TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

2.5 Ground Water Hydrology

This section of the mine permit application presents the ground water hydrology of the permit and adjacent areas. This section is presented in accordance with:

- Section 38-14.1-14(1)(o) and (r), North Dakota Century Code (NDCC);
- Section 38-14.1-14(2)(i), NDCC;
- Section 69-05.2-08-02, North Dakota Administrative Code (NDAC);
- Section 69-05.2-08-04, NDAC;
- Section 69-05.2-08-06, NDAC; and
- Section 69-05.2-09-12, NDAC.

The purposes of this section are: 1) to provide a description of the pre-mining (baseline) ground water hydrology of the permit and adjacent areas that may be affected by mining; 2) to describe the probable hydrologic consequences (PHC) of the SHLM on the quantity and quality of ground water based on baseline data; and 3) to describe an effective monitoring program to assess possible impacts and protect the hydrologic balance.

Ground water hydrology addresses the occurrence, distribution, movement, and chemistry of “the subsurface water that fills available openings in rock or soil materials to the extent that they are water saturated” (NDAC 69-05.2-01-02(40)). Ground water systems are defined by their recharge, storage and discharge characteristics. As such, the following section describes key hydrologic components that influence these characteristics in the vicinity of the SHLM based on previous investigations and literature as well as a site-specific study of the baseline ground water hydrology within the potentially affected area.

An essential requirement for characterizing ground water systems is defining and mapping hydrogeologic units that receive, transmit, and discharge ground water. Depending on the scale of characterization, different terms are used to describe the hydrogeologic units. The term aquifer is commonly used to describe ground water systems but the term probably has more shades of meaning than any other term in hydrology (Freeze and Cherry 1979). It can mean different things to the same person at different times (Laney and Davidson 1986). Aquifer is defined by the PSC in NDAC 69-05.2-01-02 (5) as "…a zone, stratum, or group of strata that can store and transmit water in sufficient quantities for a specific use." This defines aquifer in economic terms for water supply usage and not by its quantifiable hydraulic characteristics making it less appropriate as a technical term to describe a ground water system. A hydrogeologic, or hydrostratigraphic unit is a body of rock or earth material distinguished and characterized by its hydraulic properties. Such units are not restricted to a single geologic, lithologic, or stratigraphic component, but rather defined by their hydrogeologic characteristics such as transmissivity and storativity (Seaber 1988, Fetter 1994). As suggested in the PSC definition and supported by literature, an aquifer can be composed of one or more hydrostratigraphic units (Fetter 1994).

The term aquifer system is also used to describe a heterogeneous body of interbedded permeable and poorly permeable material that functions regionally as a water-yielding unit. An aquifer system generally consists of two or more permeable beds separated, at least locally, by confining beds that impede ground-water movement, but do not greatly affect the regional hydraulic continuity of the system (Poland et al 1972). Given this definition, the term aquifer system can describe a local or regional ground water system depending on how the units are combined and function.

For the purposes of this permit application, an aquifer is defined using the NDAC definition as a zone, stratum, or group of strata that can store and transmit water in sufficient quantities for a specific use unless otherwise noted. An important component of this definition is that an aquifer includes a "group of strata" or multiple hydrostratigraphic units. Aquifer system as used in this text refers to regional ground water systems that may consist of either several hydrostratigraphic units or multiple aquifers functioning as a regional water-yielding unit.

This section begins with a discussion of the regional ground water hydrology (Section 2.5.1). Next, the local ground water hydrology is described in detail in Section 2.5.2, including hydrostratigraphic units, ground water use, and local aquifers. Ground water Probable Hydrologic Consequences are discussed in Section 2.5.3 along with the Ground Water Hydrologic Reclamation Plan. Finally, the Ground Water Monitoring Plan is discussed in Section 2.5.4. The following tables, figures, and appendices are referenced or utilized in preparation of this section:

Tables:

- Table 2.5-1 presents the conceptual hydrogeology;

- Table 2.5-2A, Table 2.5-2B, and Table 2.5-2C provides location information for monitoring wells, staff gages, and seeps and springs, respectively;

- Table 2.5-3 provides a summary of field-derived aquifer test results;

- Table 2.5-4 provides a list of wells currently certified, probable effects of mining and reclamation, and possible reclamation actions; and

- Table 2.5-5 presents the ground water monitoring schedule.

Figures:

- Figure 2.5-1 shows the locations of ground water monitoring points including wells, staff gages, and seeps and springs in the Study Area;

- Figure 2.5-2 presents geologic cross sections;

- Figure 2.5-3, Figure 2.5-4, and Figure 2.5-5 show the potentiometric surfaces of, the Underburden – HT Butte aquifer, the water-bearing HT Butte Coal, and the Overburden – D Coal aquifer respectively;

- Figure 2.5-6, and Figure 2.5-7 present Piper plots of major anions and cations from wells completed in the underburden and HT Butte Coal and the overburden and D Coal, respectively;

Appendices:

- Appendix 2.5-1 summarizes the monitoring well boreholes and construction;

- Appendix 2.5-2 presents the lithologic boring logs from the monitoring wells;

- Appendix 2.5-3 presents geophysics logs from the monitoring wells;

- Appendix 2.5-4 presents the water levels and seep and spring flows;

- Appendix 2.5-5 discusses and presents results of aquifer testing conducted in wells in the Study Area;

- Appendix 2.5-6 presents water quality results for ground water and seeps and springs;

- Appendix 2.5-7 presents the boreholes considered for interpretation of the ground water hydrology; and

- Appendix 2.5-8 describes the well certification program.

2.5.1 Regional Ground Water Hydrology

2.5.1.1 Topography and Land Use

The South Heart Lignite Mine (SHLM) is located in the unglaciated Missouri Plateau section of the Great Plains physiographic province. The SHLM lies in the southern portion of the Williston Basin, which was described previously in Section 2.3.1. The surficial landforms consist of rolling hills with primarily cropland and native grassland. Much of the region is agricultural, with dry land farming and livestock operations.

2.5.1.2 Climate

The climate is semiarid with mean annual precipitation of approximately 16 inches in the Dickinson area. Approximately 85 percent of precipitation falls during April through October. The mean annual temperature is 42.4°F in the Dickinson area (NWS 2007).

2.5.1.3 Surface Water

The SHLM lies in the upper Heart River watershed, a tributary to the Missouri River, upstream of Patterson Lake and the City of Dickinson. The primary surface water features are the Heart River and South Branch Heart River. The surface water resources of the area are described in more detail in Section 2.6.

2.5.1.4 Geology

The primary freshwater aquifer systems are located in the Upper Cretaceous (Fox Hills and Hell Creek Formations) and Tertiary (Fort Union Group) sedimentary rock overlying the Pierre Shale which is generally considered the base of the fresh-water bearing units in western North Dakota (Armstrong 1984). The sedimentary units consist of sandstone, siltstone, claystone, and coal. Many of the local drainages and stream valleys are in-filled with Quaternary alluvium derived from the surrounding bedrock. The geology of the area is described in more detail in Section 2.3.

2.5.1.5 Ground Water

Ground water within and adjacent to the Study Area is part of the Dickinson Lignite Area and includes the Upper Cretaceous and Lower Tertiary aquifer systems of the Northern Great Plains aquifer system (Whitehead 1996, Armstrong 1984). Recharge to the aquifer systems is from infiltration of precipitation at outcrops, stream flow leakage, and lateral flow from the southwest. Discharge is generally to major streams such as the Heart River and Missouri River. The general movement of water is northeastward (Whitehead 1996). The ground water in and adjacent to the Study Area above the Upper Cretaceous Pierre Shale (approximately 1,900 ft below ground surface) is divided into four aquifer systems. Trapp and Croft (1975) and Armstrong (1984) described the aquifer systems in Hettinger and Stark Counties and the Dickinson Lignite Area of the two counties, respectively. The two reports vary slightly in their delineations of the upper two aquifer systems. The four aquifer systems in the Dickinson Lignite Area underlying and adjacent to the Study Area are described in the following sections in ascending order using the aquifer system nomenclature in Armstrong (1984) and are presented on Table 2.5-1.

Fox Hills - Lower Hell Creek Aquifer System

The Fox Hills Sandstone and lower parts of the Hell Creek Formation form a confined aquifer system above the Pierre Shale. The aquifer system consists of fine- to medium-grained sandstones interbedded with siltstone and claystone. The aggregate sandstone thickness of the aquifer system is 88 to 192 feet (ft) (Armstrong 1984) but may be as much as 270 ft thick (Trapp and Croft 1975). The top of this aquifer system is approximately 1,500 ft below ground surface near the Study Area based on interpretation from Plate 2 in Trapp and Croft (1975). An impermeable bed approximately 50 to 60 ft thick separates the aquifer system from overlying aquifer systems (Trapp and Croft 1975).

The gradient of the aquifer system is approximately 9 ft/mile and trends towards the northeast. Hydraulic heads in the aquifer system are typically lower than in overlying aquifer system (Armstrong 1984).

Recharge to the Fox Hills - Lower Hell Creek aquifer system within the Study Area is lateral flow from the southwest and possibly vertical leakage from above. Discharge from this aquifer system in the general vicinity of the Study Area is subsurface flow to the northeast (Armstrong 1984).

Transmissivities are variable in the aquifer system due to differences in the aquifer system thickness (aggregate sandstone thickness) and difference in grain sizes within the sandstones.

Transmissivities are reported to be approximately 130 feet squared per day (ft^2/d) with storage coefficients of approximately 0.0001 (Armstrong 1984). Using this transmissivity value and the range of aquifer system thickness, the hydraulic conductivities range from 1.48 feet per day (ft/d) (5.21×10^{-4} centimeters per second [cm/s]) to 0.48 ft/d (1.70×10^{-4} cm/s).

The water from the Fox Hills - Lower Hell Creek aquifer system is generally a sodium-bicarbonate type water. Total dissolved solids (TDS) concentration levels are reported to range from 1,230 milligrams per liter (mg/L) to 1,690 mg/L (Trapp and Croft 1975, Armstrong 1984). Chloride concentrations appear to increase in an easterly direction across the Dickinson Lignite Area from 57 mg/L to 190 mg/L. Sodium concentrations range from 470 mg/L to 606 mg/L (Armstrong 1984) and sodium adsorption ratio (SAR) values are generally elevated (58 to 92) (Trapp and Croft 1975). As such, the water is generally considered unsuitable for irrigation. In addition, fluoride concentrations are reported to range from 2.3 to 4.7 mg/L (Trapp and Croft 1975, Armstrong 1984). The upper end of this range is above the current Environmental Protection Agency (EPA) Primary Drinking Water Standard of 4 mg/L (EPA 2007).

Upper Hell Creek - Lower Ludlow Aquifer System

The upper Hell Creek Formation and the lower Ludlow Member of the Fort Union Group forms a regional confined aquifer system. The aquifer system consists of very fine- to medium-grained sandstone lenses with some silt and clay (approximately 30 percent). Individual sandstone lenses range from 2 to 74 ft thick; however, the aggregate sandstone thickness is approximately 324 ft. A confining bed approximately 40 to 150 ft thick separates the aquifer system from the overlying aquifer system (Armstrong 1984). The top of the aquifer system is approximately 900 ft below ground surface near the Study Area based on interpretation of Plate 2 in Trapp and Croft (1975).

The ground water flow direction is towards the northeast. Recharge to the aquifer system in the general vicinity of the Study Area is lateral subsurface flow from the southwest and possibly vertical leakage from above. Discharge is subsurface flow to the northeast (Armstrong 1984).

The transmissivities and other hydraulic properties of the Upper Hell Creek – Lower Ludlow aquifer system appear to be variable although limited data for the system are available (Trapp and Croft 1975, Armstrong 1984). Armstrong (1984) reported transmissivity values of 53 and 88 ft^2/d calculated from specific capacity data from Trapp and Croft (1975). Armstrong (1984) further reported values of 1 to

160 ft^2/d from another study with a mean value of 77 ft^2/d. Using the range of transmissivity values and the range of thicknesses, the hydraulic conductivities range from 0.003 ft/d (1.09×10^{-6} cm/s) to 80 ft/d (2.82×10^{-2} cm/s).

Ground water from the Upper Hell Creek – Lower Ludlow aquifer system is a sodium-bicarbonate type water. Concentrations provided here are based on those reported in Trapp and Croft (1975) and Armstrong (1984). Concentrations of TDS range from 1,010 to 1,890 mg/L. Chloride and sulfate concentrations are relatively low, ranging from 5.3 to 14 mg/L and from 4.8 to 127 mg/L, respectively. Sodium concentrations range from 412 mg/L to 640 mg/L, while SAR values range from 25 to 130. The elevated SAR values indicate the water is likely unsuitable for irrigation. Fluoride concentrations vary from 0.8 to 5.8 mg/L, with higher concentrations above the EPA Primary Drinking Water Standard (4 mg/L) (EPA 2007).

Upper Ludlow – Lower Tongue River Aquifer System

This aquifer system includes thin sandstone lenses of the upper Ludlow Member and the basal sandstone of the Tongue River Formation. The aquifer system is generally confined and consists of lenses of very fine- to medium-grained, semi-consolidated sandstone with varying quantities of interstitial silt and clay and fractured coal. The aquifer system contains lenses of siltstone, claystone, or shale up to 64 ft thick. Aggregate thicknesses of the siltstone, claystone, or shale lenses may be as much as 140 ft. The aquifer system thickness ranges from 36 to 161 ft. The aquifer system underlies all of the Dickinson Lignite Area at depths that generally range from approximately 440 to 700 ft below ground surface but may be deeper (Armstrong 1984). A confining bed approximately 110 to 300 ft-thick separates the aquifer system from the overlying aquifer system (Trapp and Croft 1975). Hydraulic conductivities of this aquifer system are reported to range from 1 ft/d (3.5×10^{-4} cm/s) to 4 ft/d (1.4×10^{-3} cm/s) (Trapp and Croft 1975).

The ground water flow direction of the Upper Ludlow – Lower Tongue River aquifer system is towards the northeast. Recharge to the aquifer system in the general vicinity of the Study Area is lateral subsurface flow from the southwest and possibly vertical leakage from above. Discharge consists of subsurface flow to the northeast (Armstrong 1984).

Ground water from the Upper Ludlow - Lower Tongue River aquifer system is generally a sodium-bicarbonate type water with TDS concentrations around 1,000 mg/L. However, both Armstrong (1984) and Trapp and Croft (1975) note variations in water quality in the aquifer system throughout the Dickinson Lignite Area. For example, Armstrong (1984) notes that ground water appears to shift to a sodium-sulfate type water with higher TDS concentrations (up to 1,990 mg/L) on the southwest side of the Dickinson Lignite Area with sulfate concentrations up to 1,000 mg/L. Trapp and Croft (1975) indicates a similar shift in water type for southeast Hettinger County. Sodium concentrations range from 390 mg/L to 670 mg/L and sulfate from 33 to 1,000 mg/L. Reported SAR values range from 10 to 73, indicating that the water is generally unsuitable for irrigation. Elevated fluoride concentrations from 1.4 to 5.9 mg/L are also reported for this aquifer system.

Upper Tongue River - Sentinel Butte Aquifer System

The Upper Tongue River - Sentinel Butte aquifer system is composed of discontinuous sandstone lenses, siltstone, claystone and fractured coal beds of the Sentinel Butte and upper portion of the Tongue River formations. The Tongue River formation is also referred to as the Bullion Creek formation (see Section 2.3 for more details). Both the Tongue River and Sentinel Butte formations were deposited in a freshwater fluvial environment and consist of alternating beds of claystone, siltstone, shale, sandstone, and coal (Trapp and Croft 1975, and Armstrong 1984). Armstrong (1984) indicates that, the sandstone units are generally lenticular and discontinuous resulting from their deposition in long, narrow, meandering stream channels. The sandstone lenses are generally less than 30 ft thick but some lenses have been observed in boreholes to be as thick as 147 ft. The lenses consist of very fine to medium grained sandstone with varying quantities of silt and clay and are commonly semi-consolidated. Sandstone lenses were deposited in stream channels that are nearly impossible to correlate between boreholes. The lignite beds, however, were deposited in widespread swampy areas, and some beds can be correlated for several square miles. The lignite beds range from 1 to approximately 20 ft thick. Claystone or siltstone lenses can directly overlie the lignite beds, but locally the lignite is mostly overlain directly by sandstone. Furthermore, the lignite beds are generally underlain by at least 10 ft of claystone or siltstone (Armstrong 1984).

The ground water flow direction in the Upper Tongue River - Sentinel Butte aquifer system is generally to the northeast and east but can vary locally. The discontinuous sandstone lenses that compose the aquifer system make it difficult to correlate individual sand lenses and their corresponding water levels to estimate water level gradients. Hydraulically, the deeper sandstone lenses may or may not be hydraulically connected to shallower parts of the aquifer system. Deeper parts of the aquifer system may be confined with shallower units being unconfined. Locally, these lenses may result in definition of multiple hydrogeologic units (Armstrong 1984).

Recharge to the aquifer system in the general vicinity of the Study Area is through precipitation and lateral flow from the southwest but may be locally recharged from leakage from underlying aquifer systems. Discharge consists of subsurface flow to the northeast and east and flow to the Heart River and Patterson Lake downstream of the Study Area (Armstrong 1984).

The hydraulic conductivities in the sandstone lenses are generally low (i.e., less ability to transmit water) but some well sorted and coarse-grained lenses may have higher conductivities. The coal seams are generally fractured and/or jointed; therefore hydraulic conductivities are dominated by secondary permeability. The fractures in the coal vary in size over short distances also resulting in variability in hydraulic conductivities (Armstrong 1984). Hydraulic conductivities are reported between 9.36 ft/d (3.3×10^{-3} cm/s) and 17.45 ft/d (6.2×10^{-3} cm/s). Storativity values are approximately 0.0008 to 0.001 (Trapp and Croft 1975).

Ground water from Upper Tongue River - Sentinel Butte aquifer system is reported to be sodium-sulfate or sodium-bicarbonate type water (Trapp and Croft 1975 and Armstrong 1984, respectively). Trapp and Croft (1975) note there is considerable variability in water quality in the aquifer system, and that water quality generally varies with depth. This variation of water quality with depth is likely due to the dissolution of minerals or chemical reactions as water moves downward and laterally through the aquifer system. For example, sodium and potassium ions represent more of the total cations at depth, likely due to cation exchange of calcium and magnesium for sodium as the water flows downward through the formations. Concentrations of TDS are generally around 1,000 mg/L, but range from 574 to 11,700 mg/L. Reported values for SAR range from 0.2 to 68, indicating that some of the water is not likely suitable for irrigation. Reported fluoride concentrations range from 0.0 to 6.7 mg/L, though Trapp and Croft (1975) indicate most samples did not contain excessive fluoride.

2.5.1.6 Ground Water Use

Ground water is used predominately for stock and domestic purposes. Water is not used for irrigation in the region. Wells tend to be screened across the shallowest unit that can provide sufficient water for the given use. The majority, and likely all, of the primary domestic water supply to residents in the region is from Lake Sakakawea via the Southwest Pipeline.

2.5.2 Local Ground Water Hydrology

The Ground Water Study Area (Study Area) of the SHLM is located in Stark County, west and southwest of the City of South Heart, North Dakota, and includes:

- All of Sections 15, 16, 17, 21, 22, 23, 27, 34 Township 139 North (T139N), Range 98 West (R98W);
- Portions of Sections 9, 10, 13, 14, 20, 24, 28, 29, and 33, T139N, R98W; and
- The northern portion of Section 3 T138N R98W.

The ground water hydrology in and adjacent to the SHLM is similar to that described in the literature and summarized above. The local ground water hydrology in the context of proposed mining activities was further characterized through interpretation of published data and detailed hydrologic field investigations including:

- Installation of monitoring wells, water level measurements, water quality sampling, and aquifer testing;
- Identification of seeps and springs, measurement or estimation of flow rates, and water quality sampling;

Data utilized from the field investigations are presented as follows:

- Locations of monitoring wells, staff gages, and seeps and springs are shown on Figure 2.5-1 and coordinates provided in Table 2.5-2A, Table 2.5-2B, and Table 2.5-2C;
- Well borehole and completion details are presented in Appendix 2.5-1;
- Lithologic logs of the deepest wells at each well cluster location are presented in Appendix 2.5-2;
- Geophysical logs of the upland wells are presented in Appendix 2.5-3; geophysical logs of observation wells installed prior to SHC involvement with environmental studies at the site are provided in Section 2.3 Appendix 2.3-16.
- ~~Monthly~~ Measured ground water levels and values over time are shown in Appendix 2.5-4;

- Estimated or measured flows from seeps and springs are presented in Appendix 2.5-4;
- Results from the aquifer testing program are presented in Appendix 2.5-5 and summarized in Table 2.5-3; and
- Water quality results are presented in Appendix 2.5-6.

2.5.2.1 Topography

The landforms within the Study Area are similar to that of southwestern North Dakota and consist of rolling hills with primarily cropland and native grassland. Much of the area is agricultural, with dry land farming and livestock operations. Elevation in the Study Area ranges from 2,480 feet to about 2,660 feet above mean sea level. Upland areas are dominated by generally stable one to 10 percent slopes. The most level areas are associated with river terraces and other low-lying features. The steepest slopes generally occur on river cutbanks that have slopes up to 30 or 40 percent grade. The steepest slopes in most upland areas are less than 15 percent grade.

2.5.2.2 Climate

The climate of the Study Area is semiarid, similar to that of the region, with a mean annual precipitation of approximately 16 inches falling mostly during April through October.

2.5.2.3 Surface Water

The primary drainages in the Study Area are the perennial Heart River and its intermittent tributary, the South Branch Heart River. The Heart River is a perennial stream immediately north of the Study Area. The Heart River flows east along the north boundary of the Study Area through the City of South Heart and downstream to Patterson Lake and the City of Dickinson. The South Branch Heart River is an intermittent stream that flows northeast across the Study Area and joins the Heart River west of the City of South Heart. Secondary surface water features include the west tributary to the South Branch Heart River (West Tributary) and the south tributary to the South Branch Heart River (South Tributary). The West Tributary is an ephemeral drainage that flows generally west to east and joins the South Branch Heart River upstream of the confluence with the Heart River. The South Tributary is an ephemeral drainage that flows south to north and joins the South Branch Heart River upstream of the confluence with the West Tributary. The headwaters of the South Tributary are in the

Little Badlands, an area of erodible clays that contribute high levels of clay to the stream. The surface water resources of the area are described in more detail in Section 2.6.

2.5.2.4 Geology

The geology of the Study Area is similar to that described in the literature. For this application, discussions focus on the Sentinel Butte formation and to a lesser extent, the Tongue River formation immediately beneath the Sentinel Butte. The Sentinel Butte formation consists of interbedded sandstone, claystone, siltstone, shale, and lignite. The primary coal seam encountered within the Study Area was the D Coal, the coal intended to be mined. The HT Butte coal, below the D Coal is considered the contact between the Tongue River formation and the overlying Sentinel Butte formation (Biek and Gonzalez 2001). Alluvial deposits are present along the drainage ways of the Heart River and South Branch Heart River.

2.5.2.5 Hydrostratigraphy

Within the Study Area, hydrostratigraphic units were characterized within the Upper Tongue River – Sentinel Butte aquifer system. A hydrostratigraphic unit is a body of rock or earth material distinguished and characterized by its hydraulic properties. The units are not restricted to a single geologic, lithologic, or stratigraphic unit but rather defined by its hydrogeologic characteristics such as transmissivity and storativity (Seaber 1988, Fetter 1994).

Geologic cross sections within the Study Area illustrating the geology are shown on Figure 2.5-2. The relationship of the geology, hydrostratigraphy, and aquifers between previous investigations and this study are show on Table 2.5-1. The Study Area hydrostratigraphic units of most importance to this application are described in ascending order below.

HT Butte Coal

The HT Butte Coal is the marker bed between the Sentinel Butte and Tongue River or Bullion Creek formation. It is the most laterally extensive unit at the top of the Tongue River Formation present in the Study Area. The unit was observed between 170 and 286 ft below ground surface and ranges in thickness from approximately 10 to 21 ft with an average of 13 ft. Regionally, below the HT Butte Coal is a thick zone of claystone that separates the Upper Tongue River – Sentinel Butte aquifer system from the underlying Upper Ludlow – Lower Tongue River aquifer system (Armstrong 1984).

The HT Butte is characterized by variable hydraulic conductivity likely due to variations in fracturing. Testing at one well yielded a relatively high hydraulic conductivity of 1.7×10^{-3} cm/s (4.8 ft/d). However, observations of water level recovery following sampling at two other wells suggest a lower hydraulic conductivity, likely on the order of 1×10^{-5} cm/s.

Ground water in the wells completed in the HT Butte Coal seam is generally sodium-bicarbonate type water. Laboratory pH values range between 8.2 and 8.~~7~~4 with an average of 8.3. TDS concentrations are approximately 1,300 mg/L and laboratory EC ranges from 1,880 to 2,420~~060~~ micromhos per centimeter (μmhos/cm). SAR values range from 46.5 to ~~56.3~~62.2. Water quality results are discussed in detail in Appendix 2.5-6.

Underburden

The underburden, or non-coal material above the HT Butte Coal but below the D Coal, is composed of thick sections of claystone, siltstone, and shale interbedded with discontinuous sandstone lenses of the Sentinel Butte formation. The approximate thickness of the underburden, based on borehole data, ranges from 70 to 176 ft with an average of 131 ft. According to lithologic logs reviewed by Armstrong (1984), sandstone beds are scattered throughout the Sentinel Butte, but the beds are most abundant near the base of the formation. Sandstone was observed at the base of the Sentinel Butte formation directly overlying the HT Butte in one Study Area borehole. Other Study Area boreholes drilled into the HT Butte show an interbedded claystone, siltstone, sandstone above the HT Butte. A relatively continuous claystone or siltstone varying in thickness from a few feet to greater than 50 ft unit was observed in boreholes at the top of the underburden directly underlying D Coal.

The hydraulic conductivity of the underburden is variable based on the geologic material. The estimated (geometric mean) hydraulic conductivity of the claystone and siltstone is 5.5×10^{-8} cm/s (1.5×10^{-4} ft/d) suggesting a low conductivity material that does not transmit water easily. Water levels in some monitoring wells did not appear to fully recover to static conditions between quarterly sampling events due to low hydraulic conductivity. The estimated (geometric mean) hydraulic conductivity of the sandstone is 3.6×10^{-5} cm/s (1.0×10^{-1} ft/d) similar to other sandstones in the overburden and higher than the claystone and siltstone.

Ground water in the wells completed in the underburden is generally sodium-bicarbonate type water. For every analyte, values remain fairly constant from one sampling event to the next in all wells completed in the underburden. Values of pH values range from 8.1 and 8.8. TDS concentrations range from 1,070 to 1,56~~2~~0 mg/L and laboratory EC ranges from 1,680~~700~~ to 2,310~~260~~ μmhos/cm. SAR values range from 25.7 to 70.8~~63.7~~ and generally decrease to the northeast. Water quality results are discussed in detail in Appendix 2.5-6.

D Coal

The D Coal is the primary and deepest coal seam to be mined and is laterally continuous throughout the Study Area except where it may be eroded (e.g., along the South Branch Heart River). The thickness of the D Coal averages approximately 16 ft with an observed range of 1 to 23 ft. Predominantly, the D Coal is directly underlain by a claystone or siltstone of varying thickness from a few feet to greater than 50 ft indicating a widespread confining unit at the base of the coal.

The D Coal is generally fractured and jointed and varies considerably within short distances (Armstrong 1984). Hydraulic conductivities therefore are controlled by secondary permeability and vary within the unit. The variability is illustrated by the range of estimated hydraulic conductivity from 5.1×10^{-7} cm/s (1.4×10^{-3} ft/d) to 1.8×10^{-2} cm/s (51 ft/d) with a geometric mean of 7.0×10^{-4} cm/s (2.0 ft/d). Despite this variability, the D Coal is generally considered a wide-spread hydraulically conductive unit.

Ground water from wells completed in the D Coal ~~consistently~~ ranges from sodium-bicarbonate type to sodium-sulfate type with the exception of SHMW-03C, SHMW-01S and SHMW-11S, which typically have a higher proportion of calcium and magnesium cat~~an~~ions.~~waters~~. For every analyte, values generally remain fairly constant from one sampling event to the next in all wells. Values for pH range from 6.5 to 8.2. Concentrations of TDS and laboratory EC range from 506 to 4,440 mg/L and 758 to 6,070 μmhos/cm, respectively. Ground water from one well is outside these ranges with an average TDS concentration of 8,470 mg/L and EC of 9,180 μmhos/cm possibly the result of pyrite oxidation. Values of SAR range from 0.53 to 55 and generally decrease to the northeast. Water quality results are discussed in detail in Appendix 2.5-6.

Overburden

The overburden consists of discontinuous sandstone lenses and coal stringers interbedded with claystone and siltstone within the Sentinel Butte Formation overlying the D Coal. The average thickness of the overburden is approximately 68 ft. with a range of 17 ft to 178 ft. Within the overburden, between 1 and 8 distinct sandstone units are noted above the D Coal. These sandstone units have an average thickness of approximately 11 ft with a range of less than 1 ft to 49 ft. Average aggregate thickness of these sandstone units is approximately 40 ft but can be as thick as

68 ft in the Study Area based on observations while drilling monitoring wells for the Study Area field investigation. The discontinuous individual sandstone lenses are difficult to correlate laterally across the Study Area due to the manner in which they were deposited in a fluvial environment.

Monitoring wells for the field investigation were drilled to identify any potential water bearing unit that may be impacted by mining, especially above the D Coal. Water was not always present in sufficient quantities in the overburden to supply water to a well even for monitoring purposes. Where water was present in the discontinuous sandstone, siltstone, and claystone of the overburden the hydraulic conductivity was estimated (geometric mean) at 9.0×10^{-5} cm/s (2.6×10^{-1} ft/d).

Water quality characteristics vary among the wells completed in the overburden. The major cation is sodium with one well showing no dominant type but is trending towards magnesium and calcium. The anions range from bicarbonate to sulfate. Despite the variation between wells, measured analyte values remain fairly constant between sampling events at any individual location. Laboratory pH values range from 7.2 to 8.4. Concentrations of TDS and laboratory electrical conductivity (EC) values range from 476 to 4,570 mg/L and 764 to 5,449 (μmhos/cm), respectively. Values of SAR range from 0.67 to 56.0, with values generally decreasing to the northeast. Water quality results are discussed in detail in Appendix 2.5-6.

Alluvium

Alluvium is present along the Heart River and South Branch Heart River and consists of interbedded clay, silt, and sand. Depth of alluvium ranges from approximately 23 ft to 29 ft based on wells installed adjacent to the streams. The alluvium overlies a 1 to 5 ft thick claystone, siltstone, or sandstone above a coal seam that is likely the D Coal. The alluvial ground water was assessed as part of the Alluvial Valley Floor study and discussed in Section 2.8.

Water levels measured in wells completed in the alluvium and the shallow bedrock adjacent to the streams along with stream stage indicate:

- Surface water levels within the South Branch Heart River are higher than adjacent ground water levels indicating surface water discharges to ground water. As such, the South Branch Heart River is a losing stream. No vertical hydraulic gradient was observed in the wells indicating that ground water flow is lateral and not affected by the stream except for short periods after storm events.

- Along the Heart River, ground water levels in well clusters indicate an upward gradient and are higher than surface water levels suggesting ground water discharges to surface water. Therefore, the Heart River is a gaining stream. Baseflow of the Heart River was estimated at less than 1 cubic foot per second.

Groundwater from wells completed in the alluvium varies in both the sulfate and bicarbonate proportion as well as in the calcium, magnesium and sodium proportionGround water from wells completed in the alluvium is generally sodium-sulfate type. Values for pH range from 6.3 to 7.8. Concentrations of TDS and EC range from 1,100 to 5,880 mg/L and 1,453 to 6,389 μmhos/cm, respectively. Values of SAR range from 4.3 to 19.3. Water quality results are discussed in detail in Appendix 2.5-6.

2.5.2.6 Ground Water Use

Locally, ground water is used predominately for domestic and stock purposes, consistent with regional use. Ground water use within approximately one mile of the Permit Area was evaluated from North Dakota State Water Commission (SWC) records available from the Commission's website. Those records indicate that there are approximately 50 wells located either inside or within one mile of the Permit Area that are neither monitoring nor observation wells. Of these wells, approximately 65% are used for domestic purposes and 15% for stock purposes. Records indicate that the remaining 20% of wells are used for other purposes including those identified as industrial (5%), other (10%), and unknown (5%). Based on information from local well owners, domestic wells are likely used for lawn and garden watering and not for drinking. The majority, and likely all, of the primary domestic water supply to residents in and adjacent to the Permit Area is from Lake Sakakawea via the Southwest Pipeline.

The majority of the wells within one mile of the permit area (approximately 70%), based on SWC records, are completed less than 200 ft below ground surface. The screen intervals of many of these wells include some coal, likely the D Coal or higher unit within the overburden, and sandstone or siltstone. The remaining wells are completed greater than 350 ft below ground surface, which is below the HT Butte Coal, and are screened in sandstone.

2.5.2.7 Aquifers

Aquifer, as defined in NDAC 69-05.2-01-02 (5) and described in relevant literature, is defined as a zone, stratum, or group of strata that can store and transmit water in sufficient quantities for a specific use. An aquifer can be composed of one or more hydrostratigraphic units, each having unique hydraulic parameters but can be in communication with each other (Fetter 1994).

The hydrostratigraphy of the SHLM and the surrounding region is a complicated system of interbedded claystone, siltstone, sandstone that cannot be correlated for any distance, and relatively continuous lignite seams. Ground water was encountered everywhere in the HT Butte, underburden, and D Coal hydrostratigraphic units, but not always in the overburden. Where water was present, the ability of the unit to transmit water varied over several orders of magnitude between different units and within the same units. The observed hydrostratigraphic units, ground water use, and regional hydrology were used to simplify a complicated hydraulic system into two aquifers: the Underburden – HT Butte aquifer and the Overburden – D Coal aquifer. The aquifers are named for the rock-stratigraphic units in which they exist according to the USGS aquifer naming guidelines (Laney and Davidson 1986 and Hansen 1991). The relationship of the geology, hydrostratigraphy, and aquifers between previous investigations and this study are shown on Table 2.5-1.

Underburden – HT Butte Aquifer

The Underburden – HT Butte aquifer consists of the underburden and the HT Butte Coal hydrostratigraphic units within the lower portion of the Sentinel Butte formation and the upper portion of the Tongue River (Bullion Creek) formation. These units likely represent the lower portion of the Upper Tongue River – Sentinel Butte aquifer system described by Armstrong (1984). The Underburden – HT Butte aquifer is the next lowest aquifer below the mined coal seam and lowest aquifer that may be impacted by proposed mining activities.

The Underburden – HT Butte aquifer is likely separated from the overlying Overburden – D Coal aquifer by relatively continuous claystone or siltstone confining layer directly underlying the D Coal. The underburden, as described above, is composed of thick sections of claystone, siltstone, and shale interbedded with discontinuous sandstone lenses and layers, similar to the overburden above the D Coal. The ability to transmit water varies by several orders of magnitude between the different rock types within the underburden. However, water was encountered at all well locations in sufficient quantity for monitoring and observation purposes. The HT Butte Coal is the most laterally continuous unit at the top of the Tongue River Formation and was also saturated wherever it was encountered. As is typical for lignite seams, the ability of the HT Butte to transmit water is variable across the Study Area. However, the HT Butte is a laterally continuous unit, as opposed to the discontinuous sandstones, and is generally regarded as the primary conductive unit of this aquifer.

Below the HT Butte Coal is an approximately 110 to 300 ft thick confining layer separating the Upper Tongue River – Sentinel Butte aquifer system from the underlying Upper Ludlow – Lower Tongue River aquifer system described by Armstrong (1984) and Trapp and Croft (1975).

The Underburden – HT Butte aquifer is recharged primarily through lateral subsurface inflow from the southwest while discharge is mainly subsurface outflow to the northeast and east and possibly leakage to the overlying aquifer. The ground water flow direction is generally towards the northeast and east. Water levels fluctuate seasonally in the hydrostratigraphic units by approximately 1 ft. A potentiometric surface of the Underburden – HT Butte aquifer is presented on Figure 2.5-3. In addition, a separate potentiometric surface of the water-bearing HT Butte Coal is shown on Figure 2.5-4 as required by NDAC 69-5.2-08-06 (1)(d).

The ground water chemistry of the underburden and HT Butte coal is similar between the two hydrostratigraphic units and distinct from the D Coal and overburden. The underburden and HT Butte have sodium-bicarbonate type water as compared to the varying water types of the D Coal and overburden. The similarity between the underburden and HT Butte hydrostratigraphic units suggests sufficient hydraulic connection to consider them as one aquifer. The major anion and cations indicating water type of the Underburden – HT Butte aquifer are shown on the Piper plot in Figure 2.5-6.

As described above, the majority of water supply wells in the Study Area are screened across multiple stratigraphic units (coal, sandstone, etc.) suggesting that aquifers are comprised of multiple hydrostratigraphic units. Wells screened in the underburden and the HT Butte Coal, similar to shallower screened wells, would likely need to be screened across multiple units within the underburden and the HT Butte Coal in order to produce sufficient water for a use beyond monitoring. As such, the underburden and HT Butte hydrostratigraphic units are considered one aquifer.

Overburden – D Coal Aquifer

The Overburden – D Coal aquifer exists entirely within the Sentinel Butte Formation and is primarily composed of the overburden and D Coal hydrostratigraphic units. Alluvium along the Heart River and South Branch Heart River is also a minor component of the aquifer. The D Coal is generally fractured and is the most laterally continuous and conductive unit at the base of the aquifer. A claystone or siltstone of varying thickness from a few feet to greater than 50 ft is present directly underlying the D Coal that may act as a widespread confining unit. The overburden is composed of interbedded claystone and siltstone with discontinuous sandstone lenses that cannot be correlated across the Study Area or the region.

Locally, the Overburden – D Coal aquifer is likely recharged mainly by precipitation, lateral flow, river inflows through alluvium, and leakage from the underlying aquifer. Discharge is mainly to the Heart River through the alluvium and subsurface outflow from the Study Area to the northeast (Armstrong 1984) with minor discharge to wells and seeps and springs.

Seeps and springs in the Study Area likely originate from subcrops of coal stringers and other more permeable units in the overburden above the D Coal. Within the Study Area, these lesser coal units are localized sources of water since they are not laterally continuous across the Study Area (Section 2.3). Two seep/spring locations, SHSS-16 and SHSS-17ST, appear to be developed with pipes installed in the discharge area and appear to flow continuously during the summer months when other seeps/springs are dry (Appendix 2.5-4).

As mentioned above, ground water was encountered everywhere in the D Coal hydrostratigraphic unit, but not always in the overburden. Water levels from the overburden and D Coal hydrostratigraphic units were considered to create a potentiometric surface of the Overburden – D Coal aquifer, shown on Figure 2.5-5, in accordance with NDAC 69-05.2-08-06 (1)(d). This surface is also considered to represent the potentiometric conditions of the water-bearing D Coal seam. Ground water flow direction of the Overburden – D Coal Aquifer is generally northeast and towards the Heart River. Water levels fluctuate seasonally in the hydrostratigraphic units by approximately 1 ft.

Water chemistry in the Overburden – D Coal aquifer generally follows the conceptual evolution of ground water quality presented by Moran et al. (1978) where downward percolating recharge from the surface is influenced by dissolution of evaporation-concentrated salts, such as gypsum (calcium sulfate). As water percolates deeper, sodium exchange from the abundant clays quickly increases the relative sodium content and calcite (calcium carbonate) dissolution increases the bicarbonate content, resulting in a shift from sodium-sulfate to sodium-bicarbonate type waters. Water from wells completed in the overburden and D Coal are sodium sulfate to sodium bicarbonate types suggesting hydraulic communication between the hydrostratigraphic units. The variability between wells can be attributed to differences in completion depth. This range of water types is shown on a Piper plot for wells completed in Overburden - D Coal aquifer (Figure 2.5-7).

The sodium sulfate and sodium bicarbonate water type of the overburden and D Coal hydrostratigraphic units are also distinguished from the water types in deeper hydrostratigraphic units discussed below. This further suggests that the units are a separate aquifer from the deeper hydrostratigraphic units. The results of water quality analysis are discussed and summarized in Appendix 2.5-6.

Armstrong (1984) and Trapp and Croft (1975) state that locally, the lignite beds may be the only source of ground water above the basal part of the Tongue River. However, wells for domestic and stock use completed in Overburden – D Coal aquifer are generally screened across the coal and portions of the overburden supporting the conclusion that the two hydrostratigraphic units together act as one aquifer yielding water to wells.

2.5.3 Probable Ground Water Hydrologic Consequences

The Probable Hydrologic Consequences (PHC) of the SHLM, or the reasonably expected changes in ground water quantity and quality due to mining and reclamation operations, were estimated based on the results of the baseline ground water hydrology study. Planned mining and reclamation activities will impact the ground water hydrology within and adjacent to the Permit Area. Removal of the overburden and the D Coal will eliminate the current Overburden – D Coal aquifer within pit areas resulting in a reduction in ground water storage and availability. However, continued backfilling of the mining pits with spoils provides the medium for a recharge process that continues during reclamation and ultimately establishes a saturated unit approximately in the position of the deepest lignite mined. Disturbance of the overburden and saturation of reclaimed spoils may result in a temporary increase in Total Suspended Solids (TSS) from material settling and in TDS from pyrite oxidation, mixing and salt dissolution. The potential impacts to the ground water system were reasonably overestimated for this application within the limits of the data. These potential impacts were based on data collected from the Study Area field investigations and professional judgment with the aid of various tools (e.g., analytical and numerical solutions) and information obtained from technical publications. These impacts are described in the following sections.

2.5.3.1 Impacts to Ground Water Quantity

Dewatering and removal of the coal and overburden will eliminate the Overburden – D Coal aquifer within the pit areas resulting in a reduction in ground water storage and availability. A cone of depression will be created in the potentiometric surfaces of water-bearing units in the vicinity of the pits to the depth of excavation. Water levels in the Overburden – D Coal aquifer outside of the pit areas and within the radius of influence will likely decline. The extent of significant drawdown (greater than seasonal variation) will likely be within one mile of the mine pits. The cone of depression may extend farther in the downgradient direction (northeast) given the gradient of ground water flow but still is expected to be within one mile of the mine pits. After mining, ground water flow will be predominantly into the reclaimed spoils, towards the center of the cone of depression (i.e., mine pits), until the ground water levels return to equilibrium conditions.

At the J.K. Ranch Mine of Royal Oak Enterprises north of Dickinson, where similar geologic units were disturbed, removal of the overburden and coal reversed ground water gradients resulting in temporary localized upward movement of water to the active pit from the deeper aquifer. At the SHLM, water levels may decline in the Underburden – HT Butte aquifer due to upward leakage to active pits and spoils when the overburden and D Coal are removed and backfilled. However, leakage will likely be limited by the confining unit underlying the D Coal where it is present and remains intact. As such, the Underburden – HT Butte aquifer, is considered the lower-most aquifer to be impacted by mining.

Mine pits will be backfilled with reclaimed spoils replacing the overburden and D Coal hydrostratigraphic units. Replaced mine spoils will provide a medium for recharge from precipitation and subsurface through-flow from the surrounding undisturbed hydrostratigraphic units. The spoils will likely discharge to the surrounding downgradient undisturbed hydrostratigraphic units once the backfilled spoils become adequately saturated.

The backfilled spoils will likely have a more chaotic distribution of porosity and permeability due to overburden handling and compaction resulting in spatially variable hydraulic conductivities. In general, the spoils initially may have a higher hydraulic conductivity relative to the pre-mining overburden and D Coal units due to mixing and lower bulk density. However, since the overburden is predominately clay and silt with interbedded sandstone, the hydraulic conductivity may decrease to a value similar to that of the claystone and siltstone as the material saturates and compacts further over time (Rehm, et al 1980).

2.5.3.2 Impacts to Ground Water Quality

Ground water quality is expected to change from pre-mining conditions as a result of removal, mixing, and settling of overburden and spoils. Ground water in the backfilled spoils is expected to have increased TSS and TDS, as well as elevated SAR. Increased TSS and TDS are expected to be temporary, with inflowing ground water reaching equilibrium with the replaced materials and returning the current water quality. Groundwater SAR values are elevated in the current (i.e., pre-mine) condition and that is expected to be the case following mining and return to equilibrium conditions.

The increase in TSS is expected to occur from physical disturbance of the materials. As the backfilled materials settle and as natural cements (e.g., calcite cements) again form following contact with ground water, the TSS concentration is expected to decline to current values.

The TDS concentration is expected to increase from the dissolution of natural salts or minerals in the overburden that will be disturbed and exposed during mining. Pre-mining, these minerals salts and minerals exist at equilibrium. Based on literature and observations at other North Dakota coal mine operations, TDS concentrations may increase two to three times relative to pre-mining conditions (Groenewold and Koob 1984). In addition, oxidation of overburden minerals (e.g., pyrite) and subsequent reactions (e.g., buffering or changes in metals solubility or sorption) due to surface exposure may contribute to the increased TDS concentrations. These reactions may also contribute to mobility of specific constituents, such as metals, albeit at low concentrations based on overburden leach test results, as discussed in greater detail in Section 2.3. These impacts are expected to be temporary as the reclaimed spoils settle and re-saturate. A temporary pulse of high TDS concentration is expected as the replaced materials are flushed. Following re-saturation and return of groundwater flow through the area, buffering, sorption, and ion-exchange reactions will occur between the inflowing groundwater and replaced overburden. These reactions will result in a return to equilibrium conditions that currently exist prior to mining. Any oxidation initiated while the materials are at the surface will be inhibited following re-saturation. Equilibrium water quality conditions are expected to be similar to pre-mining water quality.

Current (i.e., pre-mining) SAR values are generally elevated for ground water and most of the overburden materials. Mixing of materials with low and high SAR values (from higher and lower in the overburden column, respectively) is not expected to significantly reduce the SAR values because the majority of materials still have elevated SAR values and the abundance of clay and ion-exchange capacity will quickly contribute more sodium to mixed materials. While some change in SAR may occur due to ion exchange in disturbed clays and mixing of materials, SAR levels are expected to remain elevated following mining, similar to the current equilibrium conditions.

The temporary ground water leakage from a deeper aquifer at the J.K. Ranch Mine of Royal Oak Enterprises north of Dickinson introduced darkly stained water into discharged pit water. It is unknown, at this time if these “black water” conditions will exist at the SHLM. Initial data indicate that black water may be present in some wells in the D Coal and overburden but not in the underburden or HT Butte Coal suggesting that deeper aquifers are likely not the source of observed “black water” in D Seam wells. However, discharge from exposed D Coal and overburden hydrostratigraphic units along pit walls may contribute black water to pit inflows. Any “black water” removed from the mine pits during the mining operation that could ultimately be discharged to the surface water features in the Study Area will first be handled appropriately to meet applicable discharge standards as discussed in Section 3.6.1 of the permit application.

Near-surface ground water quality, particularly associated with plant growth, is not expected to be affected by mining methods because the topsoil and subsoil will be salvaged and replaced separately. As such, current processes affecting water quality in this zone are expected to continue, resulting in similar water quality.

Ground water flowing out of the reclaimed spoils may result in impacts to the Overburden-D Coal aquifer downgradient of the replaced spoils (i.e., to the northeast of the mine pits). However, these downgradient aquifer impacts are expected to be less due to ground water mixing and dilution and cation exchange and sorption within undisturbed materials. Additionally, ground water flow will be predominantly into the reclaimed spoils, towards the cone of depression, until the ground water levels return to pre-mining conditions. At the time discharge from the spoils to downgradient areas occurs, the reclaimed spoils will be closer to, or at, equilibrium conditions, further reducing the impacts to downgradient ground water quality. Vertical gradients between the Underburden – HT Butte and Overburden – D Coal aquifers vary in direction. Upward leakage will prevent migration of impacted ground water from the reclaimed spoils downward into the Underburden – HT Butte aquifer. Any downward leakage that may occur is expected to have a minimal effect on the ground water quality in the Underburden – HT Butte aquifer due to dilution and attenuation.

2.5.3.3 Ground Water Hydrologic Reclamation Plan

The ground water hydrology will be reclaimed by replacing the removed hydrostratigraphic units with spoils composed of mixed overburden. The new spoils hydrostratigraphic unit, in general, will likely have similar recharge, storage, and discharge characteristics as the pre-mining claystone and siltstones. Backfilling with mixed overburden will restore the capability of the land to receive and transmit recharge from precipitation and lateral flow to pre-mining conditions. However, the saturated spoils may not be suitable as an aquifer (i.e., able to provide sufficient water for a specified use) due to the general reduction in hydraulic conductivity. Ground water supplies impacted by mining activities will be supplemented or replaced as required by the regulations.

Restoration of Recharge Capacity

The aquifers in the general vicinity of the Study Area are recharged by precipitation and lateral flow from the southwest. Given the semi-arid environment of the mine site and the region, recharge is likely more limited by the availability of water and less by the physical characteristics of the earth materials (National Research Council 1990). Precipitation rates will not be influenced by mining operations. Water availability from precipitation is therefore assumed to be unchanged. Recharge from lateral flow to the aquifers in the Study Area is influenced by recharge to the upgradient portions of the aquifers which is reported to occur in permeable upland areas remote from the Study Area that are not impacted by the proposed mining activities (Whitehead 1996). Lateral flow is expected to be the more important component of recharge, to restoring water levels, than local recharge by precipitation.

Mining activities will remove the soil, overburden and D Coal resulting in significant mixing of the handled materials and temporarily eliminating the aquifer within the proposed Permit Area. Replacement of the removed overburden material (spoils) is expected to restore the storage and recharge capacities. The approximate recharge capacity or the ability of the soils and underlying materials to allow precipitation and runoff to infiltrate and reach the zone of saturation [NDAC 69-05.2-01-02(84)] will be restored during reclamation by implementing the following:

- The land surface is recontoured and stabilized to the appropriate pre-mining topography;
- The site is revegetated with plants using less or approximately the same quantity of water as pre-mining species;
- Compaction of surface soils and vadose zone materials is minimized; and
- Layers of lower permeability in the pre-mining vadose and saturated zones are broken up and dispersed in the reconstituted vadose zone by the mining and reclamation process.

The implementation techniques listed above are proposed to allow restoration of the recharge capacity to a condition which will support post-mining land use, minimize disturbance to the prevailing hydrologic balance in the mine plan area and in adjacent areas, and provide a rate of recharge that approximates the pre-mining recharge rate.

Restoration and Replacement of Wells and Developed Springs

All wells and developed springs used for ground water supply (i.e., not solely for monitoring purposes) within the pit areas will eventually be destroyed by mining activities. Wells completed in the overburden and D Coal hydrostratigraphic units outside of pit areas and within one mile of pit boundaries may experience a reduction in ground water availability as seen by declining water levels. Wells screened in the underburden and HT Butte coal hydrostratigraphic units may experience insignificant (less than seasonal variation) reduction in water levels. Wells completed in hydrostratigraphic units below the HT Butte will not be impacted by mining activities.

Existing wells and developed springs within approximately two miles of the Permit Boundary are being identified through a well and developed-spring survey program. The survey is intended to document: 1) the condition of wells/springs and other water systems used for human, animal, or agricultural purposes; and 2) the quantity and quality of water where readily available, prior to mining activities (NDAC 69-05.2-17). However, the survey may be limited to the documentation of surface conditions when other data are not readily available. The well and developed-spring certification survey is ongoing and described in more detail in Appendix 2.5-8.

Wells destroyed by mining will be plugged and abandoned prior to destruction in accordance with applicable State rules and regulations, using a certified well driller. The water supplies from these wells will be replaced during reclamation, if consistent with post-mining land use, according to NDCC 38-14.1-24(9) and NDAC 69-05.2.16-17. Wells whose supply is diminished or disrupted in quality or quantity as a result of surface mining activity will receive pump adjustments, improvements, or be supplemented from a supply that will provide the well owner with the same quantity and quality of water that is presently being used or otherwise compensated according to NDCC 38-14.1-24(9) and NDAC 69-05.2.16-17. The ground water monitoring program will identify potentially affected wells before potential impacts interfere with their uses. Table 2.5-4 provides a list of surveyed water supply wells within two miles of the Permit Area and briefly outlines examples of probable hydrologic reclamation actions for those wells that may be adversely affected by mining.

Ground water supplies may be replaced or supplemented with water from several deeper aquifers or surface water from Lake Sakakawea. While the reclaimed spoils hydrostratigraphic unit will receive, transmit, and discharge ground water across broad areas of contact with undisturbed hydrostratigraphic units, the saturated spoils may not be suitable as an aquifer (i.e., to supply water in sufficient quantities for a specific use) and therefore may be unable to serve as source of replacement water. The Upper Ludlow – Lower Tongue River, Upper Hell Creek – Lower Ludlow, or Fox Hills – Lower Hell Creek aquifer systems located below the Underburden – HT Butte aquifer will not be impacted by mining and should be available as a replacement water source if water rights can be acquired. The majority of domestic water supply to residents in and adjacent to the Study Area, including the City of South Heart, is supplied from Lake Sakakawea via the Southwest Pipeline. Water from the pipeline is a viable alternative to lost groundwater supply for residents currently obtaining their drinking water from the pipeline but using ground water for supplemental domestic uses such as lawn watering.

2.5.4 Ground Water Monitoring Plan

Ground water flow and quality will be monitored before mining begins, during mining and during reclamation. Initial monitoring established baseline conditions to describe the ground water hydrology ~~while pre-mining monitoring continues to observe the system prior to mining~~. Monitoring during mining will identify changes in monitored characteristics of ground water resources. Monitoring during reclamation will provide information on post-mining recharge and water quality. The monitoring plan is based on the ground water PHC of the SHLM described above.

2.5.4.1 Baseline Monitoring

Water levels of the significant hydrostratigraphic units in the mine area were measured monthly between November 2006 and October 2007 and quarterly from the first quarter of 2008 though the fourth quarter of 2009. Flows from springs identified in the Study Area were measured or estimated ~~monthly~~ (when present) beginning in the spring of 2007 through ~~October~~ November 200~~7~~9. Water levels and spring flows measured through ~~October~~ December 200~~7~~9 in the Study Area are presented in Appendix 2.5-4. Quarterly ground water quality samples were collected from the monitoring wells beginning with the ~~in the~~ fourth quarter of 2006 through the third quarter of 2008. In 2009, ground water quality samples were collected annually in September. ~~(December), and the first, second and third quarters of 2007 (February, May, and August).~~ In October 2009, two additional wells were installed screening the HT Butte Coal. Water level and water quality data collected from these wells were used to assist with interpretation of ground water hydrology. An attempt was made on a monthly or quarterly basis to collect spring water quality samples beginning in December 2006; however, many of the springs were dry or contained insufficient water for sample collection at the time of the monthly sampling. The results of the water quality analyses are presented in Appendix 2.5-6.

2.5.4.2 Pre-Mining Monitoring

The pre-mining monitoring program consists of the following:

- Following the baseline study period through the third quarter of 2008, ground water levels were measured and water quality samples were collect quarterly.
- Beginning in the fourth quarter of 2008 ground water monitoring has included quarterly measurement of ground water levels and annual water quality sampling and analysis.
- In October 2009, two additional wells were installed screening the HT Butte Coal. Water level and water quality data collected from these wells were used to assist with interpretation of ground water hydrology.

2.5.4.23 Monitoring Monitoring Concurrent with Mining

The monitoring plan concurrent with mining will begin at least one year prior to land disturbance for mining activities and continue throughout the active (i.e., non-reclamation) mining period. The program will consist of quarterly water level measurements and annual water quality samplingThe pre-mining monitoring plan will continue though mining according to the proposed schedule presented in Table 2.5-5. Water levels will be measured quarterly and water quality samples will be collected annually. Water levels and water quality data will be evaluated annually, as part of the annual reporting, and an alternate (i.e., reduced) list of wells and/or parameter list may be substituted if warranted and approved by the PSC. Some monitoring wells will be destroyed by mining. Monitoring will continue at these wells until they are abandoned prior to destruction. Every reasonable effort will be made to monitor wells as scheduled. However, environmental conditions or other issues may prevent scheduled data collection at some locations. These conditions will be recorded in field notes and reports.

2.5.4.43 Post-Mining/Reclamation Monitoring

Monitoring wells will be constructed in reclaimed spoils approximately one to two years after soil re-spreading and seeding is complete. Monitoring wells in reclaimed areas will monitor water levels and water quality in the reclaimed spoils. Generally, these wells will be installed near the location of previous wells destroyed by mining to facilitate pre- and post- mining comparisons. The wells will likely screen the base of the spoils and, if necessary, the Underburden – HT Butte aquifer. These new wells will be sampled for water quality and monitored for water levels on a schedule approved by the PSC as part of the monitoring program.

2.5.4.~~5~~4 Reporting

In accordance with NDAC 69-05.2-16-14, monitoring results will be presented to PSC in quarterly and annual reports or at another frequency approved by the PSC. Quarterly reporting is proposed to begin with the first quarter following commencement of mining. Annual reporting is proposed to begin at the end of the first calendar year following commencement of mining and at least two quarterly reports. The quarterly reports will summarize the water level measurements observed during the quarter. Annual reports will summarize the water level measurements observed over the entire year and will present the annual water quality data. In addition, the annual reports will present any proposed modification to the monitoring plan based on an analysis of the water quality data. These modifications could include changes to monitoring locations, frequency of monitoring, and monitoring parameters.

TABLES

FIGURES

APPENDICES

APPENDIX 2.5-1

MONITORING WELL BOREHOLE AND CONSTRUCTION SUMMARY

APPENDIX 2.5-2

MONITORING WELL LITHOLOGIC BORING LOGS

APPENDIX 2.5-3

MONITORING WELL GEOPHYSICS LOGS

APPENDIX 2.5-4

WATER LEVELS AND SEEP AND SPRING FLOWS

APPENDIX 2.5-5

AQUIFER TESTING AT THE SOUTH HEART LIGNITE MINE

APPENDIX 2.5-6

GROUND WATER QUALITY

APPENDIX 2.5-7

BOREHOLES CONSIDERED FOR INTERPRETATION OF HYDROGEOLOGY

APPENDIX 2.5-8

WELL CERTIFICATION