COYOTE CREEK

ALLUVIAL VALLEY FLOOR STUDY

Dakota Westmoreland Corporation

October 2009 Revision

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EXHIBITS **No.**

INTRODUCTION

A. PURPOSE

In response to the North Dakota Public Service Commission's review of Dakota Westmoreland Corporation's (DWC) revision 22 to mining permit KRSB-8603, an initial investigation of stream valleys within and adjacent to the permit revision areas was undertaken to ascertain if alluvial valley floors may exist within any of the stream valleys. The eastern and western segments of the initial identification areas identified on Exhibit 1 include the permit revision areas and adjacent areas. The eastern segment includes all or portions of Sections 14, 15, 22, and 23, T.143N., R.88W. The western segment includes all or portions of Sections 18, 19, 20, 30, and 31, T.143N., R. 88 W., and Sections 13, 14, 24, and 25, T.143N., R. 89 W. Revision 22 encompasses all or portions of Sections 15, 19, 20, and 22, T.143N., R.88W .

The western segment of the initial investigation area contains several stream valleys of an ephemeral, intermittent, or perennial nature. All of the stream valleys with the exception of Coyote Creek have ephemeral or intermittent flow characteristics. It is doubtful that the ephemeral stream valleys have the alluvium, or streamlaid deposits, required for alluvial valley floors. None of these lesser stream valleys have any agricultural development such as that found along portions of Coyote Creek. Limited space for agricultural crops on valley bottoms and limited water volumes are certainly disincentives for agricultural development in these sites. Our initial investigation has therefore categorically excluded all areas except the Coyote Creek stream valley from consideration as alluvial valley floors.

Identical conclusions have been reached in the eastern segment of the initial investigation area, where Brush Creek is the only perennial stream. However, Brush Creek had previously been evaluated for alluvial valley floor (AVF) status. In October 1985, Knife River Coal Mining Company submitted an AVF study for Brush Creek as part of the application for mining permit KRSB-8603. The study area was not described specifically, but the study information was essentially derived from the area containing Quarternary alluvium (see Exhibit 2.9.1 in Permit KRSB-8603). Based on the study, the Public Service Commission found that the Brush Creek stream valley did not contain an AVF. Therefore, the eastern segment of the initial investigation area did not receive further attention. This study for Coyote Creek will consider the same issues as the Brush Creek study.

As a result of our initial investigation, the Coyote Creek stream valley has been identified as a potential alluvial valley floor lying adjacent to the permit area which may be influenced by mining activities within the permit area. This stream valley lies in an area adjacent to the western segment of the permit revision area. This focused study is a reconnaissance identification study aimed at determining if an alluvial valley floor exists within the Coyote Creek stream valley. The ultimate goal, as expressed by the Office of Surface Mining's Alluvial Valley Floor Identification and Study Guidelines (U.S. Office of Surface Mining, 1983) is "to identify stream valleys which have agricultural importance and where that importance is derived from the water available in those valleys." The area of study for Coyote Creek is shown on Exhibit 1 and encompasses all or portions of Sections 19, 30, and 31 T.143N, R.88W., and Sections 13, 14, and 24, T.143N., R.89W.

A reconnaissance-level study by the Office of Surface Mining Reclamation and Enforcement looked at stream valleys in west-central North Dakota and in other states to "identify surface irrigated and subirrigated sites in the West to develop an understanding, from a regional perspective, of the types of stream valleys that may be studied further for consideration as alluvial valley floors" (U.S. Office of Surface Mining, 1985). Coyote Creek was included in one of the study areas and classified as a major tributary to a large perennial stream (i.e., the Knife River). The study noted that water availability on these streams limits surface irrigation, if it is at all possible, and that natural flood irrigation and subirrigation are important features. The study concluded that portions of higher terraces along Coyote Creek could be flood irrigated by spreading and/or pumping water. Another conclusion was that deep-rooting alfalfa probably receives beneficial moisture through subirrigation. The study utilized field investigations, supplemented by interviews with agricultural producers, information from regulatory and land management agencies, from published reports, and from aerial photographs and Landsat imagery.

B. REGULATORY BACKGROUND

The Code of Federal Regulations (CFR) defines an alluvial valley floor as

> *the unconsolidated stream-laid deposits holding streams with water availability sufficient for subirrigation or flood irrigation agricultural activities but does not include upland areas which are generally overlain by a thin veneer of colluvial deposits composed chiefly of debris from sheet erosion, deposits formed by concentrated runoff or slope wash, together with talus, or other mass-movement accumulations, and windblown deposits.* (30 CFR 701.5)

The study objective is to gather readily available information in order to determine if both geologic and hydrologic criteria defining alluvial valley floors can be satisfied. The criteria are satisfied when the following two points from Part 822 of Title 30 of the CFR are affirmed.

1. *Unconsolidated streamlaid deposits are present*

2. *Sufficient water is available to support agricultural activities, as evidenced by:*
   - *The existence of flood irrigation*
   - *The capability of an area to be flood irrigated, based on evaluations of typical regional agricultural practices, historical flood irrigation, streamflow, water quality, soils, and topography; or*
   - *Subirrigation of the lands in question derived from the ground-water system of the valley floor*

If an affirmative response is given to both criteria, the next step is to determine whether any statutory exclusions in Part 822 apply. If statutory exclusions do not apply, the permittee will provide permit application information to be used by the regulatory authority in its decisionmaking in the granting of a permit. Five points will be considered by the regulatory authority.

1. *The characteristics of the alluvial valley floor which are necessary to preserve the essential hydrologic functions throughout the mining and reclamation process;*

2. *Whether the operation will avoid during mining and reclamation the interruption, discontinuance, or preclusion of farming on the alluvial valley floor;*

3. *Whether the operation will cause material damage to the quantity or quality of surface or ground waters supplied to the alluvial valley floor;*

4. *Whether the reclamation plan is in compliance with requirements of the SMCRA, the Code of Federal Regulations (CFR), and North Dakota regulations,*

5. *Whether the proposed monitoring system will provide sufficient information to measure compliance with Part 822 during and after mining and reclamation operations.*

C. STUDY AREA

This study is a reconnaissance effort to provide information to aid in determining the existence of an alluvial valley floor within the Coyote Creek stream valley. The 560-acre study area is that portion coincident with the Coyote Creek stream valley floodplain as defined on Exhibit 1 within Sections 19, 30, and 31, T.143.N., R.88W., and Sections 13, 14, and 24, T.143N., R.89W. The floodplain was initially defined by referencing topographic contour resources and refined by groundtruthing that considered topography and evidence of streamworking and flooding. Evidence remaining after the major flooding this spring was also helpful in defining the study area.

1. GEOLOGIC INVENTORY

The following geologic data has been extracted from mine permit KRSB-8603 for the Beulah Mine. The data was last updated is November of 2008 (revision 22 to permit KRSB-8603). All exhibits referenced within this section can be found in mine permit KRSB-8603. The summarization of geology below represents a detailed characterization of the Brush Creek, Knife River, and Coyote Creek drainages. The permit area, as mentioned within the summary, can be found on Exhibit 1 (Area Map) within the AVF study report.

A. REGIONAL GEOLOGIC SETTING

1. Physiography and Topography

The permit area is located in the glaciated portion of the Missouri Plateau section of the Great Plains Physiographic Province. The topography in the area is characterized by gently rolling to hummocky upland surfaces with occasional prominent buttes rising as much as 200 feet above the surrounding land surface. These uplands are dissected by a series of generally northwesterly to southeasterly trending glacial meltwater channels which often contain small underfit intermittent streams which are tributaries of the Knife River. The Knife River is the master river in this area flowing northeasterly to its confluence with the Missouri River about twenty miles northeast of the town of Beulah. Maximum relief in the area is on the order of 400 feet.

2. Geology

The permit area lies within the southeastern portion of the Williston structural basin, and is underlain by 11,000 to 12,000 feet of sedimentary rocks which have a general regional dip of about one degree to the northwest. This sedimentary column consists of varying thickness of interbedded sandstone, shale, limestone, dolomite, and evaporites (Carlson and Anderson, 1970).

Paleozoic and Mesozoic units, including and underlying the Pierre Shale of late Cretaceous age, comprise about 80% of the sedimentary thickness in the area. Other than the Pierre, which reaches a thickness of about 2000 feet and forms an effective regional aquitard, these units are not relevant to the mining of the permit area nor the impacts of that mining.

Directly overlying the Pierre Formation are the youngest cretaceous units, the Fox Hills and Hell Creek Formations, which serve as important regional aquifers. The Fox Hills Formation was deposited in a very shallow sea with the uppermost member, the Colgate, being the last in this marine sequence. Subsequently, the seas retreated and, after erosion, the Hell Creek was deposited on stream flood plains and adjacent swamps, creating a series of sandstones and sandy shales, with some lignites. Occasional intrusions of brackish sea water resulted in the deposition of the Breien Member, a marine, glauconitic sandstone (Frye, 1969).

Cenozoic deposition began with the Ludlow Formation which is included with the other Tertiary Formations in the Fort Union Group. The Ludlow and Cannonball Formations represent the final sea transgression. These formations likely represent and intertonguing (Carlson, 1973), and a transition from the swamp deposits of the Ludlow to the marine-deposited Cannonball. As a consequence, the Ludlow consists of shales, siltstones, and lignites whereas the Cannonball varies from sandstones and shales to lenticular limestones (Carlson, 1973).

The Bullion Creek and Sentinel Butte Formations are the upper units of the Fort Union Group. The Toungue River Formation which represents the transition from the marine Cannonball below to the terrigenous Sentinel Butte above, consists of sandstones and shales with lignite, especially near its contact with Sentinel butte.

The Sentinel Butte Formation consists of interbedded sand, silt, clay and lignite and contains the most extensive coal deposits in the region. The sands are generally confined to basal and upper members. Of the lignite beds, the Beulah-Zap bed is the most persistent in quantity and quality in the Knife River area (Benson, 1952), and is currently being mined at the Knife River Coal Mining Company's Beulah Mine. Several other beds have been identified stratigraphically above and below the Beulah-Zap (Groenwold, et al., 1979). Among these is the Schoolhouse bed, which lies 45 to 50 feet above the Beulah-Zap and is also being mined at the Beulah Mine. Lignite from these beds is typically tough, compact and black to dark brown in color. Texture is often woody and fibrous, and carbonized logs and plant stems are common.

Erosion of the upland surfaces to the west and subsequent fluvial processes resulted in the deposition of the Golden Valley Formation at the top of the Fort Union Group. The Golden Valley Formation consists of siltstones and kaolinitic claystones grading upward to clayey sandstone.

Substantial erosion associated with Black Hills uplift removed much of the golden Valley Formation from the immediate vicinity of the permit area, but several outcrops have been observed to the west and the southwest (Carlson, 1973).

Surficial sediments in this region, other than bedrock, generally consist of till in the uplands, colluvium and alluvium along the valley slopes and meltwater channel bottoms, and scattered localized eolian sands and silts.

B. GEOLOGY OF THE PERMIT AREA

1. Stratigraphy

The coal seam of primary mining interest in the West Brush Creek Development Area as throughout the Beulah Mine is the Beulah-Zap bed of the Sentinel Butte Formation. The Sentinel Butte Formation of Paleocene Age is the only bedrock unit exposed in the permit area and is generally mantled by 10-20 feet of till except along sides of draws where the glacial sediment has been removed by erosion.

Exhibits 2.1.5a and 2.1.5b show diagrammatic cross sections including the permit area and adjacent area which depict the Beulah-Zap bed and its relationship to the overlying and underlying sediments. In an effort to present the maximum amount of information, the entire thickness drilled has been depicted for each drill hole. Due to the highly variable bottom hole elevations and the subtle variations in sediment type, however, no attempt has been made to correlate units from hole to hole below the lowest correlative lignite bed. Exhibit 2.1.7 shows the locations of these cross sections and the lithologic logs for these test holes are presented in Exhibit 2.1.2. All available geophysical logs for the permit area are contained in Exhibit 2.1.1.

Exploration drilling in the general area commonly penetrated the Spaer bed, the first lignite below the Beulah-Zap and also the first zone of significant permeability below the proposed mining disturbance. The following discussions of the site specific geology will focus on the stratigraphic intervals above and including the Spaer which will be disturbed or otherwise potentially affected by mining.

Moran, et al. (1978) established the practice of defining a lignite interval as those materials extending from the base of named lignite to the base of the next overlying named lignite. This practice will be followed here and discussion will begin with the Spaer interval deeper geologic units. Because of their potential as replacement water sources, will be discussed under Groundwater Hydrology (Section 2.3).

Spaer Interval

The Spaer Bed is traceable throughout the permit and adjacent areas where sufficient subsurface information exists. It occurs as a single continuous seam of lignite coal averaging two to four feet in thickness. Lithologically, the remainder of the Spaer interval is a highly variable mixture of moderately consolidated sediments ranging from silty-clay to sandy-silt with minor amounts of sand and limestone. Fine to very fine sandy-silt is probably the most predominant overall lithology. This interval appears to coarsen somewhat from north-south across the permit area. The Spaer bed as well as the overlying Beulah-Zap and Schoolhouse beds to be discussed below is a part of the Sentinel Butte Formation.

Beulah-Zap Interval

The Beulah-Zap bed is a thick and laterally continuous lignite which is present throughout the permit and general areas unless it has been removed by erosion. Within the permit area the Beulah-Zap bed averages an almost constant 12 feet in thickness with no splits or partings. The remainder of the Beulah- Zap interval is approximately 50 feet thick, where present in its entirety. This entire interval is present beneath most of the southern 2/3 of the permit area south of the line between test holes 965 and 969 (see Exhibit 2.1.7).

The lithology of this interval is a highly variable mixture of sandy silt-silty sand, clayey silt-silty clay, sand, and limestone. With the exception of the limestone, these sediments are moderately consolidated. Throughout most of the permit area sandy silt-silty sand is the predominant lithology and in most test holes an upward coarsening can be observed.

Schoolhouse Interval

The uppermost lignite bed within the permit area, the Schoolhouse, is believed to be of mineable quality only in the NE1/4 of Section 21 and NW1/4 of Section 22. The Schoolhouse lignite is commonly split into an upper and lower Seam averaging 3 and 4 feet in thickness respectively. These two seams are separated by 6 to 10 feet of sandy silt to silty clay.

The entire Schoolhouse interval was encountered near the southern boundary of the permit area and a good subsurface exposure of this interval is in the vicinity of test holes 1017-1019 where the total remaining thickness is about 65 feet. As with the underlying Beulah-Zap interval, a general upward coarsening from clayey silt-silty clay to sandy silt-silty sand or sand can be observed in these test holes.

The pebble-loam (till) of the Pleistocene Coleharbor Group unconformably overlies the Schoolhouse interval throughout the uplands of the general area and permit area as well. Within the permit area itself the thickness of this unit ranges up to 30 feet and averages about 20 feet. Lithologically, this pebble-loan contains a large portion of silt and clay and relatively few cobbles and boulders.

In general, the thickness of the entire overburden column increases uniformly across the permit area from northwest to southeast ranging from about 40 to 130 feet (See Exhibit 2.1.6).

2. Overburden and Coal Quality

The thickness of overburden to the top of the Beulah-Zap seam is depicted on Exhibit 2.1.6. The overburden within the permit area consists of the sediments of Beulah-Zap and Schoolhouse intervals and the pebble-loam of the Coleharbor Formation described above. During an exploration drilling program conducted in the summer of 1979, cuttings were collected at five-foot intervals from selected drill holes and analyzed for pH, EC, SAR, K, Na, P, net alkalinity, grain size distribution and nitrate nitrogen. The results of these analyses are presented in Exhibit 2.1.3 and sampling locations are shown on Exhibit 2.1.7. Table 2.1.1 presents the mean SAR value calculated for each of these test holes, including only those materials above the top of the Beulah-Zap lignite.

Table 2.1.1 Average SAR Values for Materials Above the Beulah Zap Lignite

Test Hole Number	Mean SAR
954	10.96
955	4.77
956	5.10
957	7.49
965	15.56
966	12.22
967	14.38
969	4.33
978	7.60
979	5.46
980	1.35
1005	18.35
1006	24.74
1007	16.62
1008	9.38
1009	14.28
1017	17.66
1018	19.35
1019	18.53
1020	15.25
1021	16.49

In general these mean SAR values increase from north to south across the permit area as the proportion of glacial sediment in the overburden column decreases in relationship to the proportion of bedrock sediment.

Analyses of the coal quality from selected drill holes are presented in Exhibit 2.1.4. These analyses indicate that the Beulah-Zap bed is of commercial quality throughout the permit area.

3. Structure

Exhibit 2.1.8 is a structure contour map drawn on the top of the Beulah-Zap lignite bed. An examination of this map reveals that the dip of the Beulah- Zap bed in the permit area averages about 1 degree and often less, approaching 2 degrees only at its steepest. As would be expected, the strike of the bed is highly variable, but a few general structural patterns are discernible.

Near the center of Section 16, in the area of the NE-SW box-cut pit, the bed strikes to the NE and dips to the SW at about 1 degree. A topographic high exists near the center of the NW1/4 of Section 21 with an elevation of 1970 feet. Dips are away from this high at about 1 degree, decreasing considerably to the north, west, and south. East of this high, through the NE1/4 of Section 21 and into the SE1/4 of Section 16, the Beulah-Zap bed strikes northerly, dipping at about 1 degree, with the strike gradually becoming northwesterly approaching the structural low in the SE1/4 of Section 16.

Exhibit 2.1.8 also shows the limit of the presently mineable coal (cropline) within the permit area. This boundary exists only at the north end of the proposed mining area where the Beulah-Zap bed has been removed by erosion. To the west, south, and east, this bed continues intact.

4. Geomorphology

The permit area is a gently rolling upland dissected in its northeast portion by a steep-sided draw which contains an intermittent tributary of Brush Creek. The heads of similar draws also extend into the permit area near its NW and SW corners, but provide far less relief (See Exhibit 2.1.8).

The highest elevation on the upland occurs near the SE corner of the permit area at about 2090 feet and from here the land slopes to the west and north at about 50-80 feet per mile. The head of the major draw originates near the south end of the centerline of Section 16 at an elevation of about 2000 feet and from here the draw runs north and then northwest, exiting the permit area near its northeast corner at an elevation of about 1860 feet. The side slopes of this draw in its steepest portions are on the order of 15 degrees.

This upland area has been mapped by Carlson (1973) as ground moraine ad further described by Clayton (1980) as "thin glacial sediment draped over and only slightly modifying the non-glacial topography existing before the last glacial advance." These descriptions are confirmed by the geologic cross sections which show that the glacial sediment does not create constructional topography. The pebble-loam has been removed along the sides of the draws where the sediments of the Sentinel Butte Formation are exposed, mantled with a foot or two of soil. Most of the upland area is veneered with wind-blown sand and silt of the Oahe Formation which is too thin to map or show in cross section.

C. INTERPRETATIONS RELATED TO COYOTE CREEK STREAM VALLEY

Stream valleys with the watershed size and other characteristics of the Coyote Creek stream valley are usually underlain by unconsolidated streamlaid deposits. For the purposes of this study, we assume this to be the case. Stream valley characteristics for Coyote Creek provide supporting evidence. For instance, oxbow lakes and truncated meanders are common throughout the length of the study area. Evidence of deposition of suspended and bed load was frequently observed during the site surveys throughout the length of the study area. Deposits of a foot or more of sediment were often found on points within and outside of the stream channel after the spring 2009 flood.

The general topography of the Coyote Creek stream valley and surrounding area is presented on the USGS topographic quad map composite appearing as Exhibit 2. A more detailed presentation of topographic contours for part of the area can be found in Exhibit 3. The cross-section in Exhibit 3 depicts a nearly level floodplain by scarp on one side and the toe of long, gradual slopes on the other side. The width of the study area (floodplain) varies considerably, but the most extensive arable portions, like that at the cross-section position, are in the vicinity of 1,200 to 1,500 feet wide. Similarly variable, channel width probably ranges from 50 to over 100 feet. The location and elevation of the nearest coal bed contours for the Beulah-Zap and Spaer coal beds and outcrop for the Schoolhouse coal bed has been developed from potentiometric maps in Permit KRSB-8603 and plotted on Exhibit 3.

2. GROUNDWATER HYDROLOGY

The following groundwater hydrologic data has been extracted from mine permit KRSB-8603 for the Beulah Mine. The data was last updated is November of 2008 (revision 22 to permit KRSB-8603), and includes additional information specific to the Coyote Creek drainage system. Watersheds for Coyote Creek, as well as Brush Creek and the Knife River, appear on Exhibit 1. All Exhibits referenced within this section can be found in mine permit KRSB-8603. The summarization of groundwater hydrogeology below represents a detailed characterization of the Brush Creek, Knife River, and Coyote Creek drainages. The permit area, as mentioned within the summary, can be found on Exhibit 1 (Area Map) within the AVF.

A. REGIONAL HYDROLOGY

The following narrative, synthesized mainly from Croft (1970), describes the hydrostratigraphy and hydrologic properties of the major water bearing units which represent potential replacement sources for water supplies which are adversely impacted by mining. A brief description of the geology of these units is contained in Section 2.1.A.

Upper Hell Creek and Lower Cannonball-Ludlow Aquifer

Fine to medium grained sandstones in the upper part of the Hell Creek and lower part of the Cannonball-Ludlow Formations form a regional aquifer in the Mercer County area. This aquifer underlies the permit area at a depth of about 800 feet. Transmissivity values on the order of $2.6(10^{-5})\ m^2 \cdot s^{-1}$ to $6(10^{-4})\ m^2 \cdot s^{-1}$ have been calculated for this aquifer, and wells tapping this unit should produce from 5 to 100 gpm. Chemically the water in this aquifer is very similar to that in the Fox Hills-Basal Hell Creek aquifer which lies beneath.

Fox Hills-Basal Hell Creek Aquifer

Sandstone units in the Upper Fox Hills and Basal Hell Creek Formations form an extensive regional aquifer which underlies the permit area at depths ranging from 1000 to 1300 feet. These fine to medium grained sandstones are interbedded with siltstones and claystones and the total aquifer thickness varies from about 150 to 350 feet (Croft, 1970).

Based on a series of recovery tests, a hydraulic conductivity ranging from $5.0(10^{-7})\ m \cdot s^{-1}$ to $5.6(10^{-5})\ m \cdot s^{-1}$ and averaging $7.4(10^{-6})\ m \cdot s^{-1}$ was calculated. Specific capacities for these wells average 0.3 gpm/foot, and the storage coefficient ranged from 0.0001 to 0.00001.

Water quality in the Fox Hills-Basal Hell Creek aquifer is a sodium bicarbonate type with a TDS range between 1200 and 2000 mg/l.

Lower Bullion Creek Aquifer

The last major regional aquifer of interest with respect to this permit is the Lower Bullion Creek aquifer. The areal extent of the Lower Bullion Creek aquifer zone is much more limited than that of the other major aquifers, being restricted largely to the Knife River Basin and adjacent areas to the north and south.

The lower part of the Bullion Creek Formation consists of numerous discontinuous sand units rather than a single widespread unit. The total composite thickness varies from 0-200 feet and includes sand units within the Hanson, Harmon, and Weller Slough intervals. This composite sand unit is referred to as an "aquifer zone" rather than as a distinct aquifer.

There is a very limited amount of data on the hydraulic properties of the Lower Bullion Creek aquifer zone within the Knife River basin. Several cores were analyzed from Dunn County and these cores showed an average hydraulic conductivity of $4.0(10^{-7})\ m^2{\cdot}s^{-1}$. Water production from this zone seldom exceeds 10 gallons per minute.

The potentiometric levels in aquifers in the Sentinel Butte Formation are generally higher than those in the Lower Bullion Creek aquifer zone. The potentiometric levels in the Upper Hell Creek and Lower Cannonball-Ludlow aquifer are also generally higher than those in the Lower Bullion Creek aquifer zone. It is evident, therefore, that water flows downward into the Lower Bullion Creek from overlying aquifers and upward into it from underlying aquifers and that the Lower Bullion Creek aquifer zone functions as a regional groundwater sink.

B. HYDROGEOLOGY OF THE GENERAL, ADJACENT AND PERMIT AREA

1. Introduction

Hydrologic instrumentation of the permit and general area was initiated in 1979 in conjunction with the exploration program which provided much of the information presented in the geology section of this permit application. Monitoring wells in the 900 and 1000 series were installed at that time along with a water quality monitoring program for selected wells. Additional monitoring wells in the 1300, 1400, 1500, and 1700 series were installed during the years 1984, 1985, 1986, and 1990, respectively. Four wells (2001-2004) were installed in 2004 to monitor Section 15, T.143N, R.88W. Wells 2005 through 2014 were installed in 2005 to monitor the area added to this permit with Revision No. 19. In October, 2008, nine new wells (2020-2028) were installed to monitor both the groundwater quality and the static water levels in the area added to the permit via Revision No. 22. Wells 2020-2025 were drilled in two cluster locations in Section 22, T143N, R88W and wells 2026-2028 in one cluster in Section 21. Static water levels readings will begin in 2009 1st quarter and well quality sampling in the 4th quarter. Most wells have been sampled at least once for water quality and selected wells have had single well response tests performed in order to determine hydraulic conductivity. Their locations are shown on Exhibit 2.3.1, Groundwater Monitoring Sites. All of the wells shown in yellow on this exhibit have been mined through, destroyed, or abandoned due to casing or grout failure.

The geophysical logs, drilling logs and original completion reports for these wells are included in Exhibits 2.1.1 and Exhibit 2.1.2. Well completion summaries are presented in this section as Exhibit 2.3.2.

The hydrostratigraphy of those units which will be disturbed or otherwise potentially impacted by mining is defined by the geology of the lignite intervals as described in Section 2.1. In the permit and general areas, the fractured lignite beds are the most permeable near-surface units, sometimes providing water for domestic uses or livestock watering while the intervening sediments function as aquitards.

In general terms the permit area could be considered a recharge area as indicated by the falling potentiometric head with depth at the paired or nested piezometer locations. How much actual groundwater recharge (net addition of water to the zone of saturation) is actually occurring within the permit area is difficult to quantify; however, previous studies of groundwater recharge in western North Dakota have found that recharge is both spatially and temporally variable (Rehm et. al., 1980). The higher potentiometric levels to the south and west and the fact that the Beulah-Zap bed is unsaturated near the center of Section 16, suggest that groundwater recharge may be greater in the adjacent area than within the permit area itself.

Recharge to the Schoolhouse Bed is by vertical infiltration during exceptional precipitation or snowmelt events; the Schoolhouse Bed discharges where it outcrops to form springs or sloughs and by slow vertical leakage to the underlying sediments. The Beulah-Zap and Spaer Beds are recharged by direct infiltration and leakage from overlying saturated sediments. Within the permit area, the Beulah-Zap Bed discharges as spring flow and by vertical leakage. Due to its greater depth, no springs associated with the Spaer Bed have been observed in the general area; with the exception of spring 17ABB-W/SP (located ½ mile north of the permit boundary). Typically discharge from this bed is by slow leakage to the underlying sediments.

A series of single-well drawdown tests were used to define the hydraulic conductivities of the Schoolhouse, Beulah-Zap, and Spaer lignite beds. The results of these tests are discussed below for the individual beds.

No site specific testing was conducted to determine storativity or specific yield values within the permit area. Previous pump testing and computer modeling suggest that storativities of about 0.0005 to 0.00001 and specific yields of about 0.01 to 0.07 are reasonable for the lignite aquifers of the upper Great Plains (Rehm et. al., 1980).

2. Twin Buttes Bed

The Twin Buttes bed overlies the Schoolhouse Bed south of the permit area It reaches a maximum thickness of about 5 feet in T. 143 N. R. 90 W., and in scattered localities north and south of that area (R. A. Brant, 1953). Geologically, the bed is located between 90 and 110 feet above the Schoolhouse lignite. (C.G. Carlson, 1973). The Twin Buttes lignite is not present within the proposed permit area, and is located up gradient and isolated from mining activities.

3. Schoolhouse Bed

The Schoolhouse bed overlies the Beulah-Zap bed throughout most portions of the permit area, most specifically in the east halves of SE¼ of Section 16 and NE¼ of Section 21. It reaches a maximum depth of just over 90 feet near monitoring well 1441, in the extreme southeastern corner of the permit area and subcrops near the surface to form the slough in the SW¼ of the NW¼ of Section 21 (Weil Slough). This slough has not been mined through but has been replaced with Pond 87. Its outcrop is represented by springs in the area of the valley fill, as shown on Exhibit 3.6.4. Generally, the Schoolhouse bed ranges from about 20 to 50 feet in depth.

Due to its high permeability relative to the underlying sediments of the Beulah-Zap interval, the Schoolhouse bed is typically partially saturated, forming a perched water table. It is likely that this perched water table merges with the true water table (potentiometric surface) somewhere in the southeastern corner of the permit area where the Schoolhouse bed is found at greater depth; however, there is not sufficient instrumentation in place to substantiate this.

Piezometers were installed in the lower split of the Schoolhouse bed at selected locations. The October 1985 static water levels from those observation wells were used to produce the potentiometric map presented here as Exhibit 2.3.3. This map shows the highest potentiometric levels throughout most of the N½ of Section 21, with levels decreasing and the gradient steepening to the northeast away from a potentiometric high located near well 1447. Evidence collected since 1985 further supports this. Table 2.3.1 displays the groundwater potential above the top of the Schoolhouse bed at monitoring wells 1372, 1395, 1444, 1447, and 1448.

Table 2.3.1
Groundwater Potential of Selected Wells

Well	Top of Coal – BLS (ft)	(1979-2004) Average SWL – BLS (ft)	Average Water Level Above Top of Coal
1372	12.0	13.11	-1.11
1395	26.0	25.16	.84
1444	52.0	47.13	4.87
1447	31.5	26.72	4.78
1448	31.0	26.16	4.84

BLS – Below Land Surface
SWL – Static Water Level

The higher water levels above the coal at wells 1444, 1447, and 1448 indicate increased potentials south of the permit area where the Schoolhouse bed is deeper and the overlying saturated thickness is greater. All of the wells listed in Table 2.3.1 have since been either mined through or destroyed. The water levels for all wells within the permit area are shown in Exhibit 2.3.5.

Water quality within the Schoolhouse bed, as illustrated by a series of samples taken from well 1394, 1444, 1447, and 1448, varies greatly, even for sampling locations in relatively close proximity of each other. Total dissolved solids values for this group range from an average of 700 mg/l at well 1444 to 7713 mg/l at 1448. It is likely, however, that the samples from 1448 and 1394, while they were in existence prior to mining, were influenced by interaction with evaporation-affected water from the nearby slough; the analyses from wells 1447 and 1444 are probably more representative of the quality of water in the Schoolhouse bed. Well 1444 has an average TDS of 700 mg/l consisting of a sodium bicarbonate sulfate type water with an average SAR of 21, whereas well 1447 has an average TDS of 2814 mg/l consisting of calcium magnesium sulfate type water with an average SAR of 1.8 (see Exhibit 2.3.6).

Hydraulic conductivity and transmissivity values for three piezometers in the Schoolhouse bed show two orders of magnitude difference, ranging from $3.1(10^{-5})$ to $2.6(10^{-7})$ $(m \cdot s^{-1})$ and $2.4\ (10^{-5})$ to $3.2\ (10^{-7})(m^2 \cdot s^{-1})$, respectively.

4. Beulah-Zap Bed

Hydrologically, the Beulah-Zap bed shows considerably more variation than the Schoolhouse, it occurs within the permit area as a confined aquifer, a partially saturated water table aquifer, and in a dry condition. Outside of and along the southern perimeter of the permit area, the Beulah-Zap bed is saturated, with potentiometric levels ranging from 2 to 33 feet above the top of the coal in the vicinity of well nos. 959, 2011, 1732, 1441, and 1445. Because the B-Z bed is saturated along the southern perimeter, sands located above this lignite bed typically act as an aquifer for the groundwater. If these sands are tapped by wells or are exposed to the surface, which then function as springs, they can serve as sources of stock, domestic, and possible irrigation water. To the north, along the west edge of the Red pit box-cut (wells 1358, 1359 and 1360), the coal is partially saturated; whereas near the northwestern (wells 2005, 2006, and 2007) and eastern (wells 2001, 2004, and 2013) areas of the permit, (wells. 1446, 1373 and 1371) the seam is dry.

The potentiometric contours on Exhibit 2.3.4 indicate that flow is generally to the east throughout most of the area, becoming more northeasterly in the NE¼ of Section 21. The highest potentiometric contour exists in S½ of Section 17 and N½ of Section 20. Caution should be exercised when interpreting flow directions from these contours; head loss and change from confined to unconfined conditions in the E½ of Sections 17 and 20 suggest a vertical component of flow in this area. The flow directions for the Beulah-Zap and Schoolhouse beds are similar throughout the NE¼ of Section 21 and the SE¼ of Section 16, although the gradient in the Schoolhouse steepens to the northeast, the potentiometric surface of the Beulah-Zap levels out probably due to the moderating effect of confined hydrostatic pressure in the Beulah-Zap bed.

Transmissivities and hydraulic conductivities for the Beulah-Zap bed were calculated based on bailer tests conducted at wells 1358, 1360 and 1443. These values show a variation of four orders of magnitude, suggesting that the calculated transmissivity and hydraulic conductivity values are largely a function of the degree of fracturing at the particular location. At these locations hydraulic conductivity values ranged from a high of $2.9(10^{-5})$ $m{\cdot}s^{-1}$ to a low of $3.0(10^{-9})$ $m{\cdot}s^{-1}$. Previous work (Rehm, et al., 1980) suggests that hydraulic conductivity values on the order of $3(10^{-6})$ $m{\cdot}s^{-1}$ to $3(10^{-7})$ $m{\cdot}s^{-1}$ are typical of North Dakota lignite. (See Table 2.3.2)

Chemically, the waters in the Beulah-Zap bed in the general area display both similarities and differences.

One of the most consistent parameters is pH, which usually ranges from about 6.5 to 7.5, except near the southern permit boundary where extremely high average pH values of 8.4 to 12.2 are found at well nos. 1441 and 1443, respectively. Well 1443 was abandoned in 1989 due to well grout failure which affected the pH and chemistry. Temperature is relatively consistent, around 8-12ºC. Total dissolved solids are one of the more variable qualities, ranging from around 1,300 to 7,400 mg/l. Most TDS values fall in the 2000 to 4000 mg/l range with few exceeding 5000 mg/l

Sodium is the dominant cation in the Beulah-Zap waters, usually exceeding the combined concentrations of calcium and magnesium by an order of magnitude; sodium concentrations from 500 to 1000 mg/l are common. Sulfate and bicarbonate are the predominant anions having a combined concentration of approximately 2000 mg/l with one anion or the other occurring in the concentration by a factor of approximately 2 to 1. Sulfate concentrations as high as 4500 mg/l and bicarbonate concentrations as high as 1572 mg/l have been observed.

5. Spaer Bed

The Spaer lignite occurs throughout the permit area at a depth of between 20 and 40 feet below the base of the Beulah-Zap lignite. The interval, or aquatard, separating the Beulah-Zap and Spaer lignite consists of relatively tight silty clay with a permeability ranging between 10^{-8} and 10^{-9} cm/sec. Similar stratigraphy occurs east of the permit area in permit KRSB-8802.

Four piezometers in the Spaer Bed (wells 1440, 1442, 1526 and 1527) were used to define the hydrology of the next water bearing zone below the Beulah-Zap lignite. Wells 1440 and 1442 were destroyed in 1994 and 1990, respectively. Well 1731 was installed as a replacement of 1442 when it was destroyed in 1990. Wells 2008, 2012, and 2014 were installed in 2005 to further define the hydrologic properties of the Spaer. Exhibit 2.3.10 is a potentiometric map of the Spaer which shows the potentiometric surface declining from a high in the center of Section 20 declining in both westerly and easterly directions. The data essentially shows flow moving west and northwest towards Coyote Creek and east towards Brush Creek. (See Table 2.3.2.)

The Spaer lignite averages approximately three feet in thickness. The Spaer is not used as a water supply in this area. The source of recharge to the Spaer and all other water bearing strata within the area occurs to the south of the permit area. The Spaer is confined in the southern extension of the permit area as demonstrated in wells 1526, 2008, 2012, and 2014. To the north, the Spaer transitions to an unconfined or dry condition, as demonstrated by well 1527. North of the permit area, the Spaer outcrops, and should discharge in valleys located north (Sections 17 and 18) of the permit area. For the exception of Spring 17ABB-W/SP, there is no evidence of spring flow from this system within the tributaries located north of the permit area.

Possible impacts to the Spaer system would be infiltration of spoil water through the clay interburden, or aquatard, which could contribute water of the quality described in the PHC to the Spaer. The clay interburden may attenuate these impacts. Possible impacts would be limited in extent since the Spaer outcrops immediately north of the permit area.

The Spaer has been monitored and will continue to be monitored because it represents a logical stratigraphic location for potential groundwater impacts from mining. Water levels have remained relatively constant over time. Levels in well 1526 rose approximately 5 feet over the past 20 years. The remaining wells are relatively unchanged.

Water quality analyses for these wells are chemically similar, though of somewhat better quality than the overlying Beulah-Zap bed. TDS values vary from a low of 172 mg/l at well 1731 (only one sample over the past 15 years) to a high of 4501 mg/l at well 2003 (only one sample since installation). The water is a sodium sulfate and sodium bicarbonate sulfate type. Over the past 15 years, water quality data collected from the Spaer is very limited.

Dakota Westmoreland has added three existing wells as quality monitoring sites located south, within the confined sections of the aquifer. Wells 1526, 1527, and new well 2012 have been added to the annual water quality sampling schedule to augment the quality data for this system.

Should groundwater quality or quantity within the Spaer show a significant change over time, additional monitoring wells will be installed downgradient or within the northern portions of the permit area.

Table 2.3.2
Hydrologic Properties of the Schoolhouse
Beulah-Zap and Spaer Lignite Beds

Piezometer Number	Transmissivity ($m^2 \cdot s^{-1}$)	Hydraulic Conductivity ($m^2 \cdot s^{-1}$)	Stratigraphic Unit
1444	3.2×10^{-7}	2.6×10^{-7}	Schoolhouse
1447	2.4×10^{-5}	3.1×10^{-5}	Schoolhouse
1448	1.5×10^{-6}	1.1×10^{-6}	Schoolhouse
1358	9.1×10^{-9}	3.0×10^{-9}	Beulah-Zap
1360	2.7×10^{-5}	2.9×10^{-5}	Beulah-Zap
1443	1.0×10^{-8}	3.0×10^{-9}	Beulah-Zap
1440	8.6×10^{-7}	8.1×10^{-7}	Spaer
1442	3.2×10^{-8}	3.5×10^{-8}	Spaer

6. "Hazen B" Bed

The "Hazen B" lignite occurs throughout the permit area at a depth of between 80 and 150 feet below the Spaer lignite within the Sentinel Butte formation (Carlson, 1973). Very little is known of this coal seam because of its depth from surface. Wells 953 and 1514 intersect this coal seam. Wells 957 and 951 extend to the sands above this coal seam.

The Hazen B wells have been monitored and will continue to be monitored to assess potential groundwater impacts from mining. Water levels have remained relatively constant over time. Over the last 15 years, the static water elevation for wells 953, 1514, 957, and 951 have remaining essentially unchanged. The elevation of all of the wells have varied less than 0.5 feet, and appear to vary based on the relationship between precipitation and infiltration from the Spaer bed.

Water quality analyses for these wells are chemically similar, and of better quality than the overlying coal beds. TDS values were only collected from well 951 after installation (1435 mg/L. Over the past 15 years, water quality data collected from the Hazen B is very limited and not impacted by mining activities.

7. Spoils

The first monitoring well located on reclaimed land in Permit 8603, No. 2029, was installed on October 29, 2008. It was drilled at the exact location of pre-mining well 1373. Well 1373 monitored the groundwater within the Beulah-Zap bed, screened at an elevation of 1948.5-1938.5 feet. Spoil well 2029 now screens the overburden at the same elevation. Data from well 2029 will start being collected during 2009 1st quarter.

C. KNOWN USES OF GROUNDWATER

Several local domestic and stock watering wells and spring sources are located within the permit and adjacent areas. Their locations are shown on Exhibit 2.3.7. Table 2.3.3 summarizes their uses, intake depths and probable sources.

Table 2.3.3
Known Uses of Groundwater

Well Identification	Use	Intake Depth	Probable Source	Well/Spring Cert. Date
Fetch No. 1	Stock watering[1]	98-115	Beulah-Zap Coal	9-30-05
Fetch No. 2	Domestic supply[1]	35	Schoolhouse Coal	5-24-91
Fetch No. 3	Domestic supply[1]	45	Schoolhouse Coal	9-30-05
PVFCo* No. 1	Domestic supply[1]	18	Beulah-Zap Sand	9-30-05
PVFCo* No. 2	Domestic supply[1]	65	Beulah-Zap Coal	9-30-05
PVFCo* Spring No. 1	Stock watering	Spring	Beulah-Zap Sand	9-30-05
PVFCo* Spring No. 2	Stock watering	Spring	Beulah-Zap Sand	9-30-05
PVFCo* Spring No. 3	Stock watering	Spring	Beulah-Zap Sand	9-30-05
Unruh No. 1	Domestic supply[1]	30	Twin-Buttes Coal	5-24-91
Unruh No. 2	Stock Watering	40	Twin-Buttes Coal	10-17-05
Unruh No. 3	Stock Watering	46	Twin-Buttes Coal	10-17-05

Unruh No. 4	Stock Watering	30	Twin-Buttes Coal	10-17-05
Reich/Unruh	Domestic supply	1450	Fox Hills Fm.	10-17-05
Reich No. 2	Stock Watering	37	Twin-Buttes Coal	10-17-05
S. Winkler (Weil) No. 1	Stock/Domestic[1]	382	Bullion Creek Fm.	9-30-05
S. Winkler (Weil) No. 2	Stock/Domestic[1]	50	Beulah-Zap Coal	9-30-05
Welk	Domestic Supply	70	Beulah-Zap Coal	9-26-05
Endreson	Domestic Supply	120	Beulah-Zap Coal	9-26-05
M. Gunsch Spring	Stock watering	Spring	Schoolhouse Coal	9-27-05
R. Gunsch Spring No. 1	Stock watering	Spring	Schoolhouse Coal	9-27-05
R. Gunsch Spring No. 2	Stock watering	Spring	Beulah-Zap Coal	9-27-05
R. Gunsch Well No. 1	Stock watering	71	Beulah-Zap Coal	9-27-05
R. Gunsch Well No. 2	Irrigation	86	Beulah-Zap Sand	9-27-05
Reich	Stock/Domestic	62	?	9-30-05
Erickson Well No. 7	Stock Watering	272	Bullion Creek Fm.	10-17-05
Erickson Spring No. 3	Stock watering	Spring	?	10-17-05
L. Winkler Spring No. 1	Stock Watering	Spring	?	9-26-05
L. Winkler Spring No. 2	Stock Watering	Spring	?	9-26-05
Voigt Spring No. 1	Stock Watering	Spring	?	9-30-05
Voigt Spring No. 2	Stock Watering	Spring	?	9-30-05
17ABB-W/SP	Stock Watering	Spring	?	No cert.
17DAC-W/SP	No Flow	Spring	?	No cert.

*PVFCo = Pleasant Valley Farming Co.
[1]Presently unused

A discussion of the Gunsch spring located in the SE¼ of Section 16 can be found in Section D-2. Probable Hydrologic Consequences, Impacts to Known Sources. Further information regarding the Gunsch spring and valley fill may be found in Section 3.6 Backfilling and Grading – Special Considerations. Section 3.6-D contains a discussion regarding groundwater management within the valley fill area.

The following discussion relates to wells and springs in and adjacent to the revision area. In October 1985, Water Supply, Inc certified and sampled these water sources to determine the quality and quantity of water available at that time.

Water Supply, Inc. re-certified the sites listed in Table 2.3.3 in the fall of 2005. The results of this certification program are presented in Exhibit 2.3.8. Most of these wells and springs are shallow and low yielding (<5 gpm) sources which tap either the Beulah-Zap or Schoolhouse coal beds.

In general these wells provide water which is of satisfactory quality for its intended purpose and although most of it is not desirable as a domestic source, it is typical of the waters often utilized in western and central North Dakota. The following is a synopsis of the water supplies listed in Table 2.3.3. These sites may be found on Exhibit 2.3.7 – Water Supply Locations.

Fetch Farmstead

Fetch well No. 1 is located inside a corral and has high nitrate content. Fetch well No. 2 was the sole source for the abandoned farmstead. It was classified by the State Health Department as usable, but not desirable for a domestic supply. Well No. 2 is located inside the pump house as shown on the certification photo. The well was drilled in 1935 and is screened in the Schoolhouse, its use was discontinued some time prior to 1991. Fetch well No. 3 was drilled in 1985 and is screened within the Schoolhouse. Use of the well was discontinued prior to 1991.

The Fetch Pond was a dugout excavated into the Schoolhouse within a small coulee. It is a saline slough used for stock watering. The area where the dugout is located has not been disturbed by mining. All of the Fetch sites are located up-gradient of the permit area and are not anticipated to be affected by mining.

Pleasant Valley Farming Co. (PVF) Farmstead

PVF well No. 1 is the sole domestic source for the house which was rented out by the Pleasant Valley Farming Co. This water is not considered potable and drinking water was hauled from Beulah. PVF well No. 2 is presently unused. PVF wells No. 1 and No. 2 will be removed as mining progresses through the area. Because the house will be removed during mining (and not replaced post-mining), mining will not impact the use of wells No. 1 and No. 2.

PVF spring numbers 1, 2 and 3 were piped into adjacent stock water tanks in the past. All three springs are functioning as of this writing; however, they are no longer utilized for stock watering. Since 1986, mining has proceeded through the NW¼ of Section 21 (T.143N, R.88W) northeast of the two wells and three spring sites with no observed impacts. The local groundwater gradient for both the Beulah-Zap and Schoolhouse in this area is from the west and north moving to the south. See Exhibits 2.3.3 and Exhibit 2.3.4. All three springs were certified in 1986 and recertified in the fall of 2005 (Exhibit 2.3.8). Springs 1, 2, and 3 will be impacted by mining as mining progresses South. Because the springs originate from the Beulah-Zap sand, impacts to the springs should be limited to the time in which an open pit is unfilled north of their location. Once the final pit has been reclaimed, the springs should re-establish in the vicinity of their original location based on the post-mine topography. These springs are different than other springs impacted because of mining due to the fact that their source is not coal that is being removed. Likewise, the impacts will be minimal simply because the stock pond located downstream (surface fed) is the major source of water for livestock in the area. The downstream stock pond will not be impacted by mining.

Reich/Unruh Farmsteads [formerly Altavilla/Unruh (Erdman/Neuberger)]

Reich/Unruh well is a deep (Fox Hills), high yield well which provides domestic water for two residences which share this farmstead site. The Unruh well No. 1 is suitable but not a desirable domestic source. This well is not presently utilized.

The Reich/Unruh domestic well is screened within the Fox Hills, far too deep to be affected by mining. The Fox Hills represents the best of several possible replacement sources for any shallower wells impacted by mining.

There are several shallow wells located at both the Reich/Unruh farmsteads, which are used for purposes other than household use. The wells are shallow with depths ranging from 30 to 50 feet. All are screened within the Twin Buttes lignite.

The Twin Buttes bed outcrops in drainage divides in the western part of the county. It reaches a maximum thickness of about 5 feet in T. 143 N. R. 90 W., and in scattered localities north and south of that area (R. A. Brant, 1953). Geologically, the bed is located between 130 and 150 feet above the Beulah Zap lignite. (C.G. Carlson, 1973)

The Twin Buttes lignite is not present within the proposed permit area. The Bed is located up gradient and isolated from mining activities. No adverse effects to the aquifer system from mining are possible.

Weil Farmstead (Sharon Winkler)

Weil well No. 1 is a potential wintertime livestock watering source. The well has a total depth of 382 feet. Well No. 2 is likely screened within the Beulah-Zap lignite. The Weil farmstead is presently not occupied and has not been occupied for nearly twenty years. Pond 87 is located where the Weil slough was located, which was not disturbed by mining. The pond is currently recharged by the Schoolhouse and is a reliable source for livestock watering. Since all of the Weil sites are located up-gradient of mining, no impacts have been observed or are anticipated.

Welk Farmstead

The Welk well is located approximately 1 mile SE of the permit area. The well is screened within the Beulah-Zap coal and is used as a domestic source. No impacts are anticipated due to its location.

Roger Endreson

The Endreson well is located SW of the Welk farmstead. The well is screened within the Beulah-Zap coal and is used as a domestic source. No impacts are anticipated due to its location.

Martha Gunsch Spring

This spring is located in the NW¼ of Section 22 south of the permit area within a minor tributary to Brush Creek. It consists of a concrete spring box piped to a water tank. It appears to be screened in the Schoolhouse lignite. The spring is currently not functioning and is ~~but~~ in need of repair to assess whether or not it could function in the future. This spring will be removed due to mining, but because the spring is not used for stock watering or any other purpose, the impact from mining will not effect its potential use.

R. Gunsch Springs 1 & 2

Spring No. 1 consists of an undeveloped spring feeding a dug-out stock pond located in the SW¼ of Section 28, or approximately 1 mile south of the Permit area. At the time of certification, no free flowing water was observed but the down stream pond was holding water. Impacts to this site are not anticipated due to its location. Spring No. 2 is a developed spring discharging to a minor tributary to Brush Creek. The spring is in good condition with a discharge rate of 1.4 gpm at the time of inspection. This site it is located approximately 1 mile NW of where mining is scheduled to occur between 2008 through 2016 (See Exhibit 3.1.1). Since Spring No.2 is located down-gradient of mining, it is possible this site may be impacted by mining. Alternate groundwater sources are available as a replacement source, if needed.

Gunsch Wells 1 & 2

Well No. 1 is located in the NW¼ of the SW¼, Section 18 approximately 1.5 miles from the western boundary of mining. It is screened within BZ lignite with a total depth of 71 feet. The well produced approximately 15 gpm at the time of certification. Well No. 1 may be impacted by mining; however, due to its location impacts may only be negligible. Alternate groundwater supplies are available if necessary.

Well No. 2 is located in the NW¼ of SW ¼ of Section 7 and is screened in the Beulah-Zap Sand. The well is permitted for 656.5 acre feet to irrigate 125.5 acres at 566.7 gpm. Impacts to this well from mining are not anticipated. The B-Z Sand is recharged from the Knife River alluvial aquifer system.

Gunsch Spring located in SE ¼ of Section 16

Detailed discussions regarding the Gunsch Spring may be found below in Section D, Probable Hydrologic Consequences. Further discussion relating to this spring may be found in Section 3.6 Backfilling and Grading – Special Considerations. In the event the Valley Fill Drainage System fails to provide the necessary quantities for the intended post mining land use at the time of bond release, alternate groundwater sources are available for use at this location.

DWC Monitored Springs

Springs 17ABB-W/SP and 17DAC-W/SP are located in the ~~N~~E½ of section 17. Both springs are monitored as part of DWC's approved ground water monitoring program under permit KRSB-8603. Spring 17ABB-W/SP is suitable for livestock watering and has a developed concrete watering tank. Spring 17ABB-W/SP has maintained an average flow of approximately 1.2 gpm over the past 25 years. Results of sampling at the spring located at 17ABB reported TDS values ranging from 129 to 4496 mg/l with an average of 1778 mg/l with a sample size of 62. No impacts are expected to this spring from mining. This spring is fed by the Spaer lignite, located below the Beulah-Zap coal bed.

Spring 17DAC-W/SP sporadically produces flow, the last of which was recorded in March of 2000. Alternate water supplies are available for these sites if necessary.

D. PROBABLE HYDROLOGIC CONSEQUENCES

1. General Quality and Quantity Changes

Possible impacts to the surface and groundwater systems within the permit, adjacent and general areas involve the issues of water quality and water quantity. Whereas these systems are highly interdependent, the probable hydrologic consequences for both systems will be addressed together in this section. Other than as noted above, minimal impacts to surface waters of the extended mine plan area are expected to result from the proposed mining activities. This statement is based on mining and hydrologic monitoring experience conducted in the area for over the past forty years.

Pond No. 81 is proposed to remain as a permanent impoundment; likewise, Pond No. 86 will be removed during final mine reclamation. Because Pond No. 81 is located in the upper reach~~es~~ of its respective drainage basin~~s~~ and intercepts only a small portion of the receiving basins total runoff, its effect on the quantity of surface water available downstream following mining will be minimal. Although DWC does not expect spring flow to reestablish to historical quantities, Pond No. 81 has been designed to allow flow-through of spring discharges. Spring flows from the Valley Fill drainage system (Gunsch premining spring located in the SE¼ of Section 16) into pond 86 are currently in a range between 1.0 to 1.5 gpm. Historical data shows an average discharge of between 60 and 70 gpm from this pond system (Pond 86 & 81) over the past 20 years. Although spring flows from the Beulah-Zap coal bed have been mostly eliminated, average flows from the Ponds 86 & 81 remain due mainly to pit dewatering activities discussed below (and, to a lesser extent, the 1 to 1.5 gpm of spoil spring flow). Over the past 10 years of mining in the area, average discharges from pond 81 have increased from 60 gpm in the early 1980's to 70 gpm in the early 2000's. Average conductivity values from Pond 81 are 2337 umhos/cm for the period of 2000 through 2002. Average conductivity values for the receiving stream (Brush Creek) is 2900 umhos/cm at site 15 BBD-W/ST. All other discharges from the West Brush Creek mining area are insignificant (less than 1 gpm average annual flow) due to the low quantity discharged

Spring flows from the Gunsch spring (16ADA-W/SP) have diminished while mining has been, and currently is, occurring in the immediate area. Thus, pre-mining water levels are not expected to re-establish to pre-mining levels as discussed below. Currently, groundwater originated from the south, and discharges into the Red Pit. The groundwater is then intercepted and pumped to the 86 and 81 pond system. Discharge quantities from Pond 81 (NDPDES discharge point 081) over the past 18 months average 40 gpm, excluding water used for dust suppression. Due to the limited drainage area above Pond 86 & 81, most of this flow is intercepted groundwater from the Red Pit.

After mining in the West Brush Creek area is completed, a small percentage of the groundwater emerging from south of the Red Pit (up gradient), will migrate through the spoils and will eventually reach the springs located down gradient, i.e. the Valley Fill drainage system. The remaining, larger portion of the groundwater will infiltrate through the spoil material into the Spaer coal bed aquifer. Groundwater levels within the spoils will be less variable than observed in the lignite due to a relatively consistent texture of the spoil materials versus the fractured nature of the lignite. Most wells within both lignite seams are either dry or contain little groundwater prior to mining.

Regarding groundwater quantity, in summary, DWC expects flows to increase in relation to current spring flows (1 to 1.5 gpm), but decrease in relation to pre-mining flows (60 to 70 gpm). DWC does not expect flows to return to pre-mining levels.

Regarding groundwater quality, studies at other mines in North Dakota (Groenewold, et al., 1983) indicate that water levels in the spoils approach pre-mining levels within a few years after mining and that these resulting spoils aquifers show a range of hydraulic conductivities similar to the coal aquifers in the pre-mining setting. The Company's experience at the Beulah Mine (KRSB-8802) indicates that water quality in the spoils was found to be approximately 2 to 3 times as mineralized as prior to mining and enriched in sodium and sulfate. (Refer to the PHC section, Permit KRSB-8802.)

Due to both the decrease in groundwater quantity, and the expected increase of mineralized post-mining groundwater quality, DWC will replace the pre-mining Gunsch spring with a well in the SE¼ of Section 16; likewise, DWC will replace a well in the N1/2 of Section 16 to provide a source of water for livestock watering. Wells installed in an aquifer below mining disturbance will provide the most viable source of water for livestock. As mentioned on page 2.3.1, the Upper Hell Creek and Lower Cannonball-Ludlow Aquifer is the next hydrostratigraphic unit whose transmissivity values make it capable of supporting wells when tapped. However, DWC is not aware of any wells within the area that are drilled into this aquifer. This, coupled with the fact that there are wells drilled down to the Fox Hills Aquifer in this region [Reich Farmstead (see Table 2.3.3) – 1450' ; Dale Neuberger residence (NE1/4, Section 8 T143NR87W) – 1455'], suggest that this aquifer is the most likely hydrostatigraphic unit that will be used to replace the pre-mining Gunsch spring. The Reich Farmstead well was sampled for quality during a round of well recertifications in October 2005. Exhibit 2.3.8 contains the lab analysis (titled M & S Altavilla) of the sample taken from this Fox Hills well. Immediately following this analysis is a page listing the constituents measured and parameter levels needed to meet U.S. Public Health Service Drinking Water Standards. It also displays the North Dakota State Health Department's Classification System relating to those same constituents. All the well sample constituents, with the exception of TDS (1300 mg/l), are well below the USPHS drinking water standard limits. The 1300 mg/l is shown as being within the Average range in the NDSDOH Classification System. For livestock consumption, TDS levels below 3000 mg/l are considered satisfactory (Boyles, 1988). Wells tapped into the Fox Hills aquifer are also capable of meeting production (quantity) requirements for human and livestock consumption. Most well owners limit their well flows to 5 to 10 gpm. Fox Hills wells generally flow at unrestricted rates of 10 to 25 gpm (Croft, 1973).

In June of 1979, the Beulah Mine drilled two wells in coal that were never mined (outcrop coal). These two wells represent baseline wells that are used to compare pre-mining and post-mining groundwater quality. In August 1984 the Beulah Mine installed four base-of-spoils wells to monitor spoil water quality after coal extraction. These four wells represent post-mining wells used to compare water quality and static water levels in the spoils, versus pre-mining water quality and static water levels. Exhibit 2.3.9 presents the water quality analyses for the two baseline wells (929 and 930), and the four base-of-spoil wells (1352, 1354, 1355 and 1357). By comparing the baseline wells to the base-of-spoil wells, the data supports the conclusion that the post-mining water quality will be approximately 2 to 3 times more mineralized than the pre-mining water quality. Three of these four wells however, show enrichment in Ca and Mg relative to Na, as well as elevated SO4 levels.

When reviewing the historical data from baseline well 930, it appears as though the first two readings of TDS concentrations are skewed high due to drilling. In some instances after drilling, TDS readings are artificially high from downhole disturbance related to the drilling process.

2. Pit Water Inflows

The following discussion was an attempt to predict initial pit in-flows using analytical methods written in 1986. The final predicted results of inflows have proven quite reasonable based on observed flows since 1986.

McWhorter (1982, pgs 60-66) presents an analytical solution which allows the calculation of inflows to the first cut and to the extent to which the potentiometric surface is lowered in affected aquifers, for the case where a surface mine is initiated by a box cut into aquifer materials, which extend laterally to great distances from the area to be mined.

This solution is applicable to the N-S box cut proposed in this permit and its attendant hydrologic impacts; analysis of those impacts based on the results of pre-mining hydrology investigations is presented below:

The discharge to one side of the pit is given by;

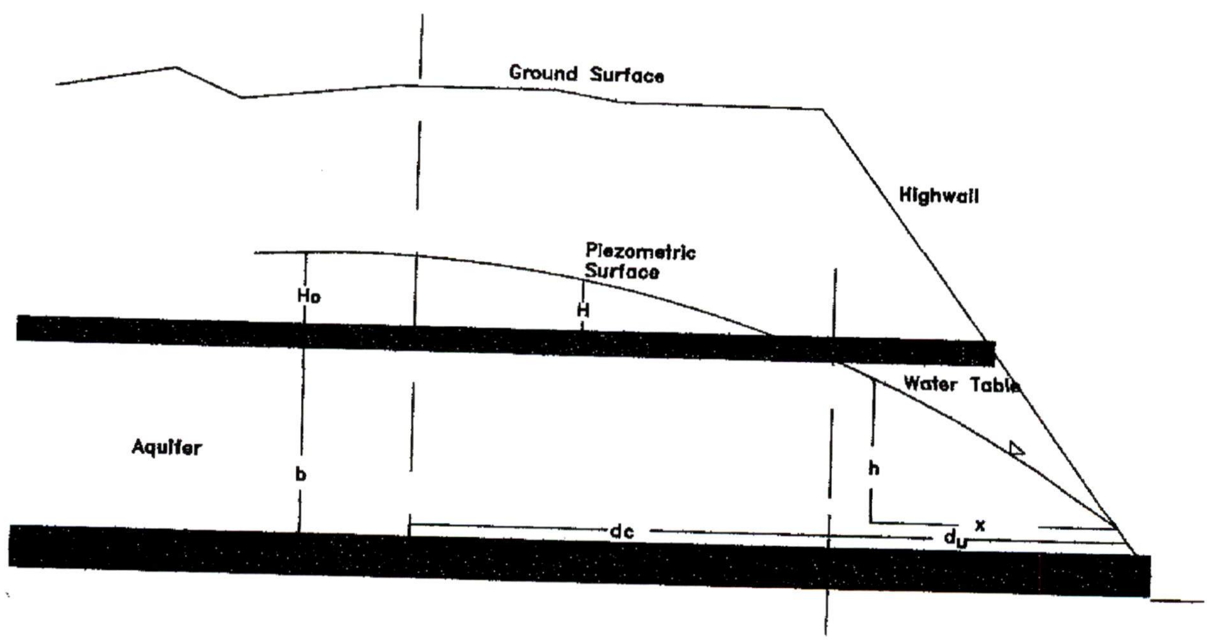
$$Q = 2R \quad \frac{S_{ya} \; Tb^2}{12} + \frac{STH_O^2}{4} \quad \frac{}{\tfrac{1}{2} t^{1/2}}, \; t \leq \frac{L}{R} \qquad (1)$$

which holds for all times during the advancement of the pit (i.e., for $t \leq L/R$, where L is the maximum length of the pit).

Figure 2.3.1 is a definition sketch for this analytical solution, and the terms defined therein and in equation (1) are:

S_{ya} = apparent specific yield
S = storage coefficient (storativity)
b = aquifer thickness (saturated)
H = height of water table above floor of aquifer
H_O = piezometer height above top of aquifer
d_U = extent of unconfined zone
d_C = distance between the boundary of the confined and unconfined zones and the point at which $H = H_O$
R = average rate of pit advancement
T = transmissivity
L = maximum length of pit
Q = total discharge to the pit
t = time since initiation of pit

Figure 2.3.1
Definition Sketch for Flow to Box Cut Pit



a. Flows To Box Cut Pit

Inflows to the box cut pit are expected from both the Beulah-Zap and Schoolhouse beds. Because field data indicates that both coals contain significantly more water at the south end of the pit, flows for the southern one-third and northern two-thirds of the pit are calculated separately.

Aquifer parameters and other terms used in this calculation are as follows:

S_{ya} = 0.1
b = Beulah-Zap N2/3:0.6m,S1/3:2.3m; Schoolhouse N2/3:0.6m,S1/3:1.2m
R = 15 m·day^{-1}

T_1 = Beulah-Zap North $1.8 \times 10^{-7}\ m^2 \cdot s^{-1}$
T_2 = Beulah-Zap South $6.9 \times 10^{-7}\ m^2 \cdot s^{-1}$
T_3 = Schoolhouse North $6.6 \times 10^{-7}\ m^2 \cdot s^{-1}$
T_4 = Schoolhouse South $1.3 \times 10^{-6}\ m^2 \cdot s^{-1}$
L_1 = North 2/3 975m
L_2 = South 2/3 488m

Maximum discharge will occur at $t = \frac{L}{R}$ therefore from equation (1)

$$Q_1 = 2R \frac{S_{ya}\ Tb^2}{12} \quad \tfrac{1}{2} t^{\frac{1}{2}} \quad \text{for } H_O = O$$

$$Q_1 = 2 \cdot 15\ m \cdot day^{-1} \quad 0.1\ 1.8 \times 10^{-7}\ m^2\ s^{-1}\ (0.6m)^2 \quad \tfrac{1}{2} \quad 65\ days^{\frac{1}{2}}$$

$$Q_1 = 2\ m^3 \cdot day^{-1} \quad \text{(Beulah-Zap North)}$$

Calculations for Q_2, Q_3 and Q_4 are performed in a similar manner using the appropriate numbers yielding: $Q_2 = 50\ m^3 \cdot day^{-1}$ (Beulah-Zap South)
$Q_3 = 3\ m^3 \cdot day^{-1}$ (Beulah-Zap North)
$Q_4 = 36\ m^3 \cdot day^{-1}$ (Beulah-Zap South)

Total inflow for one side of the pit therefore equals $91 m^3 \cdot day^{-1}$, and for both sides equals $182 m^3 \cdot day^{-1}$ or 33 gpm.

E. GROUND WATER MONITORING PLAN

Figures 2.3.2 through 2.3.11 are Piper trilinear chemistry plots for wells historically monitored for ground water quality. With the exception of wells 1359 and 1443, these wells show virtually no water quality variation since monitoring was begun in 1985. Revised Exhibit 2.3.6 contains the complete water quality analyses for these wells for the period of record. Groundwater levels and quality will be monitored according to the schedule presented in Table 2.3.4. Water levels will be measured quarterly and reported to the Commission by the end of the month following the close of the quarter. In the event that severe climatic conditions, which prevent access for water level measurement persist throughout the quarter, documentation to this effect will be submitted along with the quarterly report.

Revision No. 22 will implement the following changes to the monitoring program. Eight of the nine new wells mentioned earlier in the narrative of Section 2.3.B will supplement the documentation of the effects mining has on the three lignite beds in this permit. Wells 2022, 2025, and 2028 will be added to the Schoolhouse bed wells; 2021, 2024, and 2027 to the Beulah-Zap wells; 2020, 2023, and 2026 to the Spaer wells.

The current active wells to document the effects of mining on the Beulah-Zap bed are: 959, 1358, 1359, 1441, 1445, 1528, 1732, 2001, 2003, 2004, 2005, 2006, 2007, 2009, 2010, 2011, and 2013. The Schoolhouse bed will continue to be monitored by current active wells 1394 and 2002. The current Spaer bed wells are 1526, 1527, 1731, 2008, 2012, and 2014.

Water quality samples will be collected annually and analyzed according to the schedule outlined above for the parameters required by NDAC 69-05.2-08-06.e. The analytical results will be reported to the Commission by the end of the month following the sampling quarter. Those wells which produce sufficient water are sampled using a dedicated WaTerra sampling system. Prior to sampling, approximately three well volumes are removed. The non-pumping wells are evacuated with a bailer, allowed to recover overnight and sampled the following day. Because of water level fluctuations, some of the wells scheduled for sampling contain insufficient water to allow for collection of a representative sample. When this occurs it will be specifically stated in the quarterly monitoring report.

As mining progresses, some of the monitoring wells will be destroyed and additional base-of-spoils wells will be installed as close as possible to previous monitoring well locations and added to the monitoring program. DWC submits an annual Ground Water Monitoring Performance Standard Report each year as required by NDAC 69-05.2-16-14(3). This report includes a listing of all the monitoring wells which were mined through, destroyed, abandoned due to casing or grout failure, or lost by any other means during the previous year. Within this report, recommendations will be presented for replacement of wells deemed unusable. The groundwater monitoring plan contained herein will be updated as needed by a permit revision at the midterm review and prior to renewal.

Exhibit 2.3.1 depicts the locations of the groundwater monitoring wells. It is not intended that this map represent all wells, but only those wells in the approved monitoring program. The wells in the approved monitoring program are listed in Table 2.3.4.

Prior to abandonment, these wells will be cut off below plow depth and filled with grout by a North Dakota certified monitoring well contractor. All test holes drilled to date have been reclaimed by plugging potential aquifer zones with coarse bentonite. Any monitoring wells subsequently drilled within the permit area which will not be disturbed by mining will be reclaimed to those same standards.

Exhibit 2.3.7 also depicts two springs that are monitored annually for water quality and quantity. Water quality and quantity results from the two springs can be found in Exhibit 2.2.4 and Exhibit 2.2.8. Spring sites will be sampled in the fall during low flow, which should be worst case.

Table 2.3.4
Groundwater Monitoring Plan

Well/Spring Number	Quarterly Water Levels	Water Quality	Screened Bed
949	X		Brush Creek Alluvium
951	X		Sand below B-Z
953	X		Hazen B
957	X		Sand below B-Z
959	X		B-Z
1009	X		Spaer Sand below B-Z
1358	X	X	B-Z
1359	X	X	B-Z
~~1360~~	~~X~~	~~X~~	~~B-Z~~
1394	X		SCH
1441	X	X	B-Z
1445	X		B-Z
1514	X		Hazen B
1526	X	X	Spaer
1527	X	X	Spaer
1528	X		B-Z
1731 replacement	X	X	Spaer
1732 replacement	X	X	B-Z
2001	X	X	B-Z
2002	X	X	SCH
~~2003~~	~~X~~	~~X~~	~~B-Z~~
~~2004~~	~~X~~	~~X~~	~~B-Z~~
2005	X		B-Z
2006	X		B-Z
2007	X		B-Z
2008	X		Spaer
2009	X		B-Z
2010	X		B-Z
2011	X		B-Z

2012	X	X	Spaer
2013	X		B-Z
2014	X		Spaer
2020	X	X	Spaer
2021	X	X	B-Z
2022	X	X	SCH
2023	X	X	Spaer
2024	X	X	B-Z
2025	X	X	SCH
2026	X	X	Spaer
2027	X	X	B-Z
2028	X	X	SCH
2029	X	X	Spoil
17ABB-W/SP	N/A (Spring)	X	Spaer
17DAC-W/SP	N/A (Spring)	X	B-Z

F. INTERPRETATIONS RELATED TO COYOTE CREEK STREAM VALLEY

Coal removal within the permit area is usually restricted to the Beulah-Zap bed in most locations because it is the only seam considered commercially recoverable due to adequate thickness and quality. The approximate disturbance boundary for mining activities is displayed on Exhibit 1. The Schoolhouse bed will likely only be removed in any quantity from the southeastern extent of the permit area. One or both of these potential aquifers may outcrop within or near the southern permit boundary in Sections 19 and 20. Several springs and seeps in this vicinity feed tributaries to the tributary to Coyote Creek that flows westward through these sections. Flows in this tributary have been observed to vanish in mid to late summer in recent years; no groundwater flow has been observed entering the stock pond in the SW¼ of Section 20 during several surveys of the area conducted during these periods.

Flow direction in the Schoolhouse and Beulah-Zap coal beds has been characterized as easterly to northeasterly, although difficult to define precisely in some portions of the permit. Flow generally appears to be away from Coyote Creek. Flow in the Spaer bed that emanates from a high in the center of Section 20 is apparently directed west and north, in the general direction of Coyote Creek and eastward toward the Brush Creek area. Mining of the Beulah-Zap bed in the NE¼ of Section 19 and in Section 20 will remove springs in these areas. The flows contributed by these springs is relatively minor and water quality is poor because of high specific conductivity (salinity). The receiving tributary often dries up in mid to late summer and any flow enters Coyote Creek downstream of almost all of the agricultural fields in the study area.

Little is known about the specific geology and groundwater flow characteristics of the Coyote Creek stream valley. Croft (1973) estimated that the sandy silt and clay alluvium of Elm Creek in southwest Mercer County, a few miles southwest of Coyote Creek, at up to 40 feet thick. The depth of the sandy silt and clay alluvium of Goodman Creek in northwest Mercer County was estimated at 38 feet, based on a single sample. With a watershed of similar size, the alluvial thickness of the Brush Creek stream valley could reasonably be assumed to have a similar range. Absent data on potentiometric surfaces within the valley, we assume that groundwater flow is directed toward the Knife River.

In the reclaimed landscape, rejuvenation of groundwater supplies in the manner predicted for the Brush Creek area is expected. Re-establishment of pre-mining water levels in the graded spoils is expected after a few years. The Pleasant Valley Springs along the east quarterline of Section 20 are expected to return as well. Recharge to the Spaer coal bed will resume in time as groundwater works its way down through the spoil fill and undisturbed overburden.

As a result, the relatively minor current spring flow contributions to Coyote Creek are expected to return. Reshaping of the postmining surface will resemble premining conditions, allowing surface flows to return.

3. SOILS

The predominant soil map units occupying the agricultural fields of the Coyote Creek AVF Study Area are Shambo loam (map symbol 40), Straw silt loam (51), channeled Straw soils (67), and Straw loam (91). The locations and general information of these and other soils in the study area can be found in Exhibit 4A. Exhibit 4B has soil map unit descriptions. Straw loam is the principal soil found in the flood plain agricultural fields of the study area. Gradients range up to 2 percent and natural flooding may occur rarely for brief periods. Flood irrigation is constrained by the erodibility of constructed terraces and diversions. Locations in the study area contain oxbows, sloping areas greater than 2 percent, and a small amount of terraces.

The channeled Straw soils comprise the next largest proportion of the study area soils, but have limited current or potential agricultural use because of slopes, woody development, flood debris deposition, and small acreages of arable area. The Straw silt loam is found on about 2 percent of the area of interest defined on Exhibit 4A. This soil is suitable for irrigation, but erodibility of terraces and diversions is a concern. Most of this unit has a land use of native grassland and its single location is transgressed by Coyote Creek. A minor portion is cropped annually, but stream terraces and oxbow depressions exist in both small fields. Present in the smallest proportion, the Shambo loam is currently used primarily for cropland and hayland. Oxbow depressions punctuate portions of the cropland. This map unit has the most favorable qualities for irrigation.

4. LAND USE AND VEGETATION

Land uses in the study area consist of native grassland (including the Coyote Creek channel), cropland, hayland, and tame pastureland in descending order when considering areal coverage. Other land uses such as woodlands, wetlands, and shelterbelts have not been segregated from these primary uses, which are displayed on Exhibit 5. Native grassland is the predominant land use within the study area. Approximately 350 acres of native grassland are found in the study area. It appears that all of the native grassland is grazed annually, probably seasonlong, although use is probably reduced in the NW¼ of Section 24. Grazing paddocks include both the valley floor and adjoining uplands. The composition of the native grassland has been somewhat tainted by introduced grasses in the vicinity of the creek. The 89 acres of hayland is composed of alfalfa and appears to be under an annual harvesting routine. The 83 acres of cropland show evidence of rotation between grain and row crops. The tame pastureland (38 acres) is dominated by tamegrasses, probably smooth bromegrass or a close relative.

5. IRRIGATION

A. EXISTING FLOOD IRRIGATION

Artificial flood irrigation is currently not practiced within the study area. Conversations with the agricultural producer involved in cropping the fields in the study area confirmed that flood irrigation was not practiced. The local office of the Natural Resources Conservation Service was queried on irrigation occurring in Mercer County. The county Soil Conservationist reports that a few surface irrigation systems are established in the north and east reaches of the county in close proximity to Lake Sakakawea, Knife River, and the Missouri River, but they were not aware of any systems on Coyote Creek or other such stream valleys to the south of the Knife River.

Natural flood irrigation occasionally occurs in portions of the study area; the major flooding that occurred in April 2009 is ample evidence. However, even the exceptionally high water levels did not cover all portions of the agricultural fields. Woody debris ranging up to tree trunk dimensions was scattered over fields, silt was deposited in low lying areas and downstream-facing slopes, and sheet washing resulted in the pedestaling of perennial crop plants and wholesale surface soil loss in many areas. Given the magnitude of this year's flood, it appears that most floods would transcend too little acreage too rarely to benefit the agricultural operations in the floodplain. Large floods akin to this year's may actually have a negative effect by reducing crop yields as a result of soil loss in some locations and sedimentation in others.

B. FLOOD IRRIGATION POTENTIAL

1. Soils Potential

The preceding Soils section described the soils present in the agricultural fields of the study area. The Shambo and Straw soil map units generally possess few inherent chemical or physical limitations to the application of flood irrigation. If terraces or diversions are employed in a flood irrigation system, the erodibility of the Straw soils can be problematic.

2. Water Quantity

Flow data for Coyote Creek is limited. Streamflow data was gathered by the U.S. Geological Survey from October 1977 through the end of 1983 (USGS, 2009) on the east side of the county road bridge in Section 13. Excluding the 1982 flows which exceeded all other years by a multiple of at least four, average streamflow for June was 1.72 cubic feet per second (cfs) and July registered 1.14 cfs. These rates would provide roughly 102 and 70 acre-feet of water for June and July respectively. If 83 acres of irrigable cropland are assumed, capture of half of the streamflow in June and July would be necessary to provide an acre-foot of flood irrigation water in an "average" year. In 1978, July flows would have provided roughly 6 inches of water for the cropland acreage if the entire flow was utilized. Two years later, no flow existed for the month of July.

Generally speaking, the greatly reduced flows present on such streams after the conclusion of spring runoff requires that water storage be accomplished by damming the stream or pumping to a storage facility in the floodplain in order to provide an ample volume of water when needed. Damming is an unlikely option and there are no impoundments present in or near the study area agricultural fields that could be utilized for storage. Impoundment construction or modification of existing natural features to store water pumped water is not likely due to expense and area limitations.

3. Water Quality

The amounts of soluble salts and sodium in water are of primary concern when the quality of irrigation water is considered. Salt content is commonly measured by determining electrical (specific) conductivity (EC) or total dissolved solids (TDS) content. Excessive salt content results in a physiological drought condition whereby plants are unable to extract sufficient water from the soil even though saturated conditions may exist. Sodium content is measured in relation to the concentrations of calcium and magnesium ions and expressed as the sodium adsorption ratio (SAR). High SAR water brings about structural changes to the soil, decreasing permeability and resulting in physical drought conditions. Analysis of water samples will focus on EC and SAR levels.

The tributary to Coyote Creek that coalesces with Coyote Creek near the middle of Section 19 was sampled at a point in the SE¼ of Section 20-143-88 in May 2008 to determine water quality in this perennial drainageway. EC was measured at 4,777 µmhos/cm and SAR at 6.60. A couple hundred yards to the northwest of the tributary sampling site lies the outcrop of the three Pleasant Valley springs that empty into the tributary a little further downstream. When sampled in the fall of 2005, the electrical conductivity of water from the three springs in this area all had levels of 2,200 µmhos/cm or greater, equating to high to very high salinity levels. Based on the criteria in the following table, tributary water quality has salinity levels that render it's utility doubtful, if not unsuitable. This information can be useful when evaluating the consequences of mining that will disturb this area within a few years.

Coyote Creek water was sampled in mid-May of this year at the county road bridge. Specific conductance of the single sample came in at 1,784 µmhos/cm. Snowmelt runoff had concluded prior to sampling and all flow is assumed to have a groundwater discharge origin.

Many authorities agree that water with high salinity levels (≥2,000 µmhos) should not be used continuously on soils with restricted drainage. Use should be sporadic – one year in several. Water with very high salinity is limited to special crops under special management. Coyote Creek water has a conductivity level classifying use as "permissible", but leaching would be necessary. Conductivity in the Coyote Creek sample is approaching the conductivity level of 2,000 µmhos/cm – a level at which these restrictions begin to come into play.

Table 3.1 Suggested criteria for irrigation water use based upon conductivity.

Classes of water	Electrical Conductivity
	(dS/m)*
Class 1, Excellent	≤0.25
Class 2, Good	0.25 - 0.75
Class 3, Permissible[1]	0.76 - 2.00
Class 4, Doubtful[2]	2.01 - 3.00
Class 5, Unsuitable[2]	≥3.00

*dS/m at 25°C = mmhos/cm, 1,000 µmhos = 1mmhos
[1]Leaching needed if used.
[2]Good drainage needed and sensitive plants will have difficulty obtaining stands.

The sodium hazard of the tributary water is low. In the case of the three springs, sodium adsorption ratios of 7.39, 8.88, and 15.6 translating to a low to medium sodium hazard for all springs. The May 2009 Coyote Creek sample had an SAR of 5.74, classified as a low sodium hazard.

Table 3.2 General classification of water sodium hazard based on SAR values.

SAR values	Sodium hazard of water	Comments
1-9	Low	Use on sodium sensitive crops must be cautioned.
10-17	Medium	Amendments (such as gypsum) and leaching needed.
18-25	High	Generally unsuitable for continuous use.
≥26	Very High	Generally unsuitable for use.

Tables from Colorado State University Cooperative Extension Bulletin No. 0.506

4. Irrigable Acreage

Flood irrigation on the Coyote Creek stream valley floodplain has many impediments. Flood irrigation common to the region typically involves supplying water to canals bordering fields. It is often necessary to pump the water into the canals, wherefrom the water is distributed to fields where gentle slopes at up to roughly 2 percent carry water downslope. Water may flow into furrows or across level terrain bounded by boundary berms to constrain and direct flows. Flood irrigation fields often require precision grading and careful management of fields and water application. Large fields are usually necessary to realize benefits, even with high value crops.

The characteristics of the study area fields, whether annual or perennial crops exist, argue against the use of flood irrigation. Oxbow lakes and/or truncated meanders exist in all fields, severely restricting water distribution uniformity. Slopes can exceed the optimal gradient, and are sometimes complex. The configuration and topography of most fields would require construction of an irrigation canal through the field, eliminating potential production acres. Unlike most flood-irrigated fields in locations like the Yellowstone River valley of eastern Montana, the perimeter of most study area fields is very irregular, posing additional challenges related to water distribution. All single field acreages within study area boundaries are roughly 60 acres or smaller. Given the fragmentation of these generally small fields by surface features that limit pragmatic flood irrigation, along with other limitations involving soils and configuration, the lack of present-day flood irrigation systems is understandable.

5. Flood Irrigation History and Regional Practices

In 2007, there were only 2,348 irrigated acres in Mercer County (2007 Census of Agriculture). This was a modest increase from the 1,676 acres irrigated in 2002. Only 22 Mercer County farms harvested irrigated crops in 2007 and almost 90 percent of the harvested acreage was represented by 16 farms with a cropping acreage of 500 acres or more on each farm. It is likely that the vast majority of these farms capitalized on water resources available in the broad floodplains of the Knife River and Missouri River. Irrigated acres were reported for only four farms cropping 100 acres or less.

There is no anthropomorphic evidence that flood irrigation has been practiced in the study area. Neither the current landowner or Mercer County Soil Conservationist are aware of any instances of historic flood irrigation. As previously reported, stream valleys like Coyote Creek typically are not developed for flood irrigation purposes, especially in areas within Mercer County south of the Knife River.

C. EXISTING SUBIRRIGATION

Subirrigation is defined by the CFR as *the supplying of water to plants from underneath or from a semi-saturated or saturated zone where water is available for use by vegetation* (30 CFR 701.5). The Office of Surface Mining's guidelines for Alluvial Valley Floor Identification and Study Guidelines states that the focus of the potential influence of subirrigation on stream valley vegetation should be on agricultural plants, since they play a significant role in determining the value of agriculture in the Coyote Creek valley.

Some insights into the quality and levels of groundwater and the potential for subirrigation in the Coyote Creek stream valley can be gained from the groundwater studies conducted by Croft (1970). The studies contain data for two wells in the area of the farmstead in the S½ of Section 31, now occupied by Casey Voigt. One well had a depth of 22 feet and reported a water level at 16 feet below ground level. Electrical conductivity of this stock well was

2,500 µmhos/cm. A nearby domestic service well with a depth of 20 feet expressed a water level of 18 feet and an EC of 2,200 µmhos/cm.

The static water depths in the Voigt wells correspond to recently observed levels of the Coyote Creek soon after the passage of flood stage flows caused by snowmelt runoff. It is assumed that Coyote Creek influences the stream valley water table in the same manner as observed with Brush Creek, i.e., water table levels reflect nearby stream levels. The elevation of creek flows in mid-May of this year was estimated to be at least 12 feet below the lowest adjacent fields and roughly 20 feet below the highest fields. The landowner has also reported well water levels at 15-20 feet. Root systems of the annual crops and forage grasses grown in Sections 19, 30, and 31 typically would not tap water resources at such depths to significantly increase yields, nor would rangeland plants subjected to grazing.

The floodplain of Coyote Creek was walked in the spring of 2009 to determine the abundance of phreatophytic plant species – those plants that like to have their feet in water. These plants are particularly useful as an indicator of subirrigation conditions. Habitats such as streambanks, terraces adjacent to the creek, and oxbows received concerted attention due to their closer proximity to the water table, which would enable enterprising phreatophytes to take advantage of any subirrigation potential. Populations of plant species such as prairie cordgrass (Spartina pectinata), willows (Salix spp.), and cottonwood and aspen (Populus spp.) were keyed on because they are considered among the most reliable indicators of significant subirrigation. No phreatophyte communities, or even individuals, were noted during surveys, suggesting that the depth to the water table was too great for these plants to profit. Generally speaking, riparian woodland growth was present in these areas, but extensive, dense woodland growth was not found. The banks and most adjacent low-lying areas of Coyote Creek are densely covered by smooth bromegrass and punctuated by individuals and small colonies of woody species such as chokecherry, box elder, American elm, and green ash. Grazing of much of the floodplain and a deeply incised streambed are no doubt contributors to this condition. The lack of phreatophytes in the low-lying landforms investigated strongly suggests that subirrigation is not contributing to any increased yields for agricultural crops, most of which are grown at slightly higher elevations in the floodplain.

Following the direction of the OSM guidelines, the other plant group that received attention was the agricultural field crop group. The assessment of field crops was limited to observations of early growth alfalfa and tamegrass in the hay and tame pastureland fields respectively. Standing crop (production), plant densities, and vigor were visually assessed by walking across sections of fields. The appearance of alfalfa was considered particularly important due to its deep-rooted morphology. Surveys revealed that those plants nearest to the creek which should have the best access to subirrigation were, if anything, in poorer condition and/or had poorer population densities than the average plant in the field. The most productive plants were the beneficiaries of additional surface water, not ground water, by virtue of their location in or near the footslope position. Native grassland surveys did not uncover anything contrary to the aforementioned observations. The landowner of lands where the fields reside indicates that yields exceed those on the uplands, but do not appear to be benefitting from subirrigation.

CONCLUSIONS

Based on the information provided, we believe the following conclusions can be drawn:

1. The geologic criterion for alluvial valley floors – streamlaid unconsolidated deposits – is assumed. Stream path configuration and streamload deposition are strong indicators supporting the assumption.

2. Flood irrigation is currently not practiced in the study area or anywhere on Coyote Creek. The following factors enter in to the flood irrigation potential in this location:

   - Water quantity may be limiting in many years.
   - Surface water quality is marginal in terms of salinity; some special mitigating practices such as leaching may be necessary at slightly higher conductivity levels.
   - Fields, sometimes small, contain oxbow depressions, complex and/or steeper slopes, irregular boundaries, and other characteristics militating against the economic feasibility of flood irrigation practices.

3. There is no evidence of historical flood irrigation in the study area or any portion of Coyote Creek. The potential for flood irrigation is considered remote considering the factors previously cited.

4. Subirrigation is not playing a role in enhancement of crop production in the study area. This conclusion is evidenced by a depth to the water table that exceeds 15 feet, absence of phreatophytes, and absence of field crop production enhancement. Further, the water table in the vicinity of the Voigt farmstead has high salinity, limiting the agricultural producer to sporadic use and the implementation of a leaching program.

In summation, these conclusions on the judgment criteria for evaluation of a potential alluvial valley floor lead us to a summary conclusion that the Coyote Creek stream valley does not contain an alluvial valley floor within the study area.

The OSM draft study summarized in the introduction section noted that water availability on streams such as Coyote Creek limits surface irrigation, if it is at all possible, and that natural flood irrigation and subirrigation are important features. The study concluded that portions of higher terraces along Coyote Creek could be flood irrigated by spreading and/or pumping water. We have concluded that the limited water quantity in some years and other factors such as marginal water quality make surface irrigation unlikely. Absence of historical surface irrigation in similar stream valleys in the area also discount consideration of surface irrigation. Another conclusion of the OSM report was that deep-rooting alfalfa probably receives beneficial moisture through subirrigation. Absence of phreatophytes, poor groundwater quality, water table depth exceeding 15 feet, and lack of evidence of plant growth benefitting from additional water provided by subirrigation lead us to conclude that deep-rooted crops such as alfalfa are not being subirrigated.

LITERATURE CITED

Bauder, T.A., R.M. Waskom, and J.G. Davis. 2007. Irrigation Water Quality Criteria. Colorado State University Cooperative Extension Bulletin No. 0.506.

Brant, R.L. 1953. Lignite Resources of North Dakota. Geological Survey Circular 226. North Dakota Geological Survey, U.S Department Of Interior. Washington, D.C.

Carlson, C.G. 1973. Geology of Mercer and Oliver Counties, North Dakota. Bulletin 56 – Part 1. North Dakota Geological Survey. County Ground Water Studies 15 – Part 1. North Dakota State Water Commission. Bismarck, ND. U.S. Geological Survey, Washington, D.C.

Croft, M.G. 1970. Ground-Water Basic Data – Mercer and Oliver Counties, North Dakota. Bulletin 56 – Part 2. North Dakota Geological Survey, Bismarck, ND. County Ground Water Studies 15 – Part 2. North Dakota State Water Commission, Bismarck, ND. U.S. Geological Survey, Grand Forks, ND.

Croft, M.G. 1973. Ground-Water Resources – Mercer and Oliver Counties, North Dakota. Bulletin 56 – Part 3. North Dakota Geological Survey, Bismarck, ND. County Ground Water Studies 15 – Part 3. North Dakota State Water Commission, Bismarck, ND. U.S. Geological Survey, Bismarck, ND.

U.S. Geological Survey. 2009. USGS Surface-Water Monthly Statistics for the Nation. Retrieved May 19, 2009 from http://waterdata.usgs.gov/nwis.

U.S. Office of Surface Mining. 1983. Alluvial Valley Floor Identification and Study Guidelines, Draft of August 1983. Washington, D.C.

U.S. Office of Surface Mining. 1985. Draft Reconnaissance Maps to Assist in Identifying Alluvial Valley Floors, West-Central North Dakota.