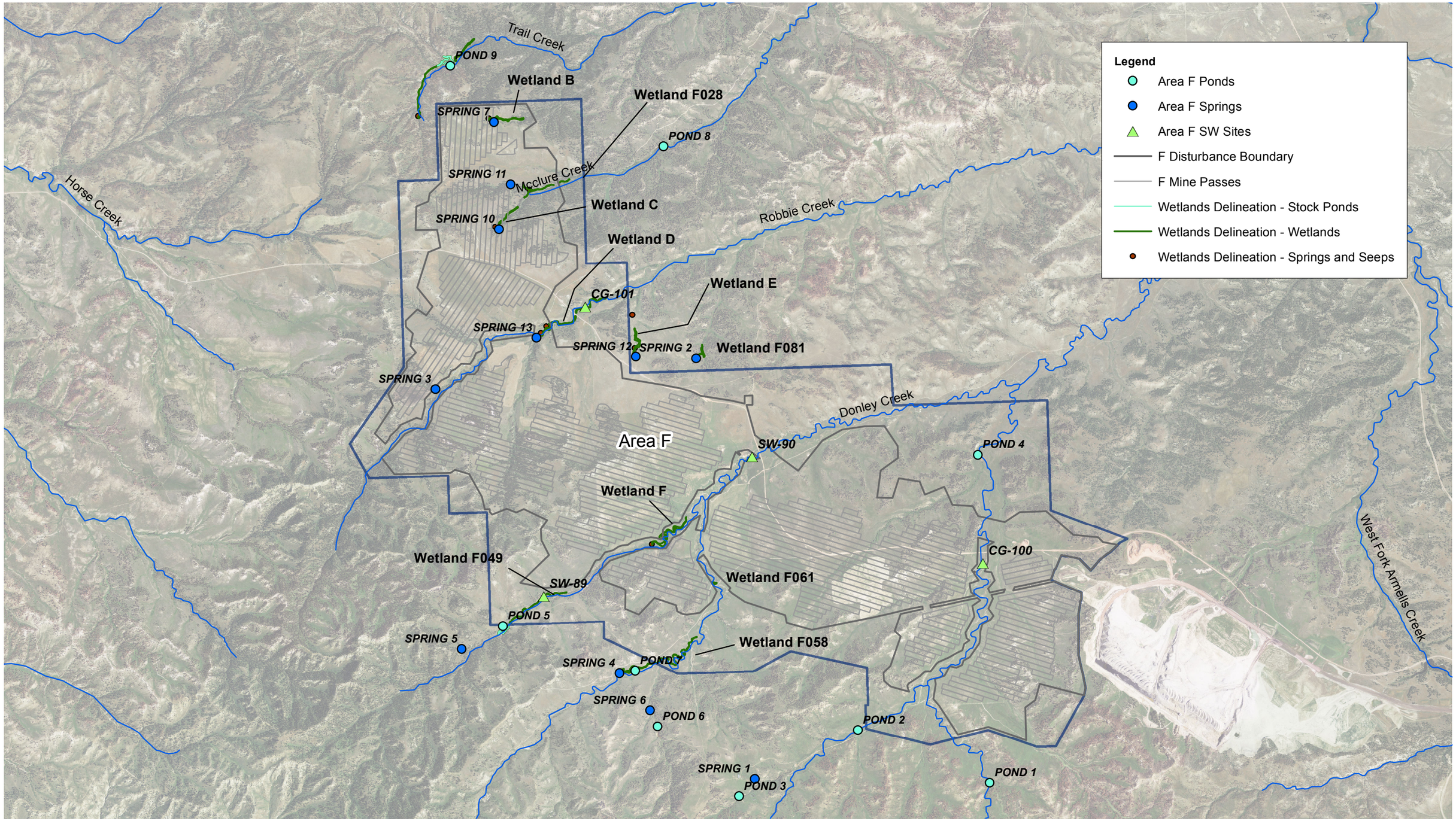
Date: 12/2/2013 File: O-5B GW DD and Use 50

Figure O-6B
Groundwater Drawdowns and Use
Fifty Years Following End of Area F Mining
Appendix O - PHC

Exhibit 33



NICKLIN EARTH & WATER, INC.

0 0.5 1 Miles

N

Notes:
1) Aerial Photographs: 2013 NAIP
2) Wetlands Delineation: Cedar Creek Associates (2013)

Date: 2/12/2016 Name: O-7 Springs, Wetlands and Ponds

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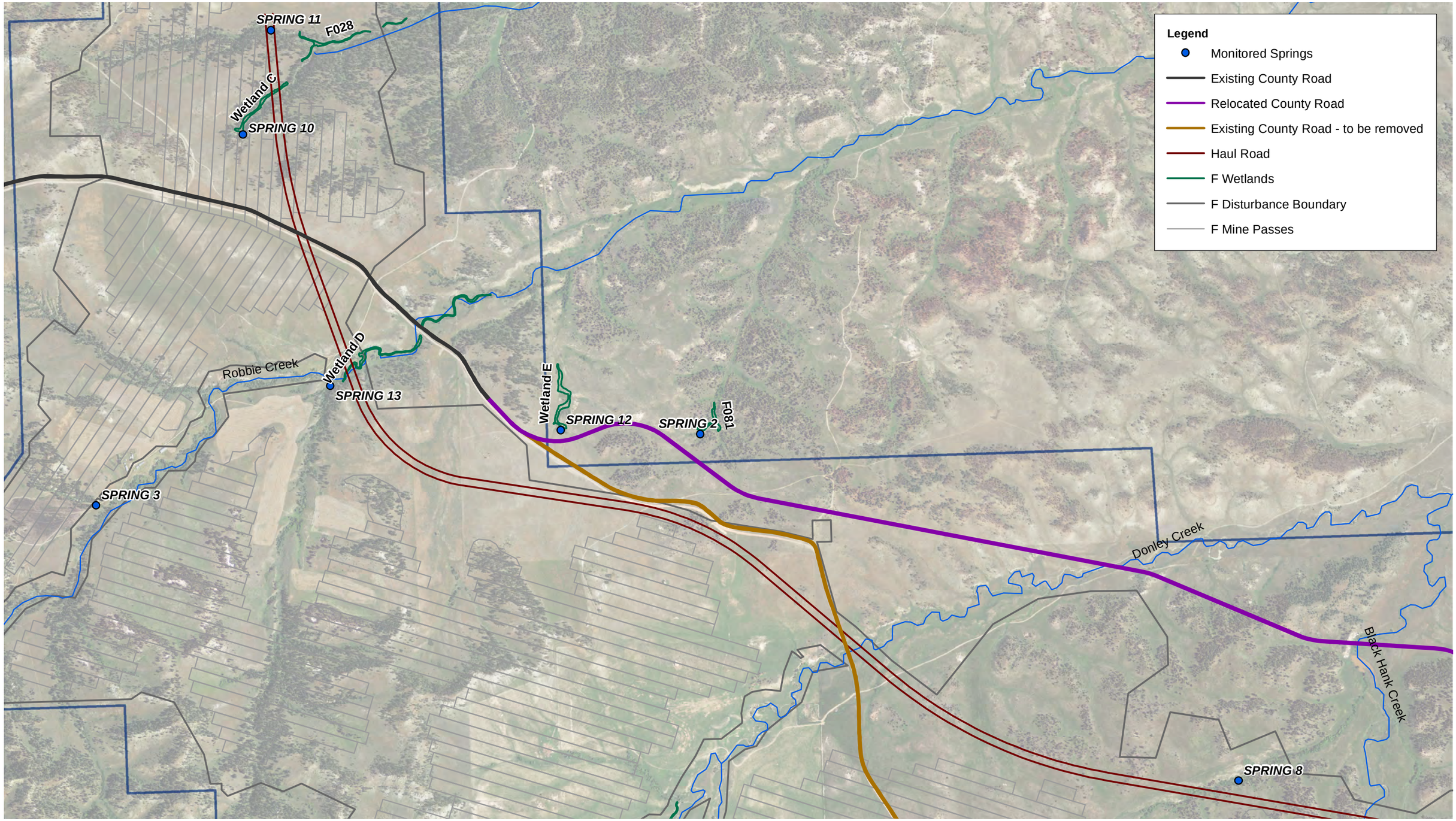
Figure 0-7
Springs, Wetlands and Ponds
Appendix O - PHC
Exhibit 33



NICKLIN EARTH & WATER, INC.

0 0.25 0.5 Miles

N

Notes:
1) Aerial Photographs: 2013 NAIP
2) Wetlands Delineation:
Cedar Creek Associates (2013)

Date: 2/12/2016 Name: O-8 Area F Road Impacts

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Figure O-8
Location of Roads, Springs and Wetlands
Appendix O - PHC
Exhibit 33

Addendum to the Comprehensive Evaluation of Probable Hydrologic Consequences Areas A, B and C Western Energy Rosebud Mine

WESTERN ENERGY COMPANY – *Rosebud Mine*

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February 2015

Exhibit 32

ADDENDUM OVERVIEW
PROBABLE HYDROLOGIC CONSEQUENCES
AREAS A, B AND C
EAST FORK ARMELLS CREEK
WESTERN ENERGY ROSEBUD MINE

The Montana Department of Environmental Quality (DEQ) has requested additional information in order to anticipate and predict the long-term effects of mining on surface water flow and quality and alluvial groundwater flow and quality. This addendum focuses on the hydrologic response of East Fork Armells Creek. The PHC was developed based on data collected through water year 2011. This addendum includes the evaluation of additional data collected in 2012 and 2013. In addition, in Attachment 1, some data collected in 2014 were included in the evaluation as described in the narrative or tables. Therefore, the evaluations and conclusions presented in this document supplement the findings of the PHC. The information requested is summarized (or paraphrased) below:

- Provide a water budget that includes inputs to the stream from:
  - The release of pond and pit water.
  - Infiltration from sediment ponds adjacent to the stream.
  - Disposal of water from operations and domestic use at the Area A facilities.
- Indicate how the additional sources of water associated with mine activity have affected stream flow.
- Address the following:
  - What is the source of the increase and at what point is the concentration expected to reach equilibrium or begin to decrease in concentration?
  - How is the increased saturation of spoil adjacent to the stream likely to affect long term water quality in the stream and alluvium?
  - What is the TDS concentration expected to be at full saturation of the spoil?
  - What are the long-term implications for stream and alluvial water quality associated with inputs from the facilities, including fate and breakdown of lignin sulfonate?

    - How have increases in specific water quality parameters affected the uses (livestock, wildlife, and aquatic life) and how will those uses likely be affected with future predicted water quality change?
- Conduct a current aquatic survey.

Four attachments are enclosed which provide much of the information requested DEQ.

- Attachment 1: Detailed Evaluation – Hydrologic Response to Mining – East Fork Armells Creek (by Nicklin Earth & Water)
- Attachment 2: Assessment of East Fork Armells Creek – Vicinity of Areas A and B (by Nicklin Earth & Water)
- Attachment 3: Memorandum – Calcium Lignin Sulfonate vs Magnesium Chloride for Dust Suppression (by Schafer Limited, LLC).
- Attachment 4: Western Energy – Rosebud Aquatic Survey Assessment (by ARCADIS).

This overview discusses how each request is addressed in a given attachment as relevant.

Develop a Water Budget

Attachment 1 provides a detailed water budget which includes information addressing the following:

- The release of pond and pit water into the stream.
- Infiltration from sediment ponds adjacent to the stream.
- Disposal of water from operations and domestic use at the Area A facilities.

A series of scenarios to represent the water budget under baseline, two different phases during mining, and post-mine conditions are presented.

Information relevant to the release of pond and pit water is given in Section 3.2.3 and 4.2.3 of Attachment 1.

The respective conclusions for items described above are the following:

- The transition in water quality observed in the EFAC alluvium is not associated with MPDES discharges of pond and pit water. This is simply because the MPDES discharges possess lower TDS concentrations than the baseline alluvial groundwater as follows (based on MPDES data collected from 1999 to 2014):

    - Average MPDES TDS concentration of 1,589 mg/L.
    - Median MPDES TDS concentration of 1,210 mg/L.
    - The baseline (pre-mine) alluvial groundwater quality showed higher TDS averaging 2,299 mg/L. Attachment 1 provides more details on how this estimate was derived.

- The relative contributions directly from pond infiltration are very limited and too small to explain the changes in TDS concentrations observed in the EFAC alluvium. The rationale for this conclusion include the following:
    - In normal years many of the ponds are dry or contain little standing water.
    - In Area B, most of the groundwater between the alluvium and the spoils flows southward (as opposed to EFAC).
    - Some limited contribution from ponds in Area A may occur as water infiltrates into mine spoil and then flows toward EFAC. However, this flow or seepage rate is small. Furthermore, many of the wells indicating a transition in TDS concentration are up-gradient of most Area A ponds. Hence, the infiltration from ponds cannot be used to explain up-gradient transitions.

- The relative contributions from the facility water uses to TDS concentrations are considered inconsequential for the following reasons:
    - The quantity of imported Colstrip water is equivalent to 0.01 cfs (per communications with WECo staff) and its use and/or destination include the following:
        - Vehicle wash water which is pumped to two lined lagoons and then evaporates.
        - Office facilities domestic water is discharged to a septic system. The primary analyte of concern of a septic system is nitrate as opposed to TDS.

- Portions of the imported water are used for lawn irrigation.
- Cleaning of two transfer houses. A portion of the wash water subsequently runs towards sediment traps.

o Given the limited flow rate of 0.01 cfs, and given that substantial portions of this flow are lost to evaporation (lined ponds and irrigation), the facility and wash operations are not considered to be a viable explanation for the TDS concentration increases observed in the last few years in the alluvial wells.

What is the Source or Cause of the Recent Increase of TDS concentration?

The best explanation for the increase in TDS concentration is associated with temporal changes in groundwater level. See discussion in Section 4.2.3 of Attachment 1. Also, please refer to Figure 15 of that attachment. Both increases and decreases in TDS in EFAC alluvial wells tend to correlate with changes in groundwater levels both on and up-gradient of the mine. Precipitation and runoff has been above normal over the last several years leading to increased MPDES discharges and increased recharge to the alluvium. It is projected that when precipitation and runoff conditions are nearer normal for an extended period of time, TDS concentrations will gradually attenuate toward baseline conditions.

Point at which concentration is expected to reach equilibrium or begin to decrease in concentration

See prior paragraph. More discussion follows below in terms of long-term projections related to flow from spoil groundwater.

How is the increased saturation of spoil adjacent to the stream likely to affect long term water quality in the stream and alluvium?

Refer to Section 4.3 of Attachment 1. The best projection that can be made at this time is that, in the long term, the average TDS concentrations in the alluvium and stream would have a net increase of about 13 percent over baseline concentrations. The rate, or point in time, that this net increase is reached is impractical to predict. However, that time frame likely involves several decades after mining in Area A and B ceases.

What is the TDS concentration expected to be at full saturation of the spoil?

See Section 4.3 of Attachment 1. The baseline average concentration for TDS was defined as 2,299 mg/L. The projected average TDS equilibrium concentration of spoils is 4,360 mg/L. The projected average TDS in the alluvium and the EFAC at equilibrium after mining is 2,599 mg/L. Attachment 1 provides a detailed description on how these estimates were obtained.

What are the long-term implications for stream and alluvial water quality associated with inputs from the facilities , including fate and breakdown of lignin sulfonate?

Attachment 3 provides a letter report discussing the fate and breakdown of lignin sulfonate. The projected implication for use of lignin sulfonate in terms of effects on sulfate concentrations in groundwater is that there will be no measurable change in background sulfate concentration (page 2 of that Attachment 3).

The impact of magnesium chloride is discussed in Section 4.2.4, Attachment 1. It is projected that, in the long term, concentrations will decline. There is some indication of pending peaking concentrations of chloride at one, possibly two of the easternmost alluvial observation wells, P-03 and P-04. Once peak concentrations occur, the rate of attenuation will depend upon a number of factors including: infiltration rates, mass of magnesium chloride present in the unsaturated zone, variations in groundwater levels, etc. It is not practical to predict the rate of attenuation once peaking occurs.

How have increases in specific water quality parameters affected the uses (livestock, wildlife, and aquatic life) and how will those uses likely be affected with future predicted water quality change?

Note that the recent changes in TDS are likely related to the changing groundwater levels.

Overall, the water quality uses from a livestock and wildlife use perspective are anticipated to remain similar to what they were under baseline conditions. Some increase in TDS (compared to baseline), and specific conductance (compared to

baseline) is anticipated to occur gradually over time until groundwater levels in the mine spoils recover leading to more flow moving into the alluvium.

Presently, most of the alluvial groundwater under baseline conditions is classified as Class II or Class III. The classification of the alluvial groundwater will remain Class II or Class III.

With regard to the effects on aquatic life, please refer to Attachment 4.

Attachments

Attachment 1

ATTACHMENT 1
Detailed Evaluation – Hydrologic Response to Mining - East Fork Armells Creek

Addendum to the
Comprehensive Evaluation
of
Probable Hydrologic Consequences
Areas A, B and C
Western Energy Rosebud Mine

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February 2015

Exhibit 32

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ATTACHMENT 1

Detailed Evaluation – Hydrologic Response to Mining East Fork Armells Creek

1.0 INTRODUCTION

This attachment to the PHC addendum to the Western Energy Rosebud Mine Areas A, B and C PHC (NE&W, January 2014) provides a supplemental evaluation of the hydrologic conditions for the East Fork Armells Creek (EFAC). The goal of this attachment is to present, to the degree feasible, a "water balance" quantification for a reach of EFAC extending from the eastern proximity of Area C to the eastern edges of Areas A and B. Figure 1 provides a general site map. Figure 2 provides details of relevant site features of interest in this evaluation.

2.0 BACKGROUND/OVERVIEW

2.1 Stream Classification

Prior to developing a water balance for EFAC, it is appropriate to determine or designate the type of stream present. The two classifications potentially relevant to EFAC are defined as follows (from ARM 17.24.301):

- "Ephemeral stream" means a stream or part of a stream which flows only in direct response to precipitation in the immediate watershed or in response to the melting of a cover of snow and ice and whose channel bottom is always above the local water table.
- "Intermittent stream" means a stream or reach of a stream that is below the local water table for at least some part of the year, and obtains its flow from both surface run-off and ground water discharge.

2.2 Definition of Classification for EFAC

It is clear that if a channel reach is ephemeral, then no direct hydraulic interaction between that reach and the alluvial groundwater exists. In this case, the analysis is greatly simplified. However, if the channel is intermittent, then some direct hydraulic interaction between the surface water and adjacent groundwater occurs. The ability to quantify the nature and or magnitude of that interaction may, or may not, be feasible depending upon just how complex that system is.

Van Voast, et al (1977) described the following condition for the EFAC upstream of Colstrip:

> *"Upstream from Colstrip, East Fork Armells Creek is generally dry except for water holes where its channel locally penetrates the water table."*

This statement indicates that Van Voast, et al (1977) did not observe flow in the EFAC upstream of Colstrip, as only "water holes" or localized expressions of "pooled" groundwater were present.

In 1982, Hydrometrics conducted the alluvial valley floor (AVF) study for WECo for the same portion of EFAC. The AVF study reported flow or standing water in short sections of the creek above Colstrip much of the year in the AVF evaluation. It should be noted that the flow and aquifer conditions in 1982 may have been influenced by above average runoff that year (see NE&W, 2014). In essence, the observations of each entity are not necessarily contradictory, but are likely explained by observations at different times under different precipitation/snowmelt runoff conditions.

Evaluations were conducted by NE&W (2014) in order to assist in defining the type of stream that is relevant for the EFAC in the vicinity of Areas B and C. Is it ephemeral or is it intermittent? Is there a transition point for stream type designation, etc.? The NE&W assessment included the following components:

- Evaluating alluvial well water level hydrographs.
- Collecting channel thalweg survey elevations located strategically near monitoring well locations possessing historic water levels that were

representative of pre-mine conditions.

- Reviewing aerial photographs from 2009, 2011 and 2013.

As a result of these analyses, the following observations/interpretations were drawn about the vicinity of EFAC adjacent to Areas A and B:

- Conditions at pre-Mine/baseline (before 1975): Portions of the EFAC reach between Areas A and B were likely intermittent before mining commenced (see Figure 2 of Attachment 2). The basis for this is that some adjacent alluvial monitoring wells exhibited water levels above nearby channel thalwegs.
- Conditions during mining ("earlier" mining – 1976 to mid 1990s): As mining commenced adjacent or near alluvial sections of the EFAC, substantial portions of that alluvium showed groundwater levels well below the channel thalweg. This was due to drawdown in areas being mined. This was readily apparent especially from the early to late 1980s and extending to the mid-1990s (see Figure 2 of Attachment 2). Hence, at least for the short-term, conditions of EFAC were akin to an ephemeral stream.
- Conditions as mining moved away from EFAC alluvium ("later" mining – mid 1990s to current). In more recent years, alluvial groundwater levels have recovered and, in some instances, exceed pre-mine water levels (see Figure 2 of Attachment 2, wells WA-101, WA-128, and P-04). One factor for this recovery is that mining moved away from the EFAC over time. Hence, there was less drawdown in the alluvium from mining. In some years, recovery was caused by greater recharge associated with above average precipitation and runoff. A key subset of this last factor is that in years of "excessive" precipitation and runoff, a significant amount of storage in sediment ponds and mine pits resulted. This necessitated a need to release flow into the EFAC channel in the form of MPDES discharge. Some of these discharges occurred over extended periods of time. This led to a substantial amount of

recharge into the EFAC alluvium and increases/recovery of alluvial water levels. In some instances, the water level recovery was profound (see Figure 2 of Attachment 2, WA-128, year 2000). The net effect is that water levels have increased substantially. Given that groundwater levels in eastern sections of the control volume are generally higher than measured prior to mining, the net effect is that surface water flow is more likely to occur at flume measuring station SW-55.

In summary, the nature of channel flow has varied over the last three decades at SW-55 as follows:

- Prior to mining, during extended periods of time when precipitation was at or below average, it is likely that base flow at SW-55 was non-existent, infrequent, or rates were nearly too low to be measured. Some temporary base flow of limited duration likely occurred following major precipitation/runoff events. However, given that the duration of these events was generally limited, the volume of recharge that occurred did not sustain base flow at SW-55 for the long-term.
- During “early” mining, it is likely that base flow at SW-55 was non-existent or the rates too low to be measured when mining was relatively near the alluvium as ground water levels declined in response to mine drawdown. This was mainly a factor when northern portions of Area B were mined near/adjacent to the EFAC alluvium. Some temporary flow exceptions existed in association with recharge from natural runoff events, and, also when MPDES discharges occurred.
- During “later” mining (recent), flow at SW-55 became more sustained as a result of groundwater levels exceeding pre-mine conditions. Again, most of this increase is in response to the extended MPDES discharges that were required for years of well above average precipitation, runoff, and subsequent pond and pit storage. This is especially so beginning in water year 2011.

The above conceptualization is validated by the flow observations summarized below for SW-55:

- Flow in the vicinity of SW-55 was infrequently observed prior to Area B mining (inferred from Van Voast et al, 1977).
- Flow events that did occur during most of the mining period are readily correlated to major precipitation and/or snowmelt runoff events. Following these events, the typical response has been for flows to be of short duration followed by a rapid attenuation to a "non-flowing or dry" condition. This is especially apparent up until water year 1994 (see Figure 9 – page 1).
- Periods of more extended base flow have been associated with water years of very high precipitation, such as water years 1994, 1995, 1997, 2000, and 2011 through 2013 (see Figure 9, pages 1 – 3).
- The most extended period of "base flow" over time has been observed during very recent mining activity, or since about 2011 (see Figure 9 – page 3). Such extended based flow is correlated to major precipitation/snowmelt runoff events coupled with significant MPDES releases to the EFAC which has led to greater local recharge (see Table 1 of Attachment 2).

Completing a water balance is indeed challenging because of the complex nature of the hydrogeologic system coupled with the highly transient stresses that are involved. Hence, any analysis that follows in this report is predicated upon a number of simplifications. Therefore, caution is clearly warranted in ascribing confidence to water balance calculations because of the confounding factors that exist and are inherent in any complex natural system.

3.0 WATER QUANTITY ASSESSMENT

3.1 Overview

This section presents the water balance evaluation, which considers the water quantity aspects of a selected control volume. This control volume is assigned to coincide with

the alluvium in the EFAC vicinity. The water balance parameters are used in the subsequent section to evaluate water quality aspects of the control volume.

Based upon the summary set forth in Section 2, the first step in the water balance evaluation is to establish the control volume and define those parameters that substantively affect the water balance of this control volume. The reach of the EFAC assigned for this analysis begins near WA-106 (up-gradient) and extends to the vicinity of the P-series wells (down gradient) (see Figure 2). The surface of this control volume coincides with the EFAC alluvium as mapped by Vuke, et al (2007) and as shown in Figure 3. The primary water balance variables assigned to this control volume are the following (See Figure 4):

- Alluvial groundwater inflow ($\mathbf{Q_{a\text{-}in}}$) and outflow ($\mathbf{Q_{a\text{-}out}}$).
- Recharge ($\mathbf{Q_r}$) into the control volume. This recharge includes surface recharge and infiltration within the EFAC channel itself.
- Lateral flow communication ($\mathbf{Q_{lat}}$) between bounding consolidating units (e.g., overburden, Rosebud coal, interburden and McKay coal). Under baseline conditions, this communication was dominated by inflow from the Rosebud coal.
- Vertical flow communication ($\mathbf{Q_v}$) may occur. However, given the extremely low vertical to horizontal hydraulic conductivity anisotropies that exist in the Tongue River member of the Fort Union, this vertical flow communication is assumed to be negligible and no further assessment of this variable is considered necessary for the water budget evaluation.
- Surface Water Outflow ($\mathbf{Q_{swo}}$). Note that EFAC at the up-gradient (west) edge of the control volume is ephemeral. Hence, no incoming base flow is assigned to the control volume. Flow at the downstream edge has been observed at times as measured at surface water gaging station SW-55. Most of these flows were historically related to runoff, or, attenuation from that runoff. At most other times, this station has exhibited either dry conditions or “base flow” rates that are very small or limited seepage. Since there have

been some "base flows" observed more recently at SW-55, $\mathbf{Q_{swo}}$ is retained for analysis purposes.

- No mine specific ponds are present within the control volume. Some wells are present. Only those stresses that are within the control volume are evaluated for the water balance. Those that are outside the control volume are factored into the other variables ($\mathbf{Q_{a\text{-}in}}$, $\mathbf{Q_{a\text{-}out}}$, $\mathbf{Q_{lat}}$).
- Alluvial aquifer storage (**S**).

Note that all these variables are transient over time. In effect, there are an infinite number of scenarios or possibilities that can be defined. As a result, simplifications must be made to establish a workable set of representative scenarios to assist in predicting the probable hydrologic consequences of mining as they pertain to EFAC alluvium.

3.2 Establishment of Flow Scenarios

The following four flow scenarios are established:

- Scenario 1: Baseline
- Scenario 2: "Early" mining (drawdown dominated phase)
- Scenario 3: "Recent" mining (water level recovery phase)
- Scenario 4: Post mining

Again, it is re-emphasized that these scenarios represent simplifications or idealizations of a very complex/transient system.

3.2.1 Scenario 1: Baseline

The variables applicable for Scenario 1 (and other scenarios) are defined in Figure 5. Information presented in Van Voast, et al (1977) provides some insights as to the magnitude of some of these variables. However, refinements to the Van Voast parameters were made based upon a more comprehensive alluvial well water level database that was collected subsequent to the Van Voast, et al effort.

Inflows

The inflows to the control volume for this scenario are simplified to incoming alluvial flow ($\mathbf{Q_{a\text{-}in}}$), areal recharge ($\mathbf{Q_r}$), and lateral inflow ($\mathbf{Q_{lat}}$) from bounding consolidated strata. The incoming flows were estimated as described below.

The estimate for $\mathbf{Q_{a\text{-}in}}$ was quantified using Darcy's law as 0.102 cubic feet per second (cfs) or 45.9 gallons per minute (gpm). Table 1 presents additional information on the derivation of this flow estimate.

Quantifying the magnitude of baseline recharge over the alluvial control volume is complicated by several variables. The most significant recharge component is likely seepage from the EFAC channel in association with episodic/short term surface water runoff that varies from year to year. Some other fractions are associated with infiltration from direct precipitation over the land surface. There is also ponding along stretches of this creek that potentially causes localized higher rates of recharge. It is noted that the actual recharge over the control volume is uncertain and cannot be directly quantified. For purposes of evaluation, it is assumed that the net baseline recharge ($\mathbf{Q_r}$) over the control volume is 5 % of the average annual precipitation. This equates to a flow rate of 0.033 cfs (14.8 gpm).

Van Voast, et al (1977) estimated a lateral flux ($\mathbf{Q_{lat}}$) through Areas A and B of about 1,050 cubic feet per day (cfd). Van Voast, et al assumed a transmissivity value of 10 ft^2/d for the Rosebud coal. A higher calibrated value of 19 ft^2/d was defined in the Rosebud Mine model (RMM). Applying the RMM transmissivity value of 19 ft^2/d leads to a higher estimated flow of 1,997 ft^3/d (or 10.4 gpm) which was subsequently assigned to $\mathbf{Q_{lat}}$ for flow from Areas A and B into the control volume.

Van Voast, et al describes flow through Areas A and B in the McKay coal as well. However, based upon NE&W evaluation of site well logs completed in the vicinity of the control volume, it is interpreted that the McKay coal is generally isolated from the alluvium over most of the footprint of this control volume. Hence, any flux into the alluvial control volume from the McKay coal was assumed to be negligible, or, it does not contribute to $\mathbf{Q_{lat}}$.

The sum of these inflow numbers ($\mathbf{Q_{a\text{-}in}}$, $\mathbf{Q_r}$, and $\mathbf{Q_{lat}}$) to the control volume is 0.158 cfs.

Outflows

Flow out of the control volume includes the alluvial groundwater outflow ($\mathbf{Q_{a\text{-}out}}$), surface water outflow ($\mathbf{Q_{swo}}$) and $\mathbf{Q_{wells}}$.

The alluvial groundwater outflow estimate ($\mathbf{Q_{a\text{-}out}}$) was quantified using Darcy's Law to be 0.139 cfs (62.3 gpm). Table 1 presents additional information on the derivation of this flow estimate.

$\mathbf{Q_{swo}}$ is unknown but assumed to be very small or negligible for the baseline condition based upon the available historic documentation and the conceptualization set forth previously.

There are four private wells documented within the control volume (See Figure 6). One well, GWIC 12003, was present before mining and used for domestic and stock watering purposes. No data are available for quantifying the amount of groundwater used at this well. However, the amount of groundwater used is deemed as likely inconsequential, at least compared to the other water budget flow parameters. Hence, for quantitative estimate purposes, private wells were not considered in this, or any of the remaining scenarios and $\mathbf{Q_{wells}}$ was assigned a discharge of 0 cfs.

Summary for Scenario 1

In summary, the difference between the inflows (0.158 cfs) and the alluvial groundwater outflows (0.139 cfs) equates to 0.019 cfs or (8.6 gpm) for $\mathbf{Q_{swo}}$. Based upon the background information set forth in Section 2.0, this flow rate seems to be a credible value to assign as a representative or "typical base flow" condition in the vicinity of SW-55 prior to mining.

The values defined above are deemed as representative, but again, it is warranted to reemphasize the inherent uncertainty associated with this complex natural system.

3.2.2 Scenario 2: "Early" Mining (drawdown scenario)

This scenario is considered the most complex of the four scenarios defined. During "early" mining, the system became highly transient. For instance, groundwater levels in the alluvium declined substantially in some portions of the control volume largely in

response to mining drawdown. These changes evolved over time with the progression of mining along the northern perimeter of Area B, and to some lesser degree because of mining at Areas A and C (east). These transient effects greatly complicate the water balance effort simply because of the changes in storage within the control volume. There are also resultant transient changes for the input and output variables of the control volume. Hence, it is deemed that developing a "representative" quantitative estimate for the control volume variables is infeasible for this "early" mining scenario. Nonetheless, this scenario is retained and discussed to illustrate the complexities during the alluvium "drawdown" phase as mining commenced.

Inflows

Again, the inflows to the control volume for this scenario include $\mathbf{Q_{a\text{-}in}}$, $\mathbf{Q_r}$, and $\mathbf{Q_{lat}}$. See Figure 7.

The incoming alluvial flow, $\mathbf{Q_{a\text{-}in}}$, is likely transient over time owing to the changes in hydraulic gradient that occurred near the up-gradient boundary of the control volume. It is projected that at first, there would be some increase in $\mathbf{Q_{a\text{-}in}}$ as the hydraulic gradient steepened. The lateral contributions from bounding strata, $\mathbf{Q_{lat}}$, in contact with the alluvial aquifer control volume changed over time as a result of transient changes in hydraulic gradient between these bounding units and the alluvium. As mining progressed, $\mathbf{Q_{lat}}$, likely became a net outflow since flow was being induced from the alluvial control volume by drawdown. This induction was likely most significant when Area B mining near the alluvium was being conducted. Yet, as mining progressed away from the alluvium, water levels were beginning to recover in the mine spoils so that this net outflow changed over time.

Another dominant transient factor involves the MPDES discharges delivered into the EFAC channel. This led to episodic/dramatic increases in recharge, $\mathbf{Q_r}$ for some years when compared to baseline conditions. Please refer to Attachment 2, Table 1 and Figure 2.

Outflows

Again, the outflows from this control volume total, in effect, the sum of alluvial groundwater outflow ($\mathbf{Q_{a\text{-}out}}$), surface water outflow ($\mathbf{Q_{swo}}$) and $\mathbf{Q_{wells}}$.

It is likely that the alluvial outflow estimate ($\mathbf{Q_{a\text{-}out}}$) is similar to, but slightly less than the calculated value of 0.139 cfs defined for the baseline scenario. Because of the drawdown that occurred during mining, it is more likely that $\mathbf{Q_{swo}}$, as measured at SW-55, showed dry channel conditions for this scenario. Again, flows associated with the pumping wells are assumed to be negligible when compared to the magnitude of the other flow factors involved.

Summary for Scenario 2

It is concluded that because of the unduly transient nature of the inflow/outflow variables involving the control volume, a representative water balance cannot be meaningfully computed for Scenario 2. Nonetheless, this scenario assists in understanding how the system has behaved over time since mining began in Areas A and Area B.

3.2.3 Scenario 3: Current Condition

The variables defined in Figure 8 are estimated in part based upon information defined in Van Voast, et al (1977). In some aspects, this scenario is reasonably similar to the baseline scenario since alluvial groundwater levels have recovered. The primary difference is that many of the alluvial wells show groundwater levels above baseline water level observations.

Inflows

Again, the inflows to the control volume for this scenario include $\mathbf{Q_{a\text{-}in}}$, $\mathbf{Q_r}$, and $\mathbf{Q_{lat}}$. The incoming flows were estimated as described below.

The estimate for $\mathbf{Q_{a\text{-}in}}$ (incoming alluvial flow) is quantified in Table 1 to be 0.061 cfs (27.3 gpm). Note that this is lower than the pre-mine $\mathbf{Q_{a\text{-}in}}$ from Scenario 1, because of a reduction in the hydraulic gradient near this area, which in turn is associated with decreased up-gradient alluvial water levels in response to mining. Note that groundwater levels in the alluvium in this portion of the mine are still in the recovery phase.

The estimate for areal recharge component of $\mathbf{Q_r}$ over the control volume was assumed to be 5 % of the annual precipitation over that control volume land surface or 0.033 cfs

(14.8 gpm).

It is noted that there have been recent (temporal) MPDES recharge contributions to the control volume as well. In a majority of years, this discharge has been small or negligible. However, in some years this element of recharge is very substantial as shown below:

Water Year 2000 (167 million gallons year [mgy]) [0.71 cfs].
Water Years 2001 – 2006 (no discharge)
Water Year 2007 (28 mgy) [0.12 cfs].
Water Years 2008-2010 (no discharge)
Water Year 2011 (61 mgy) [0.26 cfs].
Water Year 2012 (109 mgy) [0.46 cfs]
Water Year 2013 (172 mgy) [0.73 cfs].

The MPDES discharge to EFAC decreased substantially in water year 2014 down to 16 mgy (0.07 cfs). For water balance purposes, it is assumed that most of the MPDES discharge above went to recovery of storage (water levels) that had decreased during early mining phases.

Under Scenario 3, the net water year 2013 recharge (total $\mathbf{Q_r}$) is computed as 0.763 cfs.

The lateral contribution, $\mathbf{Q_{lat}}$, is presently much smaller when compared to baseline conditions. It is deemed that the proportion of contributions from Area A are similar to, or less than, what existed pre-mine. For purposes of water balance quantification, the pre-mine flux contribution from Area A used for Scenario 1 was assumed, or 0.01 cfs (4.4 gpm) was applied.

The contribution from Area B to $\mathbf{Q_{lat}}$ is likely inconsequential since the general flow at the southern edge of the control volume is toward mine spoils. It is possible that there is presently some limited flow from the spoils to the alluvium near the very down-stream end of the control volume. This would be limited to the monitoring period starting in 2011 since, prior to that time, groundwater levels in the mine spoils were below groundwater levels in the alluvium. However, if any flow is directed from the spoil into the alluvium, it is deemed at this stage to be inconsequential.

Thus, the total $\mathbf{Q_{lat}}$ is assigned to be 0.01 cfs. All this flux is from Area A for Scenario 3.

The sum of these inflow numbers ($\mathbf{Q_{a\text{-}in}}$, $\mathbf{Q_r}$, and $\mathbf{Q_{lat}}$) is 0.834 cfs.

Outflows

The outflows from this control volume total, in effect, the sum of alluvial groundwater outflow ($\mathbf{Q_{a\text{-}out}}$), surface water outflow ($\mathbf{Q_{swo}}$) and $\mathbf{Q_{wells}}$ and includes any flow from the alluvium into the Area B spoils.

The net outflow from the alluvium to Area B spoils is assumed to relatively small compared to the other outflow variables. Also, the well usage within the control volume is considered negligible when compared to the other water balance factors.

The alluvial outflow estimate ($\mathbf{Q_{a\text{-}out}}$) was quantified using Darcy's Law to be 0.140 cfs.

Groundwater wells within the control volume are shown in Figure 6 with details provided in Table 2. One of these wells is relatively deep. Three of these wells show stock water rights with one showing domestic use as well. Given the location of these wells, actual water pumpage is likely to be very limited for stock water use. Domestic uses, from a water budget perspective for the EFAC are considered inconsequential. Hence, for water budgeting purposes $\mathbf{Q_{wells}}$ was assigned a discharge of 0 cfs.

The flow $\mathbf{Q_{swo}}$ at SW-55 ranged from 0 to 10.36 cfs, with a median value of 0.043 cfs (19.3 gpm). The median flow was used as an indicator of the "base flow" (from the alluvial control volume). It should be noted that the "base flow" is likely elevated well above natural conditions because of the effect of the MPDES discharges that have occurred from 2011 through 2013.

Assuming a median flow of 0.043 cfs, then the total computable outflow ($\mathbf{Q_{a\text{-}out}}$ and $\mathbf{Q_{swo}}$) from the control volume was assigned to be 0.183 cfs.

In summary, the instantaneous difference between the inflows (0.834 cfs) and the total computable outflows (0.183 cfs) equates to 0.651 cfs or (292 gpm) over the course of the 2013 Water Year. This difference is best explained as a combination of change in storage in the control volume (net increased groundwater levels) and likely includes some outflow into Area B spoils.

3.2.4 Scenario 4: Post Mining

Once mining is completed, it is assumed that over time, the post-mining scenario will be very similar to the pre-mining scenario. This will ensue in large part once the dominant hydrologic/hydraulic feature, the EFAC alluvium, fully recovers to pre-mine conditions, and the lateral flux from the bounding strata recovers in response to groundwater level recovery. The latter will occur when groundwater levels of the mine spoils approximate pre-mine water level conditions of the Rosebud coal. Hence, for water budget purposes (and for post mine water quality assessment), the net overall water budget applied to Scenario 4 is assumed to be the same as it was under baseline or pre-mine conditions (Scenario 1).

It is anticipated that there will likely be some difference in flow contribution from mine spoil as compared to the Rosebud coal. That contribution may be higher or lower depending upon the resultant transmissivity of those spoils.

4.0 WATER QUALITY ASSESSMENT

The objectives of this section of the report are the following:

- To utilize the water balance evaluations conducted in Section 3.2 to assist in quantifying the potential impact of mine spoils and other mine operations on water quality in the EFAC control volume.
- To define other potentially relevant factors contributing to the water quality transitions that are observed.

Note that the assessment is applied only to Scenarios 1, 3 and 4 since no meaningful water balance quantification could be applied to the highly transient Scenario 2.

4.1 Scenario 1: Baseline

4.1.1 Alluvial Water Quality

All available baseline total dissolved solids (TDS) concentrations and specific conductance (SC) values for the alluvial groundwater in the water balance area are

listed in Table 3. Pre-mine TDS concentrations in the water balance area range from 1,240 mg/L to 4,320 mg/L. Using the average pre-mine TDS concentration in each well, an overall average pre-mine TDS concentration of 2,299 mg/L was calculated for the alluvial groundwater in the water balance area. Based on the SC values, about half of these pre-mine alluvial groundwater samples are considered Class II (1,000 - 2,500 umhos/cm), whereas the other half can be classified as Class III groundwater (2,500 - 15,000 umhos/cm). The classification of the baseline alluvial groundwater at the P-series wells at the down gradient boundary of the water balance area is:

- P-01: Class II-III
- P-02: Class III
- P-03: Class III
- P-04: Class III
- P-05: Class II

Note that more discussion about EFAC alluvial water quality is given Section 4.2.4.2 of the ABC PHC (NE&W, January 2014).

4.1.2 Surface Water Quality

Due to the ephemeral nature of stream flow in the vicinity of the mine, the surface water quality is highly variable. The flow variability is demonstrated using measurements collected at surface water station SW-55 since 1982 and presented in Figure 9 (Pages 1 through 3). The average baseline EFAC TDS concentration is 1,421 mg/L, with concentrations ranging from 2 to 5,180 mg/L. Van Voast et al. list pre-mine TDS concentrations near SW-55 of 1,840 mg/L, 2,010 mg/L and 2,400 mg/L. Note that these latter values are reasonably consistent with the water quality of the alluvium, indicating that the surface water samples obtained by Van Voast may have been related to base flow or surface expressions of alluvial groundwater.

More surface water quality details for EFAC are discussed in Section 3.2.3.2 of the ABC PHC (NE&W, January 2014). It is noted that the surface water quality is highly variable as would be expected in a stream whose flows are largely dependent upon runoff from precipitation and snowmelt. Figure 10 illustrates the variability of the TDS concentration at SW-55 over time.

4.2 Scenario 3 – Current Mine Conditions

4.2.1 Alluvial Water Quality

The total dissolved solids concentration is a measure of the degree of mineralization of the water. It is generally proportional to the combined concentration of common ions in the water. At Rosebud Mine the common ions present at the highest concentrations in the alluvial and spoils groundwater are sulfate, bicarbonate, calcium and magnesium. For estimating impacts of spoils influenced groundwater on the alluvial water quality, it is reasonable to assume that the concentrations of these constituents will change proportionately to changes in TDS concentrations.

In order to evaluate transitions in water quality over time, TDS time series graphs for active alluvial wells within and upgradient of the EFAC control volume were developed (see Figure 11). Under pre-mine conditions, alluvial groundwater quality was generally Class II or III (see Table 3).

Increases in TDS concentrations are apparent in several of the alluvial wells, including wells up-gradient of mined areas. The pre-mine alluvial well TDS average was defined as 2,299 mg/L. The average of the most recent TDS concentrations available for alluvial wells in the EFAC control volume is 3,309 mg/L. As is the case for pre-mine conditions, the alluvial groundwater is currently Class II or Class III.

Also, chloride levels have increased substantially as well, particularly in the eastern portions of the EFAC control volume vicinity.

Several potential factors were evaluated to assess the transitions in water quality which are observed in EFAC alluvial wells including the following:

- The hydraulic/transport relationship between mine spoils and EFAC alluvium.
- Mine operations, including operation facilities and mine haul roads. With regard to the latter, dust control agents that have been used include magnesium chloride (used historically) and lignin sulfonate (used presently).
- Natural factors.

4.2.2 Evaluation of Mine Spoils versus TDS

Assessment of Figure 11 indicates that TDS concentrations have increased significantly for several of the alluvial wells within the EFAC drainage. The following provides a general conceptual summary of the observations of TDS concentrations in alluvial wells that have a sampling period extending from early 1980 to present.

Downgradient wells (within/near the control volume)

- WA-101 (present TDS concentrations comparable to early 1980s concentrations but possible slight increase). Mining commenced in the vicinity of the well about two years following the first observations.
- WA-126 and WA-128 (exhibiting about 50 percent net increase in TDS concentrations compared to very first observations). Mining commenced in the vicinity of these wells about one year after first observation.
- WA-131 (exhibiting about a 50 percent increase in TDS concentrations compared to very first observations). Mining in the vicinity of this well preceded first observations.
- WA-124 (showing about a 50 percent net increase in TDS concentrations based upon very first observations). Mining began near this well about one year after first observation.

Upgradient (within control volume)

- WA-114 (exhibited increase in concentrations until about 1990. Some increase was observed in 2013).
- WA-104 (showed increases in TDS concentration from prior to 1979 to about 1984, then stabilized concentrations were observed until early 1990s. Mining commenced in the vicinity of this well in southeastern portion of Area C in about 1990. At about the same time, TDS began to decline until about year 2000. Since 2000, TDS concentrations have been relatively stable.

Up-gradient (west, outside of control volume)

- WA-214 and WA-171 (both showed dramatic increases in TDS concentration in the latest sampling event). These wells are sampled once every three years. Note that these wells are up-gradient of any mining activity.
- Well WA-215 (showed stable concentrations in TDS concentration for the period of record). This well is up-gradient of any mining activity.
- WA-118 (showed an increase in TDS concentration of about 50 percent in the latest observation event). This well is up-gradient of any mining activity.

In summary, wells retained for further assessment of the potential significance of mine spoils impacts are: WA-101, WA-104, WA-114, WA-124, WA-126, WA-128 and WA-131; which are adjacent Area A, B and C mining activity.

Generally, groundwater in the alluvium is considered to flow parallel to the primary axis of the EFAC stream alignment (Van Voast, et al, 1977). Hence, a practical means of assessing the potential for spoils water to enter the alluvium is to compare groundwater levels in mine spoils to alluvial groundwater levels. In effect, if spoils groundwater levels are lower than alluvial groundwater levels, groundwater is interpreted to flow from the alluvium into mine spoils deposits. If spoils water levels are higher than the alluvial water levels, then flow may be moving from the spoils into the alluvium. Figure 12 examines this condition for Area B by comparing spoils water levels to alluvial water levels for three sets of wells. Based upon the hydrograph plots, groundwater has tended to flow from the alluvium (southeastward) toward the spoils for most of the period of record.

In order to refine the analysis further, local interpretative water level contour plots were developed and are presented in Figure 13 for the following years: 1995, 2005 and 2013. Those plots demonstrate that during these years, flow from the Area B spoils toward the EFAC alluvium is unlikely. On the other hand, it is interpreted that any groundwater from Area A spoils flows toward the alluvial aquifer for the years evaluated.

Hence, assessment of potential impacts of mine spoils is limited to groundwater flow emanating from Area A spoils.

In order to project the significance of Area A spoils impacted groundwater on the alluvial groundwater under Scenario 3, an idealized representation would be to mix the alluvial groundwater directly with spoils impacted groundwater from Area A. Therefore, a simplified mass balance calculation was used to estimate the approximate percentage increase in TDS concentration at the downstream edge of the control volume assuming spoils influenced groundwater contributions were entering the control volume from Area A.

The average Area A spoils TDS concentration during water years 2011 through 2013 was 3,538 mg/L. TDS concentrations from the following Area A spoils wells were available and used to obtain this average: WS-100, WS-106, WS-107, WS-113, WS-114 and WS-115. The parameters used for this simplified mass balance calculation are as follows:

- Outgoing surface water flow, $\mathbf{Q_{swo}}$ = 0.04 cfs
- Outgoing alluvial groundwater flow, $\mathbf{Q_{a\text{-}out}}$ = 0.14 cfs
- Lateral groundwater contribution from Rosebud Coal/Mine Spoils – Area A= 0.01 cfs with a TDS concentration of 3,538 mg/L.
- The TDS concentration of incoming alluvial groundwater: 2,299 mg/L

For convenience, the recharge contribution was ignored. Again, the primary aim was to see if there is the potential that Area A spoils groundwater explains the transition in water quality observed in the alluvium.

Based on the limiting assumptions made in the above calculation, the percent increase in TDS concentrations in the water exiting the control volume would be approximately three percent assuming that thorough mixing of spoils groundwater with alluvial groundwater had occurred. Given that average alluvial TDS concentrations within the control volume have increased about 34 %, it is interpreted that the influence of Area A spoils groundwater on the observed transition in water quality in the alluvium is very limited.

Exhibit 32

4.2.3 Assessment of Other Potential Factors - TDS

Other facility features and ponds were assessed to determine their potential for impacting groundwater TDS concentrations (see Figure 14).

Facility Features near EFAC

WECo uses Colstrip water for the following purposes:

- Vehicle washing.
- Office and facilities buildings (domestic use and lawn irrigation).
- Cleaning of two transfer houses in Area A.

The combined water use for all these purposes equates to 0.01 cfs from September 2012 to August 2013. The use is not differentiated between these purposes.

The water used for vehicle washing is pumped to two lined lagoons where it evaporates and does not contribute to the groundwater. Hence, these lined ponds are not considered a factor for the water budget or for influencing the water quality of the alluvium.

There is also a drain field serving the Area A offices. The primary effluent parameter associated with drain fields is nitrate nitrogen. The most recent nitrate nitrogen concentrations for active alluvial wells in the area do not indicate any substantial increases. Also, many of wells showing transitions in TDS are located up-gradient of the drain field.

Most irrigation water applied to lawns is consumptively used via evapotranspiration.

Finally, the water used for cleaning the transfer houses in Area A runs to nearby sediment traps.

It is concluded, given the low rates of water use, the fact that portions of this water go to evaporation ponds, lawn irrigation is consumptively transferred to the atmosphere, and domestic water primarily ends up as waste-water directed to an effluent drain field; that the none of the aforementioned features are considered to be a measurable factor in

explaining the transitions in TDS concentrations being observed.

Ponds near EFAC

Figure 14 shows the presence of standing water in ponds adjacent to the EFAC alluvium in 2013. Some recharge from these ponds is anticipated. However, the following are noted:

- In most years, many of these ponds have been dry or contain much less standing water than was observed in 2013.
- Any leakage that occurs from these ponds is limited by the extremely low vertical hydraulic conductivity of the underlying interburden strata.
- Given the interpretations presented in Figure 13, most of the recharge from the Area B ponds will likely flow southward as the spoils are recharged. In this case, little, if any flow, would reach the EFAC alluvium.

Any infiltration from ponds containing water in Area A could reach the alluvium via flux through mine spoils. The ponds in Area A have a limited surface area. Again, many of the observations or transitions in water quality are being observed in the alluvium up-gradient of these ponds. Hence, recharge from the Area A ponds is interpreted as an insignificant factor affecting TDS concentrations in the EFAC alluvial wells aside from prior interpretations set forth in Section 4.2.2.

Finally, standing water in the pits in Area B is not a factor since water from those pits does not flow toward EFAC. Pit water in Area A likely adds recharge water to Area A spoils. Area A spoils groundwater flux toward the EFAC was discussed in Section 4.2.2 (last paragraph).

In summary, it is interpreted that contributions from ponds to the TDS concentrations in the alluvium are very limited, and cannot be used to explain the changes in TDS concentrations being observed in EFAC.

MPDES Discharge Water Quality

MPDES discharge water quality was examined as a potential factor for transitions in TDS concentrations. Water quality data from MPDES discharges within the control volume from 1999 to 2014 exhibited the following TDS characteristics:

Statistic for TDS Concentration (mg/L)	All discharges	Planned Discharges	Unplanned Discharges
Average	1,589	1,724	1,036
Median	1,210	1,780	793
Range	394 – 3,840	700 – 3,840	394 - 3,360
Standard Deviation	798	746	792

As described in Section 3.2.3.2 of the PHC the majority of MPDES discharges at Rosebud Mine are planned. Unplanned discharges typically occur as a result of precipitation events in excess of the 10 year 24 hour design storm. Using flow data obtained from the 2011 through 2014 Rosebud Mine Annual Hydrology Reports it can be estimated that about 25 percent of the total volume of MPDES discharge during this period was unplanned. Given that three of the ten wettest years on record occurred during this period (Colstrip weather station data, 1948 - 2014), it is reasonable to assume that the proportion of unplanned discharges is usually lower than 25 percent. However, even if all discharges were planned, the average and median TDS concentration in MPDES discharges in the water balance area (1,724 and 1,780 mg/L) is still well below the average baseline alluvial TDS concentration of 2,299 mg/L. Hence, there is no basis to conclude that TDS in MPDES discharges is responsible for the increases being observed in the EFAC control volume.

Increases in Alluvial Groundwater Levels

Another potential factor that must be considered for the increases in TDS concentrations includes temporal increases in water levels, especially if those water levels are anomalously high compared to baseline conditions. TDS concentration increases have been observed in relatively shallow observation wells throughout Montana, including the Powder River Basin, since 2011 as a result of well above average precipitation, runoff and recharge According to Mr. John Wheaton of the Montana Bureau of Mines and Geology (MBMG): "The concept is well known and often discussed" [email correspondence 2/24/15 between NE&W and the MBMG].

More specifically, as it relates to the EFAC, TDS concentrations are responsive to water level changes in the alluvium. Figure 15 provides a compelling presentation of the influence of water levels in the EFAC alluvium versus TDS concentrations. When water levels increase, TDS concentrations tend to increase. When water levels decline, TDS concentrations tend to decrease. This relative rate of response is variable but a pattern is clearly present as set forth in this figure. Some examples and other interesting observations include the following:

- WA-118: TDS concentrations rose and fell in concert with the changes in water levels. This well is located more than one mile up-gradient of any mining activity. Mining is not a factor influencing TDS concentrations in this alluvial well.
- WA-104: TDS concentrations rose and fell in concert with the changes in water levels. Some of the earlier transitions pre-date any mining in its vicinity.
- WA-128: This well showed a similar pattern as others. A notable anomaly in this pattern was observed in about water year 2000. This temporal decline in TDS is deemed to be associated with MPDES discharges which consisted of water of relatively low TDS.

It is apparent that increasing water levels are the best explanation, and the dominant factor, for the recent higher TDS concentrations observed in the EFAC alluvium. The increases in the eastern portion of the EFAC control volume are due to recharge that

consists of natural recharge combined with recharge from MPDES discharges that occur over an extended period of time. Note that precipitation and runoff, and MPDES discharges have been anomalously above average since 2011. In other cases, substantial water level increases began well before 2011 (see Figure 15).

4.2.4 Chloride Concentration Observations

Section 4.2.4.2 of the PHC discusses disproportionate increases in chloride concentrations observed in selected alluvial wells near the Area A facilities. According to the PHC, a potential source of chloride is magnesium chloride which was used as a mine dust control agent until recently. Also, the same compound was used as a dust control agent by the county on the gravel roads in the area.

The highest concentrations of chloride observed in the alluvial groundwater are primarily found at the P-series wells (see Figure 16). Note that time series in Figure 16 were updated with data through the end of water year 2014. It is likely that runoff from roads, and collection of runoff water in sediment ponds, followed by infiltration led to magnesium chloride being transported into the underlying alluvium. This is likely the primary factor leading to the increases in chloride concentration that have been observed.

Recently, the mine has ceased using magnesium chloride as a dust control agent and replaced it with lignin sulfonate (see Attachment 3).

The time series plots provided in Figure 16 indicate that one alluvial well, P-04, and possibly well P-03, has/have shown indications of pending peaking in chloride concentrations. More monitoring over the long-term is required before this can conclusively ascertained.

Once peaking occurs, and there are some indications this is pending in the near future, chloride concentrations will gradually attenuate with time. Such attenuation will depend upon a number of factors including: infiltration rates, mass of magnesium chloride present in the unsaturated zone, variations in groundwater levels, etc. It is not practical to predict the rate of attenuation once peaking occurs.

4.3 Scenario 4 – Future Conditions

Projections for alluvial water quality for the future are predicated on the following assumptions:

- Assumption 1: The overall water budget for the EFAC alluvium will be similar to pre-mine conditions. In other words, it is assumed that the groundwater flux from the mine spoils to the EFAC alluvium will be similar to estimated historical contributions from the Rosebud coal. Some justification for this assumption is provided by Van Voast et al. (1977). They found that in general the ranges of hydraulic conductivity values in the Rosebud coal and spoils are similar. If the water levels in the spoils eventually recover to pre-mine levels, as is generally assumed, the magnitude of the incoming flow of groundwater into the alluvium from bounding strata is projected to be comparable to pre-mine estimates.
- Assumption 2: The average spoils TDS concentration will be similar to the one associated with equilibrium concentrations defined at existing spoils wells. PHC section 4.2.4.2 presents a discussion of spoils groundwater quality for data collected from 1979 to 2011. The available data were collected at spoils wells throughout the mine (PHC Figures 29A and 29B). Given the number of spoils wells and the areal distribution of these wells throughout the mine, it is reasonable to assume that the data collected to date are a good indicator of future water quality transitions. Though it is apparent that spoils groundwater quality is highly variable, it is reasonable to assume that average TDS equilibrium concentration observed at present will be similar to average TDS equilibrium concentration in the future.

Based upon Assumption 1, the water budget scenario for Scenario 1 (Figure 5) was employed for projecting future water quality in the EFAC alluvium.

In order to address Assumption 2, groundwater quality data collected from spoils wells

in Areas A, B, and C was evaluated. If a spoils monitoring well showed less than a 10 % change in TDS concentration in the last 10 years, it was assumed to exhibit equilibrium concentrations. The average equilibrium concentration was determined to be 4,360 mg/L. Table 4 provides more detailed information on how this estimate was obtained. To further investigate the validity of Assumption 2, an average spoils TDS equilibrium concentration was calculated including data from Area D and E wells using the same method (data not shown). This concentration was found to be nearly identical to the estimate obtained from the data in Table 4.

The incoming and outgoing groundwater quantity and quality (TDS) were assigned as follows:

- $\mathbf{Q_{lat\text{-}in}} * C_{l\text{-}in}$ = 0.023 cfs * $C_{l\text{-}in}$ (with $C_{l\text{-}in}$ = 4,360 mg/L)
- $(\mathbf{Q_{a\text{-}out}} + \mathbf{Q_{swo}}) * C_{a\text{-}s}$ = 0.158 cfs * $C_{a\text{-}s}$ (with $C_{a\text{-}s}$ unknown)
- $(\mathbf{Q_{a\text{-}in}} + \mathbf{Q_r}) * C_{a\text{-}r}$ = 0.135 cfs * $C_{a\text{-}r}$ (with $C_{a\text{-}r}$ = 2,299 mg/L)

Refer to Figure 5 for the baseline flows. Note that baseline surface water outflow, $\mathbf{Q_{swo}}$, and alluvial groundwater outflow, $\mathbf{Q_{a\text{-}out}}$, are assumed to possess the same TDS concentration, $C_{a\text{-}s}$ (unknown). Similarly, the incoming alluvial groundwater, $\mathbf{Q_{a\text{-}in}}$, and the areal recharge water, $\mathbf{Q_r}$, are assumed to possess the same concentration, $C_{a\text{-}r}$. The TDS concentration for the spoils, $C_{lat\text{-}in}$, is applied to the projected flow of spoil groundwater (from Areas A and B).

- Solving for $C_{a\text{-}s}$ yields a TDS concentration of 2,599 mg/L which represents a thirteen percent increase in TDS concentration. Again, it is reemphasized that this is a prediction of post-mine conditions based upon the reestablishment of equilibrium flow. The rate, or point in time, that this net increase is reached is impractical to predict. However, that time frame likely involves several decades after mining in Area A and B ceases.
- Again, it is reiterated that similar increases should be anticipated for the other parameters such as sulfate, bicarbonate, calcium and magnesium which are the most common ions that define TDS concentrations.

Presently, most of the alluvial groundwater under baseline conditions is classified as Class II or Class III. Based upon water quality projections set forth above, the classification of the alluvial groundwater in EFAC will remain Class II or Class III.

5.0 SUMMARY AND CONCLUSIONS

A water balance evaluation was conducted for the following purposes:

- Provide a quantitative understanding of the hydrologic factors that explain flow conditions in the reach of EFAC between Areas A, B, and C.
- Provide an assessment of factors that are currently affecting the water quality of the groundwater in the EFAC alluvium. Transitions in TDS and chloride levels are apparent in several alluvial wells in the EFAC.
- Assess future or probable hydrologic consequences that are anticipated to occur in the vicinity of EFAC.

Based upon the above evaluation, the following are the conclusions that are drawn:

- Groundwater levels or alluvial aquifer storage under pre-mine conditions were primarily dependent upon a recharge associated with major precipitation/snowmelt runoff events.
- Generally, flow in the EFAC between Area A and B was very limited under normal climatic conditions. Surface water base flow was typically of short duration except following recharge events associated with precipitation/snowmelt runoff.
- Mining has affected water levels in the alluvium in two ways. One way is that groundwater was drawn from the alluvium during mining in close proximity to the alluvial aquifer system. The second way is that when well above average precipitation and significant runoff occurs, surface water is detained/retained in mine pits and ponds to control sediment and runoff in accordance with MPDES permitting requirements. When water ponds and pits discharges to the EFAC channel over extended periods of time, increased rates of recharge occur. These increases have led to higher groundwater levels in EFAC alluvium. In some cases, these increases result in groundwater levels that exceed pre-mine levels.

- The present water quality transitions as measured by TDS in the EFAC alluvium are dominated by changes in alluvial water levels. These transitions occur in the EFAC alluvium in the EFAC control volume reach between Areas A, B, and C and in EFAC areas up-gradient and out of the influence of the Rosebud Mine.
- Other much less significant factors for TDS transitions include groundwater flow from mine spoils, pits, ponds and facility features.
- The transport of groundwater containing higher TDS concentrations will increase with time as groundwater levels in spoils recover toward pre-mine conditions in both Areas A and B. Once those water levels fully recover, it is estimated that the increase in TDS in the alluvium will be about 13 percent when compared to baseline conditions.
- Changes in chloride concentrations, especially those observed in the eastern section of the EFAC control volume are probably explained by the use of magnesium chloride as a dust control agent at the mine. The historic use of magnesium chloride as a dust control agent for the county road may be a factor as well. Recently, the mine has ceased using magnesium chloride and presently uses lignin sulfonate as a dust control agent.

Finally, as a point of emphasis, it is noted this is a highly complex natural system. Hence, the water budget and water quality calculations applied to pre-mine, current and post-mine conditions are predicated on a series of assumptions.

6.0 REFERENCES

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Table 1
Input Variables and Assumptions Used for Groundwater Flow Calculations
ABC PHC Addendum

Basic Scenario	Flow Estimated	Hydraulic Gradient dh/dx (ft/ft)	Hydraulic Conductivity k (ft/day)	Transmissivity (ft^2/day)	Saturated depth (ft) (a)	Saturated Area A (ft^2) (f)	Flow Q (ft^3/s)	Flow Q (gpm)
Scenario 1	Pre-Mine $Q_{alluvium\ OUT}$ (a) (b) (f)	0.00568	160	1900	11.875	13200	0.139	62.3
Scenario 1	Pre-Mine $Q_{alluvium\ IN}$ (c)	0.00669	160	-	-	8250	0.102	45.9
Scenario 3	2013 $Q_{alluvium\ OUT}$ (d) (f)	0.00571	160	1900	11.875	13200	0.140	62.6
Scenario 3	2013 $Q_{alluvium\ IN}$ (e)	0.00572	160	-	-	5730	0.061	27.3

Notes
(a) Quantified on the basis of information from Van Voast, et al (1977).
(b) The hydraulic gradient was calculated based on water levels both upstream (WA-100) and downstream (P-11) from the water balance boundary. Note that well P-11 was used in the original calculations by Van Voast, et al (1977).
(c) The hydraulic gradient was calculated based on availabe alluvial water levels upgradient (WA-122) and downgradient (P-03) from the water balance boundary. The hydraulic conductivity of the gravel was assumed to be the same as at the downgradient location.
(d) The hydraulic gradient was calculated based on available water levels in WA-100 (upgradient) and P-03. WA-100 is closest to historical well WA-114 (see (b)). No close downgradient alluvial water levels were available.
(e) The hydraulic gradient was calculated based on available water levels at WA-104 and WA-114 (downgradient). No close upgradient alluvial water levels were available.
(f) Note that water bearing zone remains constant at the downstream end because of a shallow confining clay layer being present.

Table 2
Private Alluvial Groundwater Wells in Water Balance Area (a)
ABC PHC Addendum

GWIC ID	Stratum	Type	Total Depth (ft)	screening interval (ft)	Max Flow Rate (cfs)	Year Completed	Owner	DNRC Water Right Number
11977	possibly partly alluvium	Unknown	140	40-140	-	1982	Western Energy Company	
11978	bottom of well in alluvial gravel, no screen	Stockwater	38	no screen	0.022	1982	Western Energy Company / Booth Land and Livestock	42KJ 52504 00
12003	possibly alluvium	Stockwater or Domestic	50	no info	0.033	1947	Farleys Inc	
11999	alluvium, partly screened in gravel	Stockwater	84	40-84	0.022	1974	Western Energy Company	42KJ 52532 00

Notes
(a) From GWIC database and DNRC website, monitoring wells are not included.

Table 3
Pre-Mine Alluvial TDS Concentrations and Specific Conductance Measurements in Water Balance Area
ABC PHC Addendum

Station ID	Sample Date	TDS (mg/L)	SC (umhos/cm)	Average TDS per Well (mg/L)	Nearby Mining
P-01	7/12/1974	1790	2220		1977, 0.16 miles, hydrograph shows no response until about 1979
P-01	5/16/1975	1990	2460		1977, 0.16 miles, hydrograph shows no response until about 1979
P-01	7/20/1977	1982	2505	2395	1977, 0.16 miles, hydrograph shows no response until about 1979
P-02	4/15/1975	2190	2670	2670	1977, 0.20 miles, hydrograph shows no response until about 1979
P-03	5/16/1975	2380	2820		1977, mining 0.25 miles away, hydrograph shows no response until about 1979-1980
P-03	4/6/1976	2410	2900	2395	1977, mining 0.25 miles away, hydrograph shows no response until about 1979-1980
P-04	5/16/1975	2600	3040		1976, mining 0.23 miles away, hydrograph shows no response until about 1979
P-04	11/18/1976	2639	3138	2620	1976, mining 0.23 miles away, hydrograph shows no response until about 1979
P-05	5/16/1975	2000	2470	2000	1976, mining 0.22 miles away, hydrograph shows no response until about 1979
WA-102	9/9/1981	1330	1720		1995, mining 0.11 miles away
WA-102	1/28/1987	1240	1490	1285	1995, mining 0.11 miles away
WA-103	11/15/1979	1380	1690		1995, mining 0.15 miles away
WA-103	3/11/1980	1420	1680		1995, mining 0.15 miles away
WA-103	5/22/1980	1370	1740		1995, mining 0.15 miles away
WA-103	5/5/1982	2630	2920		1995, mining 0.15 miles away
WA-103	12/9/1983	3670	3810		1995, mining 0.15 miles away
WA-103	11/14/1984	4010	4000		1995, mining 0.15 miles away
WA-103	1/28/1987	4320	3800		1995, mining 0.15 miles away
WA-103	6/13/1990	4260	4640		1995, mining 0.15 miles away
WA-103	9/9/1992	4310	4190		1995, mining 0.15 miles away
WA-103	5/18/1994	3540	3430	3091	1995, mining 0.15 miles away
WA-104	11/15/1979	1650	1950		1995, mining 0.20 miles away
WA-104	3/11/1980	1840	2050		1995, mining 0.20 miles away
WA-104	5/22/1980	1800	2150		1995, mining 0.20 miles away
WA-104	5/5/1982	2430	2790		1995, mining 0.20 miles away
WA-104	12/9/1983	3170	3370		1995, mining 0.20 miles away
WA-104	11/14/1984	3406	3530		1995, mining 0.20 miles away
WA-104	1/28/1987	3650	3220		1995, mining 0.20 miles away
WA-104	6/14/1990	3610	4040		1995, mining 0.20 miles away
WA-104	9/9/1992	3530	3550		1995, mining 0.20 miles away
WA-104	5/18/1994	2940	2980	2803	1995, mining 0.20 miles away

Table 3
Pre-Mine Alluvial TDS Concentrations and Specific Conductance Measurements in Water Balance Area
ABC PHC Addendum

Station ID	Sample Date	TDS (mg/L)	SC (umhos/cm)	Average TDS per Well (mg/L)	Nearby Mining
WA-105	8/3/1979	1350	1670		1995, mining 0.23 miles away
WA-105	11/15/1979	1460	1790		1995, mining 0.23 miles away
WA-105	12/19/1979	1460	1790		1995, mining 0.23 miles away
WA-105	3/11/1980	1670	1850		1995, mining 0.23 miles away
WA-105	5/22/1980	1590	1900		1995, mining 0.23 miles away
WA-105	3/23/1981	1700	2130		1995, mining 0.23 miles away
WA-105	8/31/1981	2000	2320		1995, mining 0.23 miles away
WA-105	5/5/1982	2270	2560		1995, mining 0.23 miles away
WA-105	12/9/1983	2900	3110		1995, mining 0.23 miles away
WA-105	11/14/1984	3134	3240		1995, mining 0.23 miles away
WA-105	1/28/1987	3500	3330		1995, mining 0.23 miles away
WA-105	6/14/1990	3460	3850		1995, mining 0.23 miles away
WA-105	9/9/1992	3310	3420		1995, mining 0.23 miles away
WA-105	9/15/1993	1970	2480		1995, mining 0.23 miles away
WA-105	8/30/1994	2780	3220	2304	1995, mining 0.23 miles away
WA-106	11/15/1979	2510	2590		1989, mining 0.28 miles away
WA-106	2/21/1980	2340	2480		1989, mining 0.28 miles away
WA-106	5/22/1980	2170	2410		1989, mining 0.28 miles away
WA-106	8/28/1981	2100	2370		1989, mining 0.28 miles away
WA-106	5/3/1982	2260	2610		1989, mining 0.28 miles away
WA-106	12/16/1983	2260	2500		1989, mining 0.28 miles away
WA-106	11/14/1984	2350	2620		1989, mining 0.28 miles away
WA-106	1/28/1987	2810	2400	2350	1989, mining 0.28 miles away
WA-114	5/6/1982	1380	1770	1380	1983, mining 0.11 miles away
Average		2477	2716	**2299**	
Median		2340	2590	2395	
Minimum		1240	1490		
Maximum		4320	4640		
St. Dev.		865	757		
No. Samples		55	55		

Table 4
Determination of TDS Concentration in Spoils at Equilibrium (a)
ABC PHC Addendum

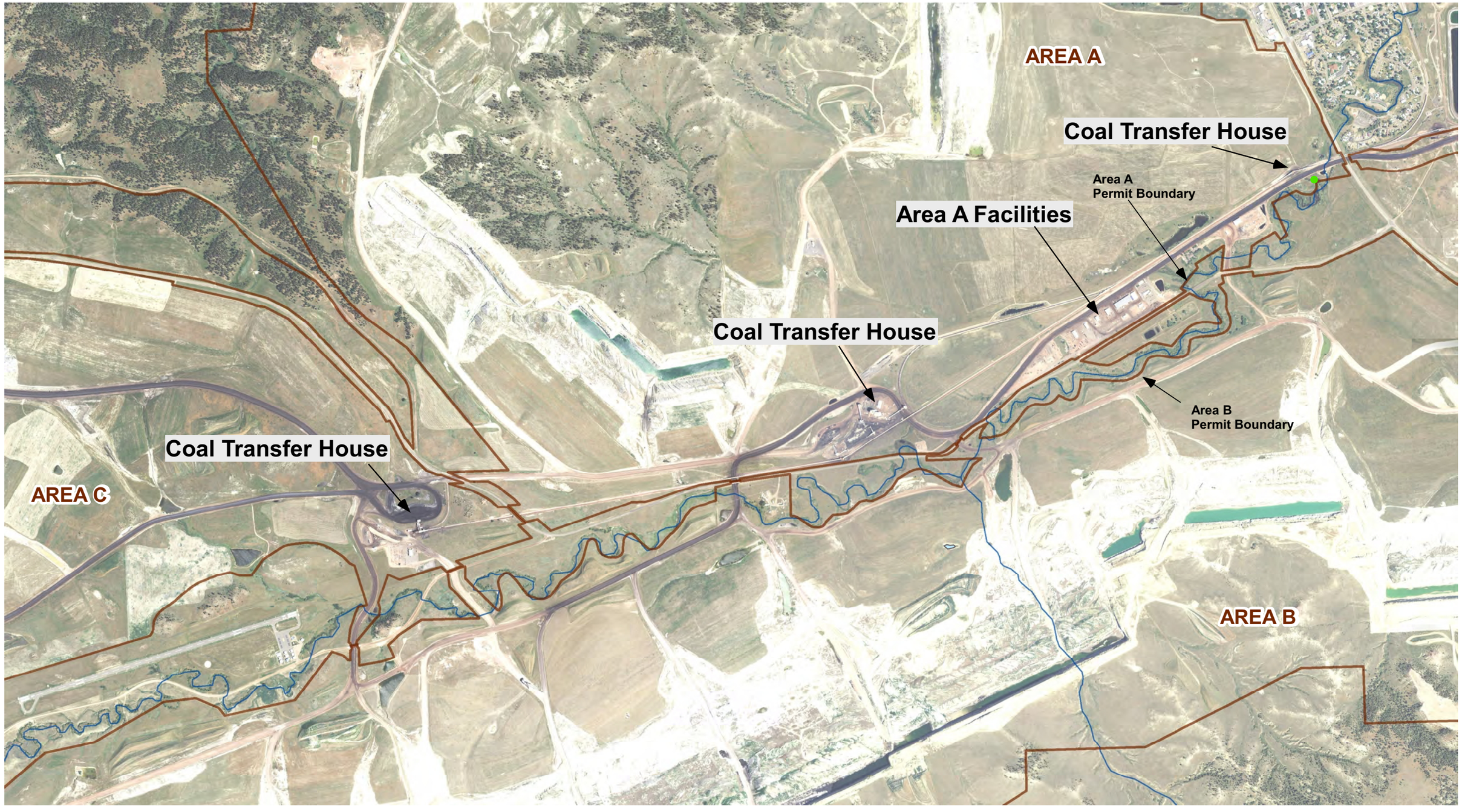
Area	Station ID	First Sample		Sample 1 (b)		Sample 2 (c)		Number of Years Between 1 and 2	Percent Change from 1 to 2	Equili-brium?	TDS (mg/L)
		Date	TDS (mg/L)	Date	TDS (mg/L)	Date	TDS (mg/L)				
A	WS-100	10/1/1981	3130	4/16/2014	5850	8/23/2006	3530	7.6	66%	no	
A	WS-101	6/18/1982	6710	5/14/1987	6120			not enough data		unknown	
A	WS-105	10/30/1989	1800					not enough data		unknown	
A	WS-106	12/20/1979	2930	9/26/2013	3200	8/10/2004	3040	9.1	5%	***yes***	3040
A	WS-107	10/17/1983	2700	9/21/2011	1510	8/26/2002	1660	9.1	-9%	***yes***	1660
A	WS-113	9/22/1983	3660	9/26/2013	5000	8/10/2004	3910	9.1	28%	no	
A	WS-114	7/18/1984	3610	9/21/2011	1270	8/26/2002	3590	9.1	-65%	no	
A	WS-115	8/16/1984	3170	4/16/2014	4240	8/24/2006	3690	7.6	15%	no	
B	WS-118	8/5/1982	1690	9/19/2012	2350	8/21/2003	2310	9.1	2%	***yes***	2310
C	WS-121	8/4/1998	2150	9/25/2013	6420	8/11/2004	7130	9.1	-10%	***yes***	7130
B	WS-157	8/17/1982	2400	9/21/2011	2670	8/27/2002	2280	9.1	17%	no	
B	WS-158	11/30/1983	5520	9/19/2012	8030	8/21/2003	8170	9.1	-2%	***yes***	8170
B	WS-159	9/10/1998	3780	9/26/2013	4220	8/10/2004	3850	9.1	10%	***yes***	3850
B	WS-184	8/29/1985	1340	9/21/2011	2350	8/28/2002	1970	9.1	19%	no	
									Average Equilibrium		***4360***

Note

(a) All spoils wells in the EFAC drainage in Areas A, B or C for which water quality data are available were evaluated. Data through April 2014 were used.

(b) Sample 1: Most Recent Sample

(c) Sample 2: Sample taken approximately 10 years prior to Sample 1.



NICKLIN
EARTH & WATER, INC.

0 1,100 2,200 Feet

Date: 1/23/15 Name: F01 - Site Map.cvx

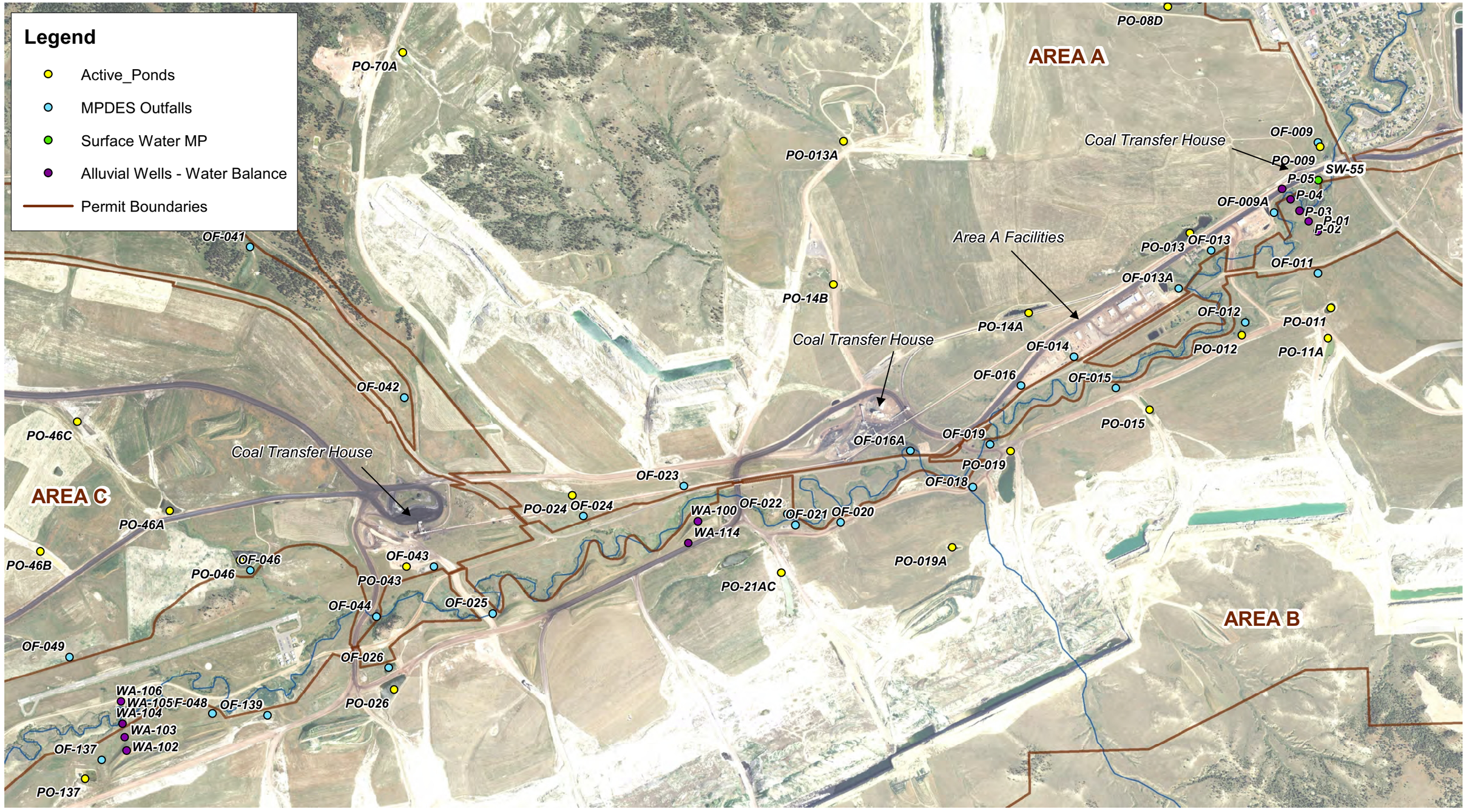
N

Notes:
1) Aerial Photographs: 2013 NAIP

WESTERN ENERGY COMPANY Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 1
Site Vicinity Map
ABC PHC Addendum

Exhibit 32



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EARTH & WATER, INC.

0 1,100 2,200 Feet

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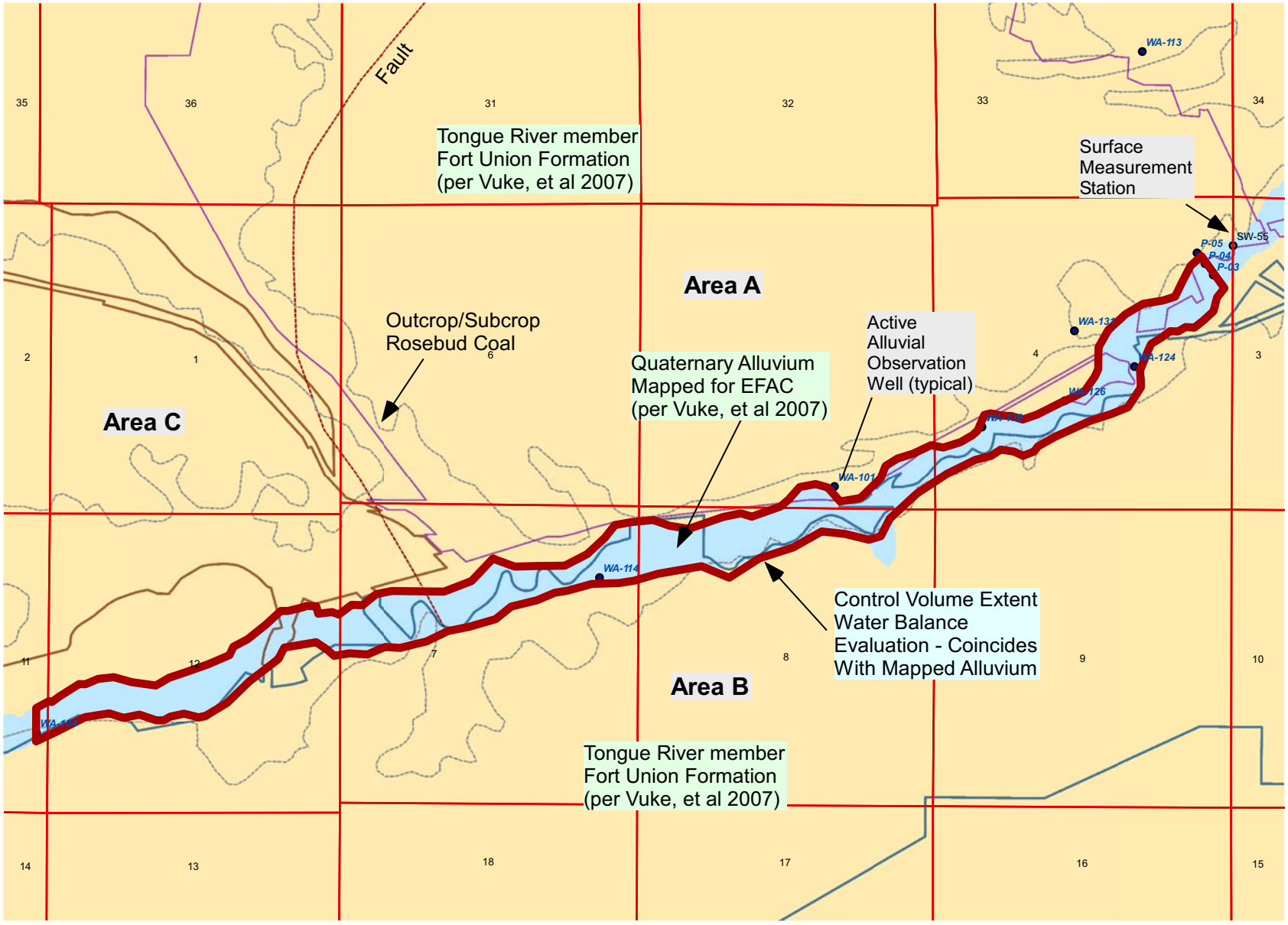
Notes:
1) Aerial Photographs: 2013 NAIP

WESTERN ENERGY COMPANY Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 2
Site Details Map
ABC PHC Addendum

Date: 1/23/2015 Name: Figure 2 - Site Details Map.cvx

Exhibit 32



Scale not indicated

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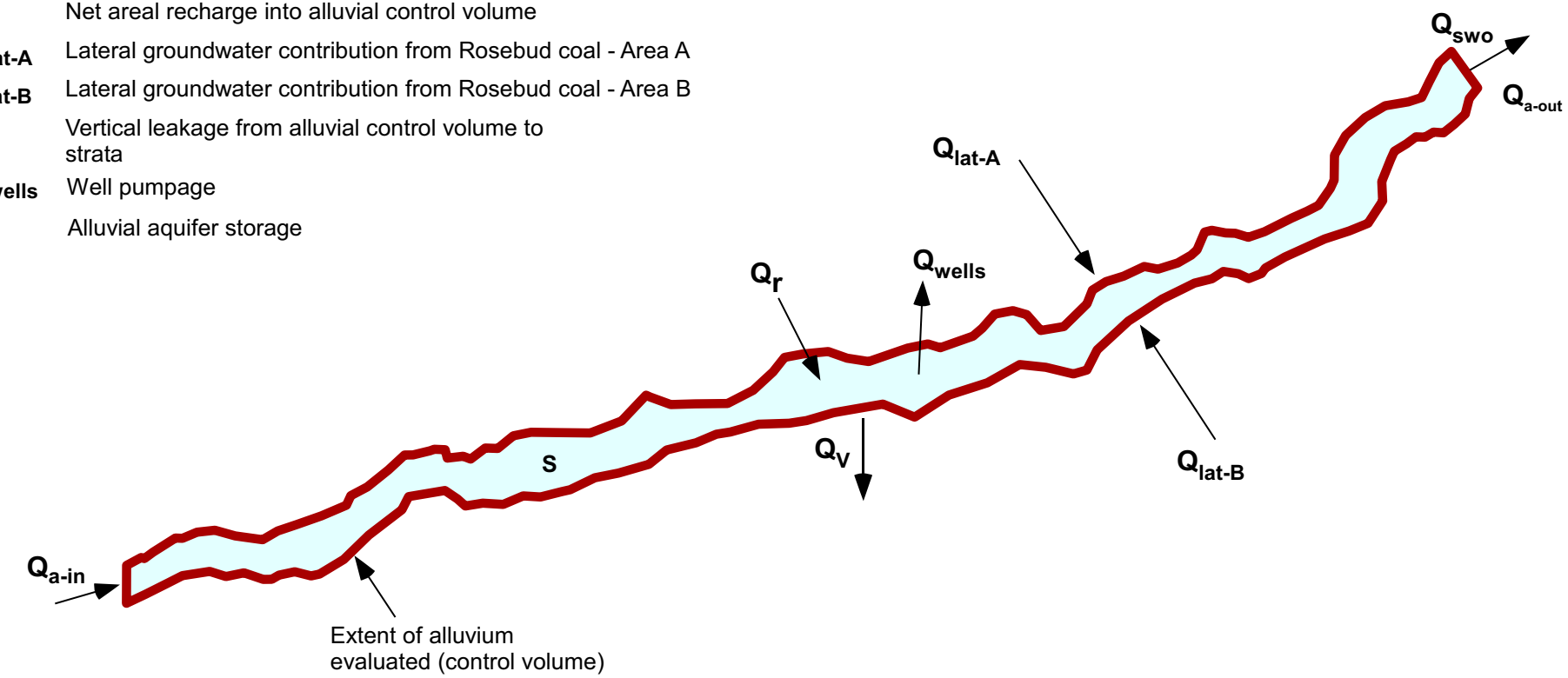
Date: 01/23/15 Name: Figure 03 - geology and wb control volume.cvx

Figure 3
Geologic Mapping
Vicinity of East Fork Armells Creek

Exhibit 32

Legend

$Q_{a\text{-}in}$	Alluvial groundwater flow into control volume
$Q_{a\text{-}out}$	Alluvial groundwater flow out of control volume
Q_{swo}	Surface water flow out of alluvial control volume
Q_r	Net areal recharge into alluvial control volume
$Q_{lat\text{-}A}$	Lateral groundwater contribution from Rosebud coal - Area A
$Q_{lat\text{-}B}$	Lateral groundwater contribution from Rosebud coal - Area B
Q_V	Vertical leakage from alluvial control volume to strata
Q_{wells}	Well pumpage
S	Alluvial aquifer storage



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Scale not indicated

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Figure 4
Alluvial Control Volume
Vicinity of East Fork Armells Creek

Date: 01/23/15 Name: Figure 04 - alluvial control volume.cvx

Exhibit 32

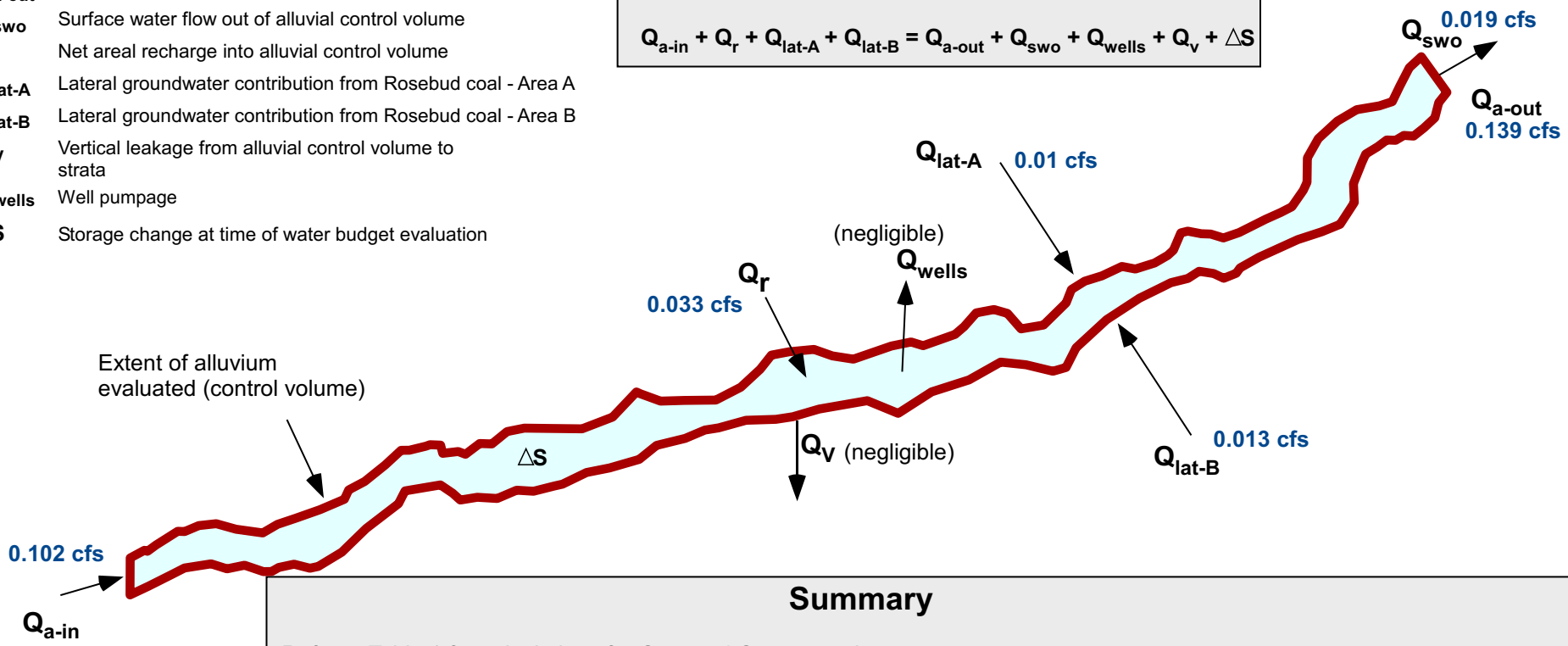
Legend

$Q_{a\text{-}in}$	Alluvial groundwater flow into control volume
$Q_{a\text{-}out}$	Alluvial groundwater flow out of control volume
Q_{swo}	Surface water flow out of alluvial control volume
Q_r	Net areal recharge into alluvial control volume
$Q_{lat\text{-}A}$	Lateral groundwater contribution from Rosebud coal - Area A
$Q_{lat\text{-}B}$	Lateral groundwater contribution from Rosebud coal - Area B
Q_V	Vertical leakage from alluvial control volume to strata
Q_{wells}	Well pumpage
$\triangle S$	Storage change at time of water budget evaluation

Water budget Equation

$$Q_{in} = Q_{out} + \triangle S \text{ or}$$

$$Q_{a\text{-}in} + Q_r + Q_{lat\text{-}A} + Q_{lat\text{-}B} = Q_{a\text{-}out} + Q_{swo} + Q_{wells} + Q_v + \triangle S$$



Summary

Refer to Table 1 for calculations for $Q_{a\text{-}in}$ and $Q_{a\text{-}out}$ premine.

(1) The net recharge, Q_r, is assigned by assuming 5 % of average annual precipitation over the area of the control volume infiltrates into the underlying alluvial aquifer.

(2) The lateral flow contributions, $Q_{lat\text{-}A}$ and $Q_{lat\text{-}B}$ are defined based upon estimates provided in Van Voast, et al which were updated using a higher transmissivity for the Rosebud coal as calibrated in the Rosebud Mine groundwater model.

(3) Little groundwater use was documented in the control volume (see Figure 6 for details). Hence, extractions by wells, Q_{wells} were assumed to be negligible.

(4) The Tongue River member strata possesses very low vertical hydraulic conductivities. Hence, vertical flow out of the control volume, Q_v, was considered negligible.

(5) The surface flow out, Q_{swo}, was calculated using the above equation under the assumption that no transient changes in water levels or changes in storage were occurring for the baseline period represented.

N

Scale not indicated

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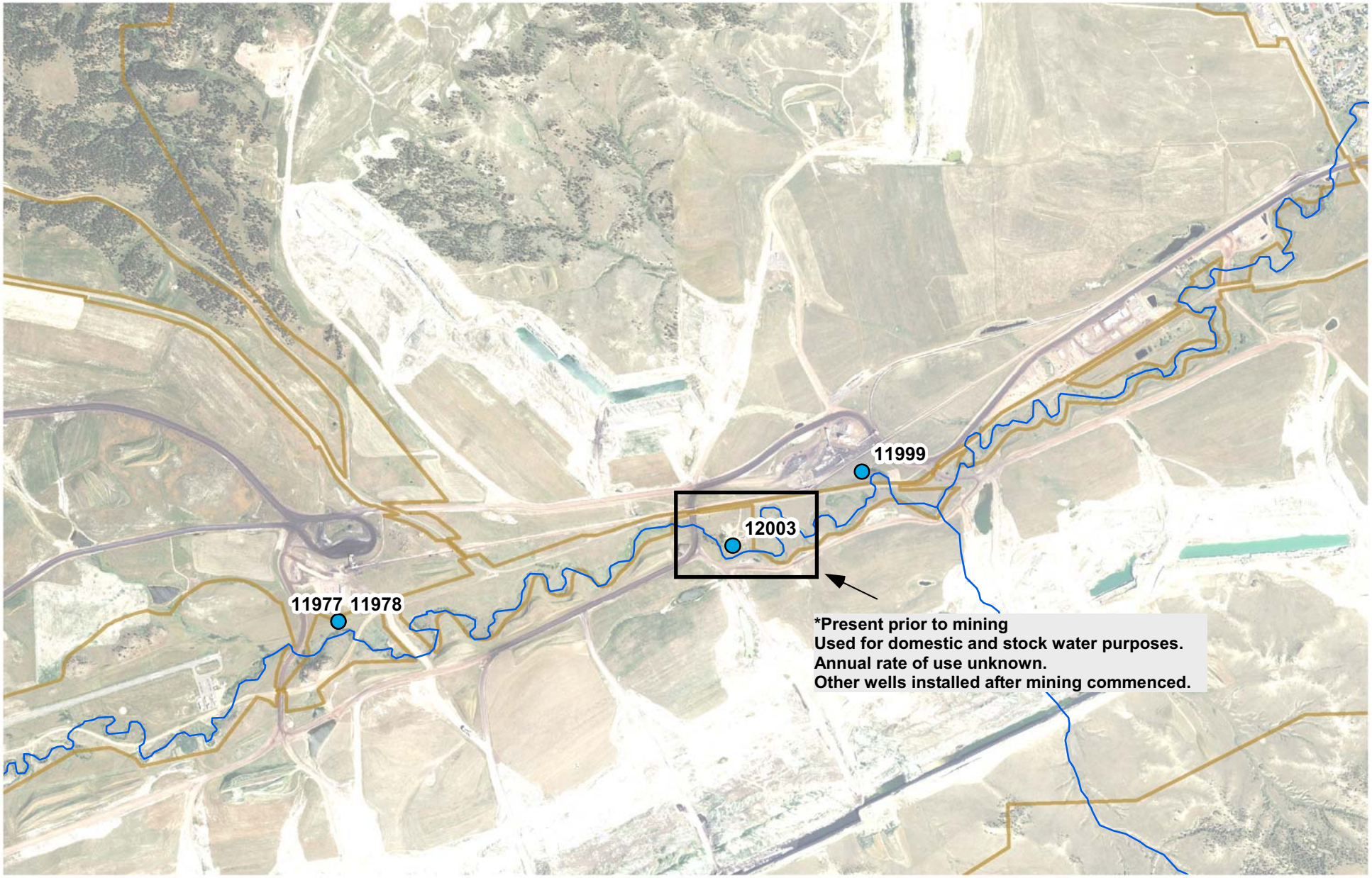
Figure 5
Scenario 1 - Alluvial Control Volume
Vicinity of East Fork Armells Creek

Date: 01/23/15 Name: Figure 05 - Scenario 1.cvx

Exhibit 32



Wells identified in Montana Bureau of Mines and Geology - Groundwater Information Center

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0 1,000 2,000 Feet

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Notes:
1) Aerial Photographs: 2013 NAIP

Date: 1/23/2015 Name: Figure 6 - Private Alluvial Wells

Figure 6
Private Alluvial Wells

Exhibit 32

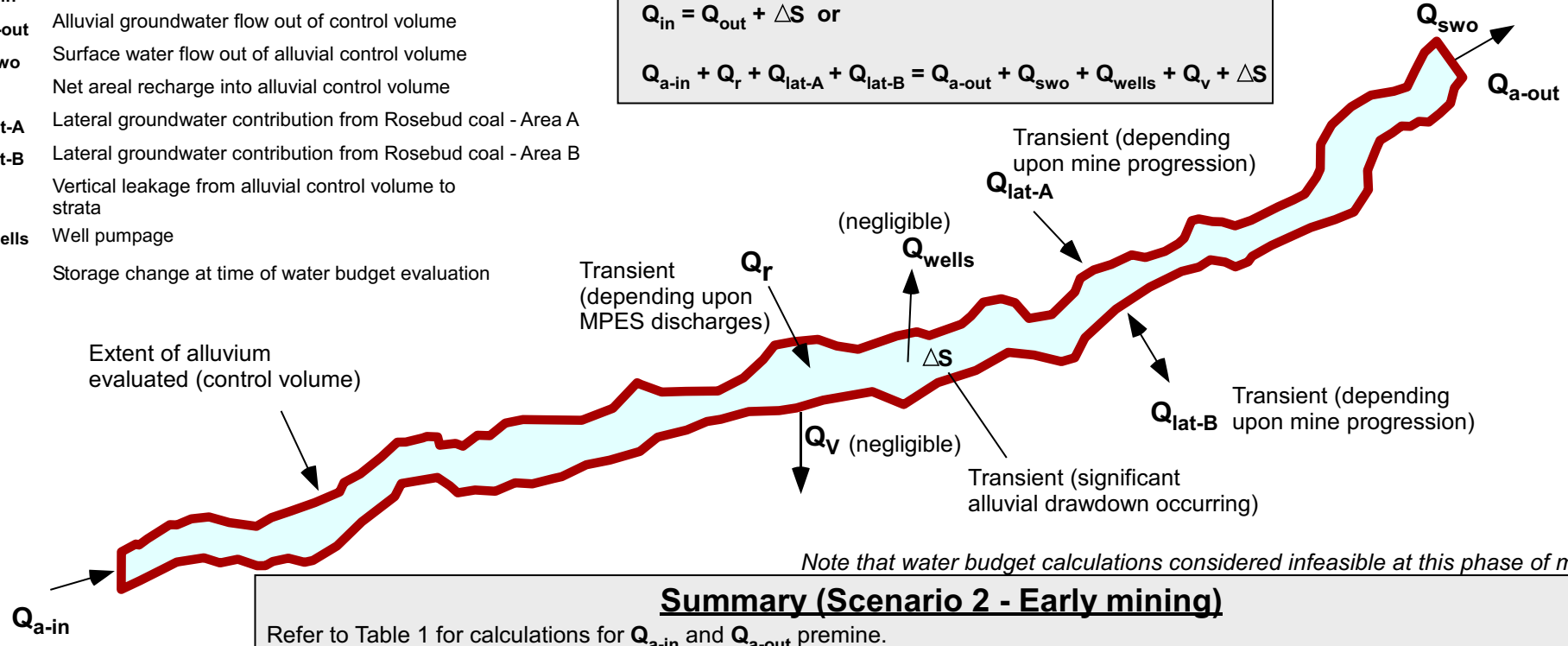
Legend

$Q_{a\text{-}in}$	Alluvial groundwater flow into control volume
$Q_{a\text{-}out}$	Alluvial groundwater flow out of control volume
Q_{swo}	Surface water flow out of alluvial control volume
Q_r	Net areal recharge into alluvial control volume
$Q_{lat\text{-}A}$	Lateral groundwater contribution from Rosebud coal - Area A
$Q_{lat\text{-}B}$	Lateral groundwater contribution from Rosebud coal - Area B
Q_V	Vertical leakage from alluvial control volume to strata
Q_{wells}	Well pumpage
$\triangle S$	Storage change at time of water budget evaluation

Water budget Equation

$$Q_{in} = Q_{out} + \triangle S \text{ or}$$

$$Q_{a\text{-}in} + Q_r + Q_{lat\text{-}A} + Q_{lat\text{-}B} = Q_{a\text{-}out} + Q_{swo} + Q_{wells} + Q_v + \triangle S$$



Note that water budget calculations considered infeasible at this phase of mining.

Summary (Scenario 2 - Early mining)

Refer to Table 1 for calculations for $Q_{a\text{-}in}$ and $Q_{a\text{-}out}$ premine.

(1) The net background recharge, Q_r, is assumed as the same at `the baseline contribution. In addition, there are likely MDPES dis charges that occurred during this scenario which acted as a source of recharge. Thus, recharge would be highly dependent upon this source of recharge when it occurred.

(2) The lateral flow contributions, $Q_{lat\text{-}A}$ and $Q_{lat\text{-}B}$ would vary as mining progressed, especially when mining was conducted near/adjacent to the alluvium. It is likely that in the case of $Q_{lat\text{-}B}$ that substantial net flow was induced out of the southern boundary of the control volume. The mining sequencing, or its proximity to mining has varied over time. Hence, these vari ables have been highly transient.

(3) Little groundwater use is documented in the control volume (see Figure 6 for details). Hence, extractions by wells, Q_{wells} were assumed to be negligible.

(4) The Tongue River member strata possesses very low vertical hydraulic conductivities. Hence, vertical flow out of the control volume, Q_v, was considered negligible.

(5) Q_{swo} during the early mine phase was likely less than baseline under normal climate conditions because of overall alluvial aquifer drawdown.

N

Scale not indicated

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Figure 7
Scenario 2 - Alluvial Control Volume
Vicinity of East Fork Armells Creek

Date: 01/23/15 Name: Figure 07 - Scenario 1.cvx

Exhibit 32

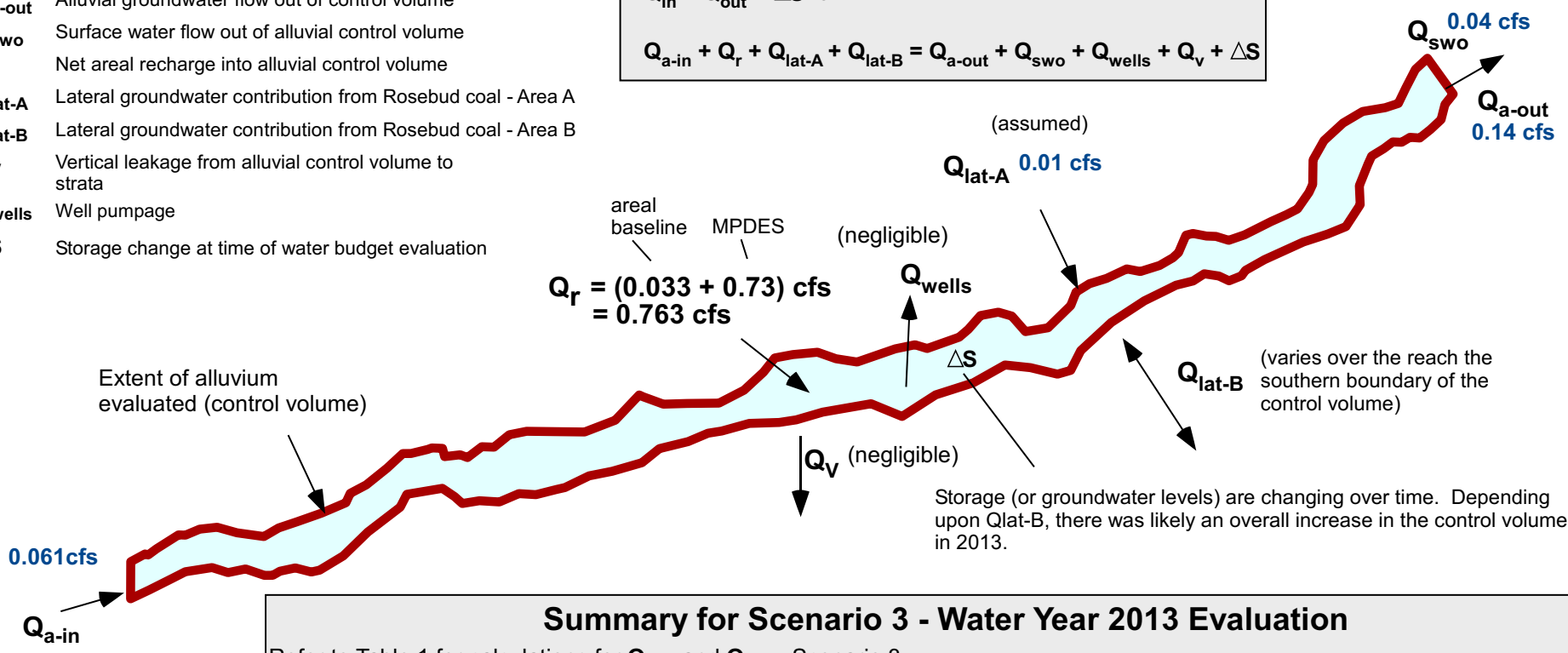
Legend

$Q_{a\text{-}in}$	Alluvial groundwater flow into control volume
$Q_{a\text{-}out}$	Alluvial groundwater flow out of control volume
Q_{swo}	Surface water flow out of alluvial control volume
Q_r	Net areal recharge into alluvial control volume
$Q_{lat\text{-}A}$	Lateral groundwater contribution from Rosebud coal - Area A
$Q_{lat\text{-}B}$	Lateral groundwater contribution from Rosebud coal - Area B
Q_V	Vertical leakage from alluvial control volume to strata
Q_{wells}	Well pumpage
$\triangle S$	Storage change at time of water budget evaluation

Water budget Equation

$$Q_{in} = Q_{out} + \triangle S \text{ or}$$

$$Q_{a\text{-}in} + Q_r + Q_{lat\text{-}A} + Q_{lat\text{-}B} = Q_{a\text{-}out} + Q_{swo} + Q_{wells} + Q_v + \triangle S$$



Summary for Scenario 3 - Water Year 2013 Evaluation

Refer to Table 1 for calculations for $Q_{a\text{-}in}$ and $Q_{a\text{-}out}$ Scenario 3.

(1) The net recharge, Q_r, is assigned by assuming 5 % of average annual precipitation over the area of the control volume infiltrates into the underlying alluvial aquifer. A net addition to this recharge was added to account for recharge from MPDES discharges.

(2) The lateral flow contributions, $Q_{lat\text{-}A}$ was assigned for Area A spoils to be similar to the Rosebud coal contribution (pre-mine). The 2013 flow for Qlat-B is considered to be variable an not quantifiable owing to range of mining activity in Area B and B-Extension. In some areas there is flow out of the control volume and in other areas of prior mining, flow interchange is very limited.

(3) Little groundwater use was documented in the control volume (see Figure 6 for details). Hence, extractions by wells, Q_{wells} were assumed to be negligible.

(4) The Tongue River member strata possesses very low vertical hydraulic conductivities. Hence, vertical flow out of the control volume, Q_v, was considered negligible.

(5) The surface flow out, Q_{swo}, was defined using the median flow measurement value defined at SW-55 for the 2013 water year.

N

Scale not indicated

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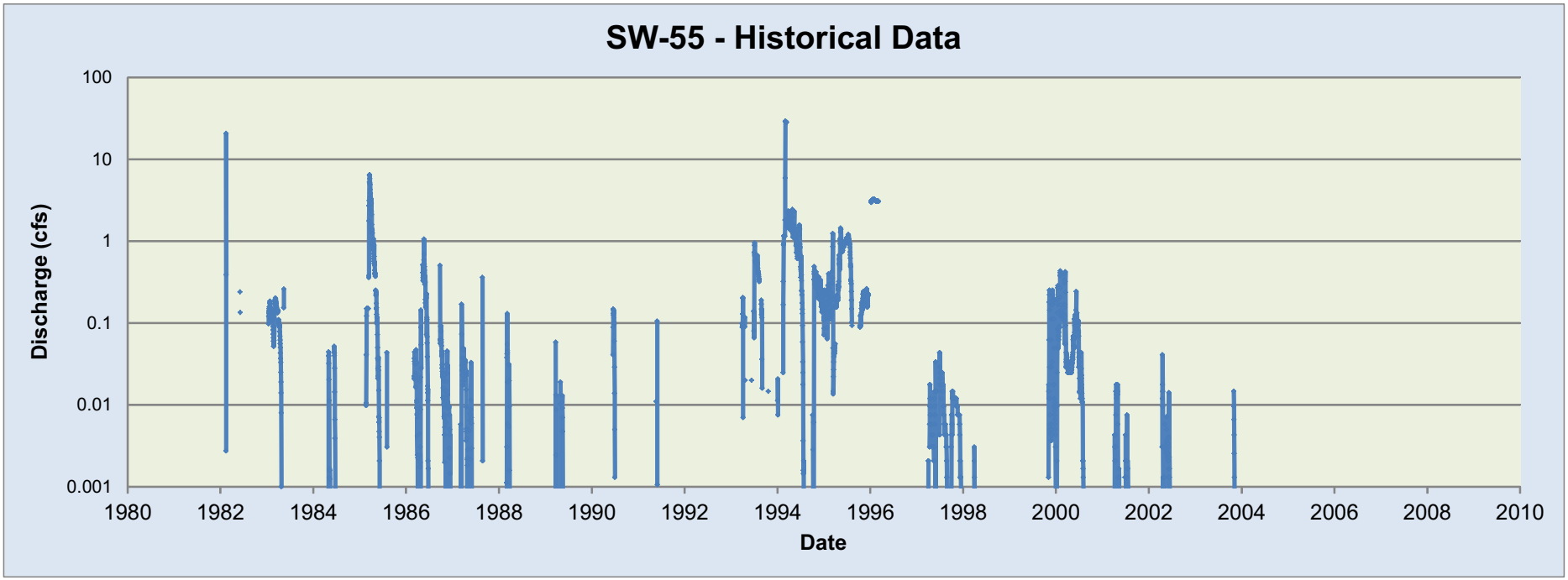
Figure 8
Scenario 3 - Alluvial Control Volume
Vicinity of East Fork Armells Creek

Date: 01/23/15 Name: Figure 05 - Scenario 1.cvx

Exhibit 32



Historic flow measurements via Stephens Recorder.

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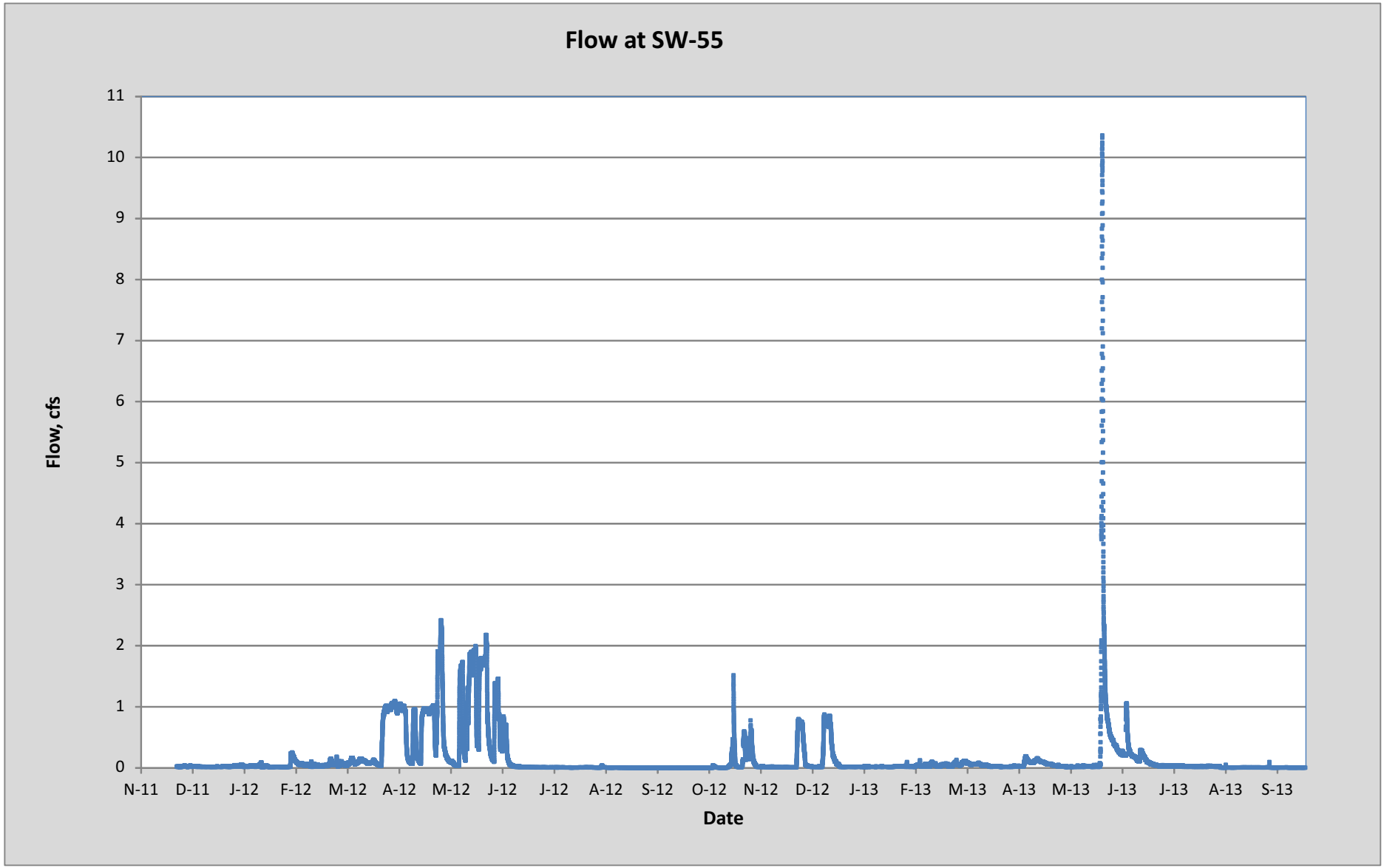
Date: 1/26/15 Name: Figure 9 - Flow at SW-55-1

Figure 9 - Page 1
Flow Measurements - SW-55

Exhibit 32



The flow during this period varied from 0 to 10.36 cfs.

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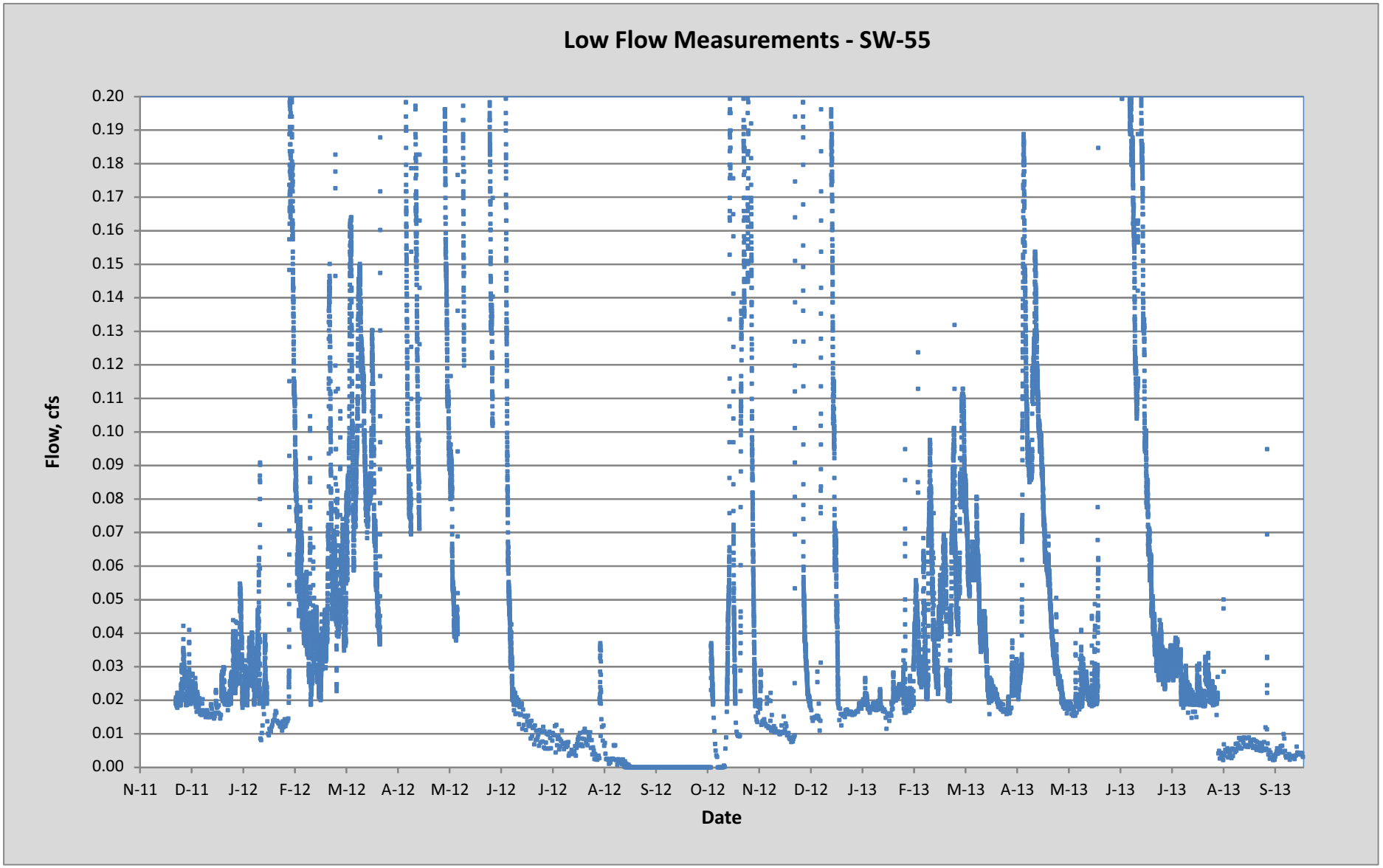
Date: 1/26/15 Name: Figure 9 - Flow at SW-55-2

Figure 9 - Page 2
Flow Measurements - SW-55

Exhibit 32



Only low flow measurements are shown. The flow during this period varied from 0 to 10.36 cfs.

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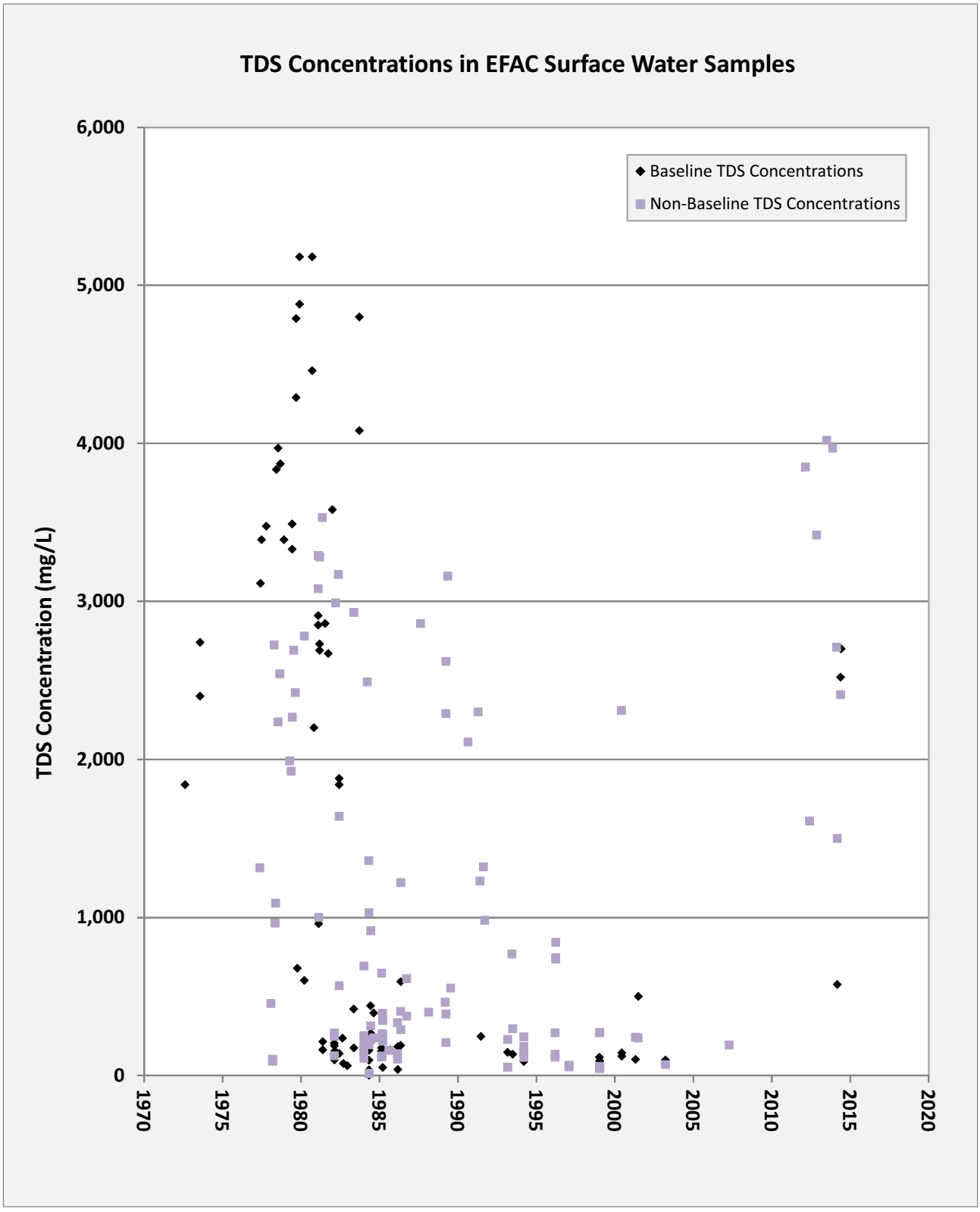
Date: 01/26/15 Name: Figure 9 - Flow at SW-55-3

Figure 9 - Page 3
Flow Measurements - SW-55
(Flows less than 0.20 cfs)

Exhibit 32



Note: Only East Fork Armells Creek samples taken between the mine areas and upgradient from the mine were included.

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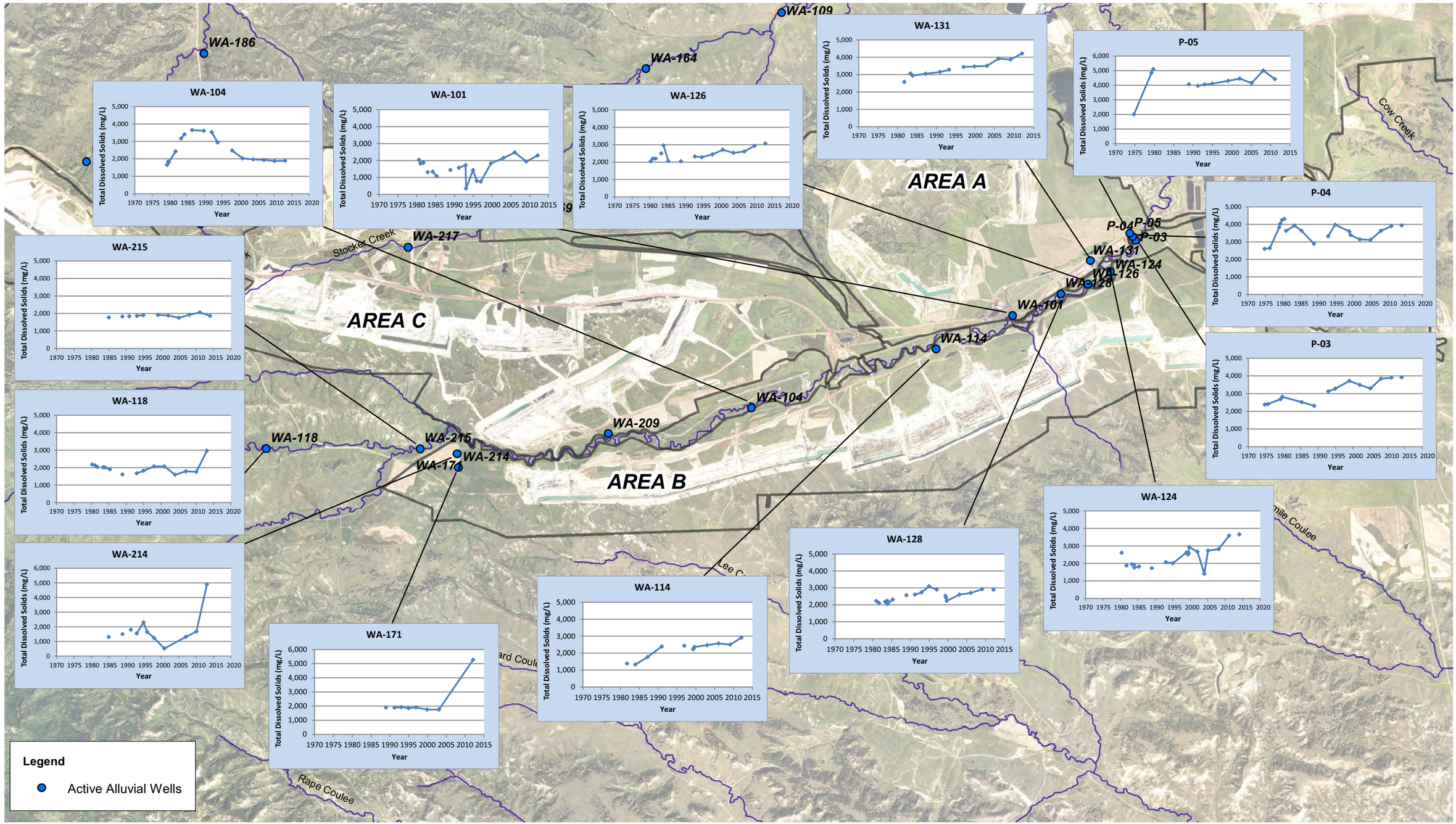
Date: 01/26/16 Name: Figure 8 - TDS in EFAC.cvx

Figure 10
TDS concentrations
East Fork Armells Creek
ABC PHC Addendum

Exhibit 32



Well WA-209 has been dry since 1999

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0 3,500 7,000 Feet

N

Notes:
1) Aerial Photographs: 2011 NAIP

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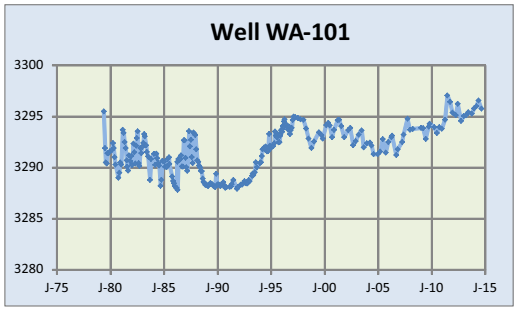
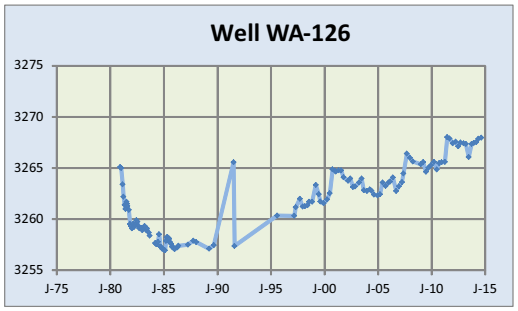
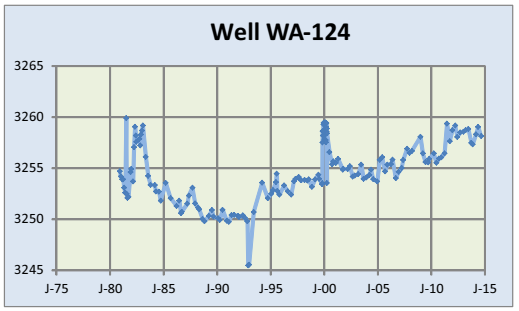
Date: 1/26/2015 Name: Figure 11 - TDS EFAC Alluvium

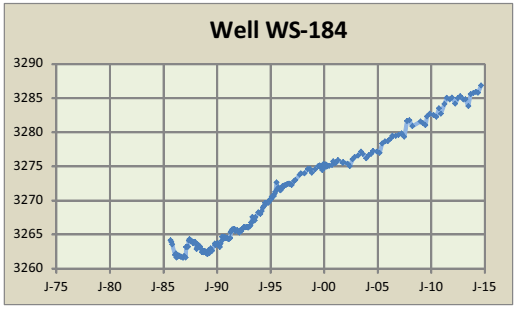
Figure 11
TDS Time Series Graphs
Active Wells - East Fork Armells Creek

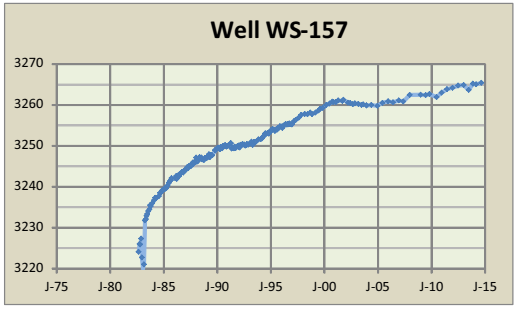
Exhibit 32

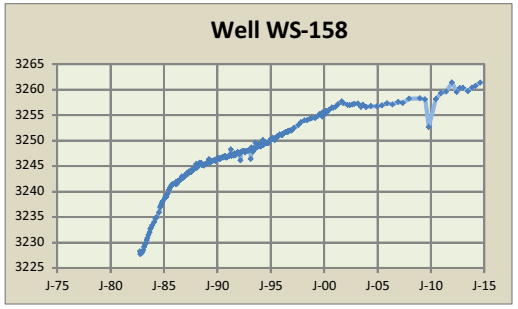










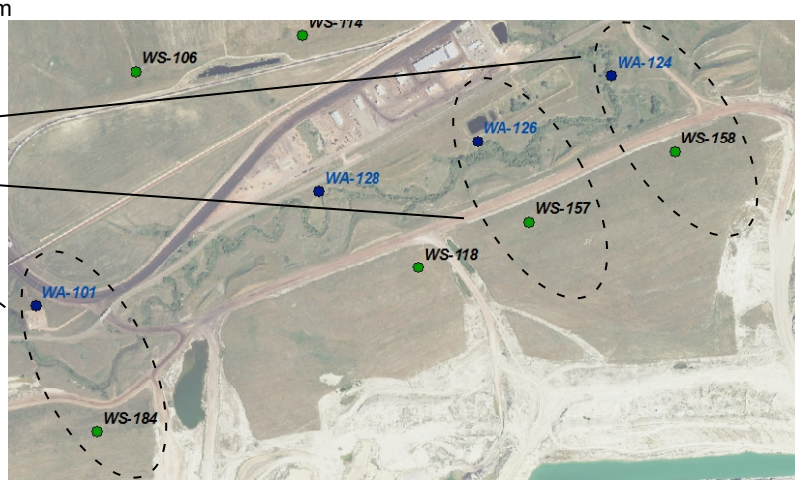


Water levels in well alluvium as represented by well WA-101 have always been above the water levels in the mine spoil as represented by WS-184. Hence, flow is interpreted to be from the alluvium into the mine spoils in this vicinity of the mine. Thus, any transitions in water quality in the vicinity of WA-101 are not related to flow from Area B spoils.

Water levels in well alluvium as represented by well WA-126 have always been above the water levels in the mine spoil as represented by WS-157. Hence, flow is interpreted to be from the alluvium into the mine spoils in this vicinity of the mine. Thus, any transitions in water quality in the vicinity of WA-126 are not related to flow from Area B spoils

Water levels in well alluvium as represented by well WA-124 were above the water levels in the mine spoil as represented by WS-158 until the mid-1990s. Thereafter, spoil water levels at WS-158 were similar to slightly above water levels in the alluvium. See Figure 13 for further discussion.

Wells selected for paired hydrograph comparison.



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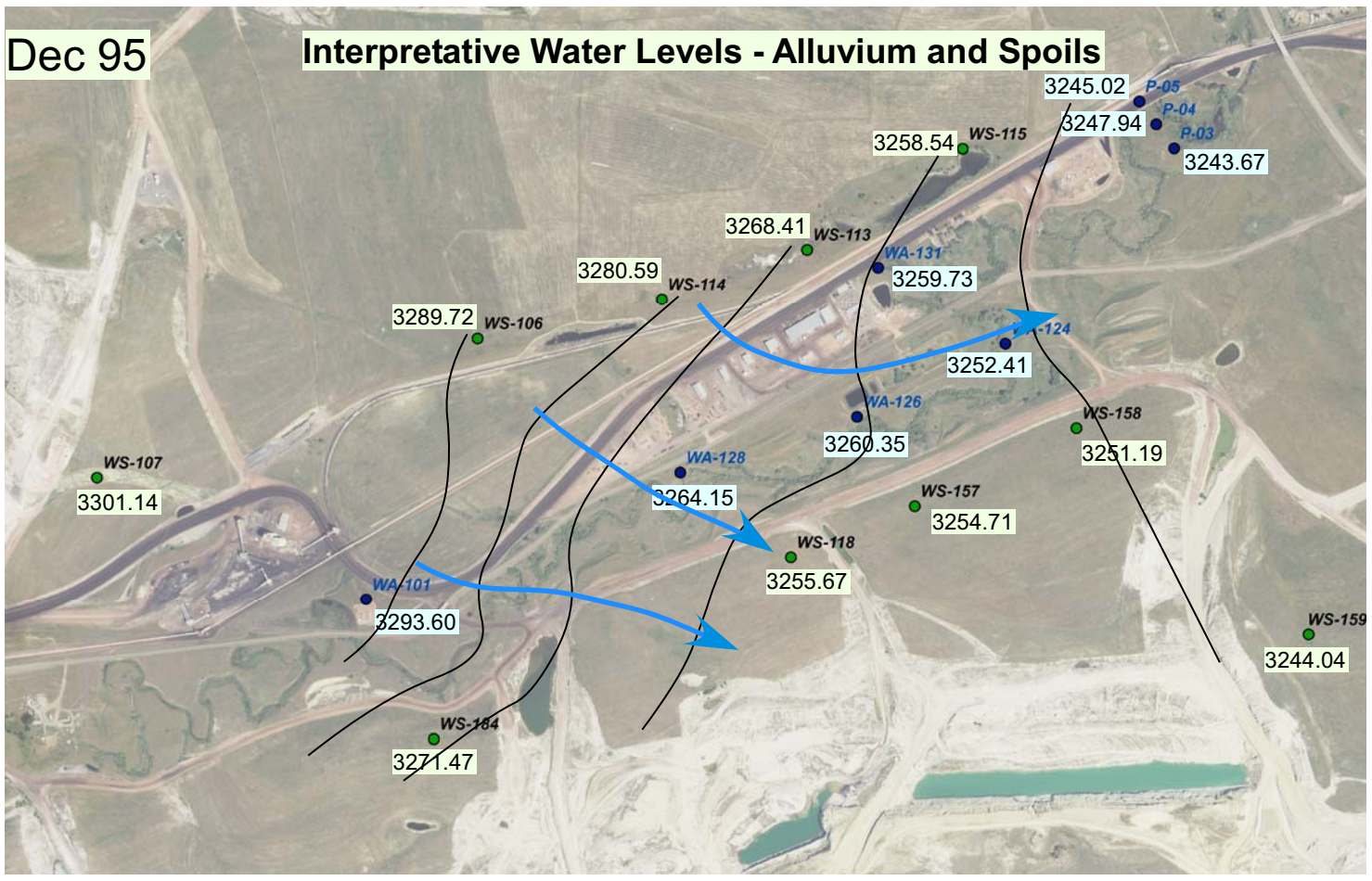
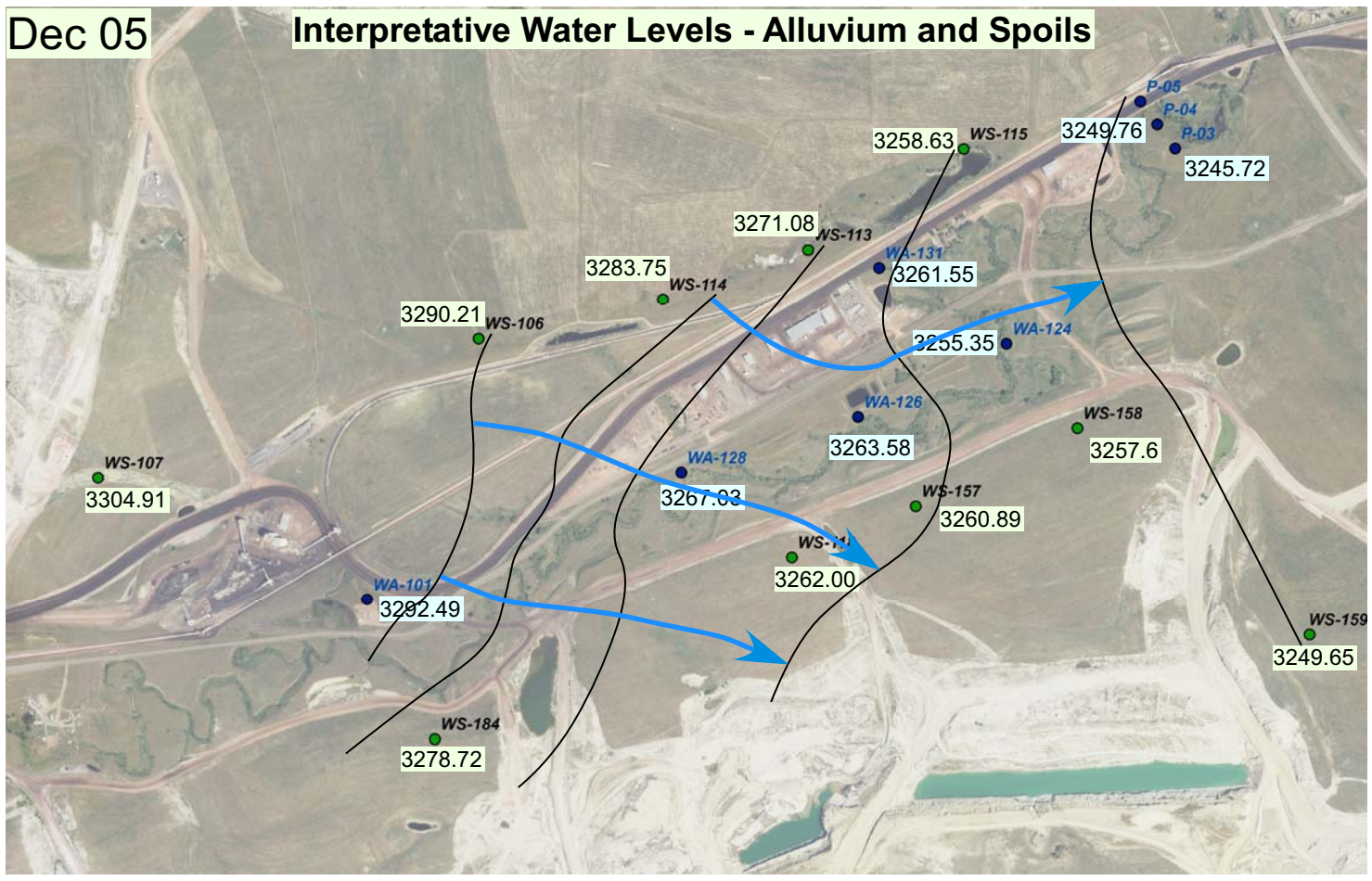
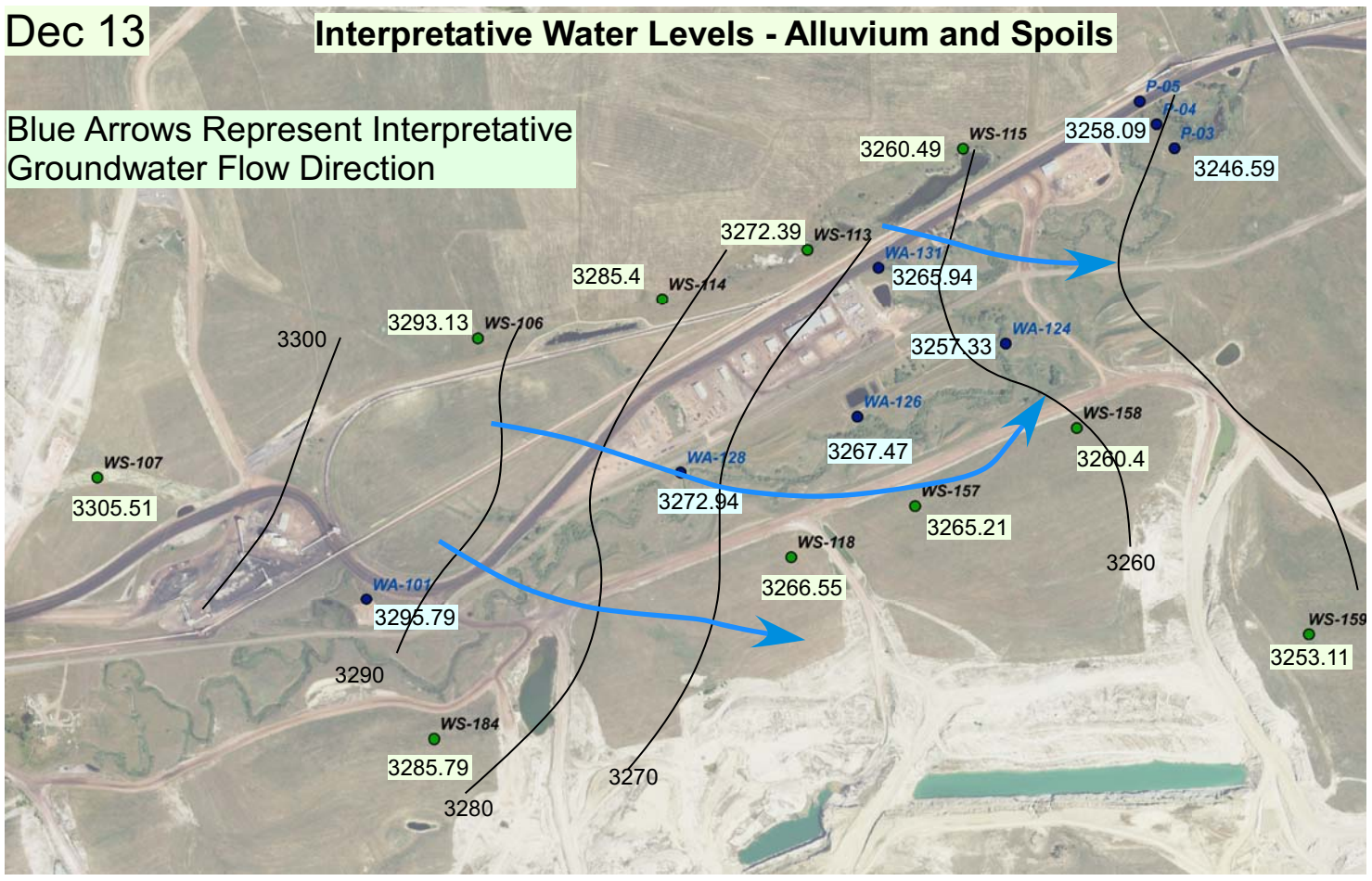
Date: 1/26/15 Name: Figure 12 - Alluvial versus Spoil

Figure 12
Alluvial Well versus Spoil Well Water Levels

Exhibit 32

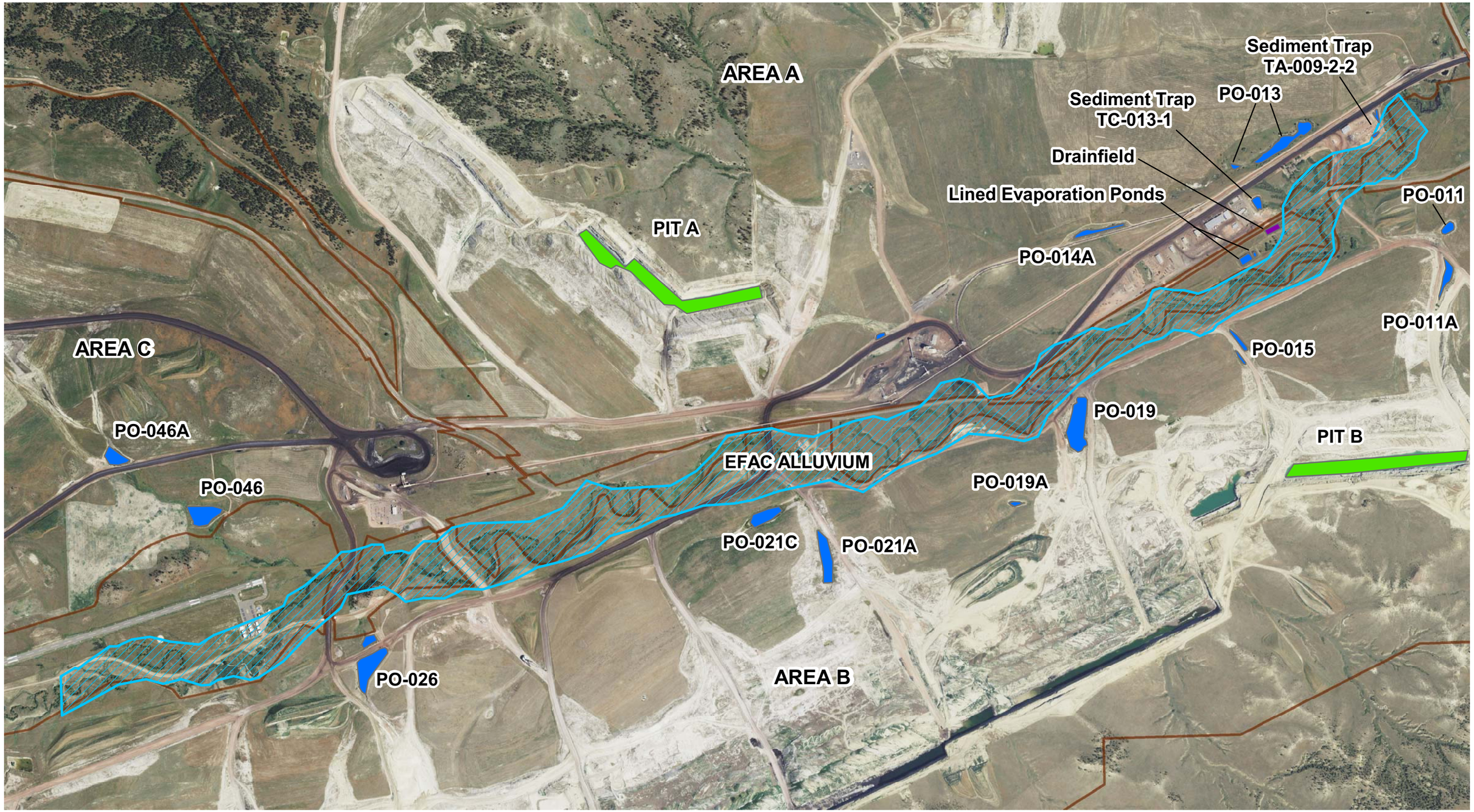






Date: January 26, 2015 d://figure 13-pot.cvx Issued for Western Energy	NICKLIN EARTH & WATER, INC.	Interpretative Potentiometric Map Alluvium and Adjacent Spoils EFAC Vicinity	Figure 13

Exhibit 32



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0 1,000 2,000 Feet

Date: 1/26/2015 Name: Figure 13 - Facility Features and Ponds

N

Notes:
1) Aerial Photographs: 2013 NAIP

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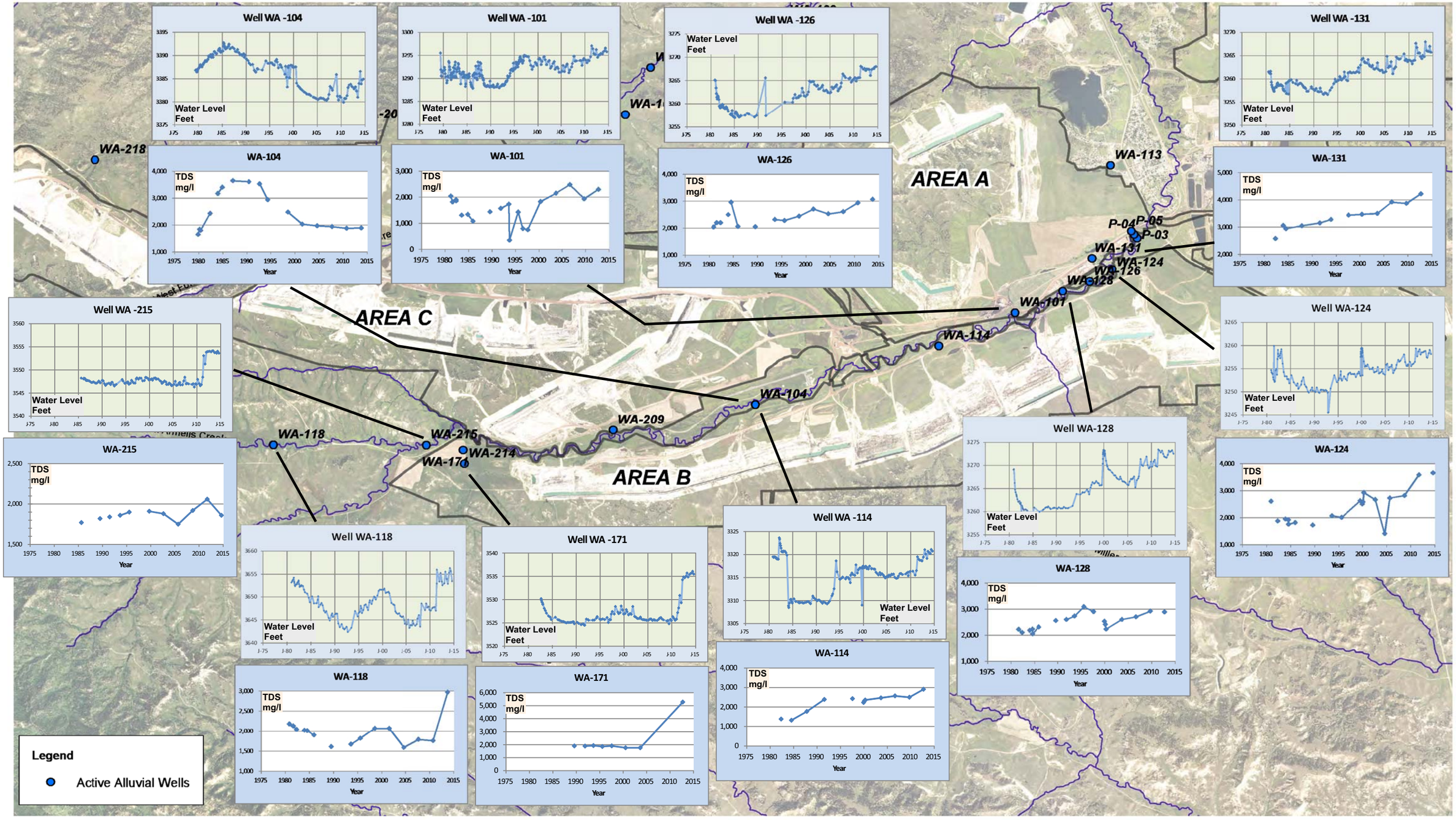
Figure 14
Facility Features
Ponds and Pits with Standing Water 2013

Exhibit 32



NICKLIN
EARTH & WATER, INC.

0 3,500 7,000 Feet

N

Notes:
1) Aerial Photographs: 2011 NAIP

Date: 1/26/2015 Name: Figure 15 - TDS vs WL

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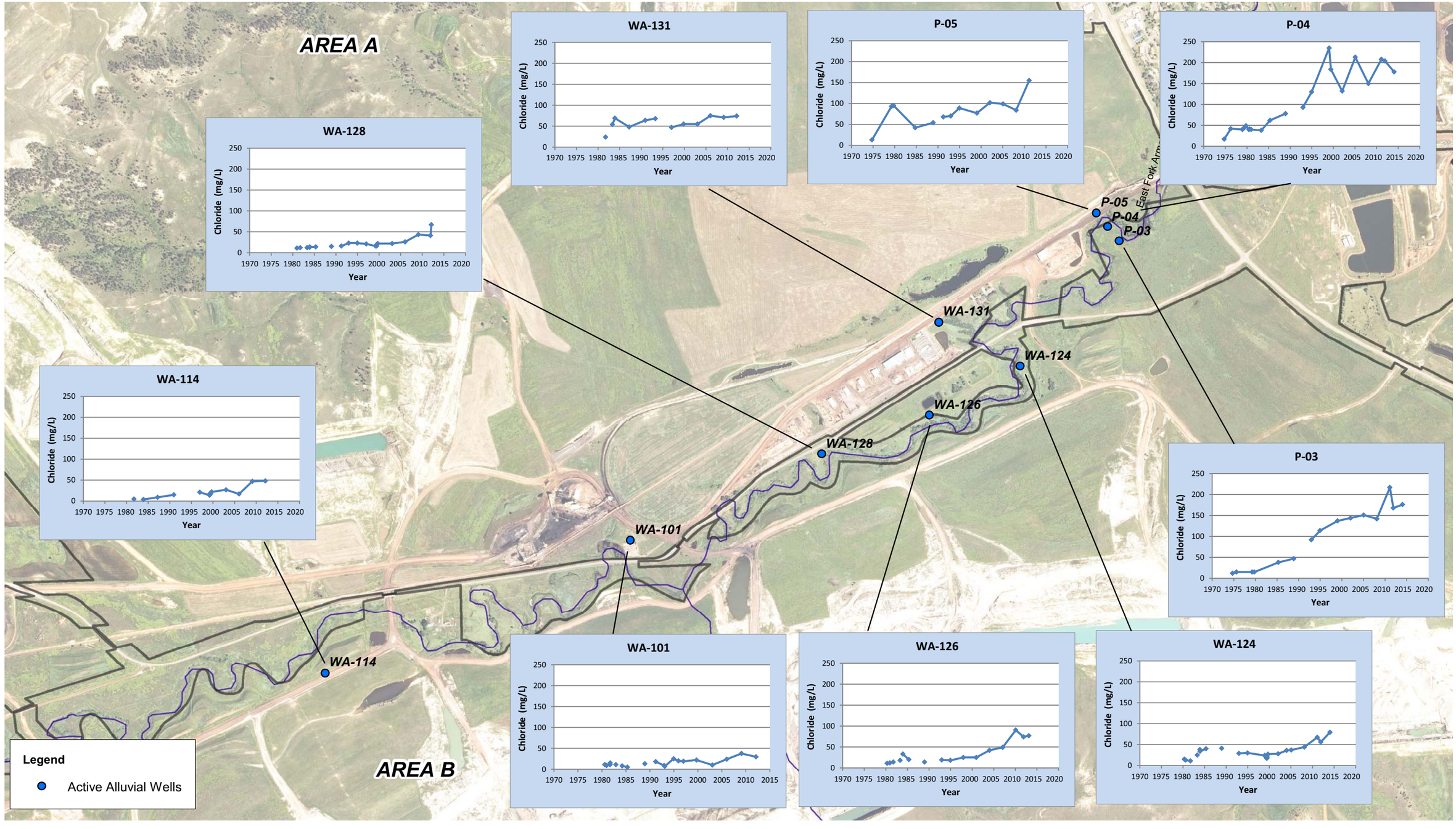
Figure 15
Comparison of TDS versus Water Levels
Active Alluvial Wells East Fork Armells Creek

Exhibit 32



NICKLIN EARTH & WATER, INC.

0 750 1,500 Feet

N

Notes:
1) Aerial Photographs: 2011 NAIP

Date: 1/26/2015 Name: Figure 16 - Alluvium Chloride

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PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 16
ChlorideTime Series Graphs
Active Wells - East Fork Armells Creek
ABC PHC Amendment

Exhibit 32

Attachment 2

Report
Assessment of East Fork Armells Creek Vicinity of Areas A and B

Prepared for:

Western Energy Company - Rosebud Mine

PO Box 99
Colstrip, MT 59323
406-748-5100

Prepared by:

NICKLIN
EARTH & WATER, INC.

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Bozeman, MT 59718
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Exhibit 32

Report
Assessment of East Fork Armells Creek
Vicinity of Areas A and B
by
Michael E. Nicklin, PhD, PE

1.0 BACKGROUND

The purpose of this report is to provide a synopsis of the nature of the relationship between the groundwater and the East Fork Armells Creek (EFAC) in the portion of the Western Energy Company's Rosebud Mine between permitted Areas A and B. The focus of this investigation was to assess if it is likely or not that this portion, or portions, of this creek should be considered as ephemeral or intermittent.

The following activities were performed in this assessment:

- Reviewed prior reports completed by others.
- Assessed alluvial well hydrographs in the vicinity of Areas A and B.
- Collected supplemental survey elevations of the EFAC channel thalweg at locations near selected alluvial wells. The evaluation focused on locations where pre-mining water level data were available.
- Evaluated the significance of other influences, such as mining, Montana Pollutant Discharge Elimination System (MPDES) discharges, etc. to alluvial aquifer conditions and potentially to surface water flows between Areas A and B.

2.0 PREVIOUS INVESTIGATIONS

One of the more relevant prior investigations which addressed the hydrologic conditions of the EFAC between Areas A and B was conducted by Van Voast, et al (1977). Pre-mine data up to 1976 were considered in the Van Voast investigation. The following are selected/relevant excerpts from the Van Voast, et al report:

> *"Most streams flow only during periods of snow-melt and after infrequent events of high-intensity rainfall. Rosebud Creek and East Fork Armells Creek downstream from Colstrip have perennial flow generated by continuous ground-water discharge. . . ."*
>
> Pertinent to Areas A and B:

> *"Flow of ground water in alluvium along East Fork Armells Creek is almost parallel to the water course. The alluvium is recharged vertically from precipitation and streamflow, and laterally from subcrops of bedrock aquifers. Most water in the alluvium is transmitted within the basal gravel beds. . .".*
>
> *"Upstream from Colstrip, East Fork Armells Creek is generally dry except for water holes where its channel locally penetrates the water table."*

Hence, it seems that Van Voast, et al characterizes this section to be a losing reach, i.e., water infiltrates from the stream into the alluvial aquifer. Thus, if EFAC flows were present, they were not dependent upon base flow from groundwater.

Another study was the alluvial valley floor (AVF) evaluation conducted for WECo by Hydrometrics (1982). That report described groundwater flow nearly parallel to the watercourse, similar to the interpretations defined in Van Voast et al (1977). That same report also described flow or standing water in short sections of the creek above Colstrip much of the year in the AVF evaluation.

A significant factor described in both studies that will affect the hydraulic communication between a stream and an adjacent alluvial aquifer is the nature of the geologic substrate between the stream channel and that underlying aquifer. Both the Van Voast, et al and AVF studies described a significant thickness of silt and clay between the base of the EFAC channel and the underlying alluvial aquifer. Such a condition will limit to some degree, any potential surface water and groundwater interaction.

The Environmental Impact Statement (EIS) for Area C (MDSL, 1982) states that the East Fork Armells Creek is intermittent in the vicinity of Area C.

Hence, it is clear that differences of opinion exist regarding the nature EFAC in the reach of interest. Therefore, the focus of this evaluation is to provide better resolution of the nature of the channel in the EFAC vicinity near Areas A and B.

3.0 OTHER FACTORS AND RECENT OBSERVATIONS

There are two primary human factors that affect EFAC flow in the Colstrip area and they are:

- Importation of Yellowstone River water to Colstrip, and
- Mining of coal at the Rosebud Mine.

Other human factors which can be locally influential include the presence of local stock ponds and roadway culverts, etc.

3.1 Importation of Yellowstone River Water to Colstrip

The overall water balance of the hydrogeologic regime in the Colstrip area has been altered via the importation of Yellowstone River water for use at the power plant. This imported water is stored in the surge pond (Castle Rock Lake). This imported water also serves to provide water supplies to Colstrip. Some portions of this imported water contribute recharge from pond leakage. For instance, leakage results from the surge pond and it is discussed in Van Voast et al. Another example is discharge of municipal waste water which leads to recharge and increased flow in EFAC within and downstream of Colstrip.

All these factors have resulted to increases in the EFAC alluvial water levels in the Colstrip area. Given that the EFAC alluvial aquifer is hydraulically continuous throughout the Colstrip area, some increase in the alluvial aquifer water levels is anticipated to have occurred in eastern portions of EFAC between Areas A and B as a consequence. The relative degree of this effect is not simple to quantify and is not evaluated in this report.

3.2 Influence of Mining Activity

Mining activity also influences the relative relationship between surface water conditions of EFAC and the underlying alluvial aquifer system. The following counterbalancing effects have been observed during mining:

- Dewatering of the Rosebud coal during mining reduces groundwater flows in the alluvium near EFAC. When water is taken from a coal seam during mining, water flows out of the alluvial aquifer and groundwater levels decline. The amount of this flow induction (and water level decline) is dependent upon the degree of hydraulic connectivity between the coal seams mined and the EFAC alluvium. The degree of connectivity, in large part, depends upon the proximity of mine passes to the alluvium. Between Areas A and B, the Rosebud coal is in contact with the EFAC alluvium. The EFAC alluvial deposits are much nearer mine passes in Area B when compared to mining in Areas A and E. Hence, mining in northern portions of Area B affects the aquifer most. The degree of the mining impacts from a water quantity perspective diminishes as Area B mine passes move away (generally south) from the EFAC alluvium, and as spoils are placed between the alluvium and the active mining passes.

- Recovery of alluvial water levels is dependent upon recharge from a combination of following sources:

- Runoff can be a major source of groundwater recharge along the main stem of EFAC. In some years, significant runoff occurs in association with either snowmelt and/or precipitation.
- Local recharge to nearby land surfaces also occurs but this recharge is much less significant compared to recharge from EFAC channel runoff.
- Recharge during mining results from MPDES discharges to the EFAC channel. This factor has been particularly dominant in years when precipitation and runoff is above average. The net result of above normal precipitation is that much greater volumes of water are retained/detained in ponds and mine pits. This stored water is then discharged to the EFAC channel over an extended period of time. Hence, a large volume of recharge occurs. Table 1 provides a summary of documented MPDES flow volumes into the EFAC drainage. Substantial discharges were observed in water years 2000, 2011, 2012 and 2013.

  Based upon observations of WECo mine staff, the MPDES discharges directed to EFAC infiltrate from the channel base, thus recharging the underlying alluvial aquifer. Such recharge has led to rapid recovery of water levels and even increases in alluvial groundwater levels exceeding pre-mine water level conditions. Thus, the key effect of MPDES discharges is to act a major recharge source to the EFAC alluvium between Areas A and B.

It is instructive to compare the significance of mining activity and the effects of MPDES discharges using observation well WA-101 (see Figure 1). The surveyed EFAC channel elevation (as interpolated) near this well is 3291.04 feet (see Figure 2). This elevation is compared to water level elevations of alluvial well WA-101. The following is an interpretative summary of the groundwater levels in this well over time:

- Water levels in this alluvial well prior to mining in the area showed a seasonal response likely related to early season runoff and the consequent increase in recharge to the alluvium from this runoff. Water levels tend to oscillate above and below the projected channel thalweg. The levels are more likely to be above the thalweg during runoff season and more likely to be below the thalweg during the drier portion of the year.
- Mining in Area B and Area C commenced near this well in 1983. As a result, water levels in the alluvium were drawn down slightly and were more likely to be below the channel base. After 1988 the groundwater levels remained persistently below the channel until about 1993.
- When mining in Areas B and C moved away from the EFAC alluvium near WA-101, water levels began to recover gradually over time until they were at,

or above, pre-mine levels by about 1994. The water levels continued to increase over time to reach levels exceeding pre-mine conditions. This increase is likely due to a combination of distance to mining passes, natural recharge, and discharge from mine pits/ponds into the EFAC drainage above or near this well.

- Beginning in 2011, water levels at WA-101 increased well above pre-mine conditions. This latter response is associated with the substantial MPDES discharges into EFAC since that year (Refer to Table 1). It was also likely affected to a lesser degree by natural recharge primarily related to runoff contributed from more up-gradient portions of the drainage during these years.

4.0 OTHER HYDROGRAPH EVALUATIONS

In addition to WA-101, other observation wells in the EFAC alluvium were compared to nearby surveyed channel thalweg elevations. Each of these is discussed below. Refer to Figure 2 for location and hydrographs for each respective well discussed.

Before proceeding with well specific discussions, it is noted that direction of alluvial groundwater flow will tend to follow the primary axis of the alluvial valley floor as opposed to following the sinuous alignment of the channel thalweg. This is especially true if there is little or no hydraulic connection between the stream channel and the alluvium. Channel thalweg elevations were collected as near to each specific alluvial well as feasible, and, along an equivalent projected potentiometric head elevation. The purpose was to provide a comparison of pre-mine alluvial groundwater levels to channel bases in the vicinity. In three instances, interpolated elevations from the survey data were employed.

WA-114 versus thalweg elevation - 3321.27 feet

See Figure 2 for the location of channel thalweg survey point and the hydrograph for alluvial well WA-114.

Early water levels (prior to 1982) for alluvial well water WA-114 indicate groundwater levels were interpreted to be about two feet below the base of East Fork Armells Creek at the surveyed thalweg location. In 1982, water levels increased abruptly during late winter and early spring at this well potentially indicating that channel recharge had occurred in association with a snow-melt and/or precipitation runoff event. The well water levels had risen above the surveyed channel thalweg elevation. Thereafter, water levels were observed to decline to below the surveyed channel thalweg elevation. The seasonal increase in groundwater levels in 1982 was likely affected significantly by the runoff water captured in a nearby stock pond embankment. When this stock pond

captures EFAC surface water flow, it tends to infiltrate (recharge) the underlying alluvium. Hence, it is difficult to quantify what "normal" water level conditions would be at WA-114 had it not been for the pond.

Additional evaluations are presented in Section 5.0 discussing the potential for historical/current existence of ephemeral or intermittent conditions for EFAC in the vicinity of WA-114.

Mining commenced in the vicinity of WA-114 in late 1983 resulting in substantial drawdown beginning in early 1984. Since 1984, water levels had persistently remained well below pre-mine levels until about 2011. At that time, water levels had recovered to near, if not slightly above, pre-mine levels. This recovery is interpreted to be from the far above average precipitation/runoff/recharge beginning in 2011. A substantial fraction of this recharge is a result of the increased MPDES discharges into the EFAC channel which subsequently infiltrated into the underlying alluvium. Again, the pond embankment also causes significantly increased recharge in this area. Even with the increased recharge from the MPDES discharges and the pond embankment, groundwater levels at this well have remained below the surveyed thalweg elevation.

EX-40 versus thalweg elevation (interpolated) – 3313.66 feet

See Figure 2 for location of channel thalweg survey point and hydrograph for alluvial well EX-40.

Alluvial well EX-40 (abandoned) has a limited water level data set extending from June 1980 to July 1983. All data were collected at this well prior to mining in its vicinity which commenced in the latter part of 1983. The water levels in this well are interpreted to have varied from below to slightly above the channel thalweg. It is likely that the higher water levels are associated with early year runoff. For instance, as in the case of WA-114, the water levels increased beginning early 1982, probably as a result of increased recharge associated with a significant snowmelt/precipitation runoff event(s) that occurred that year. As in the case for WA-114, the local groundwater elevations at this location may have been affected to some degree by nearby stock pond(s) [see Figure 2]. This includes the pond described in the vicinity of WA-114. There was also a stock pond very near EX-40. As a result, it is difficult to project what "normal" water level conditions at EX-40 would have been without the ponds being present.

Additional evaluations are presented in Section 5.0 discussing the potential existence of ephemeral or intermittent conditions for EFAC in the vicinity of EX-40.

WA-101 versus thalweg elevation (interpolated) – 3291.04 feet

See prior discussion for this well in Section 3.0.

EX-27 versus thalweg elevation (interpolated) – 3282.30 feet

See Figure 2 for locations of channel thalweg survey point (interpolated) and hydrograph for alluvial well EX-27.

Alluvial well EX-27 (abandoned) has a limited water level data set extending from June 1980 to May of 1987. Mining commenced in the vicinity of this well location in the latter part of 1983. The water levels in this well are interpreted as being substantially below the channel thalweg for the entirety of its observation history.

WA-128 versus thalweg elevation – 3271.51 feet

See Figure 2 for location of channel thalweg survey point and hydrograph for alluvial well WA-128.

This alluvial well has a water level measurement history from late 1980 to present. Based upon the data set one water level measurement of 3269.1 feet was taken prior to mining commencing in this vicinity of Area B in early 1981. That measurement is about 2.4 feet below the surveyed channel thalweg elevation of 3271.51 feet.

As in the case of WA-101 and WA-114, water levels in WA-128 show a historic response to the effects of drawdown from mining, and in turn, the recovery of water levels over time, particularly in response to MPDES discharges. Notable responses in this well's hydrograph correspond to MPDES release that occurred in year 2000, 2007 and 2011 (refer to Table 1 for MPDES discharges by year).

Recent water levels have been persistently about three feet above the pre-mine water level measurement collected in December 1980. Water levels since 2011 have also been observed to be persistently above the surveyed channel thalweg demonstrating the significance of the MPDES discharges into EFAC.

WA-126 versus thalweg elevation – 3265.97 feet

See Figure 2 for locations of channel thalweg survey point and hydrograph for alluvial well WA-126.

This alluvial well has a water level measurement history from late 1980 to present. One water level measurement of 3265.1 feet was taken prior to mining commencing in this vicinity of Area B in early 1981. That measurement is about 0.9 feet below the surveyed channel thalweg elevation of 3265.97 feet.

The water levels in this well exhibited a historic response to nearby mining activity. Water levels since 2011 have been above the thalweg elevation, due primarily to the effects of MPDES discharges to EFAC.

WA-124 versus thalweg elevation – 3258.91 feet

See Figure 2 for locations of channel thalweg survey point and hydrograph for alluvial well WA-124.

This alluvial well has a water level measurement history from late 1980 to present. Based upon the data set one water level measurement of 3254.7 feet was taken prior to mining commencing in this vicinity of Area B in early 1981. That measurement is about 4 feet below the surveyed channel thalweg elevation of 3258.91 feet.

Note that water levels did show increases from about 1982 to 1983 as mining in Area B had been on-going. A logical explanation for this increase is that groundwater collected during mining was being discharged into EFAC near, or just upgradient of, this alluvial well. Water levels were ultimately drawn down to about 9 feet below the thalweg in the late 1980s to mid-1990s. Presently, water levels in this well are very near the surveyed channel thalweg elevation.

P-04 versus thalweg elevation – 3245.96 feet

See Figure 2 for locations of channel thalweg survey point and hydrograph for alluvial well P-04.

This alluvial well has a water level measurement history from late 1974 to present.

Water levels in this well are likely affected by a down-gradient ponded area. The embankment causing this impoundment is possibly a relic embankment associated with a road alignment shown on United States Geological Survey topographic mapping.

The historic water levels prior to mining in Area B exhibited relatively regular seasonal variation centered about the surveyed thalweg elevation. This seasonal variation may, at least in part, be a result of seasonal runoff and pond storage.

The water levels in this well declined to below the thalweg when Area B mining commenced. In about 1990, water levels recovered to levels similar to those that were observed prior to Area B mining. Area B mining had gradually moved away from the alluvial channel vicinity by this time.

Since approximately 1993, water levels in P-04 have been well above the channel thalweg. Presently, the water levels at this location have been at their highest in year 2000 and since 2011. These high water levels are associated with the elevated MPDES discharges as defined in Table 1.

5.0 INTERPRETATIVE DEFINITION OF STREAM DESIGNATION

The information and interpretations provided previously, coupled with evaluation of recent aerial photography, allows for better resolution of the "point" along EFAC where it transitions from ephemeral to intermittent conditions. Figure 3 presents aerial photography for the following dates:

- August 11, 2009
- July 16, 2011
- July 21, 2013

An evaluation of the EFAC channel condition between observation wells WA-114 (upgradient) and WA-101 (downgradient) was conducted. Note that prior evaluations had indicated the existence of intermittent channel conditions near WA-101. The conditions near up-gradient (west) wells WA-114 and EX-40 (see Figure 2) were less conclusive because of the existence of pre-mine stock ponds.

Figure 3 also includes water level hydrographs for alluvial wells WA-114 and WA-101. The following are noted on Figure 3:

- Water levels at WA-101 were observed to be above pre-mine observations for 2009, 2011 and 2013.
- Water levels at WA-114 were observed to be near pre-mine observations for 2009, 2011 and 2013.

Hence, the channel conditions near/between these wells for the above aerial photographs should provide information regarding the following:

- Was the channel ephemeral or intermittent historically (pre-mine)?
- What is the current condition as consequence of mining activity and other factors?

The aerial photographs were each evaluated to determine if channel (standing/flowing) water was present. Note that channel water may be associated with either direct surface runoff and/or groundwater. This analysis makes no attempt to distinguish between standing water versus flowing water from the aerial photographs.

On the August 11, 2009 aerial photograph the first channel water was interpreted to begin at the point designated as A1 (upper left on Figure 3). No significant precipitation/runoff events were documented near this date. Hence, the presence of channel water at A1 is interpreted to be from groundwater. In summary, the channel was dry up-gradient (west) of A1. Based upon the 2009 aerial photograph, the EFAC between from the vicinity of WA-114 to A1 is ephemeral. The channel below A1 is intermittent.

On the July 16, 2011 aerial photograph some localized surface water (SW) were interpreted to be present up-gradient (west) of A1. It is noteworthy that a major precipitation event occurred on July 15, 2011. Hence, there is a significant likelihood that the localized surface water observed in the channel is from direct runoff event as opposed to being an expression of groundwater.

On the July 21, 2013 aerial photograph the first channel water was interpreted to begin at the point designated as B1 (lower left on Figure 3). No significant precipitation/runoff events could be discerned near this date. Hence, the presence of channel water at B1 is interpreted to be from groundwater. In summary, the channel was interpreted to be dry upgradient (west) of B1. Based upon the 2013 aerial photograph, the EFAC between from the vicinity of WA-114 to B1 is ephemeral. The channel below B1 is intermittent.

Given that groundwater levels at WA-101 are elevated (increased) relative to historical conditions, it is likely that the "transition point" between an ephemeral to an intermittent condition has migrated up-gradient slightly from what it was historically. Again, the increased water levels are largely attributable to an increase in recharge from the MPDES discharges necessitated from the far above average precipitation that has been observed in recent years (see Table 1).

Finally, even with elevated groundwater levels, there is no evidence of channel water near WA-114. Hence, the channel near WA-114 is deemed to have been ephemeral historically as well as currently.

6.0 SUMMARY AND CONCLUSIONS

ARM 17.30.602 defines an ephemeral stream as a stream or part of a stream which flows only in direct response to precipitation in the immediate watershed or in response to the melting of snow and ice whose channel bottom is always above the local water table.

Based upon the opinions expressed by Van Voast, et al, and based upon the evaluation conducted herein, I conclude the following:

- Based upon the aforementioned ARM definition, the transition point where the EFAC is interpreted to become ephemeral under current conditions is located up-gradient (west) from observation well WA-101 (point B1 in Figure 3). For historic conditions it is more likely that the ephemeral conditions began nearer vicinity of point A1 (Figure 3).
- Imported water for use at the power plant and for municipal purposes has affected groundwater levels in the vicinity of Colstrip.

- Mining has had a dual impact on the relationship between the EFAC between areas A and B and the alluvial aquifer as follows:
    - When mining was nearer the EFAC alluvium, groundwater level declines resulted.
    - MPDES discharges increased the groundwater levels. When significant discharges occurred, those discharges ultimately led to groundwater level conditions well above base-line conditions.
- The recent groundwater level conditions, and the current persistent flows observed in the EFAC, are not indicative of the natural condition for this portion of the creek. The water levels have been affected by far above average precipitation and the resultant increase in MPDES discharges that have occurred since 2011. Other human caused changes, such as stock ponds, have affected water levels and flows in EFAC as well.
- It is projected that when precipitation/runoff conditions return nearer to normal the following will transpire:
    - Alluvial groundwater levels will decline; and
    - Flows in EFAC will return nearer to pre-mine baseline conditions
- Finally, there are other factors and limitations to the evaluation that was conducted including the following:
    - In some areas, such as the very eastern portion of Area B, there is only one pre-mine groundwater elevation. Therefore, it is difficult to project with scientific certainty normal groundwater levels.
    - There are other factors affecting the degree of communication, or lack thereof, between a stream and an aquifer. One of these factors is existence of silt and clay between the EFAC channel thalweg and the underlying aquifer. This natural barrier reduces the degree of any potential surface water and groundwater interaction. Apparently though, the observations of mine staff are that MPDES discharges do infiltrate into the alluvium. Given that well hydrographs do respond (rise) accordingly, there is some degree of hydraulic connection between the EFAC channel and the underlying alluvial aquifer.

REFERENCES

Hydrometrics. 1982. Comprehensive alluvial valley floor investigation – East Fork Armells Creek Stocker Creek and Cow Creek. Report prepared for Western Energy Company.

Montana Department of State Lands and US Office of Surface Mining, 1982. Final Environmental Impact Statement, Western Energy Company's Rosebud Mine, Area C, Block 1.

Van Voast, W.A., R.B. Hedges, J.J. McDermott. 1977. Hydrogeologic conditions and projections related to mining near Colstrip, Southeastern Montana. Montana Bureau of Mines and Geology. Bulletin 102. June, 1977.

Table 1

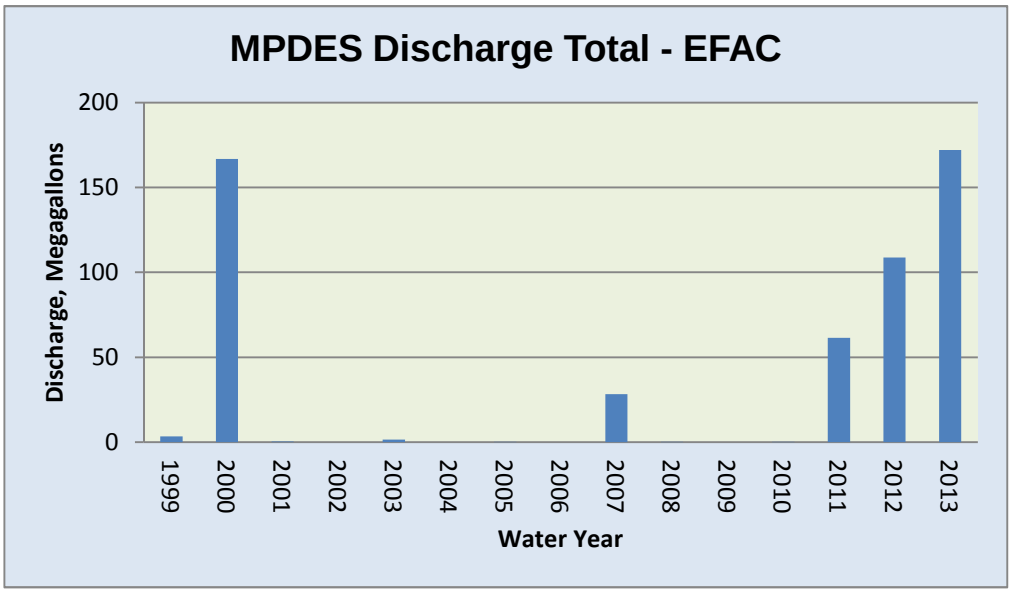
Total MPDES Discharge from 1999 through 2013 at Rosebud Mine, MT.

Water Year	Total discharge (megagallons)	Total Discharge in EFAC drainage (megagallons)
1999	4	4
2000	167	167
2001	6	0
2002	0	0
2003	2	2
2004	0	0
2005	3	0
2006	46	0
2007	102	28
2008	20	0
2009	44	0
2010	3	0
2011	173	61
2012	136	109
2013	185	172

Notes

No flow measurements are available for some unplanned discharges in WY 2000, 2001, 2008 and 2011.

EFAC = East Fork Armells Creek



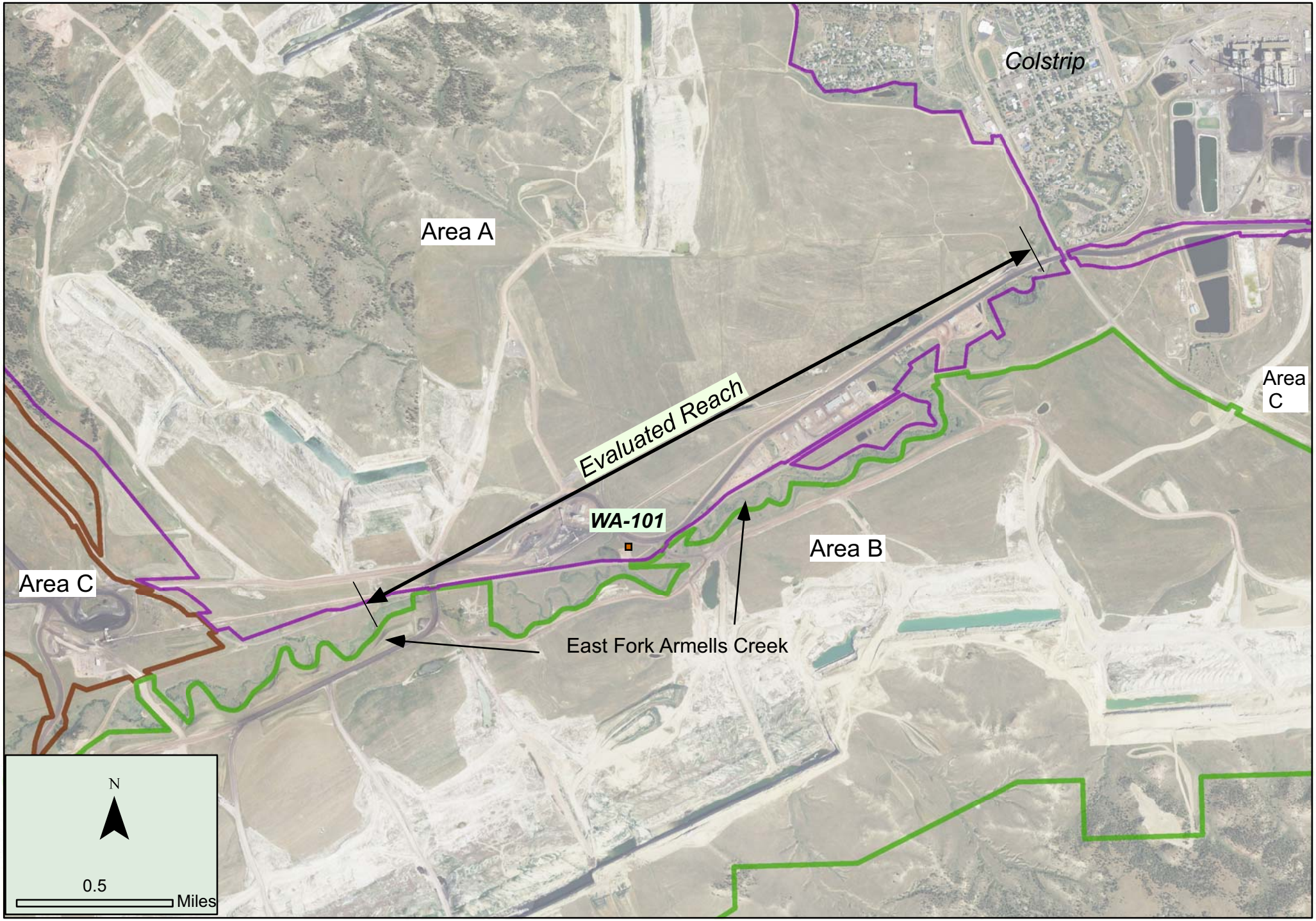


Figure 1. Reach evaluated along East Fork Armells Creek.

Exhibit 32

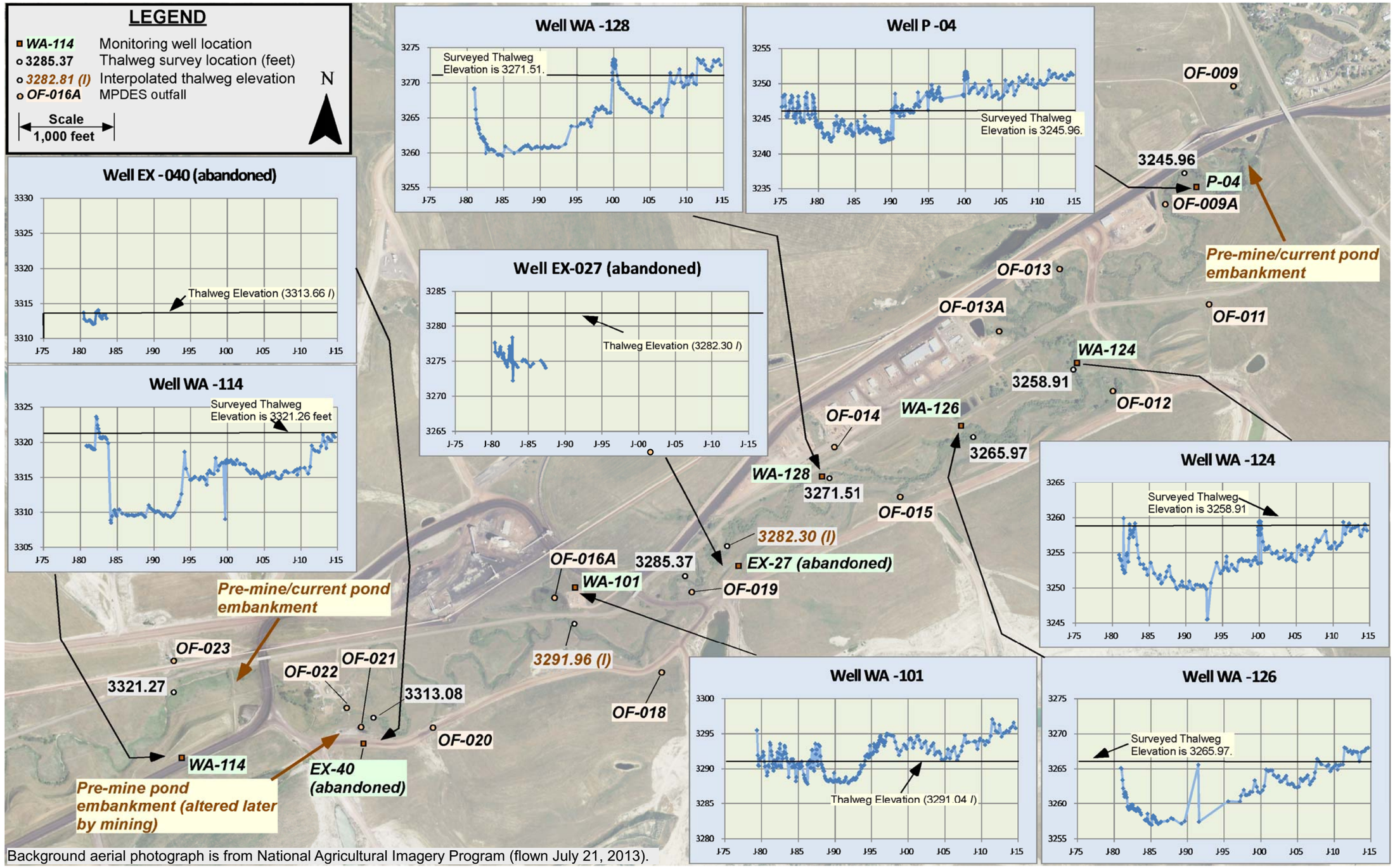
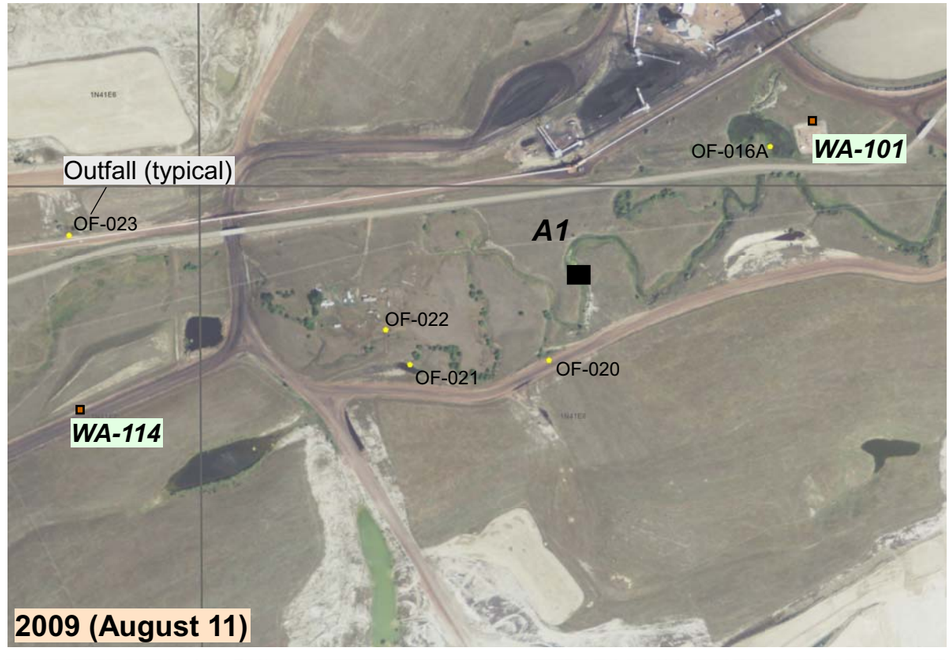
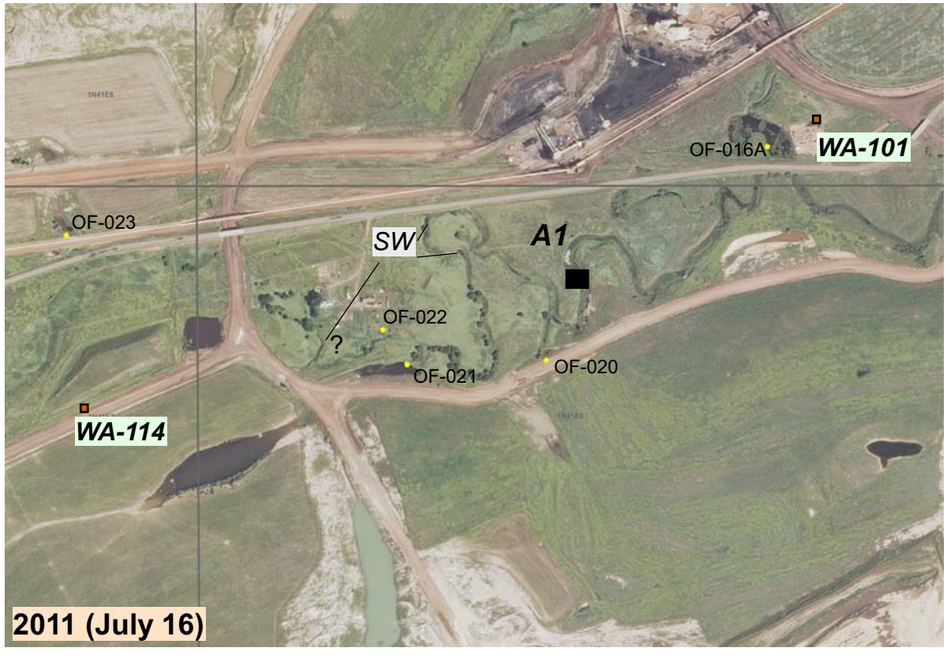


Figure 2. Comparison of East Fork Armells Creek alluvial well hydrographs to nearby surveyed channel thalweg elevations (feet).





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Scale not indicated

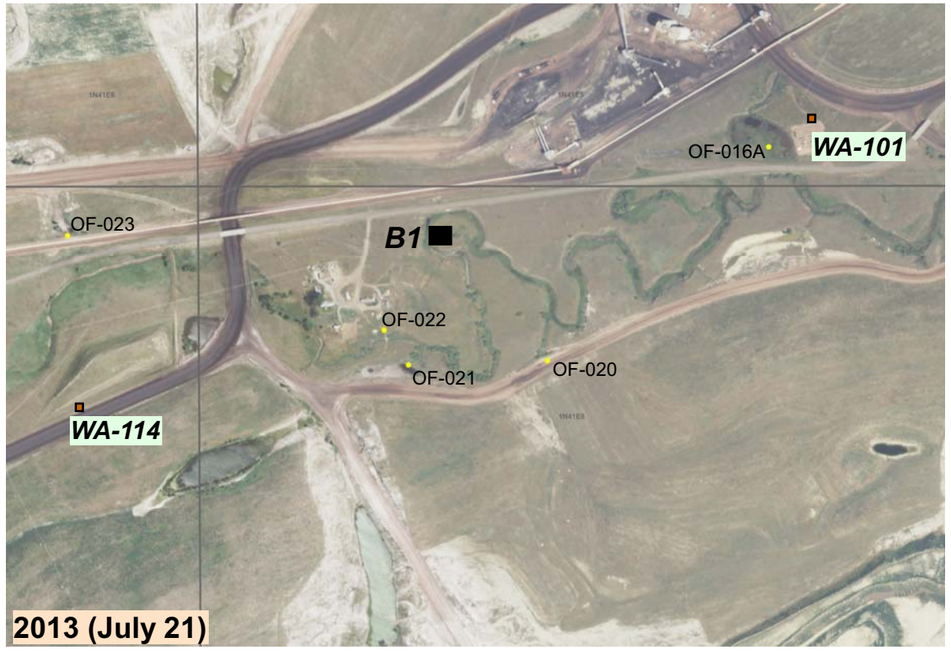
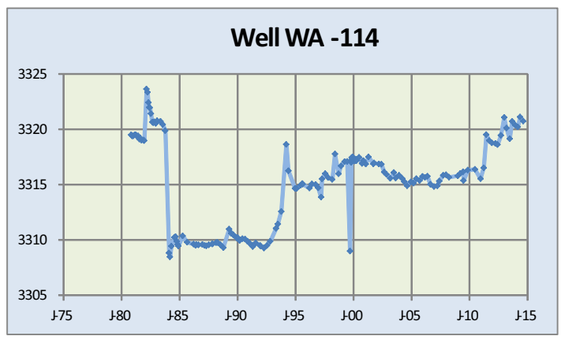
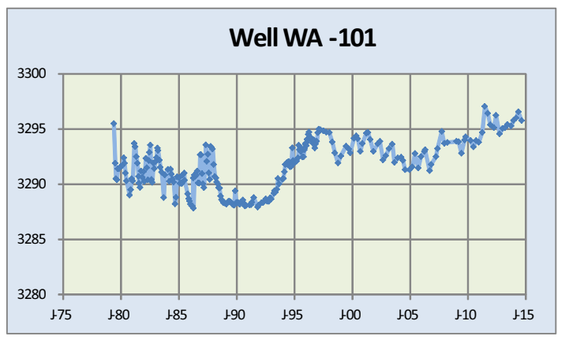


Figure 3. Evaluation of transition from ephemeral to intermittent channel.





2009 summary .

1. Channel condition dry above point A1. Channel water observed downgradient of point A1.
2. Hydrograph at WA-114 shows water levels below pre-mine conditions.
3. Hydrograph at WA-101 shows water levels above pre-mine conditions.

2011 summary (a major precipitation/runoff event occurred on July 15, 2011).

1. Some limited zones of standing water (SW) observed upgradient (west) of point A1. Given the near coincidence of runoff event to aerial photography, the source of the standing water observed is inter preted to be from direct runoff (as opposed to groundwater).
2. Hydrograph at WA-114 shows water levels have recovered to pre-mine conditions.
3. Hydrograph at WA-101 shows water levels well above pre-mine levels.

2013 summary

1. Some standing water (SW) interpreted to be present at point B1 with some limited pooling downgradient.
2. Hydrograph at WA-114 shows water levels at or above pre-mine conditions. Yet, no standing water near this well. Hence, the channel near WA-114 is deemed ephemeral.
3. Hydrograph at WA-101 shows water levels above pre-mine levels.

Attachment 3

Memorandum

August 26, 2014

To: Wade Steere, Western Energy

From: Bill Schafer, Schafer Limited LLC

Re: Calcium Lignin Sulfonate vs. Magnesium Chloride for Dust Suppression

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Background

Magnesium chloride has been historically used on haul roads at Westmoreland's Rosebud Mine for dust suppression. Westmoreland is evaluating the potential effects of changing to Calcium Lignin Sulfonate (CaLS) for use as a dust suppressant. The primary issue evaluated in this memorandum is the potential for application of CaLS to increase sulfate in area surface water.

The approach used to assess potential sulfate loading from CaLS was to compare the application rate of CaLS to that of magnesium chloride. The potential sulfate loading (from CaLS) was estimated based on observed chloride trends in surface water (from magnesium chloride). Comparison of magnesium and chloride concentration in various samples collected in the East Fork Armells basins (Figure 1) shows that median background chloride in surface water is only about 14 mg/L, and the ratio of magnesium to chloride is typically around 10:1. Some samples, however, show higher chloride concentrations (rarely over 200 mg/L) and have elevated chloride relative to magnesium. In these samples, the ratio of Mg/Cl is closer to that found in magnesium chloride ($MgCl_2$ - 0.22:1), suggesting that dissolution of applied magnesium chloride from haul roads may be a source of chloride.

Sulfate release from CaLS, while possible, would be less pronounced than for chloride release from magnesium chloride for several reasons.

1. The sulfur in CaLS is combined in the organic molecular structure as shown in Figure 2. The lignin molecules have high molecular weight (500 to 100,000) and therefore have very low solubility. In order for the sulfur to be released, the lignin molecule would need to biodegrade. Degradation of lignin occurs very slowly.

2. The amount of sulfur contained in CaLS is lower than the chloride in magnesium chloride. Even using the lowest formula weight for CaLS (calcium 3-(2-hydroxy-3-methoxyphenyl)-2-[2-methoxy-4-(3-sulfonatopropyl) phenoxy] propane-1-sulfonate - $C_{20}H_{24}CaO_{10}S_2$) yields a sulfur content of 12.12 % (which is equivalent to 36.4% as sulfate), compared to the chloride in magnesium chloride of 74.2 %. Based on typical application rates for magnesium chloride and CaLS (Table 1), the amount of sulfate added per unit area of haul road surface is less than half the amount for chloride. Manufacturers literature on CaLS suggests an even lower sulfur content of 3.1 % (total

S of 31,100 ppm)

3. Finally, the background (median) levels of chloride (14 mg/L) and sulfate (783 mg/L) in the East Fork Armells basin samples differ by about 50 times. Even if the chemical mobility of sulfate was as great as that of chloride (which it is not), the effect of CaLS on background sulfate levels should be less than 1 % of the relative contribution of chloride from magnesium chloride.

Given the low mobility of sulfur in CaLS, the lower application rate of sulfur versus chloride, and the higher natural abundance of sulfate, the potential overall sulfate loading from CaLS will be low. Application of CaLS is not expected to cause a measurable change in background sulfate.

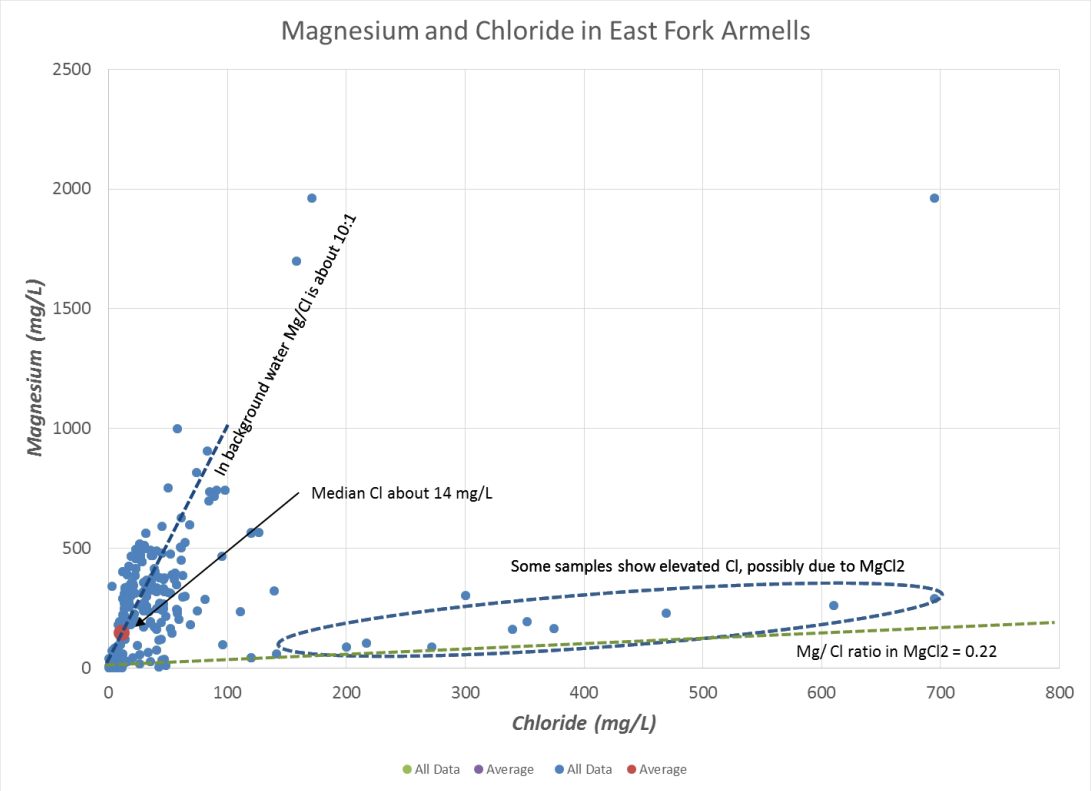


Figure 1. Magnesium and chloride in East Fork Armells Creek samples.

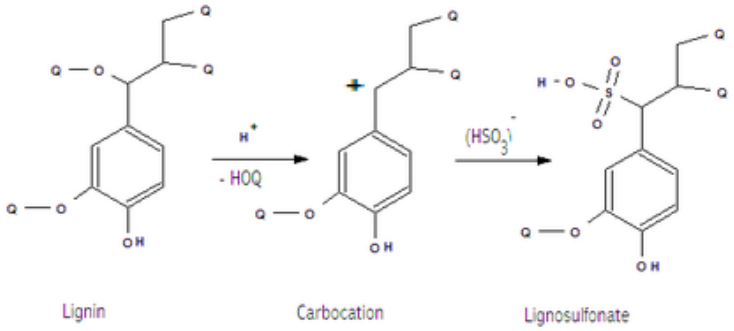


Figure 2. Molecular structure of lignin and CaLS.

Table 1. Application rates for magnesium chloride and CaLS.

Formula	**$MgCl_2$**	**CaLS**
Applications/Year	2	2
Application Rate (L/m^2)	2.25	2.25
Percent Solids Grav (%)	25%	25%
Specific Gravity (g/cm^3)	1	1
Chloride %	74.2%	NA
Sulfur as SO_4 %	NA	36.4%

Analysis of the Ammonium Lignin Sulfonate Liquor on March 27, 2001 by Institute of Paper Science

Vapor Pressure

	10% Solids	15% Solids	25% Solids	50% Solids
Vapor Pressure @100^{0}F, psi	0.23	0.22	0.20	0.31
Vapor Pressure @200^{0}F, psi	1.02	0.99	0.95	0.98

Vapor Density

	10% Solids	15% Solids	25% Solids	50% Solids
Vapor Density @100^{0}F (air=1)	1.147	1.257	1.265	1.296
Vapor Density @200^{0}F (air=1)	1.204	1.244	1.289	1.317

Additional Tests (results are reported on an "as received" wet weight basis unless noted otherwise)

Test Parameter	Result
pH	5.96
Boiling Point, ^{0}F	213
Flash Point, ^{0}F	256
Specific Gravity @15^{0}C/15^{0}C	1.2250
Heat of Combustion, Bomb Calorimetry, BTU/lb	3890
Volatiles, EPA Method 25, wt.%	0.18
Aluminum, ppm	10
Calcium, ppm	484
Copper, ppm	0.6
Iron, ppm	12
Magnesium, ppm	300
Manganese, ppm	76
Phosphorus, ppm	92
Sodium, ppm	102
Total Kjeldahl Nitrogen, wt.%	7.96

Test Parameter	**Result**
Ammonia Nitrogen, wt.%	6.71
Nitrate, as NO_3^- , ppm	1070
Nitrite, as NO_2^- , ppm	<100
Sulfur, Total, ppm	31100
Sulfate, as $SO_4^=$, ppm	8370
Thiosulfate, as $S_2O_3^=$, ppm	1960
Sulfite, as $SO_3^=$, ppm	8140
Acetic Acid, as CH_3COO^- , ppm	48200
Lignin, wt.%	17.41
Rhamnose, wt.%	<0.1
Arabinose, wt.%	0.30
Xylose, wt.%	7.64
Mannose, wt.%	0.37
Galactose, wt.%	<0.1
Glucose, wt.%	2.85
Chloride, as Cl^-, ppm	<100
Chemical Oxygen Demand (COD), ppm	596000
Biochemical Oxygen Demand (BOD_5), ppm	64050
Volatile Solids, ignited @525^{0}C, wt.%, o.d. basis	97.49
Total Solids, dried @ 105^{0}C, wt.%	50.29
Total Organic Carbon (TOC), ppm	133500
Arsenic, ppm	<3
Cadmium, ppm	<0.3
Chromium, Total, ppm	0.3
Lead, ppm	<2
Mercury, ppm	<1
Selenium, ppm	<3
Silver, ppm	<0.2
Barium, ppm	20
Boron, ppm	3

Attachment 4

ARCADIS U.S., Inc.
1687 Cole Blvd.
Suite 200
Lakewood
Colorado 80401
Tel 303 231 9115
Fax 303 231 9571

MEMO

To:
Western Energy Company

Copies:

From:
Penny Hunter, ARCADIS
Jason Vogel, ARCADIS

Date:
December, 2014

ARCADIS Project No.:
CO001837.00001

Subject:
Western Energy - Rosebud
Aquatic Survey Assessment

---

1. INTRODUCTION

The following letter report describes the results of the aquatic habitat assessment and benthic community survey work performed by ARCADIS on October 9, 2014 within the East Fork Armells Creek (EFAC).

2. SAMPLE LOCATIONS

Aquatic surveys within EFAC were conducted to support existing permitting efforts for surface water discharges, per recent comments received by Montana Department of Environmental Quality (MDEQ). These recent comments included a June 3rd, 2014 MDEQ letter to Western Energy Company (WEC) stating that their application for Permit ID C1984003B Amendment AM4 was deficient and that WEC needed to "confirm, based on current and future anticipated concentrations in the stream, that uses have not or will not be impaired (MDEQ 2014)." In addition, MDEQ requested that WEC "conduct a current aquatic survey along stretches of East Fork Armells Creek (EFAC) adjacent to the Rosebud Mine permit areas (Areas A, B, and C) to identify assemblages of aquatic life using the stream habitat." MDEQ states the data collected from the aquatic survey will be used for future permit revisions in Area A and Area C.

Prior to conducting the aquatic survey, two ARCADIS scientists performed a reconnaissance along the stretch of EFAC adjacent to the Rosebud Mine permit areas (Areas A, B, and C) on October 9, 2014. The reconnaissance was performed to confirm existing drainage conditions (i.e., wetted extents and potential

Exhibit 32

habitat types) that would be representative of the current EFAC aquatic community. Based on the largely homogeneous aquatic habitat observed, consisting of primarily low-gradient drainage with minimal flow, heavy siltation, and riparian and emergent wetlands, two representative locations were selected to survey the current benthic community. The attached Figure 1 indicates the locations of EFAC1 and EFAC2. Location EFAC1 is positioned lower in the EFAC drainage. Compared to more upstream stretches, EFAC1was less impounded, had more visible flow sections and a higher degree of meander and sinuosity patterns in the drainage. This location had an established riparian zone with herbaceous, shrub, and tree vegetation layers, and some in-channel woody debris. Location EFAC2 is found in the middle portion of the EFAC drainage and near the upper extent of the wetted conditions observed during the reconnaissance. EFAC2 represents a low-gradient drainage. Compared to EFAC1, this location had a minimally developed flowing channel, relatively wider and more impounded wetted channel, and less meander and sinuosity. The riparian zone contained emergent vegetation.

3. SURVEY METHODS

Benthic macroinvertebrates were surveyed on October 9, 2014. Survey protocols and taxonomic identification of the benthic community organisms followed both MDEQ's sampling and analysis protocols *Sample Collection, Sorting, Taxonomic Identification, and Analysis of Benthic Macroinvertebrate Communities Standard Operating Procedure* (MDEQ SOP) (MDEQ 2012) and USEPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (RBP) (Barbour et al. 1999). The MDEQ SOP details a semi-quantitative reach wide sampling technique to collect samples from a known area, which allows the estimation of population density, in addition to diversity and abundance. This sampling technique includes the use of a d-frame net at a total of 11 transects within a sampling reach to be collected as kick samples working downstream to upstream. Barbour et al. (1999) recommends either 40 times the wetted stream width or a representative 100 meter reach (as a minimum for smaller-sized streams) for sampling. Based on drainage conditions, an approximate 100 meter reach was established at each benthic community survey location. Following RBP methodologies, general aquatic habitat conditions were detailed to include measurements of water quality parameters and physical characterization of riparian vegetation, instream features, presence of aquatic vegetation and large woody debris, and sediment and substrate components.

Based on existing habitat observed, the number of transects to provide a representative benthic community sample was reduced down from 11 to 8. Based on professional judgment, the MDEQ SOP methodology and its applicability to these low gradient survey reaches was compromised by the lack of riffles, exposed inorganic substrate, and the largely homogeneous habitat observed within each of the survey reaches. The individual area (1 ft^2 – 0.093 m^2) sampled within each survey reach was increased slightly (1.3 ft^2 – 0.12 m^2) to account for the difference and to obtain a representative 1 m^2 area sampled for the reach. Benthic organism abundance was noted throughout the collection process and available habitats were sampled to provide the representation of the existing community. For EFAC1, this included kick net samples, sweeps of emergent vegetation, and hand-picking and rinsing of functional large woody

debris. For EFAC2, the primary habitat was emergent vegetation and exposed root mats of emergent vegetation within a limited free-flowing narrow channel, which was sampled primarily by sweeping emergent vegetation and kicking substrate and root mat and detritus into kick net.

A representative area (approximately a 1.3 ft^2 quadrat) was selected along each transect to collect each of the kick samples. In an area of flow, the kick sample was collected within the representative area, by using hands with a hand trowel or by feet to disturb the area and wash and large rocks, sticks, or debris into the net for a period of 30 seconds. For slackwater habitats with emergent vegetation, the kick net was swept through the vegetation for 30 seconds within the representative area. All individual kick net samples were composited into a 5 gallon bucket and then elutriated to remove large debris. Contents were sieved using a standard #35 (500 micron) mesh size and then transferred to a wide-mouthed plastic sample jar. Samples were preserved with 90% isopropyl alcohol, and sent to Normandeau Environmental Consultants (Normandeau) in Stowe, Pennsylvania, for taxonomic identification. Normandeau taxonomic identification and community sample processing followed by MDEQ protocols to subsample an approximate 500 ± 10% organisms.

Water quality parameters were collected using a YSI 556 multimeter and a Hach 2100P turbidity meter at representative locations within EFAC1 and EFAC2.

4. RESULTS

The aquatic conditions of EFAC are indicative of low-gradient streams, with influences from a mixture of water origins (seasonal runoff, groundwater), and supportive of a tolerant benthic community. Existing habitat is characterized by heavy siltation, low flow, and high amount of organic substrates, with prevalent emergent vegetation along riparian zones.

Table 1 provides a summary of the temperature, specific conductance, dissolved oxygen, pH and turbidity measured at each location. Table 2 summarizes the main physical characteristics and substrate observations for both EFAC1 and EFAC2. Attachment 1 includes observations included during the RBP assessment of aquatic habitat and a set of photographs detailing the habitats surveyed at EFAC1 and EFAC2.

Table 3 provides the results of the taxonomic identification for the EFAC1 and EFAC2 benthic community samples. Community diversity and abundance was similar between the two locations, with a total of 25 and 26 taxa identified at EFAC1 and EFAC2, respectively. Communities were represented by eight orders of aquatic organisms, including aquatic worms, snails, amphipods, mayflies, damselflies, caddisflies, beetles, midges, and fly larvae. Within EFAC1, the side swimmer amphipod within the genus of *Hyalella* was the most dominant benthic organism observed. Within EFAC2, the non-biting midge within the genus of *Paramerina* was the most dominant benthic organism observed. For both locations, mainly tolerant Dipteran taxa comprised over 50% of the community, with *Hyalella* following closely at nearly 25% and

above within the community. Based on the MDEQ protocols, a community indicator metric (Hilsenhoff Biotic Index [HBI]) was calculated using Montana-specific tolerance values for identified taxa. The HBI metric represents the relative sensitivity of the sample to nutrient perturbation. The HBI, based on 2005 operable Taxonomic Units (taxonomic endpoints) found in Appendix A of the MDEQ SOP, was calculated for both locations (6.98, 7.90), and indicates “fairly poor” to “poor” conditions (Hilsenhoff 1987).

In summary, the aquatic habitat assessment and benthic community survey was conducted in general accordance with RBPs and MDEQ SOP protocols to satisfy the current deficiency letter and to support the potential for future permitting within existing areas A, B, C within the EFAC.

.

Attachments

Figure 1 – Aquatic Habitat Assessment and Benthic Community Survey Locations

Table 1 – Water Quality Parameters for East Fork Armells Creek

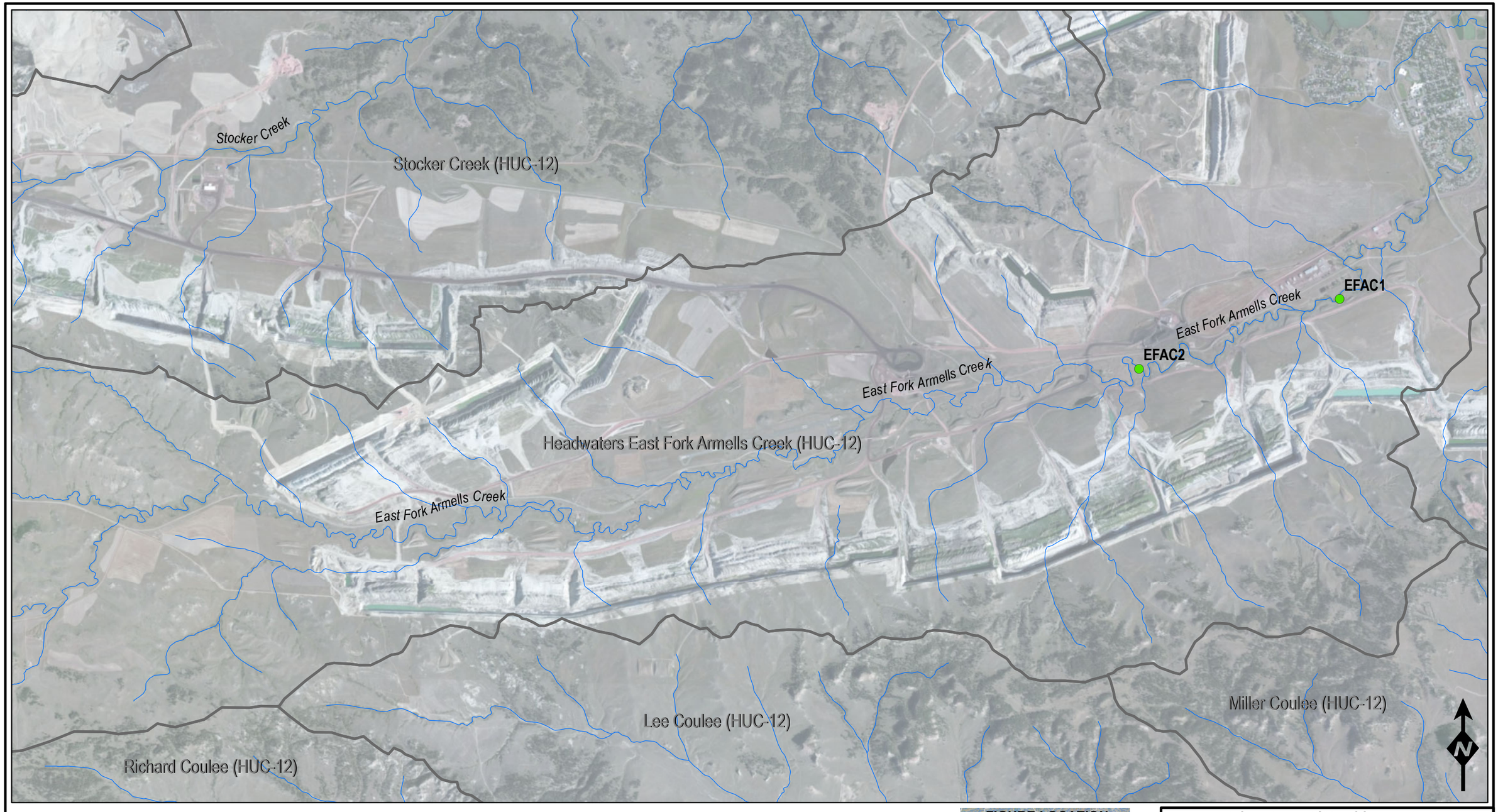
Table 2 – Physical Characterization and Substrate Summary for East Fork Armells Creek

Table 3 – Benthic Community Samples for East Fork Armells Creek

Attachment 1 – Photolog

Exhibit 32

FIGURE AND TABLES



Aquatic Habitat Assessment and Benthic Community Survey Location

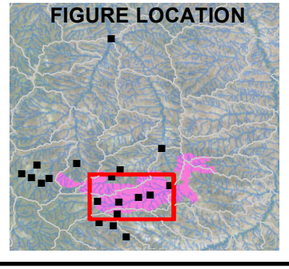
- Benthic Community Survey
- USGS NHD Streams
- Watershed Boundaries (HUC12)

0 2,000 4,000 Feet

GRAPHIC SCALE

Notes:
Projection: UTM Zone 13 NAD83
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

FIGURE LOCATION



WESTERN ENERGY - ROSEBUD MINE
COLSTRIP, MONTANA

AQUATIC HABITAT ASSESSMENT AND BENTHIC COMMUNITY SURVEY

EAST FORK ARMELLS CREEK AREA

ARCADIS

FIGURE 1

Exhibit 32

Document Path: Z:\GISPROJECTS_ENV\Western_Energy_Rosebud\MXD\2014\WE_Rosebud Benthic Community Assessment 0001.mxd

Table 1. Water Quality Parameters for East Fork Armells Creek (Rosebud, MT)

Parameter	EFAC1	EFAC2
Temperature (°C)	16.9	12.9
Specific Conductance (mS/cm)	2.5	2.4
Dissolved Oxygen (mg/L)	9.90	3.52
pH (std units)	8.8	8.4
Turbidity (NTU)	2.49	25.4

Notes:
°C = degress Celsius
mS/cm = milliSiemens per centimeter
mg/L = milligrams per liter
NTU = Nephelometric Turbidity Units

Table 2. Physical Characterization and Substrate Summary for East Fork Armells Creek (Rosebud, MT)

Parameter	EFAC1	EFAC2
Reach Length (m)	100	100
Average Wetted Width (m)	1.9	5.3
Average Stream Depth (in)	5.4	4.5
Average Stream Velocity (ft/sec)	0.22	0.078
Large Woody Debris (m^2)	40	0
Aquatic Vegetation (%)	60	90
Detritus (%)	75	60
Muck-Mud (%)	25	40
Inorganic Substrate Type (Dominant, %)	100% Silt	100% Silt

Notes:
m = meter
in = inch
ft/sec = feet per secon
m^2 = square meter

Table 3. Benthic Community Samples for East Fork Armells Creek (Rosebud, MT)

Sample Date: October 9, 2014
Gear: Kick Net (Montana DEQ: 500-specimen sub-sample)

Taxon	Tol.*	Common name	EFAC1 Number	EFAC1 Percent	EFAC2 Number	EFAC2 Percent
Nematoda	5	round worm			2	0.4%
Haplotaxida						
Enchytraeidae	4	earth worm	2	0.4%		
Tubificinae						
Ilyodrilus	10	tube worm			3	0.5%
Limnodrilus	10	tube worm	1	0.2%	1	0.2%
Basommatophora						
Lymnaeidae						
Fossaria	6	pond snail	15	3.1%		
Physidae						
Physa/Physella	8	pouch snail	6	1.2%	22	4.0%
Amphipoda						
Hyalellidae						
Hyalella	8	side swimmer	187	38.6%	134	24.4%
Ephemeroptera						
Baetide						
Callibaetis	9	mayfly	1	0.2%	4	0.7%
Odonata						
Coenagrionidae	7	damselfly	11	2.3%	16	2.9%
Argia	7	damselfly			25	4.5%
Trichoptera						
Limnephilidae	3	caddisfly			2	0.4%
Coleoptera						
Dytiscidae						
Agabus	5	diving beetle	7	1.4%		
Hydroporini	5	diving beetle			1	0.2%
Diptera						
Chironomidae						
Alotanypus	-	midge			4	0.7%
Apsectrotanypus	8	midge	42	8.7%	18	3.3%
Chironomus	10	midge			1	0.2%
Diplocladius	5	midge	11	2.3%		
Heterotrissocladius	0	midge			7	1.3%
Micropsectra	4	midge	63	13.0%	6	1.1%
Natarsia	-	midge			4	0.7%
Orthocladiinae	10	midge	5	1.0%		
Paramerina	-	midge	25	5.2%	211	38.4%
Parametriocnemus	5	midge			3	0.5%
Paratendipes	10	midge	2	0.4%	4	0.7%
Tanypodinae	-	midge	4	0.8%	42	7.6%
Tanytarsus	6	midge	59	12.2%	1	0.2%
Thienemannimyia gr.	-	midge	16	3.3%		
Other Diptera						
Ceratopogonidae						
Atrichopogon	6	sand fly			1	0.2%
Culicoides	10	sand fly	8	1.7%	28	5.1%
Dasyhelea	6	sand fly	1	0.2%	1	0.2%
Palpomyia gr.	6	sand fly	5	1.0%	8	1.5%
Probezzia	6	sand fly	7	1.4%		

Table 3. Benthic Community Samples for East Fork Armells Creek (Rosebud, MT)

Sample Date: October 9, 2014
Gear: Kick Net (Montana DEQ: 500-specimen sub-sample)

Taxon	Tol.*	Common name	EFAC1 Number	EFAC1 Percent	EFAC2 Number	EFAC2 Percent
Other Diptera (continued)						
Empididae						
Chelifera	5	dance fly	1	0.2%		
Ephydridae	6	shore fly			1	0.2%
Simuliidae						
Simulium	5	black fly	3	0.6%		
Tipulidae						
Limnophila	3	crane fly	1	0.2%		
Ormosia	6	crane fly	1	0.2%		
Total Individuals			484	100.0%	550	100.0%
Total Taxa			**25**		**26**	
Hilsenhoff Biotic Index			**6.98**		**7.90**	
(water quality rating: from Hilsenhoff, 1987)			(fairly poor)		(poor)	

Reference:*

Tol = Tolerance values as found in Appendix A of:

Montana Department of Environmental Quality (MT DEQ). 2012. Sample Collection, Sorting, Taxonomic Identification, and Analysis of Benthic Macroinvertebrate Communities Standard Operating Procedure. MT DEQ, WQPBWQM - 009

ARCADIS

ATTACHMENT 1

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1344

Date: 10/9/14

Direction Photo Taken:

Facing northwest

Description:

Wetland area on EFAC approximately 0.4 stream miles downstream of EFAC1 survey location. Standing water present.

Lat: 45.869200
Long: -106.63763

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1345

Date: 10/9/14

Direction Photo Taken:

Facing southeast

Description:

Wetland area on EFAC approximately 0.4 stream miles downstream of EFAC1 survey location. Standing water extends under Castle Rock Road through culvert.

Lat: 45.868820
Long: -106.637500

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1348

Date: 10/9/14

Direction Photo Taken:

Facing northwest

Description:

Wetland area on EFAC approximately 0.8 stream miles downstream of EFAC2 survey location. Proximate to intersection of EFAC, Castle Rock Road, and haul road.

Lat: 45.861580
Long: -106.652240

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1349

Date: 10/9/14

Direction Photo Taken:

Facing northwest

Description:

Wetland area on EFAC approximately 0.5 stream miles downstream of EFAC2 survey location. Castle Rock Road in distance

Lat: 45.860400
Long: -106.656270

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No.	Date:
1351	10/9/14

Direction Photo Taken:

Facing west

Description:

Upstream extent of EFAC wetland area. Standing water present. Approximately 0.2 stream miles upstream of EFAC2 survey location. Dry conditions observed continuing upstream.

Lat: 45.859860
Long: -106.664020

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No.	Date:
1352	10/9/14

Direction Photo Taken:

Facing southwest

Description:

Dry channel approximately 0.75 stream miles upstream of EFAC2 survey location. Castle Rock Road observed on right edge of photo.

Lat: 45.859930
Long: -106.670680

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1353

Date: 10/9/14

Direction Photo Taken:

Facing northwest

Description:

Dry channel approximately 1.1 stream miles upstream of EFAC2 survey location. Castle Rock Road observed n upper right of photo.

Lat: 45.857170
Long: -106.675190

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1354

Date: 10/9/14

Direction Photo Taken:

Facing northeast

Description:

Dry channel approximately 2.3 stream miles upstream of EFAC2 survey location.

Lat: 45.854550
Long: -106.686500

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No.	Date:
1355	10/9/14

Direction Photo Taken:

Facing downward into water

Description:

Downstream extent of EFAC1 at EFAC1-1 transect. Kicksweep area. Substreate consists of detritus and much/mud. Principally silt.

Lat: 45.86633
Long: -106.63821

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No.	Date:
2356	10/9/14

Direction Photo Taken:

Facing southwest - upstream

Description:

Near to downstream extent of EFAC1 at EFAC1-2 transect. Kicksweep area. Substreate consists of detritus and muck/mud. Principally silt. Woody debris present.

Lat: 45.86628
Long: -106.63821

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1360

Date: 10/9/14

Direction Photo Taken:

Facing northeast - downstream

Description:

Near to midstream extent of EFAC1 at EFAC-1-6. Sample collected from sweeping of watercress. Silt streambed material. Emergent vegetation, woody debris, and coarse plant material.

Lat: 45.86595
Long: -106.63861

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1362

Date: 10/9/14

Direction Photo Taken:

Facing west - downstream

Description:

Upstream extent of EFAC1 at EFAC-1-8. Kick area. Silt streambed material. Emergent vegetation, woody debris, and coarse plant material.

Lat: 45.86581
Long: -106.63855

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1363

Date: 10/9/14

Direction Photo Taken:

Facing northwest - upstream

Description:

Downstream extent of EFAC2 at EFAC2-1 transect. Shows extent of survey area. Decaying root matt. Silty/fine/muck and mud bed. Sedges present in area.

Lat: 45.85940
Long: -106.66233

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 3364

Date: 10/9/14

Direction Photo Taken:

Facing southeast - downstream

Description:

Downstream extent of EFAC2 at EFAC2-1 transect. Shows downstream of survey area. Sedges in foreground and cattails in background downstream.

Lat: 45.85940
Long: -106.66233

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1370

Date: 10/9/14

Direction Photo Taken:

Facing northwest - upstream

Description:

Near to upstream extent of EFAC2 at EFAC-2-7 transect. Open water and decaying sedges. Cattails in area. Silt bottom and iron oxide sheen present.

Lat: 45.85970
Long: -106.66307

ARCADIS

PHOTOGRAPHIC LOG

Property Name:	Location:	Project No.
Rosebud Mine	Rosebud, Montana	CO1837.0001

Photo No. 1372

Date: 10/9/14

Direction Photo Taken:

Facing southeast - downstream

Description:

Upstream extent of EFAC2 at EFAC-2-8 transect. Upstream of cattail os photo 1370. Silty bed. Decaying sedges and root matt.

Lat: 45.85976
Long: -106.66317

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George Otis Smith, Director

Bulletin 812—A

THE FORSYTH COAL FIELD

ROSEBUD, TREASURE, AND BIG HORN COUNTIES MONTANA

BY

C. E. DOBBIN

Contributions to economic geology, 1929, Part II
(Pages 1–55)

UNITED STATES
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WASHINGTON : 1929

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CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1929

PART II. MINERAL FUELS

THE FORSYTH COAL FIELD, ROSEBUD, TREASURE, AND BIG HORN COUNTIES, MONTANA

By C. E. DOBBIN

INTRODUCTION

Location and relations of the field.—The Forsyth coal field embraces an area of about 800 square miles in southern Montana, south of Yellowstone River and east of the 107th meridian, and includes parts of Rosebud, Treasure, and Big Horn Counties. (See pl. 1.) The Forsyth field is only a fractional part of the great coal field which extends from the Big Horn and Musselshell Rivers eastward into the Dakotas and southward into the Powder River Basin, Wyo. The coal of this broad region ranges in grade from lignite, which occurs in the Dakotas and the extreme eastern part of Montana, to subbituminous coal in the Forsyth, Tullock Creek, Sheridan, and Bull Mountain fields.

Interest in the Forsyth field has been stimulated recently by the construction of a branch line of the Northern Pacific Railway 30 miles long up Armells Creek and the East Fork of Armells Creek to one of the thick Fort Union coal beds long known to occur in the region. The field is of present importance because it contains a large tonnage of coal that can be recovered by strip mining.

Field work and acknowledgments.—The Forsyth field was examined to collect data upon which to classify the public land included in it with regard to its value as coal land. The geologic mapping was done with the plane table and telescopic alidade, and all locations were tied to land corners. Altitudes are based on the United States Coast and Geodetic Survey bench mark at Finch railroad station and upon precise levels established by the engineers of the

Exhibit 31

Northern Pacific Railway and the Northwestern Improvement Co. The field work was done in the summer of 1923, and the writer was assisted by Prof. C. R. Fettke, C. M. Clark, and D. S. Mossom. The examination was made under the supervision of W. T. Thom, jr., and the writer feels indebted to him for suggestions both in the office and in the field. Acknowledgments are due to Mr. S. P. Sawyer, resident engineer of the Northwestern Improvement Co., and his associates for their unfailing courtesy and kindness in furnishing altitudes and other data necessary to properly carry on the work. Thanks are also due to the residents in the field for the many favors they showed. Finally, the writer takes this means of publicly thanking his assistants for their efficient work during the field examination.

Land surveys.—The earliest land surveys in the Forsyth field were made in the Yellowstone Valley in the years 1878 and 1879 and embraced T. 6 N., Rs. 38–41 E. In 1885 land surveys were made along Armells Creek in Tps. 2 and 3 N., Rs. 40 and 41 E., T. 4 N., R. 40 E., and T. 5 N., R. 39 E. In 1886 T. 1 S., R. 41 E., was surveyed. Except T. 5 N., R. 38 E., and T. 1 S., R. 40 E., surveyed in 1903 and 1908, respectively, all other townships in the field were surveyed in the period 1909–1916.

Many land-corner marks in Yellowstone Valley and along Rosebud and Armells Creeks are missing. In the upland areas practically all corner marks searched for were found, and to them all geologic mapping was tied. The corners of all townships surveyed before 1911 were marked by stones many of which have been so much weathered that all identification marks have been obliterated.

Previous work.—The general geology along the Yellowstone Valley has been described by Campbell[1] and that north of the Forsyth field and beyond the Yellowstone River by Bowen.[2] In 1920 C. E. Dobbin and W. T. Thom, jr., made a reconnaissance study of the principal geologic features of the coal-bearing area of southeastern Montana, the results of which were released in a press notice.[3] The Tullock Creek coal field, which adjoins the Forsyth field on the west, has been described by Rogers and Lee.[4] The location of other coal fields in the region surrounding the Forsyth field that have been

[1] Campbell, M. R., Guidebook of the western United States, Part A, The Northern Pacific Route: U. S. Geol. Survey Bull. 611, 1915.

[2] Bowen, C. F., Possibilities of oil in the Porcupine dome, Rosebud County, Mont.: U. S. Geol. Survey Bull. 621, pp. 61–70, 1915.

[3] Oil possibilities in southeastern Montana: U. S. Geol. Survey Press Notice 14846, 1921.

[4] Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek coal field, Rosebud and Big Horn Counties, Mont.: U. S. Geol. Survey Bull. 749, 1923.

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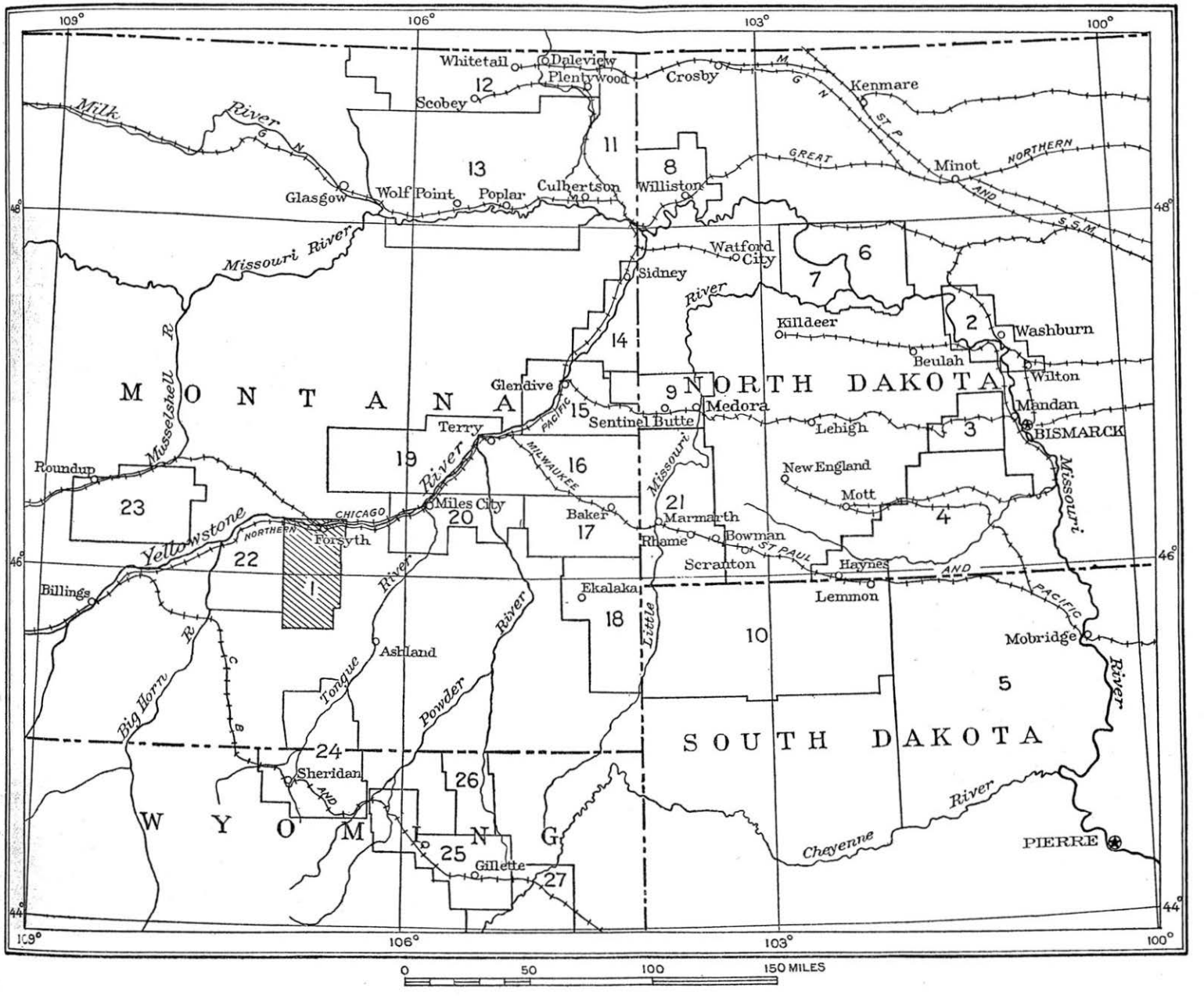
Exhibit 31



INDEX MAP SHOWING LOCATION OF FORSYTH COAL FIELD, MONTANA

See page 1

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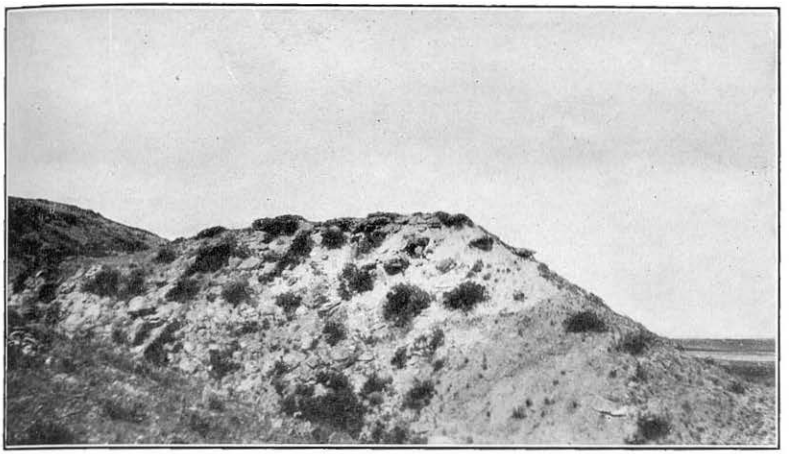
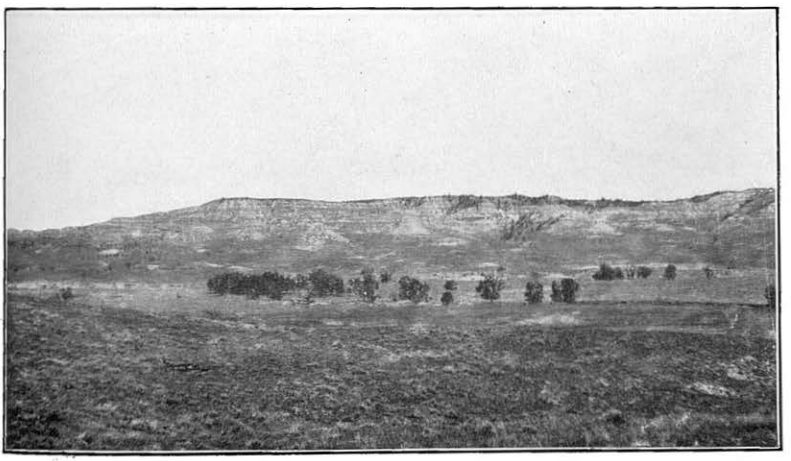
Exhibit 31

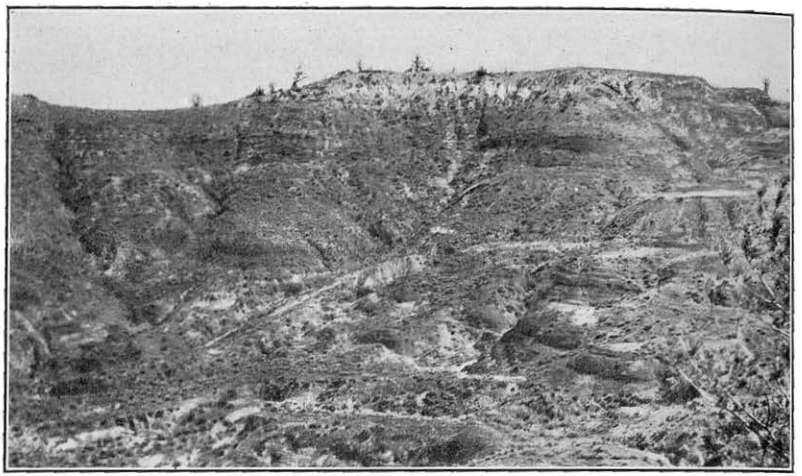


A. LIGHT-COLORED SANDSTONE AND BROWN SANDY SHALE AT THE TOP OF THE JUDITH RIVER FORMATION, NEAR FINCH, MONT.

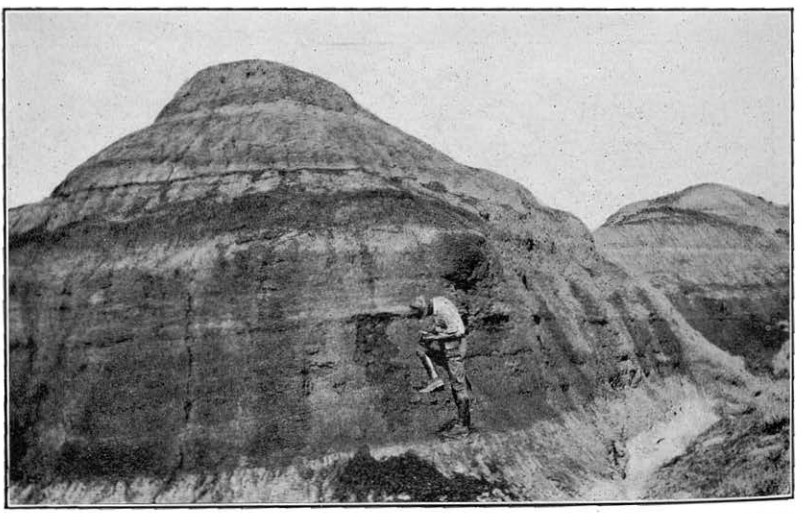


B. ESCARPMENT OF THE TULLOCK MEMBER OF THE LANCE FORMATION ON ARMELLS CREEK, T. 5 N., R. 40 E., MONTANA

Exhibit 31

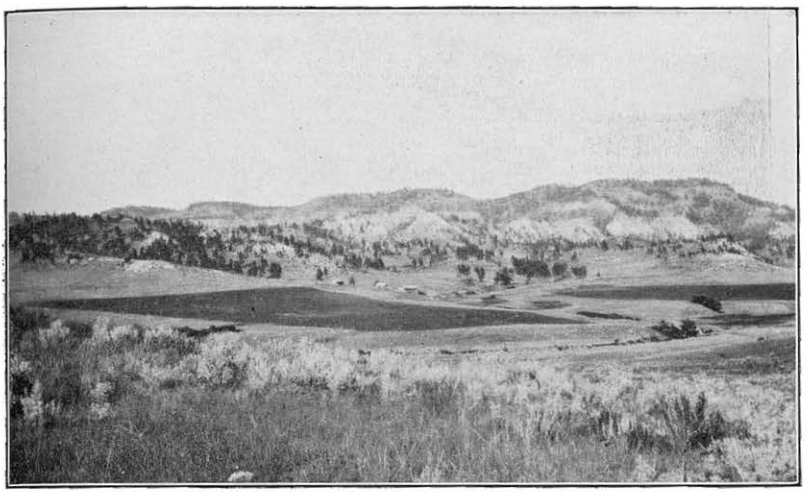


A. LEBO SHALE MEMBER OF THE FORT UNION FORMATION OVERLAIN BY THE TONGUE RIVER MEMBER, SEC. 31, T. 5 N., R. 41 E., MONTANA



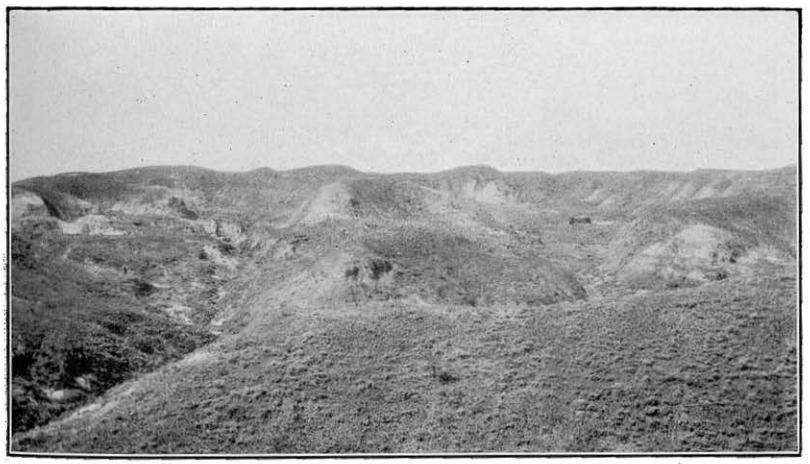
B. BIG DIRTY COAL BED AT THE BASE OF THE LEBO SHALE MEMBER OF THE FORT UNION FORMATION, SW. ¼ SEC. 31, T. 3 N., R. 41 E., MONTANA

Exhibit 31



A. WEST SIDE OF THE WOLF MOUNTAINS FROM THE EAST QUARTER CORNER OF SEC. 25, T. 1 N., R. 38 E., MONTANA

Showing the character of the topography where the Tongue River member of the Fort Union formation crops out



B. VIEW IN SEC. 13, T. 3 N., R. 40 E., MONTANA

Showing type of topography characteristic of areas where the Lebo shale member of the Fort Union formation crops out

Exhibit 31

Exhibit 31

described by the Geological Survey is shown on Plate 1. The names of the fields designated by numbers on the map and references to the Geological Survey publications in which they have been described are as follows:

Coal fields whose locations are shown in Plate 1

No.	Field	Bulletin	No.	Field	Bulletin
1	Forsyth	812-A.	14	Sidney	471-D.
2	Washburn	381-A.	15	Glendive	471-D.
3	New Salem	726-A.	16	Terry	471-D.
4	Cannonball River	541-G.	17	Baker	471-D.
5	Standing Rock and Cheyenne River.	575.	18	Ekalaka	751-F.
			19	Little Sheep Mountain	531-F.
6	Fort Berthold	381-A and 471-C.	20	Miles City	341-A.
			21	Marmarth	775.
7	do	726-D.	22	Tullock Creek	749.
8	Williston	531-E.	23	Bull Mountain	647.
9	Sentinel Butte	341-A.	24	Sheridan	341-B and 806-B.
10	Northwestern South Dakota	627.			
11	Culbertson	471-D.	25	Powder River	381-B.
12	Scobey	751-E.	26	Little Powder River	471-A.
13	Fort Peck	381-A.	27	Gillette	796-A.

GEOGRAPHY

Land forms.—The Forsyth field lies in the Great Plains province and is a much dissected plateau across which the Yellowstone River and its tributaries have cut their valleys. To a large extent the topography of the field is determined by the nature of the underlying rocks. Where the surface strata are soft and incoherent clay and shale the upland areas have a subdued, rolling, and barren appearance, becoming rougher and minutely dissected in parts subject to stream erosion. These types of topography are characteristic of areas where the Bearpaw shale and the Lebo shale member of the Fort Union formation crop out. (See pl. 4, *B*.) In those areas where the rocks of the Lance formation are the surface strata the land is rough; the divides are long and narrow and the intermittent streams flow in narrow and deep valleys and invariably have their sources in narrow ravines trenching the edge of an escarpment several hundred feet high which is capped by a resistant sandstone. (See pl. 2, *B*.) Such an escarpment is a prominent topographic feature on the east side of Armells Creek. Although some rather broad and nearly flat lying areas have been developed in parts of the field where the Tongue River member of the Fort Union formation crops out, these parts are generally characterized by isolated buttes, mesalike hills, and long, narrow divides. These eminences usually have a cap rock of slag or clinker formed by the burning of one of the several thick coal beds of the member. The rocks between successive beds of clinker, except certain massive sandstones to be described later,

Exhibit 31

are much less resistant than the clinker and weather into steep and bare light-colored slopes.

The divide between Armells and Sarpy Creeks in T. 1 N., R. 39 E., and adjoining townships rises rather abruptly several hundred feet above the surrounding country. (See pl. 4, *A*.) This divide is less than a quarter of a mile wide and is capped with a coal clinker 50 feet or more thick. The top of the ridge is about 4,780 feet above sea level and is the highest point in the Forsyth field. The point of lowest altitude is 2,511 feet above sea level and is on the Northern Pacific Railway at the east line of T. 6 N., R. 41 E. The range of relief in the field is thus about 2,269 feet.

East of Armells Creek the flood plain of the Yellowstone River has a maximum width of slightly less than 1 mile at Forsyth, and in some places it has been obliterated by the river undercutting its banks. West of Armells Creek the flood plain attains a maximum width of about 2 miles near Howard and is extensively cultivated. South of the flood plain are rolling areas of Bearpaw shale and terrace gravel, which extend southward 8 miles from the river in Tps. 5 and 6 N., R. 38 E.

On the divide between Sarpy and Armells Creeks, in Tps. 3 and 4 N., Rs. 38 and 39 E., is a fairly extensive deposit of terrace gravel capping an escarpment at an altitude of 3,650 feet, or a little more than 1,000 feet above the level of the Yellowstone River, which corresponds to the highest gravel terrace of the Tullock Creek field.[6] Several hills and ridges in the northern part of T. 4 N., R. 41 E., capped by the same gravel are prominent landmarks. The most extensive gravel terrace is that which occurs in T. 6 N., R. 41 E., east of Forsyth, at a height of 200 feet above the Yellowstone River.

The flood plain of Rosebud Creek is about a quarter of a mile wide and is bordered on both sides by steep bare bluffs several hundred feet high capped by clinker. Viewed from any high point the tributaries of Rosebud Creek in this field appear to run in U-shaped valleys cut in a plateau of clinker, remnants of which make the cap rock on prominent and persistent escarpments rimming the valleys. The valley bottoms are broad and fairly level. Toward the headwaters of these streams the land becomes increasingly rough and, save for a few poor trails, is accessible by saddle horse only.

Drainage and water supply.—The northern part of the field is skirted by the Yellowstone River, which receives all the drainage of the field either directly or by its tributaries, the largest of which are Sarpy, Armells, and Rosebud Creeks. West of Armells Creek the Yellowstone meanders along the north side of its flood plain and

[6] Rogers, G. S., and Lee, Wallace, op. cit., pp. 44–47, 1928.

Exhibit 31

has a border of alluvium averaging 1½ miles wide. Hay and Reservation Creeks cross its flood plain and enter the river near Finch and Howard post offices, respectively. Reservation Creek is about 16 miles long and contains little water during the dry months. East of Armells Creek the Yellowstone flows near the south side of its flood plain, and has undercut its banks and obliterated nearly all of its flood plain along that side except a tract nearly a mile wide on which the town of Forsyth stands. Armells Creek is about 12 miles long and forks in sec. 21, T. 4 N., R. 40 E. Its West Fork extends southwestward about 18 miles and its East Fork southeastward about 16 miles and thence westward about 14 miles. The main creek and both forks contain flowing water the year round. Several short dry streams are tributary to Armells Creek; the largest is Cottonwood Creek, which drains eastward along the south line of T. 5 N., R. 39 E. In T. 2 N., R. 39 E., the larger tributaries of West Fork of Armells Creek are Trail and Donley Creeks, each about 7 miles long and having a north and a south fork. Sheep, Sevenmile, Corral, and Stocker Creeks are the larger tributaries of the East Fork of Armells Creek and except the flow from a few springs in their bottoms contain no water during the dry season. The western border of the field is drained by tributaries of Sarpy Creek. The East Fork of Sarpy Creek in this field is about 7 miles long and is a perennial stream. East Bear, East Beaver, and Horse Creeks, tributaries to Sarpy Creek in order from north to south, are not over 5 miles long and are usually dry. Rosebud Creek, which drains the southern part of the field, is a perennial stream. Its flood plain ranges in width from a few hundred feet to half a mile and locally is irrigated. The larger tributaries of Rosebud Creek from the west are, in order from north to south, Miller Coulee, Lee Coulee, Richard Coulee, Slough Grass Creek, Little Cottonwood Creek, Big Cottonwood Creek, and Lynch Coulee. Rye Grass Creek is the only notable stream which enters it from the east. Practically all these streams have shallow pools of water here and there along their courses in the dry season, and for short distances there may be a slight surface flow of water.

Many springs occur in the field, but water for domestic use and for stock is obtained chiefly from dug or drilled wells. Fair water in small amounts can be obtained from seepages in the terrace gravel along the Yellowstone River. No springs were observed in that part of the field where the Bearpaw shale is the surface formation. Good water issues from the sandstones near the base and at the top of the Lance formation in several places. The spring most used and most easily accessible is on the Yellowstone trail between Forsyth and

Exhibit 31

Armells Creek. This spring is protected by a concrete cover and furnishes a steady supply of drinking water. Another spring which yields satisfactory drinking water is on Sevenmile Creek near the southeast corner of sec. 1, T. 3 N., R. 40 E. The water issues from the base of the massive sandstone at the top of the Lance formation and is the supply used by stockmen and sheep herders for miles around. Springs can also be found in most of the deep and narrow coulees in the middle of the Lance formation, but the water in some of them is highly mineralized. No springs were observed in the Lebo shale anywhere in the field, and sandstones, which might yield water, are usually absent from the Lebo or if present are extremely lenticular and discontinuous.

Springs issue from nearly all the coal beds in the upper part of the Fort Union. This is especially true of the Rosebud bed where it crops out in bottoms of streams. The quantity of water supplied by such springs differs greatly. In some places there may be only enough water to make small pools in the bed of the stream; in others, as along the outcrop of the Rosebud bed in T. 2 N., R. 39 E., and in Miller Coulee, T. 1 N., R. 41 E., a number of springs may contribute enough water to make a small but steady flow even during the summer. Several drilled wells have obtained an abundant supply of water from the sandstones overlying the Rosebud coal bed. One of the best of these wells is at the Hafer place in sec. 12, T. 1 N., R. 41 E. The ground-water resources in the part of this field in Rosebud County have been discussed by Renick,[7] and the ground-water conditions in Treasure and Big Horn Counties were studied by Hall.[8]

Railroads, settlements, and roads.—The Northern Pacific Railway follows the south bank of the Yellowstone River across the northern edge of the field, and a branch line 30 miles long has been constructed up Armells Creek and its East Fork to Colstrip, a coal-mining camp of about 100 people in sec. 34, T. 2 N., R. 41 E. The Chicago, Milwaukee, St. Paul & Pacific Railway follows the north bank of the Yellowstone as far west as Forsyth where it swings northwestward and crosses over into the basin of Musselshell River. The projected North & South Railway will follow the valley of Tongue River east of this field and will connect with the Northern Pacific and Chicago,

[7] Renick, B. C., Base exchange in ground water by silicates as illustrated in Montana: U. S. Geol. Survey Water-Supply Paper 520, pp. 53–72, 1924; Some geochemical relations of ground water and associated natural gas in the Lance formation: Jour. Geology, vol. 32, pp. 668–684, 1924. Renick, B. C., and Riffenburg, H. B., Geology and ground-water resources of central and southern Rosebud County, Mont.; U. S. Geol. Survey Water-Supply Paper 600, 1929.

[8] Hall, G. M., and Howard, C. S., Ground water in Yellowstone and Treasure Counties, Mont.; U. S. Geol. Survey Water-Supply Paper 599, 1929. Hall, G. M., Ground water in Big Horn County, Mont.: U. S. Geol. Survey Water-Supply Paper — (in preparation).

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Milwaukee, St. Paul & Pacific railways at Miles City, and with the Chicago, Burlington & Quincy Railroad at Sheridan, Wyo.

Forsyth, the county seat of Rosebud County, with a population of about 1,850, is the largest town in the field and is the chief shipping and trading center. The small stations, Howard and Finch, west of Forsyth on the Northern Pacific Railway, serve as shipping points for cattle and farm products.

The Yellowstone Trail crosses the central part of T. 6 N., R. 41 E., on the gravel bench and descends to the flood plain of the Yellowstone River at Forsyth. West of Forsyth it roughly parallels the Northern Pacific Railway to the western limit of the field. The Electric Trail, which follows approximately the Chicago, Milwaukee, St. Paul & Pacific Railway, starts at Forsyth and leads northwestward to Vananda, Ingomar, Sumatra, Roundup, and other towns in the Musselshell Valley. A graded county road follows Armells Creek and its West Fork to the northwest corner of T. 1 N., R. 40 E., where it connects with ungraded roads traversing the central part of the field. A graded road follows the East Fork of Armells Creek to Colstrip and leads thence to the Hafer ranch in sec. 12, T. 1 N., R. 41 E., from which two graded roads lead to Rosebud Creek. The graded road between Forsyth and points along Rosebud Creek and the Tongue River leaves the Yellowstone Trail 4½ miles east of Forsyth and runs southeastward into the valley of Rosebud Creek.

The road following Rosebud Creek in this field leads southwestward to Lame Deer, Busby, and Sheridan. On the geologic map are shown practically all the roads in the field. (See pl. 7.) These roads can be traversed by automobiles, though driving may be difficult in places where the roads cross the drainage lines at right angles.

Sarpy post office, in sec. 36, T. 1 N., R. 38 E., receives mail twice a week from Hysham on the Northern Pacific Railway about 12 miles west of this field. All other post offices in the Forsyth field not on the railroad receive their mail by stage from Forsyth.

GEOLOGY

The Forsyth field contains exposed rocks of Upper Cretaceous, Tertiary, and Quaternary ages, comprising the Judith River formation, Bearpaw shale, Lance and Fort Union formations, Oligocene or Miocene (?) terrace gravel, terrace gravel of Pleistocene age, and Recent alluvium. Exposures of the rocks are good throughout the field, and it was possible to obtain many detailed stratigraphic sections, some of which are given in the following pages. The pub-

Exhibit 31

lished sections were selected with the purpose of showing in detail the character of all the rocks in the field above the Bearpaw shale.

Geological section in the Forsyth coal field

System and series	Group and formation	Character	Thickness (feet)
Quaternary.		Recent alluvium and Pleistocene terrace gravel.	0-50
Tertiary (Oligocene or Miocene series).		Terrace gravel cemented into a conglomerate; largely made up of andesitic porphyry. Crops out 1,000 to 1,100 feet above Yellowstone River.	60
Tertiary (Eocene series).	Fort Union formation.	Tongue River member. Prevailingly light-colored sandstone and sandy shale; several of the sandstones thick and massive and weathered into many varied shapes; contains several thick coal beds which have burned along their outcrops and have fused the overlying rock into a slag or clinker.	1,686
		Lebo shale member. Soft incoherent dark gray to black shale, clay, and sandy shale with abundant ferruginous concretions; weathers into gentle treeless slopes and diminutive badlands. Big Dirty coal bed at base.	105-170
Tertiary (Eocene ? series).	Lance formation.	Tullock member. Light-yellow calcareous sandstone and sandy shale closely resembling the strata of the Tongue River member of the Fort Union; sandstones well stratified and rarely massive; usually crops out in a prominent escarpment; contains many thin coal beds, few of which are burned.	240-270
		Hell Creek member. Massive, thick sandstones in the lower part grading upward into greenish-gray and grayish-yellow sandy shale and clay; contains no workable coal in the Forsyth field. Basal sandstone may correspond to the Colgate sandstone member of the Fox Hills sandstone of eastern Montana.	660-675
Cretaceous (Upper Cretaceous series).	Montana group. Bearpaw shale.	Dark-gray fissile marine shale with abundant fossiliferous calcareous concretions. Transition zone, 40 to 60 feet thick, at top may correspond to lower part of Fox Hills sandstone of eastern Montana.	1,000±
	Montana group. Judith River formation.	Upper member composed of grayish-white massive sandstone succeeded below by brown marine shale. Not all of formation exposed in this field.	95+

CRETACEOUS SYSTEM

MONTANA GROUP

Judith River formation.—The rocks of the Judith River formation are the oldest rocks exposed in the Forsyth field and were brought to the surface by the Porcupine uplift. They crop out in the bluffs about a quarter of a mile south of the Northern Pacific Railway between Reservation Creek and the western limit of the field. The

Exhibit 31

top of the formation consists of a very hard, heavily bedded, grayish-white sandstone about 20 feet thick, which makes a prominent bench protruding through terrace gravel. (See pl. 2, *A*.) Its marine origin is shown by the fairly abundant but rather fragmentary remains of *Baculites* and other marine invertebrates. Beneath this sandstone there is 75 feet of brown sandy shale exposed at irregular intervals in the gravel-covered slopes above the level of the alluvium. No fossils were found in the shaly part of the formation.

Bearpaw shale.—Here as elsewhere throughout its outcrop in eastern Montana the Bearpaw is made up almost entirely of dark-gray fissile marine shale containing an abundance of light-brown calcareous concretions. These concretions are rounded and of various sizes, and some contain numerous marine invertebrate fossils of many kinds. At the top of the Bearpaw is a transition zone of thin-bedded sandstone and sandy shale, 40 to 60 feet thick, below the massive sandstones of the overlying Lance formation. This sandy zone represents the final stage of the last marine invasion in Montana and may be of the same age as the lower part of the marine Fox Hills sandstone of the Dakotas.

The Bearpaw, like the Judith River, has been brought to the surface in the northwestern part of the field by the Porcupine uplift and dips about 3° S. It crops out in low rounded hills covered by a mantle of terrace gravel, so that good exposures of the shale occur only in the stream valleys. No direct measurements of its thickness can be made in this field. Measurements made by the writer in the steep bluffs of the Musselshell River in western Garfield County showed that its average thickness for this general region is about 950 feet.

TERTIARY (?) SYSTEM

LANCE FORMATION

In the Forsyth field the lithologic difference between the upper and lower parts of the Lance formation warrants the separation of the formation as mapped into the Hell Creek[9] and Tullock[10] members.

In the opinion of the writer it is probable that more refined study of the lower part of the Hell Creek member would demonstrate the equivalence of its massive basal sandstone as here mapped with the upper or Colgate sandstone member of the Fox Hills sandstone of eastern Montana[9] and would lead to its combination with the sandy

[9] Thom, W. T., jr., and Dobbin, C. E., Stratigraphy of the Cretaceous-Eocene transition beds in eastern Montana: Geol. Soc. America Bull., vol. 35, pp. 481–506, 1924.

[10] Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek coal field, Rosebud and Big Horn Counties, Mont.: U. S. Geol. Survey Bull. 749, 1923.

Exhibit 31

strata which are here provisionally included in the upper part of the Bearpaw, but which, it is thought, correspond to the lower part of the Fox Hills. The most striking differences between the Hell Creek and Tullock members of the Lance in this field are the contrast in their topographic expression and the absence of coal in the Hell Creek member. Further details regarding their lithologic differences are given below.

HELL CREEK MEMBER

The Hell Creek member of the Lance formation as here mapped rests conformably on the sandy transition zone at the top of the Bearpaw shale, and no hard and fast line can be drawn between them. The basal part of the member is made up of grayish-brown cross-bedded sandstone, probably corresponding to the Colgate sandstone member of the Fox Hills sandstone of eastern Montana, and crops out west of Armells Creek in a pine-clad escarpment south of the rolling, treeless areas of Bearpaw shale. Sandstones slightly higher in the member crop out along the Yellowstone Trail between Armells Creek and Forsyth, and some are more than 50 feet thick.

Although the Hell Creek member in this field does not contain very great thicknesses of somber-colored clay and shale, such as are characteristic of the member at its type locality on Hell Creek, northern Garfield County, yet by far the greater part of the shale has a greenish-yellow tint that is decidedly different from the more yellow sandy shale of the Tullock member. The top of the member was consistently drawn at the base of the Wright coal bed, which is a persistent bed, though in many places it may be less than a foot thick or may consist entirely of carbonaceous shale.

The areas where the Hell Creek member crops out are, unless modified by terrace gravel, very rough and in many places almost inaccessible even to saddle horses. Badlands in the Hell Creek member occur on Armells Creek up to its forks and on Smith and Reservation Creeks. Throughout the field the lower 450 feet of the member is made up chiefly of gray and brown sandstone with alternating beds of very light gray and greenish-yellow shale. The sandstones are commonly as much as 50 feet thick, and many of them are cross-bedded and full of clay balls. One sandstone contained clay balls as much as 9 inches in diameter. Most of the thick beds have a brown sandstone cap rock which is much harder than the lower part of the bed and projects as a shelf. The action of the wind on the softer material beneath the cap rock has produced many fantastic erosion forms. The presence of cross-bedded conglomerate layers, some of which contain pebbles an inch or more in diameter, and the lack of distinctive bedding planes in the lower part of the member suggest that the rocks are of fluviatile origin and were deposited in stronger currents

Exhibit 31

than those flowing when the upper part of the member was laid down. The lenticularity of the massive sandstones in the lower part of the Hell Creek is very striking here as elsewhere in Montana where the member crops out. A sandstone may persist for several miles as a rather prominent ledge and be replaced by sandy shale within a few hundred feet.

The upper 175 feet of the Hell Creek member is made up almost invariably of light-colored sandy shale containing lenses of gray and brown ledge-making concretionary sandstone. Locally on Armells Creek the upper part of the Hell Creek member is made up of typical "somber beds" containing ferruginous concretionary layers and soft, incoherent cross-bedded sandstone. In these places the contrast in color and composition between the Hell Creek and Tullock members is very striking. In most places, however, the one grades insensibly into the other, and were the Wright coal bed absent there would be no definite horizon to mark their limits.

In the railroad cut at the mouth of Armells Creek the basal sandstone of the Hell Creek member contains thin partings of plant-bearing clay at a horizon probably not more than 50 feet above the Bearpaw. The material is very soft, friable sandy shale and clay and contains no perfect leaves. The following determinations of fragmentary material from this horizon were made by F. H. Knowlton:

7656. From sec. 23, T. 6 N., R. 39 E.:
Populus sp.
Zizyphus? sp.
Populus cuneata Newberry.
Fragments of several dicotyledons.

The *Populus* identified with a fair degree of certainty is a Fort Union species, according to Knowlton.

The following section measured from the mouth of Armells Creek, in sec. 23, T. 6 N., R. 39 E., eastward along the Yellowstone Trail to Smith Creek, thence southward up Smith Creek to sec. 12, T. 5 N., R. 40 E., illustrates the nature of the Hell Creek member of the Lance formation in the Forsyth field:

Section from Armells Creek to Smith Creek and up Smith Creek

Base of Tullock member.	Feet
Shale, light colored, sandy	9½
Shale, carbonaceous	1
Shale, light colored, sandy	42
Shale, gray, sandy, and gray concretionary sandstone	110
Sandstone, brown	60
Shale, greenish	26
Sandstone, gray, concretionary	27
Sandstone, dark brown; makes a cap rock	4
Sandstone, light brown	24

Exhibit 31

	Feet
Shale, brown, sandy	13
Shale, light colored, sandy	42
Sandstone, brown; contains clay balls with a maximum diameter of 9 inches	52
Shale, greenish, sandy	9
Sandstone, light gray	34
Sandstone, gray, cross-bedded	28
Shale, dark, soft	9
Shale, sandy, concretionary layers at base and top	14
Shale, gray and yellow, sandy	59
Sandstone, orange-brown, cross-bedded; contains several lenses with wavy top	58
Clay, dark	4
Sandstone, light brown, cross-bedded; contains thin partings of plant-bearing clay; probably corresponds to the Colgate sandstone member of the Fox Hills sandstone of eastern Montana	11+
Interval to Bearpaw shale about 50 feet.	636+

TULLOCK MEMBER

The Tullock member of the Lance formation is made up of light-colored sandstone, sandy shale, and several thin but fairly persistent coal beds. The base of the member is drawn at the base of the Wright coal bed and its top at the base of the Big Dirty coal bed. Its thickness is fairly uniform throughout the field and ranges from 240 to 270 feet. Along Armells and Smith Creeks the Tullock crops out in a steep escarpment (see pl. 2, *B*), which in some places may be obscured by a mantle of river gravel. The top of the Tullock is marked by a very resistant calcareous sandstone rim rock 2 to 15 feet thick, which may be underlain by either a much softer sandstone or a sandy shale. The sandstone rim rock is overlain by the Lebo shale, which crops out in gentle slopes slightly back of the edge of the Tullock escarpment, producing a striking physiographic contrast. The sandstones of the Tullock are light yellow, evenly bedded, calcareous, and rarely massive, unlike the sandstones of the Tongue River member of the Fort Union formation.

Only two coal beds were mapped in the Tullock—the Wright bed at its base and the Hamre bed about 35 feet below its top. These beds, in common with all other coal beds in the Tullock member, are usually persistent but only locally contain coal. Several sections measured on the west side of Armells Creek and the east side of Reservation Creek failed to show any coal more than a foot thick in the member.

Exhibit 31

Section of the Tullock member of the Lance formation in sec. 30, T. 5 N., R. 40 E.

	Ft.	in.
Base of Lebo shale member.		
Sandstone, brown, concretionary; makes cap rock on conspicuous escarpment	2	
Sandstone, yellow, soft	34	
Coal and carbonaceous sandstone (Hamre bed)		10
Coal (Hamre bed)		4
Carbonaceous sandstone (Hamre bed)		1
Coal, dirty (Hamre bed)	3	5
Sandstone, yellow, soft	48	
Sandstone, brown, ledge maker	4	
Clay		7
Sandstone, whitish, soft, conspicuous bed	23	
Coal	1	4
Shale, gray, sandy	56	
Coal		5
Clay		7
Coal		10
Clay, gray, sandy	16	
Sandstone, yellow	6	
Coal		10
Sandstone and sandy shale, yellow	18	
Coal	2	1
Clay	1	3
Shale	1	0
Coal	1	10
Clay, gray	5	
Clay, brown, sandy	17	
Coal; Wright bed	3	5
	247	10

Section of the Tullock member of the Lance formation in secs. 12 and 13, T. 5 N., R. 40 E.

	Ft.	in.
Base of Lebo shale member.		
Sandstone, yellow; makes prominent rim rock	10	
Shale, light colored, sandy, and concretionary sandstone	51	
Shale, light colored, sandy	17	
Shale, carbonaceous bed at top	15	
Sandstone, yellow	26	
Shale, light colored, sandy	23	
Sandstone, and sandy shale, yellow	20	6
Sandstone, brown, concretionary	2	
Sandstone and sandy shale, yellow	12	
Shale, slightly carbonaceous	2	
Sandstone, cream colored, very soft	7	
Coal and carbonaceous shale	1	3
Shale, light colored, sandy	11	
Sandstone, yellow, with thin rim rock of brown sandstone	18	
Clay, purple	3	
Sandstone, light yellow, very soft	9	

Exhibit 31

	Ft.	in.
Sandstone, yellow, shaly	3	
Clay		4
Shale, carbonaceous		3
Shale, light colored, sandy	22	
Carbonaceous shale		8
Coal	1	
Shale, light colored, sandy	7	
Shale, carbonaceous		8
Sandstone, yellow, shaly	2	
Shale, carbonaceous; Wright bed	4	6
	269	2

TERTIARY SYSTEM

FORT UNION FORMATION

The Fort Union formation in the Forsyth field is readily separable on lithologic grounds into two members, a lower one, the Lebo shale, and an upper one, consisting of yellow sandstone, sandy shale, and coal beds, called the Tongue River member.

LEBO SHALE MEMBER

The Lebo shale member of the Fort Union formation is made up of dark-gray to black clay and shale, largely of volcanic origin. By its somber aspect it is readily distinguished from the underlying Tullock member of the Lance formation and the overlying Tongue River member of the Fort Union. (See pl. 3, *A*.) It contains beds of soft, gray cross-bedded sandstone, some of which may be as much as 10 feet thick, but none are persistent for more than a few hundred feet. Ironstone concretions occur in the Lebo in great numbers and usually collect in piles where they have been washed out of small bare buttes or slopes. Some of the ferruginous concretionary layers are not more than 6 inches thick and are fairly persistent horizon markers.

The base of the Lebo is drawn at the base of the Big Dirty coal bed, which rests directly on the rim rock making the top of the Tullock member of the Lance formation. The top of the member is drawn at the point where there is a change from somber-colored clay to yellow sandstone and sandy shale. The thickness of the Lebo ranges from 105 to 170 feet and is least in the western part of the field.

Because of its infertile character the Lebo supports only a little vegetation, chiefly sagebrush. On the divides the Lebo forms a broad zone of rolling, treeless country between the escarpment-forming sandstones of the Tullock member of the Lance and the Tongue River member of the Fort Union. In the stream valleys,

Exhibit 31

however, because of its softness and thinness, it erodes readily into a narrow zone of badlands most intricately dissected and almost worthless for any use. Representative sections of the Lebo in the Forsyth field are given below.

Section of the Lebo shale member of the Fort Union formation in the NE. ¼ sec. 25, T. 3 N., R. 39 E.

Base of Tongue River member.		Ft.	in.
Shale, light gray		10	8
Shale, dark gray		6	6
Shale, carbonaceous			9
Shale, dark gray		7	8
Shale, greenish yellow, with clay-ironstone concretions		5	4
Shale, yellowish green, with sandstone lentils		3	10
Shale, yellowish green, tuffaceous		23	2
Shale, dark gray, with clay-ironstone concretions		6	4
Shale, yellowish green, sandy		39	4
Shale, brownish gray		3	2
Carbonaceous shale	Big Dirty bed		5
Coal, bony		4	7
Bone			2½
Coal		1	1
Shale			½
Coal		1	8½
Shale			1
Coal		1	9
Carbonaceous shale			2½
Clay		1	1
		117	11

Section of the Lebo shale member of the Fort Union formation in sec. 24, T. 5 N., R. 40 E.

Base of Tongue River member.	Ft.	in.
Clay, dark blue, bentonitic	7	
Shale, gray	21	
Clay, gray bentonitic	24	
Concretionary layer		6
Clay, gray, bentonitic	2	
Coal, impure	1	
Clay, bentonitic	3	
Sandstone, rusty		6
Clay, gray, sandy	13	
Calcareous concretionary layer	2	
Clay, gray, bentonitic; contains many ferruginous and carbonaceous layers	63	
Clay, dark, with ironstone concretions	13	
Fire clay	1	
Clay, greenish		8

Exhibit 31

		Ft.	in.
Bone	Big Dirty bed		11
Coal, impure, and bone		1	11
Bone			9
Coal, fair		1	1
Coal, impure, and carbonaceous sandstone			11
Bone, coal, and carbonaceous sandstone		1	
		158	3

Section of the Lebo shale member of the Fort Union formation in the SE. ¼ sec. 30, T. 4 N., R. 41 E.

	Ft.	in.
Shale, gray and blue, with thin carbonaceous layers	48	
Clay, containing many ferruginous concretions	48	
Coal		6
Clay, grayish blue	17	
Clay, grayish blue, containing many ferruginous concretions	1	
Clay, gray	28	4
Shale, carbonaceous	1	
Clay, grayish white	22	8
Shale, carbonaceous, with streaks of bony coal, Big Dirty bed	3	
	169	6

TONGUE RIVER MEMBER

The Lebo shale grades upward through a transition zone of sandy shale into a group of beds of light-colored sandstone, sandy shale, carbonaceous shale, and coal, which constitute the Tongue River member of the Fort Union formation. There is 1,686 feet of the member in the Forsyth field, included between the top of the Lebo shale and the clinker that makes the cap rock on Wolf Mountain. The rocks in this member are much more resistant than the Lebo clays and usually crop out in steep bluffs above Lebo lowlands or badlands. The lower 125 feet contains no workable coal. The succeeding 600 feet, however, contains eight coal beds ranging in thickness from 3 to 30 feet. These beds constitute the principal coal deposits of the field. The thick coal beds in this interval have burned along their outcrops and baked the overlying strata to various shades of red and brown. The slag or clinker thus formed is a distinctive feature of this part of the section, not only in the Forsyth field but elsewhere in Montana, and serves to distinguish the coals from those of the Tullock member, which occur in strata similar in color and lithology but are rarely burned. The clinker is much more resistant than the underlying rocks, and where it has been cut through by narrow stream gorges it makes a protective cap rock above steep and bare slopes. Where a thick coal bed has been burned over a considerable area remnants of its clinker form the summits of the divides, which may be less than half a mile wide and more than 5 miles long.

Exhibit 31

On the accompanying map (pl. 7) the areas thus covered by clinker are designated by a special pattern. The principal use for clinker at the present time is for road metal or railroad ballast.

The most prominent sandstone in the Tongue River member is that which commonly occurs above the Rosebud coal bed. (See pl. 5, *A*.) In places this sandstone is 150 feet thick and crops out as a persistent and easily recognized ledge at the base of a yellow bluff of softer sandstone and shale. It is especially well developed near Castle Rock, in Miller Coulee, and along Rosebud Creek and its tributaries. In the Rosebud Creek area it is split into two benches separated by the Lee coal bed. It is grayish-yellow, fine grained, usually massive, and arkosic. Castle Rock, in sec. 31, T. 2 N., R. 40 E., is an outlier of this sandstone about 60 feet high. Other similar but larger outliers of this sandstone occur in Richard Coulee, in T. 1 S., R. 41 E.

The Sawyer coal bed, which occurs about 725 feet above the base of the member, is the uppermost of the thick coal beds of considerable economic value in the section. Above the Sawyer bed is about 1,000 feet of sandstone, sandy shale, and thin but persistent coal beds. In the Wolf Mountain area (see p. 43) the sandstone and sandy shale are normally yellow. The sandstones, however, are usually well bedded, in contrast to those in the lower part of the member. Somber-colored clay occurs in many places in the Wolf Mountain section but nowhere through an interval greater than 30 feet.

The following fossils from the Tongue River member are Fort Union forms, according to F. H. Knowlton:

7657. From a sandstone above the Proctor coal bed, sec. 18, T. 1 N., R. 40 E.:
Onoclea sensibilis fossilis Newberry.
Sapindus grandifolius Ward.
Celastrus curvinervis? Ward.

7658. From a sandstone 350 feet above the Popham coal bed, sec. 9, T. 1 N., R. 39 E.:
Equisetum sp.
Populus acerifolia Newberry.
Viburnum newberryanum Ward.
Dicotyledon, new?
Sapindus sp. cf. S. grandifolius Ward.

7659. Horizon of Sawyer coal bed, SE. ¼ sec. 7, T. 1 N., R. 40 E.:
Populus amblyrhyncha Ward.
Populus acerifolia Newberry.

7660. From a sandstone 100 feet above the Sawyer coal bed, SW. ¼ sec. 19, T. 1 N., R. 40 E.:
Viburnum newberryanum Ward.

7661. From sandstone below Rosebud coal bed, SW. ¼ sec. 27, T. 2 N., R. 40 E.
Populus amblyrhyncha Ward.
Viburnum asperum Newberry.
Populus sp.

Exhibit 31

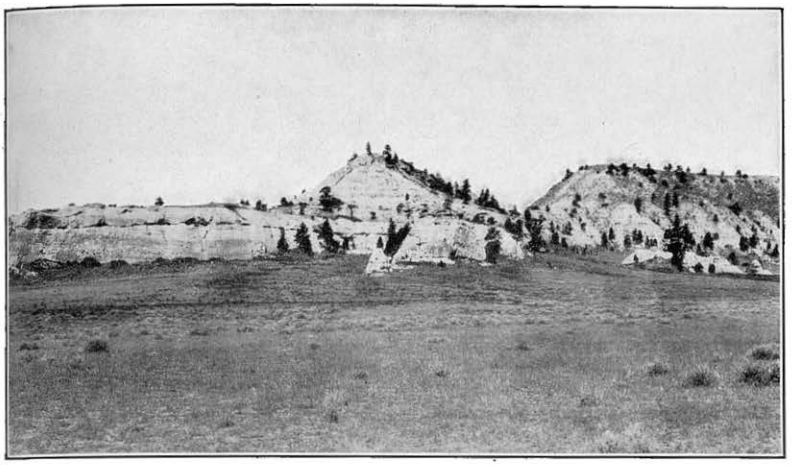
7662. From sandstone at horizon of Richard coal bed, SE. ¼ sec. 36, T. 1 N., R. 39 E.:

Thuya interrupta Newberry.
Viburnum sp.
Populus sp.
Oreodaphne sp.

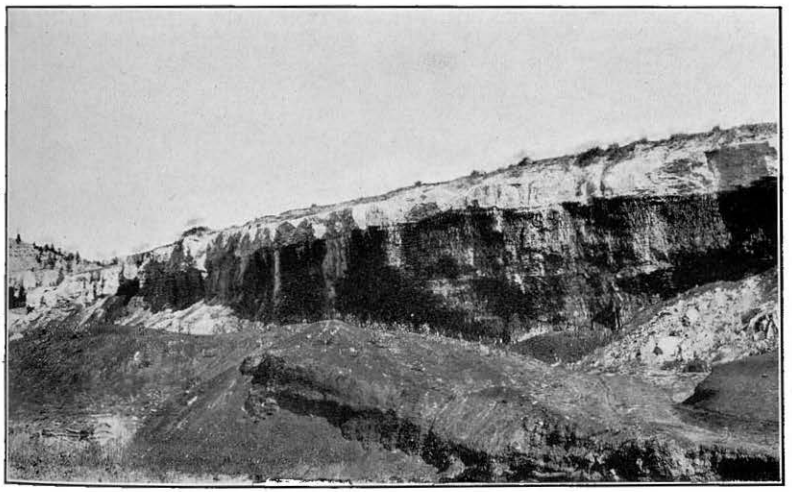
Section of part of the Tongue River member of the Fort Union formation in secs. 34 and 35, T. 2 N., R. 39 E., and secs. 3, 8, 9, and 10, T. 1 N., R. 39 E.

	Ft.	in.
Clinker; makes cap rock on Wolf Mountain	28	
Sandstone and sandy shale, yellow; contains thin and nonpersistent coal beds	306	
Coal	4	
Sandstone, brown, concretionary; makes a bench	17	
Sandstone, yellow, massive	34	
Sandstone, brown, concretionary; makes a bench	6	
Sandstone, yellow; contains many carbonaceous layers	40	
Sandstone, brown, calcareous	17	
Shale and clay, grayish black	28	
Sandstone, yellow, well stratified	67	
Coal	4	
Sandstone, grayish white	23	
Sandstone, brown; makes a prominent bench	28	
Shale, sandy; contains many thin burned coal beds	68	
Sandstone and sandy shale, grayish white and yellow; containing many concretionary lenses and thin carbonaceous beds	110	
Shale, carbonaceous		8
Coal } Richard bed	1	
Shale, carbonaceous	1	
Sandstone, yellowish white	11	
Shale, somber colored	30	
Sandstone, brown	17	
Shale, carbonaceous	2	
Coal		6
Clay, carbonaceous	2	
Sandstone, grayish white	5	
Coal, dirty, and carbonaceous shale		10
Coal	3	
Sandstone, yellowish brown	32	
Coal, Proctor bed	3	
Shale, yellow, sandy	10	
Coal	1	
Sandstone, yellowish brown	80	
Sandstone, yellow, concretionary	40	
Shale, carbonaceous	3	
Clay, sandy	8	
Carbonaceous shale	7	
Coal	2	
Bone } Popham bed		1
Coal	2	

Exhibit 31



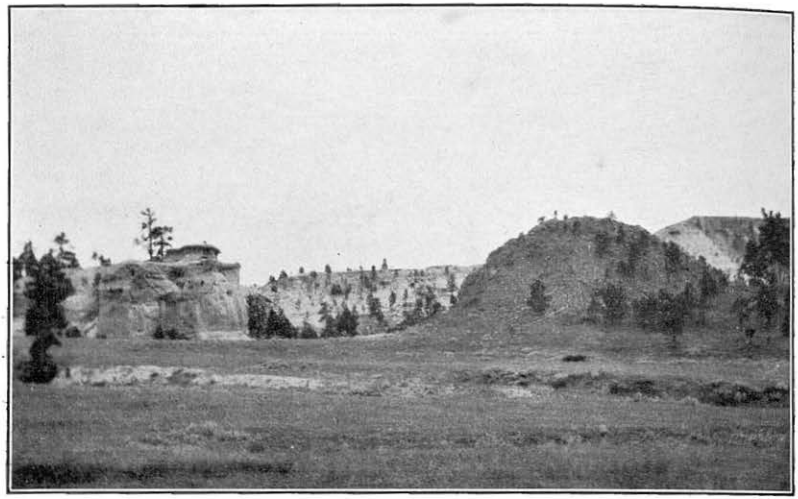
A. MASSIVE SANDSTONE ABOVE THE ROSEBUD COAL BED, SEC. 13, T. 1 N., R. 41 E., MONTANA



B. OUTCROP OF THE ROSEBUD COAL BED IN THE NORTH COAL BANK COULEE, SEC. 24, T. 1 N., R. 41 E., MONTANA

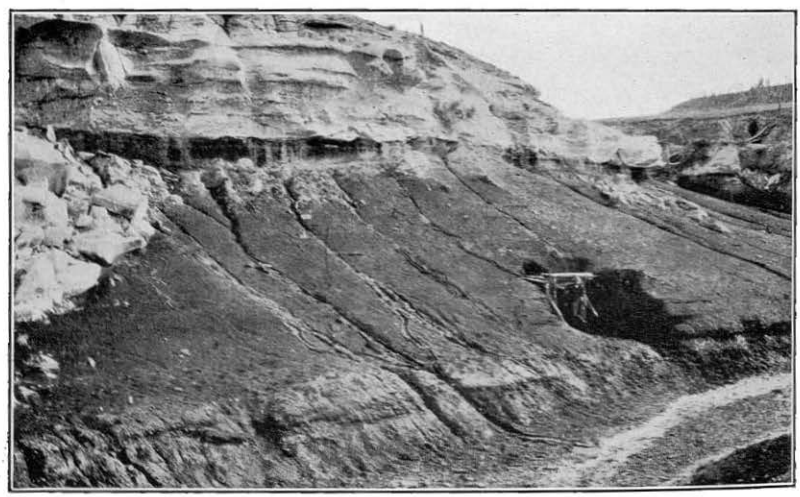
Thickness of coal bed about 28 feet

Exhibit 31



A. VIEW IN SEC. 31, T. 2 N., R. 40 E., MONTANA

At the right the massive sandstone has been fused and baked by the burning of the Rosebud coal bed



B. PROSPECT ON OUTCROP OF THE ROSEBUD COAL BED IN SOUTH COAL BANK COULEE, SE. ¼ SEC. 15, T. 1 N., R. 41 E., MONTANA

Amount of coal exposed about 28 feet

Exhibit 31

	Ft.	in.
Sandstone, yellow, massive	23	
Coal, dirty, and carbonaceous shale	1	
Sandstone, grayish yellow	17	
Shale, greenish	28	
Carbonaceous shale	2	
Coal, dirty	2	
Carbonaceous shale	4	
Clay, yellow, sandy; contains several ferruginous concretionary layers	11	
Sandstone, gray, massive, makes a prominent rim rock	45	
Clay carbonaceous	1	6
Sandstone, yellow	24	
Sandstone, gray, massive, concretionary; weathers into fantastic erosion forms	96	
Sandstone, gray, well stratified	11	
Clay, blue	6	
Coal; Rosebud bed.		
	1,313	7

ection of *part of the Tongue River member of the Fort Union formation in N. ½ sec. 24 and S. ½ sec. 13, T. 1 N., R. 41 E.*

	Ft.	in.
Sawyer clinker.		
Clay, greenish, sandy	11	
Sandstone, light gray; makes prominent ledge	3	
Shale, greenish, sandy	22	
Sandstone, brown, concretionary	5	
Shale, gray, greenish, and olive-colored	35	
Sandstone, yellow, soft, platy	12	
Clay, drab, gypsiferous	12	
Sandstone, yellow, very soft	6	
Sandstone, yellowish brown, concretionary	6	
Sandstone, grayish, very soft	11	
Coal and carbonaceous shale	1	
Sandstone, yellow, soft; contains many harder brown concretionary masses	34	
Sandstone, yellow, cross-bedded in places, usually massive; contains clay balls; fine grained, pitted; a very prominent ledge maker in this general area	134	
Sandstone, yellow, and light-colored sandy shale	17	
Sandstone, yellow, massive	17	
Clay, light gray, sandy	12	
Coal	10	
Bone		2
Coal — Rosebud bed	9	
Bone		2
Coal	9	
Shale, gray, sandy	2	
Shale, purple, carbonaceous		6
Clay, gray, sandy	4	
Coal; McKay bed	10	
	382	10

Exhibit 31

Section of part of the Tongue River member of the Fort Union formation in sec. 34, T. 3 N., R. 38 E.

	Ft.	in.
Shale, brown, sandy.		
Coal		3
Clay } Rosebud bed		1
Coal	11	7
Shale, gray	13	
Coal		10
Sandstone, light yellow	9	10
Coal; McKay bed	8	
Shale, gray, with thin lenses of sandstone	21	8
Shale, carbonaceous		6
Shale, gray, sandy	9	10
Coal; Stocker Creek bed	2	10
Shale, gray, sandy	35	10
Coal	1	5
Clay, gray		4
Coal		5
Shale, carbonaceous		3
Clay, gray		5
Sandstone, light gray, massive	61	6
Coal	1	8
Shale, carbonaceous		6
Coal		8
Shale, gray	26	4
Coal	1	1
Clay Robinson bed		3
Coal	5	4
Clay, gray	21	8
Sandstone, yellow, massive	21	8
Coal; Burley bed	2	8
	255	5

Section of part of the Tongue River member of the Fort Union formation in the SW. ¼ sec. 6, T. 4 N., R. 41 E.

	Feet
Sandstone, yellow, well stratified	57
Sandstone, grayish yellow	1
Coal; Burley bed	1
Sandstone, yellow, massive	58
Shale, carbonaceous	2
Sandstone, yellow, massive	12
Coal	1
Sandstone, yellow	34
Sandstone, yellow, concretionary	2
Sandstone, yellow, shaly	40
Lebo shale member.	
	208

OLIGOCENE OR MIOCENE (?) GRAVEL

The oldest gravel deposit in the field caps a plateau on the divide between Armells and Sarpy Creeks in the northwest corner of T. 3 N. and the southwest corner of T. 4 N., R. 39 E. (See pl. 7.)

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Gravel occurs at the same level on the tops of the highest hills and ridges in the northern part of T. 4 N., R. 41 E. These gravel deposits are small remnants of a much larger river terrace and stand 1,050 to 1,100 feet above Yellowstone River. The gravel, which is 60 feet thick, is thoroughly cemented at the base into a conglomerate. The deposit contains boulders a foot or more in thickness and consists of igneous rocks ranging in composition from granite to basalt, particularly andesitic porphyries. Agate, silicified wood, and fragments of coal clinker occur in it, indicating that at least some of the coal has been burned along its outcrop before the gravel was deposited.

This gravel terrace is equivalent to similar terraces in the Tullock Creek field described by Rogers,[11] which stand 1,100 feet above the Yellowstone. In the area south of Huntley deposits of gravel and conglomerate make prominent plateaus at an altitude of 3,900 to 4,000 feet, or about 1,000 feet above the Yellowstone River, and are probably equivalent to the deposits just described.[12] On the divide between the Yellowstone and the Missouri, north of Terry, remnants of a gravel terrace 1,200 feet or more above the Yellowstone probably represents this same level.

According to Alden[13] the amount of cutting by Yellowstone River since these gravel deposits were laid down and a study of relative altitudes suggest that they are to be correlated either with the gravel capping the Cypress Hills in Canada, which McConnell[14] and Lambe[15] determined by fossils to be of Oligocene age, or with the Flaxville gravel, of Miocene or Pliocene age, in northeastern Montana.[16]

The northern edge of the Oligocene or Miocene (?) gravel deposits is about 12 miles south of the terrace along the Yellowstone River, and the vertical interval between them is 900 to 1,000 feet. The area intervening between the Oligocene (?) gravel deposits and the well-defined terraces bordering the Yellowstone is covered with a mantle of gravel which is not arranged in any well-defined system

[11] Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek coal field, Rosebud and Big Horn Counties, Mont.: U. S. Geol Survey Bull. 749, p. 47, 1923.

[12] Hancock, E. T., Geology and oil and gas prospects of the Huntley field, Mont.: U. S. Geol. Survey Bull. 711, pp. 128–129, 1920.

[13] Alden, W. C., Physiographic development of the northern Great Plains: Geol. Soc. America Bull., vol. 35, pp. 385–424, 1924.

[14] McConnell, T. G., On the Cypress Hills, Wood Mountain, and adjacent country: Canada Geol. Survey Ann. Rept., new ser., vol. 1, pp. 1c–78c, 1886.

[15] Lambe, L. M., A new species of *Hyracodon* (*H. priscidens*) from the Oligocene of the Cypress Hills, Assiniboia: Canada Roy. Soc. Proc. and Trans., 2d ser., vol. 11, sec. 4, pp. 37–42, 1906; Fossil horses of the Oligocene of the Cypress Hills: Idem, pp. 43–52; Vertebrata of the Oligocene of the Cypress Hills, Saskatchewan: Canada Geol. Survey Contr. Paleontology, vol. 3, pt. 4, 1908.

[16] Collier, A. J., and Thom, W. T., jr., The Flaxville gravel and its relation to other terrace gravels of the northern Great Plains: U. S. Geol. Survey Prof. Paper 108, pp. 179–184, 1918.

Exhibit 31

of terraces and has been reworked so many times that its relations are obscured. A small remnant of a terrace with gravel locally cemented to a conglomerate 10 feet thick, in the central part of T. 5 N., R. 41 E., stands 700 feet above the river. If the higher gravel corresponds to that on the Cypress Hills, this may correspond to the Flaxville gravel, of late Tertiary age.

QUATERNARY SYSTEM

PLEISTOCENE DEPOSITS

A broad and well-defined terrace borders the Yellowstone River on the south about 200 feet above the river flood plain. The gravel capping this terrace consists of smoothly rounded unconsolidated pebbles of many kinds of igneous rock, quartz, jasper, and limestone and is undoubtedly of Pleistocene age. This terrace is well preserved at somewhat varying heights above the Yellowstone throughout much of the river's course in eastern Montana. Farther west it extends for several miles up the southern tributaries of the river and is especially well developed on the Big Horn River and Fly and Pryor Creeks in the Huntley field.[17]

RECENT ALLUVIUM

The fine sand, silt, and gravel now being deposited in the flood plain of the Yellowstone River and its tributaries constitute the most recent deposit in the Forsyth field. It ranges in thickness from a few feet to about 40 feet and underlies some of the best agricultural land in the field. This land is irrigated and produces large crops of sugar beets and alfalfa. (See pl. 7.) The flood plains of the larger tributaries of the Yellowstone range from half a mile in width near their mouths to a few hundred feet near their sources, and all of them are cut up into small areas by the meandering of the streams.

STRUCTURE

The Forsyth field lies in a broad, shallow syncline or structural trough pitching gently southeastward, which connects the Powder River Basin and the structural depression of the Bull Mountains. The axis of this syncline in the Forsyth field follows closely a line drawn between Castle Rock and the northeast corner of T. 1 S., R. 41 E., and separates the Big Horn and Porcupine uplifts on the west and north, respectively. The strongest dips in the field occur in its northwest corner, where the rocks are affected by the Porcupine uplift. The sandstone member of the Judith River formation, which

[17] Rogers, G. S., and Lee, Wallace, op. cit. Hancock, E. T., op. cit.

Exhibit 31

is the lowest formation brought to the surface by the uplift, dips 3° SE. in this area. Dips of like amount were observed on concretionary layers in the Bearpaw shale. The basal sandstone of the Lance crops out in a prominent escarpment striking about east and dipping 2°–3° S. South of the escarpment, however, the rocks flatten out appreciably and over large areas have a normal southeasterly inclination of less than 1°. The western limb of the sandstone member of the Judith River dips beneath the alluvium of the Yellowstone River at an angle of about 2° a few miles upstream from the western limit of the field.

Within the major structural depression between the Big Horn and Porcupine uplifts the rocks are gently folded into several small anticlinal and synclinal folds. Nearly all the dips are less than 1° and they are determined only by noting the altitudes of coal beds and the distribution of their outcrops. Two gentle anticlines belonging to the Porcupine dome system of uplifts cross the area approximately parallel to the axis of the major syncline. One of these anticlines follows a line drawn between the northwest corner of sec. 2, T. 1 S., R. 41 E., and the southeast corner of sec. 11, T. 3 N., R. 39 E. Gentle doming, which has affected the position of the outcrop of coal beds, occurs along the axis of this fold near the SW. ¼ sec. 29, T. 1 N., R. 41 E., sec. 12, T. 1 N., R. 40 E., and sec. 11, T. 3 N., R. 39 E. West of the line of folding the rocks dip gently into the axis of the major syncline, west of which they rise uniformly westward at an angle less than 1°. Another line of folding, modified by a fault zone, also crosses the field in a northwesterly direction from the northwest corner of T. 2 N., R. 41 E. Several small normal faults, having maximum throws of about 60 feet, occur near the axis of this uplift along the boundary between T. 3 N., R. 40 E. and T. 3 N., R. 41 E. Further details regarding the structure are included in the township descriptions.

ECONOMIC GEOLOGY

COAL

GENERAL SECTION

The coal in the Forsyth field occurs in the Tullock member of the Lance formation and in the Lebo shale and Tongue River members of the Fort Union formation. The strata are nearly horizontal, and the coal beds crop out in regular order one above another from the vicinity of Forsyth southward to the top of Wolf Mountain. The coals of the Tullock member though persistent are generally too thin and dirty to be of much economic importance in this area, which contains a number of thicker beds near by.

Exhibit 31

Only one coal bed, the Big Dirty bed, was mapped in the Lebo shale member of the Fort Union. The Big Dirty bed, as its name implies, is usually dirty and consists of carbonaceous shale, carbonaceous sandstone, bone, and thin stringers of coal. Locally, as described below, it contains as much as 11 feet of apparently clean coal, though it is suspected that an analysis of this coal would show a high ash content. The Lebo member contains several carbonaceous zones above the Big Dirty bed, but the layers of coal in them are only an inch or two thick and alternate with much thicker beds of shale.

The principal coal reserves in the field occur in the Tongue River member of the Fort Union formation. There are eight coal beds, ranging from 3 to 30 feet in thickness, in the lower 725 feet of this member, and these will best repay attention by persons interested in the exploitation of the coal. The upper 1,000 feet of the Tongue River member contains four coal beds of extremely irregular thickness. These beds all crop out in the rough, timbered country at the foot and in the slopes of Wolf Mountain and at present are valuable only as sources of domestic fuel for individual homesteaders living near by.

The stratigraphic position of the coal beds in the Forsyth field and their relations to the coals of the Tullock Creek field are shown graphically in Plate 8. The following brief summary gives the names of the principal coal beds and the average intervals between them:

Sequence and average thickness of the coal beds in the Forsyth coal field, and distances between them

	Feet
Clinker; caps Wolf Mountain.	
Interval (upper part of Tongue River member)	310
Coal	3
Interval	200
Coal	3
Interval	230
Coal; Richard bed	4
Interval	103
Coal; Proctor bed	3
Interval	90
Coal; Sawyer bed	7
Interval	50
Coal; Popham bed	3
Interval	160
Coal; Lee bed	10
Interval	110
Coal; Rosebud bed	20
Interval	18
Coal; McKay bed	6

Exhibit 31

	Feet
Interval	30
Coal; Stocker Creek bed	6
Interval	130
Coal; Robinson bed	6
Interval	45
Coal; Burley bed	4
Interval	130
Base of Tongue River member of Fort Union formation.	
Interval	130
Coal; Big Dirty bed	7
Base of Lebo shale member of Fort Union formation.	
Interval	35
Coal; Hamre bed	3
Interval	200
Coal; Wright bed	3
Base of Tullock member of Lance formation.	
Interval	675
Base of Hell Creek member of Lance formation.	
Interval	1,000
Base of Bearpaw shale.	

Some of the beds listed above contain workable coal in parts of their extent in the Forsyth field, and the distribution of the tracts containing valuable coal reserves is outlined in the following descriptions of the several beds.

THE COAL BEDS

The coal beds in the Forsyth field were mapped by stadia traverses tied to land corners. The outcrop lines of practically all accessible coal beds of workable thickness and quality as thus determined are shown on Plate 7. The numbers along the outcrop lines indicate the locations where the coal beds were measured and refer to Plate 10 where the measurements are represented graphically. A more detailed description of the character of the coal beds than that given below will be found in the township descriptions.

COALS OF THE TULLOCK MEMBER OF LANCE FORMATION

Wright bed.—The Wright bed, at the base of the Tullock member of the Lance formation, is the lowest coal in the Forsyth field. Because of its stratigraphic position it crops out nearer the Yellowstone Valley than any of the overlying coals and has been mined for a number of years to supply local demand in Forsyth. In several mines in the basins of Smith and Armells Creeks and vicinity it ranges from 3 to 4 feet in thickness. (See pls. 7 and 10.) This bed crops out in the rough country at the base of the bluffs on the east side of Armells Creek and extends about 2 miles up the forks of the creek before it passes beneath the stream level. Along Armells

Exhibit 31

Creek it ranges from a foot or less to 3 feet in thickness and at many points occurs in two benches about 26 feet apart. (See pl. 10, locations 22, 23, 24, 25.) On the west side of Armells Creek below its forks and along Reservation Creek the Wright bed is persistently present but nowhere was observed to contain more than a foot of coal.

Hamre bed.—The Hamre bed occurs at an average interval of 200 feet above the Wright bed and crops out at the base of the heavy sandstone which makes the rim rock at the top of the Tullock member. It averages 3 feet in thickness and for the most part is made up of carbonaceous shale and coal, interbedded with which are innumerable thin stringers of carbonaceous sandstone. On the east side of Armells Creek, in T. 5 N., R. 40 E., it contained locally as much as 3 feet of coal in its basal part, and its outcrop was mapped for a little more than 3 miles. (See pl. 10, secs. 7–13.) The Hamre bed was recognized at many other places in the northwestern part of the field, but because of its generally worthless character it was not mapped.

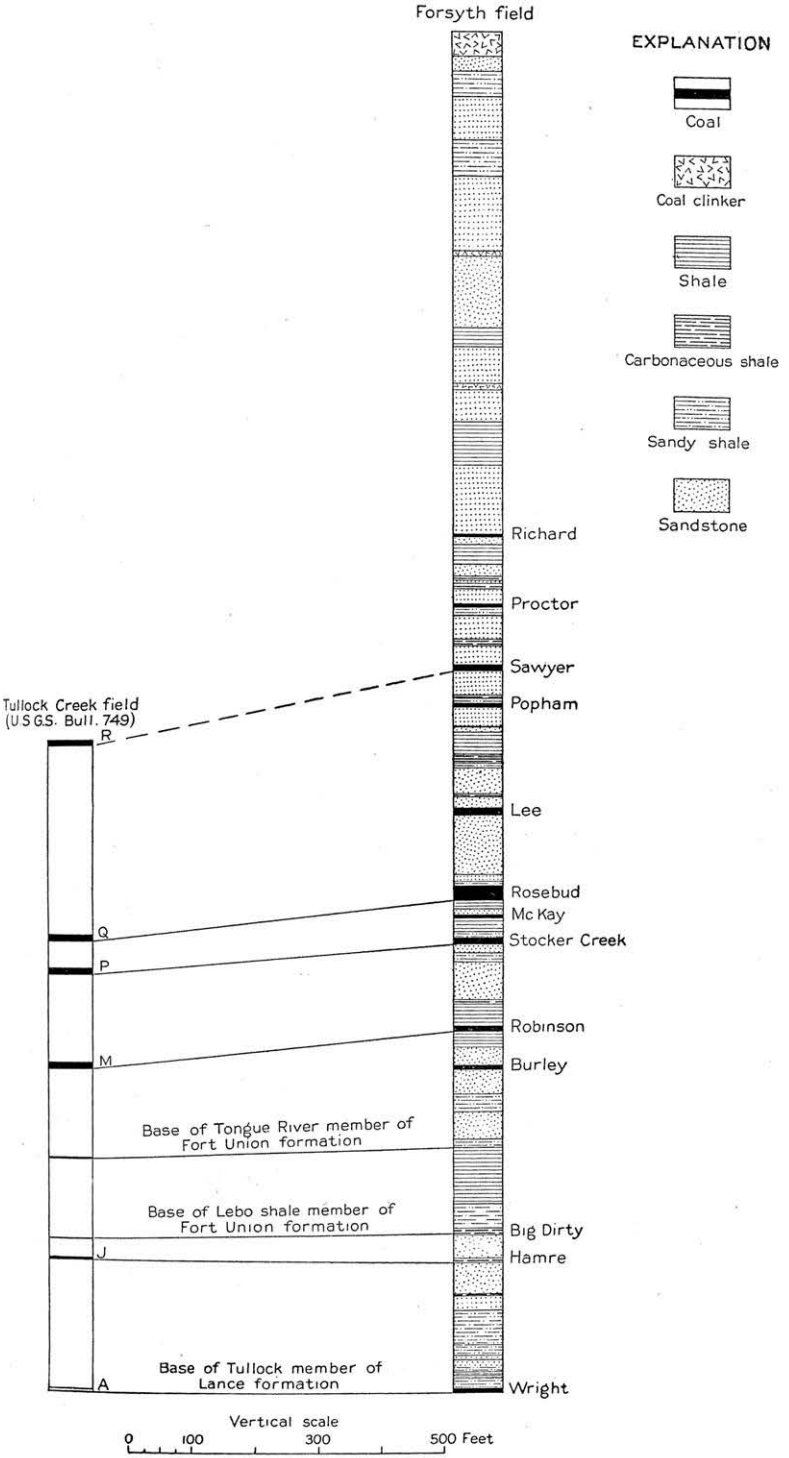
In the interval between the Wright and Hamre beds there are several thin beds of coal which in places may attain a maximum thickness of 2 or 3 feet on their outcrops. They are, however, very narrow lenses, and because of their uneven thickness they were not mapped.

COALS OF THE LEBO SHALE MEMBER OF FORT UNION FORMATION

Big Dirty bed.—The Big Dirty bed, which lies at the base of the Lebo shale member of the Fort Union formation and 35 feet above the Hamre bed, ranges from 3 to 13 feet in thickness and usually consists of carbonaceous shale, carbonaceous sandstone, and thin lenticular beds of coal. (See pl. 10.) Locally where it is more than 6 feet thick its lower part may contain as much as 3 feet of coal. The only place in the field where the Big Dirty bed was observed to contain coal of workable thickness and quality was along the boundary between T. 3 N., R. 40 E., and T. 3 N., R. 41 E., and along the East Fork of Armells Creek near by, where it contains from 6 to 11 feet of what is apparently a fair grade of coal. (See pl. 10, secs. 76, 77, 79, etc.) Along the tributaries of the West Fork of Armells Creek in T. 3 N., Rs. 39 and 40 E., the Big Dirty bed locally contains 3 feet of coal in its lower part overlain by 7 feet of carbonaceous shale and thin beds of coal some of which attain in places a thickness of 3 feet or more. (See pl. 10, secs. 46, 47, 70, 71.)

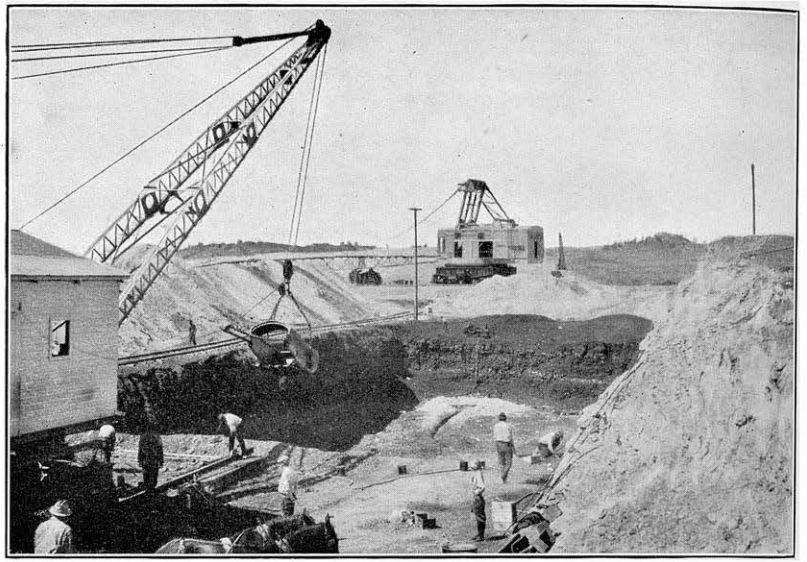
As previously stated, thin layers of coal associated with beds of carbonaceous shale occur elsewhere in the Lebo member within the Forsyth field, but they are of no value and will not be described.

Exhibit 31

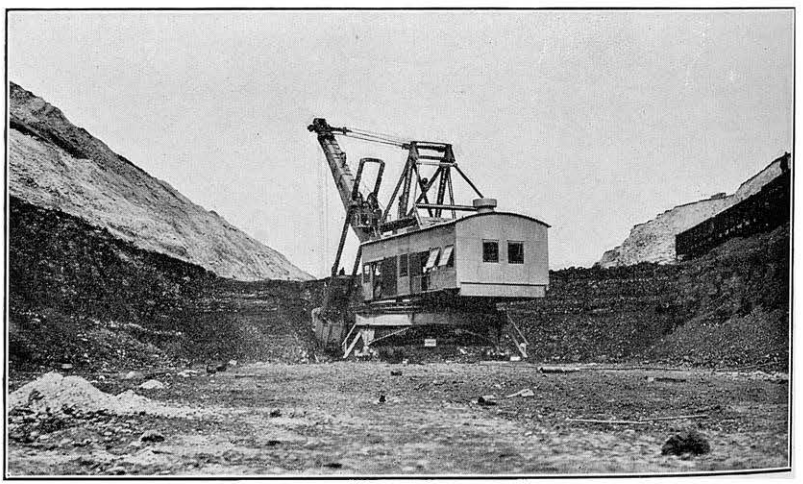


STRATIGRAPHIC SECTIONS OF THE LANCE AND FORT UNION FORMATIONS IN THE FORSYTH AND TULLOCK CREEK FIELDS, MONTANA, SHOWING POSITION AND CORRELATION OF THE COAL BEDS

Exhibit 31



A



B

STRIP PIT OF THE NORTHWESTERN IMPROVEMENT CO. AT COLSTRIP, MONT.

Exhibit 31

COALS OF THE TONGUE RIVER MEMBER OF FORT UNION FORMATION

Burley bed.—The Burley bed, 130 feet above the base of the Tongue River member of the Fort Union, is the lowest of the valuable coals in the field. It is extensively burned in the vicinity of the Burley ranch, in the SE. ¼ sec. 24, T. 3 N., R. 41 E., where it contains about 5 feet of coal. (See pl. 10, locations 83–85.) Measurements of this bed along the West Fork of Armells Creek in T. 2 N., Rs. 38 and 39 E. (pl. 10, secs. 41, 119, 120), showed that its average thickness for that area is about 3 feet.

Robinson bed.—In the Armells Creek area the Robinson bed occurs 43 feet above the Burley bed, and its outcrops can be traced almost continuously across the field. East of the East Fork of Armells Creek, in T. 2 N., R. 41 E., it ranges from 2½ to 4½ feet in thickness. (See pl. 10, secs. 148, 149.) In the valleys of the West Fork of Armells Creek and its tributaries, in T. 2 N., R. 39 E., it attains a maximum thickness of about 8 feet. (See pl. 10, sec. 114.) On the east side of the Sarpy Creek-Tullock Creek divide, in T. 3 N., R. 39 E., it maintains an average thickness of 5 feet and is correlated with bed M of the Tullock Creek coal field.[18] (See pl. 10, secs. 52–58.)

Stocker Creek bed.—The Stocker Creek bed lies 130 feet above the Robinson bed and crops out in that part of the field northwest of the northwest corner of T. 1 N., R. 41 E. Measurements of this bed along Stocker Creek and on tributaries of the West Fork of Armells Creek, in T. 2 N., R. 40 E., showed its average thickness to be about 6 feet. (See pl. 10, secs. 123–128.) The maximum thickness of the bed observed in the field was 9 feet in the SW. ¼ sec. 15, T. 2 N., R. 38 E. (See pl. 10, sec. 97.)

McKay bed.—Throughout a large part of this field the McKay bed may be considered a split of the Rosebud bed, for many measurements showed that the interval between them in several places is less than 7 feet. (See pl. 10, secs. 221, 222.) The maximum observed interval between the Rosebud and McKay beds in the field is 30 feet at location 95, in the NE. ¼ sec. 3, T. 2 N., R. 38 E.

Rosebud bed.—The Rosebud bed, about 360 feet above the base of the Tongue River member of the Fort Union, is the most valuable coal bed in the Forsyth field and is exploited by the Northwestern Improvement Co. at Colstrip. Although outcrops of the bed are rare, its position where unexposed can be determined very closely by tracing the contact of the heavy and conspicuous slag formed by the burning of the bed with the unburned overburden, it being assumed that burning of the bed has not taken place through more than a few

[18] Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek coal field, Montana: U. S. Geol. Survey Bull. 749, pp. 75, 76, 1923.

Exhibit 31

hundred feet beyond the point where the clinker abuts against unbaked rock.

North of the divide between Rosebud Creek and the East Fork of Armells Creek, the Rosebud bed maintains an average thickness of about 20 feet, as estimated from measurements of part of the bed and thicknesses reported from drill holes. The maximum observed thickness for this part of the field was 23 feet at location 102, in the SW.¼ sec. 35, T. 2 N., R. 39 E. (See pl. 10.) The best exposures of the Rosebud bed occur in small tributaries of Miller Coulee in the southeastern part of T. 1 N., R. 41 E. (pls. 5, *B*; 6, *B*), where it crops out in cut banks at locations 221 and 222 and has clean exposures of about 28 feet of coal. (See pl. 10.) The lack of exposures along Rosebud Creek prevented the detailed mapping of the Rosebud bed in that area though a number of measurements of part of the bed were made. Observations in Lee Coulee, in Tps. 1 N. and 1 S., R. 41 E., suggest that the Rosebud bed in the general area of Rosebud Creek is replaced by sandstone and sandy shale in many places, and this condition would account for the small number of exposures of the bed.

Lee bed.—The Lee bed, which lies about 115 feet above the Rosebud bed, is not present in that part of the field north of the area drained by Rosebud Creek. Along Rosebud Creek it ranges from a thin trace up to 11 feet in thickness.

Popham bed.—The Popham bed, though it does not average more than 3 feet in thickness, is very persistent. It lies 50 feet below the Sawyer bed, or about 290 feet above the Rosebud bed. It was mapped in detail only in T. 1 N., R. 40 E.

Sawyer bed.—The Sawyer bed, 336 feet above the Rosebud bed, has been burned out over a large area, and its slag now makes a resistant cap rock on the divides along the main drainage lines. It is unburned in the rough and inaccessible country along the foothills of Wolf Mountain and ranges from a thin trace to 20 feet in thickness. It is replaced by carbonaceous shale northwest of T. 1 N., R. 40 E.

Proctor bed.—The Proctor bed lies 90 feet above the Sawyer bed and was mapped only in the rough country at the base of Wolf Mountain in T. 1 N., R. 39 E., at locations 164 to 168, where its average thickness is slightly more than 3 feet. (See pl. 10.)

Richard bed.—The Richard bed crops out at the base of Wolf Mountain and was mapped for about 3 miles in the southeastern part of T. 1 N., R. 39 E. It contains an average of 3½ feet of coal but is of no economic value because of its general inaccessibility.

Exhibit 31

PHYSICAL AND CHEMICAL CHARACTER

The coal in the Forsyth field is of subbituminous rank, has a conchoidal fracture, and is shiny black on a freshly exposed surface. This coal, like that of the Sheridan field, slacks after a short exposure to weather. Owing to loss of moisture it becomes dull black, and a network of cracks, some of which are at right angles to each other, develops in it, so that the small pieces which fall off as the coal crumbles are roughly cubical.

Of the several samples taken in the field, the analyses of which are given below, that from the unweathered Rosebud bed at the Colstrip mine of the Northwestern Improvement Co. (No. 19659) most nearly represents the true character of the coals. The sample of the Wright bed (No. 96584), the lowest coal in the field, was taken 50 feet from the entry of the Wright mine, in sec. 7, T. 5 N., R. 40 E. This mine has been abandoned for a year or more, and the sample consequently consisted of weathered coal. The sample of the Sawyer bed (No. 96587) was taken from an open pit at location 206A in a coulee, where a face of coal about 75 feet long had been cut back by settlers a maximum distance of 25 feet. Care was taken to obtain as fresh coal as possible under these conditions, but it was slightly weathered. The sample of the Lee bed at the McKay mine (No. 96583) was cut from a face of coal 150 feet from the entry of a drift mine less than a week after the mine had been active for a short time. The thickness of the Lee bed at this mine is nearly 11 feet, but only the upper 6 feet is mined, and only that part was sampled. It should be remembered, therefore, in comparing the value of the coal in the Forsyth field with that of coals from other fields where fresh samples have been cut by standard methods in underground mines, that the analysis of the Rosebud bed is the only one truly representative of the Forsyth coals given in this report, the heating values of the other samples as shown in the table of analyses on page 30 and in Figure 1 being probably somewhat too low.

In the following table analyses of representative samples from Williston, N. Dak.; Glendive, Miles City, Red Lodge, Bear Creek, Bull Mountain (Roundup), and Sand Coulee, Mont.; Sheridan, Wyo.; Hocking Valley, Ohio; and Pittsburgh, Pa., are also given in order to afford a basis of comparison between the Forsyth coal and other coals with which it will have to compete in the market. These analyses are given in four forms: Form A represents the composition of the sample as it is received in the laboratory. The amount of moisture contained in a sample "as received" is proportional to the amount of moisture and water in the mine at the

Exhibit 31

several analyses of samples from the same bed may differ widely. Form B represents the composition of the sample after it has been air-dried under uniform conditions until its weight becomes constant. This form of analysis is best adapted for general comparisons. Form C shows the theoretical composition of the coal after all the moisture has been eliminated. Form D represents the composition of the coal as it would be if all the ash and moisture were removed. Forms C and D represent conditions that do not actually exist in nature.

Analyses of samples of coal from the Forsyth field and of average samples from other fields

Laboratory No.	Source	Air-drying loss	Form of analysis	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Heating value	
									Calories	British thermal units
96584	Forsyth, Mont., Wright bed, Wright mine, SE. ¼ sec. 7, T. 5 N., R. 40 E.	6.5	A	23.7	28.6	35.7	12.0	0.6	4,489	8,080
			B	18.4	30.6	38.2	12.8	.7	4,800	8,640
			C	------	37.5	46.8	15.7	.8	5,883	10,590
			D	------	44.5	55.5	------	1.0	6,978	12,560
19659	Forsyth, Mont., Rosebud bed, Colstrip mine, sec. 34, T. 2 N., R. 41 E., composite of 4 analyses.	6.6	A	24.1	28.4	40.2	7.3	.7	5,050	9,090
			B	18.7	30.4	43.1	7.8	.8	5,406	9,730
			C	------	37.4	53.9	9.6	1.0	6,644	11,960
			D	------	41.4	58.6	------	1.1	7,350	13,230
96587	Forsyth, Mont., open pit on Sawyer bed, NW. ¼ sec. 30, T. 1 N., R. 40 E.	8.1	A	26.6	28.9	37.7	6.8	1.8	4,489	8,080
			B	20.1	31.5	41.0	7.4	2.0	4,889	8,800
			C	------	39.4	51.4	9.2	2.5	6,117	11,010
			D	------	43.4	56.6	------	2.7	6,739	12,130
96583	Forsyth, Mont., Lee bed, McKay mine, SW. ¼ sec. 34, T. 1 S., R. 41 E.	8.4	A	23.9	28.7	40.3	7.1	.6	5,089	9,160
			B	16.9	31.3	44.0	7.8	.6	5,550	9,950
			C	------	37.7	52.9	9.4	.8	6,683	12,030
			D	------	41.6	58.4	------	.8	7,372	12,270
	Williston, N. Dak., average of 7 mine samples. Bull. 531, pp. 100–101.	30.9	A	41.5	26.9	26.2	5.3	.63	3,512	6,320
			B	14.8	39.1	38.3	7.8	.93	5,124	9,222
			C	------	46.0	44.8	9.1	1.08	6,011	10,820
			D	------	50.7	49.3	------	1.20	6,612	11,902
	Glendive, Mont., field. Snider mine. Average of 5 samples. Bull. 471, p. 274.	13.9	A	32.9	26.6	32.9	7.49	1.04	4,056	7,300
			B	21.7	31.0	38.5	8.82	1.22	4,764	8,577
			C	------	39.7	49.1	11.21	1.55	6,038	10,870
			D	------	44.7	55.3	------	1.75	6,776	12,197
	Miles City, Mont. Average of 5 samples from Kircher bed.	17.9	A	30.1	27.5	33.4	9.05	.68	4,195	7,551
			B	14.7	33.6	40.6	11.03	.83	5,047	9,086
			C	------	39.3	47.7	12.95	.98	5,994	10,789
			D	------	45.1	54.8	------	1.12	6,917	12,452
	Sheridan, Wyo. Average of 20 mine samples.	10.4	A	23.3	32.2	41.1	3.46	.35	5,194	9,350
			B	14.3	35.9	45.9	3.86	.39	5,801	10,442
			C	------	41.9	53.6	4.51	.45	6,771	12,188
			D	------	43.9	56.1	------	.48	7,091	12,756
29466	Red Lodge, Mont.	6.3	A	11.3	33.6	44.5	10.6	.72	5,795	10,440
			B	5.3	35.9	47.5	11.3	.77	6,185	11,140
			C	------	37.9	50.2	11.9	.81	6,535	11,760
			D	------	43.0	57.0	------	.92	7,420	13,360
15130	Bear Creek, Mont.	3.0	A	10.0	33.9	44.8	11.3	2.26	5,885	10,590
			B	7.2	35.0	46.2	11.6	2.33	6,065	11,920
			C	------	37.7	49.8	12.5	2.51	6,535	11,760
			D	------	43.1	56.9	------	2.87	7,475	13,450
	Bull Mountain, Mont. Average of 9 mine samples. Bull. 647, pp. 51–53.	6.5	A	15.0	29.9	48.8	6.29	.58	5,974	10,754
			B	8.8	32.1	52.4	6.72	.63	6,409	11,539
			C	------	35.2	57.4	7.41	.69	7,026	12,651
			D	------	38.0	61.9	------	.75	7,624	13,662

Exhibit 31

Analyses of samples of coal from the Forsyth field and of average samples from other fields—Continued

Laboratory No.	Source	Air-drying loss	Form of analysis	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Heating value	
									Calories	British thermal units
4115	Sand Coulee, Mont.	2.4	A	6.0	28.4	51.4	14.2	2.38	6,195	11,150
			B	3.7	29.1	52.7	14.5	2.44	6,350	11,430
			C	------	30.3	54.7	15.0	2.53	6,590	11,870
			D	------	35.6	64.4	------	2.98	7,760	13,970
7712	Coal No. 6, Hocking Valley, Ohio	5.5	A	9.4	32.4	53.4	4.43	.54	6,805	12,250
			B	4.5	34.3	56.5	4.69	.57	7,200	12,960
			C	------	35.9	59.2	4.91	.60	7,535	13,570
			D	------	37.8	62.2	------	.63	7,925	14,270
23097	Pittsburgh coal, Fayette County, Pa.	1.2	A	2.5	35.7	53.6	8.17	1.76	7,585	13,650
			B	1.3	36.1	54.3	8.27	1.78	7,675	13,820
			C	------	36.6	55.0	8.38	1.81	7,780	14,000
			D	------	40.0	60.0	------	1.98	8,490	15,290

The Lance coal (No. 96584) in the Forsyth field shows a high ash content. Its sulphur content, however, is no higher than that of the three Fort Union coals in the same area (Nos. 19659, 96583, and 96587). Its heating value is equal to that of the Sawyer bed (No. 96587), which showed a similar amount of weathering when sampled. The coal from the Rosebud bed (No. 19659) is the most representative of the several samples. A comparison of this sample with the average of 20 fresh samples from the Sheridan field shows that the Forsyth coal is slightly inferior in quality to the Sheridan coal. From the analyses given above Figure 1 has been prepared in order to give a rough means of comparison of the coals. This figure shows clearly that the coals of the Fort Union formation in North Dakota, Montana, and Wyoming rise in rank the nearer they approach the areas of mountainous uplift. This is seen on comparing the heating value of the Williston lignite, which lies in nearly flat undisturbed rocks, with that of the coal from the Sheridan field, which is nearer the Big Horn Mountains.

In Figure 1 the line marked "coal as mined" represents the heating value of the coal as it is received from the mine—that is, its heating value in approximately the condition in which it will be put on the market and consumed. The line marked "pure coal" shows the heating value of the coals after their ash and moisture have been theoretically eliminated. The line marked "coal as mined" shows the relative value of the coals to the consumer, and the coals rank in the order in which they stand in Figure 1, Williston lignite being the lowest grade of coal given and Pittsburgh bituminous the highest. Figure 1 shows that the unweathered samples of Forsyth coal are only slightly lower in rank than the

Exhibit 31

time the sample was taken, therefore the amount of moisture in fresh samples from the Sheridan field and that both are somewhat lower than the Red Lodge, Bear Creek, and Bull Mountain coals. From a study of these comparative values it can be concluded, therefore, that the coals with which the Forsyth field will have to compete are those from Sheridan and vicinity, Red Lodge, Bear Creek, the Bull Mountains, and Sand Coulee.

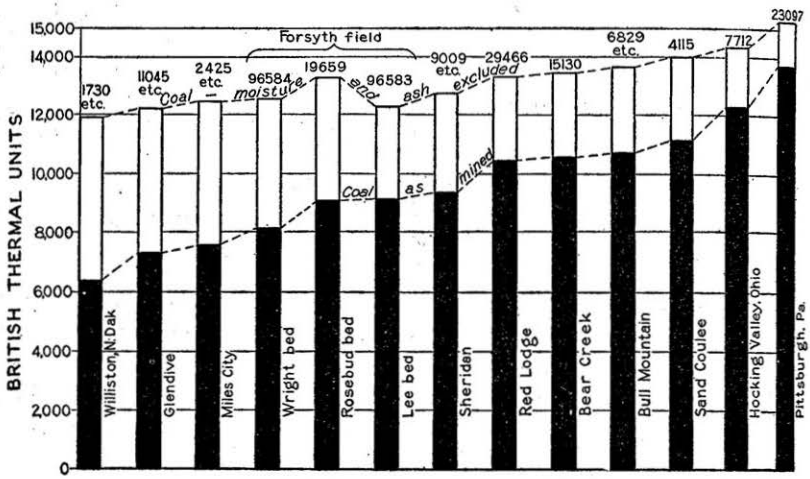


FIGURE 1.—Heating value of coals from Forsyth, Mont., and some other coals

COAL CLINKER

Where the rocks of the Tongue River member of the Fort Union formation crop out in the Forsyth field the clinker or "scoria" formed by the fusing and baking of clay, shale, and sandstone by a burning coal bed is very conspicuous. Because it offers greater resistance to erosion than the associated rocks the clinker usually occurs as a cap rock on buttes, ridges, and divides. The coal beds in the Tullock and Lebo members of the Lance and Fort Union formations, respectively, are burned in few places, and those that have been burned are only a few inches thick.

The burning of coal beds on the outcrop is probably due to spontaneous combustion or occasionally to fires set by man. Where a thick coal bed has burned slowly for a considerable period the slag thus formed may be 100 feet or more in thickness. The slag of the Sawyer bed, which is well exposed on the divide between the East Fork of Armells Creek and Rosebud Creek in the central part of T. 1 N., R. 41 E., and elsewhere in the southern part of the field, and that of the Rosebud bed in the Armells Creek area average about

Exhibit 31

50 feet in thickness. The Burley and Lee beds are clinkered extensively along their outcrops, and so are several thinner beds in the upper part of the Tongue River member of the Fort Union.

The amount of rock fused or baked by the burning of the coal depends upon the thickness of the coal bed and upon the proportion of lime in the rock. Where the cover is thick burning probably does not extend back more than 75 feet from the outcrop. If the coal bed lies flat and the cover is fairly thin the bed may burn over several square miles. Where two thick coal beds are separated by a small interval and both have burned to some extent the great quantity of clinker either in place or slumped down makes it impossible in some places to determine the amount of coal left unburned in the two beds, particularly in the lower bed. This is well illustrated in the Armells Creek area, where the McKay bed, which lies from 7 to 21 feet below the Rosebud bed and averages 7 feet in thickness, can not be mapped accurately because it is usually concealed by débris from the overlying Rosebud clinker.

The rapidity of the burning is determined by the supply of air. When heated to a kindling temperature the coal smolders until slumping takes place and crevices are formed along which air is admitted as through natural chimneys. The heat close to these vents becomes intense, and the overlying rocks are fused into a vesicular slag. Back from the outcrop and away from natural vents the burning becomes slower until a point is reached where no free oxygen is present and burning ceases.

The character of the clinker depends partly on the amount of heat to which the rock has been subjected, and partly on the amount of lime in the heated rock. Near the sources of air supply, or where the absence of lime renders the rocks readily fusible, their original texture has been destroyed and they are converted into a bright reddish-green or purple vesicular slag with flow structure. In the upper part of the slag the rocks have been merely baked to a brick-red color and retain their original texture. It is common to find perfectly preserved fossil plant impressions in the upper part of thick clinkers. Further details of the physical and chemical changes accompanying the formation of clinker are given in a paper by Rogers.[19]

DEVELOPMENT

At the time when the Forsyth field was examined development of the coals was restricted to its northern part, where several

[19] Rogers, G. S., Baked shale and slag formed by the burning of coal beds: U. S. Geol. Survey Prof. Paper 108, pp. 1–10, 1918.

Exhibit 31

small mines within 5 or 6 miles of Forsyth exploit the Wright bed to supply the local market. Several openings, referred to as the Lore mines, have been driven in on the Wright bed in secs. 1 and 2, T. 5 N., R. 41 E. The largest of these openings is about 200 feet long and comprises several rooms. The Wright mine, in sec. 7, T. 5 N., R. 40 E., was opened to supply Forsyth in times of coal shortage but is now abandoned. The Woodward and Griggs mines, on Smith Creek in sections 22 and 23, respectively, of the same township, are small entries from which coal is mined only part of the year. An attempt was made to mine the Hamre bed near the W. ½ sec. 29, T. 5 N., R. 40 E., but after an entry had been driven about 100 feet it was abandoned because of the poor quality of the coal.

The thick coal beds in the Tongue River member of the Fort Union formation have been used for years as a source of fuel by settlers. The usual procedure is for several settlers working together to obtain their winter's supply of coal by blasting it off from the face of one of the several well-known outcrops in the field. Practically all the prominent exposures of coal are in this way sources of domestic fuel, and for this reason they are discussed in detail only in the individual township descriptions. Several small timbered entries have been driven on the Lee bed on Rosebud Creek.

The completion of the Armells Creek branch of the Northern Pacific Railway has made accessible an enormous tonnage of subbituminous coal contained in the Rosebud and other coal beds. The coals are thick, persistent, and comparatively free from partings. Furthermore, a great quantity of this coal can be recovered by strip mining, and until this supply is exhausted there will probably be no attempts to mine the coal from underground diggings.

The Northwestern Improvement Co. is strip mining the Rosebud coal bed on a large scale at Colstrip, where the bed averages about 28 feet in thickness. The coal is mined in a completely electrified open pit, the power being supplied by the Montana Power Co., which extended its 55,000-volt 3-phase 60-cycle power line from Billings to Colstrip, a distance of 100 miles.

The pit was opened by a Marion model 360 electric stripper, with a 155-foot drag-line boom with 6-yard bucket and a 90-foot shovel boom with 6-yard bucket. The coal-loading shovel is a Bucyrus model 175–B, with a 75-foot boom and 7-yard bucket. Other electrical equipment in the pit consists of one gasoline drag-line 2½-yard bucket, with a 60-foot boom; one 20-ton locomotive crane, two 60-ton electric storage-battery locomotives, one electric well drill, and two portable-type air compressors. The coal is first blasted and then loaded directly into standard 50-ton steel coal cars,

Exhibit 31

which run on a track laid on top of the coal. The shovel loads a 50-ton car in about 6 minutes, or a 10-car train in approximately 1 hour. At the present time about 3,300 tons of coal are mined daily. The coal is used by the Northern Pacific Railway between Jamestown, N. Dak., and Missoula, Mont.

Excellent conditions for stripping the Rosebud bed exist on the low divide between the headwaters of the West Fork of Armells Creek and Stocker Creek, near Castle Rock, in Tps. 1 and 2 N., R. 40 E. A spur track about 9 miles long up the valley of Stocker Creek would make this area accessible. Further details of the mining conditions in the field are included in the several township descriptions.

Timber necessary for mining is abundant, especially in those areas where the Tongue River member of the Fort Union formation crops out. It is not believed that a water supply from artesian flows will be obtained where coal mining on a large scale is likely to be undertaken. Wells drilled to a depth of 600 to 1,400 feet below the Rosebud coal will undoubtedly encounter beds containing water, which will rise part way to the surface but will not flow. The water in the well 1,520 feet deep at Colstrip stands about 400 feet below the top of the casing. Flood waters impounded in reservoirs may be more satisfactory for use in boilers than well water, which may cause foaming.

Profitable strip mining of the Rosebud coal bed will depend upon the thickness and nature of the cover overlying the bed. For the Rosebud bed at Colstrip 100 feet has been arbitrarily considered to be the maximum thickness of overburden that can be economically removed by steam shovels under ordinary conditions. As shown by the sections on pages 18 and 19, the greater part of the 100-foot interval above the Rosebud bed in this field in places consists of hard massive sandstone, which must be blasted before it can be removed by shovels. At Colstrip and in the Castle Rock area this sandstone has been largely eroded or is loosely consolidated and should present no serious obstacle to stripping, except possibly in and near low divides where its basal portion may be more indurated.

Springs issue from the bases of most of the coal beds in the field, owing to the presence of an impervious shale bed beneath the coal. For this reason it is suggested that drift mines and other openings on coal beds be so located that the entries will follow the rise of the beds and supply a natural drainage of the mine.

Exhibit 31

Estimated quantity of coal present and recoverable in the Forsyth coal field, by townships, in net tons

Township	Estimated reserves [1]		Known reserves estimated to be recoverable by present methods.	
	Known	Possible additional	By strip mining	By underground mining
T. 4 N., R. 38 E.		6,000,000		4,000,000
T. 3 N., R. 38 E.	49,256,000	89,240,000		35,000,000
T. 2 N., R. 38 E.	438,240,000	193,536,000	8,640,000	308,000,000
T. 1 N., R. 38 E.	466,560,000	200,000,000		329,000,000
T. 3 N., R. 39 E.	24,000,000	62,208,000		17,500,000
T. 2 N., R. 39 E.	341,800,000	164,512,000	11,520,000	245,500,000
T. 1 N., R. 39 E.	953,856,000	622,080,000	2,600,000	665,000,000
T. 5 N., R. 40 E.	13,824,000	46,080,000		9,800,000
T. 4 N., R. 40 E.	16,128,000	39,168,000		11,200,000
T. 3 N., R. 40 E.	89,000,000	83,000,000		63,000,000
T. 2 N., R. 40 E.	200,064,000	124,416,000	13,000,000	140,000,000
T. 1 N., R. 40 E.	760,320,000	621,080,000	39,000,000	532,000,000
T. 1 S., R. 40 E.	228,152,000	829,440,000		161,000,000
T. 2 S., R. 40 E.	52,208,000	172,800,000		42,000,000
T. 3 N., R. 41 E.	55,296,000	27,648,000		38,000,000
T. 2 N., R. 41 E.	342,520,000	138,240,000	78,000,000	240,000,000
T. 1 N., R. 41 E.	975,000,000	400,000,000	107,000,000	682,500,000
T. 1 S., R. 41 E.	253,440,000	300,000,000		175,000,000
T. 2 S., R. 41 E.	180,000,000	120,000,000		126,000,000
	5,439,664,000	4,239,448,000	259,760,000	3,824,500,000

[1] Beds less than 3 feet thick not included in the estimate.

TOWNSHIP DESCRIPTIONS

In the following pages are presented detailed data upon the stratigraphy and structure of the rocks in the several townships, with especial emphasis laid upon the position, character, and thickness of the coal beds. General conclusions drawn from these data have been given in preceding pages. All coal beds mapped are represented on Plate 7, and the location of points where detailed sections were measured along outcrop lines are indicated by numbers. Corresponding numbers are used in Plate 10, in which the coal sections are represented graphically.

On the map the outcrop lines of the coal beds where exposed, inferred, or represented by slag are indicated by distinctive patterns, and so are those areas where the Rosebud coal bed can be worked by strip mining. The townships are described in tiers from west to east, beginning with the northern township in each tier.

T. 6 N., R. 38 E.—The alluvial plain of the Yellowstone River in T. 6 N., R. 38 E., is bordered on the south by a bluff of the sandstone member of the Judith River formation and terrace gravel. (See pl. 2, *A*, and pp. 8–9.) The remainder of the township is occupied by Bearpaw shale overlain by terrace gravel and presents a rolling, monotonous type of topography, unbroken except where crossed by the larger streams. The outcrop of the sandstone member of the Judith River represents the highest structural point in the Forsyth field and the dip of the member is about 3° SE. This township contains no coal.

T. 5 N., R. 38 E.—The southern part of T. 5 N., R. 38 E., where the Hell Creek member of the Lance formation crops out, has been extensively dissected

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by Reservation Creek and its tributaries, making it rough and almost impassable. The northern part of the township has the Bearpaw shale as the highest formation, and this shale and the terrace gravel produce a rolling, grass-covered country devoid of prominent topographic features. The strata in the township are on the southern limb of the Porcupine uplift and, as near as could be determined, dip about 2° S. No coal of any value occurs in this township.

T. 4 N., R. 38 E.—The southern part of T. 4 N., R. 38 E., is moderately rough and is unsettled. Its central part is occupied by the divide between East Bear and Blacktail Creeks, which is covered with a mantle of terrace gravel. The land in the northern part of the township is very rough and inaccessible. A fair road follows the valley of East Beaver Creek and forks in section 26, one branch crossing the divide in section 25 into the basin of Reservation Creek, and the other branch taking a southerly direction to the crest of the gravel-capped terrace in sec. 1, T. 3 N., R. 38 E.

The Hell Creek and Tullock members of the Lance formation and the Lebo shale and Tongue River members of the Fort Union formation crop out in this township as shown on Plate 7. The Hell Creek member consists here of light-colored sandstone and sandy shale similar to the beds of the overlying Tullock member, which is exposed in an escarpment striking nearly east in the northern part of the township. The Lebo shale weathers into low, rounded hills capped with terrace gravel, becoming approximately level as the crests of the divides are approached. The Tongue River member crops out as a conspicuous gravel-covered escarpment in the southeastern part of the township. In the SE. ¼ sec. 36, there is a small remnant of the Oligocene or Miocene (?) gravel terrace standing at an altitude of about 3,650 feet. Reworked gravel from this horizon is spread over practically the entire township.

The structure in the township is exceedingly simple. The rocks are slightly affected by the southwest end of the Porcupine uplift and dip uniformly southward at an angle of not more than 1°.

No exposures of coal were observed in the Tullock member in the township, and if any are concealed in the gravel slopes they are in all probability too thin to be of any value. Only one exposure of the Big Dirty bed was seen, at location 26 in section 28, where the overlying gravel had been removed and 4 feet 8 inches of dirty coal was found. Although the Big Dirty bed was not mapped in detail its position is shown with a fair degree of accuracy on Plate 7 by the line of contact between the Tullock and Lebo members. The only coal bed that should occur in the Tongue River member in this township is the Burley bed, and its outcrop should be restricted to the extreme southeastern part of the township. No outcrop of this bed or any other Tongue River coal was observed in this area, however.

T. 3 N., R. 38 E.—The divide between the drainage basins of Sarpy Creek and Armells Creek, in the southeastern part of T. 3 N., R. 38 E., is so heavily forested and so rugged that it is accessible only by saddle horse. In the northern part of the township a fair road crosses the divide and follows a northwesterly direction along the valley of East Beaver Creek. The township is everywhere maturely dissected. The streams are all intermittent and flow in narrow canyons, the walls of which are usually of massive sandstone. The main divide rises about 400 feet above the lowest parts of the township in sections 23 and 24 and is composed of massive light-colored sandstone, capped in sections 14 and 23 by remnants of the Oligocene or Miocene (?) river gravel bench.

The upper part of the Lebo shale member of the Fort Union formation and the lower 400 feet of the Tongue River member crop out in T. 3 N., R. 38 E.

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Rock exposures are generally poor owing to the presence of timber. A detailed section of the coal-bearing rocks in the township is given on page 20.

The Burley bed was measured at location 44, where it contained 2 feet 8 inches of coal. (See pl. 10.) At location 41 it is 4 feet thick and crops out in the bottom of the North Fork of Trail Creek near the Robinson ranch. At the Thompson prospect, in the SW. ¼ sec. 1, a bed assumed to be the Burley contained 3 feet 10 inches of coal. An abandoned prospect on this same bed at location 43 was reported to have shown a thickness of 3 feet of coal. In the central and northern parts of the township the mantle of gravel caused by the disintegration of an Oligocene or Miocene (?) gravel deposit has concealed the Burley as well as the coal beds above it.

The Robinson bed is well exposed in a cut bank along a narrow ravine at location 35 (pl. 10), where it contains 7 feet of coal. It is somewhat clinkered in the general vicinity of this location. It crops out again under similar conditions at location 36, where it contains 6 feet 5 inches of coal with a 3-inch clay parting. No exposures of it were observed farther north on the west side of the main divide and its crop line as shown on Plate 7 is inferred. Only one outcrop of the Robinson bed was observed on the east side of the divide, at location 37, where is was 7 feet 1 inch thick.

The Stocker Creek bed was measured on the side of a hill at location 40 (pl. 10), where it consists of an upper and a lower bench of coal 1 foot and 1 foot 7 inches thick, respectively, separated by 3 feet of carbonaceous shale. At location 42 it crops out in the bottom of a narrow coulee and is 2 feet 10 inches thick.

The Rosebud bed is nowhere well exposed in this township. Positive evidence as to its position is supplied by a partial section showing 4 feet 11 inches of coal, measured at location 38 (pl. 10), and the crop line of the basal part of the massive sandstone which lies above it. This sandstone as a rule is exceptionally well developed in this area. The McKay bed lies from 27 to 30 feet below the Rosebud in this township, and their crop lines nearly coincide. The clinkered outcrop of the Rosebud bed is very conspicuous just beneath the summit of the high divide in sections 23 and 24. The McKay bed is slightly more than 29 feet below the Rosebud bed at location 38 and contains 2 feet 3 inches of coal. At location 39 the McKay bed is 2 feet 7 inches thick and crops out about 30 feet below a moal blossom which undoubtedly represents the basal portion of the Rosebud bed. The McKay bed is 2 feet thick at location 94, but no outcrop of the Rosebud bed was observed in the heavy timber at this place.

T. 2 N., R. 38 E.—In T. 2 N., R. 38 E., the northward extension of Wolf Mountain makes the divide between Sarpy Creek and the West Fork of Armells Creek. The southeastern part of the township is rough, heavily timbered, and unsettled. In the central and northern parts the main north-south divide rises abruptly several hundred feet above the surrounding country and, though very narrow, proves a great obstacle to travel. A single road crosses the divide through a pass in section 14 and affords communication between the valleys of Sarpy and Armells Creeks.

The rocks which crop out in T. 2 N., R. 38 E., belong to the Tongue River member of the Fort Union formation and consist of light-colored sandstone, sandy shale, and coal, included in the 1,250 feet of rocks lying above the base of the Burley coal bed. The Sawyer bed is represented by carbonaceous shale in this township, but practically all other beds in the Tongue River member of the Fort Union are present, though none higher than the Rosebud were mapped.

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The Stocker Creek bed crops out in the valley of Horse Creek along the western border of the township and in the northern part of section 1. In a cut bank at location 97 (pl. 10) it contains 9 feet of clean coal. At location 96 its upper 7 feet crops out in a bench rising above a grass-covered knoll. No other outcrops of the bed were observed in the township, and its inferred position as shown on Plate 7 was determined by mapping the basal part of a massive sandstone which lies just above it. At location 99 a somewhat lower bed exposed in the bottom of a small tributary of Horse Creek showed two 1-foot benches of coal separated by 2 inches of clay.

The Rosebud bed crops out on both sides of the Sarpy Creek-Armells Creek divide and in places is heavily clinkered. No measurements of its thickness could be obtained in sections 21 and 28, though its position was easily determined by tracing clinker mounds in the grass-covered slopes. In that part of the township west of the old Crow Reservation fence it is clinkered over a large area. At location 92 (pl. 10) the Rosebud bed is 8 feet thick, showing a pronounced thinning from east to west in this particular township. In a coulee at location 91 the upper 4 feet of the Rosebud crops out, and the bed is fully exposed at location 90, where it contains 12½ feet of coal in its lower part, above which is a clay parting 8 inches thick and then 8 inches of coal. A few hundred feet downstream and 30 feet lower the McKay bed crops out at location 95 (pl. 10) and is 3 feet thick. At location 93 the McKay bed is 3 feet 5 inches thick, but the Rosebud bed where it would crop out is in the heavy timber and is not exposed. The outcrop of the Rosebud bed enters the eastern part of the township near the northwest corner of section 24, and the bed is exposed in cut banks along several small streams which have their sources at the base of the eastward-facing bluffs. In the North Fork of Donley Creek at location 86 (pl. 10) it contains 14 feet of coal in its lower part, overlain by about 4 feet of coal and bone, most of which, however, is coal. A similar measurement of the bed was made less than a quarter of a mile farther north, at location 87. The base of the coal was not exposed at either of these locations. At location 88 its upper part as exposed contains 9½ feet of coal split by a 4-inch carbonaceous shale parting. At location 89 it crops out in a cut bank, where it has been the source of fuel for settlers for many years. When the examination was made the basal part of the bed was concealed by débris. The total thickness of the bed at this location is about 25 feet, and the upper 13 feet of the bed is badly split by clay partings. (See pl. 10.)

As a rule the Rosebud bed in this township appears only in coulee bottoms and is overlain with too much overburden to be stripped advantageously. In the central and southwestern parts of section 13, however, there are several amphitheater-shaped depressions between long, narrow divides where the coal could be taken out by stripping, but it is not believed that there is a sufficient quantity available to make such an undertaking profitable at present.

Nearly all the valuable coal beds of the Tongue River member of the Fort Union formation are found in this township. It is estimated that the total tonnage of the Rosebud bed alone under the fractional part of the township here described is 300,000,000 tons.

T. 1 N., R. 38 E.—In T. 1 N., R. 38 E., the East Fork of Sarpy Creek, which is a perennial stream, contains only a little water during the summer. The land along the creek is rolling and is excellently adapted to farming. Almost all of the township is on the west side of Wolf Mountain; hence it receives a heavier rainfall than those areas east of the mountain. As a consequence of this abundant water supply the diversity of crops is far greater here than in any other part of the Forsyth field. On the northeast side of the East Fork

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of Sarpy Creek the land rises rapidly toward Wolf Mountain (pl. 4, *A*), which stands approximately 1,200 feet above the creek. The western slopes of Wolf Mountain are rough, unsettled, and accessible only by saddle horse.

The rocks exposed in T. 1 N., R. 38 E., are included in the 1,050 feet of rocks lying above the Stocker Creek coal bed.

The rocks are well exposed in the deep and narrow ravines which lead up to the top of Wolf Mountain, but on the divides they are usually concealed by grass or timber. The rocks have an inclination to the east and southeast of less than 1° and consist of alternating sandstone and sandy shale of a light-yellow color, intercalated with which are coal beds of differing thickness and persistency.

The Stocker Creek bed crops out just above creek level at location 154 (pl. 10), where it is 4 feet thick. No other exposure of this bed occurs in the township.

The Rosebud bed is extensively clinkered in the valley of the East Fork of Sarpy Creek, so the unburned coal in it is rarely exposed. A measurement of part of the Rosebud bed was obtained at location 151 (pl. 10), where its upper 5 feet crops out in a grassy hillside. A similar exposure occurs at location 152, where the upper 6 feet of the bed crops out in a natural cut beside an old wagon trail. In a ravine at location 153 the total thickness of the Rosebud bed, which is here 14 feet, is exposed. In the same ravine a few hundred feet west of the west line of section 4 the bed has been stripped by settlers.

A detailed section measured from the top of the Rosebud bed upward 1,000 feet failed to reveal any coal beds thicker than 3 feet. It is reported that a well drilled for the Tennessee Oil & Gas Co. in the SW. ¼ sec. 34 reached the depth of 1,000 feet and was then abandoned. The log of this well is not available, and no information can be given regarding the number, position, and thickness of the coal beds penetrated.

The total tonnage of coal in the Rosebud bed in this township is estimated to be 327,600,000 tons, nearly all of which could be mined by underground methods only. This fact, together with the geographic position of the township in relation to railroad lines either built or likely to be built, makes it highly improbable that the coals in the township will be exploited on a large scale in the near future.

Tps. 1 and 2 S., R. 38 E.—The eastern two tiers of sections of T. 1 S., R. 38 E., and not quite two full sections of T. 2 S., R. 38 E., are included in the Forsyth field. These areas lie on the western slopes of Wolf Mountain and are rough and heavily timbered. The surface strata belong to the Tongue River member of the Fort Union formation and, though not mapped in detail, are known to contain valuable coals.

T. 6 N., R. 39 E.—In T. 6 N., R. 39 E. the outcrop of the Bearpaw shale south of the alluvial plain of the Yellowstone River makes a strip of low, rounded gravel-capped hills that become progressively wider westward. The lower part of the Hell Creek member of the Lance formation crops out in a prominent pine-clad sandstone escarpment which strikes northeast; east of Armells Creek it composes the bluffs rising abruptly above the flood plains.

The distribution of the outcrops is determined by the Porcupine uplift, and the average inclination of the strata is about 3° SE. The township contains no coal.

T. 5 N., R. 39 E.—Armells Creek, in T. 5 N., R. 39 E., is bordered on both sides by very rough country. Travel is restricted to the main county road along Armells Creek; elsewhere the township, except for a trail leading up Cottonwood Creek a few miles, is inaccessible to vehicles.

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The Bearpaw shale crops out in parts of sections 5 and 6 and is bordered by a pine-clad escarpment of the lower sandstone of the Hell Creek member of the Lance. This sandstone is massive and usually forms barriers to travel that are almost impassable even on horseback. The most prominent topographic feature is the mesalike hill of sandstone of the Tullock member, which caps the divide between Reservation and Armells Creeks in section 31.

The attitude of the strata is determined by the Porcupine uplift, their inclination being to the southeast and ranging from a maximum of 4° in section 6 to less than 1° in the southeastern part of the township. A detailed hand-level section, measured from the mouth of Cottonwood Creek, in section 36, to the top of the mesalike hill in section 31, gave 401 feet as the thickness of strata of the Hell Creek member of the Lance formation exposed along the line traversed. The lower 165 feet of the Tullock member crops out in section 31 and contains several coals, none of which are more than 18 inches thick in this township.

T. 4 N., R. 39 E.—East of the divide between Armells and Reservation Creeks and in the northwestern part of T. 4 N., R. 39 E., the land is rough, broken, and unsettled, but the area at the head of Reservation Creek has a rolling surface and is easily accessible. The divide between the two creeks is capped by terrace gravel and is fairly level.

The Hell Creek member of the Lance formation crops out in the bluffs along Reservation Creek in the northwestern part of the township and is made up of grayish-yellow sandstone and sandy shale. The Tullock member is well exposed along Reservation Creek and in the maturely dissected areas east of the main divide, where its uppermost sandstone forms a resistant cap rock on the divides between the eastward-flowing streams. The Lebo shale member of the Fort Union formation crops out in a narrow strip having low relief. The Tongue River member of the Fort Union is the surface formation in the southwestern part of the township and is made up of yellow sandstone and sandy shale standing in bluffs above the surrounding Lebo lowlands. The crest of the main divide is formed by a narrow remnant of the Oligocene or Miocene (?) terrace, the reworked gravel from which has concealed the rocks at lower levels.

Several coal beds 1 foot or less in thickness were observed in the Tullock member in the eastern part of the township, but in its western part no coal beds were found. The Big Dirty coal bed, at the base of the Lebo shale, is persistent but is too dirty to be of any value. At location 27 it contained 3 feet 6 inches of carbonaceous shale with thin and irregular layers of coal. The Hamre bed is persistent but is also valueless. A measurement of it at location 28 gave 2 feet 6 inches of carbonaceous sandstone and coal. The bluffs of Tongue River rocks are covered with gravel washed down from the Oligocene or Miocene (?) terrace and exposures are relatively few. As only the lower part of the member is exposed, it can be safely assumed that no coals of economic importance are concealed beneath the gravel. At location 30 a coal bed 1 foot 1 inch in thickness crops out.

T. 3 N., R. 39 E.—The land west of the West Fork of Armells Creek for a maximum distance of 3 miles is broken and rough, owing to the erosion of the nonresistant sandstone and sandy shale of the Tullock and Lebo members of the Lance and Fort Union formations. The central part of the township, where the Tongue River member of the Fort Union crops out, is rolling, treeless country of moderate relief and is well adapted to dry farming. The most prominent topographic feature is the bold escarpment of Tongue River rocks which rises about 300 feet above the surrounding lowlands along the western

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edge of the township. The top of this escarpment is composed of the Oligocene or Miocene (?) terrace gravel and stands at an altitude of about 3,675 feet.

The lowest coal bed that crops out in the township is the Big Dirty bed, measurements of which made at locations 45 to 50 (pl. 10) show that it contains about 9 feet of carbonaceous shale and coal. The Robinson bed was measured at locations 52 to 58 (pl. 10) in the rough country at the base of the Tongue River escarpment; it averages 5 feet in thickness.

The only measurement of the Rosebud bed in this township was obtained at location 51 (pl. 10) where it contains 7 feet 2 inches of coal split by a 1-inch parting. Smaller beds were measured at location 59, in the NW. ¼ sec. 19, 160 feet below the Rosebud bed, where two benches of coal 1 foot 7 inches and 5 inches thick are separated by a 2-inch parting of carbonaceous shale, and at location 60 in the SW. ¼ sec. 30, 30 feet above the Robinson bed, where 1 foot 9 inches of coal was found.

An axis of gentle anticlinal folding passes across the northeastern part of the township and local doming on it occurs in section 11. Strong southwest dips were observed in section 23 and gentle southeast dips in the western parts of the township.

T. 2 N., R. 39 E.—The lower part of the Tongue River member of the Fort Union formation crops out in the northern part of T. 2 N., R. 39 E., and forms a rolling plain of moderate relief. In the central part of the township the Rosebud clinker forms a plateau dissected by many streams. The clinker makes a prominent rim rock along the creek valleys, and the slopes below it are covered with débris, which effectively conceals the coal beds. In the southern part of the township, where the Rosebud bed is unburned, the land is of moderate relief near the outcrop of the bed, but at a short distance back it becomes rough and broken.

The Burley bed crops out on the West Fork of Armells Creek at locations 119 and 120 and averages 4 feet in thickness. (See pl. 10.) West of the creek it is either concealed or absent and no measurements of it were obtained.

The Robinson bed is usually concealed where its outcrop line occurs in the bluffs, and measurements of it are obtainable only where streams have cut through it. Measurements made at locations 111 to 114 on the West Fork of Armells Creek show that it contains about 5 feet of coal in its lower part, overlain by about 3 feet of coal split by bone partings. (See pl. 10.) At location 115 a measurement of part of the bed showed more than 4 feet of coal. At location 116, in the bottom of the South Fork of Donley Creek, 3 feet of the bed crops out and its top is eroded. At locations 117 and 118, in the South Fork of Trail Creek, it is more than 3 feet thick.

The Stocker Creek bed, which occurs near the base of a rather prominent sandstone, was measured at locations 105 to 110 (pl. 10); it contains on the average 6 feet of coal overlain by 3 feet of coal and carbonaceous shale.

The Rosebud bed underlies a portion of the southern part of the township and is exposed, either wholly or in part, in narrow ravines. At location 101 (pl. 10) 5 feet of coal crops out in the side of a small mound. In the bottom of a ravine, at location 102, its total thickness of 23 feet is exposed, and at location 103 its upper 15 feet crops out. At location 104 its upper 12 feet is exposed in a cut bank. West of location 104 there are no exposures of the Rosebud bed and the position of its outcrop line as shown on Plate 7 was determined by mapping the contact of baked and unbaked rock.

The Rosebud can be mined by stripping in the E. ½ sec. 33 along the South Fork of Donley Creek. The land adjoining the creek is fairly level over

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approximately half a section, and the measurement at location 104 indicates that the coal is more than 12 feet thick.

From the measurements given above it is estimated that there are 125,000,000 tons of Rosebud coal in the township, most of which can be taken out only by underground mining.

T. 1 N., R. 39 E.—Almost all of T. 1 N., R. 39 E., lies in the rough country composing Wolf Mountain, which crosses the southwestern part of the township and makes the divide between Armells and Sarpy Creeks. The summit of the mountain is formed by a thick clinker, which stands about 1,300 feet above the surrounding country. The mountain slopes are heavily timbered and accessible only by saddle horse.

The rocks that crop out in the township belong to the Tongue River member of the Fort Union formation, and as the relief is great, about 1,300 feet of the member is exposed. (See pp. 18–19.)

The Rosebud bed crops out at locations 155 and 156 and is more than 15 feet thick. (See pl. 10.)

The Popham bed averages 4 feet in thickness and was measured at locations 157 to 163. (See pl. 10.)

The Proctor bed also averages about 4 feet in thickness and is represented on Plate 10 by locations 164 to 168.

The Richard bed crops out along the east line of the township, and measurements made at locations 169 to 173 (pl. 10) show that its average thickness is about 3½ feet.

Two unnamed coal beds are clinkered along their outcrops on both sides of Wolf Mountain, and no measurements of their thicknesses were obtainable. The position of their outcrop lines as shown on Plate 7 is only approximate.

Tps. 1 and 2 S., R. 39 E.—Tps. 1 and 2 S., R. 39 E., are crossed by Wolf Mountain and are rough, heavily timbered, and unsettled. The rocks which crop out in these areas are included in the interval between the Sawyer coal bed and the clinker making the summit of the mountain. The absence of thick coal beds and the general inaccessibility of this area make it unlikely that the coal in these townships will be exploited in the near future. A reconnaissance examination of the area was made and the following section was measured.

Section of the Tongue River member of the Fort Union formation in sec. 15, T. 1 S., R. 39 E.

	Ft.	in.
Sandstone, yellowish white, with brown concretionary lenses	53	
Shale, carbonaceous, slightly clinkered	4	
Sandstone, yellowish white	63	
Sandstone, brown; makes a ledge	20	
Sandstone, yellowish white, very soft and shaly	110	
Shale, grayish white	26	8
Shale, carbonaceous	2	
Sandstone, yellowish white, concretionary	30	
Coal		6
Carbonaceous shale	1	2
Coal	1	6
Carbonaceous shale	5	
Sandstone, whitish, concretionary	53	4
Shale, dark gray	26	8
Coal	1	8

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	Ft.	in.
Shale, gray	15	
Sandstone, whitish; makes a ledge	42	
Shale, gray	5	
Coal	5	8
Shale, gray	5	
Sandstone, gray, soft	23	
Coal	3	
Carbonaceous shale		1
Coal; Richard (?) bed	3	
Carbonaceous shale		7
Coal	5	
	505	10

T. 6 N., R. 40 E.—That part of T. 6 N., R. 40 E., which lies within the Forsyth field is rough and broken. West of Smith Creek the Yellowstone is undercutting its south bank, but east of the creek it swings northward, making a flood plain about a mile wide on which Forsyth is situated. The bluffs south of Forsyth rise abruptly several hundred feet above the flood plain and are capped with river gravel.

The rocks which crop out in this township belong to the Hell Creek member of the Lance formation and consist of alternating light and dark colored sandstone and sandy shale showing marked lateral variation and dipping slightly eastward. The nature of the Hell Creek member is indicated by the general section on pages 11–12. No coal occurs in this township.

T. 5 N., R. 40 E.—In T. 5 N., R. 40 E., the divide between Armells and Smith Creeks breaks off suddenly on the west, making a conspicuous escarpment which stands about 600 feet above the level of Armells Creek. (See pl. 2, *B*.) The crest of the divide is covered with terrace gravel and slopes gently toward the Yellowstone River. The drainage basin of Smith Creek consists of very rough land, and travel within it is restricted to the main valley and the divides. The southeastern part of the township consists of badlands and is inaccessible to vehicles.

The Hell Creek member of the Lance formation crops out at the base of the bluffs along the western edge of the township and is overlain by the escarpment-forming Tullock member. (See pl. 2, *B*.) Similar conditions exist on Smith Creek, although the area occupied by the Hell Creek member is larger. Representative sections of the Tullock member measured in this township are given on pages 13 and 14.

The Lebo shale member of the Fort Union formation crops out in the southern and eastern parts of the township and is eroded into almost impassable badlands. The basal sandstone and sandy shale of the Tongue River member make conspicuous bluffs above the Lebo badlands in section 36 and occur as outliers on a gravel-covered Lebo plain in sections 24 and 25.

The Wright coal bed, at the base of the Tullock member of the Lance formation, is the only coal bed of economic importance in the township and has been opened in three places to supply domestic fuel to Forsyth. At the Wright mine, in section 7, it contains 4 feet 2 inches of coal split by a 1-inch clay parting. (See pl. 10.) There are two timbered entries at this mine; the larger one is about 100 feet long and 5 feet high. At the time of examination the mine was abandoned and badly caved. Coal sample No. 96584 (p. 30) was taken at the Wright mine. Other measurements of the Wright bed in this vicinity are given in sections 2 to 4, Plate 10. At location 2 it is 1 foot 1 inch thick, and for nearly 4 miles to the south it was not mapped in detail. At location 5 it is 2

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feet 6 inches thick, and to the north it is concealed in terrace gravel. At the Griggs mine, in section 23, the Wright bed is 4 feet 4 inches thick and is all clean coal. This mine was formerly equipped for drift mining on a small scale, but at the time of examination most of the equipment had been removed and the mine was idle. The Woodward mine, in section 22, consists of two entries, each about 200 feet long, in which the Wright bed is 4 feet 1 inch thick. No outcrops of the Wright bed were observed in the gravel-covered slopes in the northeastern part of the township. At location 1, in section 30, the Wright bed suddenly thickens and contains 3 feet 5 inches of coal cropping out in a ravine at the base of the Tullock escarpment.

The Hamre bed crops out about 35 feet below the sandstone that makes the rim rock on the Tullock escarpment and consists of a mixture of coal and carbonaceous sandstone. An entry about 100 feet long was driven in on the outcrop of the Hamre bed at location 10, but was abandoned because of the bony character of the coal. At locations 7 to 9 and 11 to 14 (pl. 10) it contains a maximum amount of 3 feet 5 inches of dirty coal in its lower part, which may be replaced by carbonaceous shale and bone within a few hundred feet of the point where the measurements were made.

At location 17 a coal lens 60 feet below the Hamre bed gave the following measurements:

Section at location 17, T. 5 N., R. 40 E.

	Ft.	in.
Coal		4
Sandstone		½
Coal		3
Sandstone		1
Coal	2	3
	2	11½

The Big Dirty bed crops out at several places in the township, but because it is impure it was not mapped in detail. The following measurements illustrate its character.

Section at small prospect in sec. 24 (Big Dirty bed), T. 5 N., R. 40 E.

	Ft.	in.
Carbonaceous shale and bone		7
Clay	1	
Carbonaceous shale and streaks of coal		8
Bone		4
Shale		1
Bone		10
Bone with streaks of coal		3½
Bone		11
Coal		10
Bone and carbonaceous sandstone		11½
Bone with streaks of coal	1	
Coal	1	
	8	6

The Hamre bed near this prospect consists of 7 feet of carbonaceous shale, bone, and thin lenses of coal; the thickest lens of coal measures 7 inches. At location 18 the Big Dirty bed crops out as shown in the following section:

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Section at location 18, T. 5 N., R. 40 E.

	Ft.	in.
Carbonaceous shale		2
Coal		2½
Carbonaceous shale		4
Carbonaceous shale, bone, and thin streaks of coal	3	8
Shale		½
Coal		2
Shale		¼
Coal		3
	4	10¼

T. 4 N., R. 40 E.—Armells Creek and its forks in T. 4 N., R. 40 E., flow in relatively narrow valleys bordered by nearly vertical bluffs of sandstone and sandy shale several hundred feet high, which make natural barriers to travel across drainage lines. Outside the valleys of the creeks the land is rough, broken, and unsettled.

The Hell Creek member of the Lance formation here consists of somber-colored sandstone and clay. The Tullock member makes a conspicuous escarpment along the creek valleys which extend several miles up the larger tributaries. Here, as farther north, the top of the member consists of a resistant sandstone which makes a persistent and conspicuous rim rock. The Lebo shale member of the Fort Union formation, as usual, makes a low, featureless plain above the Tullock escarpment. The outcrop of the Tongue River member is restricted to a narrow promotory in section 1.

The Wright bed is the only coal of value in T. 4 N., R. 40 E.; it crops out near the base of the bluffs along Armells Creek. The bed occurs in two benches separated by a maximum interval of 27 feet. Both benches are persistent in position, but rarely do both contain coal at the same location. At location 19 the lower bench contains 2 feet 4 inches of coal in two layers separated by 1½ inches of carbonaceous shale. Similar measurements of the lower bench were made at locations 20, 21, 24, and 25. (See pl. 10.) Both benches of the Wright bed are present at location 22, where the lower bench contains 2 feet 8 inches of coal split by a 1-inch parting of carbonaceous shale and the upper bench 1 foot 4 inches of carbonaceous shale overlain by a like amount of coal. At location 23 on the promontory between the forks of Armells Creek, the upper and lower benches contain 2 feet 4 inches and 2 feet 2½ inches of coal, respectively, and are 26½ feet apart. No exposures of the Wright bed were observed in the northwestern part of the township west of Armells Creek.

The Big Dirty bed was not mapped in detail in this township. Its character is indicated by the following measurement:

Section of Big Dirty bed at location 61, in the SW. ¼ sec. 36, T. 4 N., R. 40 E.

	Ft.	in.
Coal, bony	2	
Coal		7
Bone		7
Coal		8
Bone	1	
Coal		8
	5	6

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The Hamre bed, although persistent in this township, is so impure that it is unworkable. The following measurement obtained on the promontory in the SE. ¼ sec. 23 illustrates its character:

Section of the Hamre bed in T. 4 N., R. 40 E.

	Ft.	in.
Coal		8
Bone		7
Coal		3
Bone		8
Coal		11
	3	1

T. 3 N., R. 40 E.—The land on both sides of the divide in T. 3. N., R. 40 E., is rough and generally inaccessible. The escarpment of the Tullock member of the Lance formation is a prominent topographic feature in the western part of the township and is overlain by the Lebo shale member of the Fort Union formation, which makes a fairly level top on the divide but is more dissected where it lies on the slopes. (See pl. 4, *B*.) The Tongue River member of the Fort Union occurs as outliers on a plain of Lebo shale in the northern part of the township and underlies a much larger area in its southern part, where it gives rise to rolling country of moderate relief.

A line of gentle anticlinal folding passes diagonally across the eastern part of the township. A fault with a throw of about 50 feet occurs on the east limb of this fold in sections 13 and 14.

The Big Dirty coal bed crops out persistently and contains about 10 feet of coal and carbonaceous shale. At location 70 its upper part contains 4 feet 10 inches of coal, and this is the maximum thickness of coal observed in a single part of it in the township. Other sections of the Big Dirty bed, measured at locations 62, 63, 69, and 71, are represented in Plate 10.

A coal bed which contains about 4 feet of coal and is probably equivalent to the Burley crops out at locations 73 and 74. (See pl. 10.) This bed was not observed at its horizon in adjacent coulees and is probably a small lens produced by the abrupt thickening of a thin seam of coal.

The Hamre bed is of no value in this township, and only one section of it is given here;

Section of Hamre bed at location 72, SE. ¼ sec. 36, T. 3 N., R. 40 E.

	Ft.	in.
Carbonaceous shale	2	5
Bony coal		9
Carbonaceous shale	1	1
Bone and bony coal	3	9
	8	

T. 2 N., R. 40 E.—In the northern part of T. 2 N., R. 40 E., the land is rolling, and exposures of beds other than the sandstone rim rocks are poor. In the southern part of the township, where the coal-bearing part of the Tongue River member crops out, the land is rough and broken. The creeks flow in narrow valleys rimmed by massive sandstone and clinker. The sandstone above the Rosebud bed averages about 60 feet in thickness and makes a conspicuous wall at the base of the highest bluffs. (See pl. 6, *A*.)

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The Robinson, Stocker Creek, and Rosebud beds underlie parts of the township. Measurements of the Robinson bed on the west side of the main divide were made at locations 129 to 133 (pl. 10), where it contained about 4 feet of coal. The Robinson bed could not be traced in the northern part of this township. At location 136 what is probably the Robinson bed contains 3 feet 2 inches of coal. A bed in the stratigraphic position of the Robinson contains about 3 feet of coal at locations 134 and 135. (See pl. 10.) A small outlier at location 137 is encircled by a coal bed 4 feet 8 inches thick, which may be the Robinson bed.

Several measurements of the Stocker Creek bed showed that it is 60 feet below the Rosebud and ranges from 3 to 6 feet in thickness. Sections of it are shown by locations 123 to 128. (See pl. 10.)

The Rosebud bed underlies the divide in the southwestern part of the township and several outliers in section 21 and vicinity, where it is not entirely burned. The only exposures of the bed observed were at locations 121 and 122, where 5 feet and 10½ feet, respectively, of unburned coal crops out. It is estimated that the total quantity of Rosebud coal underlying the township is 42,000,000 tons, of which 13,000,000 tons can be advantageously recovered by strip mining.

T. 1 N., R. 40 E.—The valley of the East Fork of Armells Creek in T. 1 N., R. 40 E., is about a mile wide and is well adapted to dry farming. It is separated from the valley of Stocker Creek on the north by a narrow divide about 300 feet high, which is crossed by several roads and trails. The divide between the East Fork of Armells Creek and Lee and Richard Coulees, tributaries of Rosebud Creek, occupies the central part of the township and is fairly accessible on its north side. On its south side, however, clinker escarpments stand about 250 feet above the bottom strips along the creeks, and the land is rough and broken, becoming almost impassable on the slopes of Wolf Mountain in the southwestern part of the township.

The axis of the syncline between the Big Horn and Porcupine uplifts crosses the central part of the township and is paralleled on the east by a line of gentle anticlinal folding, on which local doming has occurred in section 12. The position of this dome is outlined by the outcrop of the Rosebud coal bed, which rises above the level of the East Fork of Armells Creek in the NE. ¼ sec. 7, T. 1 N., R. 41 E., and dips beneath the creek again in the SW. ¼ sec. 11, T. 1 N., R. 40 E. (See pl. 7.)

The rocks that crop out in the township belong to that part of the Tongue River member of the Fort Union formation which is included in the interval between the Rosebud and Richard coal beds. The rocks other than coal beds consist of light-colored sandstone and sandy shale.

The gentle doming of the strata in section 12 has exposed the Rosebud bed at location 176 (pl. 10), where nearly 11 feet of it crops out. No other exposures of the bed occur in this immediate vicinity, as its outcrop is clinkered. At location 175 the upper 13 feet of the Rosebud bed crops out in a cut bank, and its total thickness at this location is reported to be 28 feet. The outcrop of the Rosebud bed is extensively clinkered west of location 175, and no exposures of unburned coal were observed. A well drilled near the Cooley ranch in section 4 is reported to have penetrated 24 feet of coal beginning at a depth of 6 feet below the surface.

The Lee bed crops out at location 177, in section 35, and contains nearly 9 feet of coal split by two thin partings of sandy shale. (See pl. 10.) The Lee bed is not developed in the northern part of the township.

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The Popham bed crops out 45 feet below the Sawyer bed and although it averages only about 4 feet in thickness was mapped in detail. Sections along its outcrop line at locations 178 to 200 are given on Plate 10.

The Sawyer bed is unburned only in the western part of the township and has a maximum thickness of more than 17 feet at location 213. (See pl. 10.) It thins rapidly toward the northwest and at location 203 is only 1 foot 8 inches thick. Other sections of the Sawyer bed are represented in Plate 10 by sections 201, 202, 204–a, 205, 206, 206–a, and 209 to 213. At location 206–a, in the NW. ¼ sec. 30, the Sawyer bed is 6 feet 8 inches thick and a face of it about 75 feet long has been cut back a maximum distance of 25 feet. Coal sample 96587 was taken at this location. (See p. 30.)

A measurement of the Richard bed made at location 215, at the south quarter corner of section 31, showed 6 feet 4 inches of coal, and one made at location 217, in the SW. ¼ sec. 19, showed 3 feet 2 inches of coal overlain by 3 inches of carbonaceous shale.

At location 204, in the SW. ¼ sec. 18, a coal bed 1 foot 3 inches thick crops out 78 feet above the Popham bed.

Conditions excellent for the recovery of a large tonnage from the Rosebud bed by strip mining exist in parts of sections 4, 5, and 6 of this township and in parts of secs. 31 and 32, T. 2 N., R. 40 E. The land lies in a topographic saddle between the headwaters of Stocker Creek and the West Fork of Armells Creek and is fairly level. The record of the well at the Cooley ranch, in section 4, and exposures at locations 155 and 156, in sec. 1, T. 1 N., R. 39 E., show that the Rosebud bed is more than 20 feet thick. The approximate outline of the area from which coal in the Rosebud can be taken out by strip mining, including tracts in sections 11, 12, 13, and 14, is shown on Plate 7. A rough estimate of the coal thus recoverable in this township is placed at 39,000,000 tons.

T. 1 S., R. 40 E.—The principal tributaries of Rosebud Creek in T. 1 S., R. 40 E., are separated by long, narrow, and level clinker-capped divides, which stand about 250 feet above the valley bottoms. The clinker makes a resistant cap rock above bluffs of yellow sandstone and sandy shale and protects dissected remnants of a former extensive slag-covered plateau. The coals are unburned in the western part of the township, and the land is very rugged and inaccessible. Trails extend part way up all the creeks, and most of them end at deserted ranches. The inaccessibility of the area and the lack of good drinking water have served to keep this township almost unsettled.

The rocks in the township belong to that part of the Tongue River member of the Fort Union formation which is included in the interval between the Lee and Richard coal beds. The dip is uniformly about 1° SE. The Lee bed crops out near the base of the bluffs throughout the township and is extremely clinkered. Its maximum thickness in Slough Grass Creek is 6 feet 4 inches at location 249. Other measurements of it in Slough Grass Creek are given on Plate 10 by locations 250 to 254. Only one measurement of it was obtained in Little Cottonwood Creek, at location 255, where it contains 5 feet 7 inches of coal split by 3 inches of shale. At location 256 slightly more than 2 feet remains unburned. At location 257 it is nearly 14 feet thick but includes a sandstone parting more than 5 feet thick in its middle part in addition to several smaller partings. (See pl. 10.)

The Sawyer bed crops out in the almost impassable badlands in the western part of the township. On the Middle Fork of Richard Coulee, at location 258, it is more than 9 feet thick and is badly split by partings. (See pl. 10.) Its maximum observed thickness occurs at location 265, where it consists of an

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upper and a lower bench, containing 4 feet 5 inches and 8 feet 5 inches of coal, respectively, separated by a bed of carbonaceous shale 15 feet thick. Other sections are given in Plate 10 by locations 259 to 264 and 266. The Popham bed crops out in the township, but because of its close vertical proximity to the Lee and Sawyer beds it was not mapped in detail. Its general character in the township is illustrated in Plate 10 by sections 267 and 268.

T. 2 S., R. 40 E.—That part of T. 2 S., R. 40 E., which was examined includes slightly less than two tiers of sections lying north of the Cheyenne Indian Reservation. The land included in this area is very rugged and is largely occupied by the divide between Big Cottonwood Creek and Lynch Coulee.

On Big Cottonweed Creek, at location 278, 4 feet 10 inches of coal, with its base unexposed, crops out in the stream bottom and may be the top of the Rosebud bed. The Lee bed is 4 feet 9 inches thick at location 269. The Sawyer bed is extensively burned along its outcrop and no measurements of its thickness could be obtained.

T. 6 N., R. 41 E.—The alluvial plain south of the Yellowstone River in T. 6 N., R. 41 E., is less than a quarter of a mile wide and is bordered by gravel-capped bluffs about 200 feet high. The rest of the township is occupied by a terrace of Pleistocene river gravel, which is traversed by good roads and is well settled.

The Hell Creek and Tullock members of the Lance formation underlie the terrace gravel in this township and crop out at irregular intervals along Slaughter House Creek and in the bluffs of the Yellowstone River. No coal was observed in this township.

T. 5 N., R. 41 E.—The divide which occupies the central part of T. 5 N., R. 41 E., stands about 700 feet above the level of the Yellowstone River. Its summit is composed of terrace gravel locally cemented into a conglomerate 10 feet thick and represents a river terrace intermediate in age between the Oligocene or Miocene (?) bench in T. 4 N., Rs. 39 and 41 E., and the main terrace along the Yellowstone River. As indicated on pages 20–22 this deposit may represent the Flaxville gravel, of Miocene or Pliocene age. East of the main divide and in the drainage basin of West Rosebud Creek the land is very rough and broken and is traversed by only one road, which follows the creek bottom. In the western part of the township a mantle of terrace gravel has produced a rolling type of topography which becomes increasingly rough toward the head-waters of West Rosebud Creek.

The contact line of the Hell Creek and Tullock members of the Lance formation as shown on Plate 7 is inferred, for the lack of continuous exposures makes it impossible to draw a well-defined line between them. The Lebo shale member of the Fort Union formation underlies the divide in the central part of the township and makes an extensive badlands area along the West Fork of Rosebud Creek. The Tongue River member of the Fort Union crops out on long, narrow spurs and outliers in sections 30 and 31.

The Wright coal bed has been opened at six places along a coulee in sections 1 and 2 to supply domestic fuel to Forsyth. These openings are referred to as the Lore mines. The largest opening extends in 200 feet and comprises several rooms. The main openings are 5 feet high and 5 feet wide and have a soft sandstone roof. The section on page 51 illustrates the character of the Wright bed at these openings.

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Section on the Wright coal bed in T. 5 N., R. 41 E.

	Ft.	in.
Carbonaceous shale		2½
Coal		5
Carbonaceous shale		1
Coal		6½
Carbonaceous shale		1½
Coal	2	
	3	4½

A coal bed 2 feet 4 inches thick was seen in the bluffs on the West Fork of Rosebud Creek, at the center of section 25, but thinned to less than 1 foot within a few hundred feet. The Hamre bed crops out below the Tullock rim rock as follows:

Sections of the Hamre coal bed in T. 5 N., R. 41 E.

SE. ¼ sec. 9	Ft.	in.
Coal, dirty	1	9
Carbonaceous shale		2
Coal, soft, bony	2	3
	4	2

NE. ¼ sec. 34	Ft.	in.
Carbonaceous shale and coal		10
Carbonaceous shale		¾
Bone		5
Carbonaceous shale		1
Bone		6½
Carbonaceous shale		1
Coal		6
Carbonaceous shale		1½
Coal		9
	3	4¾

The Big Dirty bed averages about 6 feet in thickness and is made up of carbonaceous shale and dirty coal. The best exposure of it in the township occurs on the narrow ridge in the NW. ¼ sec. 22, where it is nearly 7 feet thick but very dirty. The Big Dirty bed was not mapped in detail, but its outcrop is represented with fair precision on Plate 7 by the contact line between the Tullock and Lebo shale members.

T. 4 N., R. 41 E.—The plateau-like divide which crosses T. 4 N., R. 41 E., ranges in width from less than a mile in its southern part to a maximum of about 5 miles in its northern part. Its most prominent topographic features are several flat-topped hills and ridges capped with Oligocene or Miocene (?) gravel, which rise several hundred feet above the general level of the divide in sections 8, 14, 15, and 16. (See pl. 7.) The land on either side of the divide is exceedingly rough and has neither roads nor trails.

The upper part of the Tullock member of the Lance formation crops out in the stream bottoms along the borders of the township. The Lebo shale member of the Fort Union formation is nearly 170 feet thick (see p. 16) and crops out in a relatively narrow band between the escarpment-forming sandstones of the Tullock and Tongue River members. The lower 208 feet of the Tongue River member crops out in bold escarpments above the somber-colored Lebo clays and is made up of yellow sandstone and thin lenticular coal beds. (See p. 20.)

No coal of value occurs in the township. The Hamre bed contains 18 inches of coal at location 33 in the SW. ¼ sec. 19. The Big Dirty bed is persistent but thinner and more bony than at any other place along its outcrop in the entire field. The following measurements show its character and thickness:

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Sections of the Big Dirty bed in T. 4 N., R. 41 E.

Location 31, NE. ¼ sec. 31

	Ft.	in.
Coal		10
Coal, dirty		3
Coal		9
Bone	1	8
	3	6

Location 32, SE. ¼ sec. 30

	Ft.	in.
Coal and carbonaceous shale	3	

Location 34, NE. ¼ sec. 25

	Ft.	in.
Coal		6
Bone		8
Carbonaceous shale and coal	3	6
	4	8

T. 3 N., R. 41 E.—The divide in the northern part of T. 3 N., R. 41 E., is characterized by long narrow ridges of Tongue River sandstone, bordered by badland slopes of Lebo shale. In the southern part of the township near the East Fork of Armells Creek the land is of moderate relief but becomes rougher as the main divide is approached, and west of the creek is so dissected as to be almost impassable.

The East Fork of Armells Creek flows along the axis of a syncline paralleling an anticline which crosses the southwestern part of the township. West of the creek the rocks rise at an angle of about 3°, which is sufficient to expose the upper part of the Tullock member in the stream bottoms. This line of folding is modified by a northwestward-trending fault zone which runs slightly east of the anticlinal axis. The faults are normal and are dropped on the west about 60 feet. (See pl. 7.)

At location 75, in the NE. ¼ sec. 6, the Big Dirty bed contains about 4 feet of coal and carbonaceous shale. At location 76, about 1½ miles to the south, it is 6½ feet thick and of fair quality. Along the fault zone in the southeastern part of the township it attains a maximum thickness of 11 feet at location 77 and appears to consist of a good grade of subbituminous coal. Other measurements of this bed are represented in Plate 10 by sections 78, 79, and 80. At locations 81 and 82 it again assumes its normal dirty character, as the following sections will show:

Sections of the Big Dirty bed in T. 3 N., R. 41 E.

Location 81, SE. ¼ sec. 31

	Ft.	in.
Carbonaceous shale	1	1
Coal		2
Bone		5
Coal	1	6
Bone		5
Coal		8
Coal, sandy		7
Coal		6
Bone	1	
Clay		5
	6	7

Location 82, SW. ¼ sec. 31. (See pl. 3.)

	Ft.	in.
Coal	1	1
Clay		2
Coal		1
Clay		2
Coal		1
Clay		1
Coal		½
Clay		7
Bone		1½
Coal, dirty	1	1
Sandstone		½
Coal		5
Sandstone		½
Coal, dirty	1	8
Bone		3
Coal		10
	6	9

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The Burley bed underlies the highest part of the divide in the central and southern parts of the township and is in places extensively burned. Outcrops of the bed are rare, however, on account of the rolling, grass-covered nature of the country. It was measured at locations 83, 84, and 85 (pl. 10) and showed an average thickness of 4½ feet.

T. 2 N., R. 41 E.—In the northern part of T. 2 N., R. 41 E., the East Fork of Armells Creek is bordered by bluffs that rise 300 feet above the level of the creek, and in the southern part of the township the clinker made by the burning of the Rosebud coal bed has produced a continuous line of bluffs and rounded hills along the creek. In those areas along the creek where the Rosebud bed has not been burned the land is gently rolling and rises in smooth grass-covered slopes to higher and rougher areas in sections 31 and 32. The Armells Creek branch of the Northern Pacific Railway and the main road to Forsyth follow the valley of the East Fork of Armells Creek, and a branch road to Castle Rock follows Stocker Creek.

In the southern part of the township the rocks have an average dip eastward of about 20 feet to the mile, the dip increasing slightly toward the west. In the central and northern parts of the township the dip is about 30 feet to the mile to the east, and there may be a slight reversal of dip in sections 17 and 18.

The Burley coal bed crops out at the head of Sprague Basin in sections 1 and 2 and at the base of the bluffs along the east side of the East Fork of Armells Creek. At location 143 (pl. 10) it contains 5 feet of coal, and at the Wimer place, location 144, some 2 feet of the bed shows in a spring, and it is reported to be 6 feet thick. At location 145 the bed shows 4 feet 4 inches of coal, and at location 146 it contains 4 feet of coal. A bed which may be the Burley bed contains 3½ feet of coal at location 147. It was impossible to trace this bed in the grass-covered and forested areas along Stocker Creek.

The Robinson bed crops out at the base of a sandstone which makes a prominent rim rock near the base of the bluffs on the east side of the East Fork of Armells Creek and is 50 feet above the Burley bed. Although exposures of this bed are few its position is easily determined by noting the outcrop of the massive sandstone immediately above it. At location 148 (pl. 10) it contains 2½ feet of coal; at location 149 it contains 4½ feet of coal. The outcrop line south of location 148 shown for it on Plate 7 is inferred.

The McKay and Rosebud beds are extensively burned in this township. The divide between the East Fork of Armells Creek and Stocker Creek and the divide between the East Fork of Armells Creek and Spring Creek in sections 13, 14, and 15 consist largely of clinker formed by the burning of these beds. Both beds are burned in sections 25 and 36 also. In the absence of outcrops the present margin of the Rosebud bed was mapped by reference from the contact of its clinker with cover, it being assumed that the coal would lie unburned back of this contact a distance directly proportional to the thickness of the cover. The McKay bed lies from 8 to 21 feet below the Rosebud bed and where unburned itself is usually concealed by clinker of the Rosebud bed. At location 150 (pl. 10) it is exposed directly beneath the Rosebud slag in a coulee and is more than 6 feet thick.

On Pony Creek, at location 142 (pl. 10), the upper 10 feet of the Rosebud bed is exposed, and is extensively burned in the next township on the east. At location 217, some 6 feet of the Rosebud bed crops out in a reservoir just south of the township line. At location 141 a 14-foot bed of coal, containing two bone partings 1 and 10 inches thick, crops out in a narrow ravine, with the base of the bed unexposed. Measurements of part of the bed at locations 138, 139, and 140 (see pl. 10), averaged about 6 feet. The average thickness of the Rosebud

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bed in this township, as determined by drill records, is reported to be 28 feet. On Plate 7 those areas in this township where the coal in this bed can be recovered by strip mining are shown in stippled pattern. It is estimated that the Rosebud bed contains 187,000,000 tons of coal in T. 2 N., R. 41 E., of which about 78,000,000 tons can be taken out by stripping.

T. 1 N., R. 41 E.—The flood plain of the East Fork of Armells Creek is about a quarter of a mile wide in T. 1 N., R. 41 E., and the land on each side of the creek bottom for about half a mile is made up of smooth rounded slopes which become rougher farther away from the valley. The divide between Armells and Rosebud Creeks is capped by clinker from the burning of the Sawyer coal bed and stands about 375 feet above the level of the surrounding country. Miller Coulee and its tributaries occupy a basin about 3 miles wide which is almost surrounded by precipitous clinker-capped bluffs of sandstone and sandy shale. The topographic features along Lee Coulee are similar to those of Miller Coulee, though its valley is narrower. Roads traverse the valleys of the larger streams along the township borders, but none cross the inaccessible divide in its central part.

In the central and eastern parts of the township the rocks rise westward about 25 feet to the mile. Gentle doming of the strata occurs near the southwestern corner of section 29 along the axis of a minor anticlinal fold. (See p. 23.) Similar doming on the same anticlinal axis occurs in sec. 12, T. 1 N., R. 40 E., and has increased the westward rise of the rocks in secs. 6 and 7, T. 1 N., R. 41 E., to about 1½°.

The rocks that crop out in T. 1 N., R. 41 E., belong to that part of the Tongue River member of the Fort Union formation included in the interval between the McKay and Sawyer coal beds. (See p. 19.) The sandstone above the Rosebud coal bed is about 140 feet thick in Miller and Lee Coulees, where it makes a conspicuous ledge at the base of the precipitous bluffs. (See pl. 5, *A*.)

The upper 6 feet of the Rosebud bed crops out in a small reservoir at location 217. (See pl. 10.) Along the East Fork of Armells Creek west of location 217 the Rosebud bed is covered until brought above stream level by the increased westward rise of the rocks, and at location 216 it crops out 11½ feet. At the Kimball ranch in the SW. ¼ sec. 6, a coal bed 8 feet thick 40 feet below the surface was penetrated in a well and is probably the Stocker Creek bed. At location 218 the Rosebud bed is 18 feet thick at an abandoned prospect, and at location 218–a (pl. 10) the McKay bed is 7 feet thick. The Rosebud and McKay beds are fully exposed in cut banks at locations 221 and 222 and are about 28 and 10 feet thick, respectively. (See pls. 5, *B*; 6, *B*; and 10; and p. 19.) No other exposures of the Rosebud bed were observed in Miller Coulee, and the outcrop line of the bed as shown on Plate 7 was mapped largely by reference to the contact of baked and unbaked rock. At location 223 the upper 11 feet of the Rosebud bed crops out and is cut off by a fault having a throw of about 32½ feet. (See pl. 7.) The McKay(?) bed is unburned at locations 227 and 228 and has a maximum thickness of 4 feet 5 inches. At an abandoned prospect at location 224 the Rosebud bed is 10 feet thick, and farther downstream it is only a foot thick, having been almost entirely replaced by sandstone and sandy shale. No other exposures of the Rosebud bed were observed in Lee Coulee, though heavy clinker at its horizon in sections 29 and 30 indicates that it is at a slight depth below the surface.

The Lee bed is 105 feet above the Rosebud and first appears along Lee Coulee, where it is heavily clinkered. Only one measurement of it was made, at location 225, where its upper 6 feet crops out.

The Sawyer bed is unburned at location 226 (pl. 10) and is 11 feet thick.

Exhibit 31

Those parts of the township where the coal of the Rosebud bed can be recovered by strip mining are indicated on Plate 7 by stippled pattern. The best belt for strip mining lies along the East Fork of Armells Creek, where the coal is at a depth of less than 60 feet over a considerable area, and the overburden is loosely consolidated sandstone and sandy shale. Smaller stripping areas occur in SE. ¼ sec. 12 and in and near the northern part of section 24. It is estimated that the total quantity of coal in the Rosebud bed (exclusive of the McKay bed) within the township is 843,000,000 tons, of which approximately 107,000,000 tons can be recovered by strip mining.

T. 1 S., R. 41 E.—In T. 1 S., R. 41 E., Rosebud Creek has a flood plain ranging from a few hundred feet to nearly half a mile wide. Its tributaries occupy U-shaped valleys separated by continuous and rather narrow clinker-capped divides, which stand about 350 feet above the stream bottoms. (See pl. 7.) Good water is obtained from drilled wells at ranches along Rosebud Creek, but in other parts of the township the water is too alkaline for drinking. The road between Forsyth and Sheridan follows Rosebud Creek and is graded. Other roads and trails which traverse the township are shown on Plate 7.

The rocks in the township belong to that part of the Tongue River member of the Fort Union formation which lies between the Rosebud and Sawyer coal beds. The interval between the Rosebud and Lee coal beds is 115 feet and is largely occupied by massive sandstones. A similar sandstone about 60 feet thick crops out above the Lee bed, so that a double sandstone bench appears to run along the creek valleys.

The maximum thickness of the Rosebud bed reported in the township is 12 feet in a well near the Groves place, at location 232. Measurements made at locations 229, 230, 231, 233, and 234 are shown graphically in Plate 10. It was impossible to obtain more measurements of the bed because of the soil cover at its horizon along the valleys of the creeks. The general westward rise of the rocks and an occasional small clinker mound near stream level suggest, however, that it is at only a slight depth beneath the surface on all the western tributaries of Rosebud Creek.

On the west side of Rosebud Creek the Lee bed crops out high in the bluffs and is nearly everywhere inaccessible. East of Rosebud Creek it has been opened at two places by settlers. At the McKay mine, in the SW. ¼ sec. 34, it is about 11 feet thick, but only 6 feet of it is mined. This mine has been driven in about 150 feet and is well timbered. Coal sample No. 96583 was taken at this mine. (See p. 30.) The Lynch mine, in the SE. ¼ sec. 25, has a timbered entry about 150 feet long on the Lee bed, the upper 7 feet of which crops out in a coulee beneath a massive sandstone. Other measurements of the Lee bed in this township are represented in Plate 10 by sections 236 to 245.

No unburned coal of the Sawyer bed remains in the township.

T. 2 S., R. 41 E.—Approximately the northern third of T. 2 S., R. 41 E., is included in the Forsyth field. The rocks exposed in this area belong to the Tongue River member of the Fort Union formation and crop out in nearly vertical bluffs rising about 350 feet above Rosebud Creek.

The Rosebud bed has a maximum observed thickness of 13 feet at location 247. Other measurements were made at locations 246 and 248. (See pl. 10.) No exposures of the Lee bed were observed in the bluffs. East of Rosebud Creek the Sawyer bed is unburned in places on the divide between Rosebud and Rye Grass Creeks, but its outcrop is everywhere heavily clinkered.

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Exhibit 31

Exhibit 31

Exhibit 31

R. 38 E. R. 39 E. R. 40 E. R. 41 E.

T. 6 N. T. 5 N. T. 4 N. T. 3 N. T. 2 N. T. 1 S.

YELLOWSTONE RIVER
CHICAGO, MILWAUKEE, ST PAUL AND PACIFIC
NORTHERN PACIFIC YELLOWSTONE TRAIL
YELLOWSTONE TRAIL
TO ASHLAND
Finch
Malaga
Orinoco
FORSYTH
Reservation
Blacktail Creek
Cottonwood Creek
Armells Creek
Smith Creek
E Fk Smith Creek
Slaughterhouse Cr
Wright bed
Big Dirty bed
Hamre bed
Robinson bed
Rosebud bed
Stocker Cr bed
Burley bed
Sheep Cr
Bear Creek
E Fk Beaver Cr
N Fk Cottonwood Cr
Mid Fk Cottonwood Cr
Cottonwood Cr
N Fk Trail Cr
S Fk Trail Cr
Trail Cr
N Fk Donley Cr
S Fk Donley Cr
Donley Cr
Horse Cr
Corral Creek
Burley Creek
W Fk Rosebud Creek
Sarpy Cr
E Fk Sarpy Cr
S Coal Bank Coulee
Miller Coulee
Lee Coulee
S Fk Lee Coulee
Richard Coulee
Grass Cr
Big Cottonwood Cr
Middle Fork
North Fork
South Fork
West Fork
E Fk
N Fk
S Fk
Rosebud Creek
Sarpy Creek
Little Stough
Stough
Lane
Proctor bed
Popham bed
Sawyer bed
Lee bed
Robinson bed
Burley bed
Rosebud bed
Stocker Cr bed
Big Dirty bed
Hamre bed
Wright bed
Wright Mine
Griggs Mine
Woodward Mine
Lore Mine
McKay Mine
Ranch Mine
Thompson Prospect
Robinson Ranch
Edwards Ranch
Burley Ranch
Davidson Ranch
McKay Ranch
Huntington Ranch
Kelly Ranch
Cooley Ranch
Castle Rock
Cooley
Kimball
Sherman
Colstrip
Hafer
Frazer Ranch
Wolf Mountains
Tullock Creek
Rosebud Mountains
TREASURE COUNTY
ROSEBUD COUNTY
BIG HORN COUNTY
BIG HORN CO.
TONGUE RIVER
INDIAN RESERVATION
BASE LINE

EXPLANATION

QUATERNARY	Recent	Qal — Alluvium
TERTIARY	Oligocene or Miocene (?)	Tg — Terrace gravel
TERTIARY	Eocene — Ft. Union formation	Tfut — Tongue River member
TERTIARY	Eocene — Ft. Union formation	Tful — Lebo shale member (*Big Dirty coal bed at base*)
TERTIARY (?)	Eocene (?) — Lance formation	Tlt — Tullock member (*Wright coal bed at base*)
TERTIARY (?)	Eocene (?) — Lance formation	Tlhc — Hell Creek member
CRETACEOUS	Upper Cretaceous	Kb — Bearpaw shale
CRETACEOUS	Upper Cretaceous	Kj — Judith River formation

Coal clinker

37 — Outcrop of coal bed (*Number referred to in text*)

Contact of baked and unbaked rock

Area where coal can be recovered by stripping

Fault

Mine

Base from author's field sheets and U. S. Land Office plats

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

Geology by C. E. Dobbin assisted by C. R. Fettke, C. M. Clark, and D. S. Mossom

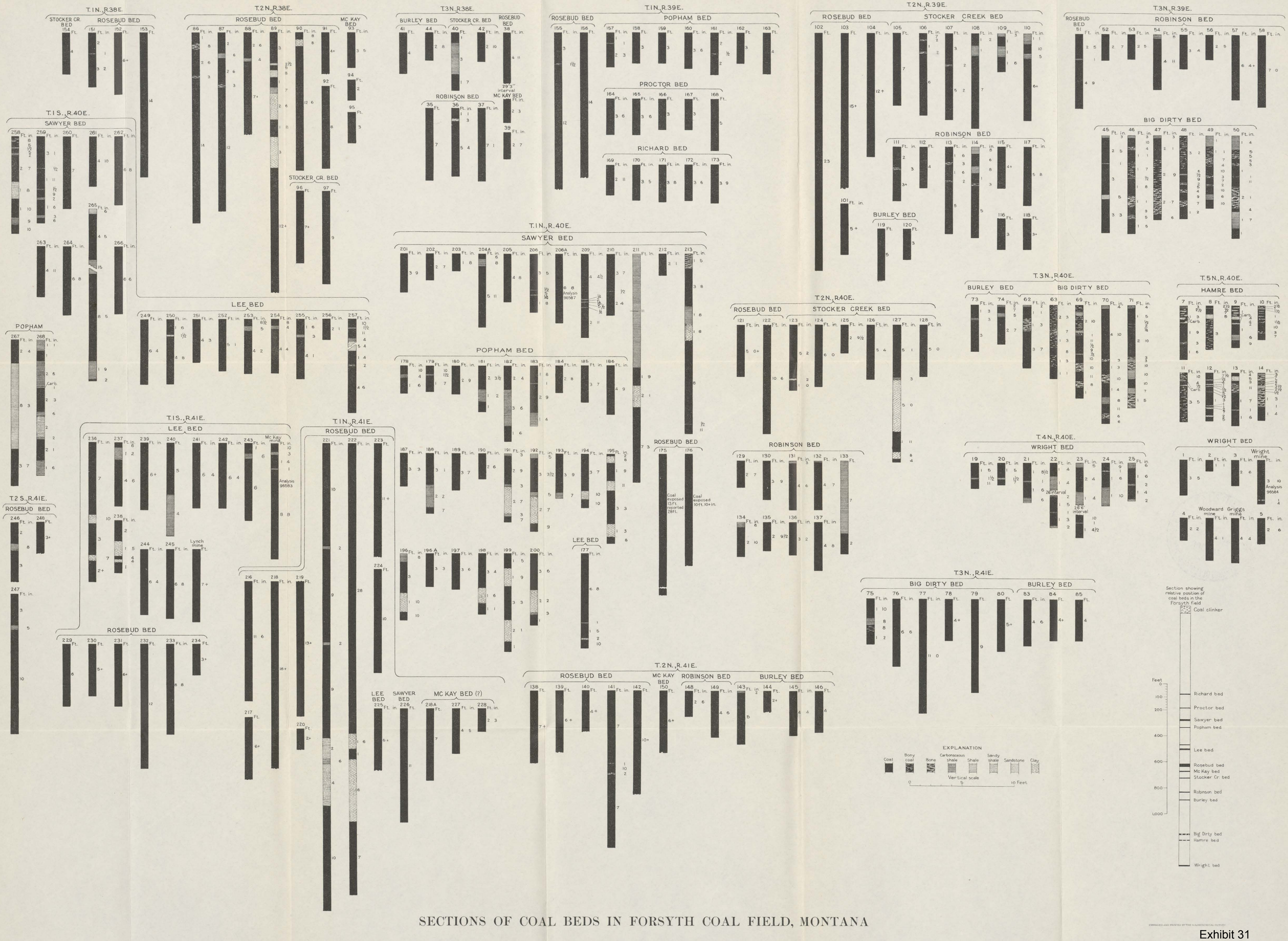
MAP OF THE FORSYTH COAL FIELD, MONTANA, SHOWING AREAL GEOLOGY AND POSITION OF COAL BEDS

Scale 1/125,000

0 1 2 3 4 5 6 7 8 9 10 Miles

1929

Exhibit 31



SECTIONS OF COAL BEDS IN FORSYTH COAL FIELD, MONTANA

Exhibit 31

Exhibit 31

NANCY SWEENEY
CLERK DISTRICT COURT

2013 [illegible] 08

FILED
BY [signature]

MONTANA FIRST JUDICIAL DISTRICT COURT
LEWIS AND CLARK COUNTY

MONTANA ENVIRONMENTAL INFORMATION CENTER and SIERRA CLUB, Plaintiffs, v. MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY, Defendant, and WESTERN ENERGY COMPANY, Defendant-Intervenor.	Cause No. CDV-2012-1075 **MEMORANDUM AND ORDER ON JUDICIAL REVIEW**

Plaintiffs filed this action December 21, 2012, challenging a permit issued to Western Energy Company (WEC) by the Montana Department of Environmental Quality (DEQ) on September 14, 2012. Plaintiffs allege violation

Exhibit 30

of both the federal Clean Water Act (CWA) and the Montana Water Quality Act (WQA) by issuance of Final Modified Permit number MT0023965, effective in modified form September 8, 2014. The permit allows the discharge of pollutants by the Rosebud Mine (owned and operated by WEC) into surrounding waters.

Plaintiffs also seek a determination and declaration that the Montana system for issuance of the permit is unlawful pursuant to both federal and Montana law, given its failure to ensure water quality standards. Finally, Plaintiffs seek "reasonable attorneys' fees and expenses as damages," as well as the costs of the lawsuit. (Verified Compl. & Application Writ Mandate & Declar. Relief, at15 (Dec. 21, 2012).)

All parties have moved for summary judgment. Plaintiffs seek summary judgment on its assertions stated above. WEC seeks summary judgment, asserting that Plaintiffs do not have standing to bring this lawsuit and that the permit process and resulting permit is not violative of law. DEQ seeks summary judgment on similar bases.

STANDARD OF REVIEW

The parties agree the Montana Administrative Procedure Act (MAPA) does not apply in this case[1] and assert the standard of review of DEQ's administrative decisions is set out by the Montana Supreme Court in *Clark Fork Coalition v. Department of Environmental Quality*, 2012 MT 240, ¶¶ 19-20, 366 Mont. 427, 288 P.3d 183:

> An agency's interpretation of its rule is afforded great weight, and we will defer to that interpretation unless it is plainly inconsistent with the spirit of the rule. *Clark Fork Coalition v. Dep't of Envtl.*

[1] No party asserts this is a contested case as defined in MAPA or argues the plain language of Montana Code Annotated § 2-4-702(2)(d).

Quality, 2008 MT 407, ¶ 20, 347 Mont. 197, 197 P.3d 482. We will sustain an agency's interpretation of a rule so long as it lies within the range of reasonable interpretation permitted by the wording. *Clark Fork Coalition*, ¶ 20. Of course, we need not defer to an incorrect agency interpretation. *Clark Fork Coalition*, ¶ 20.

We review an agency decision not classified as a contested case under the Montana Administrative Procedure Act to determine whether the decision was arbitrary, capricious, unlawful or not supported by substantial law. *Clark Fork Coalition*, ¶ 21. In reviewing an agency decision under the arbitrary and capricious standard, we consider whether the decision was "based on a consideration of the relevant factors and whether there has been a clear error of judgment." *N. Fork Preservation Ass'n v. Dep't of State Lands*, 238 Mont. 451, 465, 778 P.2d 862, 871 (1989) (citing *Marsh v. Oregon Natural Resources Council*, 490 U.S. 360, 378, 109 S. Ct. 1851, 1861, 104 L. Ed. 2d 377 (1989)). Although our review of agency decisions is narrow, we will not automatically defer to the agency "'without carefully reviewing the record and satisfying [ourselves] that the agency has made a reasoned decision . . . .'" *Friends of the Wild Swan v. Department of Natural Res. & Conservation*, 2000 MT 209, ¶ 28, 301 Mont. 1, 6 P.3d 972 (quoting *Marsh*, 490 U.S. at 378, 109 S. Ct. at 1861).

BACKGROUND

The applicable federal law regarding water quality is called the Clean Water Act (CWA), found within the Federal Water Pollution Control Act. 33 U.S.C. § 1251, et seq. The CWA applies to water flowing out of an area such as the Rosebud Mine and to the quantities, rates, and concentrations of components or elements (chemical, physical, biological) in the water.

The federal and state laws in this realm dovetail, as both refer to each other and state the same goals and similar requirements. For example, both federal and state law provide for permits for discharges to navigable waters

(National Pollutant Discharge Permit System (NPDPS), Montana Pollutant Discharge Elimination System (MPDES)). In this case, the MPDES permit is at issue, but there is applicable and relevant federal law. It is undisputed that the permitting process is meant to control and assure water quality through establishment and maintenance of water quality standards, as well as monitoring of water-affecting activities.

As stated by the Eighth Circuit Court of Appeals:

> Since 1972, the states and the federal government have worked together "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters," in a partnership governed by the Clean Water Act (CWA). 33 U.S.C. § 1251(a). With this goal in mind, the CWA authorizes states to establish water quality standards for bodies of water within its borders. 33 U.S.C. § 1313(a)-(c). Water quality standards "define[] the water quality goals of a water body, or portion thereof, by designating the use or uses to be made of the water and by setting criteria necessary to protect the uses." 40 C.F.R. § 131.2. **They comprise (1) the designated use(s) of the waters (e.g., water supply, propagation of fish, or recreation), 40 C.F.R. § 131.10; (2) the water quality criteria necessary to safely permit those designated uses, 40 C.F.R. § 131.11; and (3) antidegradation requirements to protect waters whose quality is better than required, 40 C.F.R. § 131.12. 40 C.F.R. § 131.6.** States must review their water quality standards at least every three years. 33 U.S.C. § 1313(c)(1). And under the CWA, each state must create a "continuing planning process" (CPP) to, among other things, govern the process for revising its water quality standards. 40 C.F.R. § 130.5(a). "In designating uses of a water body and the appropriate criteria for those uses, the State shall take into consideration the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment

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and maintenance of the water quality standards of downstream waters." 40 C.F.R. § 131.10(b).

El Dorado Chem. Co. v. United States EPA, 763 F.3d 950, 952-53 (8th Cir. 2014) (footnote omitted; emphasis added); *see also PUD No. 1 v. Wash. Dep't of Ecology*, 511 U.S. 700, 704-05; *Pennaco Energy, Inc. v. Mont. Bd. of Envtl. Review*, 2008 MT 425, ¶ 10, 347 Mont. 415, 199 P.3d 191.

DEQ's consideration of water quality in Montana must involve application of standards, practices, and compliance with both federal and state law. Title 75, chapter 5, of the Montana Code Annotated sets out the statutes relevant to water quality. Montana Code Annotated § 75-5-103(30) (a) defines "pollution" as:

> (i) contamination or other alteration of the physical, chemical, or biological properties of state waters that exceeds that permitted by Montana water quality standards, including but not limited to standards relating to change in temperature, taste, color, turbidity, or odor; or
>
> (ii) the discharge, seepage, drainage, infiltration, or flow of liquid, gaseous, solid, radioactive, or other substance into state water that will or is likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, or welfare, to livestock, or to wild animals, birds, fish, or other wildlife.

Title 17, Chapter 30 of the Administrative Rules of Montana relate to water quality. Both Montana statutes and administrative rules refer to applicable federal law.

In Montana, we also have a constitutional mandate regarding our environment:

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> **Protection and improvement.** (1) The state and each person shall maintain and improve a clean and healthful environment in Montana for present and future generations.
>
> (2) The legislature shall provide for the administration and enforcement of this duty.
>
> (3) The legislature shall provide adequate remedies for the protection of the environmental life support system from degradation and provide adequate remedies to prevent unreasonable depletion and degradation of natural resources.

Mont. Const. art. IX, § 1. *See Montana Envtl. Info. Ctr. v. Dep't of Envtl. Quality*, 1999 MT 248, ¶¶ 64-80, 296 Mont. 207, 988 P.2d 1236.

The administrative record in this case establishes there has been and will be water quality concerns related to the large geographic area disturbed by the Rosebud Mine and the affected surface waters. By its very nature, the practice of disturbing large tracts of land as described in the permit increases the probability of discharge of pollutants.

While the study and implementation of water quality standards involves a high level of scientific analysis, common sense has a role in the application of the legal standards. For example, review of the maps included in the administrative record reveals that a segment of East Fork Armells Creek is surrounded by the Rosebud Mine. There are many claims and much argument in the parties' briefs regarding this segment of the stream, but it is undisputed that the downstream segment of the stream is impaired. DEQ's responsibility for maintaining Montana water quality requires full study and recognition of the effect of the Rosebud Mine on the entire East Fork Armells Creek and the waters into which it flows.

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It is also clear that compliance issues arise regularly with regard to discharges by the Rosebud Mine, which are handled or not handled by state and federal regulators. This is a permit case, rather than a compliance case, but there is a general issue regarding the cumulative effect of the mine on Montana's water quality in the streams (ephemeral or not) into which the Rosebud Mine discharges. The renewal process is consistent with the requirement that DEQ regularly revisit our water quality. Yet the years taken by DEQ to renew this permit negate these requirements, or at least the effectiveness of the required procedures.[2]

The following timeline is relevant to the issues raised:

1. December 1, 1999 - DEQ Authorization to Discharge Under the Montana Pollutant Discharge Elimination System (MPDES) issued to WEC for the Rosebud Mine in or near Colstrip, Montana. The 17-page permit was a renewal of a permit issued in 1989. The named receiving waters include nine creeks, two coulees, and one reservoir. Admin. R. at 1836-52.[3] The permit expired at midnight September 30, 2004. Admin. R. at 1836.

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[2] "It is the national policy that to the maximum extent possible the procedures utilized for implementing this Act [33 USCS §§ 1251 et seq.] shall encourage the drastic minimization of paperwork and interagency decision procedures, and the best use of available manpower and funds, so as to prevent needless duplication and unnecessary delays at all levels of government." 33 USCS §§ 1251(f).

[3] References to the administrative record provided by DEQ (in the form of a computer disc) are to "Admin. R." and page numbers shown in the administrative record in the lower right hand corner of each page. The computer disc is Exhibit A to an Affidavit of Melissa Sjolund filed October 10, 2014. The record consists of documents and attachments totaling over 2,300 pages. It was provided in only moderately organized fashion and with confusing labels. And rather than providing a single, succinct chronology of events related to the process used by DEQ, the parties filed multiple briefs on the three motions for summary judgment.

2. The five-page Statement of Basis relevant to the 1999 permit renewal (dated July1, 1999) describes the processes by which discharges [4] happened at the Rosebud Mine:

> Western Energy Company is a surface coal producer, with an average annual production rate of approximately 8 million tons of sub-bituminous coal from the Rosebud Mine, located adjacent to the town of Colstrip. Coal is surface mined through dragline-implemented overburden removal, followed by a truck and shovel coal extraction operation.
>
> The coal mining process at the Rosebud mine requires surface disturbance of approximately 400 acres annually. The surface runoff generated by precipitation events occurring over these disturbed drainages is the primary source of wastewater involved in Western Energy's mining operation. Secondary sources of wastewater include groundwater inflow into the open mine pits from bisected overburden, coal and alluvial aquifers, and municipal (Colstrip) water used to wash coal dust from coal handling and loadout facilities. Under typical operational scenarios, these secondary sources provide limited quantities of water, representing only a nominal percentage of most discharges.
>
> ...

[4] "Discharge" is defined in Administrative Rule of Montana 17.30.1304(21) as follows: "[W]hen used without qualification, means the discharge of a pollutant."

> 'Discharge of a pollutant' and 'discharge of pollutants' mean any addition of any pollutant or combination of pollutants to state waters from any point source. This definition includes additions of pollutants into water of the state from: surface runoff which is collected or channeled by man; discharges through pipes, sewers, or other conveyances owned by a state, municipality, or other person which do not lead to a treatment works. This term does not include an addition of pollutants by any 'indirect discharger.'

Admin. R. Mont. 17.30.1304(22). In the 2010 draft permit, the permit dated September 14, 2012, and the modified permit dated September 8, 2014, "discharge" is defined as "the injection, deposit, dumping, spilling, leaking, placing, or failing to remove any pollutant so that it or any constituent thereof may enter in to state waters, including ground water." Admin. R. at 1397, 1702. This mirrors the definition stated in Administrative Rule of Montana 17.30.602(8).

Exhibit 30

> Sediment Ponds and traps located upstream of outfalls are designed to contain a volume of water equivalent to the runoff volume associated with the 10-Year, 24-Hour design precipitation event within an individual sub-watershed.
>
> Mine pits bisect adjacent sub-watersheds at various locations, combining runoff intercepted from multiple sub-watersheds and any groundwater inflow present. Pit dewatering is performed as operationally required, by pumping water into sediment control facilities, or loading water directly into water wagons for haulroad dust suppression.
>
> With storm runoff being the main component of WECo's wastewater and operational requirements largely dictating the disposition of this water, discharge volumes from specific outfalls are variable, and difficult to predict. However, due to the nature of runoff, the quality of the discharged wastewater is relatively constant between individual outfalls, being more dependent upon retention time prior to discharge than on source location.

Admin. R. at 2134-35. The Statement of Basis notes "sediment control facilities" which are on the perimeter of active mine area and 170 outfall[5] locations identified in the original permit. Some outfall locations were downstream of land disturbed by the mine and some were associated with future mining areas.

3. As to water quality, the 1999 Statement of Basis states:

> The limits set in the permit were based on baseline concentrations collected in the 1980's and incorporated in to the original permit issued in 1989. These limits were considered Water Quality Based Nondegradation Limits because they allowed no increase over background conditions (MCA, 75-5-306). Water Quality Based Nondegradation Limits (iron, oil and grease, sulfate, and boron) will remain in effect during stormwater events. The stream segments were

[5] The word "outfall" does not appear in Title 75, chapter 5, regarding water quality. Administrative Rule of Montana 17.30.201 states "[f]or purposes of this rule, the definitions contained in ARM Title 17, chapter 30, subchapter 10 and subchapter 13 are incorporated by reference. The following definitions also apply in this rule: . . . (k) 'outfall' means a disposal system through which effluent or waste leaves the facility or site."

> [sic] discharge takes place are ephemeral which not considered "high quality waters" (MCA, 75-5-103(10)(b)(ii)) and as such nondegradation does not apply (ARM, 17.30.705(2)(b)). This is not a new or increased source of pollution so again the nondegrdation [sic] rules do not apply (ARM, 17.30.705(1)).

Admin. R. at 2135.

4. April 15, 2004 - DEQ received WEC's permit renewal application. Admin. R. at 1719.

5. September 19, 2004 - Letter from the DEQ environmental engineer specialist to WEC stated that its application "is substantially complete." "Under ARM 17.30.1313, since you have submitted a complete renewal application, your present permit is administratively extended and remains in full force and effect until the effective date of the new permit." Admin. R. at 171

6. 2010[6] - Segment of East Fork Armells Creek from Colstrip, Montana, north to the mouth of Armells Creek was listed on State of Montana 2010 list of impaired waters. Admin. R. at 1511.

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[6] The administrative record provided by DEQ shows no action by DEQ regarding the renewal of the permit between the letter of September 2004 and June 2009. At that point, DEQ notified WEC that the draft permit and fact sheet were available to them "pre-public notice." Admin. R. at 1710. In August 2009, DEQ granted WEC's request for deferral of public notice regarding a draft permit. (The request, stated in a letter to DEQ, expressed concern regarding water classification, "appropriateness of the data used to characterize water discharged from the mine," and sampling equipment at outfalls.) Admin. R. at 1781-84. DEQ states in its brief that it developed the renewed permit in March 2010. (Br. Supp. Pls.' Mot. S.J. at 10 (Feb. 13, 2016).)

The DEQ "MPDES - Administrative Record Tracking Sheet & Checklist" shows April 18, 2011, as the date the application for a renewed permit was received and November 18, 2011, as the date the application was deemed complete. Admin. R. at 1116.

7. August 24, 2010 - DEQ issued a 41-page draft permit.[7] The maps included in the administrative record show the location of the Rosebud Mine, surrounded by the creeks and coulees into which discharges are allowed by the permit. East Fork Armells Creek flows east through or between property owned by the Rosebud Mine before it reaches Colstrip, Montana, and flows north/northwest thereafter.

8. August 26, 2010 - Written comments from Plaintiff's counsel include, among other claims, the claims made in this action.

9. September and October 2010 - The water quality documents added to the administrative record in this case during this time note the following regarding the segment of East Fork Armells Creek from Colstrip, Montana, north to the mouth of Armells Creek: "One or more uses are impaired and a TMDL [total maximum daily load] is required." Admin. R. at 1511. While the assessment had not been started, there was no description of the segment as ephemeral and the category titled "Overall Condition of Segment" includes the following:

> Physical/Chemical: East fork Armells is typical of most streams in this region. The water is very hard, saline, and high in sulfates. Where TSS data was available (2005), concentrations were low. Mining activities (including water pumped from the Yellowstone River to seeping ponds) likely have contributed to increased TDS concentrations and "water logging" below Colstrip. DEQ correspondence in 1998 estimated a 50% increase in TSC concentrations in the EFAC alluvium from 1977 to 1997. Water logging may not currently be occurring. The elevated SC concentrations make this water unsuitable for irrigation under

[7] No public notice regarding this draft permit was found by the Court in the administrative record. Plaintiffs' comments dated August 26, 2010 note a public notice dated July 12, 2010 which failed to recognize the waters listed as impaired. Admin. R. at 1630.

Exhibit 30

ordinary circumstances. This water is acceptable for use with livestock accustomed to its use, but is not recommended for pregnant or lactating cows. Data from the 1970's show the NO2+NO3 regularly exceeded criteria, although this was not the case in 2005.

In 2005, TKN at the lower site moderately exceeded the contact recreation criteria, and slightly exceeded the contact recreation criteria, and slightly exceeded the aquatic life criteria. At the middle site, contact recreation and aquatic life criteria were slightly exceeded. The most reliable metals data is from the 2005 assessment, which showed no exceedences [sic].

Other: TSS does not appear to be an accurate cause of impairment. The macroinvertebrate samples, field observations, and historical and 2005 water chemistry data indicate that nutrients may be a source of impairment. The SC values do not appear to be vastly different from other drainages in the region; however, the probable impact from municipal sources and industrial pond seepage cannot be ignored. The past and present impacts from changes in groundwater chemistry, surface flow, and atmospheric deposition merits further investigation. Salinity/TDS/chlorides will remain a cause of impairment.

Admin. R. at 1524. The same Water Quality Standards Attainment Record ends with reference to the stream segment as "Waters where one or more applicable beneficial uses have been assessed as being impaired or threatened, and a TMDL is required to address the factors causing the impairment or threat." Admin. R. at 1527.

10. May 14, 2012 - A public notice was issued by DEQ regarding MPDES MT0023965. In the notice, DEQ claimed there was no need to set TMDL standards, as the permit was not new.

11. September 14, 2012 - DEQ issued the renewed permit Number 0023965 for the Rosebud Mine. The permit had been changed from the 2010 draft permit, as outlined in a letter to the vice president and general manager of

Exhibit 30

WEC dated the same day. Admin. R. at 1348-50. The 2012 permit is 59-pages long. The related permit fact sheet is 73-pages long. Although it makes reference to it as an attachment to the renewed permit, the administrative record does not include any statement of basis attached to the 2012 permit.

12. The Permit Fact Sheet related to the 2012 permit (dated March 2012) "identifies the legal requirements and technical rationale that serve as the basis for the requirements" of the permit. Admin. R. at 1411. As stated by DEQ in this fact sheet, the coal seam accessed and removed by WEC "is approximately 100 feet below the surface, with an average thickness of 24 feet." Admin. R. at 1411. "The average annual production rate of the mine is approximately 10-12 million tons of coal, requiring about 400 acres of surface disturbance per year." Admin. R. at 1412.

13. As to the characteristics of East Fork of Armells Creek, the 2012 fact sheet states:

> The State of Montana 2010 integrated 303(d) list and 305(b) Water Quality Report lists . . . East Fork Armells Creek segment MT42K002_110 from Colstrip to the mouth is listed as a category 5 water body, indicating that one or more beneficial uses have been assessed as being impaired or threatened and a TMDL is required. This segment of East Fork Armells Creek is listed as partially supportive of aquatic life and of warm water fisheries. The probable causes of impairment are nitrate plus nitrite, electrical conductivity, TDS, and total Kjehldahl nitrogen, with agriculture and coal mining transfer of waters as probable sources of impairment. As this segment is directly downstream of the mine, the permit contains monitoring requirements or limitations for electrical conductivity, TDS, and nitrate plus nitrite to address the discharge of these pollutants from the Facility. It is not anticipated that the Facility is a source of total Kjehldahl nitrogen. If a TMDL is adopted an approved for these pollutants, the Permit may be re-opened to include effluent limitations

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based on appropriate wasteload allocations (WLAs) from the TMDL for this parameter.

Admin. R. at 1429.

As to the new outfalls in the permit, the Permit Fact Sheet states that 12 outfalls "constitute new or increased sources; accordingly, the discharge is subject to Montana Nondegradation Policy (75-5-303, MCA; ARM 17.30.705)." Admin. R. at 1452.

14. June 13, 2012 - Written comments from Plaintiff's counsel include, among other claims, the claims made in this action. Admin. R. at 109-26.

15. In its undated "Response to Public Comment," DEQ maintains the positions it now defends in this Court. Admin. R. at 1488-1510.

16. May 8, 2014 - Permit renewal application received by DEQ. WEC stated that its average annual coal production rate is approximately 10 to 12 million tons of sub-bituminous coal at the Rosebud Mine. It asserts that the mine disturbs approximately 350 acres per year. Admin. R. at 241.

17. May 2014 - Permit Fact Sheet states:

> The following modifications are included:
>
> A. Correct the identification of certain "new" source outfalls that were previously permitted and are "existing" sources;
>
> B. Transfer fifteen outfalls to Western Alkaline Standards;
>
> C. Revise water quality-based effluent limitations
>
> D. Revise effluent monitoring requirements; and
>
> E. Remove three representative monitoring outfalls.

Admin. R. at 76. The fact sheet states the new outfalls or sources either do not require the setting of new standards, or the discharges involved do not violate the applicable standards. Admin. R. at 79-80.

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18. June 9, 2014 - Public notice by DEQ regarding modification of the 2012 permit. It includes the following language:

> This is a major modification of the MPDES permit for the Western Energy company rosebud Mine. The facility discharges to East Fork Armells Creek, Stocker Creek, Lee Coulee, west fork Armells Creek, Black Hank Creek, Donley Creek, Cow Creek, Spring Creek, and Pony Creek. The modification includes the following actions; correct the identification of certain "new" source outfalls that were previously permitted and are "existing" sources; transfer fifteen outfalls to Western Alkaline Standards; revise water quality-based effluent limitations; revise effluent monitoring requirements; and remove three representative monitoring outfalls.
>
> As specified in the Administrative Rules of Montana at ARM 17.30.1361 and ARM 17.30.1365(4)(b) only the permit conditions described above are reopened and subject to this public notice and comment period. All other provisions of the permit remain in effect and are not reopened.

Admin. R. at 149-50.

19. September 8, 2014 - DEQ issued the 2012 permit Number 0023965 in modified form for the Rosebud Mine. There is a decrease in the number of outfalls designated as "new" from twelve to four. The permit expires October 31, 2017.

DISCUSSION

A. Plaintiffs' Standing

Plaintiff MEIC relies on the facts related by Steve Gilbert, a member of MEIC and outdoor recreationalist in Montana, to establish its standing to bring this lawsuit. The facts are set out in a deposition taken by the parties on February 13, 2014, as well as an affidavit of Gilbert filed February 13, 2015. Gilbert lives in Helena, Montana, and has been a resident of Montana since 1967.

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He describes his employment as a "biological consultant," and for 25 years he was "part owner and president of an environmental consulting company that specialized in wildlife, aquatics/fisheries, soils, vegetation, forestry, range and hydrology." With regard to the area of the Rosebud Mine, Gilbert has traveled regularly to the area for various purposes. He worked in the area for years and has personal knowledge of East Fork Armells Creek, Cow Creek, and Rosebud Creek. He hunted in relevant areas during the time the renewal application was before DEQ.

Gilbert's recreational use and enjoyment of the area near the Rosebud Mine has been affected and will be affected, partially because of the water pollution caused by the mining activity. He has knowledge relevant to the environmental impacts of the mine based on his personal observations and his MEIC connections. Gilbert was a member of MEIC during the years that it was involved in the administrative processes associated with this permit. He was a voting member of the MEIC council when the decision was made to file this lawsuit.

Gilbert's more recent visits to the area of Rosebud Mine have been to hunt upland game birds and to visit friends. He intends to continue those activities and is concerned regarding the degradation and pollution of the waters in the area due to the Rosebud Mine.

The standard for determining whether Plaintiffs have standing is set out in *Friends of the Earth, Inc., v. Laidlaw Environmental Services (TOC), Inc.*, 528 U.S. 167, 183-85 (2000):

> We have held that environmental plaintiffs adequately allege injury in fact when they aver that they use the affected area and are persons "for whom the aesthetic and recreational values of the area

will be lessened" by the challenged activity. *Sierra Club v. Morton*, 405 U.S. 727, 735, 31 L. Ed. 2d 636, 92 S. Ct. 1361 (1972). See also *Defenders of Wildlife*, 504 U.S. at 562-563 ("Of course, the desire to use or observe an animal species, even for purely esthetic purposes, is undeniably a cognizable interest for purposes of standing.")

. . .

[The] affidavits and testimony presented by FOE in this case assert that Laidlaw's discharges, and the affiant members' reasonable concerns about the effects of those discharges, directly affected those affiants' recreational, aesthetic, and economic interests. These submissions present dispositively more than the mere "general averments" and "conclusory allegations" found inadequate in *National Wildlife Federation*. 497 U.S. at 888. Nor can the affiants' conditional statements -- that they would use the nearby North Tyger River for recreation if Laidlaw were not discharging pollutants into it -- be equated with the speculative "'some day' intentions" to visit endangered species halfway around the world that we held insufficient to show injury in fact in *Defenders of Wildlife*. 504 U.S. at 564. . . . [W]e see nothing "improbable" about the proposition that a company's continuous and pervasive illegal discharges of pollutants into a river would cause nearby residents to curtail their recreational use of that waterway and would subject them to other economic and aesthetic harms. The proposition is entirely reasonable, the District Court found it was true in this case, and that is enough for injury in fact.

See also Mont. Envtl. Info. Ctr. v. Dept. of Envtl. Quality, 1999 MT 248, ¶¶ 41 - 45, 296 Mont. 207, 988 P.2d 1236.

Gilbert's contact with the streams and land in the area of the Rosebud Mine, together with the effect of the mine on his use and enjoyment of the area, establish injury in fact. Therefore, MEIC's standing is established. One party with standing satisfies the standing requirements for other parties. *Aspen Trails Ranch v. Simmons*, 2010 MT 79, ¶ 45, 356 Mont. 41, 230 P.3d 808.

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B. Classification of Streams

The record before this Court is not consistent as to the classification of waters involved. While much of the record lists waters as "C-3" pursuant to Administrative Rule of Montana 17.30.611(1)(c), DEQ also states that the waters are ephemeral pursuant to Administrative Rule of Montana 17.30.615 and .637(4). The classification of Montana's waters was and is the starting point for determination of applicable water quality standards.

The determination that the waters are C-3 waters cannot be changed without compliance with applicable law. Administrative Rule of Montana 17.30.615 requires:

> (2) Prior to reclassifying a specific water body classified in ARM 17.30.607 through 17.30.614 under one of the water-use classifications identified in (1)(a) through (h) and before the U.S. Environmental Protection Agency's approval of the water body's revised classification, a use attainability analysis must be conducted in accordance with 40 CFR 131.10(g), (h), and (j).

This clearly applies to the waters that are currently classified as C-3 waters and which DEQ now wishes to treat as ephemeral (with reduced water quality standards). Any reclassification regarding the waters must be pursuant to statutory requirements (Mont. Code Ann §§ 75-5-103, -301), including the required public process. *See* Admin. R. Mont. 17.30.606.

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While DEQ now admits within the context of this lawsuit that a portion of East Fork Armells Creek is not ephemeral,[8] its lack of consideration of the evidence in the administrative record showing that a portion of East Fork Armells Creek is not ephemeral during the renewal process at issue shows a clear error of judgment by DEQ during the permitting process.

DEQ maintains further modification of the permit (due for consideration in the year 2016) will address the situation as to the applicable water quality standards. There is no basis to find the situation could not have been addressed at some point between the September 30, 2004 expiration of the permit and the modification that became effective November 1, 2014. In the end, this is one example of the overall failure by DEQ to protect the relevant waters by engaging in a lengthy, arbitrary process of permitting.

DEQ's determination in the current permit that all applicable waters are ephemeral also affects the agency's conclusions regarding the need for determining TMDLs and all standards applicable to the new discharges through new outfalls. For example, it appears the agency relies on the conclusion regarding streams being ephemeral to ignore the water quality records noting that TMDLs need to be determined for a segment of East Fork Armells Creek. Given DEQ's concession that not all of the relevant streams are ephemeral, this conclusion is arbitrary and not supported by the applicable law. Mont. Code Ann §§ 75-5-103, -301; Admin. R. Mont. 17.30.615. And, as noted by DEQ in its notices and briefs, the law applicable to the system of classification of streams,

[8] In an affidavit signed February 13, 2015, Melissa Sjolund, DEQ employee and author of the permit issued in 2012 and modified in 2014, states that since the 2014 permit modification, another modification is being sought because "a recent hydrologic assessment of East Fork Armells Creek indicated that a portion of that stream . . . may be intermittent." (Br. Supp. Pls.' Mot. S.J. (Feb. 13, 2016), Ex. 1, Aff. Melissa Sjolund, at 4.)

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setting of water quality standards, and issuance of permits presumes a determination of standards such as TMDLs as prerequisite to determining whether water quality standards will be violated by discharges to any identified surface water.

Given the undisputed fact that DEQ's permit process is integral to protection of Montana's water quality, its conclusions that are not supported by the relevant objective and scientific data in the administrative record must be deemed arbitrary and unsupported and, thus, unlawful. *See Ravalli County Fish & Game Ass'n v. Mont. Dep't of State Lands*, 273 Mont. 371, 381, 903 P.2d 1362, 1369 (1995).

C. Use and Monitoring of Outfalls

The significance of the location and monitoring of outfalls at the Rosebud Mine is clearly established in the record. The outfalls are the locations where mine pollutants may touch the earth. In fact, if there is a discharge of a pollutant, it may only be at an outfall. The language of the 2012 permit, as modified in 2014, is that "[t]he authorization to discharge provided under this permit is limited to those outfalls specially designated below as discharge locations. Discharges at any location not authorized under an MPDES permit is a violation of the Montana Water Quality Act. . . ." Admin. R. at 19. "The location of each outfall regulated by this permit shall be permanently identified in the field." Admin. R. at 28.

Yet DEQ seems inconsistent in its approach to outfalls. For example, during the modification process between 2012 and 2014, public comment was made regarding the fact that some of the outfalls set out in the renewal

Exhibit 30

application by WEC were the same as previous outfalls, but identified in the 2012 permit as new outfalls. The response by DEQ was:

> Neither the permit writer nor the permittee cross referenced the geographic coordinates of the 151 outfalls contained in the renewal application with coordinates of outfalls contained in previous MPDES permits issued to WECo for the Rosebud Mine. Such cross referencing would not routinely be a part of MPDES permit application review.

Admin. R. at 8. Given the importance of outfall locations and monitoring, DEQ's procedures that do not specify and confirm the location of outfalls appear indefensible.

It is undisputed that the four new outfalls permitted by DEQ in 2014 involve new discharge points and potentially new discharge of pollutants points. It is also undisputed that nondegradation review is applicable. Admin. R. Mont. 17.30.701-08.

The current permit does not require that all outfalls be monitored in the same way or on the same schedule. The permit first identifies 151 outfalls to the relevant receiving waters or mixing zones. It then lists "Final Effluent Limitations and Monitoring Requirements" for each of the creeks and coulee, with the monitoring requirements set at the frequency of once per day, week, month, or year. The monitoring is to occur "at the overflow structure where effluent discharges as overflow from the sediment control structure, or at the end of the discharge pipe when pumped or drained, and prior to contact with the receiving water." Outfalls are associated with each creek and the coulee. This monitoring relates to 136 outfalls. Admin. R. at 23-28.

////

The permit then sets out "Alternate Numeric Effluent Limitations and Monitoring Requirements" applicable to the same 136 outfalls "applied to discharges driven by precipitation events and/or snowmelt." Admin. R. at 29-34. These appear to be in addition to the initial monitoring requirements.

But then the permit states:

> Due to the number of outfalls at the facility and inaccessibility of remote outfalls, representative monitoring will be allowed only for discharges resulting from precipitation events. Discharges consisting of stormwater runoff from areas . . . may be sampled at the representative outfalls listed in Table 16, corresponding to 20% of total outfalls.

Admin. R. at 34. Table 16 lists 20 outfalls, four of which are not within the 136 listed in the first two sections regarding monitoring. The relevant permit fact sheet adds:

> Discharges consisting of stormwater runoff from areas classified as "Alkaline Mine Drainage" (40 CFR 434 Subpart D) are materially similar in terms of activities taking place in each area, the characteristics of soil types present, the expected runoff pollutant concentrations, the type of stormwater treatment and best management practices. Therefore, the Department has determined representative sampling may be obtained at 20% of outfalls to obtain representative samples of precipitation-driven discharge.

Admin. R. at 1447. Finally, the permit lists 69 outfalls subject to "Western Alkaline Coal Mining Standards." Admin. R. at 35-38.

The language of the permit (before and after modification) leaves the permit reader with no firm knowledge regarding what monitoring practices will be applied in any given situation. Even with consideration of the administrative record in this case, there is inadequate or inaccurate bases for the

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monitoring types, locations, and frequencies. As to DEQ's conclusion that monitoring of 20 percent of the outfalls is sufficient, there is only a conclusory statement regarding soil types, runoff, and treatment. There is a distinct lack of scientific analysis supporting the conclusion that the remaining 80 percent of the outfalls previously deemed necessary no longer will be used as "representative" of the large-scale activity of the mine. There seems to be as much deference by DEQ to the logistical issues of monitoring raised by WEC as there are to the need to monitor the affected surface waters.

Plaintiffs claim the permit allows monitoring by WEC that does not adequately protect Montana's water in that it allows monitoring tailored to WEC's claims of circumstances making monitoring difficult. DEQ and WEC respond that federal regulations allow representative monitoring. DEQ and WEC assert the language of 40 CFR 122.41(j)(1) that "[s]amples and measurements taken for the purpose of monitoring shall be representative of the monitored activity." Plaintiffs cite 40 CFR 122.44 (i)(1)(ii), which provides, with regard to similar federal permits, the monitoring requirements include "[t]he volume of effluent discharged from each outfall."

Given the lack of analysis present in the record as to DEQ's decision to reduce the monitoring of outfalls, the decision is unsupportable. Failure to monitor will certainly reduce the chances of finding discharges and will certainly reduce the regulation of the water quality in an active mining area. The size of the mine, the number of outfalls, and the logistics of monitoring are relevant circumstances, but are not found within the law applicable to the ultimate goal of adequately protecting surface waters and do not mitigate DEQ's responsibilities

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for regulation. In this case, the reduced monitoring and modified standards for the waters at issue are arbitrary.

SUMMARY

When viewed in its totality, the record of DEQ's decisions as to Final Modified Permit number MT0023965 show clear errors of judgment regarding the protection of the waters into which the Rosebud Mine discharges. Rather than making reasoned decisions, the decisions are arbitrary and not supported by the law applicable to the permitting process.

Based on the foregoing, the issuance of Final Modified Permit number MT0023965, effective November 1, 2012 and modified September 14, 2014, is hereby declared invalid, and this matter is remanded to DEQ for consideration consistent with this opinion.

IT IS SO ORDERED.

DATED this 14 day of March 2016.

KATHY SEELEY
District Court Judge

pc: Shiloh Hernandez, Western Environmental Law Center, 103 Reeder's Alley, Helena MT 59601
Kirsten H. Bowers, Department of Environmental Quality, 1520 East Sixth Avenue, Helena MT 59620-0901
W. Anderson Forsythe, Moulton Bellingham PC, PO Box 2559, Billings MT 59103-2559

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"Healthy environment, healthy people"

Montana Department of
ENVIRONMENTAL QUALITY

Steve Bullock, Governor
Tracy Stone-Manning, Director

P. O. Box 200901 • Helena, MT 59620-0901 • (406) 444-2544 • Website: www.deq.mt.gov

June 3, 2014

Ms. Dicki Peterson
Western Energy Company
Rosebud Coal Mine Area B, C1984003B
P.O. Box 99
138 Rosebud Lane
Colstrip, MT 59323-0099

Permit ID: C1984003B
Revision Type: Amendment
Permitting Action: Deficiency
Subject: AM4, Seventh Round Acceptability Deficiency

Dear Dicki:

The Department of Environmental Quality (DEQ) has completed its acceptability review regarding Western Energy Company's application for Amendment AM4. The following deficiency must be adequately addressed before DEQ can determine the application acceptable:

17.24.314(4) and (5): A more complete explanation of the hydrologic response of East Fork Armells Creek to mining is needed. This information is needed to better determine the impacts to the hydrologic balance caused by current mining as well as to confirm that the proposed operation has been designed to minimize impacts to the hydrologic balance and prevent material damage to the hydrologic balance outside the permit area.

More information is needed to anticipate and predict the long-term effects of mining on stream flow and water quality of the stream and alluvium. Please provide a water budget that includes inputs to the stream from:

- the release of pond and pit water
- infiltration from sediment ponds adjacent to the stream
- disposal of water from operations and domestic use at the Area A facilities

Please indicate how the additional sources of water associated with mine activity have affected stream flow.

Review of the available data indicates the stream and alluvial wells adjacent to the facilities area are showing steadily increasing concentrations of ionic water quality components. These components have narrative standards based on uses. Please address the following:

- What is the source of the increase and at what point is the concentration expected to reach equilibrium or begin to decrease in concentration?

- How is the increased saturation of spoil adjacent to the stream likely to affect long term water quality in the stream and alluvium? What is the TDS concentration expected to be at full saturation of the spoil?
- What are the long term implications for stream and alluvial water quality associated with inputs from the facilities area, including the fate and breakdown products of lignin sulfonate?
- How have increases in specific water quality parameters affected the uses identified below and how are those uses likely to be affected with future predicted water quality changes?

EFAC existing and anticipated uses include water for livestock, wildlife, and aquatic life. Please confirm, based on current and future anticipated concentrations in the stream, that uses have not or will not be impaired. Three aquatic life surveys were completed in the 1970's but there have been none since that time. Please conduct a current aquatic survey along stretches of EFAC adjacent to the Rosebud Mine permit areas (Areas A, B, and C) to identify assemblages of aquatic life using the stream habitat. This information also will be useful for future permit revisions in Area A and Area C.

Please feel free to contact Robert D. Smith at 406-444-7444 with questions regarding this letter.

Sincerely,

Chris Yde, Supervisor
Coal and Uranium Program
Industrial and Energy Minerals Bureau
Phone: 406-444-4967
Fax: 406-444-4988
Email: CYde@mt.gov

C: Jeff Fleischman, Office of Surface Mining
Lauren Mitchell, Office of Surface Mining

FC: 620.112 (AM4)

GEOCHEMICAL PROCESSES IN GROUND WATER RESULTING FROM SURFACE MINING OF COAL AT THE BIG SKY AND WEST DECKER MINE AREAS, SOUTHEASTERN MONTANA

by David W. Clark

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95-4097

Prepared in cooperation with the
MONTANA DEPARTMENT OF STATE LANDS and the
BUREAU OF LAND MANAGEMENT

Helena, Montana
September 1995

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U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

For additional information write to:

District Chief
U.S. Geological Survey
428 Federal Building
Drawer 10076
301 South Park
Helena, MT 59626-0076

Copies of this report may be purchased from:

U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, Mail Stop 517
Denver Federal Center
Denver, CO 80225

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CONVERSION FACTORS, VERTICAL DATUM, ABBREVIATED WATER-QUALITY UNITS, AND ACRONYMS

Multiply	By	To obtain
acre	4,047	square meter
foot (ft)	0.3048	meter
foot per day [($ft^3/d/ft^2$) or ft/d]	0.3048	meter per day
foot per foot (ft/ft)	1.0	meter per meter
inch (in.)	25.4	millimeter
mile	1.609	kilometer
pound	453,600,000	microgram (µg)
	453,600	milligram (mg)
	453.6	gram (g)
	0.4536	kilogram (kg)
ton (short)	907.2	kilogram

Temperature can be converted from degrees Celsius (°C) to degrees Fahrenheit (°F) by the equation:

$$°F = 9/5\ (°C) + 32$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality units used in this report:

kcal/mol	kilocalories per mole
µg/g	micrograms per gram
µg/L	micrograms per liter
µm	micrometers (micron)
µS/cm	microsiemens per centimeter at 25 degrees Celsius
meq/100g	milliequivalents per 100 grams
mg/L	milligrams per liter
mL	milliliter
M	molar
‰	per mil
pCi/L	picocuries per liter
TU	tritium units

Acronyms used in this report:

CEC	Cation exchange capacity, in milliequivalents per 100 grams
DOC	Dissolved organic carbon
EDS	Energy dispersive spectroscopy
RS	Redox state
SEM	Scanning electron microscopy
SMOW	Standard mean ocean water
TOC	Total organic carbon

The use of industry or firm names in this report is for location purposes only, and does not impute responsibility for any present effects on the natural resources.

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GEOCHEMICAL PROCESSES IN GROUND WATER RESULTING FROM SURFACE MINING OF COAL AT THE BIG SKY AND WEST DECKER MINE AREAS, SOUTHEASTERN MONTANA

By David W. Clark

Abstract

A potential hydrologic effect of surface mining of coal in southeastern Montana is a change in the quality of ground water. Dissolved-solids concentrations in water in spoils aquifers generally are larger than concentrations in the coal aquifers they replaced; however, laboratory experiments have indicated that concentrations might decrease if ground water flows from a spoils aquifer to a coal aquifer. This study was conducted to determine if the decreases indicated in laboratory results occur onsite and, if so, which geochemical processes caused the decreases. The Big Sky and West Decker Mine areas were chosen for study as both contain coal of the Tongue River Member of the Paleocene Fort Union Formation, but have differences in mineralogy, ground-water quality, and flow processes.

Solid-phase core samples of spoils, unmined overburden, and coal and samples of ground water were collected from 16 observation wells at the two mine areas. Selected solid-phase samples were analyzed for elemental concentrations, exchangeable cations, and mineral constituents. Water samples were analyzed for major and trace constituents, selected isotopes, and dissolved gases.

In the Big Sky Mine area, changes in ground-water chemistry along an inferred flow path from an upgradient coal aquifer to a spoils aquifer probably were a result of dedolomitization caused by the irreversible dissolution of gypsum at or near calcite-dolomite saturation. Dissolved-solids concentrations were unchanged as water flowed from a spoils aquifer to a downgradient coal aquifer.

In the West Decker Mine area, dissolved-solids concentrations apparently decreased from about 4,100 to 2,100 milligrams per liter (mg/L) as water moved along an inferred flow path from a spoils aquifer to a downgradient coal aquifer. Apparent decreases in selected constituent concentrations included: sodium, from 1,500 mg/L to less than 900 mg/L; bicarbonate, from about 3,000 mg/L to less than 2,400 mg/L; and sulfate, from 1,100 mg/L to less than 100 mg/L. Data for solid-phase and aqueous geochemical characteristics, including types of reactive minerals, isotopic ratios, and dissolved-gas concentrations, were used to develop geochemical models to analyze changes in water chemistry. Geochemical processes postulated to result in the decrease in dissolved-solids concentrations along this inferred flow path include: bacterial reduction of sulfate utilizing the organic matter in coal as an energy source; reverse cation exchange of sodium ions for calcium or magnesium ions within the coal; and precipitation of carbonate and iron-sulfide minerals. Even though these processes are thought to be those most likely occurring, they are considered nonunique and might not be the only feasible processes. Questions about the sulfate system, the rate of sulfate reduction, the isotopic composition of the coal, the existence of secondary carbonates and amorphous iron-sulfide minerals in the coal, and other questions need to be resolved before the geochemical processes occurring in the system are fully understood.

INTRODUCTION

One of the potential hydrologic effects of surface coal mining in southeastern Montana is a change in the quality of ground water. Dissolved-solids concentrations in water in spoils aquifers are about 1,000 mg/L larger (Davis, 1984a) than in the coal aquifers they replaced. Laboratory experiments (Davis, 1984a; Davis and Dodge, 1986) have indicated that dissolved-solids concentrations might decrease by several hundred milligrams per liter when ground water flows from an aquifer in coal mine spoils (hereinafter referred to as spoils and spoils aquifer) back through a coal aquifer. Geochemical modeling of the results of those experiments indicated that several geochemical processes were occurring, including mineral dissolution and precipitation, and either exchange or adsorption reactions.

Exhibit 28

The Big Sky and West Decker Mine areas in southeastern Montana offered unique opportunities to study such geochemical processes onsite. Both mines are located in the Tongue River Member of the Paleocene Fort Union Formation, but distinct differences between the mine areas in mineralogy and ground-water flow processes have resulted in differences in water quality. The Big Sky Mine area has a local ground-water flow system, with at least some recharge by direct infiltration of precipitation on permeable overburden and spoils, and a calcium-magnesium sulfate type water. The West Decker Mine area has a more regional ground-water flow system, with little or no recharge through the mine spoils by direct infiltration of precipitation on overburden or spoils, and a sodium bicarbonate type water (Davis, 1984a). Knowledge of the geochemical processes occurring in each mine area and the relation of those processes to the flow systems and mineralogy can be of considerable value in evaluating future mining and reclamation efforts. Therefore, this project was conducted in cooperation with the Montana Department of State Lands and the Bureau of Land Management to further understand the geochemical processes controlling the quality of water in areas with surface mining of coal.

Purpose and Scope

This report describes the geochemical processes that occur in ground water as a result of surface mining of coal at the Big Sky and West Decker Mine areas in southeastern Montana. The report is based on data obtained during 1988 through 1990 from intensive sampling and analysis of rock material and water at several points along flow paths extending from coal aquifers upgradient of each mine, through spoils aquifers to downgradient coal or other aquifers.

Data requirements included mineralogy, elemental chemistry, and ion-exchange capabilities obtained from solid-phase samples collected by core drilling during monitoring-well installation. These data were obtained by scanning electron microscopy (SEM), X-ray diffraction and other techniques. Other data include ground-water samples analyzed for major and minor chemical constituents, isotopic composition, and dissolved gases. The data were then analyzed with geochemical models.

Previous Investigations

Numerous geohydrologic studies have been conducted in the coal-producing areas of southeastern Montana by personnel of the U.S. Geological Survey, the Montana Bureau of Mines and Geology, and Montana State University. Davis (1984a) investigated the geochemistry and geohydrology of the Big Sky and West Decker Mine areas. Davis and Dodge (1986) reported the results of laboratory experiments related to spoils-aquifer water and coal in the same mine areas; the resulting report was the catalyst for this study. Dockins and others (1980) studied sulfate reduction in ground water of southeastern Montana. Davis (1984b) estimated ground-water inflow to the pits at the West Decker Mine area and Lee (1980) studied the regional geochemistry.

Geography

The study areas are in the coal-rich Powder River structural basin, which extends from southeastern Montana to northeastern Wyoming (fig. 1), in the northern Great Plains Physiographic Province. Both coal-mining areas are drained by tributaries of the Yellowstone River. The Big Sky Mine area, near the town of Colstrip, is drained by tributaries of Rosebud Creek; altitudes within this area range from about 3,600 ft above sea level near the northwest mine boundary to about 3,000 ft near Rosebud Creek. The West Decker Mine area is drained by the Tongue River; altitudes within the area range from about 4,000 ft at the west mine boundary to about 3,400 ft near the Tongue River.

The climate of most of the non-mountainous areas in southeastern Montana is semiarid. Figure 2 shows the annual precipitation at Colstrip and Decker from 1979-90, the time period of this and studies cited in the above Previous Investigations. Average annual precipitation for 1961-90 at Colstrip was 15.06 in., and at Decker was 12.69 in. About half of the annual precipitation occurs during April, May, and June, on the basis of records from the National Weather Service.

Exhibit 28

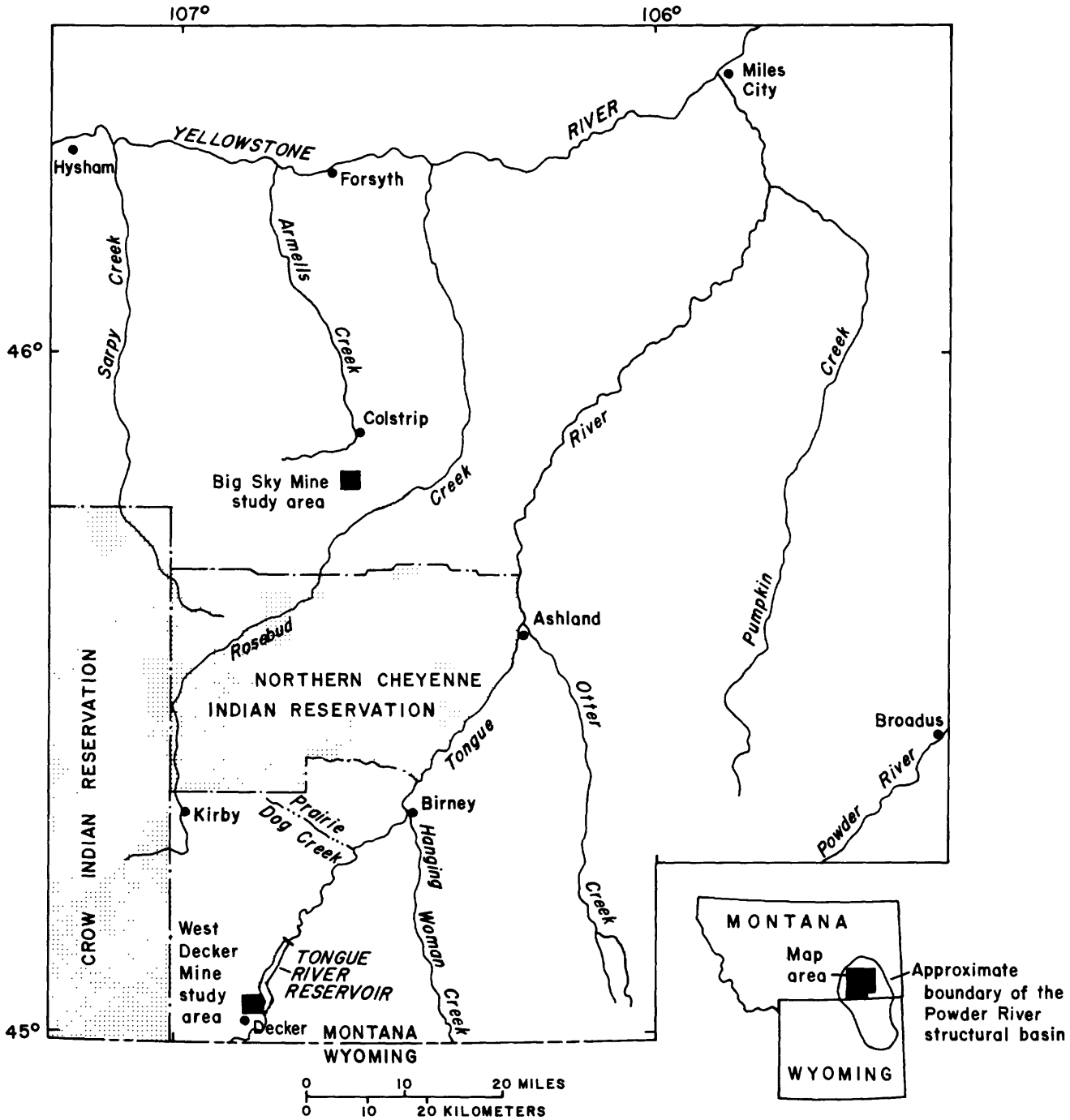


Figure 1. Location of study areas.

Exhibit 28

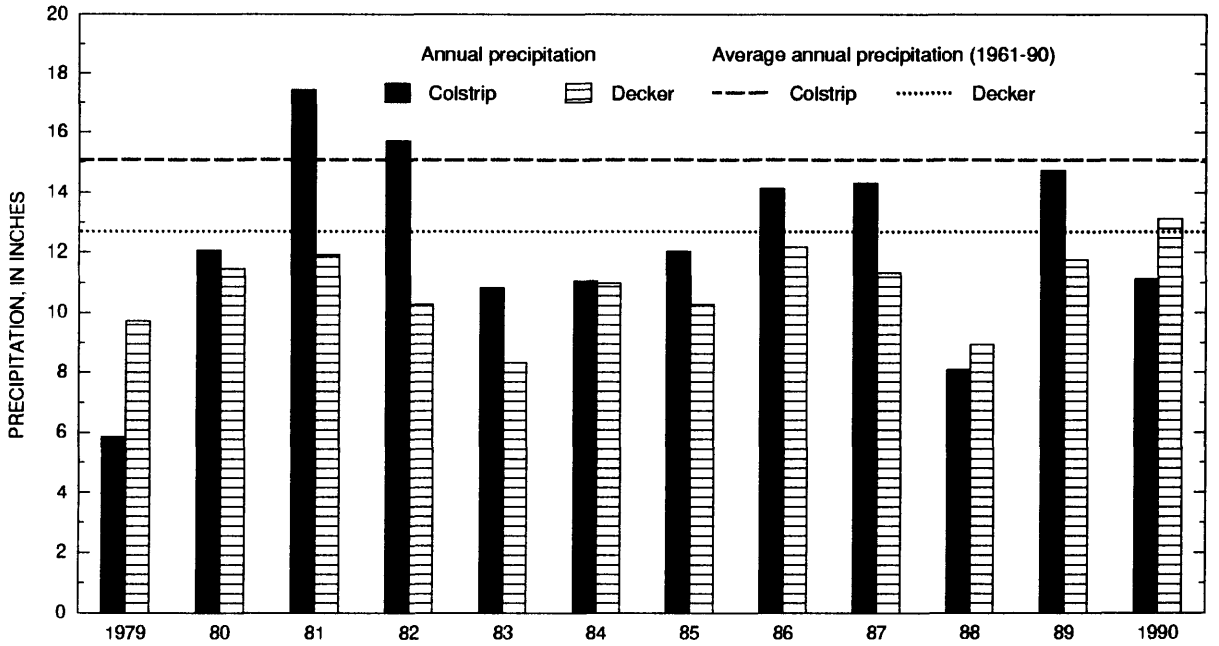


Figure 2. Annual and average annual precipitation at Colstrip and Decker, Montana.

Site-Numbering System

In this report, sites are numbered according to geographic position within the rectangular grid system used by the Bureau of Land Management (fig. 3). The site-identification number consists of 14 characters. The first three characters specify the township and its position north (N) or south (S) of the Montana Base Line. The next three characters specify the range and its position east (E) of the Montana Principal Meridian. The next two characters are the section number. The next four characters designate the quarter section (160-acre tract), quarter-quarter section (40-acre tract) quarter-quarter-quarter section (10-acre tract), and quarter-quarter-quarter-quarter section (2 1/2-acre tract), respectively, in which the well is located. The subdivisions of the section are designated A, B, C, and D in a counterclockwise direction, beginning in the northeast quadrant. The final two digits form a sequential number in order of inventory; for example, site 09S40E16BADC01 (fig. 3) is the first site inventoried in the SW1/4SE1/4NE1/4NW1/4 sec. 16, T. 9 S., R. 40 E.

Acknowledgments

The author appreciates the assistance and cooperation extended by employees of the Peabody Coal Company, the Decker Coal Company, and Peter Kiewit Sons, Inc. Many personnel of the U.S. Geological Survey also assisted in this study. In particular, acknowledgment is extended to Gene C. Whitney, Kenneth J. Esposito, and Joan J. Fitzpatrick, Branch of Sedimentary Processes (Denver, Colo.), for their assistance in the solid-phase sample analysis and interpretation. L. Neil Plummer and Donald C. Thorstenson (Reston, Va.) provided valuable assistance with the project design and data analysis and interpretation.

Exhibit 28

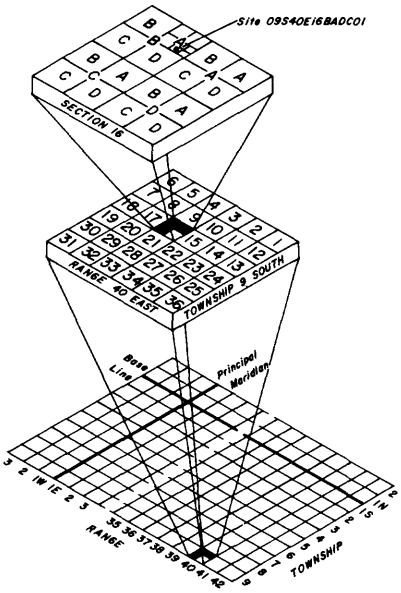


Figure 3. Site-numbering system.

METHODS OF STUDY

Changes in ground-water geochemistry within the coal mine areas were quantified primarily by the collection and analysis of solid- and aqueous-phase samples obtained through the drilling and installation of observation wells. At both mine areas, wells were completed in coal upgradient from the mine disturbance, mine spoils, and coal downgradient from saturated spoils. Details on well construction and measured water levels in the observation wells are shown in table 1. Solid-phase samples of spoils, unmined overburden, interburden, and coal were collected primarily from cores obtained during drilling. Water samples were collected by pumping or bailing after wells had been developed.

Solid-phase samples were analyzed for mineral constituents by X-ray diffraction, thin-section petrology, and scanning electron microscopy (SEM). Well-crystallized minerals were identifiable by X-ray diffraction if their abundance generally was greater than about 5 percent. Clay mineralogy was determined by X-ray diffraction of untreated samples, glycolated samples, and samples heated to 550 °C. Petrographic analysis and interpretations were completed for 10 rock samples, and petrographic analysis and analysis by SEM were completed for thin sections of selected coal samples. Solid-phase samples also were analyzed using SEM equipped with energy dispersive spectroscopy (EDS). Thin sections were prepared from cores of coal coated with a conducting layer of either carbon or gold. SEM photographs were taken and chemical constituents were analyzed with EDS for selected non-organic grains within the coal thin sections.

Cation and trace-element concentrations and exchangeable cations were determined for 20 selected core samples from overburden siltstone, sandstone, shale, clinker, and spoils by the Montana Bureau of Mines and Geology analytical laboratory. Nine coal samples collected from drill cores and one grab sample of coal were analyzed for 65 major and trace elements by the U.S. Geological Survey, Branch of Geochemistry laboratory. Selected coal samples were combusted at 800 °C to determine the percentage of ash. Fifteen mg of the ash were pulverized and sieved to pass 100 mesh and then chemically analyzed.

Ground-water samples were analyzed for a variety of properties and constituents. Analysis included major and trace dissolved constituents, onsite properties, dissolved gases, and isotopic composition. Water samples were analyzed for major and trace constituents by the Montana Bureau of Mines and Geology. Isotope and some trace-metal analyses were conducted by the U.S. Geological Survey National Water Quality Laboratory or private contractors.

Several properties and constituents including specific conductance, temperature, pH, dissolved oxygen, alkalinity, dissolved sulfide, and total and ferrous iron were measured onsite because of their potential instability. Specific conductance, temperature, pH and, where applicable, dissolved oxygen were measured in a flow-through

Exhibit 28

sampling chamber after the values had stabilized. At least three well volumes were withdrawn before water-sample collection. Water generally was pumped slowly from the well head into the sampling chamber to prevent or minimize degassing or other atmospheric interference. The dissolved sulfide and iron species were measured semiquantitatively using a field colorimeter. Samples for laboratory analysis that required filtering generally were filtered through a 0.45-µm membrane filter; some samples analyzed for dissolved aluminum, iron, and manganese were filtered through a 0.10-µm membrane filter to remove colloidal material.

Dissolved gases were collected using a sampling apparatus illustrated and described in detail by Hobba and others (1977). A sample of the vapor phase was analyzed by gas chromatographic procedures for nitrogen, argon, oxygen, carbon dioxide, methane, and ethane. Dissolved gases in water were analyzed by Donald C. Thorstenson of the U.S. Geological Survey.

Isotopic composition can be a useful indicator of hydrologic and geochemical conditions. Isotopic fractionation might occur in many elements during phase transitions and chemical and biological reactions. These fractionations are due to slight variations in the physical and chemical properties of various isotopes of an element and are proportional to the differences in their masses. The hydrologically significant isotopes considered in this report are the stable isotopes of oxygen, hydrogen, carbon, and sulfur, and tritium, a radioactive isotope of hydrogen. Samples for the stable isotopes were collected according to guidelines established by the U.S. Geological Survey National Water Quality Laboratory. Samples for carbon-13 analysis were treated onsite with a reagent of ammoniacal strontium chloride. Sulfur-34 for the sulfide ion was determined on a silver sulfate sample precipitated onsite from an acidified sample using gas stripping and a solution of silver nitrate.

Stable-isotope composition is expressed in δ (Del) notation, written as: $\delta^{18}O$ for the heavy oxygen isotope; δD for the heavy hydrogen isotope (^2H) given the name deuterium and the symbol D; $\delta^{13}C$ for the heavy carbon isotope; and $\delta^{34}S$ for the heavy sulfur isotope. Del notation (δ) is typically expressed as the per mil (‰) difference in the measured isotopic ratios of a sample and a standard given by the equation:

$$\delta = \left[\frac{R_{sample}}{R_{standard}} - 1\right] \times 1,000, \quad (1)$$

where R is the isotopic ratio of the element being considered. For example, the relation for sulfur isotopes is:

$$\delta^{34}S = \left[\frac{\left(^{34}S/^{32}S\right)_{sample}}{\left(^{34}S/^{32}S\right)_{standard}} - 1\right] \times 1,000. \quad (2)$$

The sulfur-isotopic ratios in the equation might be replaced by the ratios of $^{18}O/^{16}O$, D/H, or $^{13}C/^{12}C$ to obtain δ values for the other elements.

Stable carbon isotopes can be used to determine controlling chemical reactions and various sources of carbonate along an aquifer flow path. Dissolved carbon in ground water is derived primarily from carbonate sediments, soil organic matter, the decay of other organic material, and in some instances from atmospheric carbon dioxide (CO_2). Various sources of carbon generally have relatively distinct ranges of isotopic compositions. For example, the $\delta^{13}C$ is about 0 ± 3 ‰ for carbonate sediments, about -25 ± 5 ‰ for organic soil matter (wood and leaves), about -28 ± 4 ‰ for sedimentary organic carbon including coal, about -17 ‰ for soil CO_2 in arid climates, and about -7 ‰ for atmospheric CO_2 (Rightmire and Hanshaw, 1973, p. 959).

Sulfur isotopes can be used in geochemical studies to determine the amount of sulfate reduction that has occurred and to help define geochemical processes and flow paths. Sulfate-reducing bacteria such as *Desulfovibrio desulfuricans* reduce aqueous sulfate (SO_4^{2-}) to form hydrogen sulfide (H_2S or HS^-) in pH-neutral water. The sulfide is depleted in ^{34}S; therefore, the $\delta^{34}S$ of the remaining aqueous sulfate is enriched. When values of $\delta^{34}S$ are known for both sulfate and sulfide, the fractionation and the mass transfer of the sulfur system can be calculated. The primary source of sulfate in the study areas is $CaSO_4$, precipitated after the oxidation of pyrite and at least partly redissolved as the aquifer becomes saturated. At least part of the sulfide is derived from bacterial reduction of sulfate.

During an earlier study, Ferreira and others (1989) measured stable isotopes at 21 ground-water and 8 surface-water sites in the surface coal-mine areas of southeastern Montana in 1985. Stable-isotope ratios from the ground-

Exhibit 28

water samples ranged from -21.7 to -16.5 ‰ for $\delta^{18}O$, -167 to -134 ‰ for δD, -13.0 to 0.4 ‰ for $\delta^{13}C$, and -9.3 to 6.2 ‰ for $\delta^{34}S$. The median ground-water values, including water from alluvial, overburden, coal, and spoils wells, were -6.5 ‰ for $\delta^{13}C$ and 1.7 ‰ for $\delta^{34}S$.

Tritium concentration also can be an indicator of hydrologic and geochemical conditions. Natural tritium in precipitation ranged from about 3 to 25 TU (tritium units) prior to 1952. From 1952 to the mid-1960's, large amounts of tritium were released to the atmosphere during atmospheric testing of thermonuclear weapons. This large input of man-made tritium to the atmosphere, and the subsequent input to ground water by recharge from precipitation, makes interpretation of some ground-water tritium data ambiguous. Examples of data that are not ambiguous include tritium concentrations less than 1 TU, which indicate no contribution of post-1952 water, and tritium concentrations larger than 50 TU, which indicate the presence of a significant portion of post-1952 water (T.B. Coplen, U.S. Geological Survey, written commun., 1989).

Geochemical processes were determined by interpretation of the data, including the use of geochemical models. Equilibrium speciation calculations were determined for water samples using the computer program WATEQF (Plummer and others, 1978). These calculations provide saturation indices (SI) of minerals that may be reacting in the system. The SI of a particular mineral is defined as:

$$SI = \log \frac{IAP}{K_T} \tag{3}$$

where IAP is the ion-activity product of the mineral-water reaction and K_T is the thermodynamic equilibrium constant adjusted to the temperature of the given sample. Pertinent thermodynamic data used to calculate the saturation indices were revised from the original WATEQF (Plummer and others, 1978) and WATEQ4F (Ball and others, 1987) programs by Nordstrom and others (1990) and are summarized in table 2. The degree of saturation is expressed by the saturation indices; undersaturation is expressed as a negative saturation index, saturation is expressed as a value near zero, and supersaturation is expressed as a positive value. Saturation or supersaturation implies that the mineral might be present in the aquifer or unsaturated zone above the aquifer, whereas undersaturation implies limited contact between aquifer water and the mineral. Saturation indices, in conjunction with mineralogic information from the solid-phase samples, can be used to help determine the hydrological and geochemical processes that are important in the evolution of the observed ground-water quality.

Geochemical mass-balance models were constructed using the computer program NETPATH (Plummer and others, 1991) to determine the quantities of mineral or chemical species causing the observed changes in water quality. To solve the models, elemental concentrations and sets of plausible reacting phases for initial waters and plausible product phases for final waters are required. Mass-balance models simulate the net chemical reaction of the form:

Initial solution composition + reactant phases $\Rightarrow$ final solution composition + product phases,

where reactant and product phases represent constituents that enter or leave the aqueous phase. Possible reactant or product phases were selected using solid-phase mineralogic data, speciation calculations, geologic and hydrologic inferences, and SEM analysis. Mass-balance calculations were made using Rayleigh distillation reactions calculated with equations developed by Wigley and others (1978, 1979) to determine if a particular reaction was occurring and the isotopic composition of the final solution.

GENERAL GEOCHEMICAL PROCESSES

The quality of water in the coal and spoils aquifers in the study areas generally is controlled by one or more major geochemical processes that can occur in the unsaturated zone, such as in recharge areas, or within the saturated zone. The major geochemical processes are:

- dissolution and precipitation of carbonate minerals,
- oxidation of sulfide minerals such as pyrite,
- precipitation and dissolution of sulfate minerals such as gypsum,
- ion-exchange and adsorption reactions on clay minerals and organic material,
- sulfate reduction,
- production of sulfide and carbon-dioxide gas, and
- precipitation of sulfide minerals such as amorphous iron sulfide.

Exhibit 28

The magnitude of any of these processes depends primarily on the hydrologic and geologic characteristics of the specific area.

Carbonate minerals such as calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$), if present, might be dissolved in the near-surface unsaturated zone or in aquifers. Typical reactions might be expressed as:

$$CaCO_3 + H^+ \Leftrightarrow Ca^{2+} + HCO_3^- \quad (4)$$

and

$$CaMg(CO_3)_2 + 2H^+ \Leftrightarrow Ca^{2+} + Mg^{2+} + 2HCO_3^-. \quad (5)$$

The hydrogen ions (H^+) in reactions 4 and 5 can result from oxidation of pyrite or from reactions of water with CO_2 gas. Carbon dioxide gas from the atmosphere or organic decay reacts with water:

$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \quad (6)$$

and the resulting carbonic acid (H_2CO_3) dissociates:

$$H_2CO_3 \Leftrightarrow H^+ + HCO_3^-. \quad (7)$$

The overall effects of carbonate-mineral dissolution are to increase the concentration of calcium (Ca^{2+}), magnesium (Mg^{2+}), and bicarbonate (HCO_3^-) ions and to increase pH.

Dissolution and precipitation of carbonate minerals occur primarily within the unsaturated zone as water percolates below land surface. Dissolution of carbonates is ultimately limited by the ion-activity product of the particular mineral and whether the system is open or closed with respect to CO_2. Within the unsaturated zone, CO_2 derived from the atmosphere, from the decay of modern plants and coal, or from root respiration will dissolve in infiltrating water until the partial pressures of CO_2 in the vapor and liquid phases are equal. Dissolution of carbonate minerals will then proceed until the constraints of the ion-activity product and the vapor-liquid CO_2 pressure equality are simultaneously satisfied. In waters containing large concentrations of sodium sulfate, ion pairing reduces the free calcium- and carbonate-ion activities and permits further dissolution of calcite at a particular unsaturated-zone partial pressure of CO_2.

Oxidation of pyrite (FeS_2) or other iron-sulfide minerals might occur in the undisturbed unsaturated zone or within the overburden that has been disturbed by mining. The process initially requires the presence of oxygen, which is available from infiltrating recharge water or the atmosphere. The oxidation process consists of several steps, some of which are catalyzed by bacteria. The generalized reaction for the principal process involved is:

$$4FeS_2 + 15O_2 + 14H_2O \Leftrightarrow 4Fe(OH)_3 + 8SO_4^{2-} + 16H^+. \quad (8)$$

If calcium ions are present, calcium sulfate can be formed:

$$Ca^{2+} + SO_4^{2-} \Leftrightarrow CaSO_4. \quad (9)$$

The overall effect of the oxidation process is to increase the acidity and the concentration of sulfate ions in solution. The acid produced as a result of reaction 8 is buffered by the dissolution of carbonate minerals (reactions 4 and 5), which are present in the overburden and spoils. The sulfate ions produced in reaction 8 are either transported in solution to the aquifer or are precipitated as gypsum or other sulfate minerals as in reaction 9. These sulfate minerals might later be dissolved and transported to the aquifer by recharge water or, in a semiarid environment where annual evapotranspiration exceeds annual precipitation, might accumulate in the near-surface unsaturated zone. When disturbed by mining and replaced at depth, the sulfate minerals become available for dissolution in the saturated zone of the spoils.

Ion-exchange and adsorption reactions probably are an important process in the unsaturated zone and in the saturated spoils and coal aquifers. Generally, the process involves reactions on clay minerals where calcium, and in some cases magnesium, ions are exchanged for sodium ions:

Exhibit 28

$$Na_2\,(clay) + X_{Mg}Mg^{2+} + (1-X_{Mg})\,Ca^{2+} \Leftrightarrow \left[Ca_{(1\text{-}X_{Mg})}, Mg_{(X_{Mg})}\right](clay) + 2Na^{+} \qquad (10)$$

where X_{Mg} varies between 0 for pure Ca/Na cation exchange and 1 for pure Mg/Na cation exchange. When reaction 10 proceeds from left to right, it results in a decrease in calcium or magnesium ions and an increase in sodium ions in solution. The decrease in calcium ions in solution can cause further dissolution of calcium carbonate or calcium sulfate minerals to maintain equilibrium. Magnesium and potassium might also be involved in ion exchange or adsorption reactions. However, calcium generally has a greater affinity for exchange than magnesium, magnesium has a greater affinity than potassium, and potassium has a greater affinity than sodium. The extent to which exchange occurs largely depends on the cation-exchange capacity of the clay mineral or possibly organic material, and on the concentration of the ions in solution.

In anaerobic conditions, sulfate can be reduced to sulfide when organic material and sulfate-reducing bacteria are present. In reaction 11, organic material is represented compositionally as CH_2O, implying that nitrogen and phosphorus in the organic material are not present in sufficient quantities to affect the pH or alkalinity:

$$2CH_2O + SO_4^{-2} \xrightarrow{\text{sulfate-reducing bacteria}} H_2O + CO_2 + HCO_3^{-} + HS^{-}. \qquad (11)$$

The sulfate-reducing bacteria *Desulfovibrio desulfuricans* were found in relatively large numbers in 25 of 26 observation wells sampled by Dockins and others (1980, p. 6) in southeastern Montana and apparently most of the sulfide in those wells resulted from bacterial sulfate reduction. Reaction 11 results in an overall decrease in sulfate concentration, an increase in bicarbonate concentration, and the production of sulfide and carbon-dioxide gas. The sulfide ions produced as a gas in the reaction may then be removed from solution by precipitation of sulfide minerals, especially iron sulfide. Because sulfate reduction requires anaerobic conditions, it generally is not a factor in newly replaced spoils or in other oxygenated systems, such as some shallow ground water.

BIG SKY MINE AREA

In the Big Sky Mine area, ground-water flow is of a local nature with at least some recharge from direct infiltration of precipitation. The geochemical changes that occur as the calcium-magnesium sulfate type water moves from the unmined Rosebud coal bed into the spoils and then downgradient into the McKay coal bed and potentially offsite are the primary focus of this part of the study.

Geohydrologic Setting

The coal being mined at the Big Sky Mine area is part of the Tongue River Member of the Paleocene Fort Union Formation in the Powder River structural basin (fig. 1). The Big Sky Mine area opened to mining in 1969. The coal beds being mined are the Rosebud coal, generally about 25 ft thick, and the underlying McKay coal, about 10 ft thick. Around the mine disturbance area (fig. 4), the coal beds generally have been eroded or burned, leaving clinker or sandy material of the Tongue River Member. The burning of coal, commonly ignited by spontaneous combustion or range fires over the past hundreds of thousands of years, hardens, sinters, or sometimes melts the overlying sandstone, siltstone, and shale. The resultant rocks, collectively called clinker, are resistant to erosion because they are harder than the unbaked rocks and because baking causes increased fracture permeability, which allows water to infiltrate and, therefore, minimizes surface runoff.

Spoils consist primarily of overburden and interburden that have been removed and replaced as a result of mining. Overburden is the primary spoils material where only the Rosebud coal bed has been removed. The spoils consist of a mixture of overburden and interburden where both coal beds have been removed. The spoils might be composed entirely of interburden where the Rosebud coal has been eroded or burned.

Exhibit 28

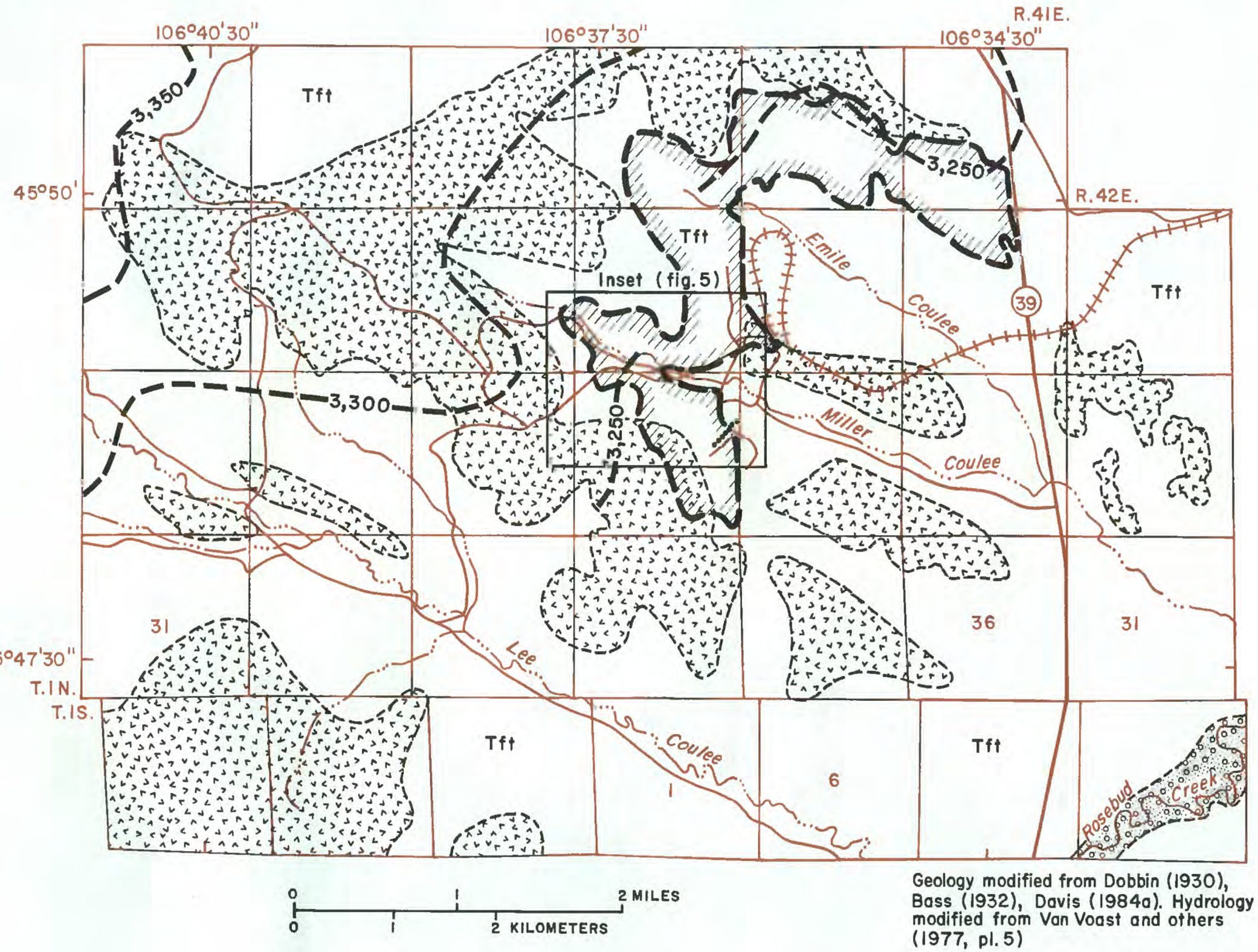


Figure 4. Location, geology, and 1976 potentiometric surface of the Big Sky Mine area, Montana. (Explanation on following page.)

EXPLANATION FOR FIGURE 4

Qal — ALLUVIUM (HOLOCENE AND PLEISTOCENE)--Also includes uncorrelated gravel deposits

Tft — TONGUE RIVER MEMBER OF FORT UNION FORMATION (PALEOCENE)--Areas of clinker (baked and fused rock formed by the burning of coal beds) shown by pattern

APPROXIMATE GEOLOGIC CONTACT

3,300 — APPROXIMATE POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells completed in the Tongue River Member or reclaimed mine spoils. Contour interval 50 feet. Datum is sea level

GENERAL BOUNDARY OF AREA MINED OR TO BE MINED

OBSERVATION WELL

The principal aquifers in the study area are the Rosebud and McKay coal beds, the spoils, and alluvium along Rosebud Creek. The coal aquifers have an average hydraulic conductivity of 8.8 ft/d and a median of 0.79 ft/d on the basis of nine aquifer tests (Davis, 1984a, p. 47). The spoils aquifer was created by placement of the removed overburden and interburden behind the advancing mine pit, creating a rubble zone of broken bedrock at the base overlain by granular material. The spoils aquifer is heterogeneous and has a large range of hydraulic-conductivity values, with an average value of 9.7 ft/d and a median of 0.028 ft/d on the basis of eight aquifer tests (Davis, 1984a, p. 47). Recharge in the Big Sky Mine area primarily is by infiltration of precipitation on nearby clinker outcrops. The relatively resistant and permeable clinker commonly caps the nearby knobs, ridges, and buttes and recharge water from these areas moves from the northwest to southeast as indicated by the potentiometric surface (fig. 4). The spoils are recharged primarily by lateral inflow from coal aquifers, and locally by infiltration of direct precipitation on sandy spoils material. Discharge from the spoils and coal aquifers primarily is by lateral flow southeastward to clinker or sand aquifers, with eventual discharge into alluvium along Rosebud Creek. Minor discharge from the coal aquifers is by domestic and stock-watering wells. Evapotranspiration from shallow parts of the aquifers might also be a source of some ground-water discharge.

The location of 10 wells drilled in the Big Sky Mine area during this study is shown in figure 5. Three wells (BSUMR1, BSUMSP1, and BSUMSP2) were drilled near the upper end of Miller Coulee with one well completed in coal and the other two wells completed in a downgradient spoils aquifer. The purpose of the wells was to quantify recharge into the mine area and geochemical changes that occur as water moves from the coal aquifer into the spoils aquifer. In this area, the Rosebud coal bed was mined during 1976 and 1977 and was replaced with spoils material that became saturated within a few years. Well BSUMR1 was completed in saturated Rosebud coal bed and the two other wells were completed in sandy spoils (table 3).

Seven wells were drilled along a downgradient flow path from the saturated spoils to the unmined McKay coal bed (fig. 5). In this area, the McKay coal was mined from 1969 to 1971, and the spoils material was replaced and became saturated within a few years. Wells BSLMSP3 and BSLMSP1 were completed in the spoils aquifer; wells BSLMMC1, BSLMMC2 and BSLMMC3 were completed in the aquifer in the unmined McKay coal bed; well BSLMMC5 was completed in an iron-rich sandstone at a depth contiguous with the McKay coal bed; and well BSLMSM1 was completed in gray sandstone of an interval stratigraphically lower than the McKay coal bed (sub-McKay) (table 3). The horizontal hydraulic gradient of about 0.01ft/ft might be at least partly controlled by an upgradient highwall pond, lateral flow from upgradient spoils (fig. 5), and infiltration of local recharge. Discharge from the unmined coal is offsite to stratigraphic equivalents and eventually to alluvium along Miller Coulee. Little or no water is thought to discharge to the sub-McKay. Additional information on the hydrology of the Big Sky Mine area is described by Davis (1984a).

Geochemistry and Geochemical Processes

The ground-water geochemistry at the Big Sky Mine area was studied to determine potential geochemical processes that might occur as water from the spoils flows into the downgradient aquifer in the McKay coal bed. Another objective was to determine processes related to changes in ground-water geochemistry as water flows from the aquifer in the unmined Rosebud coal bed into the spoils.

Exhibit 28

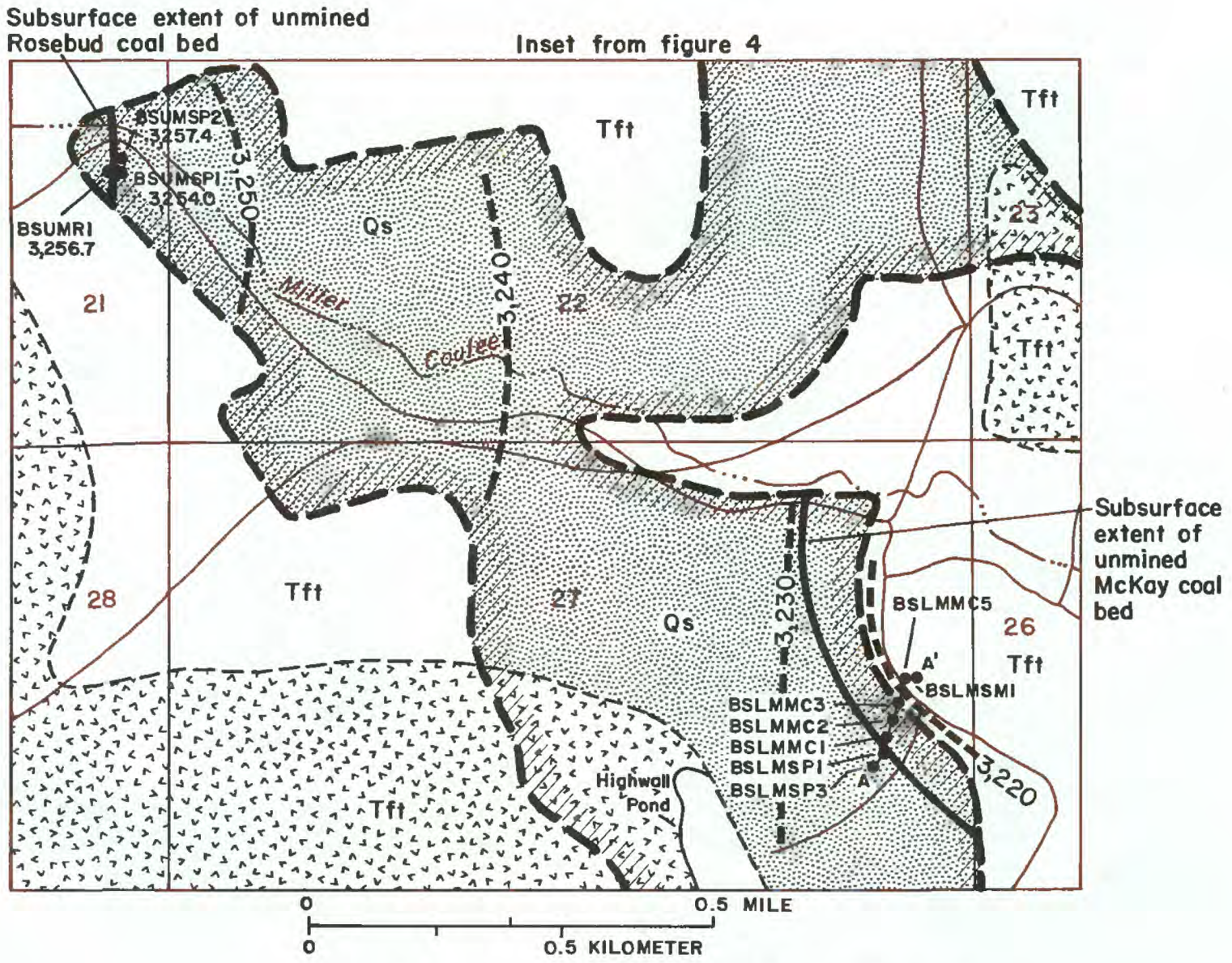


Figure 5. Location of wells, 1988 potentiometric surface, and geologic section of part of the Big Sky Mine area, Montana. (Explanation on following page.)

Exhibit 28

EXPLANATION FOR FIGURE 5

SPOILS (HOLOCENE)

TONGUE RIVER MEMBER OF FORT UNION FORMATION (PALEOCENE)--Areas of clinker (baked and fused rock formed by the burning of coal beds) shown by pattern

GEOLOGIC CONTACT--Dashed where approximately located

3,240

APPROXIMATE POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells completed in the Tongue River Member or reclaimed mine spoils. Contour interval 10 feet. Datum is sea level

GENERAL BOUNDARY OF AREA MINED OR TO BE MINED

A A'

TRACE OF SECTION

POTENTIOMETRIC SURFACE

3,790

DISSOLVED-SOLIDS CONCENTRATION--Units of milligrams per liter in water sample from well, October 1988

3,225.6

ALTITUDE OF WATER LEVEL, IN FEET ABOVE SEA LEVEL

WELL AND NUMBER

BSLMMC3

Map

BSLMMC3

Section

Screened interval

Results of Solid-Phase Analysis

Detailed analyses of samples from unmined consolidated rocks, spoils, and coal beds were essential to determine geochemical processes and water-rock interactions. Solid-phase samples were analyzed for mineralogy and for concentrations of major and trace elements and exchangeable cations. The samples of overburden of the Rosebud coal bed was composed of clayey siltstone and calcareous, fine-grained sandstone and included abundant dolomite cement, feldspars, some calcite, and traces of pyrite and glauconite. Clay in the overburden consisted of kaolinite with minor quantities of smectite, illite, and chlorite (tables 4, 5, 6). Spoils in this area created from Rosebud overburden were mineralogically similar to the unmined overburden, except that the spoils contained more calcite and less dolomite (table 5).

The mineralogy of a calcareous clayey siltstone in interburden between the Rosebud and McKay coal beds (samples from BSLMMC2, BSLMMC3, and BSLMSM1) consisted of abundant quartz, dolomite and calcite cements, muscovite, biotite, and sericite. The predominant clays were kaolinite, illite, and chlorite. Feldspars were common in most samples, gypsum was detected in minor quantities, and strontianite, and possibly thenaderite, were detected in trace quantities. Pure, crystalline gypsum, most likely a result of evaporation, was detected in fractures in a siltstone sample. Samples of spoils consisting of interburden (samples from BSLMSP3 and BSLMSP1) were mineralogically similar to samples of the unmined interburden except that the spoils generally contained more quartz, chlorite, and smectite and less calcite (tables 5, 6).

Exhibit 28

The concentrations of cations and trace elements were determined from 11 drill-core samples of spoils and unmined consolidated rock collected in the Big Sky Mine area (table 7). The predominant elements were aluminum associated with the clay minerals, calcium and magnesium associated with the carbonate cements, and iron, potassium, and silica likely associated with silicate minerals. Generally, the concentrations from the samples of unmined consolidated rock and the spoils were indistinguishable. Solid-phase samples from four cores (consisting of spoils or siltstone) were analyzed for exchangeable cations. Calcium was the most prevalent exchangeable cation, with lesser quantities of magnesium, sodium, and potassium (table 8). Results from analysis of the one spoils sample (well BSLMSP1) did not differ greatly from the analysis of the three siltstone samples.

The concentrations of major and minor oxides and trace elements were determined from laboratory ash of four samples of McKay coal (table 9). The median concentrations of selected constituents were within the range of, and generally similar to, the mean concentrations from the analyses of 410 samples from throughout the Powder River structural basin (table 10).

Results of Ground-Water Analysis

Water samples were collected 3 times from 4 of the observation wells, twice from 1 of the wells, and once from the other 5 wells. Results of analyses for major ions and trace elements are given in table 11. Predominant cations and anions are depicted on trilinear diagrams (fig. 6) for samples collected during October 1988 to illustrate the similarity in the chemical types. Water from well BSUMR1 completed in the upgradient coal bed had a dissolved-solids concentration of 2,150 mg/L and was a magnesium-calcium sulfate chemical type (fig. 6). Water from wells completed in the spoils or downgradient coal bed had an average dissolved-solids concentration of about 3,800 mg/L and also was a magnesium-calcium sulfate chemical type. The dissolved-solids concentrations are similar to the mean dissolved-solids concentration of 2,700 mg/L from 19 coal wells and 3,700 mg/L from 18 spoils wells as reported by Davis (1984a, p. 51). Stiff diagrams of coal and spoils water (fig. 6) indicate that magnesium, calcium, and sulfate concentrations increase and bicarbonate concentrations decrease as water flows from the upgradient Rosebud coal bed (well BSUMR1) into the spoils of Rosebud overburden (well BSUMSP1). Major-ion concentrations in water from the spoils of Rosebud overburden, the interburden spoils (BSLMSP3), and the downgradient McKay coal bed (well BSLMMC2) are similar.

Water samples for laboratory determination of dissolved-gas concentration were collected from five observation wells (table 12). Oxygen, carbon dioxide, and methane were the gases of primary interest. Dissolved-oxygen concentrations larger than 1.0 mg/L were detected in water from wells BSUMR1 and BSUMSP2, whereas only a trace was detected in water from wells BSLMSP1, BSLMMC1, and BSLMMC2 in the downgradient flow path. Large concentrations of carbon dioxide were detected in water from wells BSLMSP1, BSLMMC1, and BSLMMC2, which are completed in the downgradient spoils and coal beds. Smaller concentrations were detected in water from wells BSUMR1 and BSUMSP2.

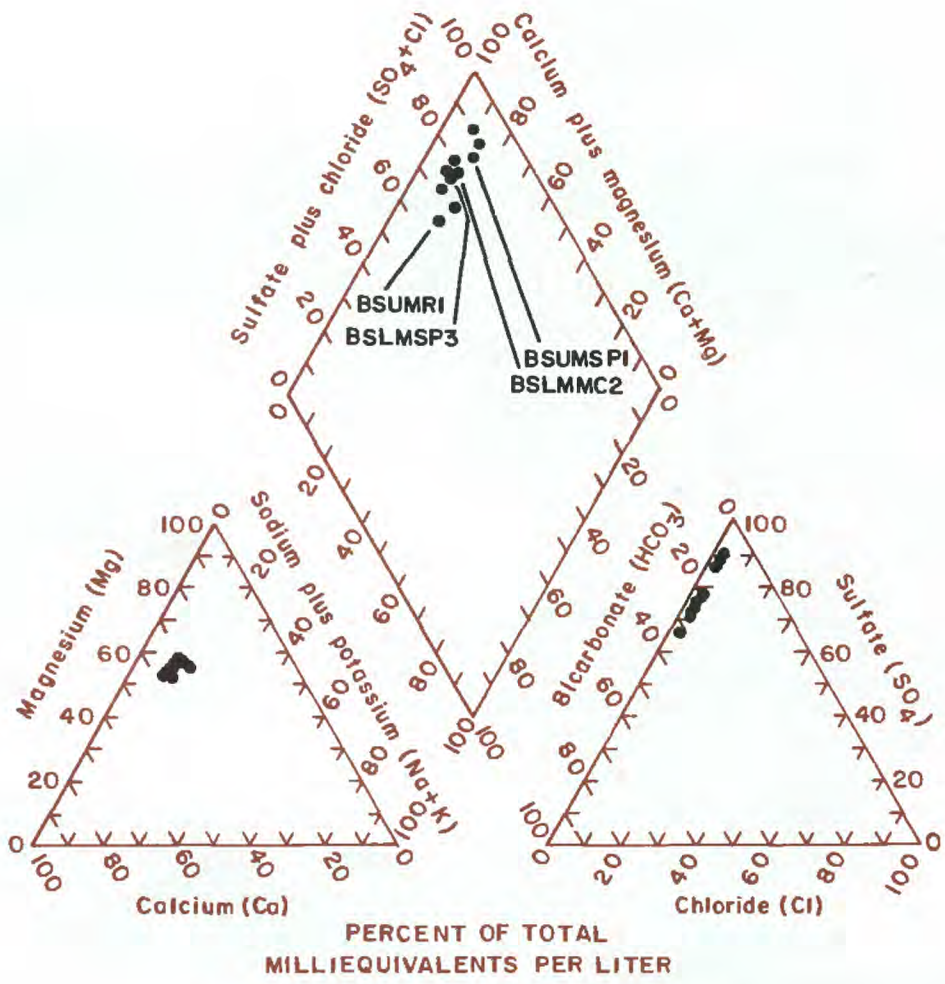
Water samples were collected for analysis of isotopic ratios or activities from five of the observation wells (table 13). Analytical results for the isotopes are virtually the same for water from the spoils well (BSLMSP1), and wells completed in the McKay coal bed (BSLMMC1 and BSLMMC2). The main isotopic dissimilarity is the difference in tritium activity between water from well BSUMR1 in the Rosebud coal bed (5.7 pCi/L) and water from well BSUMSP2 in the spoils (64 pCi/L).

Mineral-Water Equilibrium and Relation to Geochemical Processes

Thermodynamic equilibrium calculations for ground water from the Big Sky Mine area using the program WATEQF (Plummer and others, 1978) are listed in table 14. Calculations result in saturation indices of minerals that might be reacting in the system. Saturation indices denote that most water is saturated with respect to quartz, calcite, dolomite, and goethite, and is near saturation with respect to aragonite, gypsum, and celestite.

The oxidation-reduction (redox) state of the water was estimated based on dissolved-gas concentrations. Water from wells along the inferred downgradient flow path had concentrations of dissolved oxygen and hydrogen sulfide that were small and near the detection limits (table 11). Concentration of these parameters varied between samples collected from individual wells and showed no distinct differences between wells completed in spoils or coal, making it difficult to accurately determine the redox state of the water. For purposes of equilibrium calculations, an Eh value of -0.01 volt was estimated for all samples from the downgradient wells and an Eh value of 0.2 volt was estimated from dissolved-oxygen concentrations for the upgradient wells.

Exhibit 28



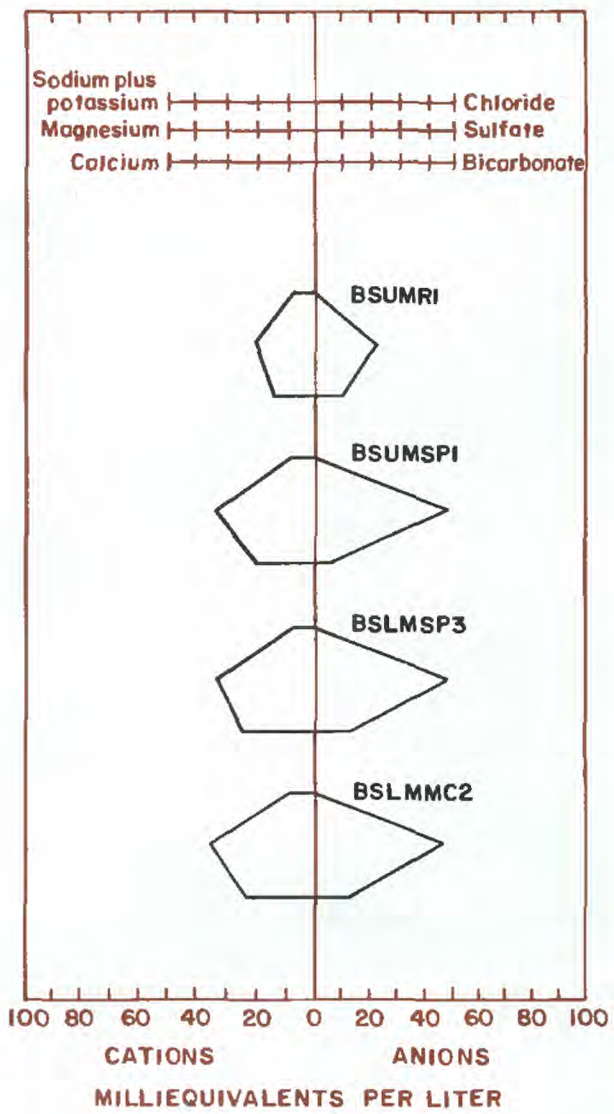


Figure 6. Trilinear and Stiff diagrams showing geochemical properties of ground water from the Big Sky Mine area, Montana.

Exhibit 28

Flow from Upgradient Coal Aquifer to Spoils Aquifer

The geochemical process of dedolomitization, the irreversible dissolution of gypsum at or near calcite-dolomite saturation, most likely occurred as water from the upgradient coal aquifer flowed into the spoils aquifer. Concentrations of calcium, magnesium, sodium, and sulfate increased and alkalinity decreased along the flow path from well BSUMR1 in the upgradient coal aquifer to wells BSUMSP1 and BSUMSP2 in the spoils aquifer (table 11). Water in the coal aquifer was saturated or nearly saturated with respect to calcite and dolomite and was undersaturated with respect to gypsum (table 14). Dissolution of gypsum added calcium to the water, which may have resulted in calcite precipitation, and caused the pH to decrease (Plummer and others, 1990, p. 1,987), owing to an increase in H^+ released from HCO_3^- during incorporation of CO_3^{2-} into the calcite. The decrease in pH and CO_3^{2-} probably caused the water to be undersaturated with dolomite, thereby increasing dissolution and increasing the concentration of dissolved magnesium. The amount of dolomite and gypsum dissolved normally would exceed the amount of calcite precipitated; therefore, the concentration of dissolved calcium normally would increase. As expected for the dedolomitization reaction (Plummer and others, 1990, p. 1,994, fig. 10), alkalinity decreased as sulfate increased. Calcite was more common in spoils samples from well BSUMSP1 than in the unmined overburden samples from well BSUMR1, whereas dolomite was more abundant in the overburden than in the spoils (table 5). This mineralization may have been due to precipitation of calcite and dissolution of dolomite within the spoils material as a result of dedolomitization. The increase in sodium concentration might have been the result of exchange of calcium ions for sodium ions on clay minerals or the dissolution of a sodium salt in the spoils material.

The dedolomitization reaction hypothesis was tested by constructing a mass-balance model to simulate the geochemical changes. The model is based on a set of probable reacting phases and the elemental concentrations corresponding to those phases for the initial and final waters. The phases selected were calcite, dolomite, gypsum, cation exchange, and carbon dioxide. Results of the simulated mass transfer, as calculated by the model NETPATH (Plummer and others, 1991), are given in table 15 and indicate the following geochemical processes: dolomite and gypsum dissolution with accompanying calcite precipitation, exchange of calcium ions for sodium ions, and transfer of carbon dioxide indicating an open system. In the overall dedolomitization reaction:

$$CaMg(CO_3)_2 + CaSO_4 \Rightarrow 2CaCO_3 + MgSO_4(aq), \quad (12)$$

where 2 moles of calcite are precipitated and 1 mole of dolomite is dissolved for every mole of $CaSO_4$ irreversibly added to solution, in a ground-water system at equilibrium with calcite, dolomite, and gypsum (Plummer and others, 1990, p. 2,010). The waters were saturated with calcite and dolomite but undersaturated with gypsum, indicating that mass transfer of gypsum might increase disproportionately to that of dolomite and calcite.

Flow from Spoils Aquifer to Downgradient Coal Aquifer

As water flowed from the spoils aquifer to the downgradient coal aquifer, the dissolved-solids concentration essentially was unchanged (fig. 5). Only small differences in concentrations of major ions were detected between the spoils wells (BSLMSP3 and BSLMSP1) and two of the coal wells (BSLMMC1 and BSLMMC2) (table 11). Concentrations of a few constituents were noticeably different only between the spoils wells and coal well BSLMMC3, as iron increased substantially, dissolved silica nearly doubled, and bicarbonate, manganese, and potassium decreased slightly. A possible explanation for the differences in concentrations was an additional source of recharge to well BSLMMC3, as water levels in well BSLMMC3 were slightly higher than those in well BSLMMC2.

Results of samples collected in October 1988 show a gradual decrease in concentrations of most trace elements along the inferred flow path. However, results from subsequent sampling did not substantiate this trend, possibly because of changes in laboratory or sampling procedures or physical changes in the ground-water system, such as slight changes in ground-water flow rate or direction. If the initial results were accurate, then the trace-element concentrations most likely decreased due to sorption of the dissolved elements onto the coal or onto clay minerals within the coal.

WEST DECKER MINE AREA

At the West Decker Mine study area, several dissolved constituents had large changes in concentration as water moved along an inferred flow path from a spoils aquifer to a downgradient unmined coal aquifer. The types

Exhibit 28

and quantities of changes, the possible causes and chemical reactions, and the mass transfer due to these geochemical changes are discussed in this section.

Geohydrologic Setting

The Decker Mine area consists of the East, North, and West Decker Mine areas (fig. 7). The West Decker Mine area was opened in 1972. The coal being mined is part of the Tongue River Member of the Paleocene Fort Union Formation. The main coal beds in descending stratigraphic order are the Anderson bed, the Dietz 1 bed, and the Dietz 2 bed. Within the West Decker Mine study area the Anderson and Dietz 1 are combined into one bed that generally is about 50 ft thick. This Anderson-Dietz 1 bed is separated from the 25-ft thick Dietz 2 bed by as much as 65 ft of interburden. The thickness of overburden above the Anderson-Dietz 1 bed varies within the mine area, ranging from tens of feet to about 100 ft. Also within the mine area is clinker which consists of shale, siltstone, and sandstone that has been fractured and baked by the burning of underlying coal beds (fig. 8).

The predominant lithologies in the overburden are siltstone, very fine-grained sandstone, some brown and gray to grayish-black shale, and several distinct layers of gray, calcareous siltstone (tables 3 and 4). These lithologic units generally were also identified in the spoils, which is composed of removed and replaced overburden.

The principal aquifers in the study area are clinker, coal beds, spoils, and alluvium. The clinker might be locally permeable as a result of fracturing and, thus, be a productive aquifer. The coal aquifer of principal interest is the Anderson-Dietz 1 coal bed. The spoils aquifer was created by placement of the removed overburden behind the advancing mine pit, creating a rubble zone at the base that might be at least partly confined by relatively impermeable clay in the overlying spoils. Alluvial aquifers in discharge areas generally are hydraulically connected to upgradient aquifers. The unmined shale and siltstone overburden is relatively impermeable and is not considered to be an aquifer. Davis (1984a, p. 19) reported hydraulic conductivities of the spoils aquifer ranging from 0.0033 to 8.4 ft/d, with a median of 1.8 ft/d determined from 6 aquifer tests, and hydraulic conductivities of the coal aquifer ranging from 0.46 to 29 ft/d, with a median of 2.2 ft/d determined from 16 aquifer tests.

Recharge to aquifers undisturbed by mining primarily is from infiltration of precipitation on clinker outcropping in regional recharge areas (fig. 8). Natural discharge from the unmined coal aquifers primarily is to the Tongue River Reservoir or clinker and alluvium along the valley of the Tongue River.

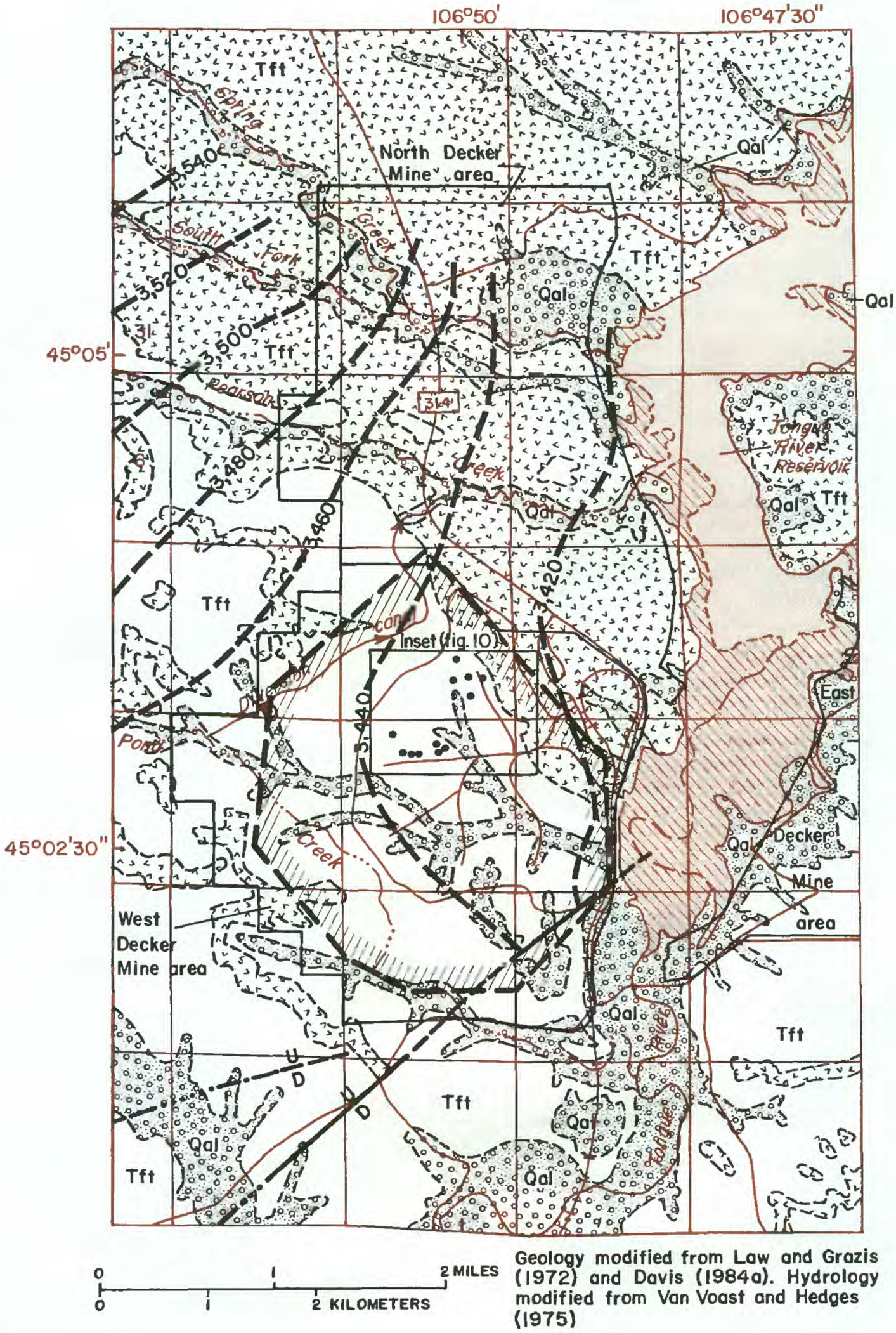
Ground-water inflow to the mine areas primarily is from adjoining clinker and coal beds. Infiltration of precipitation through the spoils probably is not a significant source of recharge. In many of the active mine areas, excavations are at a level lower than the Tongue River Reservoir at its normal stage of 3,412 ft. Because of the excavations, the natural gradient of the potentiometric surface might be reversed in local areas, especially near the reservoir, and water from the reservoir might be recharging the aquifers and discharging to the mine pits in those areas (fig. 8).

Water levels in spoils wells within about one-quarter mile of the Tongue River Reservoir apparently respond to seasonal fluctuations in the stage of the reservoir with water levels rising in summer in response to spring runoff refilling the reservoir. However, water levels in wells one-half mile or greater from the reservoir apparently do not respond to these seasonal reservoir fluctuations (data from Montana Bureau of Mines and Geology). Wells used during this study are at least one mile from the reservoir and water levels in these wells show no response to the seasonal changes in the reservoir stage.

Hydrographs of long-term water levels in the West Decker Mine area (fig. 9) indicate that when mining of the Anderson-Dietz 1 coal bed started in the early 1970's, water levels in that coal bed (well WR-01) (fig. 10) declined about 40 ft in 2 years. Water levels gradually declined in the Dietz 2 coal bed (well WR-07) (Van Voast and Reiten, 1988, sheet 2). Water levels in well WR-01 recovered partly during the late 1970's and early 1980's. When mining of the Dietz 2 coal in the southeast part of the mine area started in the early 1980's, water levels in that coal bed declined an additional 30 ft and water levels in the Anderson-Dietz 1 coal bed (well WR-01) declined gradually (fig. 9).

Figure 11 shows fluctuations of long-term water levels for a spoils well and two Anderson-Dietz 1 coal wells about one-quarter mile east and downgradient from the spoils well. Water levels in the spoils well, DS-6A, rose about 14 feet in 1976, and continued to rise another 10 feet in the next two years, most likely in response to initial saturation of the spoils aquifer. Water levels began to decline in 1981 and dropped about 20 feet in one year probably in response to mining of both the Anderson-Dietz 1 and the Dietz 2 coal southeast of the well. The hydrographs of the two coal wells WR-01 (104 feet deep) and WR-06 (135 feet deep), are similar to each other and show trends similar to the spoils-well hydrograph. The coal-well hydrographs indicate that water levels began to rise in 1977, about one year after the water-level rise in the upgradient spoils well, and began to decline in 1980, about 1-2 years before the water level declined in the spoils well. These water-level fluctuations may indicate the relative hydraulic

Exhibit 28



Geology modified from Law and Grazis (1972) and Davis (1984a). Hydrology modified from Van Voast and Hedges (1975)

Figure 7. Location, pre-mining geology, and pre-mining potentiometric surface of the Decker Mine area, Montana. (Explanation on following page.)

Exhibit 28

EXPLANATION FOR FIGURE 7

Qal — ALLUVIUM (HOLOCENE AND PLEISTOCENE)--Also includes uncorrelated gravel deposits

Tft — TONGUE RIVER MEMBER OF FORT UNION FORMATION (PALEOCENE)--Areas of clinker (baked and fused rock formed by the burning of coal beds) shown by pattern

NORMAL RESERVOIR STAGE 3,412 FEET ABOVE SEA LEVEL

MAXIMUM RESERVOIR STAGE 3,424 FEET ABOVE SEA LEVEL

APPROXIMATE GEOLOGIC CONTACT

U / D — FAULT--Dashed where approximately located; dotted where inferred. U, upthrown side; D, downthrown side

3,440 — APPROXIMATE POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells completed in the Tongue River Member or reclaimed mine spoils. Contour interval 20 feet. Datum is sea level

GENERAL BOUNDARY OF WEST, EAST, AND NORTH DECKER MINE AREAS

GENERAL BOUNDARY OF AREA MINED OR TO BE MINED, WEST DECKER MINE

• OBSERVATION WELL

connection between the spoils aquifer and the coal aquifer. Water saturating the spoils aquifer in 1976 apparently then flowed into the coal, resaturating that aquifer within one year. Mining of the coal aquifers southeast of the wells resulted in water-level declines in the coal wells starting in 1980. Within 1-2 years water levels in the upgradient spoils wells began to decline. Assuming that water in the spoils aquifer recharged the coal aquifer and that the resaturation occurred within one year, then the water flowed at a rate of more than one foot per day, a relatively fast travel time.

The location of six wells drilled in the West Decker Mine area as part of this study is shown in figure 10. Three wells (WDFCL1, WDFD12, and WDFSP3) are near the active mine area boundary and the other three (WDESP1, WDESP2, AND WDED11) are in either the saturated spoils aquifer or the downgradient coal aquifer. Lithologies determined in drilling the wells are listed in table 3. Well WDFCL1, located near the boundary of active mining, is completed in about 30 ft of unmined Anderson-Dietz 1 coal. Well WDFD12, located within the mine disturbance area, also was completed in Anderson-Dietz 1 coal. Well WDFSP3, completed in the spoils, was downgradient of coal and clinker. Water levels in well WDFD12 recovered slowly after being pumped dry, and the hydraulic conductivity, although not measured, was assumed to be at the lower end of coal-aquifer values. Water levels in well WDFCL1 recovered relatively quickly upon cessation of pumping sustainable yields of over a gallon per minute, indicating a substantially larger hydraulic conductivity. Water levels in well WDFSP3 recovered very slowly after bailing small quantities of water, indicating a small hydraulic conductivity, assumed to be at the lower end of spoils-aquifer values.

Figure 10 illustrates a cross-sectional view of wells WDESP1, WDESP2, and WDED11. The wells were drilled through spoils material, overburden, or the Anderson-Dietz 1 coal bed, and a few feet into the underlying interburden. The approximate potentiometric surface of the water levels in the spoils aquifer and Anderson-Dietz 1 coal aquifer (fig. 10) indicates flow from the north toward the south-southeast. Dewatering effects of mining, the initial saturation of the spoils aquifers, and the consequent resaturation of coal aquifers have greatly changed the hydrologic processes at the West Decker Mine area. Even though water levels have dropped significantly in this

Exhibit 28

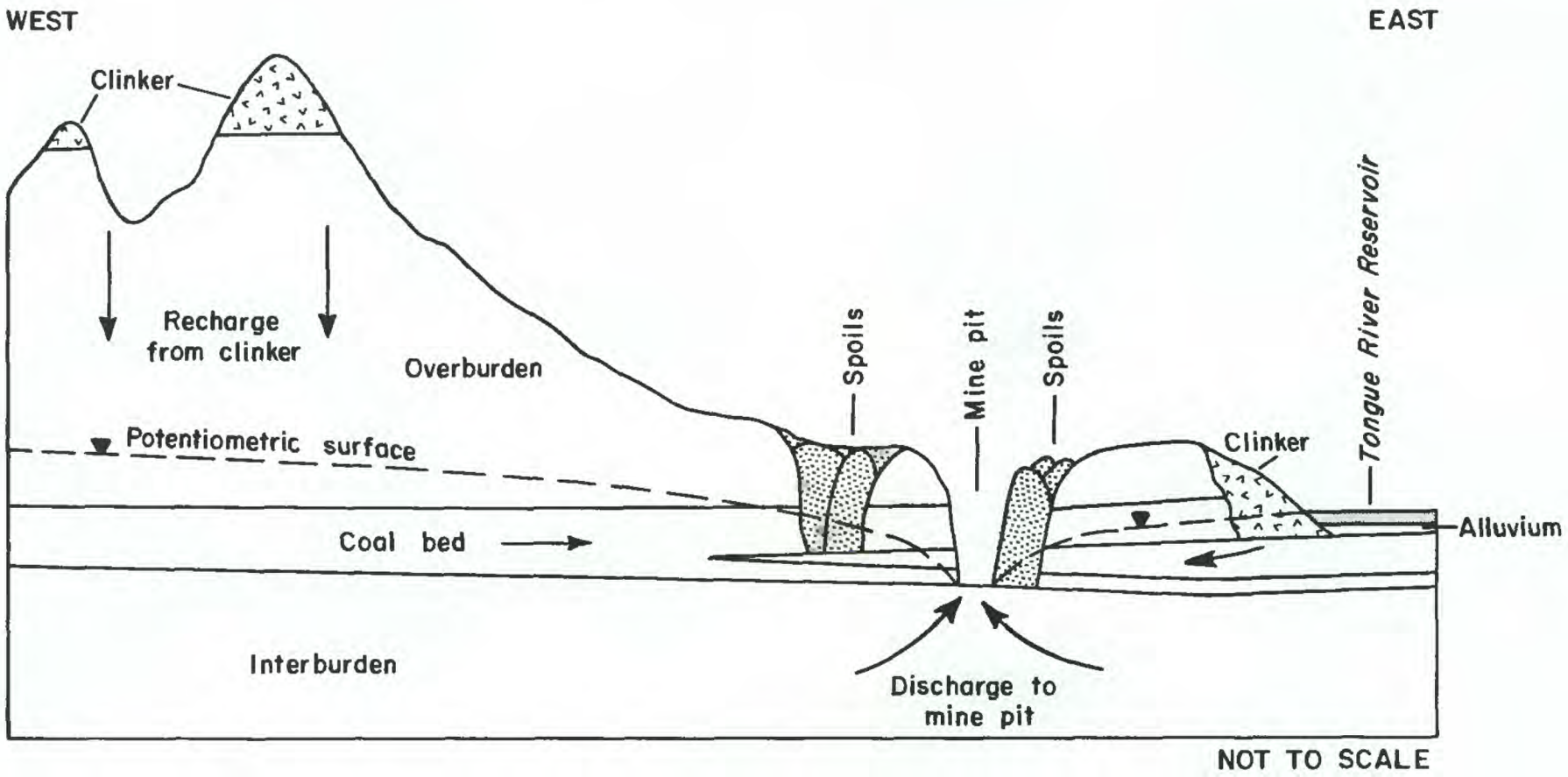


Figure 8. Generalized hydrogeologic section showing coal beds of the Fort Union Formation and associated strata after mining of the West Decker Mine area, Montana. Arrows indicate general direction of ground-water flow.

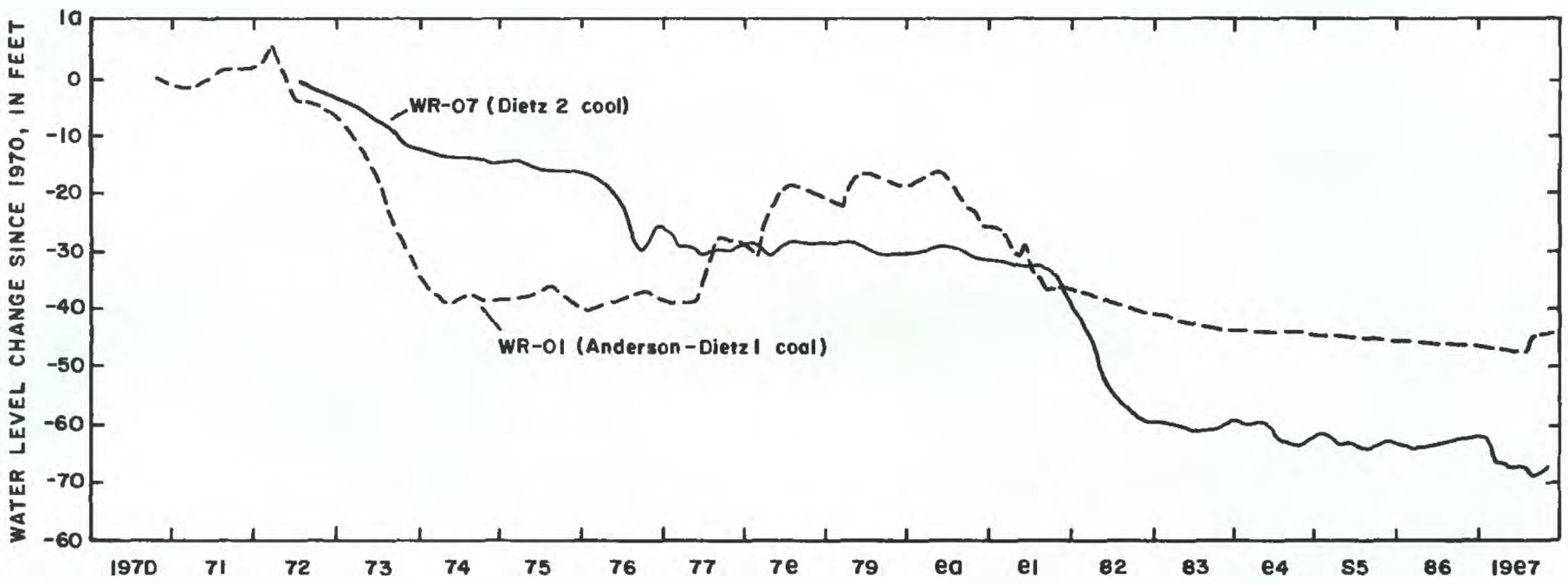


Figure 9. Water levels in wells in the West Decker Mine area, Montana, 1970-87 (data from Van Voast and Reiten, 1988, sheet 2).

Exhibit 28

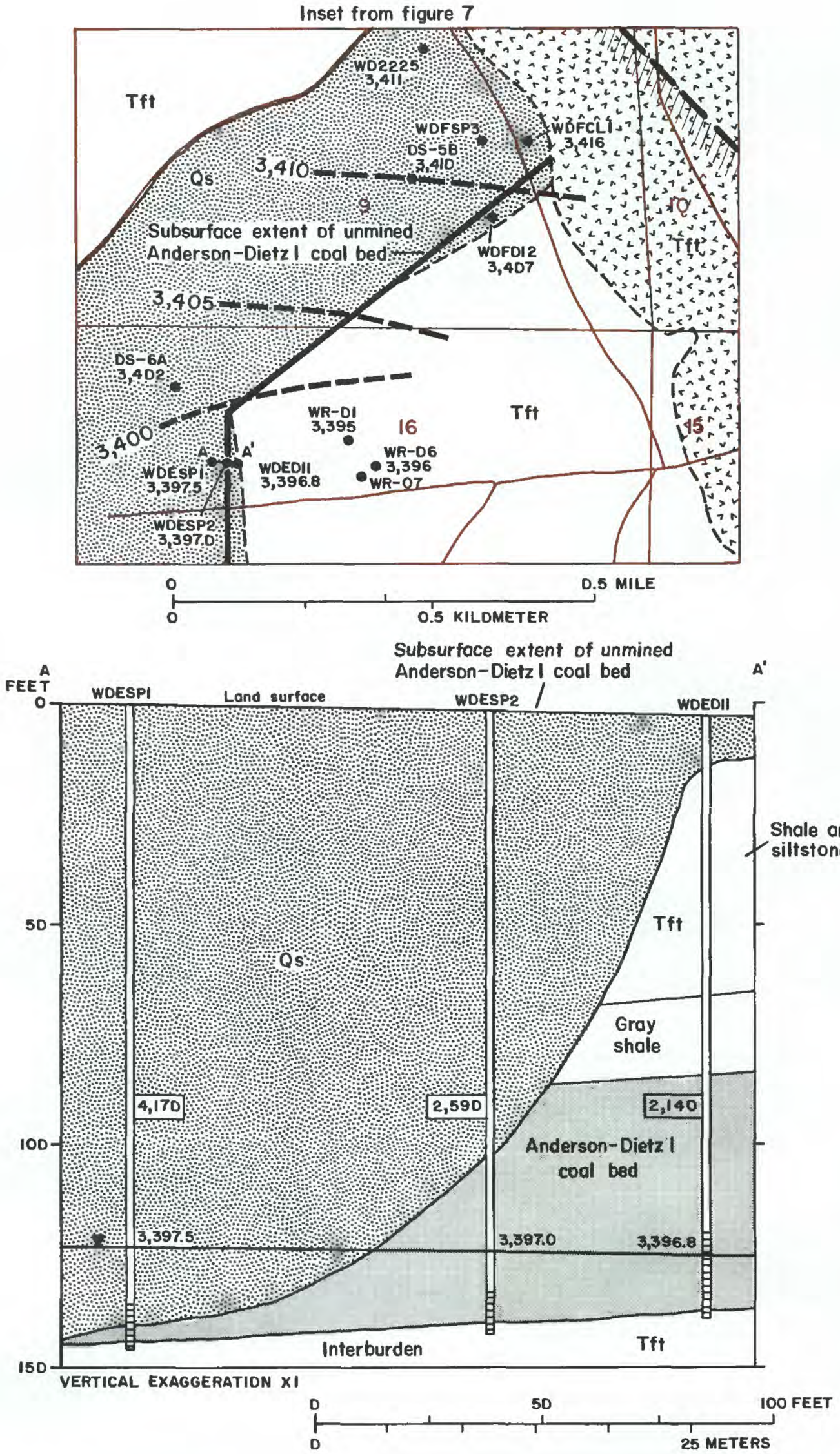


Figure 10. Location of wells, 1988 potentiometric surface, and hydrogeologic section of part of the West Decker Mine area, Montana. (Explanation on following page.)

Exhibit 28

EXPLANATION FOR FIGURE 10

Qs — SPOILS (HOLOCENE)

Tft — TONGUE RIVER MEMBER OF FORT UNION FORMATION (PALEOCENE)--Areas of clinker (baked and fused rock formed by the burning of coal beds) shown by pattern. May include some alluvium not disturbed by mining

GEOLOGIC CONTACT--Dashed where approximately located

3,405 — APPROXIMATE POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells completed in the Tongue River Member or reclaimed mine spoils. Contour interval 5 feet. Datum is sea level

GENERAL BOUNDARY OF AREA MINED OR TO BE MINED

A — A' TRACE OF SECTION

POTENTIOMETRIC SURFACE

4,170 — MEDIAN DISSOLVED-SOLIDS CONCENTRATION--Units in milligrams per liter in water sample from well, October 1988

3,397.5 — ALTITUDE OF WATER LEVEL, IN FEET ABOVE SEA LEVEL

WELL AND NUMBER

WDESPI — Map

WDESPI — Section

Screened interval

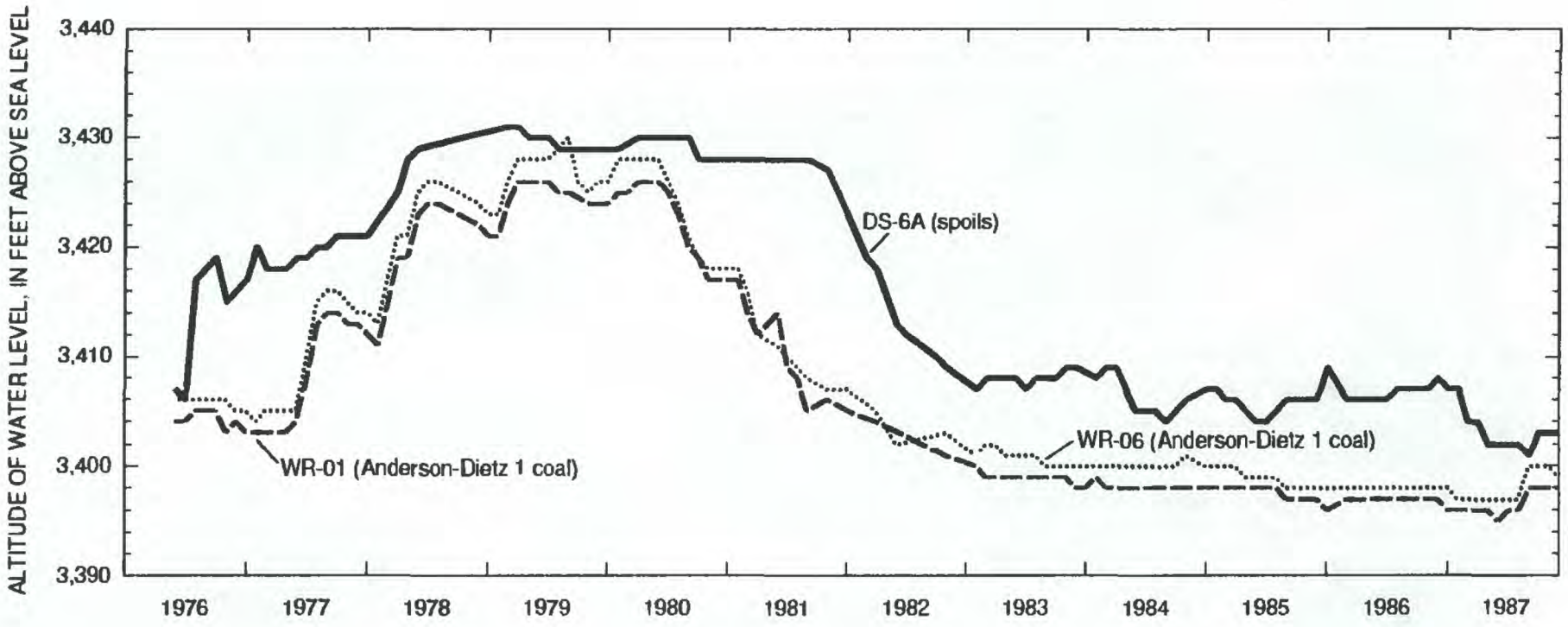


Figure 11. Water levels in three wells in the West Decker Mine area, Montana, 1976-87.

area since mining began in the early 1970's, the general configuration of the water table has not changed substantially. Prior to mining, water flowed from the recharge areas north and west of the mine area to discharge areas near the Tongue River Reservoir (fig. 7). The potentiometric surface in 1988 (fig. 10) is about 20 to 30 feet lower than the pre-mining potentiometric surface (fig. 7). The hydraulic gradient of the potentiometric surface shown in figure 10 is about 0.005, the change in head between the three wells shown in the cross-section is also about 0.005, whereas the pre-mining gradient in this area (fig. 7) is about 0.003 indicating that mining effects have steepened the gradient. Further information on the hydrology of the West Decker Mine area including a ground-water flow model is in Davis (1984a).

Water levels in wells shown in the hydrogeologic section (fig. 10) are higher in the spoils well and lower in the coal wells, indicating flow from the spoils into the coal. Although it is possible that wells WDESP1, WDESP2, and WDED11 might not be along a direct flow path, it is assumed for the purpose of this report that they are along a direct flow path. However, because of these uncertainties, this flow path will be referred to in this report as the inferred flow path.

Geochemistry

The major emphasis of the study of geochemistry at the West Decker Mine area was to determine the potential for geochemical changes as ground water flows from a spoils aquifer into an unmined coal aquifer. Results of analyses of solid-phase samples from spoils, unmined consolidated rock, and coal, and ground-water samples were essential to the determination of geochemical processes and water-rock interactions.

Results of Solid-Phase Analysis

The mineral content of the unmined consolidated rock (overburden and clinker) and spoils collected from drill-core samples is listed in tables 4, 5, and 6. The clinker sample, collected from well WDFCL1 at a depth of 50 ft, was a fine-grained clayey siltstone that primarily contained quartz, muscovite, feldspars, and trace amounts of iron (tables 4 and 5). Unmined overburden from well WDED11 included a slightly calcareous clayey siltstone with calcite and dolomite cement and trace amounts of gypsum, and a calcareous siltstone containing abundant calcite and dolomite and a trace of barite (tables 3 and 5).

The mineral content of mine spoils was determined by X-ray diffraction of 11 drill-core samples (tables 5 and 6). Quartz was the most abundant mineral in all samples. Carbonate minerals, particularly dolomite, and feldspars were common in most samples. Trace quantities of thenardite (a sodium-sulfate mineral), siderite, and celestite were detected in some samples. The clay content of the spoils included abundant kaolinite and smectite (table 6). This

Exhibit 28

was markedly different from the clay content at the Big Sky Mine area, where the expandable clays of the smectite (montmorillonite) group were much less common. The expandable clays typically have a much larger cation-exchange capacity (CEC) than other clays and, therefore, a greater effect on ground-water chemistry. A range of CEC for clay minerals, as reported by Carroll (1959, p. 754) in meq/100 g, are: kaolinite, 3-15; illite, 10-40; chlorite, 10-40; and smectite, 70-100.

The chemical concentrations of cations and trace elements were determined from nine drill-core samples of unmined overburden, mine spoils, and clinker from the West Decker Mine area (table 7). The predominant elements are aluminum, silica, iron, and potassium, probably associated with clay minerals, and calcium and magnesium, associated with the carbonate minerals. The median sodium concentration in samples from the West Decker Mine area is much larger than the median sodium concentration in samples from the Big Sky Mine area. The range of values for most major constituents, except calcium, is small, and no substantial difference is indicated between the chemistry of the unmined overburden and mine-spoils samples.

Concentrations of exchangeable cations were determined on four drill-core samples from spoils and unmined overburden from the West Decker Mine area. Calcium and sodium were the most prevalent exchangeable cations, with lesser amounts of magnesium and potassium (table 8). The median concentration of exchangeable sodium ions from the West Decker Mine area samples is about 900 µg/g, whereas the median concentration of sodium ions from the Big Sky Mine area samples is about 60 µg/g, which demonstrates the more sodic nature of the rock material in the West Decker Mine area.

Two coal samples from the upgradient well WDFCL1 and four coal samples from wells WDESP2 and WDED11 downgradient from the spoils aquifer were analyzed for concentrations of major and minor oxides and trace elements (table 9). Concentrations from all coal samples are similar. The median concentrations of selected constituents were compared to the mean concentrations from analyses of 410 coal samples from throughout the Powder River structural basin (table 10). Concentrations of sodium, strontium, and barium at the West Decker Mine area are larger than or near the maximum values detected from the 410 Powder River coal samples. Concentrations of silica, aluminum, manganese, zinc, and percent of ash at the West Decker Mine area are near or less than the minimum values detected in the Powder River coal samples.

Results of Ground-Water Analysis

Water samples were collected three times from wells WDESP1, WDESP2, and WDED11 along the inferred flow path from the spoils aquifer to the downgradient coal aquifer, and once from wells WDFCL1, WDFD12, and WDFSP3. Results of the analyses for major ions and trace elements are shown in table 11. Ground water in the area was a sodium bicarbonate type, with large variations in dissolved-solids concentration. The dissolved-solids concentration in water from well WDFCL1, completed in the coal aquifer upgradient of the active mine area, was 1,430 mg/L, which is similar to that reported by Davis (1984a, p. 34). The dissolved-solids concentration in water from coal aquifer wells within the active mine area (WDED11, WDESP2, and WDFD12) ranges from about 2,100 to 2,800 mg/L. Dissolved-solids concentrations in water from two wells completed in the spoils aquifer range from about 4,100 to 5,700 mg/L, compared to an average concentration of 2,500 mg/L reported by Davis (1984a, p. 35) for a larger number of wells. The concentration of 5,700 mg/L in water from well WDFSP3 is much larger than the average concentration and is probably one of the largest concentrations in water from the spoils aquifer. The water having 4,100 mg/L concentration, although larger than the 2,500 mg/L average concentration, probably can be assumed to be representative, as the chemical character of this water is virtually the same as other spoils water with smaller dissolved-solids concentrations.

Predominant cations and anions are depicted on diagrams (fig. 12) for samples collected during October 1988. The data on the trilinear diagram for all six wells indicate the overall similarity of the ground water in the area, the predominance of the sodium and bicarbonate ions, and the paucity of calcium, magnesium, and chloride ions. Data for water samples from four selected wells, plotted as Stiff diagrams (fig. 12), indicate differences in the ground-water quality between the coal and spoils aquifers. Water from the spoils aquifer (well WDESP1) had larger concentrations of sodium, bicarbonate, and sulfate ions than water from the upgradient coal aquifer (well WDFCL1), which potentially recharged the spoils aquifer. Concentrations of all ions, particularly sulfate, decreased between the spoils well WDESP1 and the downgradient coal wells WDESP2 and WDED11.

Water samples for laboratory determination of dissolved-gas concentrations were collected from five wells, with oxygen, carbon dioxide and methane being the gases of primary interest (table 12). Oxygen was detected at trace levels in all five wells. Concentrations of carbon dioxide decreased substantially, from 280 to 51 mg/L, along the inferred flow path from well WDESP1 to WDED11. Methane concentrations of less than 1 mg/L were detected in samples from wells WDFCL1, WDFD12, and WDESP1, whereas concentrations of 8.8 and 6.6 mg/L were detected in samples from wells WDESP2 and WDED11.

Exhibit 28

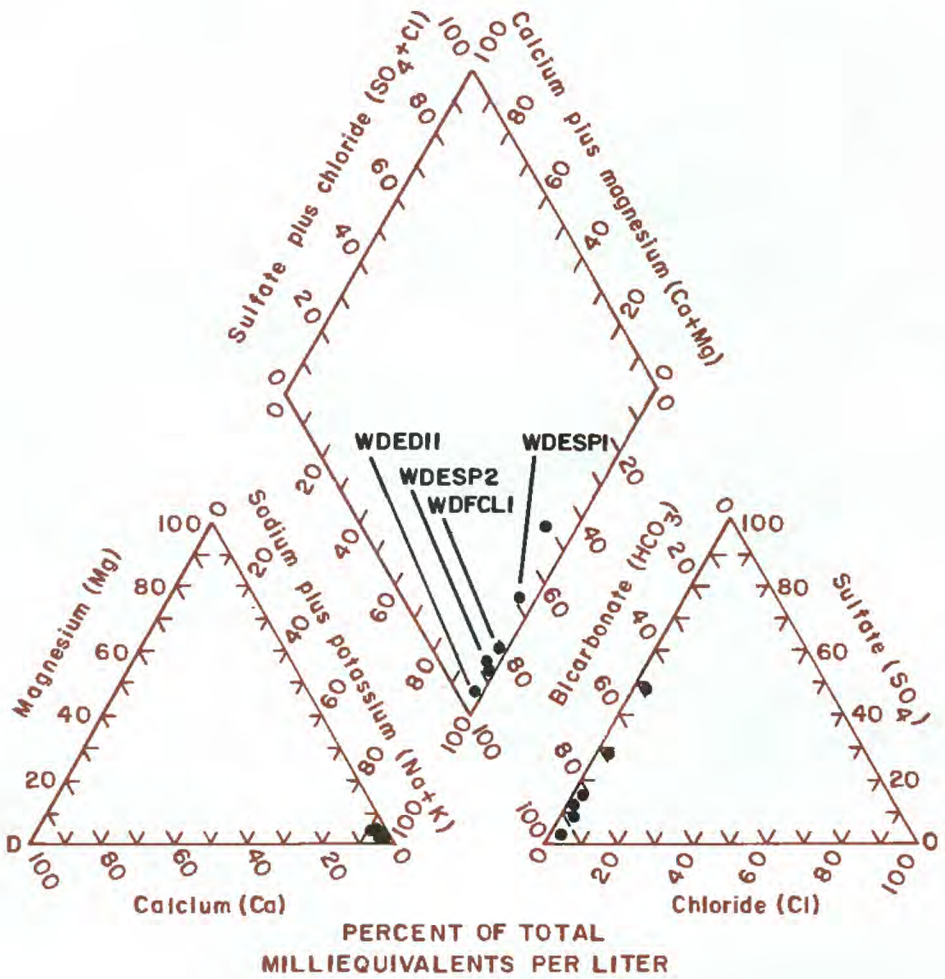


Figure 12. Trilinear and Stiff diagrams showing geochemical properties of ground water from the West Decker Mine area, Montana.

Exhibit 28

The tritium-activity values in water from wells WDESP1, WDESP2 and WDED11 were similar (10, 11, and 8 TU) (table 13). The values might indicate a similar source for the water. Although similar values may not necessarily substantiate other data to indicate that the wells were along a flow path, the values do most likely indicate that the water in the wells has relatively similar ages. Tritium-activity values in water from wells WDFCL1 and WDFD12 were larger than values in water from the other wells, possibly indicating a younger source of recharge water to these wells. Conversely, the tritium data might indicate that some water recharging the spoils aquifer, represented by well WDESP1, originated from an older source having small tritium values, possibly from the aquifer in the Dietz 2 coal bed by way of unplugged exploration drill holes (Van Voast and Reiten, 1988, p. 4).

Thermodynamic speciation calculations for water from the West Decker Mine area were made using the program WATEQF (Plummer and others, 1978) (table 16). Saturation indices listed are for minerals considered to be potentially reacting in the ground water. Saturation indices demonstrate that, in general, the water was saturated with respect to quartz, calcite, aragonite, and barite, near saturation with respect to dolomite, and undersaturated with respect to strontianite, gypsum, anhydrite, and celestite. The saturation indices for the iron minerals siderite, goethite, and amorphous FeS demonstrate that the water might have been either saturated or undersaturated with respect to the minerals, depending on the concentration of dissolved iron and the redox state of the water. Eh values were not measured but were calculated by the WATEQF model based on ion pairs. An Eh value of 0.18 volts calculated from the dissolved-oxygen concentration was used for saturation calculations for water from well WDESP1 (table 11). The Eh values for the other samples which contain dissolved sulfide and Fe^{2+} were calculated from the sulfur-ion concentrations, and ranged from -0.24 to -0.16 volts.

Geochemical Processes Along an Inferred Flow Path From Upgradient Coal Aquifer to Spoils Aquifer

The geochemical processes along an inferred flow path from an upgradient, unmined coal aquifer to a spoils aquifer were studied using solid-phase, ground-water, and hydrologic data. Dissolved-solids concentrations in water from the spoils aquifer were more than three times the concentrations in the assumed recharge water from the coal aquifer (table 11). In water from the coal aquifer within the mine area (well WDFD12), the dissolved-solids concentration was about 50 percent more than the concentration in water from the upgradient coal aquifer.

No direct evidence was available to determine the amount of water, if any, that might have been recharged from the upgradient coal aquifer represented by well WDFCL1 to the spoils aquifer represented by well WDFSP3. Although the potentiometric-surface data (fig. 11) indicate that water flowed from the coal aquifer toward the mine area, hydrologic barriers may have prevented some water from entering the spoils. Some recharge water to the upgradient coal aquifer might have been from the Tongue River Reservoir, because mine dewatering has lowered aquifer water levels below the level of the reservoir. Primary recharge sources prior to mining were aquifers northwest of the mine area (Davis, 1984a, fig. 7), which potentially continue to be major sources of recharge. Upward migration from deeper aquifers through exploratory drill holes (Van Voast and Reiten 1988, p. 19) was another possible source of recharge.

The water in well WDESP1, completed in spoils, is assumed to be most representative of water in the spoils aquifer. Although actual dissolved concentrations might be larger or smaller than median values for the spoils aquifer, the reactions necessary to create the spoils water from upgradient coal aquifer water are assumed to be similar.

The changes in water chemistry between the recharge water and water in the spoils aquifer most likely were the result of only a few processes. The large increases in dissolved sulfate and sodium concentrations were likely a result of an initial dissolution of gypsum followed by the exchange of calcium or magnesium ions for sodium ions on the smectite clays in the spoils aquifer. The increase in bicarbonate concentration was likely the result of dissolution of the carbonate minerals calcite or dolomite.

Results of solid-phase analyses show that calcite and dolomite generally were common to abundant in the spoils. Gypsum was detected at only trace levels; however, it might have been concentrated in zones that were not sampled or it might have been in quantities too small for detection. Pyrite, which was abundant near the top and bottom of the coal bed, probably was oxidized when exposed by mining, thereby increasing acidity and the concentration of dissolved sulfate ions. The acidity probably was buffered by dissolution of the carbonate minerals. The sulfate ions were either transported to the aquifer or precipitated as gypsum or possibly other sulfate minerals in the unsaturated zone, and then dissolved and transported to the aquifer by recharge water.

Changes in isotopic composition of the waters could not be attributed to a specific or evident process. Differences in isotopic composition of water from well WDFCL1 and water from wells WDFD12 and WDESP1 (table 13) might have been the result of dilution or dissolution rather than isotopic fractionation.

Exhibit 28

Mass-balance models were used to simulate possible geochemical changes that might occur as water from the coal aquifer recharged the downgradient spoils aquifer. Simulations were made for paths from the coal aquifer, represented by well WDFCL1, to the spoils aquifer, represented by wells WDFSP3 and WDESP1. The results of the simulation indicate that the major geochemical processes were the dissolution of gypsum, calcite, and some dolomite; the exchange of calcium ions for sodium ions; the consumption of carbon dioxide gas; and the dissolution of minor quantities of strontianite and halite (table 17). The results of the simulations generally were supported by the solid-phase and gas analysis. Calcite, dolomite, and gypsum were detected by X-ray diffraction techniques and substantial quantities of carbon dioxide in the water were confirmed by gas analysis (table 12).

Geochemical Processes Along an Inferred Flow Path from Spoils Aquifer to Downgradient Coal Aquifer

The concentrations of major dissolved ions, some dissolved trace elements, stable isotopes, and dissolved gases were substantially different in water from well WDESP1 in the spoils aquifer than in water from wells WDESP2 and WDED11 in the downgradient coal aquifer. Selected median dissolved-ion concentrations for samples from each well are given in table 18. The dissolved-solids concentration decreased by nearly one-half, from 4,170 to 2,140 mg/L, along the inferred flow path from well WDESP1 to well WDED11 (fig. 10). Large decreases in median concentrations of major dissolved ions include sulfate, from 1,100 to 64 mg/L; bicarbonate, from 3,080 to 2,390 mg/L; and sodium, from 1,500 to 890 mg/L. Changes in concentrations of other ions along the inferred flow path include calcium, magnesium, manganese, strontium, all of which decreased to less than 30 percent of initial values, and barium which increased about 3,000 percent from the initial value. Although the relative concentrations of major ions decrease substantially along this inferred flow path, the chemical character of the water remained a predominantly sodium bicarbonate type (fig. 12).

This study was conducted as a follow-up to the laboratory experiments conducted by Davis and Dodge (1986). As a means of comparison, selected median values from the report by Davis and Dodge (1986) are included in table 18. A comparison between water from spoils and coal shows similar changes in laboratory and onsite results for most of the selected constituents, including decreases in concentrations of calcium, magnesium, sodium, bicarbonate, dissolved solids, manganese, and strontium, and increases in barium concentrations. Sulfate changed relatively little in the laboratory experiments but decreased substantially under onsite conditions because the experiments did not simulate the reducing environment found onsite. Davis and Dodge (1986, p. 7) concluded that the reactions causing the changes observed in the laboratory experiments included adsorption or ion-exchange reactions involving sodium ions exchanging for calcium ions and the precipitation of calcite.

Saturation indices calculated for minerals that might be reacting along the inferred flow path are given in table 16. The saturation state of dolomite and possibly goethite changed from saturated to near saturated or unsaturated as water flowed from the spoils aquifer to the coal aquifer. The saturation state of quartz, calcite, and strontianite was virtually unchanged, whereas the saturation state of the sulfate minerals gypsum, anhydrite, and celestite decreased substantially. Results for the remaining selected minerals generally were mixed.

The large change in the $\delta^{34}S$ isotopic ratio in sulfate of -0.2 to 62.5 ‰ along the inferred flow path was due to enrichment of the heavier sulfur isotope, whereas the change in the $\delta^{13}C$ in carbon of -0.8 to -9.4 ‰ was due to enrichment of the lighter carbon isotope (table 13). The magnitude of these isotopic changes is significant in that the changes occurred along a relatively short inferred flow path. Concentrations of carbon dioxide gas decreased substantially along the inferred flow path, and concentrations of methane increased (table 12).

Analytical results of solid-phase samples collected from drill cores were used to help substantiate potential geochemical reaction processes. Calcite and dolomite were relatively common to abundant in the spoils; gypsum, pyrite, siderite, and barite were identified in trace amounts; and smectite and kaolinite were the prevalent clay minerals (tables 4, 5, 6). Relatively large concentrations of sodium (table 7) and exchangeable sodium (table 8) demonstrate the sodic nature of the rock material in the West Decker Mine area. The presence of iron-bearing minerals such as goethite, pyrite, and siderite indicates that iron was available for the precipitation of iron-sulfide minerals.

Potential Reaction Processes

The changes in ground-water chemistry that occurred as water flowed from the spoils aquifer to the coal aquifer were likely the result of at least several reaction processes. The largest changes were decreases in the concentration of sodium, sulfate, and bicarbonate ions, and increases in dissolved sulfide. Possible reaction processes were the exchange of sodium ions for calcium ions on the surface of organic matter, bacterial reduction

of sulfate which decreased sulfate concentrations and produced sulfide ions, removal of the produced sulfide ions by precipitation of sulfide minerals, and decreases in the concentration of bicarbonate by precipitation of carbonate minerals. For all these processes to proceed in the same system, specific hydrogeochemical reactions must have occurred.

Ion-Exchange and Adsorption Reactions

Ion-exchange and adsorption reactions within saturated coal might have been important processes resulting in the decrease in cations as water flowed from the spoils aquifer to the coal aquifer. Typically, calcium or magnesium ions exchange for sodium ions (equation 10). If the reaction is reversed, the concentration of sodium ions in solution decreases and the concentration of calcium or magnesium ions increases. The extent to which exchange occurs primarily depends on the cation-exchange capacity (CEC) of the solid and the ion concentrations in solution.

The CEC for specific clay minerals generally is well known (Carroll, 1959, p. 754). Although coal and other organic material potentially have a relatively large CEC, only sparse information is available. Data for lignite samples from the Tongue River Member of the Fort Union Formation at a mine area in North Dakota (Donald C. Thorstenson, U.S. Geological Survey, unpub. data, 1985) indicate that the CEC of the lignite averages about 70 meq/100g, which is similar to the value of 70-100 meq/100g for smectite, an expandable clay, as reported by Carroll (1959, p. 754).

Typically, divalent calcium or magnesium ions in solution will exchange preferentially for monovalent sodium ions. However, in somc solutions containing large sodium concentrations (Drever, 1982, p. 84, Davis and DeWiest, 1966, p. 91) and in solutions containing virtually no dissolved calcium or magnesium and relatively large concentrations of dissolved sodium (Palmer and Cherry, 1984, p. 49), the sodium ions in solution tend to be exchanged for calcium or magnesium ions. Monovalent sodium ions in solution are unlikely to displace divalent ions unless the sodium percentage, which is the percentage of total cations in milliequivalents made up by sodium, is considerably greater than 50 (Hem, 1985, p. 161). The sodium percentage for the water from wells in the West Decker Mine area is considerably greater than 50 and generally greater than 90.

The possibility of the exchange of sodium ions for calcium ions in coal has been addressed in previous studies. Davis and Dodge (1986, p. 6) hypothesized about this exchange on the basis of experiments. During an earlier study of sodium and associated elements in the Anderson-Dietz 1 coal bed near Decker, Mont., Hildebrand (1988, p. 218) reasoned that the coal contains significantly larger concentrations of sodium, strontium, and barium and significantly smaller concentrations of potassium, calcium, and magnesium than samples from the Powder River structural basin owing to ion exchange. That study concluded that a large sodium percentage in the ground water causes chemical disequilibrium, which in turn causes sodium cations to be adsorbed by the coal in preference to other dissolved cations. The other adsorbed cations, particularly potassium, calcium, and magnesium, are then exchanged for the adsorbed sodium ions, resulting in a gradual increase in the sodium content in the coal. Large concentrations of barium and strontium in the coal could also be a result of cation adsorption.

Sulfate Reduction

Another major geochemical change along the inferred flow path was the substantial decrease in the concentration of dissolved sulfate from about 1,100 to 64 mg/L (table 17) and the subsequent increase in the concentration of dissolved sulfide. The removal of most of the sulfate is assumed to be the result of bacterial reduction with oxidation of organic carbon as the energy source. Dockins and others (1980, p. 6) found relatively large numbers of the sulfate-reducing bacteria *Desulfovibrio desulfuricans* in 25 of 26 observation wells sampled in southeastern Montana, and reported sulfide concentrations of about 1 mg/L. The occurrence of the sulfide in water in these coal aquifers probably can be attributed to bacterial reduction of sulfate and not to the slow kinetics of abiotic sulfate reduction.

Two assumptions are made for sulfate reduction and associated reactions to occur--the organic carbon source utilized is the subbituminous coal (represented compositionally by CH_2O) and the Fe_2O_3 is present as a source for iron and FeS_2 is present as a sink for sulfur (Thorstenson and others, 1979, p. 1,493). Using these assumptions, sulfate reduction with iron-sulfide precipitation can be represented by the following irreversible reaction:

$$15CH_2O + 2Fe_2O_3 + 8SO_4^{2-} + H_2CO_3 \xrightarrow{\text{sulfate-reducing bacteria}} 4FeS_2 + 16HCO_3^- + 8H_2O\,. \qquad (13)$$

Exhibit 28

With the completion of sulfate reduction, decomposition of the organic matter might continue according to the reaction:

$$2CH_2O \Rightarrow CH_4 + CO_2 \,. \qquad (14)$$

On the basis of results of hypothetical geochemical models, Martin and others (1988, p. 91) indicate that an ideal situation for large decreases in dissolved-solids concentrations within a coal aquifer involves populations of sulfate-reducing bacteria, organic-carbon sources that can be utilized by the bacteria, and a source of iron that will facilitate removal of the produced sulfide by mineral precipitation. Because coal at the West Decker Mine area is subbituminous, and in some instances nearly lignitic, the source of organic carbon for the bacteria was assumed to be the coal itself, which likely contains an unlimited supply of aromatic carbon compounds available to the bacteria.

Both dissolved sulfate and methane were detected in water samples from the coal aquifer (tables 11, 12). This geochemical incongruity is potentially explained by the existence of microzones within the coal aquifer, where all dissolved sulfate has been removed by reduction and where methanogenesis predominates. Chapelle and others (1988, p. 170) suggest that such bacterial microenvironments produce a mosaic of redox conditions, resulting in apparent redox non-equilibrium conditions. Sulfate-reducing bacteria generally will outcompete the methanogens in the same system, primarily because both rely on the same fermentation products, including hydrogen, an intermediate product in the decomposition of organic matter. When sulfate concentrations are not limiting, the sulfate-reducing bacteria maintain hydrogen at a concentration so small that methane production from hydrogen is thermodynamically unfavorable (Loveley and Goodwin, 1988, p. 2,994). However, at minimal sulfate concentrations, the metabolism of the sulfate reducers is so limited that methanogens might be able to outcompete the sulfate reducers and prevent further sulfate reduction.

Precipitation of Sulfide and Carbonate Minerals

Potential products of the reaction processes are iron-sulfide and calcium-carbonate minerals. Plummer and others (1990, p. 1,994-1,998) report laboratory studies wherein reactions of sulfide gas with goethite ($HFeO_2$) at temperatures of 22 to 24 °C formed an iron-sulfide precipitate that was assumed to be either a form of very fine-grained pyrite or amorphous iron sulfide. If iron was available within the coal aquifer, either dissolved or as goethite, then the sulfide gas produced during sulfate reduction could have reacted with the iron and precipitated an iron-sulfide mineral. Therefore, in a system where sulfide concentrations are small, sulfate reduction might still occur at relatively fast rates because the sulfide is being precipitated. Results of petrographic analysis for this study (table 4) indicate the presence of iron oxides, chemical analyses of water (table 11) indicate relatively large concentrations of dissolved iron, and thermodynamic calculations (table 16) indicate that some water is supersaturated with respect to goethite. Therefore, sufficient iron was assumed to be available for the precipitation of iron-sulfide minerals. The form of the iron-sulfide minerals was not determined as part of this study.

Carbonate minerals, such as calcite or magnesian siderite, might have precipitated as a result of reaction processes. A relatively large decrease in bicarbonate concentration along the inferred flow path (table 11) was likely a result of carbonate-mineral precipitation. Even though concentrations of calcium decreased along the inferred flow path (table 11), speciation calculations (table 16) show that all waters were slightly oversaturated with respect to calcite. The degree of oversaturation required to precipitate calcite given the observed field conditions is unknown, but the calculated oversaturation was assumed to be sufficient for precipitation.

Results of Laboratory Experiment

A laboratory experiment was conducted to determine if the decrease in dissolved-sodium concentrations along the flow path could be the result of preferential exchange of sodium ions in solution for calcium and magnesium ions in the coal. The experiment was conducted using coal samples from the West Decker Mine area collected during the drilling of observation wells, and concentrated solutions of sodium sulfate (Na_2SO_4). The experiment was conducted using samples of coal collected from the saturated and unsaturated zones. Samples from each zone were used to determine the effect of soluble minerals in samples from each zone on the experiment results.

Four of five crushed coal samples were initially mixed with deionized wash water for 48 hours to determine the quantity of soluble minerals within the coal. The mixing water was then decanted, filtered through a 0.45-µm filter, and analyzed for major ions. The coal was air-dried for 48 hours. The fifth coal sample, used as a control, was not mixed with deionized water. The five coal samples were then mixed using a 1:1.5 weight ratio with a Na_2SO_4 solution in 500-mL bottles. Two concentrations of Na_2SO_4 solution, 0.05 and 0.1 M, were used. The bottles, filled completely to eliminate oxygen, were shaken periodically for 48 hours. The mixtures settled, and the

Exhibit 28

coal and solutions were separated by decanting and filtering through a 0.45-μm filter. The filtered samples and the Na_2SO_4 solutions were analyzed for major ions.

Results of analyses of post-mixing wash water indicated substantial differences in the concentrations of the major constituents between mixtures using coal from the unsaturated zone and mixtures using coal from the saturated zone. The dissolved-solids concentration in the wash water from the unsaturated-zone mixtures was about twice that of the wash water sample from the saturated-zone mixtures (table 19). In addition, the wash water from the unsaturated-zone mixture was a sodium sulfate type, whereas the wash water from the saturated-zone mixture was a sodium bicarbonate type. These results might indicate that as water levels declined, soluble sodium-sulfate or sodium-carbonate minerals were precipitated above the water table.

When the sodium-sulfate solutions were added to the coal samples, analyses of the post-mixing solutions showed a general decrease in sodium concentrations and a large increase in the concentrations of calcium and magnesium ions. Sodium ions from the 0.05 M Na_2SO_4 solution apparently were exchanged for about 150 mg/L of calcium ions and about 60 mg/L of magnesium ions (table 19). Sodium ions from the 0.1 M Na_2SO_4 solution apparently were exchanged for about 340 mg/L of calcium ions and about 130 mg/L of magnesium ions, or approximately twice the amount exchanged from the 0.05 M Na_2SO_4 solution.

The results of the experiment indicate that sodium ions in solution can be preferentially exchanged on coal for calcium and magnesium ions. A large concentration of sodium ions in solution, especially when compared to small concentrations of calcium and magnesium ions, might control the direction of the exchange reaction (equation 10) and the quantity of exchange. The large concentration of sodium ions in the spoils water relative to the concentration of calcium and magnesium ions (table 11) indicates that the conditions for exchange of sodium ions for calcium or magnesium ions existed in the study area.

Mass-Balance Reaction Models

An objective of the geochemical modeling was to identify reactions or processes that resulted in the initial quality of ground water and caused chemical changes to occur along inferred flow paths. Ideally, the modeling would determine the quantities and types of minerals reacting in the system, either precipitating or dissolving, and would calculate speciation and isotopic effects as the reactions progressed. Geochemical mass-balance models were constructed to calculate the mass transfer of phases between water in the spoils aquifer and water in the downgradient coal aquifer. Possible reactant or product phases are listed in table 20.

The wells along the inferred flow path were sampled three times from October 1988 to May 1990. However, mass-balance calculations are presented only for the October 1988 samples, for which dissolved-gas analyses and full isotope analyses were available. Sulfur-isotope analyses for sulfate and sulfide in water collected in May 1989 from well WDESP2 were used in calculations. Mass-balance calculations were made using water-quality data for four wells (table 21).

Plausible Phases

Eight plausible reactant or product phases were considered for mass-balance reaction modeling (table 20). Organic matter was assumed to represent a carbon source and was included as a probable energy source and electron donor for bacterial reduction of sulfate. Sources of available iron species, such as goethite, are assumed to be present in sufficient quantities for the precipitation of pyrite or other iron-sulfide mineral forms such as amorphous FeS. Dissolved sulfide was included as a product of sulfate reduction because of the presence of sulfate-reducing bacteria. Carbon dioxide was included as a product of the oxidation of the organic matter. Calcite and magnesian siderite were included as plausible sinks for the removal of bicarbonate. Cation exchange of sodium ions for calcium or magnesium ions was included as a plausible phase for removing sodium ions from solution and for providing calcium and magnesium ions necessary to precipitate calcite, magnesian siderite, or other carbonate minerals.

Oxidation-reduction reactions are considered plausible along the inferred flow path, including sulfate reduction and the oxidation of organic matter and ferric hydroxide. The redox state (RS) shown in table 21 is a method of keeping track of electron transfer for redox reactions. The redox state is defined as follows:

Exhibit 28

$$RS = \sum_{i=1}^{I} m_i v_i \qquad (15)$$

where

I = the number of species in solution,
m_i = the molality of the i'th species in solution, and
v_i = the operational valance of the species.

Further description of operational valance and redox state is addressed by Plummer and others (1990, p. 1,991).

Isotopic Ratios

Stable-isotope data for dissolved carbon, sulfate, and sulfide were used in conjunction with other water-quality data to construct geochemical-reaction models for the inferred flow path from the spoils aquifer to the downgradient coal aquifer. Isotopic data were included in reaction modeling because they might provide an independent constraint without adding an additional phase. The sulfur- and carbon-isotope data were treated as Rayleigh distillation and not as dilution or isotope mass balance. Rayleigh distillation is a process where products in a chemical or physical reaction differ isotopically from the reactants and are isolated from the system after formation. Rayleigh distillation reactions were used to calculate the isotopic composition of the final solutions. The calculations were an independent check, because the correct reaction model would be among those predicting the observed isotope composition. The equation used for this report is described by Busby and others (1991, p. 43) and was adapted for Rayleigh distillation of the sulfur-isotope composition of dissolved sulfate from the equations developed by Wigley and others (1978, 1979).

To model fractionation and evolution of isotopes along the inferred flow path, isotopic values of initial sources and final products or isotopic sinks are needed. The value for a dissolved source, such as sulfate, can be determined from an aqueous sample. However, determining values for a solid source, such as an amorphous or microcrystalline precipitate, can be considerably more difficult. Some data are available in the literature for isotopic ratios of various sources and sinks.

Carbon

Dissolved carbon in ground water primarily is derived from carbonate sediments, soil organic matter, the decay of other organic material, and in some instances, atmospheric CO_2. The $\delta^{13}C$ of the dissolved carbon can vary widely depending on the source of the carbon. Values of $\delta^{13}C$ for coal range from -24 to -30 ‰ for samples collected from the Powder River structural basin, including the West Decker Mine area (Holmes, 1988, p. 211). Other values of $\delta^{13}C$ for coal include -28 $\pm$ 4‰ for sedimentary organic carbon (Rightmire and Hanshaw 1973, p. 959). The $\delta^{13}C$ of -0.8 ‰ in the initial water, well WDESP1 (table 13), was likely derived from dissolved carbonate or CO_2. The $\delta^{13}C$ of the dissolved carbon changed substantially along the inferred flow path to -8.8 and -9.4 ‰--potentially a result of bacterial fractionation of the carbon in the subbituminous coal.

The concentration of dissolved organic carbon (DOC) in water in the coal aquifers probably was significant. DOC samples were not collected during this study; however, concentrations in about 40 DOC and total organic carbon (TOC) samples collected by Lee (1979) from wells completed in the Tongue River Member of the Fort Union Formation ranged from 0.1 to 83 mg/L and had a median value of about 5 mg/L. This median value was assumed to be representative of DOC in the coal aquifer at the West Decker Mine area, and the $\delta^{13}C$ of the DOC was assumed to be the same as the $\delta^{13}C$ of the coal from which it presumably was derived.

Sulfur

The difference between the $\delta^{34}S$ values of the sulfide and sulfate ($^{34}\Delta$) determined in one sample was calculated by the equation:

Exhibit 28

$$^{34}\Delta = \delta^{34}S_{H_2S} - \delta^{34}S_{SO_4}. \quad (16)$$

The $^{34}\Delta$ used for this study, as calculated from the values at well WDESP2 (table 13), was -41.2 ‰ at a temperature of 17 °C. The equilibrium value for $^{34}\Delta$ for this system is not known; however, various studies indicate an approximate value of about -65 ‰ (Back and others, 1983, p. 1,422). The value of -41.2 ‰ most likely represents non-equilibrium conditions controlled by microorganisms or, in other words, a kinetic fractionation mediated by bacterial action.

Plummer and others (1991, p. 19) present an equation:

$$\delta^{34}S_{H_2S} = \delta^{34}S_{SO_4} - 54 + 0.40t, \quad (17)$$

to calculate $^{34}\Delta$ based on linear function of temperature (t in °C). Using the temperature of 17 °C in equation 17, the calculated $^{34}\Delta$ would be -47.2 ‰ which is in general agreement with the $^{34}\Delta$ determined for this study (-41.2 ‰). The value of -41.2 ‰ was therefore assumed to be the sulfur-isotope fractionation value representative of water from wells in the West Decker Mine area.

Water from 15 wells completed in alluvial, coal, shale, sandstone, and spoils aquifers in southeastern Montana was analyzed for $\delta^{34}S$ values for sulfide and sulfate (Dockins and others, 1980, p. 6). Values of $\delta^{34}S$ for sulfides ranged from -38.50 to 6.68 ‰ and averaged -23.80 ‰, whereas values for sulfate ranged from -0.20 to 45.17 ‰ and averaged 7.96 ‰. The $^{34}\Delta$ for these samples ranged from -9.54 to -48.13 ‰ and averaged -32.31 ‰.

Requirements for Preparing Mass-Transfer Models

The $\delta^{13}C$ value of organic matter (CH_2O) used in the models varied between -20 and -32 ‰, but generally ranged from about -28 to -30 ‰. Although this range is slightly isotopically lighter than the -25 ‰ that is commonly referenced, it does fall within the range of values reported by Rightmire and Hanshaw (1973, p. 959) and Holmes (1988, p. 211).

The initial $\delta^{34}S_{SO_4}$ was assumed to be equivalent to the value from well WDESP1 of -0.2 ‰. No additional input of $\delta^{34}S$ from other sources such as gypsum, anhydrite, or pyrite was likely because dissolved-sulfate concentrations decreased along the inferred flow path. The $^{34}\Delta$ fractionation of -41.2 ‰ was assumed to be the fractionation value along the inferred flow path; therefore, the $\delta^{34}S_{H_2S}$ used for samples from wells WDESP1 and WDED11 was calculated by subtracting the fractionation value from the values of $\delta^{34}S_{SO_4}$.

Amorphous iron sulfide (FeS) was included as a product because of the presence of H_2S, and goethite ($HFeO_2$) was included as a reactant. A laboratory study (Price and Shieh, 1979) indicated reactions of H_2S with goethite precipitated fine-grained pyrite, and the pyrite had only a slightly different $\delta^{34}S$ than that of the H_2S source, indicating little fractionation occurred between H_2S and the precipitated pyrite. Therefore, for the purpose of the mass-transfer model, the $\delta^{34}S$ of precipitated amorphous iron sulfide was assumed to be equal to that of dissolved H_2S.

Sulfate reduction was assumed to have occurred at relatively fast rates. Even though dissolved H_2S was detected in relatively minor quantities, the H_2S might have either degassed or precipitated as an iron-sulfide mineral in the presence of goethite. At least two products for the reduced sulfate were therefore considered in the model: H_2S gas, and precipitation of an iron-sulfide mineral in conjunction with the dissolution of an iron mineral such as goethite.

Another likely product was siderite, an iron-carbonate mineral detected in solid-phase samples from the West Decker Mine area (table 5). Siderite apparently is rarely found as pure $FeCO_3$ and the substitution of Fe^{2+} by other metallic ions such as magnesium (Mg) and manganese (Mn) is common (Deer and others, 1966, p. 487). Siderite might contain Mg in substitution for Fe to a complete solid solution as magnesite ($MgCO_3$). For the purpose of this mass-transfer model, magnesian siderite was assumed to precipitate at atmospheric temperatures and pressures with a composition of $Fe_{0.7}Mg_{0.3}CO_3$.

Exhibit 28

Ion exchange probably was an important reaction along the inferred flow path, as evidenced by results from the laboratory experiments and by the decrease in dissolved sodium ions. Ion exchange was calculated primarily for sodium ions exchanging for calcium ions, and to a lesser extent, for sodium ions exchanging for magnesium ions.

Traces of methane (CH_4) were detected in dissolved-gas analyses (table 12). Although methane was not considered to significantly affect the overall geochemical results, it may have affected the calculated value of $\delta^{13}C$, and therefore was included in the geochemical modeling. Methane production was assumed to occur either in microzones where sulfate had been removed, or after sulfate reduction had virtually eliminated dissolved sulfate from the entire system. The $\delta^{13}C$ of methane was assumed to have a value of 50 ‰ less than the measured $\delta^{13}C$ in water from each well (Plummer and others, 1990, p. 1,999).

The supply of water from some wells was not adequate to accurately measure all parameters in a closed flow cell, including onsite measurement of some pH values. In such instances, the pH values were calculated using concentrations of alkalinity and CO_2 gas (table 12) (Pearson and others, 1978). A substantial difference between the onsite and calculated values was detected only for the sample collected from well WDED11 in October 1988. The onsite value of 7.2 was corrected to a calculated value of 7.8 for use in thermodynamic calculations (table 21).

Mass-Transfer Results

The results of mass-transfer calculations for calcite, magnesian siderite, organic matter, goethite, iron sulfide, H_2S gas, CO_2 gas, and ion exchange, in millimoles per kilogram of water, are listed in table 22. The calculated and observed $\delta^{13}C$ and $\delta^{34}S$ values, and the assumed isotopic composition of organic matter and sulfur-isotope fractionation values, are also listed in table 22. The mass-transfer results are listed for four combinations of wells along the inferred flow path. Path 1 has water from spoils well WDESP1 as the initial water and water from coal well WDED11 as the final water, path 2 has water from spoils well WDESP1 as the initial water and water from coal well WDESP2 as the final water, and path 3 has water from coal well WDESP2 as the initial water and water from coal well WDED11 as the final water. In addition, transfer was calculated along a fourth path, which included initial water from spoils well WDESP1 and mixing of water from an underlying coal bed and coal well WDED11 as the final water. When the results from paths 2 and 3 are added together, the sum generally should equal the results from path 1, excluding the isotopic ratios.

The computed mass transfer from the initial water to the final water (table 22) represents net millimoles of each phase entering (positive sign) or leaving (negative sign) a kilogram of water. For example, water from spoils well WDESP1 moving along path 2 to coal well WDESP2 (table 22) might evolve according to the following net reaction:

$$\text{Water from well WDESP1} \overbrace{+\ 17.5\ CH_2O + 5.64\ HFeO_2 + 10.0\ CaMgX}^{\text{phases entering solution}} \Rightarrow$$

$$\text{Water from well WDESP2}\ \underbrace{+\ 9.09\ CaCO_3 + 8.06\ Fe_{0.7}Mg_{0.3}CO_3\ + 8.38\ H_2S + 11.8\ CO_2\ + 10.0\ Na_2X}_{\text{phases leaving solution}} \qquad (18)$$

The principal calculated mass transfers (table 22) were the oxidation of organic matter, the corresponding production of CO_2 gas, the exchange of sodium ions in solution for calcium and magnesium ions, and the corresponding precipitation of calcite and magnesian siderite. Two separate plausible reactions were calculated for the sulfur "sink": production of H_2S gas, and the dissolution of goethite with the corresponding precipitation of iron sulfide. Most likely, the sulfur "sink" was a combination of H_2S production, which was detected, and precipitation of iron sulfide.

Most of the mass transfer was calculated to occur between spoils well WDESP1 and coal well WDESP2 (path 2, table 22), where water from the spoils aquifer flows into the coal aquifer, and where sulfate reduction and exchange of sodium ions for calcium or magnesium ions is initiated. Calculated mass transfer along the path from coal well WDESP2 to coal well WDED11 indicate the same processes; however, the magnitude of the mass transfer was less than between wells WDESP1 and WDESP2. The results considered to be most representative of the inferred flow path are those calculated for the entire path from spoils well WDESP1 to coal well WDED11, path 1 in table 22.

Exhibit 28

To use the isotopic data as an additional modeling constraint, the mass-transfer results and the Rayleigh distillation equations of Wigley and others (1978, 1979) were included in the geochemical model NETPATH (Plummer and others, 1991) to predict observed values of $\delta^{13}C$ and $\delta^{34}S$ at the downgradient wells (table 22). An example of these detailed calculations is given in the NETPATH manual (Plummer and others, 1991).

Comparison of the calculated and observed $\delta^{13}C$ values helps in determining whether the predicted reactions might represent plausible reactions. The calculated and observed results for $\delta^{13}C$ along path 1 (table 22) were similar and based on representative isotopic values for the reacting and product phases. The results indicate that the isotopically light carbon of the subbituminous coal (-29.5 and -28 ‰) was likely utilized as an energy source by the sulfate-reducing bacteria. The utilization of the carbon caused the $\delta^{13}C$ in the water to become increasingly light along the path from a $\delta^{13}C$ value of -0.8 ‰ in the initial water to a value of -9.4 ‰ in the final water. The input values of $\delta^{13}C$ (-29.5 and 28 ‰) for both sets of mass-transfer calculations for path 1 are within an acceptable range of values. However, for the separate halves of the path (paths 2 and 3), the $\delta^{13}C$ values needed for the calculated values to approximate the observed values were unrealistically heavy, -21 ‰, or light, -31 ‰ (table 22).

Additional carbon inputs were dissolved organic carbon (DOC) and methane (CH_4). Both DOC and CH_4 were assumed to contribute carbon as an energy source for sulfate reduction. However, concentrations of both were relatively small compared to the quantity of carbon from organic matter necessary for the reactions to occur as postulated and therefore were not included in the mass-transfer calculations.

Mass-transfer results indicate that a large quantity of organic matter was oxidized and a correspondingly large quantity of CO_2 gas was outgassed. Although the quantity of CO_2 gas calculated to be outgassing was large, the quantity might not be unreasonable. The aquifer was relatively shallow and contained highly fractured coal, the overburden had been removed or replaced by spoils, and test holes which could vent CO_2 gas had been drilled throughout the area. In addition, relatively large concentrations of CO_2 gas were observed in samples collected in the West Decker Mine area (table 12).

Sulfur-isotope results were used to provide an additional constraint in the mass-transfer modeling. Sulfur-isotope values ($\delta^{34}S$) changed from -0.2 ‰ in water from spoils well WDESP1 to 33.2 ‰ in water from coal well WDESP2, to 62.5 ‰ in water from coal well WDED11. For the October 1988 samples, the dissolved-sulfate concentration decreased from 1,100 mg/L in water from WDEPS1, to 250 mg/L in water from WDESP2, to 51 mg/L in water from WDED11. This change was postulated to be the result of bacterially mediated sulfate reduction and not necessarily the result of another process such as dilution. Thermodynamically, the reduction of sulfate in the presence of reduced carbon (subbituminous coal) should proceed to the virtual disappearance of sulfate throughout the aquifer.

The magnitude of sulfate reduction observed is not unlikely when compared to other studies. Laboratory experiments performed by Fritz and others (1989, p. 103) induced sulfate reduction by *Desulfovibrio desulfuricans* bacteria in anaerobic water with a known initial sulfate concentration. Results indicated that the loss of dissolved sulfate during reduction was paralleled by increasing $\delta^{34}S$ values in the remaining sulfate (fig. 13). Experiments conducted for 211 to 228 days showed the largest isotope enrichment, whereas an experiment conducted for 50 days showed less isotope enrichment. The dissolved-sulfate concentration and isotope data from wells WDESP1, WDESP2 and WDED11 plotted on figure 13 show a similar pattern of decreasing sulfate and increasing enrichment of $\delta^{34}S$, indicating the loss in sulfate likely was due to sulfate reduction. The data from the experiments by Fritz and others (1989) including initial and final sulfate concentrations and $\delta^{34}S$ values closely match the data from the three wells. The time for the sulfate-reduction reaction for the experiments, 50 to 228 days, probably is similar to the time needed to produce the sulfate-reduction results observed in the three wells. These data would appear to provide further support for the assumption that wells WDESP1, WDESP2, and WDED11 are along a flow path.

Results of initial mass-transfer modeling using observed data and assumed values for input resulted in calculated $\delta^{13}C$ values closely approximating the observed $\delta^{13}C$ values. However, these same input data, including a $^{34}\Delta$ of -41.2 ‰, resulted in calculated $\delta^{34}S$ values that were about twice the observed $\delta^{34}S$ values. For the calculated values to approximate the observed values for the entire inferred flow path, a $^{34}\Delta$ factor of about -20 ‰, or about one-half the observed value, was needed. Additional model hypotheses were made in an attempt to have both carbon and sulfur isotope constraints result in calculated values that approximated observed values.

One hypothesis was adding a source for mixing water along the inferred flow path, causing the decrease in sulfate to be a result of both dilution and reduction. A potential source of mixing water is upward leakage from the underlying Dietz 2 (Dz2) coal bed. Upward leakage of water from the Dz2 coal bed into the Anderson-Dietz 1 (A-Dz1) coal bed is conceivable either through abandoned test holes or by diffuse seepage when water levels in the Dz2

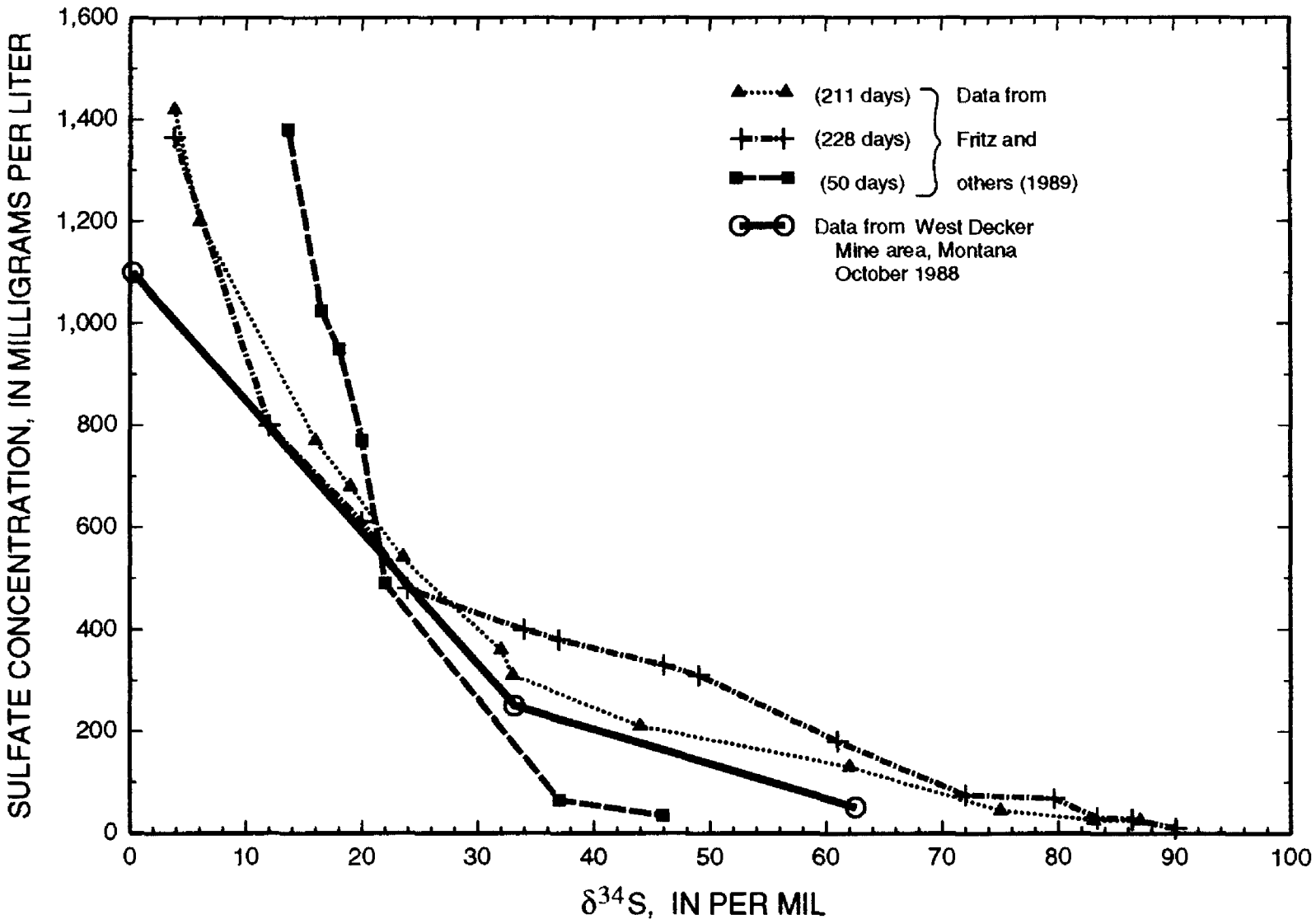


Figure 13. Relation of sulfate concentration in water to $\delta^{34}S$ values in residual sulfate after bacterial sulfate reduction.

coal bed were above the bottom of the A-Dz1 coal bed, and may have occurred during the late 1970's and early 1980's (Van Voast and Hedges, 1975, p. 14). Data from a ground-water flow model (Davis, 1984a) indicate the potential for a small quantity of premining vertical flow from the Dz2 to the A-Dz1 coal beds. Premining water-quality data from well WR-07 (tables 1 and 21) were considered to be representative of mixing water from the Dz2 coal bed. Isotopic values of $\delta^{13}C$ and $\delta^{34}S$ for the mixing water were assumed to be the same as the values from coal well WDED11, which contained the water with the smallest ion concentrations.

Mass-transfer model simulations were made with a range of mixing proportions, from about 10 percent Dz2 water and 90 percent spoils water to about 40 percent Dz2 water and 60 percent spoils water. Results from a model with 20 percent Dz2 water and 80 percent spoils water are given in table 22. When the results of path 4 are compared to path 1, a substantial decrease in the mass transfer of all reactant and product phases is indicated. In order for calculated values of $\delta^{13}C$ to match observed values, the addition of mixing water required changing the assumed $\delta^{13}C$ isotopic composition of the organic matter from -28 ‰ to -31 ‰, which is perhaps unrealistically light. Mixing the low-sulfate Dz2 water with the spoils water resulted in a slight change in the sulfur-isotope fractionation input factor from about -20 ‰ to about -23 ‰, which is still not close to the observed factor of -41.2 ‰. When a larger percentage of Dz2 water was used in the mixing models, the sulfur-isotope fractionation value that resulted was more negative, but the assumed $\delta^{13}C$ input value needed to be lighter and therefore even more unrealistic. Therefore, using mixing of waters in the mass-transfer models did not help solve problems related to the sulfur-isotope constraints.

Another possible explanation of the problem with the sulfur system is that water along the inferred flow path was not in chemical equilibrium. This explanation might mean that the sulfur concentration in the initial well, eventually reduced to the concentration in the final well, might have been considerably smaller than the observed 1,100 mg/L. However, results from mass-transfer models, wherein the sulfate concentration in the initial well was decreased from 1,100 to 500 mg/L or less, showed only a slight change in the sulfur-isotope fractionation factor and large discrepancies in the carbon-isotope results.

Exhibit 28

Mass-transfer models with isotopic constraints gave inconclusive results, especially with regard to the sulfur system. Observed and input data for the carbon-isotope system appear to be realistic; however, assumptions made about the sulfur system apparently are incomplete. If the sulfur-isotope fractionation factor were approximately -20 ‰ rather than -41.2 ‰, the model results would approximate observed results. Data in the literature support sulfur-isotope fractionation factors ranging from 0 to -65 ‰, and where the reaction is fast, kinetic fractionation is relatively small. However, no explanation is apparent as to why the observed difference between $\delta^{34}S$ of sulfide and sulfate was -41.2 ‰.

The most significant parameter in modeling error and inconsistency was $^{34}\Delta$, the sulfur-isotope fractionation factor, which was measured at only one of three wells along the flow path. In addition, unknowns about the $\delta^{13}C$ of the coal and the form of sulfide precipitate contributed to potential errors. Some parts of the modeling results, including the product and reactant phases, the proportions of the quantities transferred, and the carbon-isotope system, probably represent a reasonable solution to the geochemical processes that occurred along the inferred flow path. However, an almost unlimited number of small variations in isotopic composition, product phases, or minor changes in some analytical data due to uncertainties would also result in calculated values of $\delta^{13}C$ in close agreement with the observed values. Therefore, the calculated results are nonunique and semiquantitative. Possible reasons why the sulfur system could not be adequately modeled with observed data include that the water did not flow directly from the spoils aquifer to the coal aquifer without other influence, the water was not evolutionary, or additional isotopic data are needed to resolve the problem.

Verification of Results

Important phases in the mass-balance results were precipitation within the coal matrix of iron-sulfide minerals and the carbonate minerals, calcite and magnesian siderite. The quantity of either precipitate was likely very small in comparison to the mass of the coal matrix and therefore was difficult to confirm. The thermodynamic conditions and relatively short time frame probably equate to amorphous or microcrystalline mineral formation, making it unlikely that the quantities and size of precipitated iron-sulfide or carbonate minerals were large enough to be identified by standard techniques.

Minerals within fractures in the coal were extracted where possible, and analyzed by X-ray diffraction. Clay minerals were detected most frequently, including large quantities of almost pure crystalline kaolinite. In addition, significant quantities of pyrite, barite, and fibrous gypsum, apparently formed by the oxidation of microcrystalline pyrite, were found on the surface of the coal. In general, X-ray diffraction was not suitable for detecting the microscopic minerals expected to precipitate, primarily because of the lack of a method to extract the minerals from within the structure of the coal.

Scanning electron microscopy (SEM) also was used to quantify minerals precipitated within the coal. Thin sections prepared from coal having visible fracturing and from small fragments of coal affixed to slides were coated with a conducting layer of either carbon or gold for SEM analysis. Energy dispersive spectroscopy (EDS) was used to identify elements of non-organic material within the coal samples. Amorphous or microcrystalline minerals precipitated as a result of geochemical changes would likely be found in relatively porous areas of the coal such as fractures, cleats, or vugs. Therefore, SEM and EDS primarily were used to search cemented microscopic fractures for carbonate and iron-sulfide minerals. The SEM and EDS were used in an attempt to verify the existence of these minerals and not necessarily to quantify them.

A photomicrograph from SEM of a fracture in coal collected from well WDESP1 at a depth of 123 ft is shown in figure 14a and an enlargement of a section of that fracture is shown in figure 14b. The SEM was used with backscatter, which accentuates areas with heavy minerals such as iron sulfide. The lighter area around the fracture (fig. 14b) might be iron sulfide as the EDS graph for that area (fig. 14c) indicates a predominance of iron and sulfur. The physical structure of the material within the lighter area (fig. 14b) does not appear to be significantly different from the surrounding organic material, possibly indicating that the iron sulfide identified using EDS does not have a definite crystal structure but is instead amorphous. Similar SEM photomicrographs and EDS graphs indicating non-crystalline iron-sulfide were obtained for several other samples containing cemented fractures.

Carbonate-mineral precipitation was a major part of simulated water-quality changes along the inferred flow path. However, examples of precipitated calcite were difficult to locate and identify positively. If calcite did precipitate within the coal aquifer, the crystal form and association with organic or non-organic material would be unknown. Numerous samples observed using SEM and EDS contained crystals that were primarily calcium; however, these crystals were relatively large (5 to 20 µm) and not always within the structure of the coal. Other samples had non-organic material identified as predominantly silicon and calcium at various ratios, possibly indicating calcite associated with quartz. Examples of minerals containing both calcium and sulfur were fairly

Exhibit 28

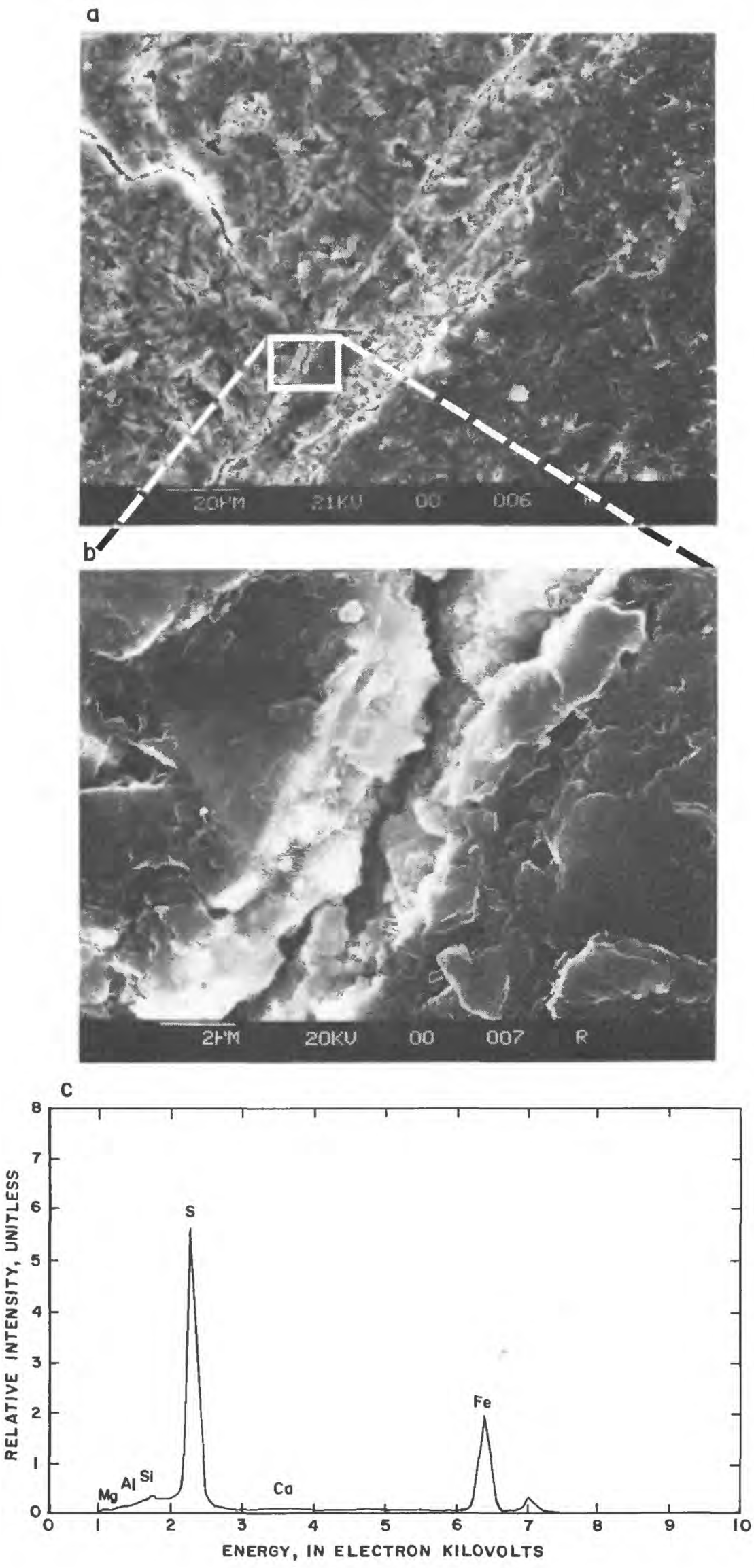


Figure 14. Photomicrographs (a,b) and graph showing elemental composition (c) of apparent amorphous iron-sulfide precipitate from a coal sample collected from the West Decker Mine area, Montana.

Exhibit 28

common, generally indicating gypsum; however, several samples contained ratios of calcium to sulfur substantially larger than the ratio expected for gypsum.

Several predominantly organic areas indicated by a large nondescript "hump" on the EDS graphs had substantial calcium associated with the organic material. Figure 15 shows an EDS graph of an area, about 2- to 4-µm in length, lining a small vug within the coal matrix of a sample collected from a depth of 123 ft in well WDED11. The figure shows that calcium and silicon are the predominant discernible ions within an organic matrix. In the center of a photomicrograph of another sample collected from well WDED11 at a depth of 123 ft is a 1-µm crystal (fig. 16). The crystal is most likely calcite; however, whether it was a primary or a secondary precipitate is unknown. Even though no definitive proof of secondary calcite precipitation as a result of mass transfer was found, there is substantial evidence from SEM and EDS of calcium within the coal that conceivably could be calcite.

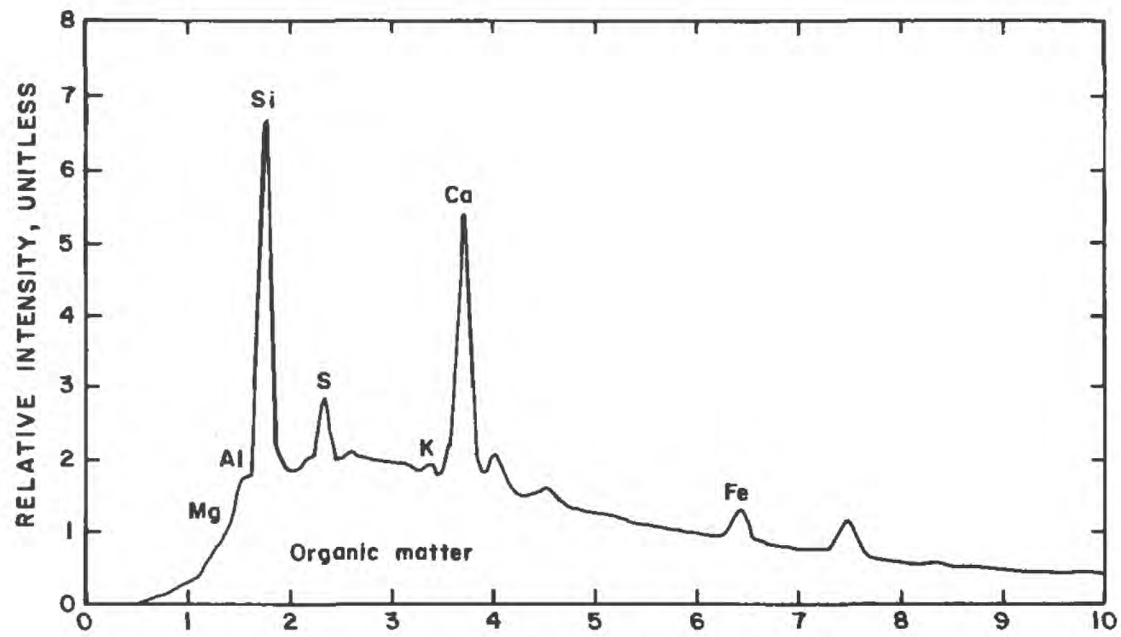


Figure 15. Elemental composition of apparent calcite crystal from a coal sample collected from the West Decker Mine area, Montana.

Processes Causing Geochemical Changes at the West Decker Mine Area

Processes postulated to cause geochemical changes in water as it moves along a potential flow path from the recharge area, to a spoils aquifer, and then to a downgradient coal aquifer at the West Decker Mine area are as follows:

1. Recharge Area
   - Entry of carbon dioxide into the system either by production in the soil or from the atmosphere.
   - Dissolution of carbonate minerals, primarily calcite and dolomite, resulting in an increase in the concentration of calcium, magnesium, and bicarbonate ions in solution.
   - Oxidation of pyrite, resulting in an increase in acidity and the concentration of sulfate ions in solution.
   - Precipitation of gypsum, or other salts, by evapotranspiration, resulting in an accumulation of sulfate minerals in the near-surface unsaturated zone.
2. Spoils Aquifer
   - Dissolution of gypsum, other salts, calcite, and dolomite resulting in a large increase in the concentration of dissolved solids.

Exhibit 28

- Cation exchange on clays in the spoils. Calcium and magnesium ions from dissolved gypsum and carbonate minerals exchange for sodium ions on clays, resulting in sodium bicarbonate or sodium sulfate type water. Exchange allows additional dissolution of gypsum and carbonate minerals.

3. Downgradient Coal Aquifer
   - Reverse cation exchange within the coal--exchange of sodium ions in solution for calcium and magnesium ions--which decreases sodium ion concentration and increases calcium and magnesium ion concentrations in solution.
   - Sulfate reduction by *Desulfovibrio desulfuricans* bacteria, with the production of H_2S and CO_2 gas and the use of coal as an energy source by the bacteria, resulting in large decreases in dissolved-sulfate concentrations.
   - Precipitation of calcium and iron-magnesium carbonate resulting in a decrease in bicarbonate concentration, and precipitation of iron sulfide as a sink for the sulfide produced by sulfate reduction.

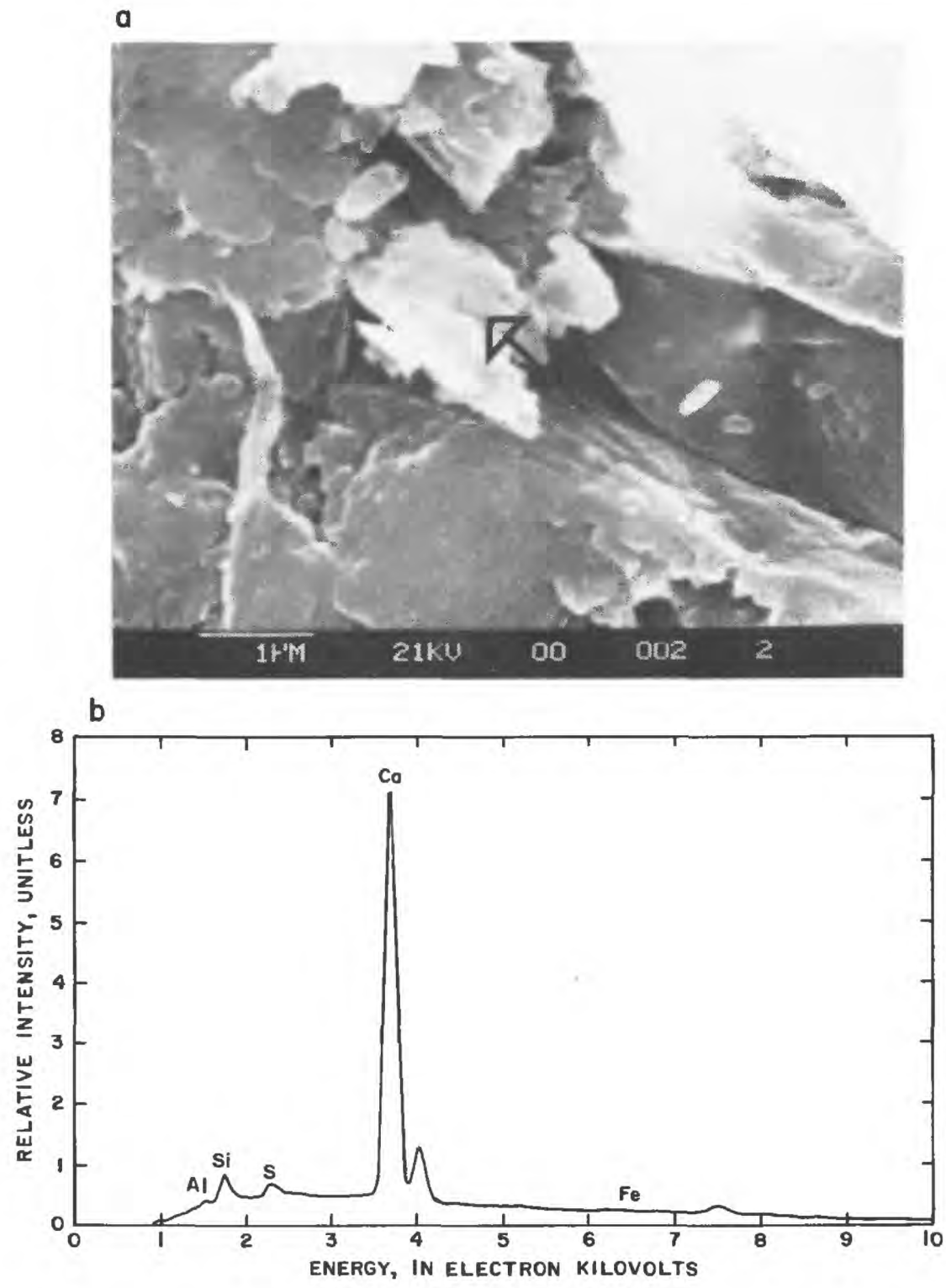


Figure 16. Photomicrograph (a) and graph showing elemental composition (b) of apparent calcite crystal from a coal sample collected from the West Decker Mine area, Montana. Arrow points to crystal.

Exhibit 28

The geochemical processes postulated to occur in the West Decker Mine area are the results of detailed sample collection and analysis. Even though the processes enumerated are thought to be those most likely occurring, they are considered nonunique and might not be the only feasible processes. Questions about the sulfate system and the $^{34}\Delta$ factor, the rate of sulfate reduction, the presence of sulfate and methane in the same water, the $\delta^{13}C$ of the coal, the large quantity of CO_2 apparently produced, the verifiable existence of secondary calcite and amorphous iron-sulfide precipitates in the coal, and other questions need to be resolved before the geochemical processes occurring in the system are fully understood.

IMPLICATIONS OF THE STUDY

Changes in ground-water chemistry along several inferred flow paths in two surface-coal mine areas of southeastern Montana were analyzed during this study. The two areas studied, the Big Sky and West Decker Mine areas, have distinct differences in mineralogy and ground-water geochemistry, and some differences in ground-water flow processes. Results indicate substantial increases in dissolved-solids concentrations as water flowed from an upgradient, offsite coal aquifer to a spoils aquifer. The general processes along the inferred flow paths from coal to spoils were similar at both areas and predominantly were the result of simple dissolution of soluble minerals such as gypsum, cation exchange within the spoils material, and potentially precipitation of carbonate minerals.

Changes in ground-water geochemistry also can occur when water flows from a spoils aquifer to a downgradient coal aquifer. Results differ substantially between the two study areas. At the Big Sky Mine area, only minor changes in dissolved-solids concentrations occurred along this path, whereas at the West Decker Mine area, large decreases in the concentration of several dissolved ions occurred along the inferred flow path. It is not fully understood why geochemical processes resulted in changes at the West Decker Mine area but not at the Big Sky Mine area. Probable reasons include differences in the mineralogy of the spoils material, age of the reclamation, differences in redox conditions, and bacterial reduction of sulfate.

Water at the Big Sky Mine area primarily was a calcium-magnesium sulfate type, whereas water at the West Decker Mine area was a sodium bicarbonate type, reflecting the mineralogy of the spoils material and coal in each area. Gypsum, calcite, and dolomite in the spoils and unmined material at the Big Sky Mine area were controlling factors on the geochemistry. At the West Decker Mine area, the sodic nature of the spoils material affected cation exchange processes, and thereby increased dissolved-sodium concentrations in the water in the spoils.

The primary processes involved in the decrease in dissolved-solids concentrations at the West Decker Mine area were: reverse cation exchange within the coal, bacterial reduction of sulfate and the consequent production of H_2S and CO_2 gas, and precipitation of carbonate or iron-sulfide minerals. These processes might not have occurred at the Big Sky Mine area for several reasons. Concentrations of dissolved sodium greatly exceeded those of calcium at the West Decker Mine area (table 11) allowing reverse cation exchange within the coal. At the Big Sky Mine area, however, concentrations of dissolved calcium were substantially larger than those of sodium, which negated the possibility of reverse exchange.

At the Big Sky Mine area, sulfate reduction was not a major geochemical process within the coal aquifer, even though dissolved-sulfate concentrations were large (table 11). Dissolved oxygen and sulfide concentrations varied, even between samples at the same well (table 11), indicating that oxidizing and reducing conditions might have alternately existed in the coal aquifer, thereby decreasing the opportunity for sulfate reduction. In addition, it is unknown if a viable population of sulfate-reducing bacteria existed in the coal aquifer at the Big Sky Mine area.

The results of this study include probable geochemical processes responsible for major decreases in concentrations of several dissolved ions as water flowed from a spoils aquifer into an unmined coal aquifer at the West Decker Mine area. The processes indicated by this study are assumed to include all major processes, although additional processes might occur. The saturated coal bed, where the major decreases occurred, was about 10 ft thick and 50 ft in length. The results of this study indicate that, under certain conditions, concentrations of certain dissolved ions in spoils water will decrease if allowed to flow into a layer of coal. Some of the geochemical conditions that would most likely result in large decreases in dissolved-solids concentrations are:

1. An indigenous population of sulfate-reducing bacteria.

2. Organic carbon that can be utilized as an energy source by the sulfate-reducing bacteria.

3. A source of iron that can assist in the removal of sulfide by precipitation of iron-sulfide minerals.

Exhibit 28

4. The capacity of the coal, or other organic-carbon source, to exchange sodium ions for calcium or magnesium ions in order to reduce concentrations of dissolved sodium ions and facilitate carbonate-mineral precipitation.

SUMMARY

A potential hydrologic effect of surface mining of coal in southeastern Montana is a change in the quality of ground water. Dissolved-solids concentrations in water in spoils aquifers generally are larger than concentrations in the coal aquifers they replaced; however, laboratory experiments have indicated that the concentrations might decrease if ground water flows from a spoils aquifer to a coal aquifer. This study was conducted to determine if the decreases indicated in laboratory results occur onsite and, if so, which geochemical processes caused the decreases. The Big Sky and West Decker Mine areas were chosen for study as both contain coal of the Tongue River Member of the Paleocene Fort Union Formation but have differences in mineralogy, ground-water quality, and flow processes.

Solid-phase drill-core samples of spoil, unmined overburden, and coal and ground-water samples were collected from 16 observation wells at the two mine areas. Observation wells were installed along inferred flow paths to obtain samples for quantifying possible geochemical changes as ground water flowed from an upgradient coal aquifer to a spoils aquifer, and from a spoils aquifer to a downgradient coal aquifer. Selected solid-phase samples were analyzed for elemental concentrations, exchangeable cations, and mineral constituents. Water samples were analyzed for major and trace constituents, selected isotopes, and dissolved gases. Equilibrium relations and mass-balance calculations were determined for water samples using geochemical models.

In the Big Sky Mine area changes in ground-water chemistry varied according to the inferred path studied. Along a path from the upgradient coal aquifer to the spoils aquifer, dissolved-solids concentrations increased from about 2,200 to 3,800 mg/L. These changes probably were a result of dedolomitization caused by the irreversible dissolution of gypsum at or near calcite-dolomite saturation. In contrast, along a path from the spoils aquifer to the downgradient coal aquifer, dissolved-solids concentrations were unchanged and concentrations of most dissolved ions were relatively small and probably not solely related to geochemical processes.

In the West Decker Mine area dissolved-solids concentrations increased substantially as water from an upgradient coal aquifer potentially flowed into a spoils aquifer. Increases in the concentration of dissolved sulfate and sodium most likely were the result of dissolution of gypsum followed by exchange of calcium or magnesium ions in solution for sodium ions on the smectite clays in the spoils aquifer. An increase in bicarbonate concentration was likely due to dissolution of calcite or dolomite.

Along an inferred flow path from a spoils aquifer to a downgradient coal aquifer at the West Decker Mine area dissolved-solids concentrations apparently decreased from about 4,100 to 2,100 mg/L. Apparent decreases in selected constituent concentrations included: sodium, from 1,500 mg/L to less than 900 mg/L; bicarbonate, from about 3,000 mg/L to less than 2,400 mg/L; and sulfate, from 1,100 mg/L to less than 100 mg/L. Data for solid-phase and aqueous geochemical characteristics, including types of reactive minerals, isotopic ratios, and dissolved-gas concentrations, were used to develop geochemical models to analyze changes in water chemistry. Geochemical processes postulated to result in the decrease in dissolved-solids concentration along this inferred flow path include: bacterial reduction of sulfate utilizing the organic matter in coal as an energy source; reverse cation exchange with sodium ions in solution exchanging for calcium and magnesium ions within the coal; and precipitation of carbonate and iron-sulfide minerals. Results of geochemical modeling were substantiated by solid-phase analysis and by applying Rayleigh distillation equations to the fractionation of carbon isotopes as an additional mass-balance constraint. Geochemical-modeling results using sulfur-isotope data as an additional constraint were inconclusive, implying that assumptions may have been incorrect or additional data were required. Even though these geochemical processes are thought to be the most likely to occur, they are considered nonunique and might not be the only feasible processes. In addition to sulfur-isotope data, questions about the rate of sulfate reduction, the isotopic composition of the coal, the large quantity of CO_2 produced, the existence of secondary carbonates and amorphous iron-sulfide minerals in the coal, and other potential questions need to be resolved before the actual geochemical processes occurring in the system are fully understood.

On the basis of results from this study, it can be assumed that concentrations of some dissolved ions in spoils water will decrease if allowed to flow to a coal bed under certain geochemical conditions. Some of the geochemical conditions most likely to result in large decreases in dissolved-solids concentration include a population of sulfate-reducing bacteria, organic carbon suitable for use by sulfate-reducing bacteria as an energy source, a source of iron to facilitate the precipitation of iron-sulfide minerals, and the capacity of the coal to exchange sodium ions in solution for calcium or magnesium ions.

Exhibit 28

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(Exhibit 28 follows)

Exhibit 28

SUPPLEMENTAL INFORMATION

Exhibit 28

Table 1. Records and water levels of observation wells from the Big Sky and West Decker Mine areas, Montana

[Site-identification numbering system described in text. Altitude of measuring point: Accuracy variation due to surveying method. Aquifer zone--Big Sky Mine area: R, Rosebud coal bed; Sr, spoils from mining of the Rosebud coal bed; Sm, spoils from mining of the McKay coal bed; Mc, McKay coal bed; sub-Mc, sandstone below the McKay coal bed; Se-Mc, stratigraphic equivalent of the McKay coal bed. West Decker Mine area: A-Dz1, combined Anderson-Dietz 1 coal bed; Sp, spoils from mining of the Anderson-Dietz 1 coal bed; Dz2, Dietz 2 coal bed]

Observation well no.	Site identification no.	Altitude of measuring point above sea level (feet)	Depth of well below land surface (feet)	Screened interval (feet)	Aquifer zone	Depth to water below measuring point (feet)	Altitude of water level above sea level (feet)	Date water level measured
			Big Sky Mine area					
BSUMR1	01N41E21DADB01	3,325.43	104	84-108	R	69.5	3,255.93	09-22-88
						68.79	3,256.64	10-05-88
						68.74	3,256.69	10-20-88
						68.54	3,256.89	04-19-89
						67.69	3,257.74	05-10-90
BSUMSP1	01N41E21DADA01	3,321.14	75	55-75	Sr	70.4	3,250.74	09-22-88
						67.13	3,254.01	10-20-88
						67.02	3,254.12	04-19-89
						67.03	3,254.11	05-10-90
BSUMSP2	01N41E21DADA02	3,322.94	78	58-78	Sr	65.37	3,257.57	10-04-88
						65.58	3,257.36	10-20-88
						65.59	3,257.35	04-19-89
						65.59	3,257.35	05-10-90
BSLMSP3	01N41E27ADDB01	3,261.34	50.5	32-50	Sm	35.63	3,225.71	10-05-88
						35.64	3,225.70	10-18-88
						35.38	3,225.96	04-19-89
						35.49	3,225.85	05-23-89
						35.42	3,225.92	05-09-90
BSLMSP1	01N41E27ADDB02	3,259.35	51	41-51	Sm	33.68	3,225.67	09-15-88
						33.76	3,225.59	10-05-88
						33.72	3,225.59	10-18-88
						33.68	3,225.67	04-19-89
						33.58	3,225.77	05-23-89
						33.49	3,225.86	05-09-90
BSLMMC1	01N41E27ADAC01	3,257.49	44.5	38-44	Mc	32.60	3,224.89	09-15-88
						32.69	3,224.80	10-05-88
						32.68	3,224.81	10-18-88
						32.58	3,224.91	04-19-89
						32.19	3,225.30	05-22-89
						32.44	3,225.05	05-09-90
BSLMMC2	01N41E27ADAC02	3,256.55	40.5	30-40	Mc	33.05	3,223.50	09-15-88
						33.18	3,223.37	10-05-88
						32.89	3,223.66	10-18-88
						32.46	3,224.09	04-19-89
						32.47	3,224.08	05-22-89
						32.19	3,224.36	05-09-90
BSLMMC3	01N41E27ADAC03	3,257.93	37	29-37	Mc	33.40	3,224.53	09-15-88
						33.49	3,224.44	10-05-88
						33.54	3,224.39	10-18-88
						33.36	3,224.57	04-19-89
						33.29	3,224.64	05-23-89
						33.28	3,224.65	05-09-90

Exhibit 28

Table 1. Records and water levels of observation wells from the Big Sky and West Decker Mine areas, Montana (Continued)

Observation well no.	Site identification no.	Altitude of measuring point above sea level (feet)	Depth of well below land surface (feet)	Screened interval (feet)	Aquifer zone	Depth to water below measuring point (feet)	Altitude of water level above sea level (feet)	Date water level measured
			Big Sky Mine area--Continued					
BSLMSM1	01N41E27ADAB01	3,233.09	62	52-62	sub-Mc	41.67	3,191.42	09-15-88
						41.66	3,191.43	10-05-88
						41.44	3,191.65	10-19-88
						40.85	3,192.25	04-19-89
						41.44	3,191.65	05-10-90
BSLMMC5	01N41E27ADAB02	3,232.11	22	12-22	Se-Mc	19.94	3,212.17	10-19-88
						19.45	3,212.66	04-19-89
						19.50	3,212.61	05-10-90
			West Decker Mine area					
WDFCL1	09S40E09DACD01	3,498.0	96	84-96	A-Dzl	82.25	3,415.75	10-26-88
						83.82	3,414.18	03-27-89
						84.12	3,413.88	05-10-89
						85.68	3,412.32	05-09-90
WDFSP3	09S40E09DACC01	3,492.5	94	83-94	Sp	83.7	3,408.8	09-12-88
						88.64	3,403.86	10-26-88
						87.56	3,404.94	03-27-89
						88.53	3,403.97	05-10-89
						90.17	3,402.33	05-09-90
WDFD12	09S40E09DDBC01	3,507.3	108	98-108	A-Dzl	100.49	3,406.8	10-26-88
						99.66	3,407.6	03-27-89
						99.77	3,407.5	05-10-89
						100.38	3,406.9	05-09-90
WDESP1	09S40E16BADC01	3,522.0	144	134-144	Sp	125.7	3,396.3	09-12-88
						124.49	3,397.5	10-25-88
						125.31	3,396.7	03-27-89
						125.39	3,396.6	05-10-89
						128.04	3,394.0	05-08-90
WDESP2	09S40E16BADC02	3,521.2	135	125-135	A-Dzl	126.8	3,394.4	09-12-88
						124.18	3,397.0	10-25-88
						125.08	3,396.1	03-27-89
						125.35	3,395.8	05-10-89
						128.24	3,393.0	05-08-90
WDED11	09S40E16BADC03	3,519.8	136	116-136	A-Dzl	123.1	3,396.7	09-12-88
						122.98	3,396.8	10-25-88
						124.05	3,395.8	03-27-89
						124.28	3,395.5	05-10-89
						127.6	3,392.2	05-08-90
WD 2225	09S40E09DBAD01	3,517	120	100-120	Sp	106.63	3,410	09-29-88
DS-5B	09S40E09DCAB02	3,506	140	100-140	Sp	96.28	3,410	09-10-88
						96.06	3,410	05-10-89
WR-01	09S40E16ABCA01	3,498	104	--	A-Dzl	103.22	3,395	05-10-89
WR-06	09S40E16ABCD01	3,499	135	115-135	A-Dzl	103.07	3,396	05-10-89
WR-07	09S40E16ABCD02	3,498	207	180-200	Dz2	107.12	3,391	05-10-89
DS-6A	09S40E16BABD01	3,515	157	142-154	Sp	112.76	3,402	05-10-89

Exhibit 28

Table 2. Summary of revised thermodynamic data

[Data from Nordstrom and others (1990) except where noted. Abbreviation: ΔH_r°, enthalpy of reaction; log K, equilibrium constant; Kcal/mol, kilocalorie per mole. Symbol: --, no data]

Mineral	Reaction	ΔH_r° (kcal/mol)	log K
Quartz	$SiO_2 + 2H_2O = H_4SiO_4$	5.99	-3.980
Calcite	$CaCO_3 = Ca^{3+} + CO_3^{2-}$	-2.297	-8.480
Aragonite	$CaCO_3 = Ca^{2+} + CO_3^{2-}$	-2.589	-8.336
Dolomite[1]	$CaMg(CO_3)_2 = Ca^{2+} + Mg^{2+} + 2CO_3^{2-}$	-9.436	-17.09
Strontionite	$SrCO_2 = Sr^{2+} + CO_3^{2-}$	-.40	-9.271
Siderite[2]	$FeCO_3 = Fe^{2+} + CO_3^{2-}$	--	-10.89
Gypsum	$CaSO_4 2H_2O = Ca^{2+} + SO_4^{2-} + 2H_2O$	-.109	-4.58
Anhydrite	$CaSO_4 = Ca^{2+} + SO_4^{2-}$	-1.71	-4.36
Celestite	$SrSO_4 = Sr^{2+} + SO_4^{2-}$	-1.037	-6.63
Barite	$BaSO_4 = Ba^{2+} + SO_4^{2-}$	6.35	-9.97
Goethite	$HFeO_2 + 3H^+ = Fe^{3+} + 2H_2O$	--	-1.0
FeS(ppt)[3]	$FeS = Fe^{2+} + S^{2-}$	--	[4]-3.915

[1]Thermodynamic data are for ordered dolomite.

[2]Thermodynamic data are for crystalline siderite.

[3]Amorphous iron-sulfide precipitate.

[4]Data from Plummer and others (1978).

Exhibit 28

Table 3. Logs of observation wells from the Big Sky and West Decker Mine areas, Montana

[Thickness penetrated is in feet. Bottom of depth interval is in feet below land surface]

Lithology	Thickness penetrated	Bottom of depth interval
Big Sky Mine area		
Observation well BSUMR1; drilled September 22, 1988		
Fill, topsoil	5	5
Mine spoils, gray, sandy	30	35
Mine spoils, sandy, clinker, calcareous	15	50
Mine spoils, grayish-green, sandy	17	67
Siltstone, gray	2	69
Sandstone, gray, very fine grained, calcareous	2	71
Sandstone; wet	12	83
Coal (Rosebud); water	21	104
Shale, gray; dry	1	105
Observation well BSUMSP1; drilled September 21, 1988		
Fill, topsoil, clinker, shale	5	5
Mine spoils, sandy; moist	5	10
Mine spoils, sandy, contains gravel, calcareous	12	22
Mine spoils, sand, clinker, coal; moist	38	60
Mine spoils, sand; wet	34	94
Shale	1	95
Observation well BSUMSP2; drilled September 21, 1988		
Mine spoils, sandy; moist	20	20
Mine spoils, sand, clinker, coal; moist	65	85
Mine spoils, sand; wet	12	97
Shale	1	98
Observation well BSLMSP3; drilled September 21, 1988		
Mine spoils, coal	10	10
Mine spoils, sand	10	20
Mine spoils, sandy, dark	5	25
Mine spoils, coal; wet	13	38
Mine spoils, siltstone, sandy, coal; water	12	50
Sandstone (sub-McKay)	.5	50.5
Observation well BSLMSP1; drilled September 13, 1988		
Mine spoils, clinker, coal	5	5
Mine spoils, sandy, calcareous	19	24
Mine spoils, sandy	8	32
Mine spoils; water	10	42
Mine spoils, coal, shale; water	7	49
Sandstone (sub-McKay)	2	51

Exhibit 28

Table 3. Logs of observation wells from the Big Sky and West Decker Mine areas, Montana (Continued)

Lithology	Thickness penetrated	Bottom of depth interval
Big Sky Mine area--Continued		
Observation well BSLMMC1; drilled September 13, 1988		
Mine spoils, yellowish-brown	10	10
Mine spoils, sand	5	15
Mine spoils, sand, rocks, brown	9	24
Mine spoils, sand, coal, clinker	8	32
Mine spoils, siltstone, sandy	3.5	35.5
Coal (McKay)	8.5	44
Sandstone (sub-McKay)	.5	44.5
Observation well BSLMMC2; drilled September 14, 1988		
Mine spoils	23	23
Siltstone, gray	6	29
Coal (McKay)	10	39
Sandstone (sub-McKay)	1.5	40.5
Observation well BSLMMC3; drilled September 14, 1988		
Mine spoils	5	5
Mine spoils, clinker	5	10
Mine spoils, calcareous	5	15
Siltstone, calcareous	3	18
Siltstone, grayish-green, calcareous	5	23
Siltstone, yellowish-brown, sandy	2	25
Organic, dark, non-coal	2.5	27.5
Coal (McKay)	9	36.5
Sandstone (sub-McKay)	.5	37
Observation well BSLMSM1; drilled September 14, 1988		
Fill, clinker	8	8
Shale, light-brown	5	13
Siltstone and sandstone, hard, red	2	15
Siltstone, sandy	15	30
Sandstone	7.5	37.5
Siltstone, gray, slightly calcareous (sub-McKay)	12.5	50
Siltstone, gray, some sand (sub-McKay)	5	55
Sand, gray (sub-McKay); water	7	62
Observation well BSLMMC5; drilled September 20, 1988		
Fill, clinker	5	5
Shale	14	19
Sandstone and siltstone, red; moist	1	20
Siltstone, gray	2	22

Exhibit 28

Table 3. Logs of observation wells from the Big Sky and West Decker Mine areas, Montana (Continued)

Lithology	Thickness penetrated	Bottom of depth interval
West Decker Mine area		
Observation well WDFCL1; drilled September 12, 1988		
Fill, shale and siltstone, calcareous	5	5
Mine spoils, clinker	4	9
Mine spoils, brown shale, calcareous	3	12
Mine spoils, coal and sand	24	36
Mine spoils, sand and clinker	1	37
Mine spoils, sand	2	39
Mine spoils, coal	2	41
Mine spoils, sand and coal	6	47
Clinker	13	60
Clinker, sandy; moist	7	67
Coal (Anderson-Dietz 1)	18	85
Coal (Anderson-Dietz 1), contains some pyrite; wet	10	95
Shale; dry	1	96
Observation well WDFSP3; drilled September 11, 1988		
Mine spoils	30	30
Mine spoils, gray siltstone, calcareous	5	35
Mine spoils, gray shale	17	52
Mine spoils, gray siltstone, calcareous	1	53
Mine spoils, coal and clinker	2	55
Mine spoils, gray shale	3	58
Mine spoils, contains some clinker	7	65
Mine spoils, gray shale	5	70
Mine spoils, coal, and siltstone, calcareous	4	74
Mine spoils, brown shale, clinker, and coal	6	80
Mine spoils, gray shale	4	84
Mine spoils; contains some coal	8	92
Shale	2	94
Observation well WDFD12; drilled September 10, 1988		
Mine spoils	25	25
Mine spoils; wet	2	27
Mine spoils, gray, calcareous; contains coal; dry	3	30
Mine spoils, brownish-gray	11	41
Mine spoils, siltstone, calcareous	8	49
Shale	5	54
Coal (Anderson-Dietz 1)	43	97
Coal (Anderson-Dietz 1); wet	10	107
Shale	1	108

Exhibit 28

Table 3. Logs of observation wells from the Big Sky and West Decker Mine areas, Montana (Continued)

Lithology	Thickness penetrated	Bottom of depth interval
West Decker Mine area--Continued		
Observation well WDESP1; drilled September 8, 1988		
Mine spoils	6	6
Mine spoils, calcareous	2	8
Mine spoils	5	13
Mine spoils, calcareous	2	15
Mine spoils, rocks, coal, calcareous	35	50
Mine spoils, coal	5	55
Mine spoils, gray siltstone, calcareous	10	65
Mine spoils, dark shale	18	83
Mine spoils, brown shale, calcareous	19	102
Mine spoils, gray siltstone, calcareous	2	104
Mine spoils, brown, soft	12	116
Mine spoils, rock	3	119
Mine spoils, gray, fine-grained	13	132
Mine spoils; water	7	139
Mine spoils, coal	3	142
Shale; dry	2	144
Observation well WDESP2; drilled September 10, 1988		
Mine spoils, fine-grained, slightly calcareous	45	45
Mine spoils; contains some coal	19	64
Mine spoils, powdery, contains some coal	31	95
Mine spoils; soft, coal	7	102
Coal (Anderson-Dietz 1)	32	134
Coal (Anderson-Dietz 1), pyrite	1	135
Shale	.5	135.5
Observation well WDED11; drilled September 9, 1988		
Mine spoils	11	11
Siltstone, yellowish-brown, slightly calcareous	7	18
Siltstone, gray, calcareous	3	21
Siltstone, brown	6	27
Shale, grayish-black	10	37
Siltstone, gray, calcareous	2	39
Shale, grayish-black	4	43
Siltstone, gray, calcareous	2	45
Shale, gray	17	62
Siltstone, gray, calcareous	2	64
Shale, gray	16	80
Coal (Anderson-Dietz 1)	50	130
Coal (Anderson-Dietz 1); water	5	135
Shale, whitish-brown; dry	1	136

Exhibit 28

Table 4. Petrographic analyses of selected core samples from mine spoils and unmined consolidated rock from the Big Sky and West Decker Mine areas, Montana

[Depth of sample: in feet below land surface. Symbol: --, no data]

Observation well no.	Depth of sample (feet)	General lithology	Major identifiable mineral (5 percent or more of total)	Minor identifiable mineral (less than 5 percent of total)
		Big Sky Mine area		
BSUMR1	68	Siltstone, clayey, coarse-grained.	Clay, dolomitic cement, quartz, fine-grained lithics, feldspar.	Muscovite, biotite, coalified debris.
BSUMR1	71	Sandstone, clayey, calcareous, very fine grained.	Quartz, dolomitic cement, fine-grained lithics, clay, biotite, feldspar.	Muscovite, glauconite, pyrite.
BSLMSP1	50	Sandstone, clayey, kaolinitic, very fine grained.	Fine-grained lithics, quartz, clay.	Feldspar, carbonates, biotite, muscovite, heavy minerals, glauconite.
BSLMMC2	28-29	Siltstone, clayey, calcareous, very fine grained.	Illite, carbonates, quartz/ feldspar, sericite, biotite.	--
BSLMMC3	21-23	Siltstone, clayey, calcareous, medium-grained.	Clay, carbonate cement, quartz/feldspar, muscovite.	Biotite.
BSLMSM1	13-15	Siltstone, and sandstone, containing iron,very fine grained.	Iron oxides, fine-grained lithics, quartz, carbonates.	Dolomite, feldspar, muscovite.
		West Decker Mine area		
WDFCL1	50-52	Siltstone, clayey, containing iron, fine-grained.	Quartz/feldspar, biotite, illite, carbonates, muscovite, hematite.	--
WDESP1	103	Siltstone, and sandstone, calcareous, fine-grained.	Dolomite, quartz/feldspar, chert, schist, fine-grained lithics.	Calcite, muscovite, biotite.
WDESP1	117-119	Siltstone, clayey, calcareous.	Illite, calcite, quartz/feldspar, organics.	Biotite, muscovite, framboidal pyrite.
WDED11	13	Siltstone, clayey, calcareous, fine-grained.	Illite, quartz/feldspar, muscovite, carbonates.	Manganese and iron oxides.

Exhibit 28

Table 5. Bulk mineralogy determined by X-ray diffraction analysis of samples of mine spoils and unmined consolidated rock from the Big Sky and West Decker Mine areas, Montana

[Depth of sample: in feet below land surface. Type of material: Ms, mine spoils; Um, unmined consolidated rock. Bulk mineralogy content: MA, most abundant, greater than 40 percent; A, abundant, 10-40 percent; C, common, 5-10 percent; M, minor, 1-5 percent; T, trace, less than 1 percent; ND, not detected. Other minerals: BA, barite; CE, celestite; GO, goethite; PY, pyrite; SD, siderite; SR, stronianite; TH, thenaderite. The detection limit using X-ray diffraction is about 1-2 weight percent. Symbols: --, no data; ?, probable detection]

Observation well no.	Depth of sample (feet)	Type of material	Bulk mineralogy										Other minerals
			Quartz	Calcite	Dolomite	Gypsum	Potassium feldspar	Plagioclase feldspar	Smectite	Muscovite/illite	Kaolinite	Chlorite	
Big Sky Mine area													
BSUMR1	68	Um	MA	M	A	ND	T	M	M	C	C	M	--
	71	Um	MA	T	A	ND	M	T	T	M	C	T	--
BSUMSP1	80	Ms	MA	C	C	ND	T	M	M	M	C	M	TH
BSLMSP3	45	Ms	MA	M	A	T	T	M	M	C	C	M	--
BSLMSP1	32	Ms	MA	M	A	ND	T	M	T	C	C	M	TH,SD?
	41	Ms	MA	T	C	ND	T	C	M	T	M	M	--
BSLMMC2	28	Um	A	ND	A	M	M	C	ND	C	C	C	TH, SR
BSLMMC3	18	Um	A	MA	A	ND	T	M	M	C	C	M	--
BSLMSM1	13	Um	MA	M	A	M	M	M	M	M	C	M	GO, PY
	50	Um	MA	C	A	ND	M	M	M	M	C	T	TH?
West Decker Mine area													
WDFCL1	50	Um	MA	ND	ND	ND	ND	C	ND	A	ND	ND	--
WDFSP3	72	Ms	MA	M	M	T?	T	C	M	C	C	M	--
	80	Ms	MA	C	C	ND	T	C	C	C	C	C	TH
	85	Ms	MA	C	C	ND	M	C	C	C	C	C	TH,SD?
WDESP1	13	Ms	MA	M	C	ND	M	C	M	C	C	M	TH,CE
	65	Ms	MA	A	C	ND	T	C	M	C	C	M	TH
	75	Ms	MA	M	C	ND	M	C	M	A	C	M	--
	103	Ms	MA	A	C	ND	M	A	M	C	C	M	--
	115	Ms	MA	M	A	ND	M	C	M	C	C	M	TH
	117	Ms	MA	M	C	ND	M	C	M	C	C	M	TH
	123	Ms	MA	C	C	ND	T	C	M	C	C	M	TH?
WDESP2	85	Ms	MA	M	C	T?	T	C	M	C	C	M	TH, SD?
WDED11	13	Um	MA	C	C	T?	M	C	C	C	C	C	--
	63	Um	MA	A	A	ND	M	C	M	M	C	M	BA

Table 6. Bulk mineralogy determined by X-ray diffraction analysis of the less than 2-micron size fraction from samples of mine spoils and unmined consolidated rock from the Big Sky and West Decker Mine areas, Montana

[Depth of sample: in feet below land surface. Type of material: Ms, mine spoils: Um, unmined consolidated rock. Bulk mineralogy content: MA, most abundant, greater than 50 percent; A, abundant, 20-50 percent; C, common, 10-20 percent; M, minor, 1-10 percent; T, trace, less than 1 percent; ND, not detected. Other minerals: CA, calcite; CL, iron chlorite; DO, dolomite; PL, plagioclase. The detection limit using X-ray diffraction is about 1-2 weight percent. Symbol: --, no data]

Observation well no.	Depth of sample (feet)	Type of material	Bulk mineralogy					Other minerals
			Smectite	Muscovite /illite	Kaolinite	Chlorite	Quartz	
			Big Sky Mine area					
BSUMR1	68	Um	A	M	MA	M	T	DO
BSLMSP1	32	Ms	M	A	MA	A	T	--
BSLMMC2	28	Um	ND	A	A	C	M	DO
BSLMMC3	21	Um	ND	A	MA	C	M	--
			West Decker Mine area					
WDFSP3	80	Ms	C	C	MA	M	M	--
WDESP1	13	Ms	A	C	MA	C	M	--
	75	Ms	MA	C	A	C	M	--
	103	Ms	MA	M	A	M	M	CA, DO
	117	Ms	A	C	MA	M	M	--
	123	Ms	A	C	A	C	M	CL
WDESP2	85	Ms	C	A	MA	C	T	--
WDED11	13	Um	A	A	A	C	M	CA, DO, PL

Exhibit 28

Table 7. Cation and trace-element concentrations in core samples from mine spoils and unmined consolidated rock from the Big Sky and West Decker Mine areas, Montana

[Analyses by Montana Bureau of Mines and Geology. Depth of sample: in feet below land surface. Type of material: Cl, clinker; Ms, mine spoils; Sh, shale; Slt, siltstone; Ss, sandstone]

Observation well no.	Depth of sample (feet)	Type of material	Concentration, in micrograms recovered per gram of solid										
			Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Silica (SiO_2)	Phosphorous (P)	Aluminum (Al)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)
						Big Sky Mine area							
BSUMR1	68	Slt	42,000	26,000	6,200	20,000	22,000	630	56,000	1,100	7.1	68	25
BSUMR1	71	Ss	36,000	22,000	5,700	17,000	14,000	610	48,000	650	4.9	72	13
BSUMSP1	80	Ms	38,000	15,000	5,600	17,000	8,000	510	48,000	280	5.8	54	12
BSLMSP3	45	Ms	37,000	21,000	4,700	21,000	12,000	570	58,000	580	5.8	54	12
BSLMSP1	32-34	Ms	38,000	25,000	6,200	21,000	25,000	650	57,000	1,400	5.2	89	20
	41-42	Ms	42,000	19,000	5,000	20,000	23,000	570	52,000	920	5.9	100	21
	49-50	Ss	4,800	8,500	5,600	21.000	6,000	880	65,000	330	3.6	81	28
BSLMMC2	28-29	Slt	32,000	30,000	6,400	29,000	35,000	570	75,000	1,800	6.5	78	32
BSLMMC3	18	Sh	190,000	21,000	4,100	15,000	41,000	450	39,000	2,000	4.9	43	23
	21-23	Slt	73,000	33,000	5,400	22,000	40,000	600	59,000	1.800	5.1	57	27
BSLMSM1	13-15	Slt, Ss	24,000	17,000	4,900	14,000	28,000	590	44,000	1,400	17	48	16
Median			38,000	21,000	5,600	20,000	23,000	590	56,000	1,100	5.8	72	13
						West Decker Mine area							
WDFCL1	50-52	Cl, Slt	29,000	14.000	9,900	26,000	37,000	1,000	91,000	1,700	10	93	56
WDFSP3	72-74	Ms	8,300	11,000	8,500	26,000	17,000	700	90,000	780	10	90	50
	80-82	Ms	26,000	15,000	8,300	24,000	15,000	810	80,000	660	6.3	79	46
WDESP1	103	Ms	130,000	16,000	9,000	12,000	44,000	570	48,000	2,200	8.9	49	50
	117-119	Ms	31,000	17,000	8,900	24,000	24,000	830	80,000	1,200	7.9	87	50
	123	Ms	30,000	16,000	9,900	23,000	36,000	840	80,000	1,700	8.0	120	48
WDESP2	85	Ms	25,000	16,000	8,300	23,000	26,000	860	82,000	1,200	7.2	85	47
WDED11	13-15	Slt	28,000	20,000	10,000	24,000	56,000	850	80,000	2,800	8.8	82	46
	63	Slt	110,000	21,000	8,600	12,000	41,000	540	49,000	2,200	5.0	81	41
Median			29,000	16,000	9,000	24,000	36,000	830	80,000	1,700	8.0	85	48

Exhibit 28

Table 7. Cation and trace-element concentrations in core samples from mine spoils and unmined consolidated rock from the Big Sky and West Decker Mine areas, Montana (Continued)

Observation well no.	Concentrations, in micrograms recovered per gram of solid										
	Iron (Fe)	Lead (Pb)	Lithium (Li)	Manganese (Mn)	Molybdenum (Mo)	Nickel (Ni)	Strontium (Sr)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)	Zirconium (Zr)
					Big Sky Mine area						
BSUMR1	20,000	43	25	340	16	23	77	1,700	77	59	66
BSUMR1	12,000	44	21	210	8.1	27	62	2,200	60	50	87
BSUMSP1	30,000	72	22	580	14	23	110	1,700	61	57	65
BSLMSP3	27,000	100	32	450	16	25	81	1,400	68	61	48
BSLMSP1	22,000	72	30	380	16	24	72	1,500	65	52	59
	22,000	62	28	420	14	25	93	1,300	63	53	56
	17,000	54	22	130	9	37	86	1,900	83	92	60
BSLMMC2	29,000	72	46	520	17	37	55	2,400	83	95	88
BSLMMC3	25,000	27	23	730	14	19	200	990	51	44	43
	27,000	53	33	670	14	27	110	2,100	74	70	89
BSLMSM1	130,000	47	14	1,300	14	45	74	1,700	60	83	68
Median	25,000	54	25	450	14	25	81	1,700	65	59	65
					West Decker Mine area						
WDFCL1	43,000	123	39	1,100	21	56	290	3,500	140	140	60
WDFSP3	24,000	50	43	280	24	42	170	3,100	140	110	75
	27,000	62	39	740	19	50	170	2,200	120	110	51
WDESP1	22,000	4.7	20	500	14	13	370	1,700	51	57	59
	39,000	83	38	1,000	13	41	190	2,500	130	97	65
	34,000	60	35	830	26	70	210	2,800	120	120	81
WDESP2	38,000	87	39	820	13	46	180	2,600	130	110	68
WDED11	56,000	83	40	1,200	22	47	340	2,100	140	120	71
	25,000	77	20	530	13	17	370	1,400	52	48	52
Median	34,000	77	39	820	19	46	200	2,500	130	110	65

Exhibit 28

Table 8. Exchangeable cations in core samples from mine spoils and unmined consolidated rock from the Big Sky and West Decker Mine areas, Montana

[Analyses by Montana Bureau of Mines and Geology. Depth of sample: in feet below land surface. Type of material: Ms, mine spoils; Slt, siltstone. Symbol: <, less than]

Observation well no.	Depth of sample (feet)	Type of material	Exchangeable cations, in micrograms per gram of solid									
			Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Silica (SiO_2)	Phosphorus (P)	Aluminum (Al)	Boron (B)	Cadmium (Cd)	Chromium (Cr)
Big Sky Mine area												
BSUMR1	68	Slt	2,400	380	20	78	250	<2	<0.6	1.6	<0.04	<0.04
BSLMSP1	32-34	Ms	3,900	850	110	35	170	<2	<.6	5.8	<.04	<.04
BSLMMC2	28-29	Slt	1,300	930	76	55	61	<2	<.6	2.3	<.04	<.04
BSLMMC3	21-23	Slt	4,800	420	38	37	45	<2	<.6	.83	<.04	<.04
West Decker Mine area												
WDFSP3	80-82	Ms	3,400	280	760	120	38	<2	<.6	.44	<.04	<.04
WDESP1	123	Ms	2,100	360	1,000	130	4.9	<2	<.6	<.4	<.04	<.04
WDESP2	85	Ms	2,200	330	750	110	33	<2	<.6	<.4	<.04	<.04
WDED11	13-15	Slt	2,700	830	1,300	100	37	<2	1.7	.82	.088	.048

Exhibit 28

Table 8. Exchangeable cations in core samples from mine spoils and unmined consolidated rock from the Big Sky and West Decker Mine areas, Montana (Continued)

Observation well no.	Exchangeable cations, in micrograms per gram of solid											
	Copper (Cu)	Iron (Fe)	Lead (Pb)	Lithium (Li)	Manganese (Mn)	Molybdenum (Mo)	Nickel (Ni)	Strontium (Sr)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)	Zirconium (Zr)
					Big Sky Mine area							
BSUMR1	0.50	0.12	<0.8	<0.04	12	<0.4	0.66	8.2	0.23	0.073	1.2	<0.08
BSLMSP1	.15	.17	<.8	<.04	4.6	<.4	<.2	11	.29	<.04	.24	<.08
BSLMMC2	.12	.17	<.8	.098	3.4	<.4	<.2	4.5	.11	<.04	.28	<.08
BSLMMC3	.14	.18	<.8	<.04	14	<.4	<.2	15	.33	.070	.11	<.08
					West Decker Mine area							
WDFSP3	.32	.096	<.8	.22	23	<.4	1.0	39	.25	<.04	.94	<.08
WDESP1	.21	.15	<.8	.12	17	<.4	.25	47	.17	<.04	.48	<.08
WDESP2	.23	.18	<.8	.12	19	<.4	.24	37	.14	<.04	.73	<.08
WDED11	.077	2.4	<.8	.35	4.8	<.4	<.2	81	.37	.11	<.06	.10

Exhibit 28

Table 9. Ash content and concentrations of selected major and minor oxides and selected trace elements in laboratory ash of coal samples from the Big Sky and West Decker Mine areas, Montana

[Analyses by U.S. Geological Survey, Branch of Geochemistry. Depth of sample: in feet below land surface. Coal ashed at 800 degrees Celsius. Source of coal: Mc, McKay; A-Dzl, combined Anderson-Dietz 1. Symbols: <, less than; >, greater than]

Observation or location well no.	Depth of sample (feet)	Source of coal	Ash content (percent)	Concentration in laboratory ash, in percent								
				Calcium (CaO)	Magnesium (MgO)	Sodium (Na_2O)	Potassium (K_2O)	Silica (SiO_2)	Phosphorous (P_2O_5)	Aluminum (Al_2O_3)	Iron (Fe_2O_3)	Titanium (TiO_2)
				Big Sky Mine area								
BSLMMC1	36-37	Mc	5.9	6.9	7.6	0.26	<0.06	26	<0.16	9.6	1.1	0.25
BSLMMC1	37-38	Mc	6.4	6.7	6.0	.23	.12	28	<.16	9.3	1.4	.48
BSLMMC2	37-39	Mc	2.6	11	8.6	.51	.11	8.8	<.16	6.6	5.7	.14
Mine wall[1]		Mc	6.1	6.6	5.8	.22	.27	21	<.16	4.7	.56	.25
				West Decker Mine area								
WDFCL1	87-88	A-Dz1	2.0	18	4.0	12	.40	1.1	.32	4.5	2.9	.57
WDFCL1	88-89	A-Dz1	2.2	20	4.5	10	.30	3.9	1.1	4.5	3.1	1.2
WDESP2	124-125	A-Dz1	2.4	15	4.3	12	.45	6.2	.32	3.2	1.2	1.4
WDESP2	133-134	A-Dz1	3.5	14	4.1	7.8	.25	11	.34	3.2	1.7	.62
WDED11	125	A-Dz1	2.3	17	3.7	12	.41	6.2	.30	2.5	1.1	.52
WDED11	129	A-Dz1	3.6	15	4.3	8.1	.22	11	1.6	3.8	1.7	1.5

[1]Sample collected from upgradient mine wall, Big Sky Mine.

Exhibit 28

Table 9. Ash content and concentrations of selected major and minor oxides and selected trace elements in laboratory ash of coal samples from the Big Sky and West Decker Mine areas, Montana (Continued)

Observation or location well no.	Concentration in laboratory ash, in percent													
	Barium (Ba)	Beryllium (Be)	Boron (B)	Cadmium (Ca)	Cerium (Ce)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Europium (Eu)	Gallium (Ga)	Germanium (Ge)	Holmium (Ho)	Lanthanum (La)	Lead (Pb)
Big Sky Mine area--Continued														
BSLMMC1	300	7.2	720	<22	<63	22	7.3	28	<0.7	.24	<5	<2	49	8.8
BSLMMC1	190	26	720	<22	80	21	37	100	2.9	40	51	<2	50	64
BSLMMC2	300	54	>1,000	<22	79	34	140	39	7.9	150	27	7.2	70	20
Mine wall[1]	130	31	550	<22	170	71	22	89	7.4	94	26	9.0	64	56
West Decker Mine area--Continued														
WDFCL1	17,000	2.0	680	<22	<63	28	18	34	<.7	32	<5	<2	<10	28
WDFCL1	13,000	2.2	550	<22	190	39	19	230	<.7	31	<5	<2	73	28
WDESP2	14,000	<2	420	<22	<63	35	17	440	<.7	33	<5	<2	32	23
WDESP2	11,000	2.0	380	<22	<63	44	19	84	<.7	24	<5	<2	29	28
WDED11	14,000	<2	540	<22	<63	29	16	33	<.7	34	<5	<2	30	26
WDED11	17,000	<2	300	<22	190	54	13	490	2.7	43	<5	<2	79	37

Exhibit 28

Table 9. Ash content and concentrations of selected major and minor oxides and selected trace elements in laboratory ash of coal samples from the Big Sky and West Decker Mine areas, Montana (Continued)

Observation or location well no.	Concentration in laboratory ash, in percent														
	Lithium (Li)	Manganese (Mn)	Molybdenum (Mo)	Nickel (Ni)	Niobium (Nb)	Samarium (Sm)	Scandium (Sc)	Silver (Ag)	Strontium (Sr)	Tin (Sn)	Vanadium (V)	Ytterbium (Yb)	Yttrium (Y)	Zinc (Zn)	Zirconium (Zr)
Big Sky Mine area--Continued															
BSLMMC1	72	290	10	34	6.3	6.4	8.3	0.22	2,100	<5	28	1.7	19	84	150
BSLMMC1	47	250	7.9	83	13	7.3	14	.32	2,800	5.9	49	7.7	64	60	260
BSLMMC2	<10	230	18	210	1.5	12	11	.20	6,600	10	33	11	170	110	88
Mine wall[1]	69	670	34	57	23	11	33	.33	1,000	7.7	110	16	180	460	340
West Decker Mine area--Continued															
WDFCL1	20	160	12	30	7.1	<4	24	.38	16,000	14	94	3.2	24	<15	120
WDFCL1	20	190	12	31	9.1	9.1	27	.61	23,000	<5	110	3.0	25	<15	150
WDESP2	31	150	13	24	14	<4	28	.55	14,000	<5	120	2.0	18	15	200
WDESP2	26	170	11	46	4.5	<4	35	.23	9,300	<5	120	2.6	27	<15	160
WDED11	29	130	14	19	3.3	<4	24	.26	18,000	8.8	88	1.7	13	140	130
WDED11	22	120	7.1	34	11	11	32	.81	15,000	11	130	3.1	24	<15	170

Exhibit 28

Table 10. Comparison of median values of ash content, selected major and minor oxides, and selected trace-element concentrations in laboratory ash of coal samples from the Big Sky and West Decker Mine areas, Montana, to analyses of coal samples from throughout the Powder River structural basin

[Symbol: <, less than]

	Concentration, in percent								Concentration, in parts per million				
	Ash	Calcium (CaO)	Magnesium (MgO)	Sodium (Na_2O)	Silica (SiO_2)	Aluminum (Al_2O_3)	Iron (Fe_2O_3)		Barium (Ba)	Copper (Cu)	Manganese (Mn)	Strontium (Sr)	Zinc (Zn)
Big Sky Mine area (4 samples)													
Median[1]	6.0	6.8	6.8	0.24	24	8.0	1.2	Median[1]	240	64	270	2,400	97
West Decker Mine area (6 samples)													
Median[1]	2.4	16	4.2	11	6.2	3.5	1.7	Median[1]	14,000	160	160	16,000	<15
Powder River Structural Basin (410 samples)													
Minimum[2]	3.2	.36	.28	.03	5.8	2.6	.39	Minimum[3]	100	24	100	150	15
Mean[2]	9.9	18	4.0	1.8	30	14	7.3	Mean[3]	3,000	110	510	2,000	200
Maximum[2]	85	49	12	8.7	69	30	77	Maximum[3]	20,000	760	4,430	7,000	2,200

[1]Calculated from table 9.

[2]Hatch and Swanson, 1977, p. 156.

[3]Recalculated from a whole-coal basis to a laboratory-ash basis, on the basis of the ash mean of 10 percent (Hatch and Swanson, 1977, p. 157).

Exhibit 28

Table 11. Properties and concentration of chemical constituents in water from observation wells in the Big Sky and West Decker Mine areas, Montana

[Aquifer zone--Big Sky Mine area: R, Rosebud coal bed; Sr, spoils from mining of the Rosebud coal bed; Sm, spoils from mining of the McKay coal bed; Mc, McKay coal bed; sub-Mc, sandstone below the McKay coal bed; Se-Mc, stratigraphic equivalent of the McKay coal bed. West Decker Mine area: A-Dzl, combined Anderson-Dietz 1 coal bed; Sp, spoils from mining of the Anderson-Dietz 1 coal bed. Laboratory analyses by Montana Bureau of Mines and Geology except as noted. Concentrations are dissolved except as noted. Abbreviations: µS/cm, microsiemens per centimeter at 25 °C; °C, degrees Celsius; ND, not detected. Symbols: --, no data; <, less than; >, greater than]

Observation well no.	Aquifer zone	Date of sample	Specific conductance (onsite) (µS/cm)	pH (onsite) (units)	Water temperature (onsite) (°C)	Concentration, in milligrams per liter							
						Dissolved oxygen (onsite)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (onsite) (HCO_3)	Bicarbonate (laboratory) (HCO_3)	Carbonate (CO_3)
						Big Sky Mine area							
BSUMR1	R	10-20-88	2,740	7.0	11.0	--	240	230	100	7.3	780	670	0
BSUMSP1	Sr	10-20-88	3,900	7.0	11.0	--	370	400	150	20	510	490	0
BSUMSP2	Sr	10-20-88	--	7.2	12.0	--	390	450	170	20	420	400	0
BSLMSP3	Sm	10-19-88	4,170	6.7	12.0	--	470	390	130	15	920	720	0
		05-23-89	4,000	6.5	13.0	0.35	470	390	120	14	910	900	0
		05-09-90	3,900	6.6	12.5	ND	460	390	130	16	960	880	0
BSLMSP1	Sm	10-18-88	3,780	6.5	12.0	--	460	410	130	15	930	820	0
		05-23-89	4,000	6.5	12.5	.5	470	410	130	15	930	900	0
		05-09-90	3,900	6.6	12.5	.05	450	390	130	15	950	880	0
BSLMMC1	Mc	10-18-88	3,800	6.5	12.0	--	440	420	130	11	1,000	940	0
		05-22-89	3,950	6.5	13.5	ND	450	430	120	10	970	950	0
		05-10-90	4,100	6.6	12.5	ND	450	430	130	11	980	940	0
BSLMMC2	Mc	10-18-88	3,800	6.5	12.0	--	440	420	140	9.6	930	860	0
		05-22-89	4,120	6.4	14.0	1.5	450	440	120	9.6	890	880	0
BSLMMC3	Mc	10-19-88	4,200	6.4	11.5	--	450	410	100	9.1	770	690	0
		05-22-89	4,050	6.3	13.5	.35	460	440	90	7.8	740	750	0
		05-10-90	4,000	6.4	12.5	--	440	430	110	9.7	780	740	0
BSLMSM1	sub-Mc	10-19-88	3,240	7.0	11.5	--	240	280	160	11	720	610	0
BSLMMC5	Se-Mc	10-19-88	5,100	7.2	12.5	--	600	480	150	9.7	460	430	0

Table 11. Properties and concentration of chemical constituents in water from observation wells in the Big Sky and West Decker Mine areas, Montana (Continued)

Observation well no.	Concentration, in milligrams per liter								Concentration, in micrograms per liter						
	Alkalinity (onsite) (as $CaCO_3$)	Sulfide (onsite) (H_2S)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (Fl)	Silica (SiO_2)	Dissolved solids, calculated	Nitrate (as N)	Aluminum (Al)	Aluminum[1] (Al)	Barium (Ba)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)
							Big Sky Mine area--Continued								
BSUMR1	638	0.13	1,200	6.3	0.3	18	2,150	0.13	80	<10	--	410	<2	17	15
BSUMSP1	418	.05	2,400	9.9	.2	17	3,630	.10	60	20	--	370	6	14	23
BSUMSP2	344	.03	2,700	10	.2	15	3,980	.11	60	20	--	330	<2	17	25
BSLMSP3	751	.15	2,400	16	.1	13	3,780	.19	60	10	--	970	8	18	25
	749	ND	2,200	17	<.1	14	3,680	.32	<30	--	13	830	7	15	<4
	790	ND	2,200	15	.1	14	3,710	.07	<40	--	<10	700	<5	<5	<4
BSLMSP1	761	.04	2,300	17	.1	13	3,790	.48	<30	10	--	1,100	<2	13	22
	761	ND	2,300	17	<.1	14	3,800	.39	<30	--	7	870	19	24	9
	776	ND	2,200	16	.1	14	3,630	.07	<40	--	<10	780	<5	<5	<4
BSLMMC1	769	.02	2,300	17	.2	15	3,780	.19	<30	20	--	1,700	<2	10	21
	793	.04	2,300	18	<.1	14	4,000	.39	<40	--	<1	1,400	<5	<5	<4
	804	.2	2,300	17	.2	15	3,800	<.05	<40	--	<10	1,200	<5	<5	<4
BSLMMC2	761	.1	2,300	18	.1	17	3,790	.07	<30	20	--	1,500	<2	6	19
	728	ND	2,300	17	<.1	16	3,830	.22	<40	--	1	1,200	<5	<5	<4
BSLMMC3	630	.05	2,400	18	.1	26	3,770	.13	<30	30	--	1,300	<2	3	14
	610	.19	2,400	17	<.1	25	3,840	.39	60	--	3	1,000	7	<5	<4
	641	ND	2,400	16	.2	24	3,810	.07	<40	--	<10	950	<5	<5	<4
BSLMSM1	590	.05	1,600	10	.2	18	2,580	.10	50	20	--	380	<2	14	20
BSLMMC5	377	.04	3,300	21	.1	20	4,750	2.1	100	20	--	2,200	<2	23	48

Exhibit 28

Table 11. Properties and concentration of chemical constituents in water from observation wells in the Big Sky and West Decker Mine areas, Montana (Continued)

Observation well no.	Concentration, in micrograms per liter														
	Iron, total (onsite) (Fe)	Iron (Fe)	Iron[1] (Fe)	Iron, ferrous (onsite) (Fe)	Lithium (Li)	Manganese (Mn)	Manganese[1] (Mn)	Molybdenum (Mo)	Nickel (Ni)	Silver (Ag)	Strontium (Sr)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)	Zirconium (Zr)
Big Sky Mine area--Continued															
BSUMR1	80	22	40	40	40	340	260	<20	20	11	7,800	18	20	10	24
BSUMSP1	60	16	40	40	48	2,500	2,100	50	32	12	4,400	83	78	130	190
BSUMSP2	30	11	40	10	51	2,000	1,700	90	40	15	4,200	18	23	78	29
BSLMSP3	--	16	40	70	71	940	650	<20	28	12	11,000	16	22	7	22
	30	4	--	ND	68	1,100	--	<40	42	7	11,000	<4	11	24	11
	15	27	--	ND	69	1,100	--	<40	<20	<4	11,000	28	9	<6	<6
BSLMSP1	120	110	90	80	70	870	620	<20	19	7	12,000	15	17	19	12
	250	63	--	250	69	880	--	<40	60	30	10,000	5	36	23	42
	250	140	--	250	71	820	--	<40	<20	<4	11,000	32	11	<6	<6
BSLMMC1	200	100	90	130	54	210	160	<20	20	3	13,000	15	15	15	<4
	300	150	--	300	50	220	--	<40	37	4	11,000	<4	6	14	<6
	300	250	--	300	59	230	--	<40	<20	<4	12,000	29	10	<6	<6
BSLMMC2	>2,000	1,800	1,900	>2,000	46	180	150	<20	18	<2	14,000	15	12	24	<4
	14,000	2,400	--	1,800	46	190	--	<40	43	9	12,000	<4	9	54	11
BSLMMC3	--	6,800	6,700	>2,000	76	490	370	<20	19	<2	12,000	11	5	13	<4
	8,800	6,400	--	7,200	69	520	--	<40	42	11	10,000	<4	17	30	13
	8,000	6,100	--	4,800	70	540	--	<40	<20	<4	11,000	32	11	<6	<6
BSLMSM1	>2,000	1,200	1,000	1,200	57	60	50	<20	25	13	8,100	19	20	12	26
BSLMMC5	50	20	60	30	85	90	60	23	44	19	4,400	17	28	9	38

Exhibit 28

Table 11. Properties and concentration of chemical constituents in water from observation wells in the Big Sky and West Decker Mine areas, Montana (Continued)

Observation well no.	Aquifer zone	Date of sample	Specific conductance (onsite) (µS/cm)	pH (onsite) (units)	Water temperature (onsite) (°C)	Concentration, in milligrams per liter							
						Dissolved oxygen (onsite)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (onsite) (HCO_3)	Bicarbonate (laboratory) (HCO_3)	Carbonate (CO_3)
West Decker Mine area													
WDFCL1	A-Dz1	10-26-88	2,200	6.7	14.0	ND	7.5	2.5	560	3.9	1,360	1,260	0
WDFSP3	Sp	10-26-88	8,000	7.1	13.0	--	98	46	1,900	24	3,150	2,560	0
WDFD12	A-Dz1	10-26-88	3,310	7.1	13.5	ND	16	4.7	850	5.8	2,210	2,090	0
WDESP1	Sp	10-25-88	6,150	7.1	14.0	ND	42	30	1,500	14	3,080	2,940	0
		05-11-89	7,500	7.1	17.5	.6	59	47	1,700	19	3,330	3,260	0
		05-08-90	7,000	7.2	15.5	.5	48	35	1,500	16	3,080	3,000	0
WDESP2	A-Dz1	10-25-88	4,080	7.5	15.0	ND	19	8.3	1,000	8.0	2,680	2,480	0
		05-11-89	4,650	7.2	17.0	--	24	12	1,100	9.5	2,890	2,760	0
		05-09-90	3,800	7.3	12.5	--	21	9.4	1,000	9.1	2,620	2,580	0
WDED11	A-Dz1	10-25-88	3,150	7.2	15.0	ND	12	4.5	890	6.0	2,390	2,330	0
		05-11-89	3,550	7.4	15.0	--	13	5.2	850	6.7	2,340	2,220	0
		05-08-90	3,600	7.6	12.5	--	14	6.2	920	7.7	2,450	2,330	0

Exhibit 28

Table 11. Properties and concentration of chemical constituents in water from observation wells in the Big Sky and West Decker Mine areas, Montana (Continued)

Observation well no.	Concentration, in milligrams per liter								Concentration, in micrograms per liter						
	Alkalinity (onsite) (as $CaCO_3$)	Sulfide (onsite) (H_2S)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (Fl)	Silica (SiO_2)	Dissolved solids, calculated	Nitrate (as N)	Aluminum (Al)	Aluminum[1] (Al)	Barium (Ba)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)
							West Decker Mine area--Continued								
WDFCL1	1,100	0.18	200	9.5	3.4	22	1,430	0.12	<30	30	--	90	<2	<2	<2
WDFSP3	2,580	.03	2,400	14	.1	8.0	5,720	.30	<30	20	--	110	<2	<2	<2
WDFD12	1,810	.08	190	15	2.6	13	2,130	.26	<30	40	--	90	<2	<2	<2
WDESP1	2,520	.05	1,100	18	.4	13	4,120	.17	<30	20	--	80	<2	<2	<2
	2,730	ND	1,200	52	.9	14	4,710	<.01	<30	--	<1	60	<5	<5	<4
	2,520	ND	1,000	42	1.2	15	4,170	.11	220	--	37	80	<5	<5	<4
WDESP2	2,200	.26	250	18	1.8	13	2,590	.10	<30	<10	--	90	<2	<2	<2
	2,370	8.0	220	18	1.7	16	2,760	<.07	<40	--	150	70	<5	<5	<4
	2,150	1.2	200	17	2.2	16	2,560	.04	160	--	180	120	<5	<5	<4
WDED11	1,960	.28	51	15	2.0	14	2,140	.19	<30	30	--	60	<2	<2	<2
	1,920	.68	64	14	1.9	15	2,060	.23	100	--	670	70	<5	<5	<4
	2,010	2.0	90	15	2.6	17	2,220	.13	85	--	450	100	<5	<5	<4

Exhibit 28

Table 11. Properties and concentration of chemical constituents in water from observation wells in the Big Sky and West Decker Mine areas, Montana (Continued)

Observation well no.	Concentration, in micrograms per liter														
	Iron, total (onsite) (Fe)	Iron (Fe)	Iron[1] (Fe)	Iron, ferrous (onsite) (Fe)	Lithium (Li)	Manganese (Mn)	Manganese[1] (Mn)	Molybdenum (Mo)	Nickel (Ni)	Silver (Ag)	Strontium (Sr)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)	Zirconium (Zr)
West Decker Mine area--Continued															
WDFCL1	250	90	80	150	120	4	10	<20	<10	<2	490	<1	<1	23	<4
WDFSP3	80	40	50	50	510	360	260	<20	<10	<2	6,400	<1	<1	4	<4
WDFD12	510	180	140	200	180	30	40	<20	<10	<2	810	<1	<1	<3	<4
WDESP1	60	120	140	50	350	80	70	<20	<10	<2	3,500	<1	<1	23	<4
	1,200	57	--	220	440	95	--	<40	<20	<4	4,000	<4	<4	25	<6
	--	990	--	--	460	94	--	<40	<20	<4	3,900	<4	<4	19	<6
WDESP2	1,200	70	10	170	240	10	10	<20	<10	<2	1,200	<1	<1	16	<4
	350	420	--	350	280	17	--	<40	<20	<4	1,300	<4	<4	11	<6
	--	300	--	--	300	27	--	<40	<20	<4	1,300	<4	<4	<6	<6
WDED11	--	30	50	--	190	3	20	<20	<10	<2	820	<1	<1	<3	<4
	250	180	--	250	200	7	--	<40	<20	<4	790	<4	<4	<6	<6
	200	160	--	100	240	6	--	<40	<20	<4	950	<4	<4	<6	<6

[1]Analyses by U.S. Geological Survey, filtered through 0.10 micrometer membrane filter.

Exhibit 28

Table 12. Results of analyses for dissolved gases in ground water from the Big Sky and West Decker Mine areas, Montana

[Analyses by U.S. Geological Survey. Abbreviations: °C, degrees Celsius; T, trace present; ND, not detected]

Observation well no.	Date of sample	Onsite temperature (°C)	Partial pressure of dissolved gas, in atmospheres at onsite temperature						Concentration of dissolved gas, in milligrams per liter					
			Nitrogen (N_2)	Argon (Ar)	Oxygen (O_2)	Carbon dioxide (CO_2)	Methane (CH_4)	Ethane (C_2H_6)	Nitrogen (N_2)	Argon (Ar)	Oxygen (O_2)	Carbon dioxide (CO_2)	Methane (CH_4)	Ethane (C_2H_6)
						Big Sky Mine area								
BSUMR1	10-20-88	11.0	0.75	0.008	0.023	0.037	ND	ND	17	0.60	1.2	84	ND	ND
BSUMSP2	10-20-88	12.0	.77	.010	.036	.012	ND	ND	18	.68	1.9	26	ND	ND
BSLMSP1	10-18-88	12.0	.89	.010	T	.13	0.001	ND	20	.71	T	290	0.023	ND
BSLMMC1	10-18-88	12.0	.84	.009	T	.12	ND	ND	19	.67	T	260	ND	ND
BSLMMC2	10-18-88	12.0	.77	.009	T	.15	ND	ND	17	.64	T	330	ND	ND
						West Decker Mine area								
WDFCL1	10-26-88	14.0	.76	.009	T	.10	.002	ND	16	.59	T	210	.060	ND
WDFD12	10-26-88	13.5	.62	.008	T	.10	.032	ND	14	.51	T	210	.89	ND
WDESP1	10-25-88	14.0	.87	.011	T	.14	.012	ND	19	.73	T	280	.32	ND
WDESP2	10-25-88	15.0	.54	.007	T	.055	.33	0.001	11	.47	T	110	8.8	0.089
WDED11	10-25-88	15.0	.65	.008	T	.026	.25	.001	14	.53	T	51	6.6	.069

Exhibit 28

Table 13. Isotopic ratios for oxygen, hydrogen, carbon, and sulfur and activity of tritium in water samples from observation wells at the Big Sky and West Decker Mine areas, Montana

[Analyses by U.S. Geological Survey. Aquifer: R, Rosebud coal bed; Sr, spoils from mining of the Rosebud coal bed; Sm, spoils from mining of the McKay coal bed; Mc, McKay coal bed; A-Dz1, combined Anderson-Dietz 1 coal bed; Sp, spoils from mining of the Anderson-Dietz 1 coal bed. Abbreviations: $\delta^{18}O$, oxygen-18/oxygen-16 isotopic ratio; δD, deuterium/hydrogen isotopic ratio; $\delta^{13}C$, carbon-13/carbon-12 isotopic ratio; $\delta^{34}S$, sulfur-34/sulfur-32 isotopic ratio; TU, tritium units. Symbol: --, no data]

Observation well no.	Aquifer	Date of sample	Isotopic ratio, in per mil					Tritium (TU)[2]
			Oxygen ($\delta^{18}O$)[1]	Hydrogen (δD)[1]	Carbon ($\delta^{13}C$)[1]	Sulfur		
						Sulfate (SO_4) ($\delta^{34}S$)[1]	Sulfide (H_2S) ($\delta^{34}S$)[1]	
			Big Sky Mine area					
BSUMR1	R	10-20-88	-19.20	-151.5	-3.6	5.0	--	5.7
BSUMSP2	Sr	10-20-88	-18.85	-148.5	-5.8	4.7	--	64
BSLMSP1	Sm	10-18-88	-17.65	-139.5	-6.2	1.4	--	36
BSLMMC1	Mc	10-20-88	-17.65	-140.0	-6.4	1.2	--	38
BSLMMC2	Mc	10-20-88	-17.60	-140.0	-6.7	.9	--	40
			West Decker Mine area					
WDFCL1	A-Dz1	10-26-88	-19.85	-154.0	-3.4	2.6	--	33
WDFD12	A-Dz1	10-26-88	-19.25	-151.0	2.7	8.0	--	18
WDESP1	Sp	10-25-88	-19.00	-151.5	-.8	-.2	--	10
WDESP2	A- Dz1	10-25-88	-19.75	-155.5	-8.8	33.2	--	11
	A- Dz1	05-11-89	--	--	--	36.4	-4.8	--
WDED11	A-Dz1	10-25-88	-20.00	-156.5	-9.4	62.5	--	8.0

[1]Per mil values of $\delta^{18}O$ and δD are reported relative to Vienna-SMOW (Standard mean ocean water). $\delta^{13}C$ and $\delta^{34}S$ are in per mil relative to the PDB (Peedee belemnite) and CDT (Canyon Diablo troilite) standards, respectively.

[2]One TU is one atom of tritium in 10^{18} atoms of hydrogen.

Exhibit 28

Table 14. Results of thermodynamic calculations for water from aquifers at the Big Sky Mine area, Montana

[Abbreviation: Log P_{CO_2}, logarithm of the partial pressure of carbon dioxide; FeS-ppt, amorphous iron-sulfide precipitate. Symbols: --, concentration of barium less than minimum reporting level; -, not calculated]

Observation well no.	Date of sample	Calculated log P_{CO_2}	Saturation Index											
			Quartz (SiO_2)	Calcite ($CaCO_3$)	Aragonite ($CaCO_3$)	Dolomite [$CaMg(CO_3)_2$]	Strontianite ($SrCO_3$)	Siderite ($FeCO_3$)	Gypsum ($CaSO_4 \cdot 2H_2O$)	Anhydrite ($CaSO_4$)	Celestite ($SrSO_4$)	Barite ($BaSO_4$)	Goethite ($HFeO_2$)	FeS-ppt
BSUMR1	10-20-88	-1.23	0.69	0.24	0.09	0.56	-0.71	-1.41	-0.47	-0.72	-0.25	--	6.95	-1.90
BSUMSP2	10-20-88	-1.75	.60	.26	.11	.72	-1.16	-2.05	-.12	-.37	-.37	--	7.79	-4.40
BSUMSP1	10-20-88	-1.51	.66	.26	.04	.52	-1.19	-1.56	-.16	-.41	-.37	--	6.99	-3.57
BSLMSP3	10-19-88	-.87	.53	.19	.03	.41	-.91	-1.74	-.08	-.34	.00	--	6.67	-2.43
	05-23-89	-.67	.54	.01	-.14	.07	-1.11	-2.86	-.11	-.36	-.04	0.20	-.90	-
	05-09-90	-.77	.54	.14	-.01	.34	-.95	-1.89	-.11	-.36	-.02	--	.30	-
BSLMSP1	10-18-88	-.69	.54	.01	-.14	.09	-1.06	-1.54	-.10	-.35	.01	--	6.83	-3.43
	05-23-89	-.69	.56	.03	-.13	.13	-1.17	-1.66	-.10	-.36	-.05	-.05	6.28	-
	05-09-90	-.78	.54	.14	-.02	.33	-.96	-1.33	-.11	-.36	-.02	--	7.49	-
BSLMMC1	10-18-88	-.69	.59	.06	-.10	.21	-.94	-1.46	-.13	-.38	-.05	--	6.55	-4.21
	05-22-89	-.71	.54	.08	-.07	.30	-1.01	-1.21	-.14	-.39	-.04	--	6.49	-2.60
	05-10-90	-.82	.57	.18	.03	.47	-.86	-.88	-.13	-.38	.01	--	6.23	-1.38
BSLMMC2	10-18-88	-.71	.64	.01	-.14	.11	-.97	-.18	-.12	-.37	-.08	--	7.84	-1.28
	05-22-89	-.61	.60	-.08	-.24	-.03	-1.16	-.28	-.12	-.37	.00	-.93	8.42	-
BSLMMC3	10-19-88	-.72	.83	-.15	-.30	-.23	-1.17	.25	-.10	-.35	.06	--	7.80	-1.16
	05-22-89	-.61	.78	-.24	-.40	-.36	-1.37	.10	-.10	-.35	-.03	-.43	8.25	-.60
	05-10-90	-.70	.79	-.14	-.29	-.16	-1.20	.21	-.12	-.37	.01	--	7.62	-
BSLMSM1	10-19-88	-1.30	.68	.19	.04	.57	-.74	.02	-.43	-.68	-.18	--	8.24	-1.27
BSLMMC5	10-19-88	-1.69	.72	.45	.30	.94	-1.15	-1.57	.08	-.17	-.33	--	7.76	-4.75

Exhibit 28

Table 15. Simulated mass-transfer results for flow from the Rosebud coal aquifer to the spoils aquifer at the Big Sky Mine area, Montana

[Transfer is negative for precipitation or degassing, positive for dissolution. Ion exchange: calcium ion exchanged for sodium ion]

Observation well no.		Date	Millimoles per kilogram of water				
Initial water	Final water		Calcite	Dolomite	Gypsum	Ca/Na ion exchange	Carbon dioxide (gas)
BSUMR1	BSUMSP2	10-20-88	-20.1	9.14	15.9	1.36	-6.08
BSUMR1	BSUMSP1	10-20-88	-15.5	6.95	12.7	1.01	-4.22

Exhibit 28

Table 16. Results of thermodynamic calculations for water from aquifers at the West Decker Mine area, Montana

[Aquifer zone: A-Dz1, combined Anderson-Dietz 1 coal bed; Sp, spoils from mining of the Anderson-Dietz 1 coal bed. Abbreviations: Log P_{CO_2}, logarithm of the partial pressure of carbon dioxide; FeS-ppt, amorphous iron-sulfide precipitate. Symbols: --, concentration of barium less than minimum reporting level; -, not calculated]

Observation well no.	Aquifer zone	Date of sample	Calculated log P_{CO_2}	Saturation Index: Quartz (SiO_2)	Calcite ($CaCO_3$)	Aragonite ($CaCO_3$)	Dolomite [$CaMg(CO_3)_2$]	Strontianite ($SrCO_3$)	Siderite ($FeCO_3$)	Gypsum ($CaSO_4 \cdot 2H_2O$)	Anhydrite ($CaSO_4$)	Celestite ($SrSO_4$)	Barite ($BaSO_4$)	Goethite ($HFeO_2$)	FeS-ppt
WDFCL1	A-Dz1	10-26-88	-0.67	0.71	-1.10	-1.25	-2.53	-1.73	-0.71	-2.48	-2.74	-1.93	--	-1.38	-1.42
WDFSP3	Sp	10-26-88[1]	-.71	.31	.38	.23	.56	-.13	-.52	-.80	-1.07	-.14	--	8.15	-2.12
WDFD12	A-Dz1	10-26-88	-.86	.50	-.24	-.40	-.89	-1.00	.07	-2.26	-2.53	-1.85	--	-.51	-.91
WDESP1	Sp	10-25-88	-.75	.51	.16	.01	.34	-.32	-.37	-1.37	-1.64	-.67	--	8.12	-1.92
		05-11-89	-.70	.49	.36	.21	.85	-.22	-.28	-1.21	-1.46	-.59	--	5.67	-
		05-08-90	-.79	.53	.29	.14	.63	-.29	.99	-1.33	-1.59	-.65	0.49	7.01	-
WDESP2	A-Dz1	10-25-88	-1.20	.46	.29	.14	.41	-.34	-.58	-2.17	-2.41	-1.62	--	-1.02	-1.03
		05-11-89	-.89	.54	.18	.03	.27	-.56	.01	-2.13	-2.38	-1.67	.68	-.45	.94
		05-09-90	-1.04	.62	.14	-.01	.05	-.53	.63	-2.20	-2.47	-1.70	.83	.41	.84
WDED11	A-Dz1	10-25-88[2]	-1.53	.52	.36	.21	.50	-.26	.40	-2.99	-3.25	-2.43	--	.04	.10
		05-11-89	-1.18	.54	.06	-.09	-.09	-.63	.57	-2.84	-3.10	-2.34	.96	.44	.60
		05-08-90	-1.32	.64	.22	.07	.20	-.41	.47	-2.66	-2.93	-2.13	.96	.41	1.00

[1] Laboratory bicarbonate analysis used in calculations.

[2] pH of 7.8 used, calculated from measurements of P_{CO_2} and onsite alkalinity.

Exhibit 28

Table 17. Mass-transfer results for flow from the upgradient coal aquifer to the spoils aquifer in the West Decker Mine area, Montana

[Transfer is positive for dissolution. Ion exchange: calcium ion exchanged for sodium ion]

Observation well no.			Mass transfer, in millimoles per kilogram of water						
Initital water	Final water	Date of sample	Calcite	Dolomite	Gypsum	Stron-tianite	Halite	Ca/Na ion exchange	Carbon dioxide (gas)
WDFCL1	WDFSP3	10-26-88	6.74	1.80	22.9	0.07	0.14	29.2	6.81
WDFCL1	WDESP1	10-25,26-88	11.3	1.15	8.93	.03	.24	20.5	12.9

Exhibit 28

Table 18. Comparison of selected median dissolved-ion concentrations in water from spoils and coal to results from laboratory experiments for the West Decker Mine area, Montana

[All values in milligrams per liter except as noted. Source of data: Onsite; Spoils, median values for well WDESP1; Coal 1, median values for well WDESP2; Coal 2, median values for well WDED11; Laboratory, median values from tables 1 and 2 (Davis and Dodge, 1986); Abbreviation: µg/L, micrograms per liter]

Source of data	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Silica (SiO_2)	Dissolved solids	Barium (Ba) (µg/L)	Boron (B) (µg/L)	Manganese (Mn) (µg/L)	Strontium (Sr) (µg/L)
						Onsite							
Spoils	48	35	1,500	16	3,080	1,100	42	14	4,170	18	80	94	3,900
Coal 1	21	9.4	1,000	9.1	2,680	220	18	16	2,590	160	90	17	1,300
Coal 2	13	5.2	890	6.7	2,390	64	15	15	2,140	560	70	6	820
						Laboratory							
Spoils	22	8.0	860	8	1,700	680	7.8	12	2,330	40	100	36	1,000
Coal	9.6	3.7	790	6	1,460	660	6.4	12	2,070	200	240	3	640

Exhibit 28

Table 19. Properties and concentration of chemical constituents in water from coal samples from the West Decker Mine area, Montana, used in laboratory experiments

[Analyses by Montana Bureau of Mines and Geology. Sample: Unsaturated, coal sample collected from the unsaturated zone; Saturated, coal sample collected from the saturated zone. Type of treatment: W, washed with deionized water; U, not washed; 0.05M, sample in contact with 0.05 M Na_2SO_4 for 48 hours; 0.1M, sample in contact with 0.1 M Na_2SO_4 for 48 hours. Concentrations in milligrams per liter except as noted. Abbreviations: µS/cm, microsiemens per centimeter at 25 °C; °C, degrees Celsius; M, molar sodium sulfate (Na_2SO_4). Symbols: <, less than; --, no data or not applicable]

Sample	Type of treatment	Specific conductance (µS/cm)	pH (units)	Temperature (°C)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
Unsaturated	W	2,000	7.2	25	11	5.1	463	5.0
Unsaturated	W, 0.05M	9,000	6.8	25	153	65	2,200	13
Unsaturated	W, 0.1M	16,000	6.8	25	362	135	4,400	15
Unsaturated	U, 0.1M	16,000	6.8	25	323	120	4,200	18
Saturated	W	1,000	8.1	25	3.0	1.2	246	2.9
Saturated	W, 0.05M	9,000	7.3	25	148	61	2,200	11
Saturated	W, 0.1M	16,000	7.1	25	340	130	4,300	15
0 .05M	--	--	--	--	--	--	2,300	--
0 .1M	--	--	--	--	--	--	4,600	--

Sample	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (Fl)	Silica (SiO_2)	Dissolved solids, calculated	Nitrate (as N)	Iron (Fe)	Manganese (Mn)
Unsaturated	220	740	0.8	<2	5.8	1,340	0.02	0.12	0.016
Unsaturated	94	5,100	1.1	<2	3.3	7,670	<.04	.075	.12
Unsaturated	95	10,000	.4	<4	3.3	15,100	<.05	.072	.28
Unsaturated	133	9,600	.7	<4	3.4	14,300	.04	.037	.25
Saturated	450	134	2.1	1.5	7.1	620	.48	.76	.016
Saturated	180	4,900	1.4	<2	1.9	7,420	.04	.11	.15
Saturated	160	9,900	.7	<2	2.0	14,800	.02	.055	.31
0.05M	--	4,800	--	--	--	--	--	--	--
0.1M	--	9,700	--	--	--	--	--	--	--

Exhibit 28

Table 20. Selected reactant or product phases for mass-balance reaction modeling for the West Decker Mine area, Montana

Phase	Composition	Operational valence
Organic matter	CH_2O	0.0
Goethite	$HFeO_2$	3.0
Iron sulfide	FeS	.0
Dissolved sulfide	H_2S	.0
Carbon dioxide	CO_2	4.0
Calcite	$CaCO_3$	4.0
Magnesian siderite	$Fe_{0.7}Mg_{0.3}CO_3$	5.4
Cation exchange	$(Na_2\text{-}Ca/Mg)X$	.0

Exhibit 28

Table 21. Concentrations of the major elements and redox state used in mass-balance models for water from the West Decker Mine area, Montana

[Abbreviation: °C, degrees Celsius]

Observation well no.	Date of sample	pH (units)	Water temperature (°C)	Concentration, in millimoles per liter						
				Calcium (Ca)	Sodium (Na)	Carbon, total (C)	Sulfur, total (S)	Iron (Fe)	Magnesium (Mg)	Redox state
WDESP1	10-25-88	7.19	14.0	1.049	65.624	59.173	11.027	0.0025	1.258	300.89
WDESP2	10-25-88	7.52	15.0	.466	45.596	47.717	2.642	.0002	.343	200.45
WDED11	10-25-88	[1]7.8	15.0	.288	38.670	41.245	.541	.0009	.186	163.04
WR-07[2]	08-13-71	8.2	14.0	.115	17.992	19.276	.032	.0009	.041	67.98

[1]Calculated.

[2]Concentrations converted from Davis (1984a, table 2).

Exhibit 28

Table 22. Mass-transfer results for an inferred flow path from spoils aquifer to downgradient coal aquifer, October 1988, in the West Decker Mine area, Montana

[Path: 1. Well WDESP1 to well WDED11; 2. Well WDESP1 to well WDESP2; 3. Well WDESP2 to well WDED11; 4. Well WDESP1 to well WDED11, 80 percent of water from well WDESP1, 20 percent of water from vertical flow from Dietz-2 coal bed. $\delta^{13}C$, Carbon 13 isotope ratio: 1. calculated; 2. observed. $\delta^{34}S$, Sulfur 34 isotope ratio: 1. calculated 2. observed. Transfer is negative for precipitation or degassing, positive for dissolution. Ion exchange: negative, Na exchange for Ca and Mg on coal. All isotope values are per mil. Symbol: --, phase not included in calculation]

Path	Mass transfer, in millimoles per kilogram of water								Input isotopic composition ($\delta^{13}C(CH_2O)$)	Input sulfur fractionation factor ($^{34}\Delta$)	$\delta^{13}C$		$\delta^{34}C$	
	Calcite ($CaCO_3$)	Magnesian siderite ($Fe_{0.7}Mg_{0.3}CO_3$)	Organic matter (CH_2O)	Goethite ($HFeO_2$)	Iron sulfide (FeS)	H_2S (gas)	CO_2 (gas)	Na/CaMg ion exchange			Calculated	Observed	Calculated	Observed
1	-12.2	-10.3	21.4	7.22	--	-10.5	-16.8	-13.5	-29.5	-19.9	-9.3	-9.4	61.5	61.9
1	-12.2	-10.3	23.8	17.7	-10.5	--	-19.2	-13.5	-28.0	-19.9	-9.4	-9.4	61.5	61.9
2	-9.09	-8.06	17.5	5.64	--	-8.38	-11.8	-10.0	-31.0	-23.1	-8.2	-8.8	33.3	33.1
2	-9.09	-8.06	19.4	14.0	-8.38	--	-13.7	-10.0	-31.0	-23.1	-8.8	-8.8	33.3	33.1
3	-3.12	-2.26	3.93	1.58	--	-2.10	-5.02	-3.46	-21.0	-17.4	-9.4	-9.4	61.9	61.9
3	-3.12	-2.26	4.41	3.68	-2.10	--	-5.50	-3.46	-21.0	-17.4	-9.4	-9.4	61.9	61.9
4	-5.16	-5.00	13.4	3.49	--	-6.82	-7.85	-5.54	-31.0	-23.1	-8.8	-9.4	62.1	61.9
4	-5.16	-5.00	14.9	10.3	-6.82	--	-9.40	-5.54	-31.0	-23.1	-9.3	-9.4	62.1	61.9

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Exhibit 28

General Rosebud Mine Modeling Options
Michael Nicklin thoughts (5/15/13)

It is my sense that there is confusion evolving with respect to Rosebud Mine modeling efforts in part because of the different pending permit application runs. I recommend that we restructure the modeling presentation as follows:

1. Define ***one*** Rosebud Mine Groundwater Model for existing permits. Establish it as the baseline groundwater model which will be used for assessing significance of pending permit applications *[note that this modeling effort is effectively completed]*. **This would stand alone as a single report.**

2. Conduct application specific simulations and evaluate this as part of a pending permit.

Options that can be used for application purposes include the following:

Option 1: ***Use the Rosebud Mine Groundwater Model to evaluate significance of a proposed permit. No other pending or proposed permits that have not been approved would be a component of this modeling effort.***

Example: The baseline Rosebud Mine model will consider B-East only for evaluation of the significance of B-East Permit changes.

Advantage: Focuses on the relative significance of a given permit application.

Disadvantage: May not be as helpful to DEQ for developing a CHIA.

Option 2: ***Use the Rosebud Mine Groundwater Model to evaluate significance of all proposed permits, including the permit under consideration.***

Example: For B-East Permit Application all future pending permit applications for B-East, B-Ext, Area A MR62, Area MR66 and Area F permit to be included.

Advantage: Establishes the relative significance of all proposed permit applications and would be helpful to DEQ for developing a CHIA.

Disadvantage: Cannot isolate relative significance of given permit application.

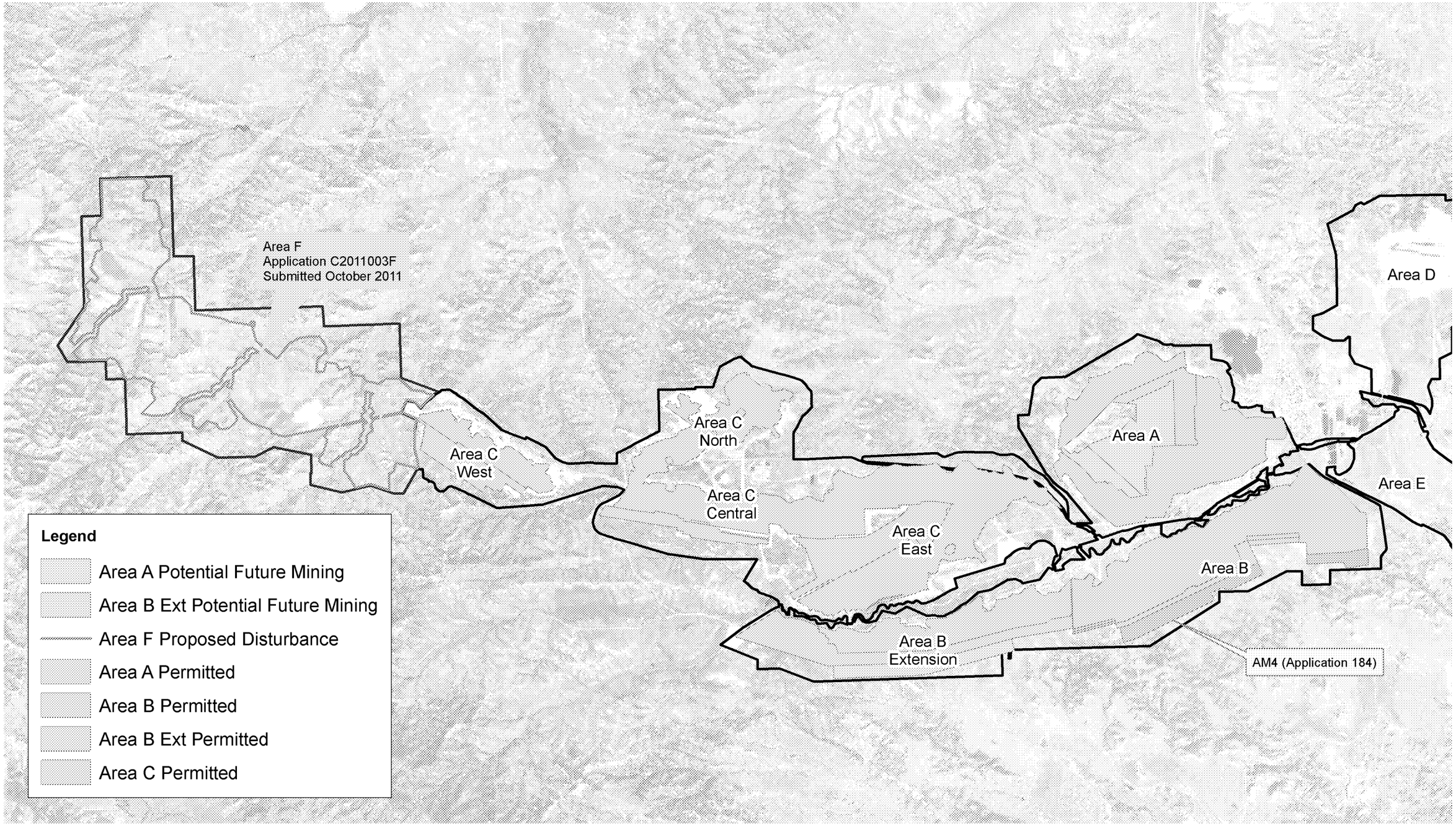
Exhibit 27

Option 3: ***Develop two application reports, each stand alone.***

One model report is permit specific evaluation, and permit specific PHC. Essentially Option 1.

Second model report provides a compilation of all existing and pending permits. This would not be a part of the given PHC. In effect, it would be a separate deliverable solely for the purpose of providing a "running tabulation" of all future pending permits which would assist DEQ in developing its CHIA.

Exhibit 27



NICKLIN EARTH & WATER, INC.

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Notes: NAIP Aerial Photo (2011)

Date: 5/21/2013 File: F03C Potential Future

WESTERN ENERGY COMPANY - Rosebud Mine
A Subsidiary of WESTMORELAND COAL COMPANY
PO Box 99 Colstrip, MT 59323 (406) 748-5100

Figure 3C
Potential Future Mining
Areas ABC PHC

Exhibit 26
WCCPROD00000707

The Ecology of East Fork Armells Creek and Some Ponds Near Colstrip, Montana

Final Report

December, 1979

Prepared by

Dennis J. Schwehr

Western Energy Company

Butte, Montana

Exhibit 25

ACKNOWLEDGEMENTS

I am grateful to Dr. George Roemhild of Montana State University for the verification or identification of some of the difficult taxonomic groups, to Richard Oswald of MSU for identification of the Chironomidae and Dr. D. G. Denning for Trichoptera. Collection and analysis of water samples was conducted by Northern Testing Laboratories.

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Exhibit 25

INTRODUCTION

Strip mining of Fort Union coal in southeastern Montana, electrical generation in Colstrip, Montana, and the associated construction activity and population growth has placed greater demands on the water resources of the region. The construction of two additional electric generators and increased coal production has necessitated the evaluation of potential impact to the aquatic ecosystems, particularly to East Fork Armells Creek which flows through the mining areas and the town of Colstrip.

A description of the existing water quality and aquatic biota will serve as a baseline for the purpose of monitoring possible future changes in the aquatic ecosystem. Water quality may be affected by changes in land use, by disturbance of groundwater aquifers, by construction activities associated with combustion facilities and population growth, and increased water use and treatment. Streamflow may be altered by mining, changes in land use and water consumption which will also affect water chemistry. The composition and distribution of benthic communities in Armells Creek may respond to long-term changes in water volume or quality.

This study was initiated in the spring of 1977, in order to examine the existing conditions of the East Fork of Armells Creek. Study objectives were to (1) describe existing water quality in the stream; (2) inventory the present macroinvertebrate communities; and (3) describe baseline ecological characteristics of the creek prior to expanded mining operations.

Armells Creek has been sampled previously (ECON, Inc., 1977) for macroinvertebrates and water quality. Chemistry of Colstrip area waters has been described by Van Voast, et al (1977), Dollhopf, et al (1977 and 1978), U. S. Geological Survey (1976, 1977 and 1978), Montana Water Quality Bureau (1978), Montana Department of Natural Resources and Conservation (1974), and Westinghouse Electric Corporation (1973).

This study also addresses the water quality and biology of Turtle Pond and the EPA Depression which are located in a reclaimed area near Colstrip. Information gathered from these ponds and other impoundments in the Colstrip area can be used in future reclamation plans relative to the creation of water impoundments for the benefit of livestock and wildlife use. There is little published information on the characteristics of existing ponds in the Colstrip area. Vocke, et al (1978) described aquatic plants and water quality of several impoundments in the Colstrip area.

STUDY AREA

East Fork Armells Creek originates about 24 kilometers (15 miles) west of Colstrip, flows east through Colstrip, then north to join the west fork and finally to the Yellowstone River, 48 km. (30 miles) from Colstrip (Figure 1). The stream drains an area of about 252 km.^{2} at a point 10.8 km. north of Colstrip (Mel White, USGS, Helena, Montana, 1978, personal communication; Surface Water Records published by the USGS reflect a drainage area of 401 km^2, which is an error) and produces an average discharge of .012 m^3/sec. (.44 cfs) at a point immediately downstream from the mouth of Stocker Creek which is about 7 km. north of Colstrip (Van Voast et. al., 1977). Van Voast estimates the average runoff rate to be 0.2 cm. per year. He reports that less than a 10th of 1 percent of the area's average annual precipitation leaves as streamflow, most of which occurs during short duration floods. Most precipitation is lost through evaporation and transpiration.

Armells Creek flows through a shallow valley with gentle slopes and is bordered by pine-covered ridges and sandstone outcrops. Sagebrush-grassland is the major habitat type of the drainage bottoms. Woody riparian vegetation is either non-existent or sparse along the creek bottom. This is due primarily to the ephemeral nature of the stream and, perhaps in part to livestock use along the stream bank. The upper portion of the East Fork

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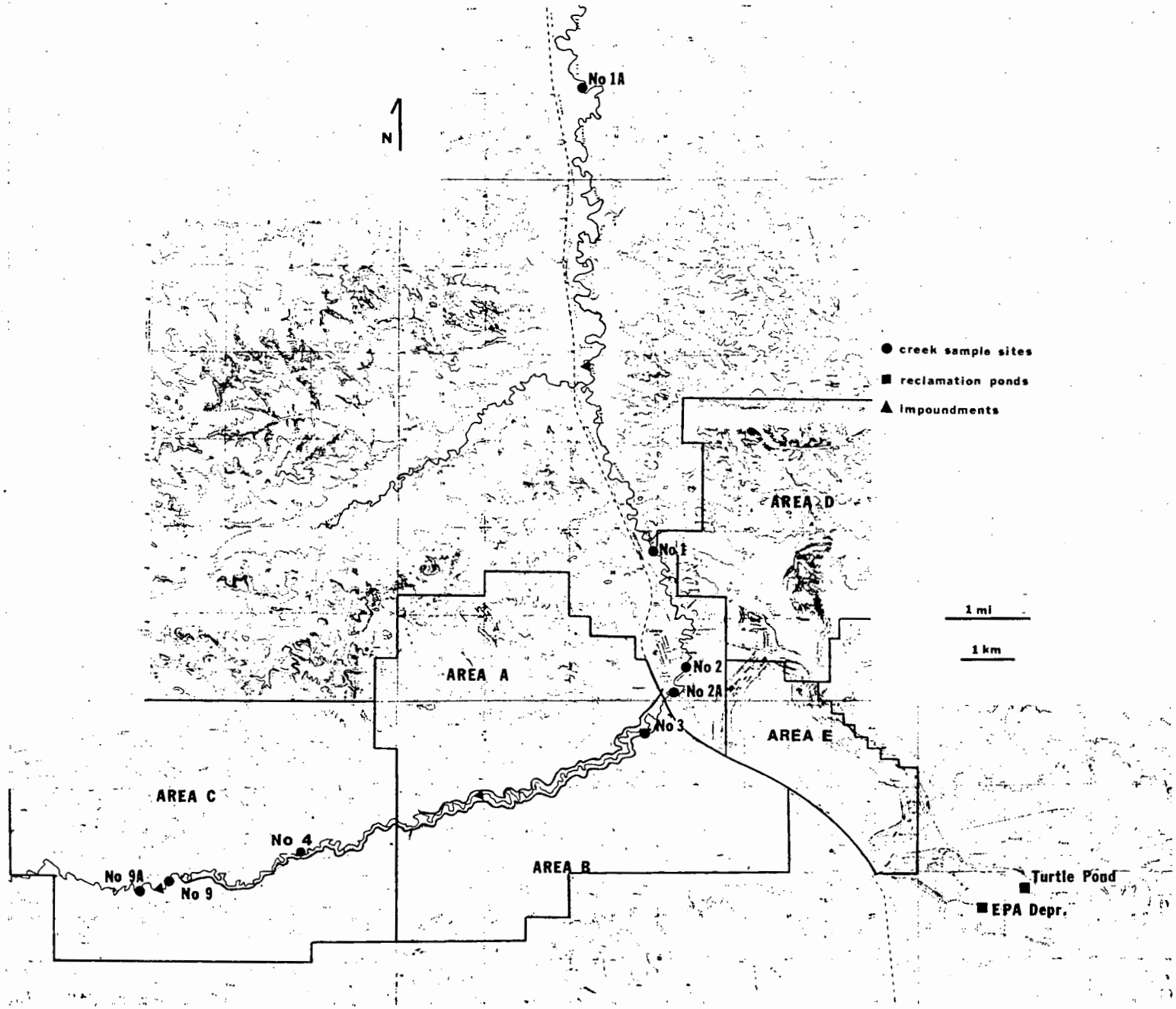

Figure 1. Study Area Map with Sampling Sites.

Exhibit 25

is dry throughout most of the year whereas below Colstrip, the stream contains some flow most of the time.

The stream bed consists of a mud substrate rich in partially decomposed organic materials. Deeper sediments are black and have the strong odor of hydrogen sulfide, produced under anaerobic conditions. The deep sediments are typical of low-gradient, meandering prairie streams. Surface runoff introduces sediments to the stream which settle to the bed because discharge is rarely sufficient to move the particles.

The major land uses of the area which have the potential to affect water quality are the strip mining of coal and agriculture, which consists primarily of livestock grazing, dryland crops and hayfields. Surface runoff from cultivated fields and concentrated livestock feeding areas can affect water resources. Surface erosion from disturbed mine areas is prevented through control measures. Strip mining will alter the characteristics of the groundwater aquifers which presently contribute to the high mineral concentrations in surface streams.

Water quality in East Fork Armells Creek changes considerably during the year in response to the influences of groundwater runoff from snowmelt or rainfall. The stream above Colstrip contains calcium-magnesium-sulfate-type water most of the time including periods of rainfall; however, the bicarbonate ion dominates during periods of runoff from snowmelt (Table 1).

Table 1. Mean Concentrations of Chemical Constituents from East Fork Armells Creek During Runoff from Snowmelt (Average of 3 Samples taken from 3/10-3/13/78) and Rainfall (Average of 2 Samples taken 5/19/78).
Source: Dollhopf unpublished and Dollhopf et al, 1978.

	Mean During Snowmelt	Mean During Rainfall
Specific Cond. (lab)	-150	1155
pH (Lab.)	8.1	8.5
Total Dissolved Solids (Calc.)	94	1041
Sodium Adsorption Ratio	0.21	1.05
Boron	-0.01	0.43
Alkalinity as $CaCO_3$	55	134
Bicarbonate as HCO_3	67	136
Carbonate as CO_3	0	6.8
Chloride	0.04	8.7
Sulfate as SO_4	36	693
Fluoride	0.06	0.26
Total Hardness as $CaCO_3$	59	679
Calcium	12	95
Magnesium	7	108
Sodium	4	63
Cadmium (Dissolved)	-0.005	-0.005
Copper (Dissolved)	0.091	0.016
Iron (Dissolved)	0.115	0.066
Lead (Dissolved)	-0.010	-0.010
Manganese (Dissolved)	0.013	0.083
Zinc (Dissolved)	0.008	0.013

Components are expressed in mg/l unless otherwise noted.

A minus sign indicates that less than the reported value was present in the sample.

Total dissolved solids were calculated at 94 mg/l in March of 1978 during a period of runoff from snowmelt (data concerning snow depth and stream discharge were not available). Morning and afternoon water samples, collected May 19, 1978, (Wayne Hedberg, Montana State University, personal communication, 1978) revealed an average total dissolved solids concentration of 1,041 mg/l during a period of heavy rainfall. Streamflow was not recorded; however, a total of 4.8 inches of rain fell during the period from May 17 through May 19 (unpublished climatological data recorded by Western Energy Company in Colstrip for the National Weather Service).

A chemical description provided in Table 2 typifies existing conditions in East Fork Armells Creek. Although these samples were taken from a site downstream from Colstrip, the water quality is not unlike that upstream from Colstrip except that below town the water is defined as sodium-sulfate type. Mean concentrations of chemical constituents in Table 2 are much higher than those shown in Table 1. This reflects the fact that relatively high flows occur for such brief periods that mean concentrations are characteristic of the usual low flow conditions.

In its natural state, Armells Creek has poor water quality. The drinking water standards of the U. S. Public Health Service are exceeded for total dissolved solids, sulfates, iron, cadmium and manganese. The Montana Department of Health and Environmental

Table 2. Chemical Analyses of Water Sampled from East Fork of Armells Creek, 10.8k m North of Colstrip (at Station No. 1A as used in this report). Source: USGS; 1976, 1977 and 1978.

	Number of Samples	Mean	Range
Specific Cond. (Micromhos/cm)	27	4116	290 - 6990
pH	27	8.1	7.5 - 8.6
Dissolved Oxygen (On Site)	25	9.6	6.0 - 12.0
Total Dissolved Solids	27	3348	178 - 4580
Turbidity (J.T.U.)	27	9.2	0.0 - 40
Sodium Adsorption Ratio	27	3.5	0.5 - 4.5
Boron	27	0.82	0.12 - 1.30
Total Alkalinity as $CaCO_3$	6	314	58 - 502
Bicarbonate as HCO_3	27	461	71 - 656
Carbonate as CO_3	27	0	0
Chloride	27	49	2 - 86
Nitrate + Nitrite as N	27	0.15	0.00 - 0.88
Sulfate as SO_4	27	2147	75 - 3000
Fluoride	27	0.4	0.00 - 0.7
Total Hardness as $CaCO_3$	27	1879	110 - 2600
Calcium	27	229	22 - 310
Magnesium	27	317	13 - 460
Sodium	27	352	13 - 490
Potassium	27	17	7.4 - 23
Ammonia Nitrogen as N	27	0.21	0.0 - 1.1
Organic Nitrogen as N	27	0.96	0.0 - 2.6
Total Kjeldahl Nitrogen as N	27	1.16	0.42 - 3.10
Silica	27	8.3	1.4 - 17
Aluminum, Total	8	0.13	0.02 - 0.21
Dissolved	7	0.009	0.0 - 0.03
Arsenic, Total	10	0.001	0.0 - 0.005
Dissolved	7	0.001	0.001 - 0.002
Cadmium, Total	10	0.011	-0.01 - 0.02
Dissolved	7	0.0003	0.0 - 0.001
Chromium, Total	10	0.007	0.0 - 0.03
Dissolved	7	0.007	0.0 - 0.02
Copper, Total	10	0.014	-0.01 - 0.04
Dissolved	7	0.003	0.0 - 0.016
Iron, Total	10	0.67	0.2 - 2.4
Dissolved	27	0.10	0.02 - 0.71
Lead, Total	10	0.10	-0.1 - 0.1
Dissolved	7	0.002	0.0 - 0.004
Manganese, Total	10	0.30	0.03 - 0.76
Dissolved	7	0.44	0.0 - 1.1
Mercury, Total	10	0.0001	0.0 - 0.0004
Dissolved	7	0.00001	0.0 - 0.0001
Selenium, Total	10	0.0004	0.0 - 0.001
Dissolved	6	0.0008	0.0 - 0.002
Vanadium, Total	--		
Dissolved	6	0.0004	0.0 - 0.0016
Zinc, Total	8	0.015	0.0 - 0.04
Dissolved	7	0.017	0.01 - 0.02
Temperature ($^{\circ}C$)	27	8.2	0.0 - 24.5

Components expressed in mg/l unless otherwise noted.
A minus sign indicates that less than the reported value was present in the sample.

Sciences has proposed to downgrade the present classification for East Fork Armells Creek. Standards for the proposed classification would still be exceeded for total and fecal coliform, iron, cadmium, boron, and conductivity.

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DESCRIPTION OF SAMPLING STATIONS

East Fork Armells Creek

Five sampling sites were established on the creek in April 1977. These locations are described in a previous report (Schwehr, 1978). Some changes in sampling locations were made prior to the 1978 field season. Figure 1 shows the locations of all sampling sites. Locations of these stations are described in Table 3.

Table 3. Creek and Pond Sampling Sites Near Colstrip

Station	Location
Armells #1A	T.3N R.41E Sec. 28 SW¼
Armells #1	T.2N R.41E Sec. 28 NE¼
Armells #2	T.2N R.41E Sec. 34 SW¼
Armells #2A	T.2N R.41E Sec. 34 SW¼
Armells #3	T.1N R.41E Sec. 4 NE¼
Armells #4	T.1N R.40E Sec. 11 SE¼
Armells #9	T.1N R.40E Sec. 15 NW¼
Armells #9A	T.1N R.40E Sec. 15 NW¼
Turtle Pond	T.1N R.42E Sec. 17 NW¼
EPA Depression	T.1N R.42E Sec. 18 NE¼

Station No. 9 is located immediately below a small impoundment on the creek. There has always been sufficient flow at this location to sample for water chemistry, however, flow is often too low to sample for invertebrates; therefore, an additional site was established immediately above the impoundment which is referred to as Station No. 9A. Either one or both of these

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sites were sampled, depending on flow volume. This is one of the few locations on the creek upstream from Colstrip which has at least some flow through most of the year. These sites are upstream from Western Energy Company's mining areas A and B and are within the future mining area C. This portion of the stream has received heavy use by cattle which has resulted in localized widening of the stream channel and a loss of riparian vegetation.

Station No. 3 was abandoned because this site often had insufficient flow for an invertebrate sample. The site was located at a point above which streamflow seldom occurred. Standing or slow moving water is usually present below Station No. 3 and reflects the effects of groundwater recharge.

All riparian vegetation at Station No. 2 was removed in 1977. To avoid potential increases in sedimentation from this loss and from adjacent construction activity, Station No. 2 was terminated. A new site, Station No. 2A, was established prior to the 1978 field season. It is located approximately 0.8 km. upstream from Station No. 2 and 1.6 km. below No. 3. Streamflow is probably permanent at this site and is greater than that of No. 3, although flow velocities are sometimes negligible. Riparian species include rose and green ash.

Station No. 1 was relocated downstream approximately 300 meters to avoid construction of new sewage facilities and to

take advantage of better access. Riparian shrubs and trees are absent, although most streambanks are protected by tall grasses.

A new site, Station 1A, was established in 1978 and is located 10.8 km north of Colstrip. The U.S.G.S. has sampled water from this location since January of 1975. However, it may not be maintained permanently (P. W. McKinley, U.S.G.S., personal communication, 1978). Flows are permanent and riparian vegetation is well developed. The site is relatively undisturbed and was established to monitor the downstream effects of the total Colstrip project.

Ponds

Turtle Pond and the EPA Depression are both located in the Pit 6 reclamation area southeast of Colstrip (Fig. 1). Turtle Pond was created in 1958 at the conclusion of strip mining by Northern Pacific. Water depth at that time was approximately 5 meters. In the spring of 1968, Western Energy Company planted quaking aspen (Populus tremuloides) around the edge of the pond. Mining was resumed in 1968 at which time water was pumped out of the pond and the surface elevation dropped considerably. The area was regraded and revegetated in 1971 and 1972. During this period, fill material was placed into the pond particularly on the south end which raised the pond elevation (Richard Hodder, Montana Agricultural Experiment Station,

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personal communication, 1979). Since the conclusion of reclamation, surface levels have not reached the treeline. At present, the pond depth fluctuates between 1½ to 3 meters. Turtle Pond receives most of its water supply from groundwater sources and is a permanent pond with a surface area of about one-half acre.

The EPA Depression was created in 1974 during the reclamation process. It is dependent entirely on surface runoff for its water supply. The Depression has a surface area of approximately two acres in the spring and a depth of about one-half meter. Evaporation in the summer months reduces the surface area considerably and in particularly dry years, the pond could be completely dry by late fall.

METHODS

Qualitative macroinvertebrate samples were collected in 1977 for the purpose of obtaining a species list and distribution information. These methods were described in a previous report (Schwehr, 1978). In 1978, a quantitative sampling device was used to provide relative abundance information, determine community diversity, and to supplement the existing data concerning species composition and distribution.

Five samples were taken at each site with an Ekman dredge which samples a 0.023 m^2 area of substrate. Flow velocities were generally low enough to permit sampling in lotic waters. Five samples were taken at each site on the creek when flows were adequate and from Turtle Pond in March, June, September and late November. Dredge samples were not taken from the EPA Depression in 1978. Each set of five samples was pooled to form one collection. Samples were then washed in a U. S. Standard No. 30 sieve, preserved in ethyl alcohol and returned to the laboratory.

Organisms were hand sorted from the samples, counted and identified to the genus or species level where possible using identification keys by Edmondson (1959), Edmunds, et al (1976), Johannsen (1977), Pennak (1953), Roemhild (1975, 1976), Usinger (1956), and Wiggins (1977). Difficult specimens were sent to

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taxomonic experts for verification or identification. Some emergent adult insects were collected for species determinations, as were some organisms from miscellaneous collections.

Community structure was described through the use of a diversity function developed by Shannon and Weaver (1963). Although it was designed for the field of communications, the index has been employed extensively by ecologists in the following form:

$$\bar{d} = -\sum_{i=1}^{s} (N_i/N) \log_2 (N_i/N),$$

where $\bar{d}$ = mean diversity

s = number of taxa

N_i = number of individuals in the ith taxon

N = total number of individuals

The index combines two components, "species richness" and "eveness" to describe community composition (Tramer, 1969). Richness is simply the number of species in a sample. Eveness or "equitability" is a measure of the distribution of individuals among the taxa.

Heip and Engels (1974), in a comparative study of several indices, claimed that the Shannon index is the best method, statistically, for describing community diversity. Numerical indices are widely used, but some valid criticisms exist.

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Dickman (1968) stated that $\bar{d}$ is unequally sensitive to relative abundances of the different levels in the trophic structure. Similarly, Hurlbert (1971) pointed out that diversity measures mask the potential ecological importance of less abundant species. This is probably true; however, that is not the intention in this application.

One characteristic of the diversity function which must be recognized is the fact that a collection containing few species and high evenness could have the same diversity as another collection with several species and low evenness (Pielou, 1977). The occurrence of this possibility may be noted in the results.

A diversity measure must also be independent of sample size (Wilhm, 1970a and Pielou, 1966). Independence is obtained by assuming that individuals are randomly distributed, equally likely to be captured, and when collections contain an equal number of samples. When distribution is not random, it is patchy, meaning that like organisms are concentrated. In this case, sample size should be increased until diversity of the pooled samples reaches an asymptote. Wilhm (1970a) sampled benthic communities of several habitats with an Ekman dredge and increased the number of samples to determine the diversity at the asymptote. For stream habitats, diversity values attained the asymptote after four or five samples.

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In this report, the Shannon-Weaver index was used to detect changes in community diversity along the stream and to describe ecosystem quality as a function of community composition.

Water samples were collected and analyzed by Northern Testing Laboratories. Samples were taken quarterly at the same locations from which invertebrates were collected. Concentrations of various ions, nutrients and metals were determined.

RESULTS

Aquatic Macroinvertebrates

Armells Creek

A checklist of aquatic macroinvertebrates from East Fork Armells Creek is presented in Table 4. Insect species composition was greatest in the orders of Odonata, Diptera, Hemiptera and Coleoptera. Community composition and diversity are very similar to that of the upper portions of Sarpy Creek (Clancey, 1978) which has similar physical characteristics.

The results of stream collections taken in 1978 are presented in Table 5. Four samples were taken at Stations 1A, 1 and 2A, however, one sample from Station 2A was destroyed in shipment. Only one collection was made at Station 9 as flow was insufficient for bottom sampling throughout most of the year. The most abundant organisms were Hyalella and members of the family Chironomidae. Forty-eight different taxa were collected in 1978, 32 of which were found at Station No. 1. Twenty-four taxa were found at Station 1A and 19 at Station 2A. Fifteen species were present in the one collection taken from Station No. 9.

Exhibit 25

Table 4. Checklist of Aquatic Macroinvertebrates of East Fork Armells Creek

Insecta
- Odonata
  - Anisoptera
    - Aeshnidae
      - *Aeshna* sp.
    - Libellulidae
      - *Libellula* sp.
      - *Plathemis lydia* (Drury)
      - *Sympetrum* sp.
  - Zygoptera
    - Coenagrionidae
      - *Amphiagrion abbreviatum* (Selys)
      - *Argia* sp.
      - *Enallagma* sp.
      - *Ischnura* sp.
    - Lestidae
      - *Lestes* sp.
- Ephemeroptera
  - Heptageniidae
    - *Rhithrogena* sp.
  - Baetidae
    - *Callibaetis* sp.
  - Caenidae
    - *Caenis* sp.
- Plecoptera
- Trichoptera
  - Hydroptilidae
    - *Mayatrichia* sp. (prob. *ayama*)
  - Hydropsychidae
    - *Cheumatopsyche* sp.
    - *Hydropsyche separata* Banks
    - *Hydropsyche occidentalis* Banks
  - Limnephilidae
    - *Limnephilus taloga* Ross
  - Leptoceridae
    - *Oecetis inconspicua* (Walker)

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Table 4. (Cont.)

- Diptera
  - Ceratopogonidae
  - Chironomidae
    - Tanypodinae
      - Tanypodini
        - *Tanypus* sp.
      - Macropelopiini
        - *Macropelopia* spp.
        - *Procladius* spp.
        - *Psectrotanypus* spp.
      - Pentaneurini
        - *Thienemannimyia* group
    - Diamesinae
      - Prodiamesini
        - *Odontomesa* sp.
    - Chironominae
      - Chironomini
        - *Chironomus* spp.
        - *Chryptochironomus* spp.
        - *Glyptotendipes* sp.
      - Tanytarsini
        - *Micropsectra* spp.
        - *Paratanytarsus* sp.
    - Orthocladiinae
      - *Acricotopus* sp.
      - *Cricotopus (Isocladius)* sp.
      - *Hydrobaenus* sp.
      - *Orthocladius* spp.
      - *Parakiefferiella/Chaetocladius* sp.
      - *Parametriocnemus* sp.
  - Empididae
  - Ephydridae
  - Liriopeidae
    - *Liriope* sp.
  - Psychodidae
    - *Psychoda* sp.
  - Simuliidae
  - Stratiomyiidae
    - *Euparyphus* sp.
    - *Odontomyia* sp.
    - *Oxycera* sp.
    - *Stratiomys* sp.
  - Tabanidae
  - Tipulidae

- Hemiptera
  - Corixidae
    - *Hesperocorixa vulgaris* (Hungerford)
    - *Sigara grossolineata* (Hungerford)
    - *Corisella tarsalis* (Fieber)
    - *Cenocorixa* sp.

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Table 4. (Cont.)

- Notonectidae
  - *Buenoa margaritacea* Bueno
  - *Notonecta* sp.
- Gerridae
  - *Gerris* sp.
- Mesoveliidae
  - *Mesovelia mulsanti* White

Coleoptera
- Dytiscidae
  - *Agabus* sp.
  - *Bidessus* sp.
  - *Laccophilus* sp.
  - *Eretes* sp.
  - *Hydaticus* sp.
  - *Rhantus* sp.
  - *Hygrotus* sp.
- Hydraenidae
- Noteridae
- Hydroscaphidae
  - *Hydroscapha* sp.
- Hydrophilidae
  - *Helochares* sp.
  - *Hydrobius* sp.
  - *Berosus* sp.
  - *Tropisternus* sp.
  - *Enochrus* sp.
  - *Helophorus* sp.
  - *Hydrophilus* sp.
- Haliplidae
  - *Haliplus* sp.
- Chrysomelidae
- Elmidae
  - *Dubiraphia* sp.

Oligochaeta

Hirudinea

Malacostraca

Amphipoda
- Talitridae
  - *Hyalella azteca* (Saussure)

Exhibit 25

Table 4. (Cont.)

Hydracarina

Gastropoda
- Basommatophora
  - Physidae
    - *Physa* sp.
  - Lymnaeidae
    - *Lymnaea* sp.
  - Planoribidae

Pelecypoda
- Eulamellibranchia
  - Unionidae

Exhibit 25

Table 5. Organisms Collected with an Ekman Dredge from East Fork Armells Creek in 1978

Station	1A				1				2A			9
Date	3/22	6/13	9/07	11/29	3/22	6/13	9/07	11/29	3/22	6/13	9/07	11/29
Odonata												
Aeshna							2					
Libellula							1					
Plathemis								4				
Amphiagrion					1			3				4
Ischnura	2	1	26			2	7	12				14
Ephemeroptera												
Callibaetis			3				7					
Caenis							1	4		1		1
Trichoptera												
Hydropsyche											1	
Cheumatopsyche					1							
Limnephilus	6			3	1							2
Diptera												
Chironomidae (unknown)		6				17						
Tanypus										1		
Macropelopia								11		26		
Procladius	16		11					15	5			
Psectrotanypus									23	12		
Thienemannimyia group												7
Odontomesa										7		
Chironomus	35								235	30		
Cryptochironomus								1		1		1
Glypotendipes						1						
Micropsectra	64					13		1	1	1		43
Paratanytarsus									3			
Acricotopus	3								6	6		

Exhibit 25

Table 5 (Cont.)

Station	1A				1				2A			9
Date	3/22	6/13	9/07	11/29	3/22	6/13	9/07	11/29	3/22	6/13	9/07	11/29
Cricotopus (Isocladius)			2			132						
Hydrobaenus	6											
Orthocladius						40				5		
Parakiefferiella/ Chaetocladius												2
Paracladius									2	12		
Parametriocnemus						1						1
Ceratopogonidae	2					1		2		1		1
Psychoda					1							
Simuliidae		3		13		30				1		
Euparyphus						1						
Stratiomys						1						
Tabanidae	2					1		2				
Ephydridae						3				1		
Hemiptera		1	1			1						
Hesperocorixa			4									
Coleoptera												
Agabus		1										
Bidessus		2	1									
Berosus		1						2				
Haliplus	1	1						2	1			10
Dubiraphia			1									
Hirudinea						1		1				
Amphipoda												
Hyalella	17	132	86	4	3	16	115	173	8	1		107
Hydracarina							1					
Basommatophora												
Physa	3	11		10			1	5				80
Lymnaea	6	5										
Planoribidae	1								7			1
TOTALS	164	164	135	30	7	261	135	238	291	80	1	300

Quantitative comparisons between 1977 and 1978 invertebrate collections are not appropriate (see appendix A for 1977 data). Collections of 1977 were qualitative in nature and were intended to provide species composition and distribution information. Sample size and dates of collection are not comparable between the two years.

Organisms were sampled quantitatively in 1978 in order to determine more accurately the relative abundance of various species. Unfortunately, the lack of an equal number of samples from each site prevented a meaningful description of population changes along the creek.

Table 6 provides a summary of organism and species numbers as well as Shannon-Weaver diversity values for collections made in 1978. Diversity ($\bar{d}$) was generally highest in samples containing the greatest number of taxa; however, this was not always true. For example, fifteen taxa were collected at Station 1 in November, and $\bar{d}$ was only 1.73. This was due to the presence of 173 amphipods in the sample. Seven organisms in 5 taxa were collected at Station 1 in March, yielding a $\bar{d}$ = 2.13, which is attributed to high "evenness." There is no consistency or trends noted in diversity on a sample by sample basis, which indicates the occurrence of a patchy distribution, seasonal optimums, inadequate sample size and/or the inability to sample all microhabitats equally.

Exhibit 25

Perhaps more meaningful are the cumulative figures for the March and June samples (Table 6). The total number of taxa were similar at Stations 1A, 1 and 2A, but diversity was lowest at 2A and increased downstream.

The values of $\bar{d}$ are used as measures of ecosystem stability or quality. Wilhm (1970b) stated that $\bar{d}$ varies between 3 and 4 in clean-water streams and less than one in polluted streams. Diversity values for Armells Creek are in the mid-range. Invertebrate diversity for this creek is not only a function of water quality but also reflects the ecosystem instability caused by periods of no flow. Flows downstream from Colstrip are more permanent and result in more diverse aquatic communities.

Exhibit 25

Table 6. Number of Organisms, Number of Taxa, and Shannon's Diversity (d) for Invertebrate Samples Collected from East Fork Armells Creek in 1978.

Station	1A				1				2A			9
Date	3/22	6/13	9/7	11/29	3/22	6/13	9/7	11/29	3/22	6/13	9/7	11/29
Number of Organisms	164	164	135	30	7	261	135	238	291	80	1	300
Number of Taxa	14	11	9	4	5	16	8	15	10	14	1	15
Shannon's d	2.73	1.25	1.69	1.77	2.13	2.36	.94	1.73	1.20	2.82	0	2.56
March and June Combined:												
Number of Organisms	328				268				371			
Number of Taxa	20				20				18			
Shannon's d	2.67				2.49				1.78			

Exhibit 25

Organism distribution along the creek is presented in Table 7, which reflects the results of collections taken in 1977 and 1978. The results from closely related stations were combined in order to accommodate the change in stations used in 1977 and 1978. The total number of taxa found below Colstrip was only slightly higher than the number found in samples from stations immediately above Colstrip. Less than half as many taxa were found at Station 9 where only three samples were taken. There were 17 genera with a continuous distribution throughout the study section. Other groups may have broader distribution but were in such low numbers that they were not collected at all stations.

Ponds

A total of 36 taxa were collected from Turtle Pond during 1977 and 1978 (Table 8) from quantitative and qualitative samples. Species composition closely resembles that of the creek community.

Only three collections were taken from Turtle Pond in 1978 (Table 9). Ice cover was too thick during the winter to collect a sample. Winter deoxygenation and severe erosion in March from the adjacent road may have contributed to the low animal density; however, organism numbers were highest in the March collection.

Table 7. Distribution of Aquatic Invertebrates of East Fork Armells Creek, Based on Kick Net and Dredge Samples of 1977 and 1978.

Station	1/1A	2/2A/3	9
Odonota			
Aeshna	X	X	
Libellula	X	X	
Plathemis	X		
Sympetrum	X	X	
Amphiagrion	X	X	X
Argia			X
Enallagma	X		
Ischnura	X	X	X
Lestes	X		
Ephemeroptera			
Rhithrogena	X		
Callibaetis	X	X	X
Caenis	X	X	X
Plecoptera	X		
Trichoptera			
Hydoptilidae	X	X	X
Hydropsyche		X	
Cheumatopsyche	X	X	
Limnephilus	X	X	X
Diptera			
Chirononidae (genera unknown)	X	X	X
Tanypus		X	
Macropelopia	X		X
Procladius	X	X	
Psectrotanypus		X	
Thienemannimyia group			X
Odontomesa		X	
Chironomus	X	X	
Cryptochironomus	X	X	X
Glypotendipes	X		
Micropsectra	X	X	X
Paratanytarsus		X	
Acricotopus	X	X	
Cricotopus (Isocladius)	X		
Hydrobaenus	X		
Orthocladius	X	X	
Parakiefferiella/Chaetocladius			X
Paracladius		X	
Parametriocnemus	X		X
Ceratopogonidae	X	X	X
Psychoda	X		

Exhibit 25

Table 7 (Cont.)

Tipulidae		X	X
Simuliidae	X	X	
Oxycera	X		
Euparyphus	X	X	X
Odontomyia		X	
Stratiomys	X		
Tabanidae	X	X	X
Empididae		X	X
Liriope			X
Ephydridae	X	X	
Hemiptera			
Hesperocorixa	X	X	
Sigara	X		
Cenocorixa	X		
Corisella	X		
Notonecta	X		
Buenoa	X		
Gerris		X	
Mesovelia		X	
Coleoptera			
Agabus	X		
Bidessus	X	X	
Laccophilus	X		
Eretes	X	X	
Hydaticus		X	
Rhantus		X	
Hygrotus		X	
Hydraenidae		X	
Noteridae		X	
Hydroscapha	X		
Hydrobius	X		
Berosus	X	X	X
Tropisternus	X	X	
Enochrus		X	
Helophorus		X	
Hydrophilus		X	
Helochares	X		
Haliplus	X	X	X
Chrysomelidae	X		
Dubiraphia	X		
Hirudinea	X	X	
Amphipoda			
Hyalella	X	X	X
Hydracarina	X	X	
Basommatophora			
Physa	X	X	X
Lymnaea	X	X	
Planoribidae	X	X	X
Total Number of Taxa	59	53	25
Number of Collections	14	10	3

Exhibit 25

Table 8. Checklist of Aquatic Macroinvertebrates Collected from Turtle Pond Near Colstrip

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Insecta
- Odonata
  - Anisoptera
    - Aeshnidae
      - *Anax* sp.
      - *Aeshna* sp.
    - Gomphidae
    - Libellulidae
      - *Libellula* sp.
      - *Micrathyria* sp.
      - *Plathemis lydia* (Drury)
      - *Sympetrum* sp.
  - Zygoptera
    - Coenagrionidae
      - *Amphiagrion abbreviatum* (Selys)
      - *Argia* sp.
      - *Ischnura* sp.
    - Lestidae
      - *Lestes* sp.
- Ephemeroptera
  - Baetidae
    - *Callibaetis* sp.
  - Caenidae
    - *Caenis* sp.
- Trichoptera
  - Phryganeidae
    - *Phryganea cinerea* Walker
- Diptera
  - Chironomidae
    - *Pseudochironomus* sp.
    - *Acricotopus* sp.
    - *Cricotopus* (*Isocladius*) sp.
  - Tabanidae
    - *Tabanus* sp.
  - Tipulidae
    - *Tipula* sp.
  - Ephydridae
    - *Ephydra* sp. A
- Hemiptera
  - Notonectidae
    - *Notonecta undulata* Say
    - *N. kirbyi* Hungerford

Exhibit 25

Table 8 (Cont.)

- Gerridae
  - Gerris insperatus Drake and Hottes
  - G. comatus Drake and Hottes
- Corixidae
  - Sigara sp.
  - Cenocorixa sp.

Coleoptera
- Curculionidae
- Dytiscidae
  - Agabus sp.
- Haliplidae
  - Haliplus sp.
- Hydrophilidae
  - Hydrobius sp.
  - Berosus sp.

Malacostraca
- Amphipoda
  - Talitridae
    - Hyalella azteca (Saussure)

Arachnoidea
- Hydracarina

Gastropoda
- Basommatophora
  - Physidae
    - Physa sp.
  - Planoribidae
    - Promenetus sp.

Pelecypoda
- Heterodonta
  - Sphaeriidae

Exhibit 25

Table 9. Aquatic Macroinvertebrates Collected with an Ekman Dredge from Turtle Pond in 1978.

DATE	3/22	6/12	9/7
Diptera			
Pseudochironomus	3		
Acricotopus	2		
Cricotopus (Isocladius)	1		
Ephydra Sp. A.	6		
Ephemeroptera			
Callibaetis	3		
Caenis		2	
Odonata			
Lestes		1	
Ischnura	22		4
Micrathyria	2		
Sympetrum			2
Hemiptera			
Notonecta	10		
Gerris	1		
Coleoptera			
Bidessus			1
Haliplus	3		1
Berosus	1		
Hydracarina	6		
Amphipoda			
Hyalella		5	14
Mollusca			
Sphaeriidae		2	1
Planoribidae		1	
Physa	1		1

Exhibit 25

In 1977, five collections, each consisting of three Ekman dredge samples, were taken from Turtle Pond from April through September (see Appendix A). Shannon's diversity values averaged 2.42.

Diversity of 1978 samples declined from 2.97 in March to 2.04 in June and 1.95 in September, for an average $\bar{d}$ of 2.32. Although fewer individuals were collected in 1978, the number of taxa and diversity values were approximately the same for both years.

Cumulative $\bar{d}$ for 1977 samples was 3.18 and for 1978, $\bar{d}$ was 3.47. These values were significantly higher than those derived from creek samples. This indicates that impoundments in mined areas have the potential of high quality aquatic ecosystems.

The EPA Depression was not sampled on a regular basis in 1978. An incidental collection was taken in April, which revealed the presence of Tipula, a crane fly, Hydrobius, a water beetle, and three water bugs, Notonecta kirbyi, Sigara alternata and Cenocorixa utahensis.

Water Chemistry

Armells Creek

The results of water quality analyses are provided in Tables 10 through 13 for Stations 1A, 1, 2A and 9A/9 respectively. Concentrations of major ions were lowest in March (Tables 10, 11 & 12). Ionic concentrations increased in June

Table 10. Chemical Analyses of Waters Sampled in 1978 from East Fork Armells Creek Station No. 1A.

Date	3/22	6/13	9/7	11/29
Specific Cond. (Micromhos/cm)	2510	4710	8260	4740
pH (Laboratory)	7.4	8.1	8.2	8.0
Dissolved Oxygen (On Site)	8.8	7.2	2.2	10.3
Total Suspended Solids	9	1	56	18
Total Dissolved Solids	2140	4310	9310	4290
Oil and Grease	-5	-5	-5	-5
Turbidity (J.T.U.)	45	1.6	22	4.2
Fecal Coliform (Col/100 ml.)	2	94	2600	2
Total Coliform (Col/100 ml.)	20	180	3800	52
Sodium Adsorption Ratio	2.55	3.65	6.07	4.27
Boron - Dissolved	0.3	1.4	1.5	0.7
Total Alkalinity as $CaCO_3$	260	421	565	459
Bicarbonate as HCO_3	317	513	689	560
Carbonate as CO_3	0	0	0	0
Acidity	0	0	0	0
Chloride	20	38	74	47
Nitrate as N	0.03	-0.01	0.08	0.79
Nitrite as N	0.31	-0.01	-0.01	0.01
Ortho-phosphate as P	-0.01	0.01	0.10	0.02
Sulfate as SO_4	1287	2620	5680	2660
Fluoride	0.01	0.19	0.23	0.25
Total Anions (meq/l)	32.66	64.01	131.70	65.95
Total Hardness as $CaCO_3$	1185	2360	4450	2310
Calcium	154	263	439	307
Magnesium	195	414	816	376
Sodium	202	407	931	471
Potassium	8	14	23	18
Ammonia Nitrogen as N	0.6	0.3	0.2	0.1
Organic Nitrogen as N	0.4	0.9	7.7	0.5
Total Kjeldahl Nitrogen as N	1.0	1.2	7.9	0.6
Silica	11	7	12	12
Total Cations (meq/l)	32.68	65.20	130.07	67.17
Aluminum, total	0.4	0.1	0.6	-0.1
Dissolved	0.2	0.1	-0.1	-0.1
Antimony, Total	-0.02	-0.02	-0.02	-0.02
Dissolved	-0.02	-0.02	-0.02	-0.02
Arsenic, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Cadmium, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Chromium, Total	-0.02	-0.02	0.03	0.02
Dissolved	-0.02	-0.02	0.03	-0.02
Hexavalent	-0.01	-0.01	-0.01	-0.01
Copper, Total	-0.01	0.01	0.03	0.02
Dissolved	-0.01	-0.01	0.01	0.02
Iron, Total	0.80	0.34	3.55	0.19
Dissolved	0.28	-0.05	0.60	0.11
Lead, Total	-0.01	-0.02	-0.02	-0.02
Dissolved	-0.01	-0.02	-0.02	-0.02
Manganese, Total	0.94	0.10	2.02	0.15
Dissolved	0.92	0.10	0.52	-0.02
Mercury, Total	-0.001	-0.001	-0.001	-0.001
Dissolved	-0.001	-0.001	-0.001	-0.001
Selenium, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Vanadium, Total	-1.0	-0.1	-0.1	-0.1
Dissolved	-1.0	-0.1	-0.1	-0.1
Zinc, Total	0.01	-0.01	0.04	0.03
Dissolved	-0.01	-0.01	0.02	0.03
Temperature (°C)		17.0	22.0	1.0

Components are expressed in mg/l unless otherwise noted.

A minus sign indicates that less than the reported value was present in the sample.

Exhibit 25

Table 11. Chemical Analyses of Water Sampled in 1978 from East Fork Armells Creek Station No. 1.

Date	3/22	6/13	9/7	11/29
Specific Cond. (Micromhos/cm)	3150	4080	4100	3310
pH (Laboratory)	7.6	8.1	8.3	8.0
Dissolved Oxygen (On Site)	8.2	10.2	12.2	8.8
Total Suspended Solids	59	7	13	274
Total Dissolved Solids	2718	3730	4020	2840
Oil and Grease	-5	-5	-5	-5
Turbidity (J.T.U.)	40	4.4	15	160
Fecal Coliform (Col/100 ml.)	44	390	970	190
Total Coliform (Col/100 ml.)	60	2900	2100	710
Sodium Adsorption Ratio	2.14	2.50	2.67	2.53
Boron	.4	1.9	1.4	0.7
Total Alkalinity as $CaCO_3$	372	458	433	355
Bicarbonate as HCO_3	453	559	528	433
Carbonate as CO_3	0	0	0	0
Acidity	0	0	0	0
Chloride	30	36	46	46
Nitrate as N	0.75	0.31	0.11	6.04
Nitrite as N	0.03	0.12	-0.01	0.04
Ortho-phosphate as P	-0.01	0.16	0.04	1.62
Sulfate as SO_4	1564	2170	2310	1700
Fluoride	0.10	0.26	0.31	0.54
Total Anions (meq/l)	40.90	55.39	58.05	44.15
Total Hardness as $CaCO_3$	1621	2200	2200	1640
Calcium	199	294	275	247
Magnesium	273	356	369	249
Sodium	198	269	289	236
Potassium	4	14	16	18
Ammonia Nitrogen as N	1.1	0.4	0.3	0.2
Organic Nitrogen as N	0.5	0.9	0.9	1.7
Total Kjeldahl Nitrogen as N	1.6	1.3	1.2	1.9
Silica	18	12	7	20
Total Cations (meq/l)	41.15	55.99	57.02	43.57
Aluminum, total	1.0	0.2	0.1	5.7
Dissolved	-0.1	0.1	-0.1	-0.1
Antimony, Total	-0.02	-0.02	-0.02	-0.02
Dissolved	-0.02	-0.02	-0.02	-0.02
Arsenic, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Cadmium, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Chromium, Total	-0.02	-0.02	-0.02	0.03
Dissolved	-0.02	-0.02	-0.02	-0.02
Hexavalent	-0.01	-0.01	-0.02	-0.01
Copper, Total	-0.01	0.02	0.03	0.03
Dissolved	-0.01	0.02	-0.01	0.01
Iron, Total	2.33	0.60	0.45	8.51
Dissolved	0.11	0.05	0.05	0.10
Lead, Total	-0.01	-0.02	-0.02	-0.02
Dissolved	-0.01	-0.02	-0.02	-0.02
Manganese, Total	1.83	0.50	0.77	1.41
Dissolved	1.80	0.50	0.77	-0.02
Mercury, Total	-0.001	-0.001	-0.001	-0.001
Dissolved	-0.001	-0.001	-0.001	-0.001
Selenium, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Vanadium, Total	-1.0	-0.1	-0.1	-0.1
Dissolved	-1.0	-0.1	-0.1	-0.1
Zinc, Total	0.02	-0.01	0.06	0.08
Dissolved	-0.01	-0.01	0.02	0.03
Temperature (^{o}C)		15.0	26.0	3.0

Components are expressed in mg/l unless otherwise noted.

A minus sign indicates that less than the reported value was present in the sample.

Exhibit 25

Table 12. Chemical Analyses of Water Sampled in 1978 from East Fork Armells Creek Station No. 2A.

Date	3/16	3/22	6/13	9/7	11/29
Specific Cond. (Micromhos/cm)	1000	1960	3130	3700	3590
pH (Laboratory)	7.9	7.2	8.0	8.0	8.1
Dissolved Oxygen (On Site)		8.7	12.5	3.8	10.3
Total Suspended Solids	4	269	5	14	10
Total Dissolved Solids	2320	1576	2820	3600	3200
Oil and Grease	-1.0	-5	-5	-5	-5
Turbidity (J.T.U.)	15	230	4.0	3.8	4.6
Fecal Coliform (Col/100 ml.)		2	350	102	4
Total Coliform (Col/100 ml.)		8	900	2500	4
Sodium Adsorption Ratio		1.36	1.91	2.34	2.06
Boron	-0.1	0.2	1.1	1.1	0.5
Total Alkalinity as $CaCO_3$	240	257	417	428	489
Bicarbonate as HCO_3	293	314	508	522	597
Carbonate as CO_3	0	0	0	0	0
Acidity	0	0	0	0	0
Chloride	6	11	17	37	22
Nitrate as N	0.10	0.56	0.13	-0.01	0.12
Nitrite as N		0.03	-0.01	0.23	0.02
Ortho-phosphate as P		-0.01	0.01	0.02	0.01
Sulfate as SO_4	353	895	1560	2080	1930
Fluoride	0.15	-0.01	0.23	0.15	0.18
Total Anions (meq/l)		24.12	41.31	52.95	50.62
Total Hardness as $CaCO_3$	504	1005	1680	2060	2010
Calcium	75	102	218	202	290
Magnesium	77	183	276	379	313
Sodium	44	99	181	245	213
Potassium	8	6	12	22	14
Ammonia Nitrogen as N	-0.1	0.9	1.5	0.6	0.2
Organic Nitrogen as N		-0.1	0.1	1.2	0.4
Total Kjeldahl Nitrogen as N	0.6	0.9	1.6	1.8	0.6
Silica		13	12	19	17
Total Cations (meq/l)		24.57	41.71	52.51	49.84
Aluminum, total	0.5	4.5	0.3	0.1	-0.1
Dissolved	0.3	-0.1	0.3	-0.1	-0.1
Antimony, Total		-0.02	-0.02	-0.02	-0.02
Dissolved		-0.02	-0.02	-0.02	-0.02
Arsenic, Total		-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005	-0.005
Cadmium, Total		-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005	-0.005
Chromium, Total		-0.02	-0.02	-0.02	0.02
Dissolved	-0.02	-0.02	-0.02	-0.02	-0.02
Hexavalent		-0.01	-0.01	-0.01	-0.01
Copper, Total		0.02	0.02	0.02	0.02
Dissolved	-0.01	-0.01	0.01	-0.01	0.01
Iron, Total	0.72	13.3	1.04	0.39	0.20
Dissolved	0.11	0.24	0.06	0.10	0.14
Lead, Total		-0.01	-0.02	-0.02	-0.02
Dissolved	-0.02	-0.01	-0.02	-0.02	-0.02
Manganese, Total		1.67	0.38	1.66	0.4
Dissolved	0.36	1.01	0.38	0.87	-0.02
Mercury, Total		-0.001	-0.001	-0.001	-0.001
Dissolved	-0.001	-0.001	-0.001	-0.001	-0.001
Selenium, Total		-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005	-0.005
Vanadium, Total		-1.0	-0.1	-0.1	-0.1
Dissolved	-1.0	-1.0	-0.1	-0.1	-0.1
Zinc, Total		0.06	-0.01	-0.01	0.07
Dissolved	-0.01	-0.01	-0.01	-0.01	0.05
Temperature (°C)			18.0	26.0	3.0

Components are expressed in mg/l unless otherwise noted.

A minus sign indicates that less than the reported value was present in the sample.

Exhibit 25

Table 13. Chemical Analyses of Water Sampled in 1978 from East Fork Armells Creek Station Nos. 9A and 9.

Date	Station 9A 3/22	Station 9A 6/13	Station 9 9/7	Station 9 11/29
Specific Cond. (Micromhos/cm)	4100	4240	3910	3780
pH (Laboratory)	7.4	8.0	7.9	8.1
Dissolved Oxygen (On Site)	5.5	11.0	5.8	9.7
Total Suspended Solids	20	11	6	12
Total Dissolved Solids	3834	3970	3870	3390
Oil and Grease	-5	-5	-5	-5
Turbidity (J.T.U.)	12	4.3	6.0	4.2
Fecal Coliform (Col/100 ml.)	-1	880	164	2
Total Coliform (Col/100 ml.)	10	1700	320	18
Sodium Adsorption Ratio	2.52	2.57	2.49	2.56
Boron	0.2	0.7	0.5	0.3
Total Alkalinity as $CaCO_3$	400	418	355	401
Bicarbonate as HCO_3	488	509	434	489
Carbonate as CO_3	0	0	0	0
Acidity	0	0	0	0
Chloride	23	17	22	19
Nitrate as N	0.11	0.01	0.08	0.38
Nitrite as N	0.11	-0.01	-0.01	-0.01
Ortho-phosphate as P	-0.01	0.01	0.01	-0.01
Sulfate as SO_4	2365	2410	2300	2140
Fluoride	-0.01	0.30	0.30	0.28
Total Anions (meq/l)	57.94	58.99	55.70	53.23
Total Hardness as $CaCO_3$	2249	2370	2140	2060
Calcium	220	252	222	242
Magnesium	414	423	386	355
Sodium	275	287	265	267
Potassium	7	12	15	14
Ammonia Nitrogen as N	0.1	0.4	0.3	-0.1
Organic Nitrogen as N	0.1	1.2	14.0	2.0
Total Kjeldahl Nitrogen as N	0.2	1.6	14.3	2.0
Silica	16	10	13	17
Total Cations (meq/l)	57.10	60.13	54.70	53.28
Aluminum, total	0.6	0.2	-0.1	0.2
Dissolved	-0.1	-0.1	-0.1	-0.1
Antimony, Total	-0.02	-0.02	-0.02	-0.02
Dissolved	-0.02	-0.02	-0.02	-0.02
Arsenic, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Cadmium, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Chromium, Total	-0.02	-0.02	-0.02	0.03
Dissolved	-0.02	-0.02	-0.02	-0.02
Hexavalent	-0.01	-0.01	-0.01	-0.01
Copper, Total	-0.01	0.02	-0.02	0.02
Dissolved	-0.01	0.02	-0.01	0.02
Iron, Total	1.23	0.61	0.55	0.21
Dissolved	0.16	0.05	0.33	0.14
Lead, Total	-0.01	-0.02	-0.02	-0.02
Dissolved	-0.01	-0.02	-0.02	-0.02
Manganese, Total	1.96	0.61	0.62	0.12
Dissolved	1.92 ~~1.02~~	0.61	0.62	-0.02
Mercury, Total	-0.001	-0.001	-0.001	-0.001
Dissolved	-0.001	-0.001	-0.001	-0.001
Selenium, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Vanadium, Total	-1.0	-0.1	-0.1	-0.1
Dissolved	-1.0	-0.1	-0.1	-0.1
Zinc, Total	0.01	-0.01	0.03	0.03
Dissolved	-0.01	-0.01	0.02	-0.01
Temperature (°C)		20.0	17.0	1.5

Components are expressed in mg/l unless otherwise noted.

A minus sign indicates that less than the reported value was present in the sample.

Exhibit 25

and September as surface runoff declined and effects of groundwater became more apparent. Concentrations declined again in late November in response to snowmelt.

Although Stations 9A and 9 are separated by a small stream impoundment, there was little difference in water chemistry between the two sites. Total anions and cations increased only slightly from March to June at Station 9A. A small increase in stream flow at Station 9 during November resulted in a slight decrease in total anions and cations. Concentrations of major constituents cannot be quantitatively correlated with streamflow because flows were not measured. References to changes in flow are based only on the relative change in the estimated width and depth of the channel.

Concentrations of many trace metals were below levels of accurate measurement and displayed no change by location or date. Concentrations of aluminum, iron and manganese varied inconsistently. The highest concentrations of total aluminum, 4.5 mg/l, occurred in March at Station 2A and 5.7 mg/l in November at Station 1. Total iron was highest at Station 2A in March with a concentration of 13.3 mg/l. A maximum of 0.6 mg/l dissolved iron occurred at Station 1A in September. Total manganese was greatest at Station 1A in September with a concentration of 2.02 mg/l followed by 1.96 mg/l at Station 9A in March.

Dissolved oxygen concentrations were lowest in September when water temperatures were highest. A low of 2.2 mg/l dissolved oxygen was observed at Station 1A. Only 3.8 mg/l dissolved oxygen was present at Station 2A at which time water temperature was 26.0 degrees. The stream was temporarily impounded at 2A due to road construction across the creek and macroinvertebrate life was virtually nonexistent. At the same time, dissolved oxygen at Station 1 was 12.2 mg/l with a temperature of 26.0 degrees. The low oxygen content at 2A was probably a result of input of unaerated groundwater to a pond-like environment. Oxygen levels at Station 1 remained high when water temperature was 26° because the flowing water enhanced the rate of oxygen solution into the water.

Information from the previous tables has been summarized in Table 14 which shows the mean concentrations of chemical constituents in all samples collected in 1978. The most significant observation in this table is the fact that the concentrations of total anions and total cations are lowest at Station 2A and increase both upstream and downstream. Streamflow is usually continuous from Station 2A through Stations 1 and 1A; therefore, the increase in chemical concentrations is real. Stations 9 and 9A are more than 15 kilometers upstream from site 2A and the majority of the intervening streambed is almost always dry; therefore, water quality at the upstream locations may neither resemble nor relate directly to conditions at Site 2A.

Table 14. Mean Concentrations of Chemical Analyses of Water Sampled from East Fork Armells Creek in 1978

Station	1A	1	2A	9	9A
Number of Samples	4	4	5	2	2
Specific Cond. (Micromhos/cm)	5055	3660	2676	3845	4170
pH (Laboratory)	7.9	8.0	7.8	8.0	7.7
Dissolved Oxygen (On Site)	7.1	9.9	8.8*	7.8	8.3
Total Suspended Solids	21	88	60	9	16
Total Dissolved Solids	5013	3327	2703	3630	3902
Oil and Grease	-5	-5	-5	-5	-5
Turbidity (J.T.U.)	18.2	55	51.5	5.1	8.2
Fecal Coliform (Col/100 ml.)	675	399	115*	83	441
Total Coliform (Col/100 ml.)	1013	1443	853*	169	855
Sodium Adsorption Ratio	4.14	2.46	1.92*	2.53	2.55
Boron	1.0	1.1	0.6	0.4	0.5
Total Alkalinity as $CaCO_3$	426	405	366	378	409
Bicarbonate as HCO_3	520	493	447	462	499
Carbonate as CO_3	0	0	0	0	0
Acidity	0	0	0	0	0
Chloride	45	40	19	21	20
Nitrate as N	0.23	1.8	0.18	0.23	0.06
Nitrite as N	0.09	0.05	0.07	-0.01	0.06
Ortho-phosphate as P	0.04	0.5	0.01*	0.01	0.01
Sulfate as SO_4	3062	1936	1364	2220	2388
Fluoride	0.17	0.30	0.14	0.29	0.16
Total Anions (meq/l)	73.58	49.62	42.25*	54.47	58.47
Total Hardness as $CaCO_3$	2576	1915	1452	2100	2310
Calcium	291	254	177	232	236
Magnesium	450	312	246	371	419
Sodium	503	248	156	266	281
Potassium	16	13	12	15	10
Ammonia Nitrogen as N	0.3	0.5	0.7	0.2	-0.3
Organic Nitrogen as N	2.4	1.0	0.5*	8.0	0.7
Total Kjeldahl Nitrogen as N	2.7	1.5	1.1	8.2	0.9
Silica	10.5	14	15	15	13
Total Cations (meq/l)	73.78	49.43	42.16*	53.99	58.62
Aluminum, Total	0.3	1.75	1.1	-0.2	0.4
Dissolved	0.1	-0.1	-0.2	-0.1	-0.1
Antimony, Total	-0.02	-0.02	-0.02*	-0.02	-0.02
Dissolved	-0.02	-0.02	-0.02*	-0.02	-0.02
Arsenic, Total	-0.005	-0.005	-0.005*	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005	-0.005
Cadmium, Total	-0.005	-0.005	-0.005*	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005	-0.005
Chromium, Total	0.02	-0.02	-0.02*	-0.03	-0.02
Dissolved	0.02	-0.02	-0.02	-0.02	-0.02
Hexavalent	-0.01	-0.01	-0.01*	-0.01	-0.01
Copper, Total	-0.02	-0.02	-0.02*	0.02	-0.02
Dissolved	0.01	-0.01	-0.01	-0.02	-0.02
Iron, Total	1.22	2.97	3.13	0.38	0.92
Dissolved	0.26	0.08	0.13	0.24	0.11
Lead, Total	-0.02	-0.02	-0.02*	-0.02	-0.02
Dissolved	-0.02	-0.02	-0.02	-0.02	-0.02
Manganese, Total	0.80	1.13	1.03*	0.74	1.29
Dissolved	0.39	0.77	0.53	0.32	1.27
Mercury, Total	-0.001	-0.001	-0.001*	-0.001	-0.001
Dissolved	-0.001	-0.001	-0.001	-0.001	-0.001
Selenium, Total	-0.005	-0.005	-0.005*	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005	-0.005
Vanadium, Total	0.3	-0.3	-0.3*	-0.1	-0.6
Dissolved	0.3	-0.3	-0.05	-0.1	-0.6
Zinc, Total	0.02	-0.04	0.04*	0.03	-0.01
Dissolved	0.02	-0.02	-0.02	-0.02	-0.01

* Mean concentration of 4 samples.
Components expressed in mg/l unless otherwise noted.
A minus sign indicates that less than the reported value was present in the sample.

Continuous stream discharge data is not available for any locations on the East Fork; however, streamflow at Station 1A is probably consistently higher than that of Station 1 because several small drainages enter the creek between these two sites. Even though streamflow at Station 1A equals or exceeds that of Station 1 the concentrations of chemical constituents is significantly greater at the downstream location.

In general, average concentrations of major chemical constituents in stream water did not change from 1977 to 1978 (see appendix B for 1977 data). Major ions were less concentrated at Station 3 in 1977 and concentrations increased downstream, which duplicates the pattern noted in 1978. Concentrations of major elements from Stations 1, 2 and 3 in 1977 were similar to those observed at Stations 1 and 2A in 1978. Chemical concentrations at Stations 9/9A in 1978 generally exceeded levels at Station 9 in the previous year.

Ponds

The results of water analyses from Turtle Pond are presented in Table 15. Except for metals, the concentrations of most constituents increased steadily during the year. Surface runoff into the pond in the spring raised the surface elevation approximately one meter. As surface runoff declined and pond elevation dropped, concentrations increased in response to

Exhibit 25

Table 15. Chemical Analyses of Water Sampled in 1978 from Turtle Pond.

DATE	3/22	6/13	9/7	11/29
Specific Cond. (Micromhos/cm)	680	1030	1350	1680
pH (Laboratory)	6.5	8.0	8.2	8.1
Dissolved Oxygen (On Site)	4.4	9.3	14.7	11.4
Total Suspended Solids	9	1	14	5
Total Dissolved Solids	520	824	1150	1320
Oil and Grease	-5			
Turbidity (J.T.U.)	2.5	0.70	3.9	1.2
Sodium Adsorption Ratio	0.18	0.23	0.24	0.27
Boron	-0.1	0.3	0.1	0.1
Total Alkalinity as $CaCO_3$	75	136	129	222
Bicarbonate as HCO_3	92	167	157	271
Carbonate as CO_3	0	0	0	0
Acidity as $CaCO_3$	60	0	0	0
Chloride	3	3	2	6
Nitrate as N	0.16	-0.01	0.05	-0.01
Nitrite as N	0.01	-0.01	-0.01	0.01
Ortho-phosphate as P	-0.01	0.01	0.01	-0.01
Sulfate as SO_4	305	474	670	810
Fluoride	-0.01	0.19	0.21	0.22
Total Anions (meq/l)	7.94	12.70	16.65	21.48
Total Hardness as $CaCO_3$	375	601	780	1020
Calcium	61	98	109	154
Magnesium	54	87	124	154
Sodium	8	13	15	19
Potassium	2	7	3	8
Ammonia Nitrogen as N	0.2	0.2	0.6	-0.1
Organic Nitrogen as N	0.7	0.7	5.6	0.5
Total Kjeldahl Nitrogen as N	0.9	0.9	6.2	0.5
Silica	3	3	2	1
Total Cations (meq/l)	7.89	12.77	16.37	21.41
Aluminum, total	0.5	0.1	0.1	0.1
Dissolved	-0.1	-0.1	-0.1	-0.1
Antimony, Total	-0.02	-0.02	-0.02	-0.02
Dissolved	-0.02	-0.02	-0.02	-0.02
Arsenic, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Cadmium, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Chromium, Total	-0.02	-0.02	-0.02	-0.02
Dissolved	-0.02	-0.02	-0.02	-0.02
Hexavalent	-0.01	-0.01	-0.01	-0.01
Copper, Total	0.02	-0.01	-0.01	0.02
Dissolved	-0.01	-0.01	-0.01	0.02
Iron, Total	0.64	0.09	0.04	0.09
Dissolved	0.09	-0.05	-0.05	-0.05
Lead, Total	-0.01	-0.02	-0.02	-0.02
Dissolved	-0.01	-0.02	-0.02	-0.02
Manganese, Total	0.42	-0.02	0.09	0.03
Dissolved	0.42	-0.02	0.07	0.02
Mercury, Total	-0.001	-0.001	-0.001	-0.001
Dissolved	-0.001	-0.001	-0.001	-0.001
Selenium, Total	-0.005	-0.005	-0.005	-0.005
Dissolved	-0.005	-0.005	-0.005	-0.005
Vanadium, Total	-1.0	-0.1	-0.1	-0.1
Dissolved	-1.0	-0.1	-0.1	-0.1
Zinc, Total	0.02	-0.01	-0.01	0.02
Dissolved	-0.01	-0.01	-0.01	0.02
Temperature (^{o}C)		22.0	23.0	1.0

Components are expressed in mg/l unless otherwise noted.

A minus sign indicates that less than the reported value was present in the sample.

Exhibit 25

effects of groundwater input. Parameters of interest in the March sample are the low pH, low dissolved oxygen, high acidity and high concentrations of iron and manganese. This combination of factors indicates the presence of anaerobic conditions in the pond. Surface ice was present from early December through mid March. At the time this sample was taken, little ice remained. The water sample was collected near the surface where dissolved oxygen was expected to be greatest. Unfortunately dissolved oxygen was not measured in deeper water. Wind action and surface runoff may have increased oxygen concentrations over levels that were present during the winter.

Concentrations of major constituents in 1978 were significantly less than concentrations from 1977 water samples (see Appendix B). For example, total dissolved solids ranged from 520 to 1,320 mg/l in 1978. In 1977, total dissolved solids varied from 1,692 to 2,994 mg/l. The differences may be due to changes in precipitation and runoff with respect to sampling dates.

Exhibit 25

DISCUSSION

The physical, chemical, and biological characteristics of the East Fork of Armells Creek are remarkably similar to those of Sarpy Creek (Clancey, 1978). Both streams are temporary and have substrates comprised of mud and organic debris. Similar macroinvertabrate communities exist in both ecosystems and are dominated by chironomids and amphipods.

The most abundant midge larvae were Chironomus, Micropsectra and Cricotopus. Of these genera, the first two are members of the subfamily Chironominae. The larvae of this group are primarily detritus feeders, many of which live in tubes constructed from the fine materials in the substrate (Bryce and Hobart, 1972). Percival and Whitehead, (1929) found that numbers of midge larvae increased as the amount of fine deposits and detritus increased.

Larvae of the subfamily Chironominae contain hemoglobin, hence the name "bloodworms". Walshe (1948) discovered that species of this group could survive without oxygen; however, the survival time varied with the species. The minimum oxygen levels survived by most species are unknown.

Larvae of the genus Cricotopus, subfamily Orthocladiinae, do not contain hemoglobin and are restricted to areas containing adequate

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oxygen supplies. The organisms commonly live on the leaves and stems of aquatic plants and eat algae from plant surfaces (Bryce and Hobart, 1972).

The genera discussed above comprised about 31 percent of the total fauna from Armells Creek in 1978. Their abundance is related primarily to the combination of physical factors in the stream, namely the high amounts of detritus and fine materials in the substrate, dense growth of aquatic vegetation and low water velocity. When periods of low oxygen content occur, oxygen deficiency is most severe near the substrate where Chironomus and Micropsectra are present. These organisms will tolerate short term anaerobic conditions. Cricotopus larvae may survive periods of low oxygen because they are attached to aquatic vegetation above the substrate where oxygen concentrations are generally greater.

Another chironomid genera which deserves mention is Odontomesa of the subfamily Diamesinae. This group is typically found in mountain springs and is adapted to cold water (Bryce and Hobart, 1972). Seven larvae were found in June at station 2A. The presence of this organism was unexpected and cannot be explained.

Hyalella azteca comprised more than a third of the total number of individuals in the creek. This organism is commonly

found in shallow waters of small ponds and slow moving streams. Hyalella inhabits areas of dense aquatic vegetation and feeds on live plant material or on organic debris in the benthos (Cooper, 1965). Studies conducted by de March (1977) revealed that reproductive activity was initiated in the spring and terminated in the fall in response to photoperiod changes. Growth and reproductive activity was enhanced when water temperatures were between 20-26 degrees C. During midsummer the females may release young as often as every eight days. Numbers are highest in the summer and decline through the fall and winter months to a seasonal low in late spring. This pattern was evident in East Fork Armells Creek except at stations where oxygen levels were severely reduced in September. Pennak (1953) states that these amphipods require an abundance of dissolved oxygen; however, Sprague (1963) observed a mortality threshold of 0.7 mg/1 dissolved oxygen for Hyalella azteca. These animals are equipped with abdominal appendages called pleopods which are used for swimming and for circulating the water over their gills. These advantages should allow the amphipod to escape areas of low oxygen content and to increase the efficiency of their gills.

Of the mollusks found in Armells Creek, Physa and Lymnaea are the most abundant. Both are omnivorous (Pennak, 1953). Species determinations have not yet been made, however Physa is probably either gyrina or integra. Both species are typically found in substrate of silt and detritus (Harman 1972). Von Brand et al

(1950) demonstrated the Physa gyrina has a limited resistance to anaerobic conditions. Many snails are capable of escaping harsh conditions. Snails will hibernate in the mud to avoid freezing conditions in the winter and will aestivate in intermittent streams during dry periods (Pennak, 1953).

The invertebrate groups discussed above dominate the faunal community of East Fork Armells Creek. Their numbers are relatively high because they comprise the largest trophic level for macroinvertebrates in the creek. These organisms are primarily detritivores. Their food base, dead plant and animal material, is a major energy source for the ecosystem. In addition to an adequate food supply, organism abundance reflects the occurrence of environmental preferences, namely low water velocity, abundant aquatic vegetation and favorable water temperatures. Some of these species have also adapted to periods of anaerobic conditions or dry periods.

The remaining insect groups comprised a small percentage of the total number of organisms found in East Fork Armells Creek. Their low populations are primarily a result of unfavorable physical conditions in their environment or a reflection of position in the trophic structure.

Many species of Ephemeroptera are inhabitants of cool, clean, rapidly flowing streams. Caenis and Callibaetis are better adapted to slow moving streams and lakes and ponds. Caenis

nymphs are more tolerant of low oxygen levels than other mayflies (Hilsenhoff, 1975).

Members of the order Trichoptera are not common in Armells Creek because most caddisfly families are better adapted to cool running waters (Wiggins, 1977). Few larvae of Cheumatopsyche and Hydropsyche were collected in 1978 relative to the numbers found in 1977 because fewer summer collections were made in 1978. The larvae of these genera construct nets which filter food particles from flowing water. Nets are constructed to withstand a limited range of water velocities which varies with each species (Edington, 1965 and 1968). Increases or decreases in velocity will cause the net to collapse and force the animal to move to another location. Streamflow and water velocity in Armells Creek are subject to sudden changes in response to rainfall and snowmelt. As streamflow decreases in late summer, water velocities are often reduced to near zero. These conditions will not allow the successful establishment of large populations of netspinning caddisflies.

Several species of odonates were found in the creek since 1977. Warm, still or slow-moving water such as that of Armells Creek is often preferred by many species of dragonflies and damselflies. As predators, these insects are near the top of the food chain; therefore, their numbers are relatively low.

The majority of the insect groups discussed above have life cycles in which the immature larvae or nymphs are rather

long-lived, spending as much as a year or more in the water; therefore, collections of these individuals can be made throughout the year. The adults, however, are short-lived and survive for as little as a few hours, days, or weeks. Their adult life is spent as aerial insects.

The Hemiptera and Coleoptera are more common and varied in Armells Creek than indicated by the 1978 data. Most collections taken in 1977 were made during the summer months when most of the immature forms of bugs and beetles were present. The adults of these two orders normally survive the winter by hibernating or in an active state and will lay eggs in the spring. Both the young and the adults live in the water and most of the species are capable of swimming, unlike the insects discussed above. For these reasons more beetles and bugs were collected in 1977 when a kick net was used. Most water bugs and beetles also share the ability to obtain oxygen at the water's surface; therefore, they are not totally restricted from waters containing low concentrations of dissolved oxygen. Most of these insects in Armells Creek are predators with the exception of the family Corixidae. This family of bugs is herbivorous which explains the fact that they are more abundant in Armells Creek than other groups of bugs and beetles (Roemhild, 1976).

In addition to physical factors, the concentrations of chemical constituents in the water can also affect the occurrence, abundance and distribution of aquatic life in water bodies; however,

specific information is limited. The Environmental Protection Agency (1976) has established water quality criteria for several organic and inorganic parameters based on information obtained from an extensive literature review. Few of the criteria relate to freshwater aquatic life, particularly aquatic insects. Determination of toxic levels of specific elements for aquatic macroinvertebrates has been difficult because toxicity is often species specific and affected by water temperature, pH, hardness and duration of exposure. Some of the chemical parameters of Armells Creek occur in concentrations which sometimes exceed water quality standards or criteria. These elements and their possible causes and effects will be discussed in the following paragraphs.

Boron concentrations in Armells Creek varied from 2.3 to 3.3 mg/l in April, 1977. Since that time, concentrations were considerably less due to a change in analytical procedures (Jay Lyndes, Northern Testing Laboratories, personal communication). Boron levels in Armells Creek are similar to those of other streams in southeastern Montana (Knapton and McKinley, 1977). The EPA (1976) has established a criterion of 0.75 mg/l for boron for irrigation of sensitive crops such as citrus. Criteria for other uses were not recommended because the EPA believed that naturally occurring concentrations of boron would not adversely affect aquatic life.

A dissolved cadmium concentration of 0.005 mg/l was recorded for all water samples collected from the east fork. The criterion for cladocerans and salmonid fishes was set at 0.0012 mg/l cadmium in hard water (EPA, 1976). The cadmium criterion for less sensitive species is 0.012 mg/l. (Note: published literature which discusses criteria and toxicity levels of metals does not always express concentrations as dissolved or total recoverable. In such cases, it is assumed that the author is referring to dissolved concentrations. The same assumption will apply to this report.)

Beisinger and Christensen (1972) determined that a cadmium level of 0.005 mg/l was toxic to Daphnia magna, a cladoceran. An unidentified cladoceran occurs in Armells Creek. A sample taken in June 1977 contained about 1,000 of these organisms. Pickering and Gast (1972) found that 0.057 mg/l cadmium decreased the survival of fathead minnow (Pimephales promelas) embryos. This species is common in southeastern Montana, including Armells Creek.

Cadmium concentrations in waters of southeastern Montana including Armells Creek are often in excess of the criterion, 0.0012 mg/l (USGS, 1976, 1977, 1978). These levels are a natural characteristic of the region and adverse effects on biological communities have not been observed.

Other metals of importance in Armells Creek are iron and manganese. The recommended criterion for dissolved iron is 1.0

mg/l for protection of freshwater life (EPA, 1976). Concentrations of dissolved iron in streams of southeastern Montana, including Armells Creek, are generally well below this level (Knapton and McKinley, 1977). Manganese is rarely found at concentrations that exceed 1.0 mg/l which is below tolerance values reported for freshwater organisms; therefore, the EPA (1976) has not recommended a criterion for this metal.

Iron and manganese concentrations in Colstrip area soils are highest near the soil surface (Schafer et al, 1979). These metals may be leached from the soil during runoff which results in increased levels in surface waters. Most of the manganese is in the dissolved form. Little of the iron is dissolved because most of it becomes associated with suspended particles (Wetzel, 1975). Concentrations of total iron in Armells Creek increase as suspended sediments increase.

Nitrogen is present in aquatic ecosystems as organic or inorganic compounds. Inorganic forms such as ammonia, nitrates and nitrites can be toxic when present in high concentrations. Ammonia concentrations increase during decomposition of organic matter, particularly under conditions of low oxygen (Reid, 1961). Ammonia concentrations reported in this document include both the unionized portion, NH_3, and the ammonium ion, NH_4^+. The unionized form can be toxic to freshwater organisms; therefore, the EPA (1976) has established a criterion of 0.02 mg/l for freshwater aquatic life. The percent unionized NH_3 in

aqueous ammonia varies with temperature and pH. Using tables developed by Thurston et al (1977), the percent NH_3 was determined for ammonia values reported in this study, and none of the concentrations exceeded EPA criteria.

Nitrate nitrogen has increased at Station 1, since new sewage facilities became operational in late 1978. Nitrate N was 6.04 mg/l at Station 1 in November 1978 and decreased to 0.79 mg/l at Station 1A. The levels known to be toxic are much higher than levels in Armells Creek. The EPA (1976) did not recommend restrictive criteria for nitrates and nitrites for freshwater aquatic life because they believed that toxic levels would rarely occur.

Sulfates in surface and groundwaters of the coal regions of southeastern Montana are relatively high. A probable major source of sulfates is the decomposition of pyritic sulfur in the coal seams (Caruccio and Geidel, 1978). Decomposition of organic sulfur and reduction of sulfate under anaerobic conditions generates hydrogen sulfide. Hydrogen sulfide may react with iron to form insoluble iron sulfide (Wetzel, 1975). These reactions likely occur in Armells Creek, particularly near the sediments. The black sediments, characteristic of sulfides are present throughout the study section, especially in areas where groundwater enters the stream. Such areas usually have stagnant waters of low oxygen content. Anoxic conditions may occur during winter or summer, in the creek or in ponds of the area.

There was little difference in community composition of invertebrates of Armells Creek and Turtle Pond. This was not surprising because both ecosystems possess similar characteristics of groundwater influence, water chemistry and substrate. More important is the occurrence of minimal water velocities in the stream, a parameter which attracts invertebrate populations that are typical of a pond-like habitat.

Unlike portions of Armells Creek, particularly upstream from Colstrip, Turtle Pond is a permanent water body; therefore, ecosystem stability, diversity and number of species in the pond are greater than they are in the upper reaches of the stream. The creek immediately below Colstrip usually contains flow and its invertebrate community is similar in diversity to that of Turtle Pond.

Turtle Pond also provides a more stable environment for aquatic life than does the EPA depression. The extreme shallowness of the depression allows significant portions of the shoreline to alternate between wet and dry conditions in response to precipitation and evaporation. This feature prevents the successful establishment and growth of benthic organisms and plant life. The lack of groundwater removes the stabilizing influence on water chemistry. Water quality is subject to extreme fluctuations as water levels change.

Although Turtle Pond was not designed to create an environment capable of supporting aquatic life, the data presented in this

report demonstrate that the ability exists to provide aquatic ecosystems in reclaimed areas. It is evident that to support an aquatic community in an artificial pond, the pond must be supported by groundwater and surface drainage in order to provide a degree of stability in chemical and physical features. Turtle Pond is not ideal in this regard because it is not located along a significant drainage and is too small to minimize effects of precipitation events, evaporation and possible deoxgenation. Preferred sites for creating ponds or impoundments in reclaimed areas include the initial box cut or the final cut in small drainages with minimal depth to groundwater. Such ponds should have shallow depths near portions of the shoreline to allow access for watering livestock and wildlife and for establishment of emergent vegetation. Maximum water depth should range from a minimum of four or five meters to prevent excess vegetative production and minimize the potential for anoxic conditions to occur. Some allowance is also required for deposition of silts.

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Exhibit 25

APPENDIX A

Exhibit 25

Table A1. Organisms Collected with a Kick Net From East Fork Armells Creek in 1977 by Date and Station.

Station	1						2						3			9		
	4/12	5/10	6/22	8/12	9/12	Total	4/12	5/10	6/22	8/12	9/12	Total	4/12	5/10	Total	4/12	5/10	Total
Odonata								1				1						
Aeshna								1				1						
Libellula				2	4	6		1		2		2						
Plathemis				1		1												
Sympetrum			1	1		2				1	1	2						
Amphiagrion	2	1	2	38	20	63	1	3		5	2	11					2	2
Argia																	1	1
Enallagma			2	4		6												
Ischnura	4	2	1	65	89	161	2	2		17	10	31					6	6
Lestes			1			1												
Emphemeroptera																		
Rhithrogena	1					1												
Baetidae			175	8	70	253			1			1	3	7	10	50	18	68
Caenis				1	2	3		7	5	7		19						
Plecoptera					2	2												
Trichoptera																		
Hydroptilidae					1	1					1	1					2	2
Cheumatopsyche				38		38		1				1	2		2			
Hydropsyche									1			1						
Limnephilus													6		6	3		3
Diptera																		
Tipulidae													2		2	2		2
Simuliidae		3	11	5	1	20			2			2						
Euparyphus							1	4				5	4	2	6	4	16	20
Odontomyia									1			1						
Tabanidae		2	3	3		8		3		1	1	5		1	1	1	1	2
Empididae													3		3	1	2	3
Liriope																1		1
Ephydridae			1			1			5			5						
Chironomidae	27	138	267	37	18	487	90	156	152	8	218	624	121	72	193	134	305	439

Exhibit 25

Table A1. (Cont.)

Station	1						2						3			9		
	4/12	5/10	6/22	8/12	9/12	Total	4/12	5/10	6/22	8/12	9/12	Total	4/12	5/10	Total	4/12	5/10	Total
Hemiptera																		
Hesperocorixa			210		4	214			7			7						
Corisella			6			6												
Cenocorixa			1			1												
Notonecta			2			2												
Gerris									1		1	2						
Mesovelia										1		1						
Coleoptera																		
Agabus		27	8	6		41							1	11	12			
Bidessus				1		1	1					1						
Laccophilus			197			197												
Eretes	1					1							1	2	3			
Hydaticus										1		1						
Rhantus									2			2						
Hygrotus								3				3						
Hydraenidae								4				4						
Noteridae													1		1			
Hydroscapha			1			1												
Hydrobius				1		1												
Berosus		1	2	1		4	1	2				3					31	31
Tropisternus			25			25				2		2						
Enochrus										1		1						
Helophorus										1		1						
Hydrophilus									1			1						
Haliplus			27	12	2	41	1	7	1	9	1	19						
Chrysomelidae		1				1												
Oligochaeta	1	3				4											2	2
Hirudinea				4		4	1	3		100		104						
Amphipoda	121	22	429	891	515	1978	717	560	37	1224	536	3074	96	25	121	51	84	135
Acari											1	1						
Mollusca																		
Physa	1		29	12	125	167			2	1	21	24		2	2	5	23	28
Lymnaea											3	3						
Planoribidae										2	2	4						
Unionidae																		
TOTALS	158	200	1401	1131	853	3743	815	756	218	1383	798	3970	240	122	362	252	493	745

Exhibit 25

Table A2. Organisms Collected with an Ekman Dredge from Turtle Pond and the EPA Depression in 1977.

	Turtle Pond						EPA Depression				
	4/11	5/10	6/22	8/12	9/12	Total	4/12	5/10	6/22	8/12	Total
Odonata											
Anax				3		3					
Gomphidae				1		1					
Libellula					4	4					
Sympetrum	5			2		7					
Amphiagrion	1					1					
Ischnura	1	1	1	24		27					
Ephemeroptera											
Baetidae					1	1					
Caenis				2	1	3					
Diptera											
Tabanus	1		1			2					
Tipula								3			3
Chironomidae	1	3				4	16	5	6	4	31
Hemiptera											
Notonecta				1		1					
Coleoptera											
Curculionidae				1		1					
Haliplus	1		2	3	1	7					
Berosus	2	2	3		7	14				9	9
Bidessus										1	1
Amphipoda	21	2		22		45					
Mollusca											
Physa	25	4	3	6	2	40					
Planoribidae	4	1		11	1	17					
Sphaeridae			3			3					
TOTALS	62	13	13	76	17	181	16	8	6	14	44

APPENDIX B

Exhibit 25

Table B1. Chemical Analysis of Waters Sampled in 1977 from Armells Creek Station No. 1

	Date			
	4/11	6/8	9/21	12/1
Specific Cond. (Micromhos/cm)	3500	3050	4140	3660
pH (Laboratory)	8.3	8.4	8.3	8.1
Dissolved Oxygen (On Site)	16.6	15.2	10.9	10.0
Total Suspended Solids	21	17	44	207
Total Dissolved Solids	3506	2796	4078	3308
Oil and Grease	-1.0	-1.0	-1.0	-1.0
Turbidity (J.T.U.)	16	4.6	24	140
Fecal Coliform (Col/100 ml.)	34	510	740	50
Total Coliform (Col/100 ml.)	450	1200	5200	500
Sodium Adsorption Ration	2.46	2.34	2.91	2.16
Boron	3.3	1.5	.6	2.5
Total Alkalinity as $CaCO_3$	449	310	473	351
Bicarbonate as HCO_3	546	357	577	429
Carbonate as CO_3	1	10	0	0
Acidity	0	0	0	0
Chloride	49	45	55	34
Nitrate as N	1.49	3.19	.95	1.22
Nitrite as N	-.01	.08	.05	.11
Ortho-phosphate as P	.10	.27	.14	.29
Sulfate as SO_4	2007	1595	2327	1951
Fluoride	.29	.34	.21	.50
Total Anions (meq/l)	52.29	40.93	59.57	48.73
Total Hardness as $CaCO^3$	2010	1545	2242	1934
Calcium	255	220	290	244
Magnesium	334	242	369	322
Sodium	254	211	317	218
Potassium	14	15	16	14
Ammonia Nitrogen as N	-1.0	-1.0	-1.0	.3
Organic Nitrogen as N	1.3	3.2	2.0	.7
Total Nitrogen as N	1.3	3.2	2.0	1.0
Silica	8	5	15	17
Total Cations (meg/l)	51.6	40.47	59.05	48.51
Diff. Anions-Cations (meq/l)	.69	.46	.52	.22
Aluminum, Total	.2	-.1	.5	6.0
Dissolved	.1	-.1	.4	.4
Antimony, Total	-.2	-.2	-.2	-.02
Dissolved	-.2	-.2	-.2	-.02
Arsenic, Total	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005
Cadmium, Total	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005
Chromium, Total	-.02	-.02	-.02	.02
Dissolved	-.02	-.02	-.02	-.02
Hexavalent	-.01	-.01	-.01	-.01
Copper, Total	-.02	-.01	.01	.04
Dissolved	-.02	-.01	-.01	.02

Exhibit 25

Table B1 (Cont'd)	Date 4/11	6/8	9/21	12/1
Iron, Total	1.07	.29	1.21	6.78
Dissolved	-.05	.09	-.05	-.05
Lead, Total	-.02	-.02	-.02	-.02
Dissolved	-.02	-.02	-.02	-.02
Managanese, Total	1.27	.21	.72	1.74
Dissolved	.97	.20	.63	1.47
Mercury, Total	-.001	-.001	-.001	.004
Dissolved	-.001	-.001	-.001	-.001
Selenium, Total	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005
Vanadium, Total	-1.0	-1.0	-1.0	-1.0
Dissolved	-1.0	-1.0	-1.0	-1.0
Zinc, Total	.03	-.01	-.01	.03
Dissolved	.03	-.01	-.01	-.01

Components are expressed in mg/l unless otherwise noted.

A minus sign indicates that less than the reported value was present in the sample.

Table B2. Chemical Analysis of Waters Sampled in 1977 from Armells Creek Station No. 2

	Date			
	4/11	6/8	9/21	12/1
Specific Cond. (Micromhos/cm)	2790	3330	3340	3420
pH (Laboratory)	8.3	8.3	8.1	8.2
Dissolved Oxygen (On Site)	14.5	11.1	14.2	9.2
Total Suspended Solids	9	58	17	88
Total Dissolved Solids	2744	3114	3226	3110
Oil and Grease	-1.0	-1.0	-1.0	-1.0
Turbidity (J.T.U.)	8.6	9.1	7.7	28
Fecal Coliform (Col/100 ml.)	4	170	360	170
Total Coliform (Col/100 ml.)	400	1800	3800	200
Sodium Adsorption Ration	1.98	1.96	1.96	1.85
Boron	2.9	.7	.5	.4
Total Alkalinity as $CaCO_3$	403	436	424	454
Bicarbonate as HCO_3	491	531	518	553
Carbonate as CO_3	0	0	0	0
Acidity	0	0	0	0
Chloride	22	20	23	21
Nitrate as N	.73	,19	.09	.06
Nitrite as N	-.01	.01	-.01	.06
Ortho-phosphate as P	.01	.02	.01	.04
Sulfate as SO_4	1577	1761	1819	1750
Fluoride	.28	.20	.19	.27
Total Anions (meq/l)	41.56	45.97	47.03	46.11
Total Hardness as $CaCO^3$	1629	1858	1891	1889
Calcium	208	225	249	247
Magnesium	270	315	309	310
Sodium	184	195	196	185
Potassium	12	12	13	11
Ammonia Nitrogen as N	-1.0	-1.0	-1.0	.4
Organic Nitrogen as N	1.3	3.6	.9	.2
Total Nitrogen as N	1.3	3.6	.9	.6
Silica	6	10	15	14
Total Cations (meq/l)	40.88	45.95	46.66	46.10
Diff. Anions-Cations (meq/l)	.68	.02	.37	.01
Aluminum, Total	.1	-.1	-.1	.5
Dissolved	.1	-.1	-.1	-.1
Antimony, Total	-.2	-.2	-.2	-.02
Dissolved	-.2	-.2	-.2	-.02
Arsenic, Total	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005
Cadmium, Total	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005
Chromium, Total	-.02	-.02	-.02	-.02
Dissolved	-.02	-.02	-.02	-.02
Hexavalent	-.01	-.01	-.01	-.01
Copper, Total	.02	-.01	-.01	.16
Dissolved	.02	-.01	-.01	.02

Exhibit 25

Table B2
(Cont'd)

	Date			
	4/11	6/8	9/21	12/1
Iron, Total	.59	.34	.75	2.20
Dissolved	-.05	.07	.32	-.05
Lead, Total	-.02	-.02	-.02	-.02
Dissolved	-.02	-.02	-.02	-.02
Managnese, Total	.72	1.47	.69	2.38
Dissolved	.56	1.30	.68	2.30
Mercury, Total	-.001	-.001	-.001	.008
Dissolved	-.001	-.001	-.001	-.001
Selenium, Total	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005
Vanadium, Total	-1.0	-1.0	-1.0	-1.0
Dissolved	-1.0	-1.0	-1.0	-1.0
Zinc, Total	.07	-.01	-.01	-.01
Dissolved	.02	-.01	-.01	-.01

Components are expressed in mg/l unless otherwis noted.

A minus sign indicates that less than the reported value was present in the sample.

Table B3. Chemical Analysis of Waters Sampled in 1977 from Armells Creek Station No. 3

	Date			
	4/11	6/8	9/21	12/1
Specific Cond. (Micromhos/cm)	2710	3010	2950	2110
pH (Laboratory)	8.0	8.3	8.2	8.1
Dissolved Oxygen (On Site)	11.1	6.4	7.5	8.8
Total Suspended Solids	13	30	32	12
Total Dissolved Solids	2526	2732	2666	1796
Oil and Grease	-1.0	-1.0	-1.0	-1.0
Turbidity (J.T.U.)	23	12	14	4.2
Fecal Coliform (Col/100ml.)	-1.0	1700	41	46
Total Coliform (Col/100 ml.)	20	1500	173	210
Sodium Adsorption Ratio	1.80	1.86	1.87	1.27
Boron	3.0	.6	.4	.3
Total Alkalinity as $CaCO_3$	544	504	595	255
Bicarbonate as HCO_3	663	615	725	311
Carbonate as CO_3	0	0	0	0
Acidity	0	0	0	0
Chloride	20	17	20	12
Nitrate as N	.5	.1	.27	.22
Nitrate as N	-.01	.01	.01	-.01
Ortho-phosphate as P	.03	-.01	.26	.06
Sulfate as SO_4	1378	1448	1390	1007
Fluoride	.26	.18	.16	.23
Total Anions (meq/l)	40.17	40.76	41.43	26.46
Total Hardness as $CaCO^3$	1602	1656	1647	1086
Calcium	222	222	182	175
Magnesium	255	268	290	158
Sodium	166	174	175	96
Potassium	11	10	16	13
Ammonia Nitrogen as N	-1.0	-1.0	-1.0	.8
Organic Nitrogen as N	.9	2.4	2.2	0
Total Nitrogen as N	.9	2.4	2.2	.8
Silica	13	15	7	35
Total Cations (meq/l)	39.54	40.97	40.96	26.23
Diff. Anions-Cations (meq/l)	.63	-.21	.47	.23
Aluminum, Total	1.4	-.1	.3	.2
Dissolved	-.1	-.1	-.1	.1
Antimony, Total	-.2	-.2	-.2	-.02
Dissolved	-.2	-.2	-.2	-.02
Arsenic, Total	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005
Cadmium, Total	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005
Chromium, Total	-.02	-.02	-.02	-.02
Dissolved	-.02	-.02	-.02	-.02
Hexavalent	-.01	-.01	-.01	-.01
Copper, Total	.03	-.01	-.01	-.01
Dissolved	.02	-.01	-.01	-.01

Table B3
(Cont'd)

	Date			
	4/11	6/8	9/21	12/1
Iron, Total	1.31	.85	1.97	.28
Dissolved	-.05	.09	.48	.05
Lead, Total	-.02	-.02	-.02	-.02
Dissolved	-.02	-.02	-.02	-.02
Manganese, Total	1.32	.57	2.13	.18
Dissolved	1.30	.54	1.88	.17
Mercury, Total	-.001	-.001	-.001	.001
Dissolved	-.001	-.001	-.001	-.001
Selenium, Total	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005
Vanadium, Total	-1.0	-1.0	-1.0	-1.0
Dissolved	-1.0	-1.0	-1.0	-1.0
Zinc, Total	.06	-.01	-.01	-.01
Dissolved	.01	-.01	-.01	-.01

Components are expressed in mg/l unless otherwise noted.

A minus sign indicates that less than the reported value was present in the sample.

Table B4. Chemical Analysis of Waters Sampled in 1977 from Armells Creek Station No. 9

	Date			
	4/11	6/8	9/21	12/1
Specific Cond. (Micromhos/cm)	3110	3570	3580	3750
pH (Laboratory)	7.6	8.0	8.0	8.2
Dissolved Oxygen (On Site)	5.5	4.2	2.8	8.6
Total Suspended Solids	17.0	8.0	6.0	5.0
Total Dissolved Solids	3114	3390	3476	3394
Oil and Grease	-1.0	-1.0	-1.0	-1.0
Turbidity (J.T.U.)	7.0	3.3	2.3	3.1
Fecal Coliform (Col/100 ml.)	2.0	96	34	2.0
Total Coliform (Col/100 ml.)	2.0	280	250	7.0
Sodium Adsorption Ration	2.17	2.21	2.30	2.24
Boron	2.3	.5	.4	.3
Total Alkalinity as $CaCO_3$	403	459	460	416
Bicarbonate as HCO_3	492	560	561	507
Carbonate as CO_3	0	0	0	0
Acidity	0	0	0	0
Chloride	19	16	17	18
Nitrate as N	.58	.07	.09	.11
Nitrite as N	-.01	-.01	-.01	-.01
Ortho-phosphate as P	-.01	-.01	-.01	-.01
Sulfate as SO_4	1774	1899	2008	2011
Fluoride	.36	.28	.28	.36
Total Anions (meq/l)	45.59	49.19	51.53	50.72
Total Hardness as $CaCO^3$	1787	1970	2006	2005
Calcium	216	235	262	228
Magnesium	303	337	329	349
Sodium	211	226	237	230
Potassium	15	15	16	14
Ammonia Nitrogen as N	-1.0	-1.0	-1.0	.2
Organic Nitrogen as N	.9	1.8	.7	.2
Total Nitrogen as N	.9	1.8	.7	.4
Silica	13	16	18	40
Total Cations (meq/l)	45.29	49.58	50.82	50.46
Diff. Anions-Cations (meq/l)	.3	-.39	.71	.26
Aluminum, Total	-.1	-.1	.2	.4
Dissolved	-.1	-.1	-.1	.2
Antimony, Total	-.2	-.2	-.2	-.02
Dissolved	-.2	-.2	-.2	-.02
Arsenic, Total	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005
Cadium, Total	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005
Chromium, Total	-.02	-.02	-.02	-.02
Dissolved	-.02	-.02	-.02	-.02
Hexavalent	.01	-.01	-.01	-.01
Copper, Total	.02	-.01	-.01	-.01
Dissolved	.02	-.01	-.01	-.01

Table B4
(Cont'd)

	Date			
	4/11	6/8	9/21	12/1
Iron, Total	2.16	.68	.50	.54
Dissolved	.13	.16	.16	-.05
Lead, Total	-.02	-.02	-.02	-.02
Dissolved	-.02	-.02	-.02	-.02
Manganese, Toatal	.61	.80	.33	.56
Dissolved	.48	.73	.33	.52
Mercury, Total	-.001	-.001	-.001	.006
Dissolved	-.001	-.001	-.001	-.001
Selenium, Total	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005
Vanadium, Total	-1.0	-1.0	-1.0	-1.0
Dissolved	-1.0	-1.0	-1.0	-1.0
Zinc, Total	.07	-.01	-.01	-.01
Dissolved	.07	-.01	-.01	-.01

Components are expressed in mg/l unless otherwise noted.

A minus sign indicates that less than the reported value was present in the sample.

Table B5. Chemical Analysis of Waters Sampled in 1977 from Turtle Pond and the EPA Depression

	Turtle Pond				EPA Depr.	
	4/11	6/8	9/21	12/1	4/11	6/8
Specific Conductance - Lab (umhos/cm)	1710	2140	2670	3000	255	237
pH (Lab)	8.2	8.5	9.2	8.2	8.4	9.7
Dissolved O_2 (On Site)	11.0	11.5	12.3	8.8	10.2	13.8
Total Suspended Solids	3.0	2.0	3.0	11	51	157
Total Dissolved Solids	1692	2022	2804	2994	172	196
Turbidity (J.T.U.)	2.0	2.4	2.0	8.3	65	230
Boron	2.7	.3	.3	.3	2.9	.1
Solium Adsorption Ratio	.31	.33	.41	.44	.08	.10
Total Alkalinity as $CaCO_3$	160	134	91	152	114	62
Bicarbonate as HCO_3	195	156	80	185	126	29
Carbonate as CO_3	0	4	16	0	6	23
Acidity	0	0	0	0	0	0
Chloride	6	3	5	6	1	2
Nitrate as N	1.12	.05	.02	.02	.53	.2
Nitrite as N	-.01	-.01	-.01	-.01	.02	.01
Ortho-phosphate as P	-.01	.01	-.01	.01	.06	.12
Sulfate	1023	1239	1786	1862	29	46
Fluoride	.24	.18	.15	.25	.18	.26
Total Anions (meq/l)	24.75	28.60	39.18	41.98	2.95	2.26
Total Hardness as $CaCO^3$	1151	1348	1842	1971	129	93
Calcium	168	166	213	225	26	15
Magnesium	177	227	319	343	16	13
Sodium	24	28	40	45	2	2
Potassium	10	8	8	11	11	11
Ammonia Nitrogen as N	-1.0	-1.0	-1.0	.2	-1.0	-1.0
Organic Nitrogen as N	1.0	1.7	1.0	.6	1.1	1.9
Total Nitrogen as N	1.0	1.7	1.0	.8	1.1	1.9
Silica	5	1	1	1.0	2	4
Total Cations (meq/l)	24.31	28.39	38.81	41.66	2.93	2.24
Diff. Anions-Cations	.44	.21	.37	.32	.03	.02
Aluminum, Total	-.1	-.1	.6	.2	1.0	2.0
Dissolved	-.1	-.1	-.1	.1	-.1	.2
Antimony, Total	-.2	-.2	-.2	-.02	-.2	-.2
Dissolved	-.2	-.2	-.2	-.02	-.2	-.2
Arsenic, Total	-.005	-.005	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005	-.005	-.005
Cadmium, Total	-.005	-.005	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005	-.005	-.005
Chromium, Total	-.02	-.02	-.02	-.02	-.02	-.02
Dissolved	-.02	-.02	-.02	-.02	-.02	-.02
Hexavalent	.01	-.01	-.01	-.01	.02	-.01
Copper, Total	.02	-.01	-.01	.01	.02	-.01
Dissolved	.02	-.01	-.01	-.01	-.01	-.01

Exhibit 25

Table B5 (Cont'd)	Turtle Pond				EPA Depr.	
	4/11	6/8	9/21	12/1	4/11	6/8
Iron, Total	-.05	-.05	.11	.29	2.22	5.28
Dissolved	- .05	.07	-.05	-.05	-.05	.32
Lead, Total	-.02	-.02	-.02	-.02	-.02	-.02
Dissolved	-.02	-.02	-.02	-.02	-.02	-.02
Managnese, Total	.04	.03	-.02	.05	.04	.10
Dissolved	-.02	.02	-.02	-.02	-.02	.03
Mercury, Total	-.001	-.001	-.001	.005	-.001	-.001
Dissolved	-.001	-.001	-.001	-.001	-.001	-.001
Selenium, Total	-.005	-.005	-.005	-.005	-.005	-.005
Dissolved	-.005	-.005	-.005	-.005	-.005	-.005
Vanadium, Total	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Dissolved	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Zinc, Total	.02	-.01	-.01	1.11	.03	-.01
Dissolved	.02	-.01	-.01	.34	.01	-.01

Concentrations expressed in mg/l unless otherwise noted.
A minus sign indicates that less than the reported value was present in the sample.

5/16/2013 PHC discussion (see agenda)
Daniel M., Rich S., Bicki P., Wade S., Michael N.,
Emily H., Angela M., Chris G.

Discussed what is needed for Area B Amendment
PHC -

- currently mining
- anticipated mining (approved but not mined)
- proposed mining
  - part of application
  - not mining that is not approved or part of the current application
- proposed Area F and add. round mining in Area A - not included.

Exhibit 24

Steere, Wade

From: Munoz, Daniel
Sent: Tuesday, August 05, 2014 4:11 PM
To: Kegley, Mike; Peterson, Dicki; Steere, Wade
Subject: FW: AM 4 Area B-East

Mike, below is an e-mail that I sent Ed Coleman on July 21. Ed's reply is also below. We later got contacted by Chris Yde that he would like to meet with us and have the DEQ's Biology Expert at the meeting.

This meeting was on July 31 in Helena. Their Expert just described the way that he would recommend that we sample the stream. He also mentioned that he had been sampling other intermittent and ephemeral streams in Eastern Montana. They did not explain any scientific reason that we would be required to perform this sampling, other than that in the process of having a CHIA, they would be asked if this was performed.

We are planning on having a conference call with Penny Hunter next week and I would like to see if you can join us to have further discussions on this.

Daniel

From: Coleman, Ed [mailto:EColeman@mt.gov]
Sent: Monday, July 21, 2014 1:08 PM
To: Munoz, Daniel
Cc: Yde, Chris; Peterson, Dicki
Subject: RE: AM 4 Area B-East

Daniel,

Let me run this email by some of our technical staff and either Chris or I will get back in touch with you. It may take a little while since we will most likely have to go outside the bureau to get the appropriate expertise. Thanks

Ed Coleman
(406) 444-4973

From: Munoz, Daniel [mailto:DMunoz@westmoreland.com]
Sent: Monday, July 21, 2014 12:57 PM
To: Coleman, Ed
Cc: Yde, Chris; Peterson, Dicki
Subject: AM 4 Area B-East

Ed,

In an effort to address the Department's request for "conducting a current aquatic survey" in the AM 4 Area B-East deficiencies dated June3, 2014, WECo hired Penny Hunter with ARCADIS. As an expert in this field, Penny participated in our meeting in Billings with your Department on July 7, 2014 via conference call. After our meeting she email Dicki Peterson with the following:

> DEQ does have a provision for collecting biological data, but it is in the context of trying to evaluate beneficial use in ephemeral streams, and when it is "practical and appropriate". My understanding of

Exhibit 23
WECO 000599

the context of the discussion yesterday was on gathering information to understand impacts of the proposed discharge, not to evaluate beneficial use. Impacts to aquatic life would be addressed by the numerical standards established for the discharges, and those wouldn't be affected by the results of biological data collection.

On the phone, DEQ was discussing collecting the data to determine what the community assemblages were and a community diversity index. The aquatic survey data to date show, and this is emphasized in the literature, that developing any kind of quantitative index of diversity or specific community assemblage is difficult/impracticable in ephemeral and intermittent streams because of the high level of variability of the samples. The study in 1979 attempted to collect 4 samples at each site throughout the year, and in both intermittent and ephemeral stream sections, a reliable estimate of diversity could not be generated. This same issue would be expected if we were to repeat the exercise. Therefore, any new data collection would be at best qualitative in nature, and the usefulness of this information is not clear, since the findings would not impact the use designation or the numerical standards used for the streams.

Based on Penny Hunter's expertise in this field, WECo would like the Department to re-consider the request in the AM 4 deficiencies for "conducting a current aquatic survey". WECo agrees that it is not "practical or appropriate" to conduct aquatic survey that is meaningful in relation to the existing water use.

Please feel free to contact me if you would like to discuss this further.

Sincerely,

Daniel Munoz, PE
Engineering Manager II
Western Energy
Rosebud Mine
903-390-5139

From: Hunter, Penny
To: Peterson, Dicki
Cc: Steere, Wade
Subject: RE: Macroinvertebrate SOP
Date: Wednesday, July 09, 2014 3:57:55 PM
Attachments: WQPBWQM-001.pdf

The only MDEQ SOP that I was able to find related to macroninvertebrate sampling was an SOP for water quality assessment to identify "impaired" waters. See attached - section 3.6 on page 13 of 17 for assessment of aquatic life use. The SOP states,

DEQ usually assesses only aquatic life use support for ephemeral waterbodies and requires only physical/habitat data (minimum SCD score = 3).
However, DEQ recommends that chemistry/toxicity or biological data should be collected when it is practical and appropriate for evaluating aquatic life use support or the use support of other beneficial uses.

So, DEQ does have a provision for collecting biological data, but it is in the context of trying to evaluate beneficial use in ephemeral streams, and when it is "practical and appropriate". My understanding of the context of the discussion yesterday was on gathering information to understand impacts of the proposed discharge, not to evaluate beneficial use. Impacts to aquatic life would be addressed by the numerical standards established for the discharges, and those wouldn't be affected by the results of biological data collection.

On the phone, DEQ was discussing collecting the data to determine what the community assemblages were and a community diversity index. The aquatic survey data to date show, and this is emphasized in the literature, that developing any kind of quantitative index of diversity or specific community assemblage is difficult/impracticable in ephemeral and intermittent streams because of the high level of variability of the samples. The study in 1979 attempted to collect 4 samples at each site throughout the year, and in both intermittent and ephemeral stream sections, a reliable estimate of diversity could not be generated. This same issue would be expected if we were to repeat the exercise. Therefore, any new data collection would be at best qualitative in nature, and the usefulness of this information is not clear, since the findings would not impact the use designation or the numerical standards used for the streams.

From: Peterson, Dicki [mailto:DPeterson@westmoreland.com]
Sent: Tuesday, July 08, 2014 1:18 PM
To: Hunter, Penny
Cc: Steere, Wade
Subject: FW: Macroinvertebrate SOP

Hi Penny –

Thank you for being available for yesterday's conference call.... Will you answer Emily's questions below and get back to me...

Thank you!

Exhibit 22

Dicki

From: Hinz, Emily [mailto:EHinz@mt.gov]
Sent: Tuesday, July 08, 2014 9:09 AM
To: Peterson, Dicki
Cc: Yde, Chris
Subject: Macroinvertebrate SOP

Dicki,

Could you find out the exact document your consultant was referring to yesterday which indicated that macroinverebrate counts were not particularly useful for intermittent reaches? I want to make sure we are looking at the same thing. A copy of the document or the name of it & number of it would be most helpful.

Emily Hinz
Hydrologist
Coal and Uranium Program
Montana Dept. of Environmental Quality
Ph (406) 444-7443

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From: Peterson, Dicki
To: "Hunter, Penny"
Cc: Munoz, Daniel; Steere, Wade
Subject: RE: Aquatic Life Meeting
Date: Friday, August 08, 2014 12:31:00 PM

Penny -

Please let me know what is good for you on Monday when you get in. I'm in all next week and we will accommodate your schedule. Thanks for everything.

Dicki

-----Original Message-----
From: Hunter, Penny [mailto:Penny.Hunter@arcadis-us.com]
Sent: Friday, August 08, 2014 12:29 PM
To: Peterson, Dicki
Cc: Munoz, Daniel; Steere, Wade
Subject: RE: Aquatic Life Meeting

Hi Dicki, I will be back in the office starting Monday, if you would like to set up a time to talk about this. I'm generally open, though I do have the occasional meeting scheduled here and there. Thank you!

-----Original Message-----
From: Peterson, Dicki [mailto:DPeterson@westmoreland.com]
Sent: Friday, August 01, 2014 10:08 AM
To: Hunter, Penny
Cc: Munoz, Daniel; Steere, Wade
Subject: RE: Aquatic Life Meeting

Hi Penny -

I hope your vacation is going well...

WECo met with DEQ coal bureau and a gentlemen named Dave Feldman (DEQ aquatic expert) yesterday morning. The attached document is what he provided for sampling for invertebrates. DEQ is still insisting that we sample before the end of September... they are requesting a "reach wide approach" for ephemeral and intermittent reaches, at least one location possibly two. They do not want us to provide statistics only what is out there.

Do we have a leg to stand on if we refuse to conduct these studies? If we give in are we setting ourselves up for disaster on the other end?

Daniel would like to have a conference call with you and Dave (DEQ) and us on Tuesday afternoon. Does that work for you? I will be out of the office Monday but I can be reached through email or you can call me 406-749-0633.

Dicki

-----Original Message-----
From: Hunter, Penny [mailto:Penny.Hunter@arcadis-us.com]
Sent: Thursday, July 24, 2014 7:24 AM
To: Peterson, Dicki
Subject: RE: Aquatic Life Meeting

Hello Dicki,

Exhibit 21

Unfortunately I will be out of the office on 7/31. I am actually going to be on vacation from 7/25 through 8/9, I hope that this is not too much of an inconvenience. I'll be away from phone and email during that time.

I could try and arrange another person to respond to the aquatic bug expert from here if you like. Give me a call this morning if you can and we can talk about that. Otherwise, I can respond when I get back.

Thank you-

-----Original Message-----
From: Peterson, Dicki [mailto:DPeterson@westmoreland.com]
Sent: Wednesday, July 23, 2014 5:09 PM
To: Hunter, Penny
Cc: Munoz, Daniel
Subject: Aquatic Life Meeting

Hi Penny -

After receiving the comments you made after the last meeting on July 7th DEQ has an expert on the aquatic bugs... We are having our quarterly meeting in Helena on 7/31 at 8:30 am... Would you like sit I. On the conversation either on conferencing in or joining the meeting?

Sent from my iPhone

From: Peterson, Dicki
To: Steere, Wade; Munoz, Daniel
Cc: Hunter, Penny
Subject: FW: Macroinvertebrate SOP
Date: Tuesday, July 22, 2014 7:48:24 AM
Attachments: EMAP-macros.pdf
WQPBWQM-009.pdf

FYI

Dicki

From: Hinz, Emily [mailto:EHinz@mt.gov]
Sent: Monday, July 21, 2014 3:31 PM
To: Peterson, Dicki
Cc: Yde, Chris
Subject: RE: Macroinvertebrate SOP

Dicki,

The document you sent is designed for assessment of water quality for impairment decisions. This involves various assessment metrics and protocols that aren't going to be applicable to the Coal Program's needs with regards to macro sampling. The Coal Program wants only to quantify the extent and nature of the aquatic community along the stretch of EFAC bordered by mining. Aquatic use needs to only be assessed in reaches with water at the time of sampling (flowing or ponded).

We suggest you use the sampling procedures from the attached EMAP document in **Section 7.2** and the general considerations in **Section 1.1** from the WQPBWQM-009 document for guidelines on the time frame appropriate for sampling. The reason you have to look at two documents is that the reach-wide sampling procedures referenced by the WQPBWQM-009 document are more for ripple-dominated sites and they didn't include the alternate sampling technique in the document. The following information should be collected along with a macroinvertebrate survey

1) Habitat / reach description including photographs and location
2) Water quality samples at the point of macro sampling
3) Water temperature
4) Flow, if any

Metrics **do not** need to be run by the consultant on the data. Reporting of the taxa alone is sufficient.

Emily Hinz
Hydrologist
Coal and Uranium Program

Exhibit 20

Montana Dept. of Environmental Quality
Ph (406) 444-7443

From: Peterson, Dicki [mailto:DPeterson@westmoreland.com]
Sent: Monday, July 21, 2014 1:13 PM
To: Hinz, Emily
Cc: Yde, Chris
Subject: FW: Macroinvertebrate SOP

Emily –

Attached is the requested document I received from our consultant.

The only MDEQ SOP that I was able to find related to macroninvertebrate sampling was an SOP for water quality assessment to identify "impaired" waters. See attached - section 3.6 on page 13 of 17 for assessment of aquatic life use. The SOP states,

"DEQ usually assesses only aquatic life use support for ephemeral waterbodies and requires only physical/habitat data (minimum SCD score = 3). However, DEQ recommends that chemistry/toxicity or biological data should be collected when it is practical and appropriate for evaluating aquatic life use support or the use support of other beneficial uses."

Dicki

From: Peterson, Dicki [mailto:DPeterson@westmoreland.com]
Sent: Tuesday, July 08, 2014 1:18 PM
To: Hunter, Penny
Cc: Steere, Wade
Subject: FW: Macroinvertebrate SOP

Hi Penny –

Thank you for being available for yesterday's conference call…. Will you answer Emily's questions below and get back to me…

Thank you!

Dicki

From: Hinz, Emily [mailto:EHinz@mt.gov]
Sent: Tuesday, July 08, 2014 9:09 AM
To: Peterson, Dicki
Cc: Yde, Chris
Subject: Macroinvertebrate SOP

Exhibit 20

Dicki,

Could you find out the exact document your consultant was referring to yesterday which indicated that macroinverebrate counts were not particularly useful for intermittent reaches? I want to make sure we are looking at the same thing. A copy of the document or the name of it & number of it would be most helpful.

Emily Hinz
Hydrologist
Coal and Uranium Program
Montana Dept. of Environmental Quality
Ph (406) 444-7443

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From: John Carstensen
To: Peterson, Dicki
Subject: B AM4 PHC
Date: Thursday, June 06, 2013 11:57:06 AM

Dicki,

It is easy for us to take any of the potential areas off the figure or take the entire figure out. Based on the definition of potential mining below, I think we should only show App 00184. As that is shown on Figure 3a, there is no need for Figure 3c.

That being said, we have no problem showing exactly what you think is best for Western Energy.

It is much more difficult to strip all of the Area F references and boundary from the main Rosebud Mine Groundwater Model Report which is meant to encompass the greater Rosebud Mine.

John

From: Peterson, Dicki [mailto:DPeterson@westmoreland.com]
Sent: Thursday, June 06, 2013 11:04 AM
To: John Carstensen
Subject: RE:

John –

My understanding of the Department's newly defined potential mining is "the proposed action for the area" – my interpretation for Area B… currently approved is the base and then App 00184 is the potential future mining. I don't know how difficult it is on your end, but at the very least B-Extension expansion would need to taken off. The Area A information was submitted as a minor and is under review (which you are aware).

When I talked to Michael this morning he didn't think leaving the line for Area F would be problematic. But I'm sure anything that involving B-Extension would be since they have not seen that information formally.

Dicki

From: John Carstensen [mailto:jcarstensen@earthandwater.com]
Sent: Thursday, June 06, 2013 10:35 AM
To: Peterson, Dicki
Subject:

Hi Dicki,

Exhibit 19

Should I take this figure out of the B AM4 PHC to be consistent with your comments?

Thanks

John