

**OTTER CREEK MINE
BASELINE REPORT 304E
TRACTS 1, 2, AND 3
BASELINE WATER RESOURCES DATA REPORT**

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TABLE OF CONTENTS

LIST OF TABLES	iv
LIST OF FIGURES	v
LIST OF APPENDICES	vi
LIST OF PLATES	vi
1.0 INTRODUCTION	1-1
1.1 PURPOSE AND SCOPE.....	1-1
1.2 STUDY OBJECTIVE.....	1-2
1.3 PROPOSED MINE AREA.....	1-2
1.4 REGULATORY REQUIREMENTS	1-3
2.0 HYDROGEOLOGY	2-1
2.1 GROUNDWATER MONITORING – 17.24.304(1)(F)(I)(B)	2-1
2.1.1 Monitoring Wells.....	2-1
2.1.2 Water Level Monitoring - ARM 17.24.304(1)(f)(i)(B).....	2-3
2.1.3 Groundwater Quality Monitoring- ARM 17.24.304(1)(f)(i)(B)	2-4
2.1.4 Aquifer Testing.....	2-5
2.2 QUALITY ASSURANCE AND CONTROL	2-6
2.3 HYDROGEOLOGY – ARM 17.24.304(1)(F)(I)(A).....	2-7
2.3.1 Geology and Stratigraphy of the Otter Creek Drainage Basin.....	2-7
2.3.1.1 Regional Geologic Setting and Structure	2-7
2.3.2 Geologic Structure.....	2-7
2.3.2.1 Stratigraphy	2-8
2.3.3 Study Area Hydrogeology.....	2-10
2.4 GROUNDWATER OCCURRENCES - 17.24.304(1)(F)(I)(A).....	2-10
2.4.1 Alluvial Groundwater.....	2-11
2.4.1.1 Lithologies.....	2-11
2.4.1.2 Hydraulic Characteristics	2-12
2.4.1.3 Groundwater Flow.....	2-14
2.4.2 Overburden	2-16
2.4.2.1 Lithologies.....	2-17
2.4.2.2 Hydraulic Characteristics	2-17

2.4.2.3 Groundwater Flow.....	2-18
2.4.2.4 Recharge and Discharge.....	2-18
2.4.3 Knobloch Coal.....	2-19
2.4.3.1 Lithologies.....	2-19
2.4.3.2 Hydraulic Characteristics	2-21
2.4.3.3 Groundwater Flow.....	2-22
2.4.4 Clinker	2-24
2.4.4.1 Lithology	2-24
2.4.4.2 Hydraulic Characteristics	2-25
2.4.4.3 Groundwater Flow.....	2-25
2.4.5 Underburden	2-26
2.4.5.1 Lithologies.....	2-26
2.4.5.2 Hydraulic Characteristics	2-27
2.4.5.3 Groundwater Flow.....	2-28
2.4.6 Springs.....	2-29
2.5 GROUNDWATER QUALITY -17.24.304(1)(F)(I)(B)	2-29
2.5.1 Quality Assurance/Quality Control	2-30
2.5.1.1 Alluvium.....	2-30
2.5.1.2 Clinker	2-32
2.5.1.3 Overburden.....	2-33
2.5.1.4 Knobloch Coal.....	2-33
2.5.1.5 Underburden.....	2-34
2.5.2 Spring Water Quality.....	2-35
2.6 SPRINGS AND PRIVATE WELLS - – 17.24.304(1)(F)(I)(C).....	2-35
2.6.1 Private Wells	2-35
2.6.2 Spring and Seep Inventory	2-35
3.0 SURFACE WATER - 17.24.304(1)(F)(II)	3-1
3.1 DESCRIPTION OF SURFACE WATER DRAINAGE SYSTEMS – ARM	
17.24.304(1)(F)(II)	3-1
3.1.1 Otter Creek	3-1
3.1.2 Tenmile Creek	3-2
3.1.3 Threemile Creek	3-2

3.1.4 Home Creek.....	3-3
3.1.5 Other Area Drainages and Basins.....	3-3
3.2 SURFACE WATER MONITORING - 17.24.304(1)(F)(II)(B).....	3-4
3.2.1 Streams and Ephemeral Drainages.....	3-4
3.2.2 Ponds.....	3-7
3.2.3 Surface Water Flow 17.24.304(1)(f)(ii)(B)(I).....	3-9
3.2.3.1 Otter Creek USGS Gaging Station Data Analysis.....	3-9
3.2.3.2 Baseline Study Data.....	3-10
3.2.4 Otter Creek Stream Flow.....	3-11
3.2.5 Tributary Steam Flow.....	3-14
3.2.6 Surface Water Quality- 17.24.304(1)(f)(ii)(B)(II).....	3-18
3.2.6.1 Otter Creek.....	3-20
3.2.6.2 Tenmile Creek.....	3-21
3.2.6.3 Threemile Creek.....	3-21
3.2.6.4 Home Creek.....	3-23
3.2.6.5 Ponds.....	3-24
3.3 ALLUVIAL VALLEY FLOOR (AVF).....	3-24
4.0 WATER RIGHTS AND ALTERNATIVE WATER SOURCES- 17.24.304(1)(F)(III).....	4-1
4.1 WATER RIGHTS.....	4-1
4.2 ALTERNATIVE WATER SOURCES- 17.24.304(1)(F)(III).....	4-1
4.2.1 Alluvial Sources.....	4-2
4.2.2 Knobloch Coal.....	4-3
4.2.3 Deeper Fort Union Formation.....	4-3
4.2.4 Hell Creek, Fox Hills Formations.....	4-3
5.0 REFERENCES.....	5-1

LIST OF TABLES

(Attached as separate PDF documents)

TABLE 2-1A	MONITORING WELL COMPLETION SUMMARY
TABLE 2-1B	BOREHOLE COMPLETION SUMMARY
TABLE 2-2	ANALYTICAL PARAMETERS
TABLE 2-3	AQUIFER TESTING RESULTS
TABLE 2-4	OTTER CREEK ALLUVIUM STATISTICAL SUMMARY
TABLE 2-5	TENMILE CREEK ALLUVIUM STATISTICAL SUMMARY
TABLE 2-6	THREEMILE CREEK ALLUVIUM STATISTICAL SUMMARY
TABLE 2-7	HOME CREEK ALLUVIUM STATISTICAL SUMMARY
TABLE 2-8	CLINKER WELLS ALLUVIUM STATISTICAL SUMMARY
TABLE 2-9	OVERBURDEN WELLS ALLUVIUM STATISTICAL SUMMARY
TABLE 2-10	KNOBLOCH COAL STATISTICAL SUMMARY
TABLE 2-11	UNDERBURDEN COAL STATISTICAL SUMMARY
TABLE 2-12	FORTUNE & COAL CREEK SPRINGS STATISTICAL SUMMARY
TABLE 2-13	PRIVATE WELL INVENTORY
TABLE 3-1	SURFACE WATER MONITORING NETWORK
TABLE 3-2	BASELINE SURFACE WATER MONITORING DISCHARGE SUMMARY
TABLE 3-3	OTTER CREEK MINE SURFACE WATER ANALYTICAL PARAMETERS
TABLE 3-4	OTTER CREEK SURFACE WATER STATISTICAL SUMMARY
TABLE 3-5	OTTER CREEK TRIBUTARIES SURFACE WATER STATISTICAL SUMMARY
TABLE 3-6	TENMILE CREEK SURFACE WATER STATISTICAL SUMMARY
TABLE 3-7	THREEMILE CREEK SURFACE WATER STATISTICAL SUMMARY
TABLE 3-8	SHORTY CREEK SURFACE WATER STATISTICAL SUMMARY
TABLE 3-9	THREEMILE CREEK TRIBUTARIES SURFACE WATER STATISTICAL SUMMARY
TABLE 3-10	HOME CREEK SURFACE WATER STATISTICAL SUMMARY
TABLE 3-11	POND SURFACE WATER STATISTICAL SUMMARY
TABLE 4-1	WATER RIGHTS WITHIN THE OTTER CREEK COAL LIFE OF MINE AREA

LIST OF FIGURES

(Attached as separate PDF documents)

FIGURE 1-1 SITE LOCATION MAP

FIGURE 2-1 TYPICAL MONITORING WELL CONSTRUCTION

FIGURE 2-2 GROUNDWATER ELEVATIONS IN ALLUVIUM, CLINKER AND
OVERBURDEN (AUGUST 2011)

FIGURE 2-3 GROUNDWATER ELEVATIONS IN ALLUVIUM, CLINKER AND
OVERBURDEN (MARCH 2012)

FIGURE 2-4 GROUNDWATER ELEVATIONS IN ALLUVIUM, CLINKER AND
KNOBLOCH COAL (AUGUST 2011)

FIGURE 2-5 GROUNDWATER ELEVATIONS IN ALLUVIUM, CLINKER AND
KNOBLOCH COAL (MARCH 2012)

FIGURE 2-6 GROUNDWATER ELEVATIONS IN ALLUVIUM AND UNDERBURDEN
(AUGUST 2011)

FIGURE 2-7 GROUNDWATER ELEVATIONS IN ALLUVIUM AND UNDERBURDEN
(MARCH 2012)

FIGURE 2-8 PIPER DIAGRAM ALLUVIUM

FIGURE 2-9 PIPER DIAGRAM CLINKER

FIGURE 2-10 PIPER DIAGRAM OVERBURDEN

FIGURE 2-11 PIPER DIAGRAM KNOBLOCH

FIGURE 2-12 PIPER DIAGRAM UNDERBURDEN

FIGURE 3-1 SCHEMATIC OF TYPICAL STILLING WELL INSTALLATION

FIGURE 3-2 TYPICAL EPHEMERAL SURFACE WATER SITE INSTRUMENTATION

FIGURE 3-3 PIPER DIAGRAM SURFACE WATER

LIST OF APPENDICES

(Attached as separate PDF documents)

- APPENDIX A MONITORING WELL AND BOREHOLE LOGS
- APPENDIX B WATER LEVEL DATA AND HYDROGRAPHS
- APPENDIX C AQUIFER TEST DATA
- APPENDIX D DATA VALIDATION REPORTS
- APPENDIX E SURFACE WATER SITES AND POND MONITORING SUMMARIES
- APPENDIX F SURFACE WATER HYDROGRAPHS/SITE PROFILES/TABULATED FLOW
- APPENDIX G SPRING AND SEEP INVENTORY INFORMATION SHEETS AND PHOTOS

LIST OF PLATES

(Attached as separate PDF documents)

- PLATE 1 HYDROGEOCHEMICAL CLASSIFICATION BY STIFF DIAGRAM
- PLATE 2 PRIVATE WELL LOCATIONS
- PLATE 3 SPRING AND SEEP INVENTORY LOCATION
- PLATE 4 SYNOPTIC RUN RESULTS

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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

In November, 2009, Ark Land Company (Ark), an affiliate of Arch Coal, Inc. (Arch), entered into a coal lease agreement with Great Northern Properties (GNP) covering coal resources on alternate sections in the Otter Creek Tracts in Powder River County, Montana. The coal reserve area is in the “checkerboard” created by railroad land grants in the late 1800’s. In April, 2010 Ark, for fair market value, obtained State of Montana coal interests on the intervening sections. These coal lease interests comprise approximately 17,900 contiguous acres containing an estimated 1.5 billion tons of surface mineable coal. Otter Creek Coal, LLC, (OCC) was formed to develop the Otter Creek Coal Tracts. Figure 1-1 shows the location of the Otter Creek project area (Study Area).

Interest in developing coal reserves in the Otter Creek area dates back to the late 1970’s. As a result, there have been some historic investigations to define the coal reserve and hydrologic conditions in the area.

The Otter Creek coal reserve consists of three “tracts” each of which holds an estimated 400 to 500 million tons of coal. Tracts 1 and 2 lie east of and adjacent to Otter Creek, and Tract 3 lies to the west. Otter Creek (with its associated alluvium) is the primary hydrologic feature in the area. The primary coal seam is the Knobloch coal which averages 60-70 feet in thickness. The Knobloch coal is nearly flat lying, although the structure shows a shallow syncline which trends upward to the north and south, with the axis near central Tract 2 and southern Tract 3; in this area the coal subcrops and partially underlies the alluvium. To the north, the coal seam is burned resulting in deposits of clinker along the valley margins. To

the south, the coal splits; clinker deposits along the valley margins presumably are a result of burning of the upper coal split.

1.2 STUDY OBJECTIVE

Initial mine development will take place on Tract 2; the mining area is shown on Map 8 - Mine Plan. The hydrologic study focused on the Tract 2 mining area, and in particular, the groundwater relationship between the overburden and Knobloch coal seam and the Otter Creek alluvium. In addition, hydrologic conditions in all three tracts and adjacent areas were investigated to obtain data to evaluate cumulative impacts of eventual mining of the coal reserve contained in Tracts 1, 2, and 3. The specific technical objectives of this study were to collect data that could be used to:

- Construct the potentiometric surfaces and evaluate hydrologic characteristics of overburden, Knobloch coal, Knobloch coal underburden and Otter Creek alluvium so that groundwater flux and direction of flow can be calculated in each of these geologic units.
- Estimate vertical and lateral groundwater flux between geologic units, particularly between the bedrock units in the mining area and alluvium.
- Document seasonal water level variations, particularly in the alluvium.
- Characterize quality of groundwater in each geologic unit.
- Document geologic and hydrologic characteristics of Otter Creek and the lower reaches of major tributaries, specifically Home Creek, Threemile Creek and Tenmile Creek, for purposes of compliance with regulatory requirements relating to identification and protection of alluvial valley floors.
- Evaluate surface water – groundwater interrelationships.
- Obtain data so probable hydrologic consequences (PHC) could be evaluated and so a cumulative hydrologic impact analysis (CHIA) can be completed.

1.3 PROPOSED MINE AREA

The proposed mine area is located adjacent to Otter Creek in northwestern Powder River County approximately 5 miles southeast of Ashland, Montana as shown on Figure 1-1. OCC

is planning initial development of the Knobloch Coal resource within Township 4 South, Range 45 East. It is anticipated that coal will be extracted from the approximate area outlined as the proposed mine area within Tract 2 as shown on Mine Plan Map 8. This mining area contains an estimated 400 million tons of coal and would support an approximate annual production rate of 20 million tons for 20 years.

It is anticipated that after initial mine development in Tract 2, mining will advance to Tracts 1 and 3, and that over the course of the life of the Otter Creek Mine, all of the minable coal in all three tracts will eventually be mined. While the hydrologic study focuses on the Tract 2 mine plan, it also includes groundwater investigations in Tracts 1 and 3 and the adjacent area at a level sufficient to enable projection of cumulative hydrologic impacts for purposes of mine permitting and environmental impact statement preparation. When mine permitting for Tracts 1 and 3 is undertaken, additional site-specific hydrogeologic information will be collected as appropriate.

1.4 REGULATORY REQUIREMENTS

Baseline groundwater investigations were conducted to collect hydrologic data required by Administrative Rules of Montana (ARM) 17.24.304. Data collection and analysis were conducted in compliance with the requirements of ARM 17.24.302 and current accepted industry methods. Hydrogeologic data obtained during this investigation are considered sufficient to define current groundwater baseline conditions in the Otter Creek tracts and surrounding areas. Furthermore, these data are sufficient to evaluate PHC, allow Montana Department of Environmental Quality (MDEQ) to prepare a CHIA and develop a plan for protection of the hydrologic balance as required under ARM 17.24.314.

Plans of study were designed to direct the collection of necessary hydrologic and geologic information to support an alluvial valley floor investigation as required by ARM 17.24.325, in conjunction with soils, vegetation and land use investigations (Hydrometrics Inc., October and November, 2010).

2.0 HYDROGEOLOGY

2.1 GROUNDWATER MONITORING – 17.24.304(1)(f)(i)(B)

Data collection began in the fall of 2010, with installation of the initial monitoring system complete in mid-2011. The baseline year began with the third quarter of 2011 and concluded in the second quarter of 2012; however, collection of monitoring data continued, with several additional monitoring stations established in the interim. This report includes data collected through through the second quarter of 2014. Hence, baseline groundwater monitoring, assessing both quantity and quality, has been conducted for three years, and monitoring continues.

2.1.1 Monitoring Wells

Eighty four monitoring wells were installed in the Study Area during the investigation at the locations shown on Map 10 - Environmental Monitoring Stations. The majority of well installations were concentrated around Tract 2, with fewer wells installed on, or around, Tracts 1 and 3. Of the 84 wells, seven were installed during 2014 and included two alluvial wells and a battery of five wells located on the USFS lands to the southeast of the proposed mining area. A complete listing of monitoring wells installed for this baseline investigation by unit is in Table 2-1A. This table includes information on well completion intervals, location, total depth, ownership, and monitoring frequency. Table 2-1B includes information for boreholes that were not completed as wells. Wells were not completed in boreholes when water was not encountered in the target interval. This occurred mostly during evaluation of the width of the Otter Creek alluvium. Detailed lithological descriptions and well construction details are on well and borehole logs contained in Appendix A.

All wells were installed under the direction of a licensed Montana monitoring well constructor in accordance with Montana Board of Water Well Contractor regulations. Cuttings from each borehole were examined and logged on-site by a geologist, hydrogeologist, or environmental engineer. Lithologic logs include information on grain-size, color, unit thickness, depth, water occurrence, and other factors useful for a baseline

hydrogeologic data evaluation. Geophysical logging was not conducted on the monitoring wells.

Monitoring wells were drilled using air-rotary methods. Where possible, the boreholes were advanced without the aid of liquid additives. However, in some cases, it was necessary to inject fresh water to aid in removal of drill cuttings. In such cases, fresh water from local sources (Ashland water supply, potable domestic supply well, etc.) was used.

Well construction was in general accordance with the construction diagram(s) shown on Figure 2-1. For wells completed in clinker, it was necessary to advance steel casing to, or near, the base of the unit. The bottom portion of the clinker was drilled out and the well completed with the bottom of the casing open – no perforations were added to the steel casing. Wells were constructed using:

- New 4.5-inch diameter or 6-inch diameter, schedule 40 PVC (flush-joint or bell and collar style).
- Perforations consist of 25-slot (0.025-inch) factory cut slots, clinker wells were completed with open bottom steel casing.
- Silica sand (10-20 mesh, or larger) was placed across the perforated interval to provide a filter pack. Sand was placed in the annulus above the well screen to allow for settlement of the filter material during development. In general, sand extends above the slotted interval one foot for every 10 feet of slotted pipe. Because of the open bottom completion, sand was not placed in clinker wells, but the surrounding baked shale serves as a filter material.
- A bentonite annular seal was installed above the filter pack in accordance with Montana Board of Water Well Contractor regulations. For clinker wells, bentonite was added to the annular space as the steel casing was advanced.
- Protective steel casing was placed at ground surface to a minimum depth of three feet below ground surface (bgs). A locking lid, secured with keyed alike locks, was installed on top of the protective casing. For clinker wells, the production casing also serves as protective steel casing.

- No surface pads were used since the surface casing and bentonite annular seal will provide sufficient protection for downward percolation of surface waters.
- Wells were developed using either airlift and/or bailing methods.
- Well measuring points were surveyed for location and elevation.

The following designations were used for well identification:

- A - Alluvium - Well identification beginning (A-1) designates wells completed in unconsolidated alluvium and/or colluvium. Wells designated with an AVF prefix are also completed in alluvial sediments but are part of the alluvial valley floor cross sections. These wells are all located in valley bottoms. Thirty six alluvial wells were installed during this investigation.
- O - Well designations ending in “-O” (B4-O) were completed in the Knobloch overburden. Nine wells were completed in the overburden. Overburden groundwater was not present at batteries that do not contain an “O” designated well.
- K – Wells completed in the Knobloch Coal are either preceded by a K (K-2) or have a K in the battery designation (B-11-K). A KU designates the uppermost Knobloch, while KL designates the second Knobloch interval from the top, where present. Wells were not completed in the lowermost Knobloch, except possibly at the B7 battery, where an upper dry coal was encountered. This approach was consistent with the Plan of Study. Twenty-one wells were completed in the Knobloch Coal.
- U – Designates wells completed in underburden, below the lowest Knobloch Coal (B11-U). Twelve wells were completed in the underburden.
- C – Designates wells completed in clinker. Five wells were completed in clinker.

2.1.2 Water Level Monitoring - ARM 17.24.304(1)(f)(i)(B)

Water levels in wells were monitored monthly beginning in August 2011. This monitoring effort is being continued into the foreseeable future on a quarterly basis. Water levels are/were measured using electronic water level probes and recorded in a project field book. In addition, water level data were entered into a project database so hydrographs, showing water level trends, could be developed (Appendix B).

2.1.3 Groundwater Quality Monitoring- ARM 17.24.304(1)(f)(i)(B)

Groundwater quality data were collected quarterly during the baseline monitoring period in accordance ARM 17.24.304(1)(f)(i)(B) and schedule shown on Table 2-1. Water quality samples were collected between March 2011 and June 2014. A total of 640 groundwater samples were collected from monitoring wells. Dissolved metals concentrations were analyzed in all samples. In addition, total recoverable metals were analyzed during the first full quarterly event. Samples were collected, handled and analyzed in accordance with the MDEQ approved Plan of Study. Well purging and water quality sampling were conducted using either submersible pumps or by bailing.

Groundwater monitoring was conducted using consistent methodology throughout the baseline period.

- Static water levels were measured immediately upon opening each well using an electric water level meter.
- Purge volumes were calculated using standard formulas to calculate three well casing volumes.
- A minimum of three casing volumes were purged using portable submersible pumps or by bailing. Wells with very low well yields were purged dry, and groundwater sampled after recharge.
- Field parameters (pH, specific conductance (SC), and temperature) were periodically measured and recorded during purging. Water samples were collected after three casing volumes of water were removed and field parameters stabilized to within 10% of the previous measurement.
- Water quality samples were collected and preserved, as required by analytical methods. Samples were placed in new sample containers obtained from the analytical laboratory.
- Sample bottles were labeled with project, sample identification number, date, time, sample preparation method (filtered/unfiltered), and preservative.

- Final field parameters (pH, SC, and temperature) were measured and the values recorded in the project field book and field sampling forms.
- Chain of custody forms were completed.
- Samples were immediately placed on ice for storage and delivery to the analytical laboratory for analysis of parameters listed in Table 2-2. Samples for metals were analyzed as “dissolved” during all monitoring events. The initial set of samples was also analyzed for total recoverable metals.

2.1.4 Aquifer Testing

Sixty-one aquifer tests were conducted. A test was conducted on each bedrock monitoring well with sufficient water. Either pump tests or slug tests were completed. The type of test was chosen based on well yield and water column height. In general, wells with low yields, less than about one gallon per minute (gpm), were slug tested. Pump tests were conducted on wells with yields exceeding one gpm and with water columns that were sufficient to accommodate a submersible pump and necessary instrumentation, while still leaving room for meaningful drawdown data to be collected.

Slug Testing

Slug tests were conducted as follows:

- Static water levels were measured using electronic water level meters.
- Electronic pressure transducers were installed and water levels were allowed to reach equilibrium before initiation of the test.
- Either slug-in or slug-out tests were conducted. A slug was lowered into the well and dropped to “instantaneously” displace water in the well (slug-in test). A slug-out test was conducted in wells with reasonable water level recovery rates during the slug-in test.
- Water level responses, following slug injection or withdrawal, were measured and recorded immediately.
- Water levels were measured until water levels recovered to at least 90% of the original water level.

- Data was entered into analytical software (Aqtesolv™) and analyzed using approved methods to calculate hydraulic conductivity and transmissivity.

Pump Testing

Pump tests were conducted on wells with sufficient yield to allow sustained pumping for 100 minutes. Pump tests generally consisted of single well tests and were completed as follows:

- Water levels were measured using electric water level probes.
- A submersible pump was installed.
- An electronic pressure transducer was installed.
- Water levels were allowed to equilibrate to near their original level.
- Water was pumped at a constant rate for 100 minutes and the corresponding water level drops were measured.
- Pumping was stopped after 100 minutes and water level recovery was measured.
- Data were entered into analytical programs and analyzed using accepted methods to calculate hydraulic conductivity and transmissivity.

Testing at AVF sections included use of observation wells during testing. Water was pumped from the pumping well and water level responses in observation wells were measured using either pressure transducers or manual methods. Water pumped from the well was directed to a location outside of the anticipated cone of depression from pumping and away from observation wells. In general, short-term testing was conducted and sufficient aquifer stress was induced to obtain data for defining aquifer characteristics. Pumping tests were conducted at five of the six AVF sections.

2.2 QUALITY ASSURANCE AND CONTROL

Field quality control (QC) samples including field blanks, rinsate blanks, duplicates, and laboratory control samples (matrix spikes, laboratory blanks, laboratory duplicates, and laboratory control samples) were used to evaluate the accuracy, precision, and consistency of data.

Groundwater sample QC consisted of one duplicate, one rinsate blank and one DI blank per 20 samples. Quality control was used to evaluate precision and accuracy of the water quality analyses. Results of data validation procedures are contained in Appendix D.

2.3 HYDROGEOLOGY – ARM 17.24.304(1)(f)(i)(A)

2.3.1 Geology and Stratigraphy of the Otter Creek Drainage Basin

2.3.1.1 Regional Geologic Setting and Structure

Otter Creek is located in the North-Central part of the Powder River Basin, an elongate geologically structural, sedimentary and physiographic basin that extends nearly north to south from southeastern Montana into northeastern Wyoming. The Powder River Basin forms a broad asymmetrical syncline with a gentle, west-dipping eastern limb and a more steeply, east-dipping west flank. The axis of the basin extends northeast-southwest from about Miles City, Montana to near Sheridan, Wyoming, then trends northwest-south-southeast along the flank of the Big Horn Mountains to near Glenrock, Wyoming.

2.3.2 Geologic Structure

In Montana, the axis of the Powder River Basin synclinal feature trends northeasterly and is traced approximately by the Tongue River. Northwest of the river, stratigraphic units dip toward the southeast, whereas east of the river beds dip regionally south-southwest (USGS, 1983a). Correlations and mapping of drilling results along the east side of the Otter Creek basin indicate beds at the base of the Knobloch Coal form a local synclinal structure. North of Tenmile Creek beds dip northerly at about one-half degree then swing around with dip to the west. Strata to the east toward the Otter Creek-Powder River divide dip west to southwesterly at about 0.75 degrees. Just east of Otter Creek, beds dip to the east at about 0.3 degrees.

During Late Cretaceous (72-65 MYa) and Tertiary Paleocene-Eocene (65-33.7 MYa) periods, as much as 8,000 feet of sediments were deposited into the Powder River Basin. These sediments were derived from weathering, erosion and transport from exposed landmasses located to the east in central North Dakota and South Dakota (Black Hills Uplift), and the actively uplifting Big Horn Mountains to the west (Curry, 1971).

2.3.2.1 Stratigraphy

Clinker/Scoria

Locally, and also over extensive areas along the exposed outcrops of many Fort Union Formation coal beds, the seams have caught fire and burned resulting in baking and fusing of the overlying strata forming a natural brick-like material, reddish-brown to orange-red in color referred to as scoria, clinker, or burn. These materials are particularly extensive on either side of Otter Creek and north of Threemile Creek.

Quaternary Sediments

Alluvial gravels derived from erosion of underlying Cenozoic strata, transport, and re-deposition occupies stream channels and flood plains. The channel bottom materials consist of clay, silt, and very fine to medium-grained sandstone and scoria/clinker. Thicknesses of the alluvium vary in each drainage from zero feet at the outer edge to near 100 feet. Continental and alluvial deposits (bedrock) of Tertiary age (USGS, 1983a and 1983b) underlie the drainage bottoms.

Cenozoic Strata

The Late Paleocene-Early Eocene age (50-57 MYa) Wasatch Formation conformably overlies the Paleocene Fort Union Formation. It crops out to the south in the headwaters region of Otter Creek and along some high ridges to the west and south in Wyoming.

Early Tertiary, Paleocene age (58-65 MYa) strata, assigned to the Fort Union Formation are the uppermost and youngest sediments exposed in the Otter Creek drainage basin. In descending order, the Fort Union Formation includes the Tongue River, the Lebo Shale, and Tullock members. Throughout most of the basin area, the upper two-thirds of the Tongue River Member, approximately 1,400 feet, has been removed by erosion. Sediments in the Tongue River Member consist of interbedded claystone and sandstone further interbedded with shale, claystone, and carbonaceous shale and laterally continuous thick to moderately thick coal beds.

About 500 feet of the lower part of the Tongue River Member is all that remains, from approximately 150 feet above the Knobloch Coal to the base of the member, which includes the Flowers-Goodale Coal (Roberts) and Kendrick (Terret) seam, and the underlying shale (Wheaton, 2008). The base of the Tongue River Member and older underlying units are not exposed in the Otter Creek drainage basin.

The Lebo Shale Member, about 600 feet thick, conformably underlies the Tongue River Member of the Fort Union Formation. It consists predominantly of alluvial-deposited dark gray, brown to black carbonaceous shale, bentonitic claystone, sandstone and siltstone with thin, localized coal beds. The unit's lower part is interbedded subordinate grayish-brown to black shale and thin coal beds (Montana DSL, 1983, Vuke, 2007).

Mesozoic Rocks

Sedimentary rocks of Upper Cretaceous age (65-72 MYa) are assigned to the Hell Creek Formation/Lance Formation and underlying Fox Hills Formation. The Hell Creek and Lance Formations are laterally equivalent, concomitant deposits that interfinger near the Montana-Wyoming border. The names have been used interchangeably; in Montana Hell Creek is the preferred use where it is as much as 1,100 feet thick (Vuke, 2007). It consists of shale and siltstone, gray to yellowish-gray silty, clayey, sandy, carbonaceous and bentonitic, locally yellowish-gray to tan sandstone containing thin coal beds. The lower contact is gradational (Montana DSL, 1983).

The Fox Hills Formation is a regionally extensive deposit about 100 to 150 feet thick (Vuke, 2007) containing several regressive, marginal-marine sandstones. In the upper part the sediments are yellowish-orange to gray, fine to medium-grained, non-calcareous trending to interbedded sandstone, siltstone, and black shale with a calcareous concretion zone in the lower part. In eastern Montana, the unit is considered a drilling target and potentially viable aquifer for both local and small communities. The monotonously uniform Bearpaw Shale (about 980 feet thick) along with numerous thin bentonite beds (Vuke, 2007) underlies the Fox Hills. To the west, the Fox Hills becomes a less viable water supply target due to thinning, discontinuity, and finer grain sizes.

2.3.3 Study Area Hydrogeology

Geology in the Study Area is dominated by the Tertiary Fort Union Formation, with Quaternary unconsolidated deposits common in valleys, ephemeral drainages, and on slopes.

Map 16 - Geologic Cross Sections was constructed using data obtained through exploration and monitoring well drilling and shows the spatial relationships between the coal, clinker, alluvium, overburden and underburden.

Monitoring and testing of these units was conducted to characterize hydrogeologic conditions. This work included installation of 84 groundwater monitoring wells, logging geological conditions, conducting aquifer tests, water level measurement, water quality sampling, floodplain mapping, conducting inventories of existing water wells and monitoring wells registered with the Montana Groundwater Information Center (GWIC). In general, this evaluation was conducted based on data collected during the baseline monitoring period. Supplemental data from outside sources was used where necessary to fill data gaps or as a comparison to historical conditions.

Results are contained in the following sections and were conducted to meet requirements in ARM 17.24.304(1)(f)(i)(A). Monitoring well logs, including geological descriptions, are in Appendix A. Water level data (elevations and hydrographs) are in Appendix B. Aquifer test data are in Appendix C. Groundwater quality data are included in tables discussed in the following sections and in Appendix D, which also includes data validation reports.

2.4 GROUNDWATER OCCURRENCES - 17.24.304(1)(f)(i)(A)

Groundwater was encountered in five hydrostratigraphic units in the Study Area: alluvium; clinker; overburden; Knobloch Coal; and Knobloch underburden. Eighty four monitoring wells were installed in these units to collect baseline data to evaluate the current conditions in the Study Area and to establish a baseline of groundwater conditions. The following sections contain descriptions of the various hydrostratigraphic units from the alluvium down to the Knobloch underburden.

2.4.1 Alluvial Groundwater

The alluvial groundwater system in the Study Area was evaluated for hydrogeological characteristics, depth to water, seasonal variations, and water quality. Work was also conducted to provide data to regulatory agencies so a determination of significance can be made for potential alluvial valley floors (AVF) as defined at 82-4-203(3)(a) MCA and associated rules. In addition to the hydrological data, evaluation criteria and data collected for AVF study purposes included geological information, surface water characterization (Section 3.0), floodplain mapping (terraces), wetland mapping, land use characterization, vegetation studies, watershed delineation, soil classification, collection of production information, and channel characterization. Results of the AVF studies are included in Baseline Report 325A - Alluvial Valley Floor Determination.

2.4.1.1 Lithologies

Thirty-six monitoring wells were installed into the alluvium in Otter Creek, Threemile Creek, Tenmile Creek and Home Creek. Two of the alluvial wells were installed in 2014. One near the permit boundary and one downgradient of the hydrologic study area, near Ashland, in support of the AVF study. In most cases, boreholes were advanced until bedrock was encountered. However, at wells A-1, A-9, AVF1-2, AVF2-3, AVF3-2, AVF5-3, AVF6-2 and AVF6-5, boreholes were advanced to well below the groundwater table and completed, without fully penetrating the alluvium.

Lithologies encountered in Otter Creek alluvial wells consisted of a shallow fine-grained layer and deeper coarser-grained sediments. Shallow sediments consisted of silty clay while deeper deposits consisted of poorly sorted silt, sand, and gravel mixtures. Sand and gravel are mostly comprised of angular to sub-rounded clinker. Total thickness of the alluvium in Otter Creek alluvial well boreholes ranged from 17.5 to 85 feet.

Bedrock encountered beneath the alluvium varied. In Otter Creek, bedrock encountered consisted of siltstone, claystone, and sandstone in the southern and northern portions of the Study Area. Coal and/or clinker were underlying the alluvium at AVF section 3 and 4.

Minor coal was also encountered at AVF-1 and AVF-2. The Otter Creek alluvium is in direct contact with clinker at several locations.

Claystone and coal was encountered beneath the alluvium in Tenmile Creek, southeast of Tract 2. This coal is interpreted to be the lowermost portions of the Knobloch Coal, which is split in the southern portion of the Study Area. It is likely that upper Knobloch Coal seams and/or burn are in lateral contact with the Tenmile Creek alluvium. Thickness of the alluvial deposits encountered at Tenmile Creek monitoring well A-4 was about 69 feet.

In general, bedrock encountered in Threemile Creek monitoring well boreholes consisted of clinker, siltstone, or claystone. Coal was encountered in one AVF borehole in lower Threemile Creek. The elevation of this coal suggests the coal is a lower remnant of the Knobloch. Claystone was encountered below the alluvium at the eastern edge of Tract 2 at well A-5. The thickness of the alluvium ranged from a minimum of 25 feet at well A-5 to as much as 66 feet at AVF section 6.

In general, bedrock beneath the alluvium in Home Creek consists of fine-grained sedimentary rocks (mudstone, siltstone, claystone, shale). Very carbonaceous shale/lignite coal was encountered at one borehole. Based on the elevation and consistency of the coal it is interpreted to be a carbon rich stringer in the Knobloch underburden. The thickness of alluvium encountered in Home Creek was about 34 feet to 71 feet.

2.4.1.2 Hydraulic Characteristics

Ten pumping tests were conducted on alluvial wells to evaluate hydraulic parameters. Both single well, and multiple well tests were conducted. Data were downloaded into Aqtesolv™ software package and analyzed to calculate hydraulic conductivity, transmissivity, and storage coefficients. Results are presented in Table 2-3.

Calculated values for the various drainages were:

Drainage	Hydraulic Conductivity (ft./day)	Transmissivity (ft.²/day)	Storativity
Otter Creek	3.4*-554	235*-7,750	0.00013-0.0027
Tenmile Creek	40	2,130	*
Threemile Creek	90	3,060	*
Home Creek	76-77	3,796-3,842	0.0067-0.0088

- *Not calculated, only single well test(s) conducted

McClymonds (1984) reported average hydraulic conductivity from several pump tests for wells completed in Otter Creek alluvium. A range of hydraulic conductivity of 40 to 360 feet per day with an average of 120 feet per day were reported. These values compare favorably with calculated values for this investigation where hydraulic conductivity averaged 128 feet per day.

Depth to Water

Near surface fine-grained sediments along Otter Creek act as a confining layer, limiting flow between the shallow alluvium and deeper more permeable alluvium. Water levels in the Otter Creek alluvial wells rise to within the fine-grained conditions demonstrating the confined/semi-confined conditions. Water level data and hydrographs are in Appendix B. The high clay content of the surficial alluvial deposits also limits flow between Otter Creek and the coarser alluvium. Confined conditions also exist in Tenmile Creek at well A-4.

Alluvium encountered in tributary drainages also tended to exhibit fine-grained near surface sediments and coarser grained deeper sediments. Near surface deposits in tributaries tended to be slightly coarser than shallow deposits observed along Otter Creek. In contrast to Otter Creek and Tenmile Creek, alluvial groundwater in Threemile and Home Creek drainages exists under water table conditions, with water levels in the coarse grained sediments rather than in fine-grained near surface sediments.

Depths to groundwater in the alluvium varied seasonally (see hydrographs Appendix B). In Otter Creek, alluvial water levels ranged from about two feet bgs to about 13 feet bgs. At AVF3-3, located east of the main Otter Creek floodplain, water levels were approximately 21 feet bgs. Depths to groundwater in Tenmile Creek at A-4 were four to five feet bgs. Depths to groundwater in Threemile Creek ranged from about four feet at A4 to 10-21 feet at AVF6. Depths to groundwater in Home Creek at well A-2 were around 49 feet bgs, while at AVF section 5, depths to groundwater were about 12 to 25 feet bgs. During the baseline monitoring period, water levels showed seasonal fluctuations of less than three feet. Higher water levels were observed in spring and early summer, a reflection of recharge from snowmelt and associated higher flow in surface water systems. Baseline Report 325A includes a map showing the depth to groundwater in the alluvium in the Study Area.

2.4.1.3 Groundwater Flow

Figures 2-2 through 2-7 include water table contours for the alluvium as well as potentiometric surface contours for bedrock units for the units presented. Groundwater flows to the north-northwest towards the confluence with Tongue River alluvium.

Groundwater flux was calculated for alluvium in Otter Creek, Tenmile Creek, Threemile Creek, and Home Creek. Calculations were made using Darcy's Equation: $Q = TWi$, where;

- Q = groundwater flux
- T = Transmissivity (thickness time hydraulic conductivity)
- W = width of transect
- I = hydraulic gradient.

Groundwater gradients calculated for Otter Creek alluvium for various reaches of Otter Creek ranged from 0.0014 to 0.0035. Average transmissivity was calculated to be 2,838 ft²/day. The average width of the alluvium is about 3,300 feet. Based on these parameters, groundwater flux through the Otter Creek alluvium ranges from about 68 gpm to about 170 gpm.

Alluvial groundwater in Tenmile Creek is flowing west under a gradient of about 0.0076 (estimated between well A-4 and Otter Creek alluvial well A-3) and the average width of the alluvium is about 1,100 feet. The transmissivity calculated at well A-4 was 2,130 ft²/day. Based on these parameters, approximately 92 gpm of groundwater flows through the Tenmile Creek alluvium. A relatively high flux calculated for the Tenmile Creek alluvium is mostly a function of the gradient, which was calculated to be approximately twice that in the Otter Creek alluvium.

Groundwater in the Threemile Creek alluvium is flowing west under a gradient of about 0.0077 (well A-5 to AVF-6-1). Transmissivity, calculated from pumping tests at AVF section 6 are on the order of 3060 ft²/day. Assuming an estimated width of sediments of 1600 feet, groundwater flux through Threemile Creek alluvium is 135 gpm.

Groundwater in Home Creek is flowing west from well A-2 to AVF5-4 under a gradient of 0.0036. Transmissivity, calculated from pumping tests at AVF section 5, averaged 3,819 ft²/day. Home Creek alluvium was estimated at 1,100 feet wide. Based on these parameters, a groundwater flux of 113 gpm was calculated for the Home Creek alluvium.

Recharge and Discharge

Recharge to the alluvium occurs primarily through infiltration of surface waters derived upstream and within the Study Area, and from bedrock units adjacent to, or otherwise in contact with the alluvial deposits. Synoptic runs conducted through the Study Area (Section 3.2.4) in the fall and spring have shown that Otter Creek is gaining through the reach from Tenmile Creek to Ashland during the spring but relatively consistent during the fall. Gaining and losing reaches were identified during each event, however. Gaining stream reaches are indicative of inflow from adjacent bedrock units (clinker and Knobloch Coal). Losing reaches are indicative of flow out of the creek. Upward gradients, capable of providing recharge from deeper sub-Knobloch units, may also occur but were not identified in the vicinity of the various drainages. Higher gains observed downstream in the spring are likely a result of additional inputs from ground thaw, snow melt and precipitation run off.

Hydraulic conductivity in the Knobloch Coal is one to two orders of magnitude lower than the alluvium. Conversely, the hydraulic conductivity of the clinker is at least one order of magnitude higher than the Otter Creek alluvium. Groundwater gradients dictate which direction flow will occur. Hydraulic conductivity, coupled with the gradient, dictate the rate at which flow between the units will occur. Where the units are in direct contact and where water level elevations are similar, flow from the alluvium to the clinker would be expected. Because of the very high hydraulic conductivity, the clinker units tend to serve as a groundwater flow “buffer”. Any increased hydraulic head in the alluvium will result in flow to the clinker. Water entering the clinker is easily transmitted in the clinker without obvious measurable mounding affects. Drops in water levels in the alluvium are easily recharged from the clinker, where the two units are in direct contact. This relationship tends to decrease water level fluctuations through the system. In addition, apparent variations in stream and alluvial groundwater flow volumes are the result of flow to and from the clinker. For example, net groundwater flow into the Otter Creek alluvium from Tenmile, Threemile and Home Creek were calculated at about 350 gpm. The flux in Otter Creek alluvium was calculated to range between 83 and 207 gpm, much lower than the tributary input. Overall surface water flows were relatively similar through the Study Area in the fall but gained in the spring. It is likely, variations observed in groundwater flux and surface waters are a function of flow through clinker units and evapotranspiration from the alluvium.

Discharge from the alluvium occurs as both an expression of increased surface water flow and flow losses to the clinker.

2.4.2 Overburden

Eight monitoring wells were installed in overburden units for baseline study purposes. Groundwater in the overburden is highly variable, with only localized areas capable of producing usable quantities of groundwater. Five of the wells were drilled within the coal tracts. One well (B10-O) was installed south of the tracts, one well (B2-0) was drilled just northwest of Tract 3 and one well (B12-CO) was installed in July 2014 on USFS lands southeast of the permit area. The designation CO refers to colluvial overburden. The overburden was dry at four batteries and wells were not installed (B-1, B-3, B7-O, B-9). At

the B7 battery, groundwater was not encountered until the interburden between the upper and middle Knobloch seams. Well B7-O was completed in this unit and is actually an interburden well rather than an overburden well as indicated on the log.

2.4.2.1 Lithologies

Overburden lithologies include shale, claystone, siltstone, sandstone, and infrequent thin coal seams. Groundwater is typically found in relatively small amounts in the sandstone, siltstone, and in coal. One overburden well, B12-CO was completed in gravelly colluvial materials encountered above the Knobloch Coal.

At well B10-O, a thin (3.5 feet) coal seam was encountered. This interval was interpreted as a separate coal seam from the Knobloch Coal. The Knobloch Coal separates into multiple seams in the southern portion of Tracts 2 and 3. A similar coal seam is present at the B-7 battery; however, the coal was dry at B-7. In both areas, the coal is laterally discontinuous. This coal was not observed in any other monitoring well borings within the Tract 1, 2, or 3 boundaries.

Logs including detailed lithologic descriptions are in Appendix A.

2.4.2.2 Hydraulic Characteristics

A regional groundwater system was not encountered in the overburden in the Study Area. Rather, small areas with saturation sufficient to yield small amounts of groundwater were identified locally, and monitoring wells were installed. The overburden was dry in other areas, specifically at batteries B1, B2, B3, B7, and B9. The variable nature of overburden groundwater is demonstrated on the potentiometric map on Figure 2-3.

Where present, groundwater in the overburden occurs in both confined and unconfined conditions. Confined conditions are present at B6-O and B8-O. Unconfined or dry conditions exist at other locations. Saturated thicknesses range from 3.5 feet at well B10-O (coal) to 53 feet at B8-O.

Wells with yields estimated at less than one gpm, or with very short water columns, were slug tested. Single well pumping tests were conducted on other wells. Types of tests and results of data evaluation are in Table 2-3.

Calculated hydraulic conductivity and transmissivity for the overburden were 0.001 to 41.4 feet per day and 0.006 to 145 ft²/day, respectively. Higher calculated values for hydraulic conductivity and transmissivity were from slug tested wells with limited saturated thickness (B10-O) and may be skewed to the high side. Therefore, representative hydraulic conductivities for the overburden are considered to be less than 2 feet per day.

2.4.2.3 Groundwater Flow

Groundwater flow in the overburden is a reflection of surface topography, flowing from topographically high areas to lower elevations. Flux through the overburden was calculated for areas interpreted to be connected using Darcy's Equation. Flux through the north portion of Tract 2 within the proposed mine area was calculated to be 0.2 gpm.

Flux through the overburden in Tract 1 was calculated to be 1.2 gpm. It should be noted that in Tract 1, saturated overburden was encountered along the east side of the area at B4-O, but the unsaturated (dry) conditions were present at B5-O. It is likely that flow from the overburden had drained into the adjacent clinker areas east of B5-O.

In Tract 3, groundwater flux was calculated at 35.2 gpm. This relatively high flux was based on groundwater gradients calculated using a combination of water levels in the overburden and the alluvium. This approach was employed since three overburden wells were not present from which gradients could be estimated. The high flows calculated for the overburden are likely overestimates for this reason.

2.4.2.4 Recharge and Discharge

Recharge to overburden in the Study Area occurs as infiltration of precipitation waters. Recharge of precipitation water from rainfall is likely very small because of the generally fine-grained nature of the overburden. The majority of recharge likely occurs from

snowmelt, when temperatures are too low to promote transpiration and evaporation is limited.

On the east side of Tract 2, groundwater was not found in the overburden in boreholes south of B11-O. At the B7 battery, groundwater was not encountered until the interburden between the upper and middle Knobloch coal. A well was completed in this interburden unit but was labeled as an overburden well.

In the southwest portion of Tract 2, groundwater was found in the overburden at well K-2 but not at K-3, located approximately 2000 feet to the south. At K-2, the overburden consists of a sandstone unit that is in direct contact with the upper Knobloch. Water in the overburden could be the result of upward flow from the coal to the overburden. At K-3 the upper Knobloch exists under unconfined conditions and a similar upflow is not possible. The water present at K-2 but not at K-3, is a function of hydrostatic pressures in the underlying coal.

Recharge to the overburden likely occurs on ridgetops and along valley walls southeast of Tract 2. Discharge from the overburden occurs as localized seeps and springs and as flow to adjacent clinker, where present.

2.4.3 Knobloch Coal

2.4.3.1 Lithologies

Twenty-one monitoring wells were completed in the Knobloch Coal. In general, wells labeled with a “K” only contained a single unit of coal without any significant partings or interbeds. A well number with a “KU” designation is completed in the upper Knobloch. One exception is at the B-7 battery, where well B7-KU is actually completed in the upper portion of the Middle Knobloch. A “KL” designation indicates a well is completed in the lower Knobloch.

Complete sections of Knobloch Coal encountered in monitoring well boreholes ranged in thickness from 61.5 to 75 feet. At well B3-K, the coal was approximately 42 feet thick, a function of partial burning or settlement associated with nearby burning and collapse of

overburden following burning. Well B3-K is located near the subcrop/burn line – the contact between burned coal and unburned coal. In the southern portion of the Tracts, the coal splits, with individual seams having variable thickness.

Knobloch Coal is present under all three Otter Creek coal tracts in minable quantities. Complete descriptions of the coal occurrences are contained in geological and mine plan sections of this permit application (Exhibit 322A Coal Conservation Plan). A general description of the Knobloch Coal is offered here to assist with hydrogeological interpretation of baseline conditions.

A complete section of Knobloch Coal is present under the north three-fourths of Tract 2, where unburned. The coal splits into multiple seams of variable thickness and stratigraphic separation to the south. The upper surface of the coal is marked by a basin, centered in Section 23 of Tract 2. This basin axis extends westward under Otter Creek to the west. The top of the coal increases in elevation to the north, east, and south of the basin center (Exhibit 322A- Coal Conservation Plan, Plate 2).

The result of this structure on the Study Area hydrology is significant. Otter Creek has eroded into or through the coal from the northern portion of section 27 (west of wells K2/K6) to near AVF section 2. In this reach, the coal is either in contact with the alluvium or clinker. As discussed, in Section 2.1.4.1, this results in flow between the various units.

Coal encountered during drilling in this area was highly weathered, very soft, and often weakly consolidated. Based on past experience with weathered coal, and observations made during drilling, the hydraulic conductivity of the coal under the alluvium is likely much higher than the competent coal found east and west of the creek. Hydraulic conductivity of the weathered coal beneath the alluvium was not evaluated but likely approaches that of the alluvium. Weather processes in coal tend to expand and connect cleats thereby increasing the permeability.

2.4.3.2 Hydraulic Characteristics

Groundwater in the Knobloch Coal generally exists under confined conditions. Water levels in wells completed in the coal raised more than 50 feet above the top of the coal in the southern and eastern portions of Tract 2. Pressurization decreases toward Otter Creek, a function of drainage to the alluvium and clinker. Near the creek, and near burn lines, the coal is either weakly pressurized or unconfined.

Twenty three aquifer tests (21 pumping tests, two slug tests) were completed on wells installed in the Knobloch Coal. The majority of tests conducted were single well tests. One extended (~ 16 hours) multiple well test was conducted by pumping well K-1 and observing water levels at wells K-5, B11-K, and well OC83-4 (installed prior to this investigation). Table 2-3 has results of pumping tests conducted on Knobloch monitoring wells in the Study Area.

Calculated average transmissivities and hydraulic conductivities were approximately 100 ft²/day and 2 feet per day, respectively. Transmissivity ranged from 0.227 (B12-KU1) to 691 ft²/day (B5-K). Hydraulic conductivity ranged from 0.02 (B12-KU1) to 9.9 feet per day (B5-K). Higher values at B5-K are a function of the location of the well near the burn line. Coal observed from this well was relatively soft and showed signs of alteration likely resulting from nearby burning of the coal. This alteration likely increases cleat openings and interconnections in the vicinity of the well.

Storativity for the coal was calculated using data obtained by pumping well K-1 and observing K-5, B11-K, and well OC83-4 (installed prior to this investigation). A value of 0.0016 was calculated from this test. This value is consistent with what would be expected for confined coal systems. Values for storativity would be higher near contacts with clinker and alluvium, where unconfined conditions no longer exist. In these areas, storage values would be equal to the effective porosity of the coal.

The United States Geological Survey (USGS) conducted several aquifer tests on wells completed in the Knobloch Coal in the 1980s (Cannon, M.R., 1985). Transmissivity for the Knobloch Coal for the tests averaged 125 ft²/day. Assuming an average thickness for the coal of 65 feet, the hydraulic conductivity would be 1.9 feet per day. Storativity was calculated for one pumping test at 0.001. Results for six pump tests conducted by USGS on Knobloch wells yielded a range 0.05 to 46 feet per day (McClymonds, N.E., 1984). The average for these tests, discounting the extremes, was 2 feet per day. The values calculated during this baseline investigation are consistent with the calculated USGS values.

2.4.3.3 Groundwater Flow

Potentiometric maps for the Knobloch Coal for August 2011 and March 2012 are presented on Figures 2-4 and 2-5. Groundwater in the coal generally flows towards Otter Creek. Potentiometric lines wrap around the creek (flow to east on west side of creek, flow west on east side of creek), an indication of discharge into clinker and alluvium near the creek. Hydraulic conductivity in the alluvium and clinker is much higher than that of the Knobloch. This allows free drainage of the coal in areas where receiving water levels are lower than in the coal.

Groundwater gradients in Tract 2 were calculated to be 0.008. The width of the coal, as measured perpendicular to the average flow direction, is about 18,600 feet. Assuming an average transmissivity of 168 ft²/day (well B5-K not included in average due to its proximity to burn line), a flux of 130 gpm was calculated through the proposed mining area.

Groundwater gradients in Tract 1 were also calculated to be 0.008. The width of the coal, as measured perpendicular to the average flow direction, is about 9,417 feet. Assuming a transmissivity of 57 ft²/day (well B4-K), a flux of 22 gpm was calculated for the Knobloch Coal in Tract 1.

Groundwater flux through Tract 3 was calculated to be 142 gpm. Flux calculations assumed two flow tubes through the area, with transmissivities of 169 and 312 ft²/day. Gradients from

the two flow tubes were 0.012 and 0.003. Individual flows calculated for the tubes were 88 gpm for the northwest tube, and 54 gpm for the southeast tube.

Recharge and Discharge

Recharge to the Knobloch Coal occurs from lateral flow into the coal in areas where more permeable hydrostratigraphic systems are in contact with the coal, at basin margins, and through minor precipitation recharge from overlying units in areas where downward gradients exist. Flow from the Tenmile Creek alluvium, via clinker units may provide some recharge to the middle and lower Knobloch, near the forest service boundary. Water levels in the alluvium in this area are near or above the levels of middle and lower Knobloch coal. Water levels in the alluvium are below the bottom of the upper Knobloch, which is dry in this area (B7 battery). Recharge from the alluvium would require flow through clinker and then into the coal. Although this may occur, the very high hydraulic conductivity typically results in relatively thin water columns in the clinker due to the propensity to drain that would tend to limit the amount of water that is available for recharge. Recharge to the lower Knobloch via this mechanism would require downward vertical flow through the shale that overlies the coal.

Recharge may also occur at the margins of the Powder River Basin (Wheaton, et. al, 2008). Recharge areas at the basin margins are well removed from the Study Area.

Both upward and downward gradients exist between the Knobloch Coal and underburden. An upward gradient from the underburden exists at batteries B5 and B11; other areas have a downward gradient from coal to underburden. Minor leakage to the deeper units from the coal is possible in these areas, although considered very unlikely due to the fine-grained sedimentary rocks that exist between the units.

Discharge from the coal occurs at contacts with alluvium or clinker at downgradient boundaries. Hydraulic conductivities of the receiving units are one to several orders of magnitude higher than the Knobloch Coal. Although not documented, this would be expected to create a slight head drop near the edges of the coal as the water drains to the

higher permeable materials. Meridith and Kuzara (MBMG 2012) concluded that coal aquifers contribute about 11% of the surface water at the mouth of Otter Creek, during low flow, as indicated by carbon isotope ratios. At time of higher surface flow the contribution from groundwater is smaller.

2.4.4 Clinker

2.4.4.1 Lithology

Clinker forms during the burning of coal. In the Study Area, the majority of clinker was derived from the burning of the Knobloch Coal near valley margins. As the coal burns it bakes the overburden resulting in various degrees of thermal alteration to become a low grade metamorphic rock. Depending on the amount of thermal alteration, the resulting rock (clinker, aka baked shale) rocks are generally harder and more resistant than the original source rock. Ranges of alteration can vary from a slight hardening to vitrification. However, as the coal burns, a void is left and the overlying rock collapses into the void. This results in a highly fractured, highly permeable clinker interval. In many cases, clinker may extend from the top of a hill to the bottom of the coal unit or to the contact with unburned coal of the same unit. Clinker surfaces provide conditions for precipitation recharge, particularly in areas where soil formation has not occurred (typically flat hilltops) and coarser materials are at the surface.

An ash layer is often found at the base of the unit, residual from the coal. In many cases, and away from the valley margins, the burning may be incomplete, leaving clinker overlying unburned, although highly altered, coal. The extent of clinker in the Otter Creek tracts has been mapped by the USGS and other parties as the resource has been studied. The extent of clinker in the Otter Creek Tracts and surrounding area is shown on the inset on Map 16 - Geologic Cross Sections. Burning of the coal in the vicinity of the Otter Creek tracts occurred in the Middle Pleistocene, about 0.33 to 0.4 MYa (+/- 0.3 MY) (Coates, D.A, Heffern, E.L., 1999).

Deep erosion of strata near Otter Creek would have exposed the Knobloch Coal. Coal burns may have started at outcrops along the margins of the creek by range fires, lightning, or other sources.

2.4.4.2 Hydraulic Characteristics

Pumping tests were conducted on two clinker wells (C2, C4). Well C2 was pumped at 90 gpm for 200 minutes with no measurable drawdown. Well C4 was pumped for 100 minutes at 369 gpm. Drawdown water levels fluctuated during the test. Data were placed in Aqtesolv™ software for analysis. A computer generated fit was used since no obvious trend was observed. Based on the computer fit, transmissivity and hydraulic conductivity of 762,200 ft²/day and 26,744 ft²/day, respectively were calculated. These calculated values are well within reported transmissivity ranges for clinker tested in the Powder River Basin (35,400 to 1,482,400 ft²/day – seven tests - Coates, D.A, Heffern, E.L., 1999), and consistent with tests conducted near Colstrip, Montana where hydraulic conductivity was around 5,000 feet per day.

Storativity could not be calculated from the pump test data. However, storativity values for clinker in the Powder River Basin range 0.15 to 0.3 (Coates, D.A, Heffern, E.L., 1999).

2.4.4.3 Groundwater Flow

Clinker has a potential to transmit and store large quantities of groundwater due to the high permeability and pore space. Clinker is typically present along the valley margins, and on hills where the burn extended further into the coal. Gradients in the clinker measured for this investigation were very flat. However, because of the extremely high conductivity, the clinker can carry large volumes of water with relatively low gradient. Flow from the clinker is towards Otter Creek alluvium, although in areas, flow also occurs from the alluvium to the clinker.

Recharge and Discharge

Recharge to the clinker is primarily from three sources; inflow from alluvium, inflow from the Knobloch Coal, and infiltration from precipitation. Recharge from the alluvium occurs

near the creek in the area where the clinker is in direct contact with the alluvium. Given the substantially higher conductivity in the clinker, flow from the alluvium to the clinker will occur when heads are similar or higher in the alluvium. Otter Creek has a fairly sinuous nature. Clinker sometimes fills the inside of large bends, or occupies a portion of the streambank adjacent to the stream. Under these conditions, groundwater flows into the clinker at the upstream edge and either stays in the clinker and is stored, or flows downstream to a discharge point back to the alluvium or creek when hydrologic relationships are favorable.

Flow from the Knobloch Coal to the alluvium results as the edge of the coal drains into the higher permeability clinker.

Precipitation appears to be a major component of water recharge to the clinker. Precipitation would be expected to infiltrate faster through coarse grained slopes, particularly on north facing slopes, and slower on flat hilltops, where surficial grain sizes may be lower. Recharge to clinker units in a study conducted on the Cheyenne Reservation in 1981 concluded about 1.2 inches of recharge from precipitation per year (Woessner, et. al, 1981).

2.4.5 Underburden

2.4.5.1 Lithologies

Twelve monitoring wells were completed in underburden units. Wells were completed in the first groundwater identified below the bottom of the Knobloch Coal with estimated yield which could potentially be used as source water for domestic or stock water purposes. Stratigraphic separation of the underburden and coal ranged from 47 feet at well B1-U and B11-U to 185 feet at B5-U. Note that the coal had been removed by burning and erosion at the B1 battery so the bottom contact of the coal was estimated.

Lithologies of the underburden are highly variable, reflecting the fluvial braided stream depositional environment of the Fort Union Formation. Groundwater occurrences were also highly variable as indicated by the large variation in completion depths below the Knobloch Coal. This depositional pattern results in numerous localized units with little lateral

continuity. Channel sandstones, capable of carrying groundwater on a regional basis may exist, but were not identified in this baseline study. Sandstone which could potentially be part of a larger regional deep groundwater system was, however, identified at well B10-U. Water from this interval is frequently used locally in the valley for stock watering or domestic purposes. Wells into this interval along Otter Creek exist under flowing artesian conditions. Multiple wells in this or deeper underburden intervals have been observed flowing to ground surface in the Study Area. One such well is actually labeled as a spring on the USGS Quadrangle maps in Section 33 (Section 33 Spring). According to local landowners, many of these wells have been flowing for years, although flow from the wells has reportedly declined. Such reported declines could be a function of water management practices, which allow unrestricted flow from the wells, thus potentially depressurizing the system.

Underburden monitoring wells were completed either in sandstone, coal, or a combination of thin coal beds and sandstone. Three wells, B3-U, B6-U and B9-U were completed in coal interpreted to be the Flowers-Goodale seam, located about 100 feet below the Knobloch Coal.

Shale, claystone, and/or mudstone, which behave as aquatards, were logged in the majority of underburden holes in the interval below the lower Knobloch Coal contact and the underburden completion zone. This results in confined conditions in the underburden.

2.4.5.2 Hydraulic Characteristics

Twelve pumping tests were conducted on wells completed in the underburden. Results of the analysis of the pump test data are in Table 2-3. Calculated transmissivity and hydraulic conductivity of the underburden at the monitoring wells tested averaged about 81 ft²/day (1 to 800 ft²/day) and 2.3 ft/day (0.01 to 19 ft/day), respectively. These results are skewed high, however, due to the higher values calculated at well B1-U. Hydrogeological conditions are somewhat different at this well due to its relatively shallow depth, and the fact that there is only short distance between the former coal, which burned at this location, and the

completion interval. Transmissivity and hydraulic conductivity for the other wells averaged 8.9 ft²/day and 0.6 feet per day, respectively.

2.4.5.3 Groundwater Flow

Figures 2-6 and 2-7 are potentiometric maps for the underburden for August 2011 and March 2012. Also shown are water table contours for the alluvium in Otter Creek and tributary drainages.

Groundwater in the underburden flows to the northwest under a gradient of approximately 0.0037. Flux was calculated for both the area under the proposed mining area in Tract 2 and for the entire width of Tracts 1, 2, and 3. The measured width of the underburden under the proposed mine area (perpendicular to flow) is about 14,425 feet. Transmissivity, calculated from all 12 underburden well pump tests, averages 80.8 ft²/day. Using these parameters, a flux of about 22 gpm is calculated for the underburden through the proposed mine area. Using a width of 39,820 feet for all three tracts perpendicular to the groundwater flow direction, a flux of about 62 gpm was calculated.

Recharge and Discharge

As illustrated on the underburden potentiometric maps (Figures 2-6 and 2-7), groundwater flows to the northwest. Recharge to the underburden is to the south-southeast. Potentiometric heads drop to the northwest and are slightly lower near the creek in the north part of the Study Area, resulting in contours that bend around Otter Creek. This would normally be interpreted as a possible discharge scenario to the creek or associated sediments. The potentiometric heads are high enough to cause upward flow to sediments in Otter Creek, Threemile Creek and Tenmile Creek. However, based on the presence of abundant fine-grained sedimentary rock layers encountered in the underburden boreholes, upward flow to sediments seems highly unlikely. Hydraulic conductivity of these units would be expected to be extremely low so only minute upward flow would occur.

Another possible explanation could be the presence of existing wells completed into the underburden that flow continuously under artesian pressure. Flowing wells are possible

wherever the potentiometric contour elevations depicted on Figures 2-6 and 2-7 are higher than the ground surface elevation at individual well sites – generally along Otter Creek and lower portions of tributary drainages. Wells completed in the underburden at elevations higher than the potentiometric surface would not flow to ground surface. Unrestricted flow to ground surface would result in a depressurization at the well and would result in a pattern similar to that of discharge to sediments along the creek. Based on observations in underburden boreholes, this appears to be a more likely explanation.

2.4.6 Springs

Three springs were originally listed for sampling in the Surface Water Plan of Study. Fortune Spring is in the eastern part of the Study Area. Coal Creek spring is about one mile east of the Study Area, on forest service property. A third site (Section 33 spring) which was identified as a spring based on labels shown on the USGS quadrangle map, turned out to be a flowing well installed deep (900 feet) into the Fort Union Formation. The “Section 33” spring site was sampled twice and then monitoring was discontinued.

Fortune and Coal Creek Springs are located at elevations of about 3340 and 3325 feet above mean seal level (MSL), respectively. Based on structure contour maps prepared for the top of the Knobloch, both springs are stratigraphically above the coal and issue from the overburden.

Flow at Coal Creek Spring during site visits ranged from 0 to an estimated 2 gpm. Fortune Spring had flows of 0 to about 2 gpm.

2.5 GROUNDWATER QUALITY -17.24.304(1)(f)(i)(B)

Groundwater sampling consisted of quarterly monitoring of 62 wells and two springs. Wells were sampled either one to twelve times during the baseline period between March 2011 and June 2014. Currently, it is planned that monitoring will be continued on a quarterly basis into the foreseeable future. Through the June 2014 sampling, a total of 640 samples were collected from the wells and analyzed. Observations (363) were also made, which involve visiting a site but noticing it cannot be sampled because it was dry or there were access

problems or safety concerns. One additional site, Section 33 spring, was actually an old well installed into the deeper Fort Union strata. This location was sampled twice. Twelve samples were collected from Fortune, and Coal Creek Springs.

2.5.1 Quality Assurance/Quality Control

A quality assurance/quality control (QA/QC) program was instituted during the baseline sampling program. Quality control samples were collected during each monitoring event. The purpose of the QC samples was to ensure that the data generated supported the intended data uses. The Otter Creek data were assessed and evaluated according to general sampling and analytical quality indicators recommended for frequency, precision, and completeness. Assessment of these non-direct measurements guides the over-all data quality.

Frequency requirements of one field blank and one field duplicate per 20 samples, or one set per day, for all monitoring events were met. Recommended precisions, and completeness goals, were evaluated and met for the entire data set. Precision is the evaluation of the field duplicate parameters within control limits and was met. The project completeness goal, acceptance of 90% of the results as valid, has been met, as no results were rejected as a result of this review. Data evaluation reports provide more detail to the QA/QC program and can be viewed in Appendix D.

2.5.1.1 Alluvium

Groundwater quality samples were collected from 15 sites in Otter Creek, Home Creek, Tenmile Creek, and Threemile Creek during baseline investigations. Nine of the sites were located along Otter Creek from the confluence with Tenmile Creek to the AVF-1 Section. Samples were collected from two wells in Home and Threemile Creek, and one well in Tenmile Creek. Plate 1 includes stiff diagrams geospatially illustrating basic water quality for the Study Area. Tables 2-4 through 2-7 contain statistical summaries for water quality from alluvial wells in Otter Creek, Tenmile Creek, Threemile Creek, and Home Creek, respectively. Figure 2-8 is a Piper diagram of the alluvial water quality for all of the wells. Data from each of the drainages is discussed in the following paragraphs.

Otter Creek Alluvium – Water Quality

A total of 87 water quality samples were collected from Otter Creek alluvial wells during the baseline period. Groundwater in the Otter Creek alluvium is most commonly basic (pH-7.9) sodium-sulfate or a sulfate type water with no dominant cation. However, water from well AVF1-2 is a sodium-bicarbonate water.

Total dissolved solids (TDS) concentrations ranged 1,080 to 6,380 mg/L (avg. 2,826 mg/L), while SC ranged 1530 to 6650 μ mhos/cm (avg. 3,607). Based on the average water quality, groundwater in Otter Creek alluvium would be a Class III water (SC 2500-15,000 μ mhos/cm). Evaluation of all the SC data from wells completed in Otter Creek alluvium shows that the 25th percentile of water quality is 3,700 μ mhos/cm, above the lower limit for Class III waters. This further supports the conclusion that the groundwater in this hydrostratigraphic unit is a Class III water. Note, however, that all water sampled from well AVF-1-2 was less than 2,500 μ mhos/SC. This reach, at least based on baseline monitoring results, has Class II groundwater. Differences in water quality in this reach may reflect flow of higher quality from Home Creek into the Otter Creek alluvium.

Sodium adsorption ratios (SAR) of groundwater from Otter Creek alluvium ranged from 5.13 to 10.6. Concentrations of dissolved and total recoverable metals were below Montana Circular 7 maximum contaminant levels (MCL's). Both iron and manganese showed levels during part of the monitoring period that exceeded secondary standards.

Tenmile Creek

Twelve samples were collected from well A-4, completed in the Tenmile Creek alluvium upgradient of the proposed mine. Water from A-4 is a basic (pH-7.7), sulfate type water with no dominant cation, SAR of 4.64 to 4.95, low nitrogen levels, and generally low metals concentrations, except aluminum, iron and manganese which exceeded secondary MCL's. The SC of the water ranged 2,600 to 3,180 μ mhos/cm.

Threemile Creek

Twenty four groundwater quality samples were collected from two monitoring wells completed in the Threemile Creek alluvium. Groundwater from these wells is a sulfate type. Water from well AVF6-3 showed no dominant cation, while groundwater from A-5 had sodium as the dominant cation.

Water from these wells was a neutral to basic (pH 7-8.2), with SC ranging 2500 to 3,940 $\mu\text{mhos/cm}$, SAR 5.28 to 6.81, low levels of detectable nitrogen, and generally low metals. Iron and manganese concentrations exceeded secondary standards.

Home Creek

Thirteen samples were collected from two monitoring wells completed in Home Creek alluvium. Groundwater from these wells was basic (pH – 7.66 avg.), SC ranging 1,300 to 3,050 mg/L, low nitrogen levels, and low metals except for dissolved aluminum, fluoride, iron and manganese, which exceeded the secondary standard. SAR level ranged from 2.93 to 7.17.

2.5.1.2 Clinker

Table 2-8 contains a statistical summary for groundwater sampled from five clinker wells. One of the five wells completed in the clinker (B1-C) was dry through most of the monitoring period. Figure 2-9 is a Piper diagram showing the average clinker water quality of the four clinker wells that contain water in the Study Area.

Groundwater from the clinker is a Class III groundwater, with average SC of 3,144 mg/L. The 25th percentile level of 2,646 for the baseline period, but the dataset is skewed low by relatively low SC values at well C-1. Well C-1 has a water column of less than one foot which occurs in an interval that would contain fine grained remnants of the burned coal seam (ash). As such, hydrogeologic conditions at C-1 may not be representative of saturated clinker conditions that occur in areas where thicker water columns exist. The clinker groundwater generally is a sodium-sulfate type water with no dominant cation, except at well

C-1, where the water is a sulfate type without a dominant cation. Further, groundwater from the clinker is near neutral to basic, has an SAR of 0.9 to 7.8, detectable levels of nutrients (nitrogen, phosphorus), and variable metals concentrations. During the baseline period, dissolved arsenic exceeded the MCL in three of four samples from well C-1. Several total recoverable metals were also exceeded at well C-1 (As, Ba, Cd, Cr, Pb, Hg, Ni). Metals concentrations at clinker wells having thicker water columns were typically low or non-detect, except for exceedances of secondary standards for several metals.

2.5.1.3 Overburden

Table 2-9 contains a statistical summary of water quality for groundwater sampled from overburden wells in the Study Area. Figure 2-10 is a Piper diagram showing the average overburden water quality for the Study Area. Water quality from the overburden is highly variable, a function of the variety of hydrostratigraphic settings that the groundwater is found. Magnesium-sulfate and sodium-sulfate type waters are present in the overburden. Groundwater in the overburden in Tract 2 is a sodium sulfate to bicarbonate type.

Groundwater from the overburden in the baseline period had an average SC of 4300 $\mu\text{mhos/cm}$, (range 2060 to 7810 $\mu\text{mhos/cm}$), was generally basic (pH-7.6 – range 5.8 to 8.5), SAR between 3.5 and 57 (avg. – 30.73), with detectable nitrogen and phosphorus constituents, and variable metals concentrations. In general dissolved metals were low or below detection limits. However, some metals concentrations did exceed occasionally primary MCL's.

2.5.1.4 Knobloch Coal

Table 2-10 contains analytical results for groundwater sampled from Knobloch Coal wells in the Study Area. Figure 2-11 is a Piper diagram showing the average Knobloch groundwater quality for the Study Area.

Two hundred and two samples were analyzed from wells completed in the Knobloch Coal. Groundwater in the Knobloch Coal is sodium-bicarbonate to sodium-sulfate type water, although water from wells K-3 and B8-KU have no dominant cation. Groundwater in the

Knobloch is a Class II groundwater with an SC that averages 2489 $\mu\text{mhos/cm}$ (25th percentile 2626 $\mu\text{mhos/cm}$), basic pH, SAR between 2.92 and 61.3 (avg. 36.43), detectable levels of nitrogen and phosphorus, and generally low concentrations of dissolved metals. Elevated concentrations of dissolved arsenic were detected in groundwater from one sample (B11-K). Total recoverable metals concentrations also exceeded the MCL for arsenic (B10-KL – 1 sample), barium (B10-KL – 1 sample, B11-K-1 sample, B7-KU-1 sample) and lead (B10-KL-1 sample, B7-KU-1 sample).

2.5.1.5 Underburden

Table 2-11 contains a statistical summary of water quality for groundwater sampled from underburden wells in the Study Area. Figure 2-12 is a Piper diagram showing the average underburden groundwater quality for the Study Area.

Groundwater from the underburden is Class II sodium-bicarbonate type water with an SC averaging 1268 mg/L (864 to 4,290 mg/L), basic pH, SAR between 1.8 and 53.7 (avg. 38.9), low levels of nitrogen and phosphorus, and generally low levels of metals. Arsenic and fluoride concentrations exceeded MCL's and aluminum, fluoride, iron and manganese exceeded secondary drinking water standards.

Overall, groundwater from the underburden would be suitable as a replacement stock watering source, and as a domestic replacement in most locations.

Section 33 Spring was initially identified as a spring from USGS topographic maps. The site has a stock tank with a feeder pipe that on first examination appears to be a developed spring. However, upon closer examination, the site was identified as a well. GWIC has a well identified for this area with a depth of 900 feet. The well is flowing to the ground surface. Since this site is not a spring, sampling was discontinued after two samples were collected. Groundwater sampled from the well is a basic sodium-bicarbonate type water, with SC ranging 2240 to 2400 $\mu\text{mhos/cm}$, low metals, and low nutrient concentrations.

2.5.2 Spring Water Quality

Water quality and flow was monitored at Fortune and Coal Creek Springs during the baseline monitoring period. Field parameters and flow were measured at Coal Creek Spring, while water quality samples were collected for analysis from Fortune Spring.

Table 2-12 contains a statistical summary of water quality for groundwater sampled at Fortune and Coal Creek Springs. Flow at Coal Creek Spring ranged from 0 to 0.96 gpm (estimated). Ranges of parameters measured at the site include: SC from 2,000 to 6,050 $\mu\text{mhos/cm}$; temperature from 8.8 to 22.7°C; pH from 7.39 to 7.7 standard units.

Water sampled from Fortune Spring was a slightly basic, Class III, (SC- 6,830 to 9,840 $\mu\text{mhos/cm}$), sodium-sulfate type water, with moderate to elevated nitrogen levels, and generally low metals.

Flow from the Fortune Spring ranged from 0 to about 2 gpm and water temperature ranged 3.2 to 16.2°C.

2.6 SPRINGS AND PRIVATE WELLS - - 17.24.304(1)(f)(i)(C)

2.6.1 Private Wells

The Montana Bureau of Mines and Geology's (MBMG) GWIC, Natural Resource Information System (NRIS), and USGS websites were searched to identify new or previously unidentified wells within a one-mile radius around, and three miles down gradient, of Tracts 1, 2, and 3 as required in 17.24.304(1)(f)(i)(C).

The updated inventory is included in Table 2-13, and private well locations are shown on Plate 2.

2.6.2 Spring and Seep Inventory

A spring and seep inventory was conducted within the Study Area on property where access was allowed within the boundaries shown on Plate 3. Investigation was initially conducted in the fall of 2010. Additional field reconnaissance was conducted in the fall of 2011 to

examine areas where additional surface access had been obtained. Visual examination of topographic maps and aerial photos was conducted on areas where ground access was not possible. Appendix G includes a photo log and descriptions of springs and seeps which were identified in the field and visited. The locations of springs, seeps, ponds, stock tanks, and other hydrologic features identified during field reconnaissance are shown on Plate 3.

Topographic maps and aerial photographs were examined for areas where access was possible and for areas without surface access. Sites identified on un-accessible land are based on the aerial photo and topographic map review.

Spring and seep inventory field work conducted where field access was possible included a combination of methods. Maps and aerial photographs were first examined. Individual drainages were then either examined using binoculars from high vantage points, walked along the drainage bottom, or both. Sites were marked on topographic maps and hand-held GPS coordinates obtained. If sufficient water was present, SC, pH, and temperature were measured. Estimates or measurement of flow were also obtained, if possible.

Based on field examination, the following sites were identified:

- Springs & Seeps
- Impoundments (stock tanks, reservoirs)
- Ponds (natural)
- Stock Ponds

3.0 SURFACE WATER - 17.24.304(1)(f)(ii)

Surface water monitoring in the Study Area was concentrated on Otter Creek and its tributary drainages that are in or are adjacent to Tract 2. Major tributaries to Otter Creek within the Tract 2 area include East Fork Otter Creek, Home Creek, Threemile Creek, Shorty Creek, and Tenmile Creek. A description of surface water stations and the drainage systems in which they are established is as follows.

3.1 DESCRIPTION OF SURFACE WATER DRAINAGE SYSTEMS – ARM

17.24.304(1)(f)(ii)

3.1.1 Otter Creek

Otter Creek drains an area of approximately 711 square miles from its headwaters in southern Powder River County, Montana to the confluence with the Tongue River, at Ashland, Montana. Otter Creek Tracts 1, 2, and 3 are in the lower portion of the drainage basin, approximately 8 miles upstream of the Tongue River confluence. While the potential for coal resource development has long existed along Otter Creek, no major coal mining activity has taken place in the drainage. The Otter Creek Valley is primarily used for livestock and hay crop production.

The USGS maintains a gaging station on Otter Creek just above its confluence with the Tongue River (USGS 06307740 - Otter Creek at Ashland). The period of record for the site spans from 1972 to present; but excludes approximately nine years of data (1986, and 1996 through 2003) when the site was not operational. In addition to discharge, measurements of SC and SAR, by regression, were recorded from 2004 to 2008. Data collected by the USGS were used to augment the baseline hydrology study of the Otter Creek Mine area. These data are discussed further in the following sections.

Major tributaries do not flow through Tract 2 in the proposed mining area, and no named drainages occur within the proposed mining area. However, Otter Creek, a perennial stream flows through the west side of Tract 2, west of the proposed mine area. Primary tributaries in

the vicinity of the Otter Creek coal tracts include Tenmile Creek along the south boundary of Tract 2, Threemile Creek, which lies between Tract 1 and Tract 2, and Home Creek along the north boundary of Tract 1. Shorty Creek is a Threemile Creek tributary that originates on the Custer National Forest (CNF) United States Forest Service (USFS) property northeast of Tract 2.

Home Creek is located along the northern boundary of Tract 1. Home Creek is ephemeral through Tract 1. However, an area of intermittent flow occurs near the confluence with Otter Creek. Baseline monitoring was conducted for both flow and quality in Home Creek.

East Fork Otter Creek is located north of the Otter Creek Coal tracts. Baseline monitoring was not conducted in this drainage.

3.1.2 Tenmile Creek

Tenmile Creek originates in the CNF and drains an area of approximately 43 square miles to the Otter Creek basin. Tenmile Creek spans roughly 14 miles from its headwaters to the confluence with Otter Creek. Portions of the Tenmile Creek basin are within the Tract 2 boundary; but the entire drainage, including the streambed, are south of the Otter Creek Mine area. The Tenmile Creek valley is narrow relative to that of Otter Creek; but lower portions of the Tenmile Creek valley support livestock and hay crop production. Flow in Tenmile Creek is ephemeral near Tract 2, but intermittent upstream of Pond P6. During the baseline study, the only surface flows observed to reach Otter Creek occurred during spring runoff.

3.1.3 Threemile Creek

The Threemile Buttes, a topographically high bedrock outcrop on the CNF, create a surface water divide between Threemile Creek, to the west, and a series of ephemeral tributaries of Pumpkin Creek, to the east. The Threemile Creek drainage encompasses approximately 51 square miles and drains to Otter Creek on the north side of Tract 2. Threemile Creek is an ephemeral tributary. It is common for surface flow to cease completely during the dry season on the entire length of Threemile Creek; however, surface discharges are more sustained in upper portions of the watershed. Intermittent flow in the middle portion of the

watershed (in the area of SW-10 and SW-11) is attributable to clinker and well-drained gravels immediately beneath the Threemile Creek streambed.

Shorty Creek, a prominent tributary to Threemile Creek, joins the main drainage with the confluence near the east side of Tracts 1 and 2 at the USFS boundary. Because of the potential for impacts to surface water drainages in and adjacent to Tract 2, investigation focused on Threemile Creek, Tenmile Creek and Otter Creek, and tributaries to each.

3.1.4 Home Creek

Home Creek drains 59 square miles from Camps Pass near the east boundary of the CNF to its confluence with Otter Creek. Home Creek has a total length of about 15.3 miles, of which about 1.5 miles flows through Tract 1. Home Creek bisects the northwest corner of Tract 1, approximately three miles north of Tract 2. Main Stem Home Creek was included in baseline investigations. Other named drainages in Tract 1 include Willow Creek, a relatively small basin draining an area along the west side of Tract 1, and lowlands near Otter Creek. Thomas Draw has headwaters on USFS property east of Tract 1. The drainage passes through the northeast corner of Tract 1 before its confluence with Home Creek.

3.1.5 Other Area Drainages and Basins

The focus of this baseline investigation of surface water conditions was Tract 2. Three named ephemeral drainages enter Otter Creek from the Tract 3 (west) side of the Study Area. These drainages will not be affected by the proposed mining in Tract 2 and were not included in this baseline investigation. Data will be obtained from these areas in conjunction with permitting of mining on Tract 3. These include:

- Brian Creek – south of the tracts
- Chromo Creek, and
- Newell Creek

Coal Creek is on USFS property on the southeast side of the tracts. This drainage flows southward into Tenmile Creek. Coal Creek is an ephemeral drainage of limited extent that derives its flow from precipitation runoff. Elevations and location of the creek make it very

unlikely that mining would affect flow in Coal Creek. One spring, Coal Creek Spring, is monitored in the drainage, however, and is discussed in Section 2.6.2.

East Fork Otter Creek is located north of Tract 2. Flow to East Fork Otter Creek originates in the Cook Mountain area, deriving its flow from runoff and baseflow units not hydrologically connected to the Knobloch Coal in Tract 2. Study of East Fork Otter Creek was not included in this baseline investigation. Refer to Plate 1 of Baseline Report 325A - Alluvial Valley Floor Determination, for delineation of drainage basins within the Otter Creek watershed.

3.2 SURFACE WATER MONITORING - 17.24.304(1)(f)(ii)(B)

Surface water monitoring in the Study Area was concentrated on Otter Creek, and the area around Tract 2. A total of 32 monitoring stations were established to collect flow and quality information. Twenty-six sites are surface water monitoring sites of which four are located on Otter Creek, 22 are situated in ephemeral drainages tributary to Otter Creek, Threemile Creek, and Home Creek, and six sites were impoundments (Ponds P1-P6) that were monitored for quality and stage height. Table 3-1 lists monitoring stations and associated instrumentation and passive water sampling devices. Locations of the surface water monitoring stations are shown on Map 10 - Environmental Monitoring Stations. A summary of all surface water site visits during the baseline monitoring period are included in Appendix E.

3.2.1 Streams and Ephemeral Drainages

Otter Creek

Surface water monitoring sites established by Hydrometrics directly on Otter Creek included SW-2, SW-16, SW-22 and SW-25. Site SW-2 is located at a ranch access road crossing of Otter Creek near the north end of Tract 2. Site SW-16 is located on a ranch access road crossing immediately west of the proposed initial mine box cuts. Site SW-22 was established upgradient of all proposed mining activity at the Tenmile Creek road crossing; the site is upgradient of the confluence of Otter Creek and Tenmile Creek. SW-25 was established in

2013 and is near the downgradient boundary of the proposed mine permit area. Photos of the sites are included in Appendix F.

Otter Creek surface water monitoring sites SW-2 and SW-16 were equipped to measure stage level using continuous monitoring instrumentation installed in well points anchored to the bottom of the stream (see Figure 3-1). Similar instrumentation was launched at surface water site SW-22, but the screened well point was fixed to the bottom of an existing culvert rather than the stream bed. Instrumentation employed at SW-25 includes continuous monitoring of water stage and specific conductance. Installation is similar to SW-2 and SW-16. Manual flows were measured at each of these sites for the range of flow conditions encountered during the baseline study, provided the stream could be safely waded. Peak stage levels that occurred in spring of 2011, 2012, 2013 and 2014 precluded manual measurements at the highest flow conditions. Streambed profiles, cross sections and channel gradients—or culvert dimensions and gradient – were surveyed to establish site hydraulic parameters that would be used to estimate flow from the stage level measurements. All surface water site profiles were based on elevations surveyed at each site with survey grade GPS instrumentation. Rating curves, developed with measured flow and associated stage level height, and hydrographs for sites SW-2, SW-16, SW-22 and SW-25 are presented in Appendix F. Further discussion of rating curve development and hydrograph preparation is included in Section 3.2.3.

Eight additional monitoring sites were established in ephemeral drainages tributary to Otter Creek (SW-13, SW-14, SW-15, SW-17, SW-18, SW-19, SW-20, and SW-21). Data collected at these sites were intended to provide a spatiotemporal characterization of water quantity and quality that may discharge to Otter Creek from contributing area in Tract 2. As indicated in Table 3-1, ephemeral sites in the Otter Creek drainage were instrumented with either crest gages or continuous water level recorders. Specifically, sites SW-13, SW-14, SW-17, SW-18, and SW-20 were equipped with TruTrack[®] WT-HR-100 water level recorders, and crest gages were installed at SW-15 SW-19 SW-21. Typical instrumentation at ephemeral surface water sites is illustrated in Figure 3-2. Consistent with the methodology used on sites with perennial flow, streambed profiles, cross sections and channel gradients—

or culvert dimensions and gradient – were surveyed to establish site hydraulic parameters that would be used to estimate flow from the stage level measurements. A photograph, channel profile, and rating curve are included for each site in Appendix F.

Tenmile Creek

Surface water site SW-23 was installed on Tenmile Creek approximately one mile upstream from the confluence with Otter Creek. The site is co-located with a county road crossing that features a two-foot diameter culvert. Site SW-23 was equipped with a crest gage upstream of the culvert; and surface flows observed during spring and early summer were measured at the culvert outlet using a calibrated bucket and stopwatch. The channel profile and culvert dimensions were used to relate crest gage heights to discharge through the culvert. Site photos, a channel profile, and rating curve for SW-23 are found in Appendix F..

Threemile Creek

Ten surface water monitoring stations (SW-3, SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, SW-10, SW-11, and SW-12) were established on Threemile Creek or tributaries thereof. Shorty Creek is a prominent tributary of Threemile Creek that flows approximately one-half mile east of and parallel to the Tract 2 boundary. The remainder of the tributaries to Threemile Creek that drain from Tract 2 are un-named.

Sites SW-3 and SW-11 were installed on Threemile Creek proper. Site SW-3 was installed in the lower watershed adjacent to AVF-6; while SW-11 was installed in the upper drainage immediately upstream of Shorty Creek. Site SW-12 was installed in Shorty Creek, immediately upstream of the confluence of Shorty and Threemile Creeks, at the Tract 2 boundary. Each of these three sites were instrumented with TruTrack[®] WT-HR-100 water level recorders.

Sites SW-4, SW-5, SW-6, SW-7, SW-8, SW-9, and SW-10 were installed in ephemeral drainages that flow from Tract 2 to Threemile Creek. Sites SW-5, SW-9, and SW-10 were instrumented with TruTrack[®] WT-HR-100 water level recorders. Crest gages were installed

at SW-4, SW-6, SW-7, and SW-8. Site photographs, channel profiles, and rating curves for all Threemile Creek sites are included in Appendix F.

Home Creek

Sites SW-1, SW-1A, and SW-24 were installed in Home Creek. Sites SW-1 and SW-24 were installed in parallel, because a man-made diversion structure is in place to separate Home Creek surface flow. Site SW-1 is positioned in the main channel of Home Creek, adjacent to monitoring well AVF5-1. Site SW-24 was established in the man-made channel that collects flow from tributary drainages to Home Creek from the south slope and/or flow that is routed via the diversion structure. Both sites were instrumented with TruTrack® WT-HR-100 water level recorders. Site SW-1A was established at the Otter Creek Road (State Secondary Route 484) crossing. The site is directly upstream of a nine-foot diameter culvert. No water level gage of any kind was installed at the site; but water quality samples were collected and surface flows were estimated based on culvert hydraulics.

3.2.2 Ponds

Six ponds were included in the water quality monitoring program. Five of the sites (P1, P2, P3, P4, & P6) are in Tract 2. Site P5 (Shorty Creek Reservoir) is located on U.S. Forest Service property east of Tract 2. A datum was established at each of the ponds so water levels could be measured and elevations calculated. A hole was excavated near each pond, above high water levels, using a post hole digger. A 4x4-inch piece of wood was installed in each hole, backfilled, and the backfill compacted. The elevation of the top of the wood was surveyed using a survey grade GPS. Water levels in the ponds were measured by setting a survey grade auto-level on the top of the wood and measuring the drop to the water surface with a survey rod. Elevations were then calculated. Detailed descriptions of the ponds and their likely sources follow.

Pond 1 is located at an elevation of about 3180 feet above MSL. This pond contained water throughout the baseline period suggesting a bedrock flow source and it also supports some riparian vegetation. Possibly there is a spring that drains a local perched groundwater horizon in the overburden as well as receiving runoff from precipitation. However, water

levels measured in overburden monitoring wells B5-O and B6-O are well below the elevation of the pond indicating that water supplying this pond is not part of a larger system.

Pond 2 only held water for a short period of time during the baseline studies. The dam for the pond is very low and a minimum amount of water derived from precipitation runoff can be stored. The level of the overburden groundwater at the nearest well (B11-O) is 25 feet below the base of the pond.

Pond 3 is at an elevation of about 3120. This pond held water through most of the monitoring period. However, there was no evidence of a spring at the location and riparian vegetation was absent. There were seep areas noticed approximately 1000 feet up the drainage from the pond, but water was not noticed flowing from the area. Overburden groundwater elevations at this area appear to be below the pond level and likely do not contribute to the pond. Water at this pond is likely derived from precipitation runoff but could potentially have a seep directly under the pond that has not been observed.

Pond 4 is at an elevation of about 3140 feet above MSL. Groundwater at B6-O is at a similar elevation. Due to drops in head as water moves downgradient, the level of overburden groundwater near Pond 4 is estimated to be about 3120 feet. Water was observed flowing into Pond 4 at surface water sites SW-9 and SW-10 for an extended period of time during the baseline period. Small seep areas were also identified in the spring and seep inventory upstream of Pond 4. Numerous large trees are present at Pond 4 suggesting a good supply of shallow groundwater. It is likely that this pond receives its water from a combination of baseflow from bedrock units, release of water from storage upstream of the dam, and precipitation. Water levels drop rapidly following runoff, a function of seepage and underflow through the dam.

Pond 5 - Shorty Creek Reservoir is located on USFS property east of Tract 2. The elevation of this pond is about 3240 feet above MSL. Water from this set of ponds is derived from runoff, and baseflow from overburden units. Monitoring is conducted on the pond that is the furthest upstream (south). Water entering this pond is a combination of runoff and baseflow.

Flow from the lower pond likely includes baseflow from bedrock units and from underflow from the upper pond. The bedrock unit horizons could be similar to those providing water to the area around well B6-O, however, the water levels are approximately 100 feet higher and gradient would need to drop substantially.

Pond 6 is located in Tenmile Creek just outside the southeast Tract 2 boundary. Water supply to this pond is the result of upwelling of waters in the alluvial groundwater system and short term runoff from precipitation. The pond is perennial, with a healthy growth of riparian vegetation around the perimeter. This pond is not fed by overburden water but upstream from sources originating on USFS or private property.

3.2.3 Surface Water Flow 17.24.304(1)(f)(ii)(B)(I)

An evaluation of surface water flows in the Otter Creek Mine Area was conducted by reviewing publically available stream flow data and by analyzing data collected at baseline surface water monitoring sites. The intent of the evaluation was to characterize minimum, maximum, and average discharge conditions which identify critical low flow and peak discharge rates of streams and springs. The results of which are included herein.

3.2.3.1 Otter Creek USGS Gaging Station Data Analysis

Discharge conditions in Otter Creek are well documented by the USGS at gauging station 06307740 Otter Creek at Ashland, which is approximately 8.5 miles downstream from the baseline Study Area boundary. The period of record for the site spans from 1972 to present; but excludes approximately nine years of data (1986, and 1996 through 2003) when the site was not operational.

Mean monthly discharge for the period of record are included in Table 2-1B of Baseline Report 325A - AVF Identification and Analysis. Mean monthly discharge in Otter Creek is highest in March (13 cfs) and lowest in September (1 cfs).

Peak discharge for Otter Creek is reported as 650 cfs and occurred during the baseline hydrologic study period on March 10, 2014. The highest peak discharge recorded prior to 2014 occurred on March 21, 1978 and was reported as 425 cfs.

The minimum average seven day flow that is expected to occur every ten years (7Q10) is often used as a design criteria to estimate critical low flow. The 7Q10 was estimated using USGS data and the statistical procedure outlined in Thomann and Mueller (1987). Based on analysis of the complete USGS average daily flow dataset, the 7Q10 is zero cfs; in fact, the data suggest that the minimum average seven day flow will reach zero cfs (i.e. become dry) in roughly 30% of all water years.

3.2.3.2 Baseline Study Data

Surface water discharge conditions were evaluated at each of the 25 surface water monitoring sites on ephemeral or perennial streams using one of or a combination of two empirical methods:

- 1.) Manning’s Equation, which estimates discharge rates with a relationship of channel geometry, channel roughness, and gaged water levels; and/or
- 2.) By pairing gaged stream flows with synoptic water level (stage) measurements to produce a best-fit power, polynomial, or exponential equation with which to relate additional stage measurements to un-gaged flows.

Manning’s equation of the imperial form was used as follows.

$Q = (1.486/n) AR^{2/3}S^{1/2}$
Where:
Q = discharge, (cfs)
n = manning's roughness coefficient, (dimensionless)
A = flow area within channel, (ft)
Rh = hydraulic radius = flow area divided by wetted perimeter (Wp), (ft)
S = energy gradient, slope (ft/ft)

Values of Manning’s roughness coefficient were estimated based on the characteristics of the channel bed (i.e. vegetative cover, streambed texture, etc.). For sites with measured

discharge, values were chosen that best approximated the relationship between known water level and flow. Geometric parameters, A, W_p , and R_h are calculated relatively easily for culverts; however, the flow area for irregular stream channels is more difficult to calculate. The Hydraflow Express Extension for AutoCAD[®] Civil 3D[®] was used to create stream channel profiles and calculate stage-discharge relationships via Manning's equation. Where possible, flow rates calculated by Manning's equation were compared to manually measured stream flows to validate the model.

Final rating curves and stage-discharge relationships are presented in Appendix F. A summary of minimum and peak flow at each site is presented in Table 3-2. Additional discussion of stream flow estimation methodology and results are discussed by drainage/site below.

3.2.4 Otter Creek Stream Flow

SW-22 – This site is located the furthest upstream of the three Otter Creek sites established during the baseline study. Flows recorded at this site are meant to quantify the flow regime upstream of the Otter Creek Mine area. A Level Troll 300 pressure transducer and data logger was installed at the bottom of the SW-22 culvert on September 16, 2011. The logger automatically records stage height entering the culvert.

Discharge at SW-22 was estimated based on a rating curve, developed using Manning's equation, for an eight-foot diameter corrugated metal pipe culvert. Specifically, discharge values were calculated for a range of probable stream gage heights. A stage-discharge plot was calculated from the synthesized data, and a best fit polynomial equation of the stage discharge line was applied to all of the automatically recorded gage heights. The final rating curve and best fit equation are included in Appendix F. The hydrograph for the period of record, to date, is also included in Appendix F.

In general, flow at SW-22 is lower than simultaneous flow recorded at downgradient sites, which indicates that Otter Creek is gaining in the reach adjacent to the Otter Creek Mine area. Prior to 2014, the highest recorded flow at SW-22 occurred during February 24 2012

and was approximated to be 55 cfs. Sometime during the peak flow event (apparently on March 6, 2012), the transducer and stilling well were scoured from beneath the culvert. Stage measurements recorded after the transducer was moved were not used to calculate flow. The stilling well and transducer were returned to the appropriate datum on March 15, 2012; however, the stilling well was unknowingly full of fine-grained sediment that prevented a hydraulic connection with the creek. Water that entered the stilling well during high flows did not drain freely to the creek, and resulted in stage heights that were not representative of those actually entering the culvert.

Peak flow at SW-22 occurred during March 7, 2014 and is approximated to be 360 cfs. This is only an approximation as the transducer and stilling well were damaged during this peak flow event similar to the high flow event in 2012. Peak flow reported at the USGS 06307740 gaging station on March 10, 2014 was 650 cfs.

SW-16 – This site was installed during the receding limb of spring runoff in 2011; however, a higher stage elevation was marked prior to installation during spring runoff. The stilling well was installed and the stream channel profile was surveyed at site SW-16 on June 14, 2011. The survey included the previously marked runoff stage elevation. Based on the rating curve established for this site, flow corresponding to the runoff elevation marked in 2011 was 167 cfs; however, it is unknown if this stage elevation occurred at peak runoff. Peak discharge reported for the USGS 06307740 gaging station was 367 cfs in 2011.

Automated water levels recorded in spring 2012 crested higher than that observed in 2011; however, it was also noted that ice accumulation at the site resulted in high water levels that were not proportional to discharge. Peak flow reported during spring runoff (March 10, 2011) for the USGS 06307740 gaging station was 112 cfs. Similar to site SW-16, water levels disproportionately higher than estimated peak flows were reported by USGS.

Water levels in January 2013 were the highest recorded at SW-16 were also suspect due to ice accumulation and were not proportional to discharge. Discharge measured at USGS

06307740 gaging station in January 2013 was approximately 4 cfs. This instrument was removed from the site in January 2014 for repairs.

A hydrograph for SW-16, with both stage height and discharge, is included in Appendix F.

SW-2 – Site SW-2 is located immediately upstream of a road crossing and culvert. Water flows over the road during spring runoff but is controlled by the culvert during most other flow regimes. Paired manual flow measurements and gaged water levels were used to create a favorable rating curve for this site without accounting for the complicated geometry introduced by the culvert and road crossing. This site was less impacted by ice than either USGS 06307740 or SW-16. The peak flow estimated at SW-2 was 99 cfs. The SW-22 hydrograph is included in Appendix F.

SW-25 – This site is downgradient of the confluence with Threemile Creek and is the most downgradient station within the permit area. It is located approximately 1500 feet upgradient of the northernmost permit boundary. Data collection began on April 9, 2013. The peak flow at SW-25 was approximated to be 820 cfs and was recorded on March 8, 2014, two days prior to the peak flow of 650 cfs reported at USGS 06307740.

Synoptic Runs – Two synoptic runs were conducted on Otter Creek that included stream flow and field water quality parameter measurements at each of the three Otter Creek monitoring sites (SW-2, SW-16, and SW-22) and five additional locations. Locations of the synoptic run monitoring sites are included in Plate 4. The first synoptic run was conducted on November 3, 2011 and the second was conducted on May 8, 2012. The intent of the two monitoring events was to characterize baseline fluctuations in surface water flow and/or water quality that may occur in the reach of Otter Creek adjacent to the Otter Creek Mine area. Opposite times of the year were selected to measure potential seasonal differences in water quality field parameters or discharge. Flow measurements made during the fall 2011 event were consistent throughout the reach, which suggests minimal gaining or losing influence from groundwater. However, a slight loss of flow may have occurred in the reach from the Thayne Culvert to Gratwohl's Crossing (Plate 4). A clinker formation is in contact

with the alluvium in this reach. During the spring 2012 synoptic run, surface flows increased incrementally along the entire reach. The gaining conditions were presumably resultant from the falling limb of spring runoff. Field water quality parameters were consistent at each site between the two events. Surface water quality is discussed further in Section 3.2.6.

Results from a study conducted by Lambing and Ferreira (USGS 1986) during 1977, 1978 and 1983, indicate differences in streamflows in Otter Creek during October and November were largely attributed to variability in precipitation during the year preceding the measurement period.

3.2.5 Tributary Steam Flow

Measurements and/or calculations of flow at each of the ephemeral surface water sites are as follows.

SW-1 – No manual surface water measurements were made at this site, as it was dry during each monitoring event. However, the continuous data logger installed at SW-1 recorded stage heights above ground during spring 2012. Based on the rating curve developed for this site, the highest estimated flow of 41.7 cfs occurred on May, 29, 2014.

SW-1A - No gaging instruments were installed at this location; however, the maximum flow measured manually was 01.5 cfs recorded on March 7, 2013.

SW-3 - A Telog 2109E with a 5 PSI transducer was originally installed at this site on lower Threemile Creek. Data from the original instrument was unrecoverable because the instrument was submerged during runoff in spring 2012. A TruTrack[®], WT-HR-1500, continuous data logger was installed to replace the original instrument in March 2012. A rating curve was constructed for SW-3, based on channel geometry and roughness. The maximum flow estimated at SW-3 was 0.396 cfs on July 22, 2012.

SW-4 – This site is typically dry; but the crest gage has been triggered four times at SW-4. A high crest gage reading of 0.8 feet above ground was recorded on June 14, 2011. This

stage height is attributable to 2011 spring runoff and resulted in an estimated discharge of approximately 15 cfs. A late summer 2011 precipitation event and 2012 spring runoff resulted in crest gage readings of 0.37 feet and 0.47 feet, respectively.

SW-5 – A TruTrack[®] WT-HR-1000 water level recorder was installed at SW-5 in the neighboring parallel drainage to SW-4. The continuous recorder logged surface water occurrences similar to those observed at the SW-4 crest gage. However, recorded stage heights and calculated discharge rates were lower in SW-5 than SW-4. Peak flow during the baseline study, estimated from the SW-5 rating curve, was 33 cfs recorded on July 22, 2012.

SW-6 and SW-7 – No surface water flows were manually measured at either of these crest gage sites in parallel drainages above Pond P3. The crest gage was triggered seven times at SW-6, while only five times at SW-7. However, the magnitude of discharge is apparently greater at SW-7. Peak flows estimated during the baseline study period at both SW-6 and SW-7 occurred during spring 2014 runoff and were 48.9 cfs and 80.6 cfs, respectively.

SW-8 – This site was established upstream of a low water crossing that is not controlled by a culvert. As such, standing surface water is often impounded at SW-8. Water delivered to the site under low flow conditions either infiltrates into the ground or slowly permeates through the low water crossing. At high flow, such as during spring runoff, surface water likely flows over the road. The stage discharge relationship and best fit rating curve equation developed for this site considered only those flows that would breach the road. Based on the site survey, the stage elevation at which water flows over the road is approximately 1.2 feet. A high crest gage reading of 1.8 feet was recorded at SW-8 on March 21, 2014. This reading corresponds to a discharge of 1.33 cfs.

SW-9 – Although this site is ephemeral, surface flows are frequently observed at SW-9. This site is likely fed from a small spring that originates approximately 1.5 miles upstream (see Plate 3 Spring and Seep Inventory). A manual surface water measurement was recorded at this site in June 2012, and the stage-discharge relationship was used to validate the Manning's flow calculations (see rating curve in Appendix F). Maximum discharge

recorded during the baseline study at SW-9 was 0.9 cfs. Unlike most of the other ephemeral surface water sites, where maximum discharge coincided with spring runoff, maximum discharge at SW-9 occurred during a precipitation event in July 2012.

SW-10 – This site is located in a drainage parallel to the SW-9 drainage, but does not typically have flowing surface water. In fact, the site has been dry during each monitoring event. The SW-10 drainage is more deeply incised than SW-9 and has a vegetative cover composed primarily of grass, as opposed to sage brush cover in the parallel drainage. Only two surface water flows were recorded at SW-10 during the baseline monitoring period, both occurred during winter/spring of 2012. The maximum stage height and estimated discharge for this site were 0.63 feet and 2.14 cfs, respectively.

SW-11 – Surface water site SW-11 was established in Threemile Creek above the confluence with Shorty Creek. Surface water has been present at the site nearly continually since automated water level recordings began in July 2011. The only recorded exception was during a freeze/thaw pattern that took place in late February 2012; however, the data logger failed to record any readings during the period from August 27, 2011 to September 28, 2011. A maximum stage height of 3.46 feet above ground was recorded by the data logger on March 8, 2012, which corresponds to an estimated discharge rate of 25.4 cfs.

SW-12 – Surface water site SW-12 is located in Shorty Creek, just above the confluence with Threemile Creek. Shorty Creek Reservoir (Pond P5) is located approximately one mile upstream of SW-12 and has hydrologic control on the SW-12 drainage. The channel at SW-12 is often dry, but surface water discharge does occur there during spring runoff and in response to precipitation events. The maximum recorded stage elevation and estimated flow for this site were 2.76 feet and 22.6 cfs, respectively, during spring runoff 2012. Ice accumulation at the site may have caused automated stage height readings that were not proportional to actual discharge at the site. Ice at the site on March 14, 2012 resulted in a gage height recording of 1.11 feet, although no surface water was flowing.

SW-13 – Similar to site SW-9, low surface water flows persist at this site for longer than other ephemeral drainages. The source of water at SW-13 is likely discharge from upstream Pond P1. This site did not dry up until mid-summer of 2011, but was already dry in March of 2012. The peak measured stage at the site occurred on May 29, 2013. The gage height and estimated flow were 1.5 feet and 24.4 cfs, respectively. Note that gage height readings were not recorded from September 25, 2011 to March 14, 2012. It is possible that winter conditions caused the logger to fail. It was reconfigured and functioned properly for the remainder of the monitoring period except for a two month period from October 21 to December 20 2012.

SW14 & SW-15 – These sites were installed in parallel drainages that contribute directly to Otter Creek from the west side of Tract 2. The sites have similar channel geometry and ground cover and are both typically dry. Based on crest gage readings, surface water flows occurred at both sites during spring runoff and in response to a precipitation event in later summer 2011. Spring runoff in 2012 triggered a third crest gage reading at SW-15. However, no crest gage reading was available at SW-14 for spring 2012. It was apparent that runoff did occur at SW-14, but the cork did not rise, as it was silted-in at the bottom of the cup. Maximum observed crest gage readings were 1.06 feet at SW-14 and 0.89 feet at SW-15; these gage heights corresponded to respective flow estimates of 20.7 cfs and 18.1 cfs.

SW-17 – This site was established at the mouth of a wide (approximately 100 feet) ephemeral channel that drains approximately 608 acres of the Otter Creek Mine area. While the site is typically dry, standing surface water and/or very moist surface soils are often present. Using the rating curve developed for the site, a discharge of 46.3 cfs was calculated for the maximum crest gage reading of 0.92 feet.

SW-18 – Maximum discharge estimated during the baseline study period at SW-18 was approximately 24 cfs. This estimate is based on a spring 2011 crest gage reading of 1.25 feet above ground. Further crest gage readings indicate that surface flows occurred during a late fall precipitation event and during spring 2012 runoff. Otherwise, this site is typically dry.

SW-19, SW-20, and SW-21 – Each of these three surface water monitoring sites are located in ephemeral drainages that are south of the mine cut area. SW-21 is located south of the permit area. SW-19 and SW-21 were established with crest gages, while a continuous recorder was installed at SW-20. Rating curves were developed for each site and used to estimate maximum discharge during the baseline study period. Maximum flows were estimated at SW-19, SW-20, and SW-21 to be 11, 1.15, and 11.9 cfs, respectively.

SW-23 – This site is located upstream of a county road crossing that includes a two-foot culvert for hydrologic control. The bottom elevation of the stream profile surveyed at SW-23 is 0.98 feet below the upstream invert of the culvert. As a result, surface water is impounded by the road crossing until stage heights reach 0.98 feet. A maximum crest gage reading of 3.14 feet was recorded on July 29, 2013. Based on the rating curve developed for the culvert at the site, this stage corresponds to a discharge of approximately 0.9 cfs.

SW-24 – No manual surface water measurements have been made at this site, as it has been dry during each monitoring event. However, the continuous data logger installed at SW-24 recorded stage heights above ground during spring runoff during all four years of operation. Based on the rating curve developed for this site, the highest estimated flow of 41.5 cfs occurred on May 31, 2013. Water level measurements indicate that the majority of flow in Home Creek is routed through this man-made diversion rather than in the natural channel (i.e. at SW-1).

3.2.6 Surface Water Quality- 17.24.304(1)(f)(ii)(B)(II)

Two hundred fourteen surface water quality samples were collected and analyzed for the parameters shown on Table 3-3. Another 110 site observations were made in which specific conditions were documented but samples were not collected. This section includes a summary of surface water quality for data collected during the baseline period for the Study Area. Individual water bodies are broken out, where applicable. Baseline surface water and pond data are included on tables discussed in the following sections and in Appendix D. Locations are shown on Map 10 - Environmental Monitoring Stations.

Grab samples were collected at sites exhibiting flowing or ponded water conditions during site visits. Flow was present at the Otter Creek monitoring sites throughout the year. Samples were collected at sites equipped with passive samplers following precipitation events, when conditions allowed access to the sites, and when samplers were not frozen in the subgrade. In these cases, water was poured from the passive samplers into labeled sample containers. In some cases, water accumulated in the passive samplers following runoff events was insufficient to allow all parameters to be analyzed. In these cases, parameters considered more critical, and those requiring less water for analysis were analyzed first. For example, metals analyses require a small aliquot of water (1mL or so) compared to turbidity, which requires relatively large volumes of water for analysis. For these reasons, water samples collected from surface water monitoring sites did not necessarily follow the complete analytical schedule.

Figure 3-3 is a Piper diagram showing the general water quality for all surface water samples collected during the baseline period. Surface water is generally sulfate anion dominant with either no clear cation, or sodium and magnesium as the dominant cations. The most clearly different surface water sampled was from Home Creek during winter conditions. This water was a magnesium-bicarbonate water. One sample from this site was collected during frozen runoff conditions. The result was very high quality non-contact runoff water. Discussion of surface water quality from specific drainages follows.

Results of the monitoring indicate that water flowing in tributary drainages is typically turbid with relatively high levels of suspended solids. However, it was also observed, that relatively clear, sediment free water was present when runoff conditions occur when ground conditions were frozen or ice was present in channel bottoms. The presence of relatively high Total Suspended Solids (TSS) and turbidity reflects the episodic nature of runoff at the site from tributary drainages.

3.2.6.1 Otter Creek

Water was flowing at SW-2, SW-16, SW-22 and SW-25¹ throughout the baseline monitoring period. A total of 42 samples were collected and analyzed during the twelve quarterly monitoring events. Water analyzed from all four monitoring sites on Otter Creek was a basic, sulfate water with no dominant cation, low nutrient concentrations, SAR between 4.81 and 8.54, and low metals concentrations. SC levels ranged from 3,260 to 4,990 $\mu\text{mhos/cm}$ with an average of 3,825 $\mu\text{mhos/cm}$. Table 3-4 contains a summary of water quality for the Otter Creek surface water monitoring sites for the baseline period.

Water in Otter Creek typically shows some discoloration with turbidity ranges of 2.3 to 69 NTU (nephelometric turbidity unit). Total suspended solids ranged from 6 to 108 mg/L.

The USGS collected 52 water samples from Otter Creek gaging station (06307740) between May 1990 and October 2005 (USGS 2007). Specific conductance measured in these samples ranged from 1,040 to 3,260 $\mu\text{mhos/cm}$ and SAR ranged from 3.08 to 6.85.

Ephemeral Tributaries to Otter Creek

Table 3-5 contains a summary of water quality ranges for tributaries to Otter Creek. Data included in the table are from SW-13, SW-14, SW-15, SW-17, SW-18, SW-19, SW-20, and SW-21. Water in the tributaries reflects runoff conditions from snowmelt and intense runoff events. The remainder of the time the sites were dry. Water running off through the drainages ranged from slightly acidic to basic (pH average 7.7), with low to high SC (173 to 11,000 $\mu\text{mhos/cm}$), moderate levels of nutrients, low to high sulfate (8 to 6,300 mg/L), SAR of 0.09 to 21.5, and generally low metals. Concentrations of total recoverable arsenic, lead, and nickel were reported in a few samples.

¹ SW-25 has been in place from April 2013 to the present.

Variations in water quality reflect the different conditions under which overland flow occurred resulting in filling of the passive samplers. Higher quality water occurred during periods when the ground was frozen and sediment was immobile.

Turbidity and TSS values varied considerably, also reflecting the different flow conditions. Turbidity was moderately high 4.4 NTU to extremely high 100,000 NTU. Total suspended solids ranged from 26 to 18,100 mg/L.

Based on the results of monitoring in ephemeral drainages, it is apparent that the tributaries to Otter Creek provide large amounts of relatively poor quality water under intense rainfall/runoff precipitation events.

3.2.6.2 Tenmile Creek

Surface water site SW-23 is located in Tenmile Creek. Tenmile Creek is intermittent, with flow generally occurring only during spring for a short distance before the water infiltrates into the sediments, or in response to precipitation runoff. Pond 6, located in Tenmile Creek near the USFS boundary contains water throughout the year. However, the channel is dry below the pond and ephemeral conditions exist at SW-23. Samples were collected at SW-23 in June 2011, March and April of 2012, June 2013, and March and May of 2014. The channel was dry when visited during other times of the monitoring period.

Water sampled at Tenmile Creek station SW-23 was a sulfate type water with no dominant cation. The water was slightly basic (pH= 7.9 to 8.2), had an SC of 2,970 to 4,520 $\mu\text{mhos/cm}$, contained low levels of nutrients, SAR between 4.98 and 6.81, and generally low levels of metals (Table 3-6). Exceptions were iron and manganese which exceeded federal secondary standards.

3.2.6.3 Threemile Creek

Monitoring sites SW-3 and SW-11 are located in Threemile Creek upstream and downstream of the proposed mine area, respectively. Five samples were collected from SW-3 but the site was otherwise dry. The samples collected were obtained with a passive sampler. Twelve

water samples were collected from upstream site SW-11. Intermittent flow was observed at/near this site in the baseline period so samples generally consisted of grab samples. When flow was observed at SW-11, it was observed to infiltrate into the sediments downstream of the site over a relatively short distance (within one mile).

Table 3-7 contains a summary of water quality for Threemile Creek. Note that the majority of samples represented in the table are for the upstream portion of the drainage, next to the USFS boundary.

Surface water in Threemile Creek is a sulfate type without a dominant cation. The water quality ranged from near neutral to basic (Avg. pH – 7.5), with SC's of 281 to 3,990 $\mu\text{mhos/cm}$, low levels of nutrients, SAR of 0.28 to 6.88, and low concentrations of most metals. Concentrations of iron and manganese exceeded secondary standards.

Turbidity was variable depending on flow conditions and ranged 0.5 to 3260 NTU. TSS values were also reflective of conditions at the time of sampling, ranging 4 to 2960 mg/L.

Shorty Creek

Monitoring site SW-12 is located on Shorty Creek, directly upstream of the confluence with Threemile Creek at the USFS boundary. This site, along with SW-11 would reflect upgradient flow and quality conditions for Tracts 1 and 2. Shorty Creek is an intermittent drainage. The majority of the drainage behaves as ephemeral with flow only occurring in response to precipitation runoff. Where flow is observed, water typically infiltrates over a short distance into the underlining sediments.

Table 3-8 summarizes results of eight samples collected at SW-12. The site was dry when visited on other occasions so samples were not obtained. Water at SW-12 is a sulfate type water with no dominant cation, basic (avg. pH = 7.9), SC of 3,160 to 3,510 $\mu\text{mho/cm}$, low nutrient levels, SAR generally between 4.8 and 5.5 (the exception of one sample with SAR of 2.7 collected after a high precipitation event), and low metals except for iron and manganese, which exceed the secondary standards.

Turbidity at the site ranged from 2.6 to 1460 NTU. Total suspended solids ranged 6 to 2,630 mg/L.

Ephemeral Tributaries to Threemile Creek

Surface water sites SW-4, SW5, SW-6, SW-7, SW-8, SW-9, and SW-10 were installed to monitor flow and quality in tributary drainages to Threemile Creek. Table 3-9 contains a summary of typical Threemile Creek tributaries. Flow conditions at these sites are highly variable, as evidenced by the high range in turbidity (0.7 to 100,000 NTU and TSS (4 to 11,000 mg/L), variable water quality (SC-155 to 7470 $\mu\text{mhos/cm}$), SAR of 0.03 to 9.36, and pH (6.5 to 8.3). Higher quality water results from runoff during times when the ground is frozen. Worse quality runoff results following intense storms.

Water at these sites has low levels of nutrients and metals, except aluminum, iron, and manganese which exceed secondary standards.

3.2.6.4 Home Creek

Two sites (SW-1 and SW-24) were established on Home Creek to monitor flow and quality. Water quality samples were collected from a third site SW-1A, located near the highway crossing. Site SW-24 was dry throughout the monitoring period. Typical water quality results from the baseline period are in Table 3-10.

Water sampled in Home Creek was a sodium-bicarbonate to a sodium-sulfate type, with very low to moderate SC (40 to 5,380 $\mu\text{mhos/cm}$), SAR from 0.05 to 9.66, low nutrients, and low metals except iron and manganese which are sometimes elevated. The very high variability of water quality in Home Creek reflects the conditions at the time of sampling. Snowmelt runoff over an icy substrate results in very good quality water whereas a poorer quality water results from rainfall runoff events.

3.2.6.5 Ponds

Pond water quality is highly variable, a function of recharge from precipitation runoff, local flushing of salts into the reservoir, and evaporation. Table 3-11 has a summary of pond water quality for the six ponds monitored. Four of the ponds P1, P2, P3, and P4 are within the Tract 2 boundary. Pond P5 is the upper Shorty Creek Reservoir pond. Pond P6 is a perennial pond located in Tenmile Creek near the USFS boundary.

Ponds most typically contained sodium-sulfate type waters, although P4 and P6 had no dominant cation. The extreme variability in water in the ponds is demonstrated by the ranges of SAR (0.42 to 23.8), SC (201 to 12,300 $\mu\text{mhos/cm}$), and sulfate (7 – 8,000 mg/L). Nutrient concentrations were typically detected but at relatively low concentrations. Metals concentrations were typically low, although the secondary standards for aluminum, iron, and manganese were exceeded in some cases.

The highest quality, and most consistent water quality was at Pond 6. Water at this pond showed the lowest variation throughout the monitoring period. The consistent water quality and supply suggests an underground baseflow source is feeding the pond.

3.3 ALLUVIAL VALLEY FLOOR (AVF)

A thorough evaluation of potential AVFs was conducted for the project area. Results of this evaluation are presented in Baseline Report 325A – AVF Report.

4.0 WATER RIGHTS AND ALTERNATIVE WATER SOURCES- 17.24.304(1)(f)(iii)

4.1 WATER RIGHTS

The Montana Department of Natural Resources (DNRC) on-line Water Right Query System (<http://nris.mt.gov/dnrc/waterrights/default.aspx>) was used to identify groundwater and surface water rights in the vicinity of the Otter Creek Coal Tracts. An advanced search was conducted on October 13, 2014 for water right diversions within the following sections:

- T3S, R44E, Sections 23 – 27, 34 – 36,
- T3S, R45E, Sections 2 – 36,
- T3S, R46E, Sections 18, 19, 30, 31,
- T4S, R44E, Sections 1 – 3, 10 – 14, 24,
- T4S, R45E, Sections 1 – 30, 34 – 36,
- T4S, R46E, Sections 6, 7, 18, 19, 30, 31,
- T5S, R45E, Sections 1 – 3, and
- T5S, R46E, Section 6.

This area includes the entire anticipated life of mine. Results from this search are included in Table 4-1. Details for each water right are listed in the table, including: water right number, registered owner(s), type of water right, water right status, priority date, water source, purpose of use, location of point(s) of diversion, and appropriated flow rate and/or volume (if given). Water rights with a status of “dismissed” or “withdrawn” were removed from the list. There were no water rights with a pending status at the time of the search.

4.2 ALTERNATIVE WATER SOURCES- 17.24.304(1)(f)(iii)

Several potential alternative water sources were identified during the baseline studies. These include alluvial systems adjacent to, and upgradient of the area, and deeper bedrock units which underlie the area.

4.2.1 Alluvial Sources

- All three of the major tributaries from Tract 2 to Otter Creek (Home, Threemile and Tenmile Creeks) contain substantial amounts of groundwater. Aquifer testing has shown that alluvial wells are capable of producing large amounts of water that is suitable for livestock use and domestic use (see Exhibit 314C – Probably Hydrologic Consequences). Since these units are largely recharged by runoff from upgradient and upstream sources, it is not expected that these zones will be impacted by mining. A comparison of yield and water quality for each major tributary follows: Home Creek: Wells A-2 and AVF5-1 are completed in alluvium of Home Creek. Yields in excess of 10 gpm occur at both locations. Water at A-2 is a sodium-sulfate type water, similar to that of the closest Knobloch well B4-K, although concentrations of dissolved solids are lower. Well AVF-5-1 exhibits a sodium-magnesium-bicarbonate-sulfate type water. Total dissolved solids (TDS) concentrations in the Knobloch Coal averages 1802 mg/L with a range of 654 to 6820 mg/L. Water from all Home Creek wells sampled had TDS of 1285 mg/L with a range of 986 to 1285 mg/L. Based on this evaluation the Home Creek alluvium would be a satisfactory replacement water source.
- Threemile Creek: Alluvial wells A5 and the AVF-6 section provide water quality for the Threemile Creek Drainages. These wells yield sufficient water for stock or domestic purposes. Water at A5 is a sodium-magnesium type and water at AVF6 is a sodium-sulfate type. Total dissolved solids (TDS) concentrations in the Knobloch Coal averages 1802 mg/L with a range of 654 to 6820 mg/L. Total dissolved solids concentrations in Threemile Creek alluvium average 2685 mg/L with a range of 2040 to 2685mg/L.
- Tenmile Creek: Well A3 is at the confluence of Tenmile Creek and Otter Creek. Well A-4 is upstream of the proposed mine area in Tenmile Creek. Water from both these wells is a sodium-sulfate type. Yield from both of these wells is sufficient for stock or domestic uses. Water from well A4 averaged 2330 mg/L and ranges 2270 to 2420 mg/L. Total dissolved solids (TDS) concentrations in the Knobloch Coal averages 1802 mg/L with a range of 654 to 6820 mg/L.

4.2.2 Knobloch Coal

Wells targeting the Knobloch Coal along the east side of the mine will re-pressurize with time and will be suitable targets for groundwater production. Groundwater modeling has shown that this area will experience a drop in hydrostatic head during mining. However, there will still be sufficient water column just outside of the mine boundaries to allow pumping. It is expected that hydrostatic pressures will increase with time after mining.

4.2.3 Deeper Fort Union Formation

Several wells are present along Otter Creek that are completed in deeper portions of the Tongue River and Tullock Members of the Fort Union Formation. Wells currently completed along Otter Creek into these units flow to the surface under artesian pressure. Proper management of existing wells (controlled flow) and proper installation and management of future wells along the creek bed will preserve this resource for future use. Targeting these units at higher elevations following mining would also be expected to yield useable quantities of groundwater for both stock water and domestic purposes. However, pumping will be necessary at the higher elevations.

4.2.4 Hell Creek, Fox Hills Formations

The Lower Hell Creek and Fox Hills Formations produce useable quantities of groundwater but are relatively deep and not typically targeted in this area. These units provide an additional potential replacement source of groundwater to the area. These units sometimes behave as a single hydrostratigraphic unit while at other times there is a confining layer that separates them into distinctly different units. Both units would be expected to be under substantial stratigraphic pressure and would rise well above the top of the units.

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