South Chouteau County Water District

PWSID # MT0001925

Highwood County Water and Sewer District

PWSID # MT0000248

and

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SOURCE WATER DELINEATION AND ASSESSMENT REPORT

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ACKNOWLEDGMENTS

The Source Water Delineation and Assessment Report for Highwood County Water and Sewer District and South Chouteau County Water District was completed by John Juras, Delta Engineering P.C. Robert Bramlette, the water system operator assisted extensively with the contaminant source inventory.

INTRODUCTION

This delineation and assessment report is intended to meet the technical requirements of the Montana Source Water Protection Program (DEQ, 1999) and the federal Safe Drinking Water Act (SDWA) Amendments of 1996 (P.L. 104-182).

The Montana Source Water Protection Program is intended to be a practical and cost-effective approach to protect public drinking water supplies from contamination. A major component of the Montana Source Water Protection Program is delineation and assessment. Delineation is a process of mapping areas that contribute water used for drinking, called source water protection areas. Assessment involves identifying locations or regions in source water protection areas where contaminants may be generated, stored, or transported, and then determining the relative potential for contamination of drinking water by these sources. The primary purpose of this source water delineation and assessment report is to provide information that helps the Highwood County Water and Sewer District and South Chouteau County Water District complete a source water protection plan to protect its drinking water source.

Limitations

This report was prepared to assess threats to Highwood County Water and Sewer District and the South Chouteau County Water District public water supply, and is based on published information and information obtained from local residents familiar with the community. The terms "drinking water supply" or "drinking water source" refer specifically to the source of the community’s public water supply and not any other public or private water supply. In addition, not all potential or existing sources of groundwater or surface water contamination in the area of Highwood County Water and Sewer District and the South Chouteau County Water District are identified. Only sources of contamination in areas that contribute water to its drinking water source are considered potential contaminant sources.

The terms "contaminant" and "toxin" are used in this report to refer to substances for which maximum concentration levels (MCLs) have been specified under the national primary drinking water standards plus certain substances that do not have MCLs but that are considered to be significant health threats. In this report we only consider those constituents that are threats to human health.

CHAPTER 1

BACKGROUND

The Community

Two communities (Public Water Systems) obtain drinking water from this source of groundwater. These communities are located in Central Montana, approximately 35 miles east of Great Falls. The community of Highwood provides services to the farms and ranches in the vicinity and also serves as a "bedroom" community for families and individuals who work in Great Falls. This public water system currently has 89 hookups serving approximately 200 people.

The South Chouteau County Water District serves 27 homes with approximately 120 residents. These homes are scattered across a wide area north of Highwood.

Highwood has a modern gravity wastewater collection system with a new aerated lagoon treatment system which is located approximately 3,000 feet downgradient (NE) of the well field.

Geographic setting

A vicinity map indicating Highwood's location in Central Montana is in Appendix A, Figure 1.

The community of Highwood lies in the foothills of the Highwood Mountains at the confluence of Highwood Creek and Big Sag Creek. Big Sag Creek is an intermittent stream that drains the Shonkin Sag, an ice-age channel carved through the Highwood Bench by the Missouri River. Big Sag Creek carries trickle flows from area springs during moist periods and also conveys runoff from snowmelt or intense summer rainstorms.

Highwood Creek drains approximately 50 square miles of the Highwood Mountains. Groundwater from the Highwood Creek Coulee is the source water for the two public water systems.

The average annual precipitation in the Highwood Mountains approaches 20 to 30 inches per year compared to approximately 15 inches in the Great Falls area. Most precipitation falls as rain during the months of May through August. Area temperatures average 45^0F year round.

General Description of the Source Water

The water systems obtain their drinking water from wells located on the south edge of the community of Highwood in the Highwood Creek Coulee (Appendix B, Figure 1).

According to area well logs and SCS Soils Data, the static water level in the area is 5 to 10 feet below ground surface. The public wells draw water from varying depths between 10 and 40 feet below ground surface from a gravelly sand.

Subsoils in the well field area consist of unconsolidated alluvial silts, sands, and clays with increasing percentages of gravel at greater depths. Clay shale bedrock underlies the alluvium at depths between 25 and 40 feet.

The Public Water Supply

The Public Water Supply Site Plan (Appendix B, Figure 2) details the layout of the existing system. A brief description of the various elements is presented below. The two systems are independent yet very similar in how they function.

The Town of Highwood's water is supplied from four 30 foot wells that draw water from the valley alluvium. Each well is equipped with a 3 HP submersible pump that delivers approximately 40 to 50 gpm. The wells are located approximately 120 to 150 feet from Highwood Creek.

South Chouteau County's water is supplied from one 30-foot well equipped with a 12 HP submersible pump. This well is located 75 feet from Highwood Creek. Both systems chlorinate their water at the supply full time and pump to storage tanks which feed the distribution systesm.

A site plan for South Chouteau County's System is not available. A site plan of Highwood's System is in Appendix A.

Water Quality

Water at Highwood is routinely monitored for compliance with drinking water standards. Bacteriological monitoring occurs monthly. Compliance with other drinking water standards is based on additional sampling on a variety of schedules. No enforcement actions for non-compliance with public drinking water regulations have been taken against Highwood County Water and Sewer District or the South Chouteau County Water District in the last five years. Water from the alluvial aquifer is good quality by nearly all standards. However, the source water can be considered as being susceptible to contamination from upstream impacts as detailed herein.

CHAPTER 2

DELINEATION

The area that contributes water to the aquifer tapped by Highwood's wells is identified in this chapter. This "source water protection area" is divided into regions according to the likelihood that contaminants will reach the well. The sub-regions are, in order of increasing size, the control zone, inventory region, and recharge region. These regions are assigned different management objectives depending on their proximity to the well. The control zone is an area adjacent to the well where direct contaminants can be introduced directly into the well or immediate area. The inventory region encompasses an area in which contaminants could flow with shallow groundwater to the well intake along unsealed well casing. The recharge region is the entire area contributing recharge to the well. Water or contaminants in the recharge region may flow to the well over long periods of time or under increased pumping.

Hydrogeologic Conditions

The primary geologic feature in the Highwood area is the Highwood Mountains (Appendix C, Figure 1), which rise above the Highwood Bench beginning approximately 3 miles east of Town.

Regional geologic mapping (Geologic Map of Montana, Ross, Andrews, and Witkind, 1955) indicates that Colorado Shale predominates the area bedrock. This shale underlies the valley alluvium at a depth of 40 to 50 feet in the well field and likely provides an effective aquitard to vertical groundwater migration below the alluvium.

The valley is bordered by Cretaceous sandstone formations that rise well above the valley floor. A series of springs flow into the alluvium from the contact point of the sandstone and shale.

The Highwood Creek aquifer from which the source water comes consists of the alluvial sand and gravel deposit which follows the valley floor. Surficial soils in the well field and upstream are classified in the Soil Survey of Chouteau County Area, Montana as Linnet-Acel Silty Clay Loam. These soils have low permeability and do not erode easily.

The Town itself is situated in the Shonkin Sag, the outlet of Glacial Lake Great Falls. A shallow, unconfined aquifer underlies the sag floor which likely contributes a very limited percentage of source water to the Highwood well field. Alluvial sediments in the sag lying upstream of the Highwood Creek confluence are primarily composed of silts and clays as indicated in the soil survey of Chouteau County Area, Montana. Additionally, the sag is just outside the capture zone of the well field.

Conceptual Model and Assumptions

The wells draw their water from a shallow, unconfined aquifer. This aquifer has a high source water sensitivity to contamination. Groundwater migration and gradient parallels the Highwood Creek Coulee except for local influences of pumped wells, spring recharge, or seepage through the bed of Highwood Creek.

No water level mapping of the aquifer has been completed. Aquifer gradients are assumed to closely match the gradient of Highwood Creek for purposes of this model. The gradient of Highwood Creek and the aquifer is 0.008 ft/ft.

The saturated aquifer thickness in the vicinity of the well field varies seasonally. Montana Bureau of Mines and Geology monitoring of Highwood's wells between 1996 and 2000 (see MBMG SWL Report in Appendix G) indicates groundwater levels of 7 to 10 feet below ground surface with deeper levels occurring in dry summer months.

The total thickness of water bearing gravels in the well field varies between 0 to 30 feet according to the well logs. The full thickness of this gravel is occasionally saturated during wetter seasons.

Groundwater recharge to the shallow aquifer in the well field originates from several sources. These include downgradient groundwater flow from upgradient gravels, seepage through the bed of Highwood Creek, springs along the sandstone/clay shale contact, and direct infiltration of precipitation. No studies have been completed to assess the relative amount of contribution from each of these sources.

Aquifer discharge occurs by way of wells and by natural features including groundwater supported flora and gaining reaches of Highwood Creek.

Well Information

The water systems obtain potable water from 5 wells. Well construction details are contained in the Appendix G. A summary of well information is presented below.

Table One – Source Well Data

-	**Source Well**	-	-	-	-
MBMG #	34640	34637	34638	34639	34645
Date Completed	1979	1940	1940	1964	1978
Depth	42	30	30	38	30
Perforated Interval	25 to 28	NR	NR	NR	NR
SWL Depth	7	NR	NR	7	2
PWL Depth	10	20	20	22	14
Drawdown	3	NR	NR	15	12
Test Pumping Rate	75	100	100	100	90
Specific Capacity	25 gpm/ft	NR	NR	NR	NR
Pumping Rate (gpm)	40	40	40	40	NR

Highwood's oldest well and the SCC well are housed inside their respective control buildings.

The oldest Highwood well will be replaced in 2001 as part of the Highwood water system reconstruction project. The replacement well is planned to be located just outside the existing control building, which will be demolished.

A preliminary analysis of the potential for the groundwater to be under the direct influence of surface water was completed by South Hills Environmental Management Consultants in November, 2000. A copy of their report is in Appendix I. To summarize,

the report made several recommendations to minimize possible contamination impacts. These recommendations are being addressed in the current project.

A formal classification of the source is documented in DEQ's February 23, 2001 letter which is contained in the Appendix I. The Highwood wells, 1 through 4, are classified as groundwater contingent with full time disinfection.

Methods and Criteria

Methods and criteria used to delineate source water protection areas for the Highwood and South Chouteau County Systems are specified in the Montana Department of Environmental Quality's Source Water Protection Program (DEQ, 1999). Specifically, the methods and criteria are those for unconfined aquifers.

One hundred-foot radius control zones were delineated for each well. Hydrogeologic mapping and a time-of-travel equation describing uniform groundwater flow were used to delineate an inventory region bounded by a three-year time-of-travel distance. The stagnation point and boundary limit delineate the special protection zone for the wells. Finally, topographic divides were used to approximate hydrologic boundaries in order to delineate the recharge region.

Time-of-Travel Calculation

For purposes of this calculation, the five wells in the well field were modeled as one well. This approximation is justified because the wells are in line with the hydraulic gradient and are less than 450 feet apart.

Travel distance for three years is calculated to approximate the combined long-term effects if the wells are pumped at their total pumping rate. The three-year time-of-travel distance determines the southern limit of the inventory region for Highwood's wells. A one-year time-of-travel distance is used in Chapter 4 to rate the hazards of potential contaminant sources.

A summary of estimates including aquifer flow properties, well discharge rate, ambient groundwater flow direction, and groundwater gradient that were used to calculate the distance corresponding to three-year times-of-travel are presented in Table 2. Aquifer flow properties estimated are hydraulic conductivity, thickness, transmissivity (T), and effective porosity. Hydraulic conductivity is a measure of the ability of an aquifer material to transmit water, transmissivity (T) is a measure of the ability of the entire thickness of the aquifer to transmit water, and porosity (n) is a measure of the percent of the aquifer that water flows through. A transmissivity (T) of 5013 ft^2/day was calculated for the Highwood WUA Well Id. 34640. The value was obtained using the USGS empirical formula for unconfined aquifers.

$$T = 1500\ (75\ gpm/3ft) = 37500\ gpd/ft/\ 7.48\ gal/ft^3 = 5013\ ft^2/day$$

Hydraulic conductivity (K) is related to Transmissivity (T) by dividing T by the aquifer thickness (b).

$$K = T/b = 5013/21 = 238.7\ ft/day$$

The information was used in the Uniform groundwater flow equations:

$X_L = Q/2\ (pi)\ K\ (b)(i)$ distance to down-gradient stagnation point

$Y_L = +\text{-}\ Q/2\ K\ (b)(i)$ lateral boundary limits

$-X_L = Kit/n$ up-gradient time-of-travel boundary

Q is well pumping rate in gallons per

pi is 3.1416

K is hydraulic conductivity in ft/day

i is hydraulic gradient

b is aquifer thickness in feet

t is time in days

n is porosity

Table Two – Estimates used to Delineate the Source Water Protection Area

Input Parameter	Range	Value Used
Transmissivity	3,300 to 5,500 ft^2/day	5,013 ft^2/day
Thickness	0 - 30 ft	21 ft
Hydraulic Conductivity	238 - 476 ft/day	238.7 ft/day
Hydraulic Gradient	0.006 - 0.010	0.008
Flow Direction	N to E	NE
Effective Porosity	0.10 - 0.30	0.25
Pumping Rate	15,000 - 25,000 ft^3/day	20,000 ft^3/day
One-year Time-of-Travel	2,000 - 4,000 ft	2788 ft
Three-Year Time-of-Travel	6,000 - 10,000 ft	8,364 ft
Stagnation Point	80 ft	80 ft
Boundary Limit	250 ft	250 ft

Delineation Results

The control zone is a 100 foot radius around the well field, all potential contamination source should be excluded from this region. The three-year time-of-travel (t-o-t) distance extends almost the entire length of this section of the Creek bank. The lateral extent of the boundaries includes all the land between the sandstone cliffs and the Creek channel. Therefore, the Inventory region will include all the land in the bottom of the coulee up to

the 90 degree turn to the northeast. The base map (Appendix D, Figure 1) shows the delineation results.

Surface Water Buffer Zone

Because Highwood's wells are located in a shallow unconfined valley aquifer, a surface water buffer zone has been established (Appendix D, Figure 1). The buffer zone extends 10 miles upstream from the wells and one-half mile on each side of the creek.

Limitations

This delineation is based on estimated groundwater flow and pumping conditions. Conclusions based on this interpretation are uncertain because the extent and properties of the aquifer, and the direction and rate of groundwater flow are not known precisely. Time-of-travel distances calculated above are conservative estimates that are based on available data and professional judgement.

CHAPTER 3

INVENTORY

An inventory of potential sources of contamination was conducted to assess the susceptibility of Highwood's drinking water source to contamination. Sources of all primary drinking water contaminants and cryptosporidium were identified; however, only potential sources of contaminants that are the greatest threat to health were selected for detailed inventory. The contaminants of greatest concern to Highwood are nitrate, pathogenic organisms, fuels, and herbicides.

The inventory for Highwood focuses on all activities in the control zone and point sources of all contaminants and certain land uses in the inventory region. General land uses and large point sources of contaminants are identified in the recharge region.

Inventory Method

All land within the three-year time-of-travel region is owned by Harris Land and Cattle Company. Information on land use, agricultural chemical application, and waste disposal practices were provided by Doran Lynch, the landowner. Robert Bramlette of Highwood conducted a windshield survey of the entire inventory region in February 2001 to confirm the location of potential contaminant sources.

Available databases were searched to identify businesses and land uses that are potential sources of regulated contaminants in the inventory region. The following steps were followed:

Step 1: Urban and agricultural land uses were identified from the U.S. Geological Survey's Geographic Information Retrieval and Analysis System "http://nris.state.mt.us/gis/datalist.html" Sewered and unsewered residential land use were identified from boundaries of sewer coverage obtained from municipal wastewater utilities.

Step 2: EPA's Envirofacts System ("http://www.epa.gov/enviro/") was queried to identify EPA regulated facilities located in the Inventory Region. This system accesses facilities listed in the following databases: Resource Conservation and Recovery Information System (RCRIS), Biennial Reporting System (BRS), Toxic Release Inventory (TRI), and Comprehensive Environmental Response Compensation and Liability Information System (CERCLIS). The available reports were browsed for facility information including the Handler/Facility Classification to be used in assessing whether a facility should be classified as a significant potential contaminant source.

Step 3: The Permit Compliance System (PCS) was queried using Envirofacts ("http://www.epa.gov/enviro/") to identify Concentrated Animal Feeding Operations with MPDES permits. The water system operator or other local official familiar with the area

included in the inventory region identified animal feeding operations that are not required to obtain a permit.

Step 4: Databases were queried to identify the following in the inventory region: Underground Storage Tanks (UST) "http://webdev.deq.state.mt.us/UST/", hazardous waste contaminated sites (DEQ hazardous waste site cleanup bureau), landfills "http://nris.state.mt.us/gis/datalist.html", abandoned mines "http://nris.state.mt.us/gis/datalist.html" and active mines including gravel pits. Any information on past releases and present compliance status was noted.

Step 5: A business phone directory was queried to identify businesses that generate, use, or store chemicals in the inventory region. Equipment manufacturing and/or repair facilities, printing or photographic shops, dry cleaners, farm chemical suppliers, and wholesale fuel suppliers were targeted by SIC code.

Step 6: Major road and rail transportation routes were identified throughout the inventory region "http://nris.state.mt.us/gis/datalist.html"

Step 7. All land uses and facilities that generate, store, or use large quantities of hazardous materials were identified within the recharge region and identified on the base map.

Potential contaminant sources are designated as significant if they fall into one of the following categories:

1) Large quantity hazardous waste generators.

2) Landfills.

3) Underground storage tanks.

4) Known groundwater contamination (including open or closed hazardous waste sites, state or federal superfund sites, and UST leak sites).

5) Underground injection wells.

6) Major roads or rail transportation routes.

7) Cultivated cropland greater than 20 % of the inventory region.

8) Animal feeding operations.

9) Wastewater treatment facilities, sludge handling sites, or land application areas.

10) Septic systems.

11) Sewer mains.

12) Storm sewer outflows.

13) Abandoned or active mines.

Inventory Results/Control Zone

The control zone includes the area within 100 feet of the five wells. Chemical use in the control region is limited to spot application of Roundup (glyphosate) and Tordon for weed control.

Highwood is currently negotiating a permanent easement for all land in the control zone of all 5 wells. This easement will allow Highwood to prevent grazing in the control area. South Chouteau County's well is approximately 75 feet from Highwood Creek so their fenced control zone can only extend to approximately 25 feet from the Creek.

No significant potential contaminant sources are located within the control zone.

Inventory Results/Inventory Region

The 3-year Time of Travel Inventory Region has no listed significant potential contaminant sources in the region.

Inventory Results/Surface Water Buffer Zone

A Surface Water Buffer Zone beyond the 3-year time-to-travel zone to 10 miles upstream of the well field has been delineated. This expansion is according to procedures outlined in the Montana Source Water Protection Guidance Manual, Chapter 3.4, Conjunctive Delineation of Groundwater and Surface Water.

The Surface Water Buffer Zone (Appendix D, Figure1) is indicated on the base map. A field inventory of the region was conducted in February 2001 by Bob Bramlette. Mr. Bramlette utilized Table 8 of the Montana DEQ SWP Manual, Part 1 – Chapter 3, entitled Potential Source of Ground Water Contamination, to identify potential contaminant sources. Specific potential point sources are located on Figure One and are detailed in the following table. No other potential point sources were identified.

Table Three – Potential Point Sources in Surface Water Buffer Zone

Identification	Distance Upstream	Well & Septic System	Above Ground Fuel Tanks
Davison Home	2 miles	Yes	No
Lynch Ranch	3 miles	Yes	Yes
Katzenberger Ranch	5 miles	Yes	Yes
Gray Home	5 miles	Yes	No
Lucas Home	6 miles	Yes	No
Schott Home	6.5 miles	Yes	No
Davis Home	7 miles	Yes	No
Empty Home	8 miles	Yes	No
Davison Ranch	9 miles	Yes	Yes

Potential non-point contaminant sources in the Surface Water Buffer Zone are described in Table 4.

Table Four – Potential Non-Point Source (Surface Water Buffer Zone)

Identification	Description
Highwood Road	Gravel County Road parallels Highwood Creek for 8 miles in the inventory area. Susceptible to spills, possible future road oiling or paving, and chemical spraying.
Cattle Grazing	No concentrated feed areas are in the inventory region. Cattle graze most of the land in the inventory region, which is not considered a significant hazard.
Weed Control	Various herbicides are applied to control weeds. 2,4-D, Tordon, and Roundup are used.

Inventory Results/Recharge Region

Land uses (Appendix E, Figure 1) in the recharge region are divided as follows:

Use	Percentage
Crop/Pasture	20%
Irrigated Crop	0%
Range	40%
Forest	40%

Land is owned in the recharge region by the US Forest Service and several agricultural concerns. The nearest ranch is located approximately 3 miles upstream of the well field. The herbicide 2,4-D used for weed control and fuels for farm machinery are potential contaminants in the recharge region. Chemicals are used infrequently in the most sensitive areas adjacent to the Creek because the landowners have mainly "given up"

these areas to noxious weeds. No significant logging is currently planned in the forest areas but this status could change.

Inventory Update

The certified operator should update the inventory every year. Changes in land uses or potential contaminant sources should be noted and additions made as needed. The complete inventory should be submitted to DEQ every five years.

Inventory Limitations

The potential sources of contaminants for Highwood and South Chouteau County Water Systems are taken from readily available data and reports. Consequently, unregulated activities or unreported contaminant releases may have been missed. The use of multiple sources of data, however, should ensure that the major contaminant threats to the source water are known.

CHAPTER 4

SUSCEPTIBILITY ASSESSMENT

Susceptibility is the potential for a public water supply to draw water contaminated by inventoried sources at concentrations that would pose concern. Susceptibility is assessed in order to prioritize potential pollutant sources for management actions by local entities, in this case Highwood and South Chouteau County Water Systems.

The goal of Source Water Management is to protect the source water by 1) controlling activities in the control zone, 2) managing significant potential contaminant sources in the Inventory Region, and 3) ensuring that land use activities in the Recharge Region pose minimal threat to the source water. Management priorities in the Inventory Region are determined by ranking the significant potential contaminant sources identified in the previous chapter according to susceptibility. Alternative management approaches that could be pursued by the Highwood and South Chouteau County Water Systems to reduce susceptibility are recommended.

Susceptibility is determined by considering the hazard rating for each potential contaminant source and the existence of barriers that decrease the likelihood that contaminated water will flow to Highwood's well. Hazard is rated by the proximity of a potential contaminant source to the well(s). Susceptibility ratings are presented individually for each significant potential contaminant source and each associated contaminant in Table 5.

Table 5. Relative susceptibility to specific contaminant sources as determined by hazard and the presence of barriers.

Presence Of Barriers	**Hazard** **High**	**Moderate**	**Low**
No Barriers	Very High Susceptibility	High Susceptibility	Moderate Susceptibility
One Barrier	High Susceptibility	Moderate Susceptibility	Low Susceptibility
Multiple Barriers	Moderate Susceptibility	Low Susceptibility	Very Low Susceptibility

The results of the susceptibility assessment for Highwood are summarized in Table 6. Hazard rating is based on density or proximity of a source to the well field. The susceptibility to potential sources of multiple contaminants is assessed separately for each contaminant. In addition, alternative management approaches that could be pursued by Highwood to reduce susceptibility are recommended in Table 6 for each significant potential source.

Hazard is rated as low for these water systems because the wells were built to Montana well construction standards. Susceptibility to contamination is rated low because there are no significant potential contaminants in the control zone, inventory region, or surface water buffer zone.

REFERENCES

1. Driscoll, F.G., 1986, Groundwater and Wells, St. Paul, Minn
2. http://www.deq.mt.gov/ppa/swp/assessment
3. Larsen, E.S., 1941, Igneous rocks of the Highwood Mtns. Montana, pt. 2, Geol. Soc. America Bull., v.52, No. 11
4. Hurlbut, C.S., Jr. 1939, Igneous rocks of the Highwood Mtns., Pt. 1, The Laccolith: Geol. Soc. America Bull. V. 50, No. 7 Pl. 3
5. Barksdale, J.D., 1937, The Shonkin Sag Laccolith: Am. Jour. Sci. 5th Ser., v. 33, No. 197. Map, p. 322
6. Buie, B.F., 1941, Igneous rocks of the Highwood Mtns., Montana, Pt. 3, Dikes and Related Intrusives: Geol. Soc. America Bull., v. 52, No. 11. Pl. 4

Appendices

APPENDIX A

VICINITY MAP

APPENDIX B

PWS SITE PLAN (FIGURE 1) (FIGURE 2)

APPENDIX C

GEOLOGIC MAP

APPENDIX D

BASE MAP

APPENDIX E

LAND USE MAP

APPENDIX F

INVENTORY SHEETS

APPENDIX G

WELL LOGS

APPENDIX H

HAZARD AND SUSCEPTIBILITY WORKSHEETS

APPENDIX I

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