Groundwater Monitoring System Report

Slag Pond Area
Big Stone Plant
Big Stone City, South Dakota

Prepared for
Otter Tail Power Company

December 2016

234 West Century Avenue
Bismarck, ND 58503
701.255.5460
www.barr.com

Groundwater Monitoring System Report
Slag Pond Area
Big Stone Plant

December 2016

Contents

List of Tables

List of Figures

List of Appendices

Certification

I hereby certify that the monitoring system identified herein has been designed and constructed to meet the requirements of § 257.91, Groundwater monitoring systems, as included in 40 CFR Part 257, Subpart D, Disposal of Coal Combustion Residuals from Electric Utilities.

Digitally signed by Paul T. Swenson
Date: 2016.12.16 14:48:36 -06'00'

Acronyms

Term	Description
Anisotropic	Where there is a directional difference in an aquifer characteristic or parameter; usually due to layered geology
ADA	Ash Disposal Area and Surrounding Area
bgs	Below Ground Surface
BMP	Below Measuring Point
CCR	Coal Combustion Residuals
EPA	Environmental Protection Agency
Facility	Big Stone Plant
FGD	Flue Gas Desulfurization
GTU	Glacial Till Unit composed of two subunits consisting of the upper Brown Till and the Gray Till below
OTP	Otter Tail Power Company
SCM	Site Conceptual Model
Site	Ponds (Slag Pond, West Brine Pond, East Brine Pond, Reclaim Pond, Cooling Pond, Evaporation Pond, and Holding Pond), Landfill (Ash Disposal Area), and Ash Storage Area (Temporary Storage Area).
Slag Pond Area	Slag Pond, Temporary Storage Area and Surrounding Area.
TOR	Top of Riser
TSA	Temporary Storage Area

1.0 Introduction

Otter Tail Power Company (OTP) owns and operates Big Stone Plant, a coal-fired generation unit in Big Stone City, South Dakota. The Site location is shown on Figure 1, which includes ponds (Slag Pond, West Brine Pond, East Brine Pond, Reclaim Pond, Cooling Pond, Evaporation Pond, and Holding Pond), landfill (Ash Disposal Area), and ash storage area (Temporary Storage Area).

The Slag Pond is an existing incised CCR surface impoundment and the Ash Disposal Area is an existing CCR landfill at Big Stone Plant that are required to comply with the provisions of the US EPA Coal Combustion Residuals (CCR) Rule (40 CFR Parts 257 and 261 Disposal of Coal Combustion Residuals From Electric Utilities). The Temporary Storage Area (TSA) also is required to comply with the applicable CCR landfill provisions of the CCR Rule since the CCR is not beneficially used offsite, not containerized, and accumulation of CCR occurs on land.

The West Brine Pond, East Brine Pond, Reclaim Pond, Cooling Pond, Evaporation Pond, and Holding Pond are not regulated by the CCR Rule.

The Slag Pond Area consists of the Slag Pond, the TSA, and the area around the Slag Pond and TSA in which the groundwater monitoring system is located. The Slag Pond Area is shown on Figure 2. The Slag Pond Area is a multiunit groundwater monitoring system as allowed by § 257.91 (d). It is not feasible to install a separate groundwater monitoring system for each CCR subunit.

The Ash Disposal Area (ADA) consists of the landfill and the area around the landfill in which the monitoring system is located. The ADA is discussed in a separate report.

This report has been prepared to document hydrogeologic and monitoring system information as required by the CCR Rule for the Slag Pond Area. It describes:

- July, August, and September 2016 field activities
- The site hydrogeology
- The CCR groundwater monitoring system meeting the requirements of the CCR Rule (40 CFR Part 257, US EPA, 2015) at Big Stone Plant (Facility)

1.1 Purpose

This document has been prepared to describe the groundwater monitoring system for the Big Stone Plant Slag Pond Area and how it has been designed to meet the requirements of the CCR Rule (Rule). Specific requirements for groundwater monitoring systems are established in § 257.91, "Groundwater monitoring systems," as follows:

> *(a) Performance standard. The owner or operator of a CCR unit must install a groundwater monitoring system that consists of a sufficient number of wells, installed at appropriate locations and depths, to yield groundwater samples from the uppermost aquifer that:*

(1) Accurately represent the quality of background groundwater that has not been affected by leakage from a CCR unit. A determination of background quality may include sampling of wells that are not hydraulically upgradient of the CCR management area where:

(i) Hydrogeologic conditions do not allow the owner or operator of the CCR unit to determine what wells are hydraulically upgradient; or

(ii) Sampling at other wells will provide an indication of background groundwater quality that is as representative or more representative than that provided by the upgradient wells; and

(2) Accurately represent the quality of groundwater passing the waste boundary of the CCR unit. The downgradient monitoring system must be installed at the waste boundary that ensures detection of groundwater contamination in the uppermost aquifer. All potential contaminant pathways must be monitored.

(b) The number, spacing, and depths of monitoring systems shall be determined based upon site-specific technical information that must include thorough characterization of:

(1) Aquifer thickness, groundwater flow rate, groundwater flow direction including seasonal and temporal fluctuations in groundwater flow; and

(2) Saturated and unsaturated geologic units and fill materials overlying the uppermost aquifer, materials comprising the uppermost aquifer, and materials comprising the confining unit defining the lower boundary of the uppermost aquifer, including, but not limited to, thicknesses, stratigraphy, lithology, hydraulic conductivities, porosities and effective porosities.

1.2 Scope of Work

The scope of work performed for this project includes:

- Collect and review existing information regarding the CCR unit to provide the information required by the CCR Rule.
- Establish and document the groundwater site conceptual model (SCM) that can be used to evaluate site data and design the monitoring system.
- Identify gaps in the existing data and perform additional field tasks to establish a monitoring system as required by the CCR Rule.
- Observe (December 2015) field investigation consisting of the following subtasks:
    - Installation of monitoring wells SLAG 1, SLAG 2, SLAG 3, SLAG 4, and SLAG 5 and soil borings B1, B2, and B3.
    - Collection of water level elevation data to document groundwater flow directions.

- Observe (July 2016) field investigation consisting of the following subtasks:
    - Installation of monitoring wells SLAG 2B, SLAG 6, SLAG 7, SLAG 9, and SLAG 9 DEEP. A pilot boring was completed near an existing monitoring well (SLAG 8) to determine the local geology. A downhole video camera was used to investigate the condition of the monitoring well, including the screen, at the existing monitoring well (SLAG 8).
    - Development of monitoring wells proposed to become part of the CCR monitoring system.
    - Collection of geotechnical samples for analysis of parameters such as grain size analysis, vertical hydraulic conductivity, and horizontal hydraulic conductivity.
    - Collection of water level elevation data to document groundwater flow directions.
    - Performance of slug tests on select wells to estimate the local hydraulic conductivity.

1.3 Report Contents

Information in this report, assembled in response to the requirements of the CCR Rule, is organized into the following sections:

- Section 1.0 Introduction (this section) which provides an overview.
- Section 2.0 Site Background which provides background information on the Site, including Site operations and setting and geologic and hydrogeological information.
- Section 3.0 Conceptual Model provides a summary of the site conceptual model for the Slag Pond Area.
- Section 4.0 Groundwater Monitoring Well System which provides a description of the CCR monitoring system.
- Section 5.0 References.

2.0 Site Background

2.1 Big Stone Plant CCR Units

The Big Stone Plant burns subbituminous coal to operate its 474 megawatt generating unit. The Big Stone Plant is a zero-discharge facility. The main coal ash products produced are: boiler slag, economizer ash, and a flue gas desulfurization (FGD) product that contains a mixture of fly ash and spent desulfurization material. Boiler slag is conveyed by water, or sluiced, to the Slag Pond (Figure 2). The material is periodically dredged from the pond and stockpiled adjacent to the pond in the TSA. The FGD product is transported by mobile equipment to the on-site CCR landfill (ADA).

2.1.1 Slag Pond Area History and Construction

The Slag Pond was constructed when the Plant began operations in 1975. It was constructed by excavation of the clayey native glacial till. The pond is unlined. Available Slag Pond engineering construction drawings were provided by OTP for review.

The TSA is located adjacent to the northwest edge of the Slag Pond. It is used for dewatering of the slag material prior to loading and selling off-site or hauling to the landfill. It is also unlined and built on native clay till material with a slightly sloped surface graded to allow drainage back into the Slag Pond.

2.2 Site Setting

The Site lies on a glacial drift plain that rises 140 ft. above Big Stone Lake to the east and the Whetstone River to the south. To the west, the ground surface rises 900 ft. in a distance of 15 to 20 miles to the crest of the Coteau des Prairies, a prominent regional highland. The local terrain, prior to construction of the Plant, had changed little since the last glaciers retreated from the area. Natural surface drainage at the Site area is relatively flat with minor changes in elevation.

Information on the Site, geology, and hydrogeology is summarized in the sections below.

2.2.1 Regional Geology

The surficial geology is composed of Late Wisconsin Des Moines Lobe glacial till. Glacial till is unsorted glacial sediment that is derived from the erosion and entrainment of material by the moving ice of a glacier. It is deposited some distance down-ice to form terminal, lateral, medial, and ground moraines. Glacial till is a heterogeneous clay with silt- to boulder-size clasts of glacial origin.

2.2.2 Regional Hydrogeology

Regionally, the Minnesota and Whetstone Rivers are groundwater discharge corridors, and the upland prairies are groundwater recharge areas. Precipitation falling on the uplands seeps to the subsurface and migrates slowly to the discharge areas. Within this regional system, depressions and gullies form local groundwater discharge areas.

Glacial till with relatively low permeability comprises most of the subsurface. Water migrates through till primarily through fractures or through more porous silt and sand seams and lenses. Free water sufficient for even limited domestic use is generally available only from sand seams and lenses within the till.

2.2.3 Site Geology

Figure 3 shows the surface geology at the Site as mapped by the South Dakota Geological Survey (SDGS, 2004). The surface geology underlying most of the Site is mapped as glacial till. Alluvium deposits are mapped to the south and east of the Site. End moraine deposits are shown south of the Slag Pond Area. End moraine deposits consist of glacial till and are characterized by elevated linear ridges with hummocky terrain locally at former ice sheet margins.

Appendix A includes a well completion log for a well that was completed August 24, 1977 near the Plant and Slag Pond. The well log shows the Site to be underlain by approximately 227 ft. of glacial till containing occasional seams and beds of sand. The uppermost till is shown to be a brown till from 0 to 51 ft. below ground surface (bgs), which is underlain by gray till from 51 to 227 ft. bgs. The well log states "black shale with gravel and lignite lenses" from 177 to 227 ft. bgs that is inferred to be glacial till. The well log shows a white coarse sand underlying the till.

Soil borings completed at the Site in December 2015 and July 2016 extended to a maximum depth of 68 ft. bgs. The geology below 68 ft. bgs is inferred from the deeper 1977 well completion log. The shallower glacial till was observed elsewhere at the Site and is described below.

Glacial Till Unit (GTU)

The surficial geology is composed of glacial till. In this report, glacial till is referred to as the Glacial Till Unit (GTU) and consists largely of lean clay with seams and lenses of clayey sand, silty sand, sand, and silt.

The GTU is a continuous lithostratigraphic unit, but it is divided into two separate hydrostratigraphic units for the purpose of this report. The uppermost portion of the GTU is oxidized and more highly fractured than the deeper portion of the till. The uppermost portion of the GTU in this report is called the Brown Till and the lower or deeper unoxidized portion of the GTU is called the Gray Till.

As mentioned in Section 2.2.3, the till is estimated to be 177 ft. thick and could be as thick as 227 ft. at the Site (Appendix A). The thickness of the GTU is anticipated to vary across the Site.

The Brown Till unit is the uppermost material encountered at the Site. The Brown Till unit consists of oxidized yellow to brown lean clay with discontinuous seams and lenses of clayey sand, silty sand, sand, and silt. The Brown Till is clayey with generally low permeability. Although locally higher permeability sand and silt seams and lenses are present within the clay matrix, the seams and lenses are laterally discontinuous and the finer-grained soils in the till likely dictate the effective horizontal hydraulic conductivity at scales that exceed the length of the coarser-grained seams and lenses. The Brown Till is generally more oxidized to brown hues near the water table. The brown oxidized zone transitions with increasing depth (varies by location) to a gray clay till of similar lithology, but it is generally unoxidized.

The Gray Till unit underlies the Brown Till and has a similar lithology as the Brown Till unit, except that is unoxidized. It is also sometimes logged to have a blue hue, which is also indicative of it being unoxidized. The Gray Till may exhibit lower moisture content which may result in lower apparent plasticity. The reduced condition of the Gray Till results because it has little interactions with oxygenated surficial water. The Gray Till would be expected to be less fractured and lower in permeability than the Brown Till as depth increases. Previous studies at the Site (Huntington, 1995) have concluded that the water in the Gray Till near the ADA has a "pre-bomb" tritium signature, indicating that the water in it was recharged prior to 1953. The geology at the ADA is similar to the geology (Brown Till overlying Gray Till) observed at the Slag Pond Area, except thicknesses and occurrences of more permeable seams or lenses are expected to vary.

Below the GTU

As mentioned above, Appendix A includes a well completion log for a well that was completed dated August 24, 1977 near the Plant and Slag Pond. The well log shows a white coarse sand at 227 ft. bgs underlying the Gray Till. It is possible the white coarse sand may be a remnant of Cretaceous Dakota Sandstone or possibly an erroneous classification for weathered granite.

2.3 Slag Pond Area Geology and Hydrogeology

The geology at the Slag Pond Area is comprised of the geology discussed in Section 2.2.3 and the hydrogeology at the Slag Pond Area consists of the more permeable saturated geology.

2.3.1 Geology

The geology at the Slag Pond Area consists of the GTU as described above. Generally, the soil boring logs show that a higher permeability brown silt, silty sand, and clayey sand seam or lens within the clayey matrix occurs roughly at an elevation of 1075 ft. MSL (varies by location). As mentioned above, the GTU is a continuous lithostratigraphic unit. The transition from Brown Till to Gray Till is gradual. Soil borings did not extend to bedrock, which is anticipated at depths greater than 227 ft. bgs.

Soil boring logs and monitoring well completion logs for the soil borings and monitoring wells shown on Figure 2 are provided in Appendix B, which includes all soil boring and monitoring well logs for investigation activities that were completed in December 2015 and July 2016.

2.3.2 Site Hydrogeology

The movement of groundwater within the geologic formations occurs within the more permeable material (e.g., seams or lenses of clayey sand, silty sand, silt, or sand) within an otherwise fine-grained geologic media (e.g., clay till). Groundwater recharge at the Site is likely from the higher regional water table (north of the Site), precipitation, and seepage from the water retention ponds.

Groundwater Flow

The uppermost aquifer for the Slag Pond Area is the saturated, locally higher-permeability seams and lenses observed within the GTU. Sandy zones reported on boring logs generally do not form correlative horizons. However, a more permeable zone located roughly at an elevation of 1075 ft. MSL frequently appears on logs of adjacent borings.

The water table is defined by the presence of groundwater that is relatively shallow (occurs from 10 to 20 ft. bgs) and is observed in monitoring wells screened across an elevation of ~1075 ft. MSL. The term Upper GTU is used to define the hydrostratigraphy that includes the water table and may include both the Brown Till and Gray Till. The term Lower GTU is used to define the hydrostratigraphy that occurs at elevations below the water table and only includes the Gray Till. Much like the transition from the Brown Till to the Gray Till, the Upper GTU gradually transitions to the Lower GTU, but the transition generally occurs at an elevation lower than the higher permeability seam or lenses at ~1075 ft. MSL.

A downward vertical gradient is apparent when comparing monitoring wells screened at different elevations, especially when comparing wells screened within the Upper GTU and Lower GTU. This phenomena exists because the till forms a natural barrier that restricts the vertical movement of water from shallower beds. These variations in water levels with depth complicate accurate delineation of the water table by making it appear to be highly irregular. This phenomenon is common in till areas and is particularly apparent near groundwater discharge corridors.

Figure 4 shows the temporal groundwater elevations (hydrograph) for monitoring wells included in the monitoring well system, which is described in more detail in Section 4.0. There are currently less groundwater elevation data for monitoring wells installed in July 2016 (SLAG 2B, SLAG 6, SLAG 7, and SLAG 9) than is available for monitoring wells installed in December 2015 (SLAG 4 and SLAG 5). The water level elevations since installation shown on Figure 4 have not fluctuated greatly between readings except for measurements taken at monitoring well SLAG 2B. The fluctuation observed in monitoring well SLAG 2B on September 16, 2016 is believed to be due to the lack of well stabilization from recent well development activities.

Figure 5 shows the groundwater elevations measured on August 8, 2016, which indicates that the water table slopes away from the Cooling Pond towards the south (towards the Whetstone River). Based on the groundwater elevations, groundwater generally flows into the Slag Pond Area from the north and flows south, toward monitoring well SLAG 5.

Laboratory Permeability and Hydraulic Conductivity

Table 1 and Table 2 summarize hydrogeological test results from the Slag Pond Area. Geotechnical laboratory data are available in Appendix C.

Table 1 Slag Pond Area Laboratory Values (GTU)

Boring/ Well	Depth (ft.)	Sample Description	GTU	USCS	Test Type	Hydraulic Conductivity, (cm/s)
SLAG 6	32-34	Clayey Sand w/ trace gravel	Brown	SC	Vertical	$6.6x10^{-7}$
SLAG 2B	28-30	Clayey Sand w/ gravel and large pockets of sand w/ silt	Gray	SC	Vertical	$1.0x10^{-6}$
SLAG 2B	28-30	Clayey Sand w/ gravel and large pockets of sand w/ silt	Gray	SC	Horizontal	$1.2x10^{-6}$
SLAG 9 DEEP	38-40	Sand w/ Silt	Brown	SP-SM	Vertical	$1.5x10^{-4}$
SLAG 9 DEEP	64-66	Sandy Lean Clay w/ a little gravel	Gray	CL	Vertical	$3.7x10^{-8}$

Slug test analysis results are summarized in Table 2 and additional details pertaining to the data analysis are included in Appendix D. Slug tests were performed at five monitoring wells (SLAG 1, SLAG 2B, SLAG 5, SLAG 8, SLAG 9 DEEP) to provide estimates of the hydraulic conductivity in the vicinity of the well screens. A slug test consists of monitoring the water-level recovery in a well following an "instantaneous" change in water level. For this work, displacement of the water level in the well was achieved by adding and removing a solid piece of PVC pipe with a known volume. A slug test in which the displacement is initiated by rapidly lowering the slug below the water level is referred to as a slug-in or falling-head test; a slug-out or rising-head test is one in which the slug is rapidly removed. At least two slug tests—slug-in and slug-out—were performed sequentially at each well listed in Table 2. The resulting water-level recovery to static, pre-test condition was monitored using a data-logging pressure transducer (InSitu LevelTroll 700).

Hydraulic conductivity values were estimated using the AQTESOLV software package (Duffield, 2007) to match the Bouwer-Rice (1976) analytical solution against the water-level recovery data. For wells with apparent storage effects (indicated by concave-upward shape in recovery data when plotted on semi-log axes as recommended by Butler (1998) for the Bouwer-Rice solution), aquifer and well construction parameter values required for the analysis were obtained from the available boring logs and well construction records.

Two sets of slug-in/out test pairs were performed at monitoring wells (SLAG 1, SLAG 2B, SLAG 5, and SLAG 8) within the Upper GTU; however the slug-in test data for SLAG 2B were not analyzed due to inadequate recovery during the testing period and the presence of an apparent background trend in the water-level data.

Table 2 Slag Pond Area Slug Test Values (Upper GTU)

Well	Monitored Unit	Hydraulic Conductivity Slug-In (cm/s)	Hydraulic Conductivity Slug-Out (cm/s)
SLAG 1	Water table, upgradient	$9.6x10^{-6}$	$4.0x10^{-6}$
SLAG 2B	Water table, downgradient	--	$2.3x10^{-6}$
SLAG 5	Water table, downgradient	$1.0x10^{-5}$	$3.8x10^{-6}$
SLAG 8	Water table, upgradient	$3.6x10^{-5}$	$5.5x10^{-5}$

The horizontal hydraulic conductivity of the Upper GTU monitoring wells shown in Table 2 ranges from $1.0x10^{-5}$ to $2.3x10^{-6}$ cm/s based on single-well slug tests, with a geometric mean of $9.4x10^{-6}$ cm/s. The data shown in Table 2 indicate that the horizontal conductivity (Kh) is roughly the same as the vertical conductivity (Kv) shown in Table 1.

Two sets of slug-in/out test pairs were performed at SLAG 9 DEEP, which is screened approximately at elevation 1055 ft. MSL within the Lower GTU; however, the slug-in test data for SLAG 9 DEEP were not analyzed due to significant noise in the data. The slug-out test for SLAG 9 DEEP indicated a Kh value of 2.2×10^{-6} cm/s, which is slightly lower than the geometric mean value for the horizontal conductivity values provided in Table 2 for wells screened in the Upper GTU. As indicated in Table 1, the Kv value for the clay matrix at SLAG 9 DEEP based on laboratory permeability testing was 3.7×10^{-8} cm/s or over two orders of magnitude less than the Kh in this unit. These data suggest that the Kh is greater than Kv in the Upper GTU, but Kv decreases dramatically in the Lower GTU even though there may be discontinuous seams in the Gray Till at depth that have comparable Kh as the Upper GTU.

Overall, this means there is more resistance to vertical flow in the Lower GTU than the Upper GTU. Based on the data presented above, it is concluded that the GTU becomes less permeable with increasing depth and acts as an underlying confining unit. Therefore the majority of groundwater flow is most likely to occur in the Upper GTU. .

Groundwater Flow Rates in the Upper GTU

The rate of groundwater flow is estimated by calculating average linear velocity derived from Darcy's equation:

$$Vt = Kh * i/n = 0.002 \text{ ft/day or } 0.70 \text{ ft/yr}$$

Where: Vt = average linear velocity
Kh = hydraulic conductivity ($9.4x10^{-6}$ cm/s)
i = gradient (SLAG 8 to SLAG 5 = 0.018; calculated from water levels)
n = effective porosity (0.25)

The porosity of sand ranges from 0.25 to 0.5 (Freeze and Cherry, 1979). Porosities of glacial outwash aquifers in the region range from 0.2 to 0.3 (Reppe et al, 2005). The assumed porosity of the GTU aquifer is 0.25.

The actual groundwater flow in the vicinity of the Slag Pond Area is likely much lower and is attenuated because the till matrix believed to surround the locally higher permeability seams and lenses will restrict groundwater flow.

Confining Unit Characteristics

The clayey material around the more permeable seams or lenses retard vertical groundwater migration in both of the GTU till units. Based on the slug tests and laboratory tests, the Lower GTU appears to be a confining unit relative to the Upper GTU. This is because the distribution of hydraulic conductivity appears to be more strongly anisotropic (e.g., directional because Kh>>Kv) in the Lower GTU than the Upper GTU, which suggests a greater resistance to vertical flow. Anisotropy is common in horizontally-deposited strata and would tend to result in a natural barrier to the downward vertical movement of water below the Upper GTU.

2.4 Potential Groundwater Receptors

Barr (1990) evaluated information on area wells and found that there are two water supply wells in the vicinity of the Slag Pond related to an ethanol plant (POET Biorefinery) well and the Plant supply well (1977 well log). A third well, called the Champion well, is located between the Slag Pond and the Brine Ponds, but is not used for potable water supply. These wells are not screened within the Upper GTU and are separated from the uppermost saturated unit by a thick layer of low-permeability clay till, and therefore are unlikely to be affected by the Slag Pond Area. The downgradient receptor of groundwater from the Slag Pond Area is the Whetstone River.

2.5 Well Development

Well development was completed to remove fines from the water column in the sand pack adjacent to the well screen and to improve formation permeability near the borehole that may have been influenced by drilling activities. Monitoring wells were surged several times initially by raising the pump up and down within the casing to settle the sand pack and collapse voids in the filter pack caused by bridging. Monitoring wells identified to be within the monitoring well system discussed in Section 4.0 were developed by a combination of higher-rate pumping followed by low-volume pumping without significant surging.

Volumes of purge water removed, relative clarity, and turbidity were measured at each well during development. Well development continued until the water from the well was relatively sediment free, appeared clear, and had decreasing trends in turbidity measurements. Table 3 provides the approximate lowest obtained turbidity measurement, total volumes purged, and the approximate well recharge rates for each well developed.

Table 3 Turbidity, Purge, and Recharge Field Measurements

Well ID	Lowest Obtained Turbidity Measurement (NTU)	Approx. Total Amount Volume Purged (gal)	Approx. Most Recent Recharge Rate (ft.) [date]
SLAG 2B	NA	NA	NA
SLAG 4	7	24	18 minutes to recharge 4 ft. [8/8/16]
SLAG 5	15	4.3	35 minutes to recharge 6 ft. [8/8/16]
SLAG 6	15	15	20 minutes to recharge 5 ft. [8/8/16]
SLAG 7	29	29	3 hours to recharge 24 ft. [8/8/16]
SLAG 8	7	13.3	30 minutes to recharge 17 ft. [8/8/16]
SLAG 9	38	90	1 hour to recharge 24 ft. [8/8/16]

NA – Not Available

Table 3 also shows the approximate recharge rate measured by pumping the well dry and then measuring its recovery. Turbidity, purge, and recharge field measurements for monitoring well SLAG 2B were conducted by OTP.

3.0 Conceptual Models

3.1 Slag Pond Area Conceptual Model

Cross section locations for the Slag Pond Area are shown on Figure 6 and include the location of cross section A-A', B-B', C-C', and D-D'. Cross section A-A' is shown on Figure 7; cross section B-B' is shown on Figure 8; cross section C-C' is shown on Figure 9, and cross section D-D' is shown on Figure 10. The groundwater elevations shown on Figure 7 through Figure 10 were collected on August 8, 2016.

In summary, Figure 7 through Figure 10 show the following features about the hydrogeology of the Slag Pond Area:

- The surface materials consist of the Brown Till.
- As mentioned in Section 2.3.2, uppermost aquifer groundwater flow is primarily within the more permeable zone located roughly at an elevation of 1075 ft. MSL that frequently persists between adjacent borings.
- The water table surface slopes approximately between 1080 ft. to 1110 ft. MSL as observed in monitoring wells.
- The boring log for SLAG 2B shows the Gray Till was observed at approximately elevation 1085 ft. MSL, which is higher than observed in other soil borings completed along the south side of the Slag Pond Area (Appendix B).
- The pilot boring completed along SLAG 8 shows the Gray Till was observed at approximately elevation 1085 ft. MSL, which is higher than observed in other soil borings completed along the north side of the Slag Pond Area (Appendix B).
- Groundwater and surface water measurements indicate that shallow groundwater flows from the Cooling Pond towards the Slag Pond Area and onward, presumably to the Whetstone River approximately one mile south of the Slag Pond Area.
- A downward vertical gradient is apparent when comparing monitoring wells screened within the Upper GTU and Lower GTU (see water level shown for SLAG 9 DEEP on Figure 7).
- The transition from the Upper GTU to the Lower GTU is gradual and occurs at an elevation lower than the higher permeability seam or lenses at ~1075 ft. MSL.
- Soil borings completed at the Site in December 2015 and July 2016 extended to a maximum depth of 68 ft. bgs

3.2 Release Conceptual Model

A release conceptual model uses the groundwater flow direction and geologic information of the site conceptual model to predict the likely pathway of a release from a CCR unit to groundwater so that a monitoring system can be positioned properly to intercept it.

A hypothetical release at the Slag Pond Area would likely be transported southeast, the downgradient direction of the water table shown on Figure 5. The downgradient wells discussed in the next section are positioned to ensure detection of any contaminants from such a release.

4.0 CCR Groundwater Monitoring System

Figure 11 shows and Table 4 describes the CCR groundwater monitoring system for the Slag Pond Area.

Table 4 Monitoring Well System Summary

Well ID	Well Placement	Rationale
SLAG 8 and SLAG 9	Upgradient	To account for hydrogeologic variability upgradient of the Slag Pond Area and to establish a sufficient number of upgradient monitoring wells at appropriate locations and depths to yield groundwater samples of the uppermost aquifer not impacted by the CCR unit (257.91(a) (1) and (2)).
SLAG 2B, SLAG 4, SLAG 5, SLAG 6 and SLAG 7	Downgradient	To detect a release from the Slag Pond Area and to account for hydrogeologic variability, establish sufficient number of downgradient monitoring wells at appropriate locations and depths to yield groundwater samples of the uppermost aquifer accurately representing the quality of groundwater passing through the waste boundary (257.91(a) (1) and (2)).

Based on our observations during sampling and well-development activities, the upgradient and downgradient monitoring wells included in the monitoring system are designed and constructed to provide representative groundwater samples. Based on the monitoring well completion logs available, each well has a casing that is screened; the annular space between the screen and borehole is filled with sand and the annular space above the sand pack is sealed. The downgradient wells listed in Table 4 are positioned to detect contaminants from a hypothetical release in the Slag Pond Area.

In summary, the groundwater monitoring system identified in Table 4 and on Figure 11 is deemed to be adequate for groundwater monitoring under the CCR Rule requirements. Table 5 provides construction details of the CCR groundwater monitoring wells.

Table 5 **CCR Monitoring Well Details**

Well	Installation Date	TOR (ft. MSL)	Total Depth BMP (ft.)	Screen Length (ft.)/ Diameter (in)	Casing/Screen/Slot
SLAG 2B	7/31/2016	1111.26	40.25	5/2.0	PVC/PVC/#6
SLAG 4	12/23/2015	1,113.15	39.02	10/2.0	PVC/PVC/#6
SLAG 5	12/23/2015	1,107.30	38.8	10/2.0	PVC/PVC/#6
SLAG 6	7/20/2016	1111.51	37.3	10/2.0	PVC/PVC/#6
SLAG 7	7/21/2016	1114.39	48.7	10/2.0	PVC/PVC/#6
SLAG 8	NA	1127.26	52.1	5/2.0	PVC/PVC/#10
SLAG 9	7/28/2016	1122.35	49.8	10/2.0	PVC/PVC/#6

NA = Not Available

5.0 References

Barr, 1990. Sludge Pond Seepage Evaluation, Big Stone Plant, prepared for Otter Tail Power, November 1990.

Bouwer, H. and R.C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Butler, J. J., Jr., 1998. The Design, Performance, and Analysis of Slug Tests, CRC Press, Boca Raton, Fla., 252 p.

Duffield, G.M., 2007. *AQTESOLV for Windows Version 4.5 User's Guide*, HydroSOLVE, Inc., Reston, VA.

Freeze A.R., Cherry J.A., 1967. Groundwater. Prentice Hall, Inc. Upper Saddle River, NJ

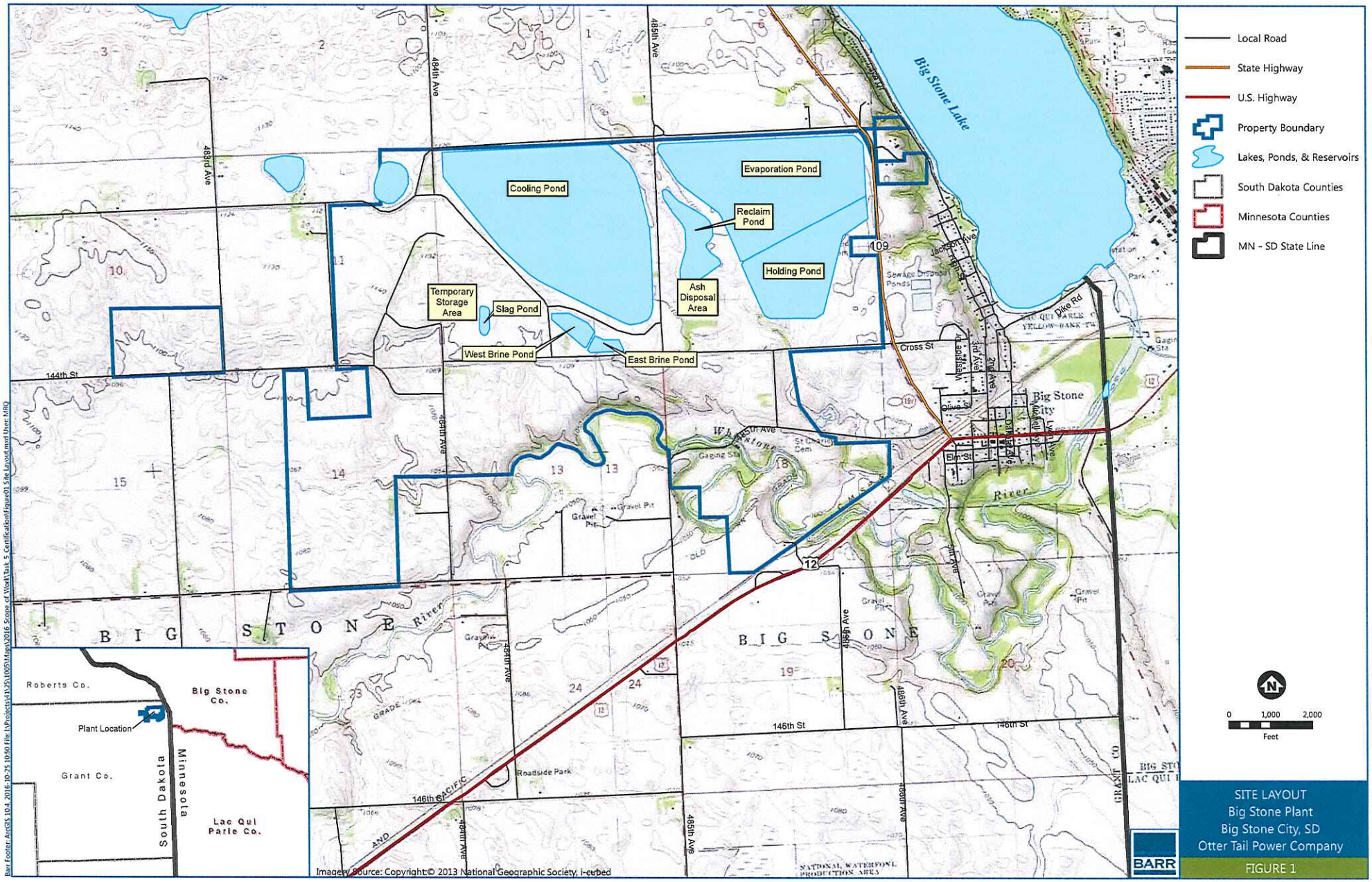
Huntington, 1995, Transmittal of Tritium Analytical Results, Otter Tail Power Company Big Stone Plant. January 6, 199. Transmittal to Mr. Herschner.

Reppe, T.H.C., Thompson, D.L., and Arntson, A.D., 2005. Ground-water availability assessment of surficial aquifers of the Red River of the North Basin, Minnesota; United States Geological Survey.

SDGS, 2004 Martin, J. E., Sawyer, J. F., Fahrenbach, M. D., Tomhave, D. W., and Schulz, L. D., 2004, Geologic Map of South Dakota: South Dakota Geological Survey.

US EPA, 2015. Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals From Electric Utilities; Final Rule, Federal Register vol. 80, no. 74.

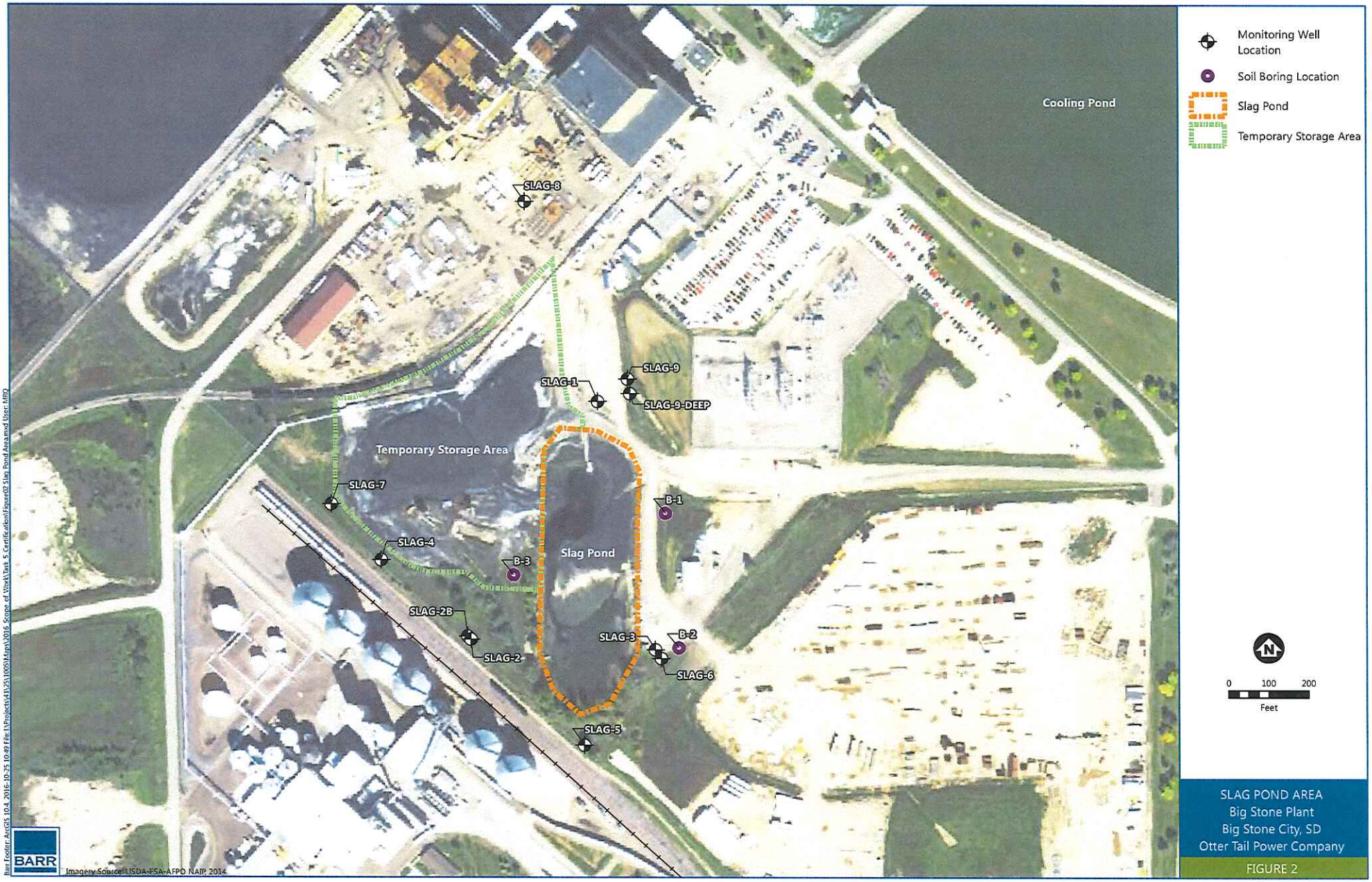
Figures

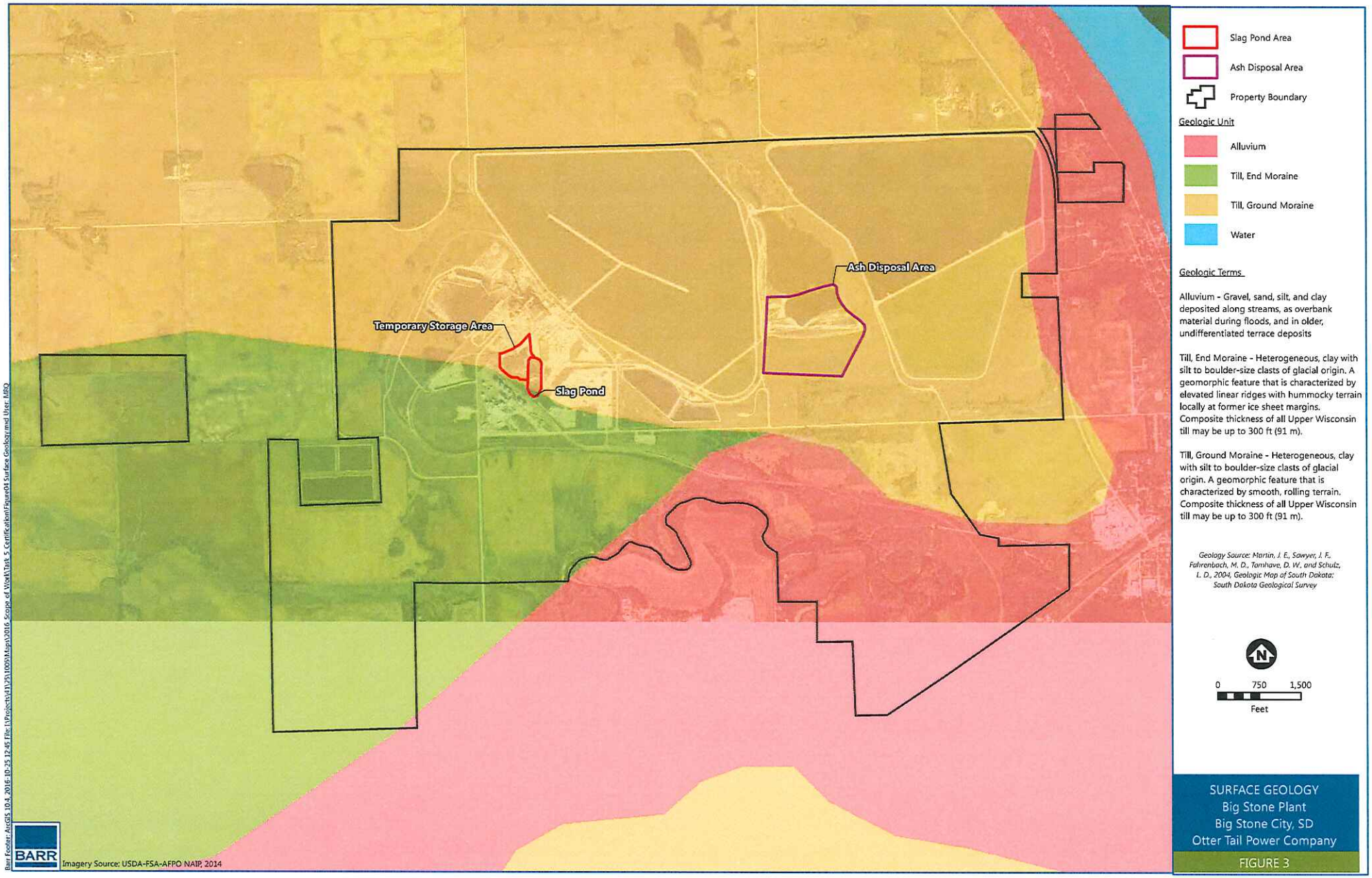


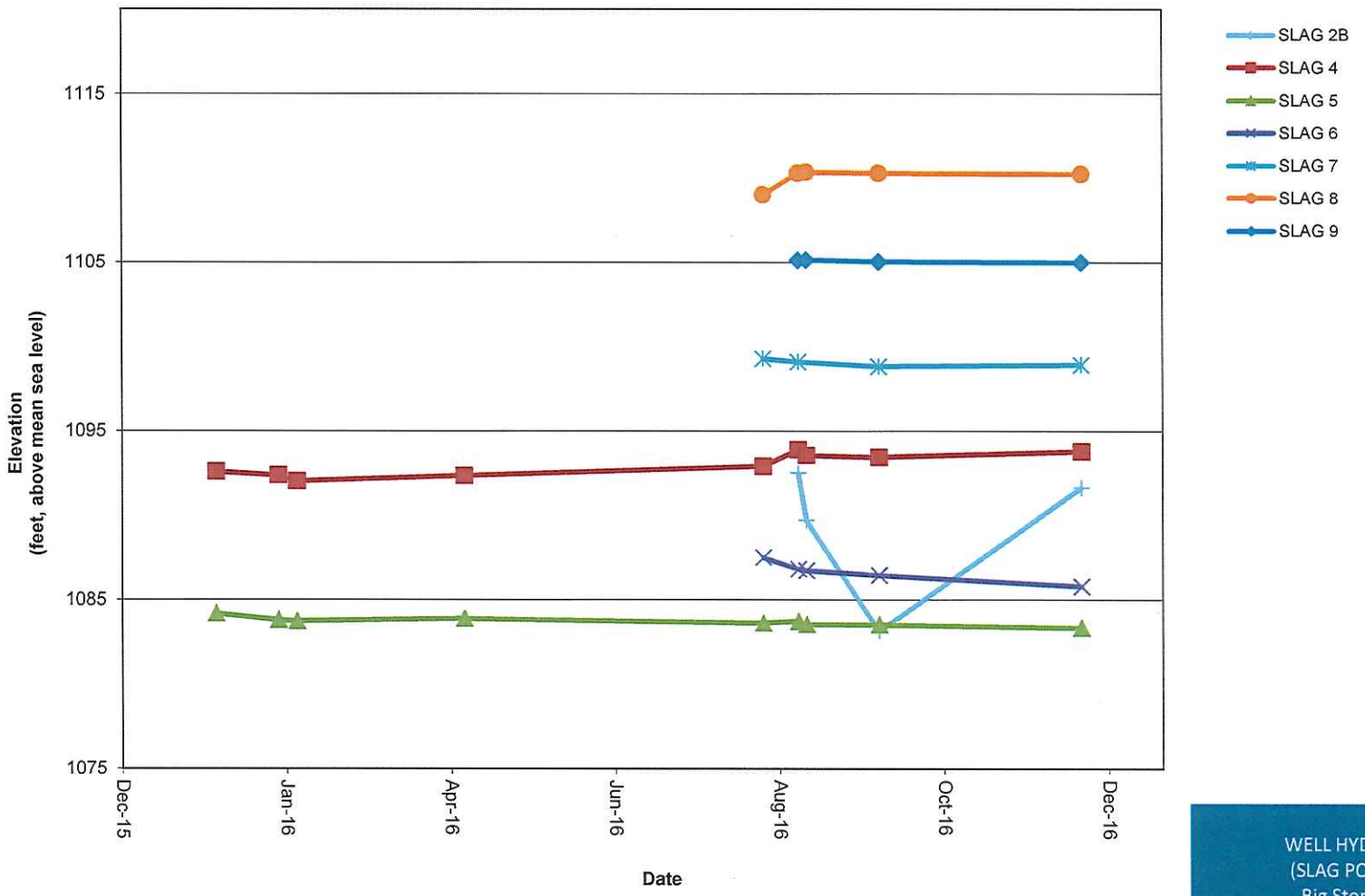
SITE LAYOUT
Big Stone Plant
Big Stone City, SD
Otter Tail Power Company

FIGURE 1

BARR


Cooling Pond
SLAG-8
SLAG-9
SLAG-1
SLAG-9-DEEP
Temporary Storage Area
SLAG-7
B-1
SLAG-4
Slag Pond
B-3
SLAG-2B
SLAG-3
B-2
SLAG-2
SLAG-6
SLAG-5
Monitoring Well Location
Soil Boring Location
Slag Pond
Temporary Storage Area
0
100
200
Feet
Imagery Source: USDA-FSA-APFO NAIP, 2014
BARR
SLAG POND AREA
Big Stone Plant
Big Stone City, SD
Otter Tail Power Company
FIGURE 2

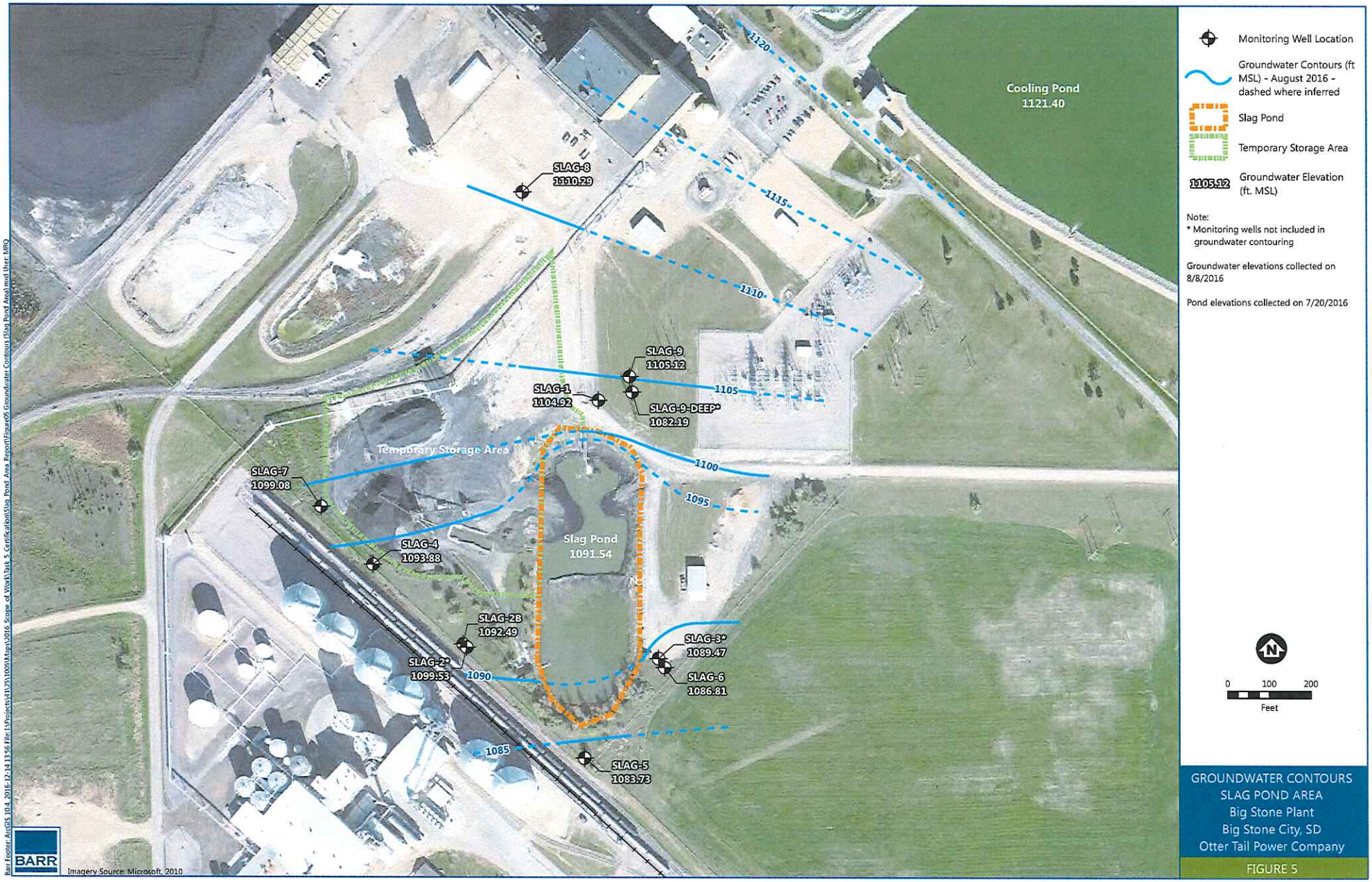




BARR

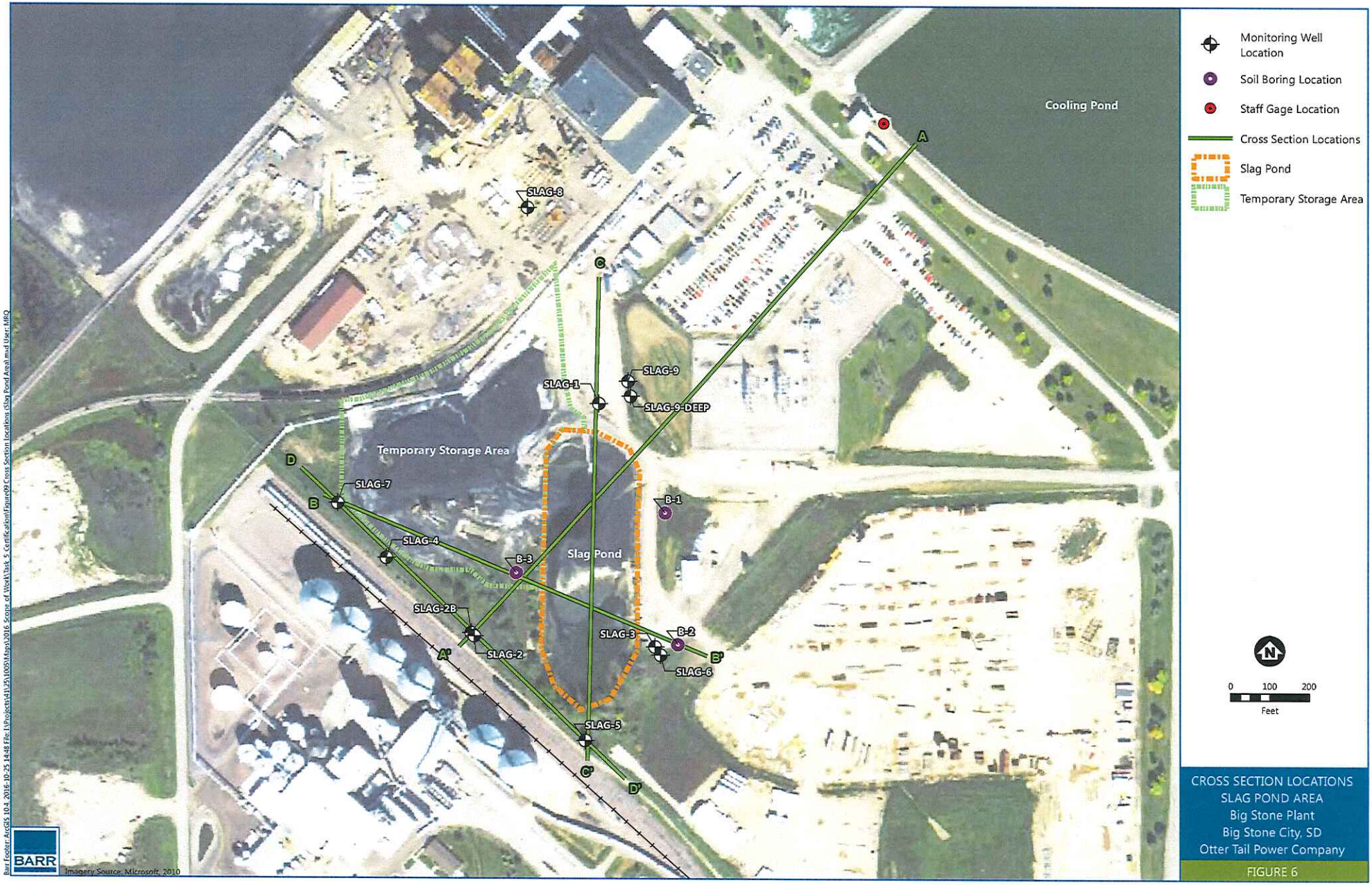
WELL HYDROGRAPH
(SLAG POND AREA)
Big Stone Station
Big Stone, SD
Otter Tail Power Company

FIGURE 4



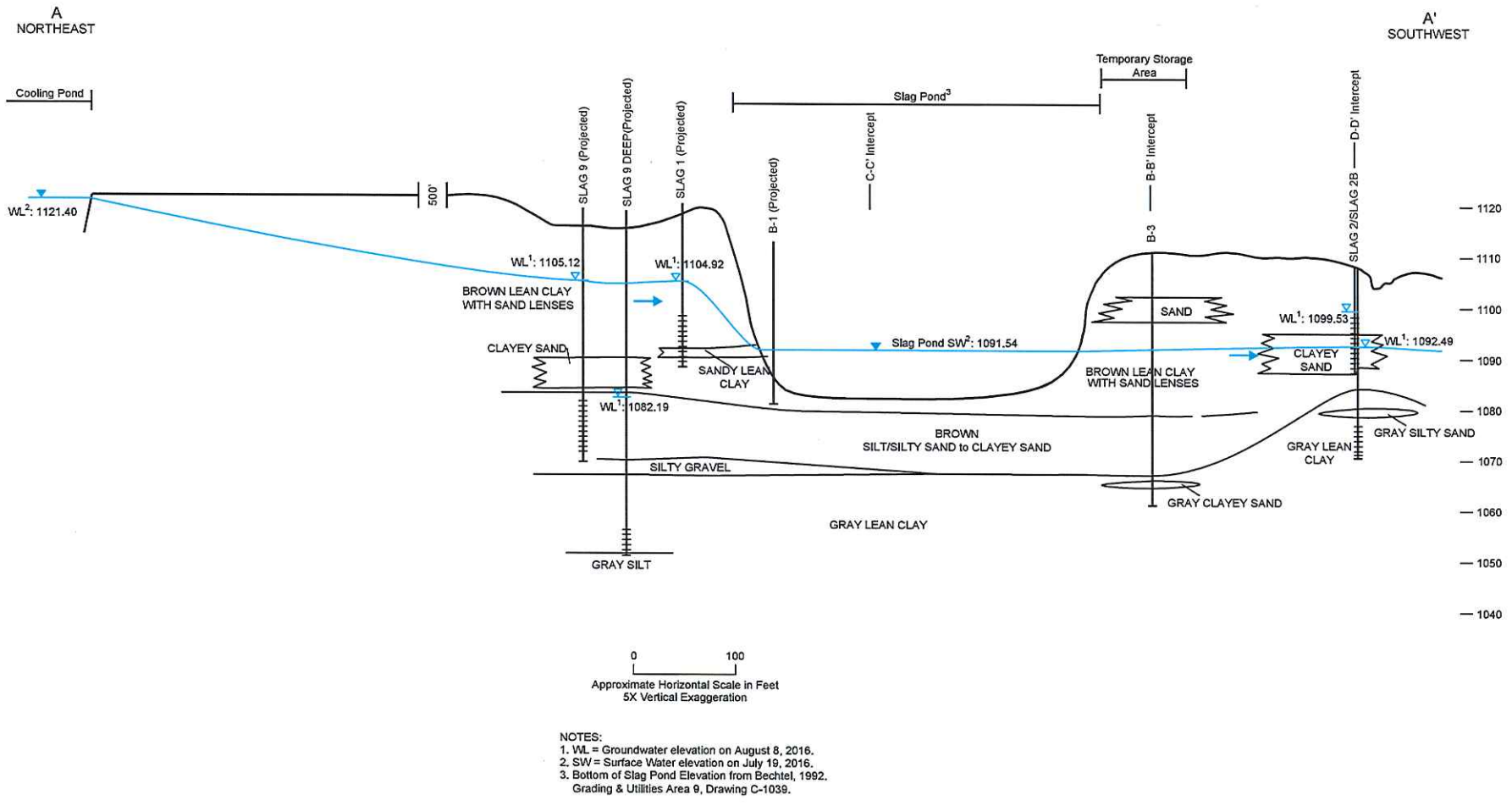
GROUNDWATER CONTOURS
SLAG POND AREA
Big Stone Plant
Big Stone City, SD
Otter Tail Power Company

FIGURE 5



CROSS SECTION LOCATIONS
SLAG POND AREA
Big Stone Plant
Big Stone City, SD
Otter Tail Power Company

FIGURE 6



NOTES:
1. WL = Groundwater elevation on August 8, 2016.
2. SW = Surface Water elevation on July 19, 2016.
3. Bottom of Slag Pond Elevation from Bechtel, 1992. Grading & Utilities Area 9, Drawing C-1039.

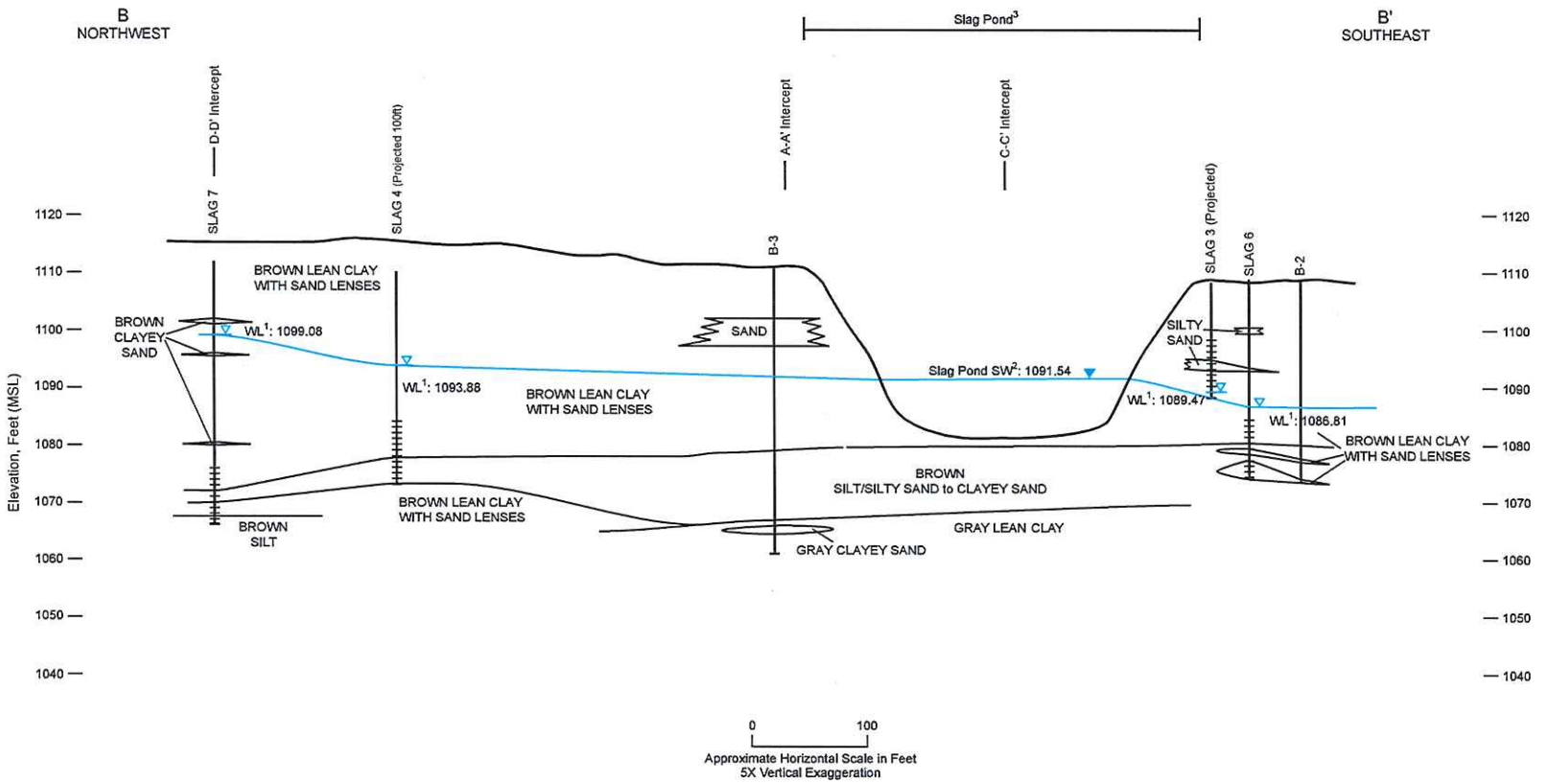
LEGEND

- Geologic Contact
- Inferred Geologic Contact
- Approximate Water table
- Monitoring Well Screen
- Soil Boring/Piezometer

BARR

Figure 7

CROSS SECTION A-A'
Slag Pond Area
Big Stone Plant
Otter Tail Power Company
Big Stone City, SD



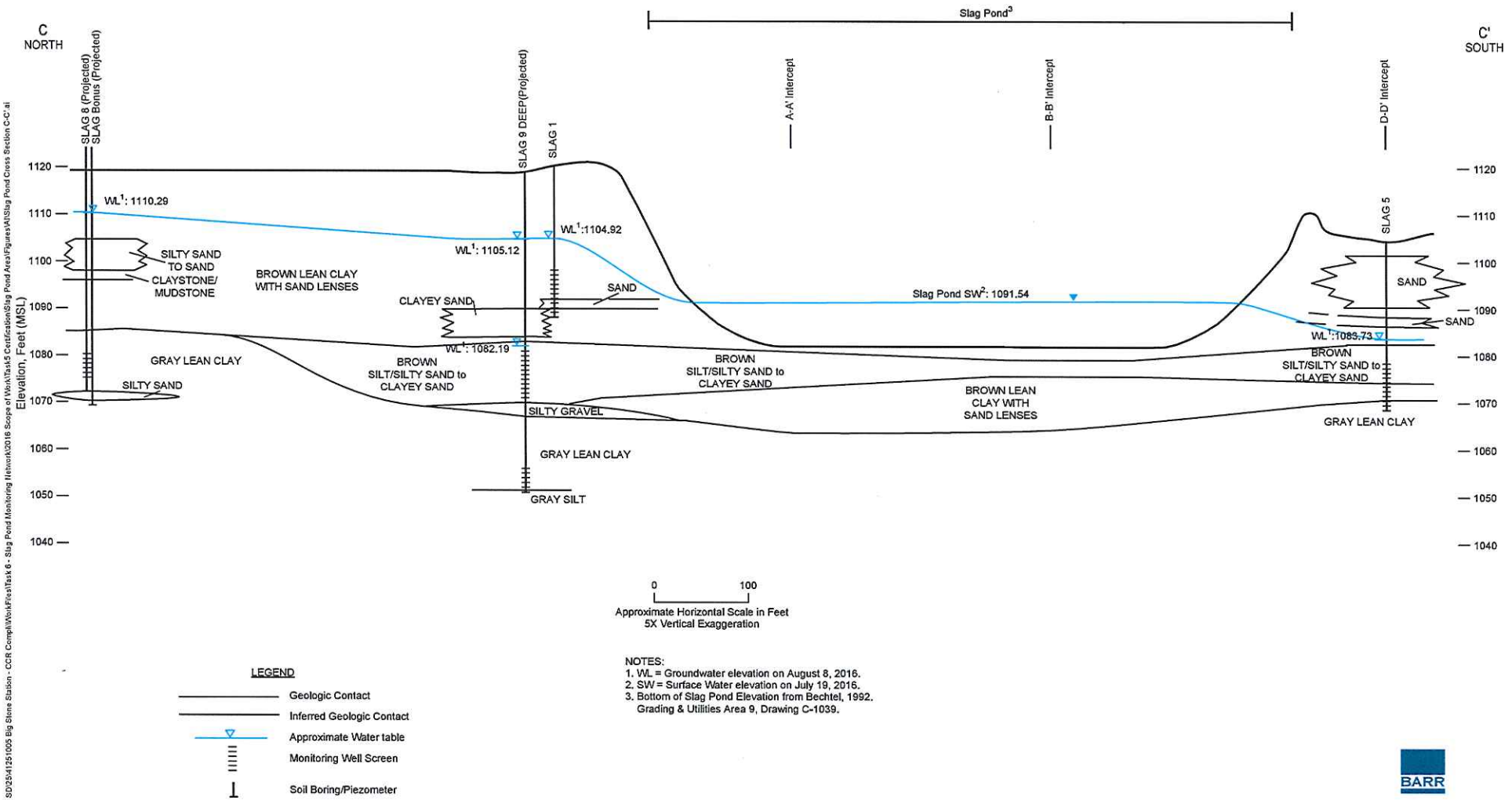
NOTES:
1. WL = Groundwater elevation on August 8, 2016.
2. SW = Surface Water elevation on July 19, 2016.
3. Bottom of Slag Pond Elevation from Bechtel, 1992. Grading & Utilities Area 9, Drawing C-1039.

LEGEND

- Geologic Contact
- Inferred Geologic Contact
- Approximate Water table
- Monitoring Well Screen
- Soil Boring/Piezometer

Figure 8

CROSS SECTION B-B'
Slag Pond Area
Big Stone Plant
Otter Tail Power Company
Big Stone City, SD

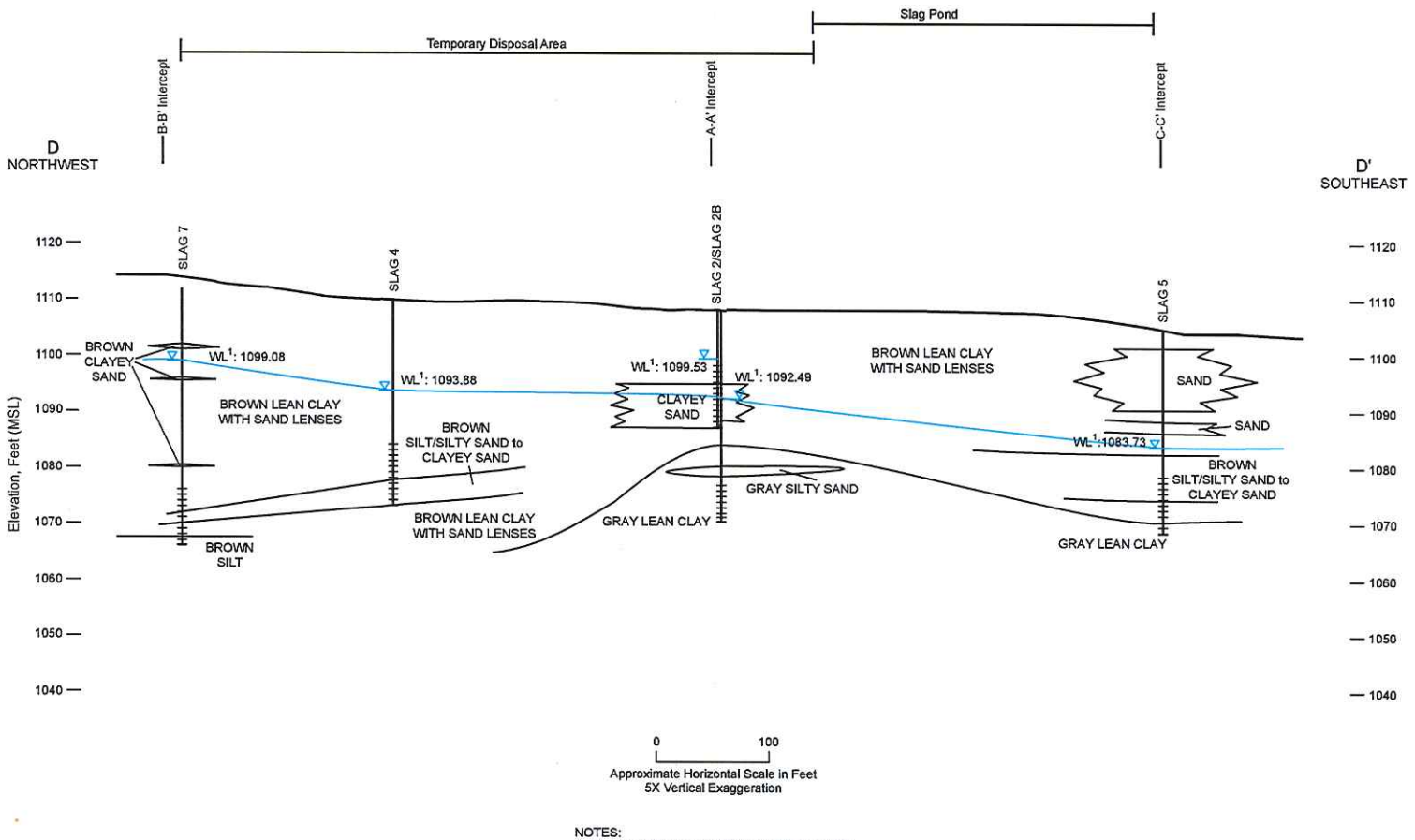


NOTES:
1. WL = Groundwater elevation on August 8, 2016.
2. SW = Surface Water elevation on July 19, 2016.
3. Bottom of Slag Pond Elevation from Bechtel, 1992. Grading & Utilities Area 9, Drawing C-1039.

BARR

Figure 9

CROSS SECTION C-C'
Slag Pond Area
Big Stone Plant
Otter Tail Power Company
Big Stone City, SD



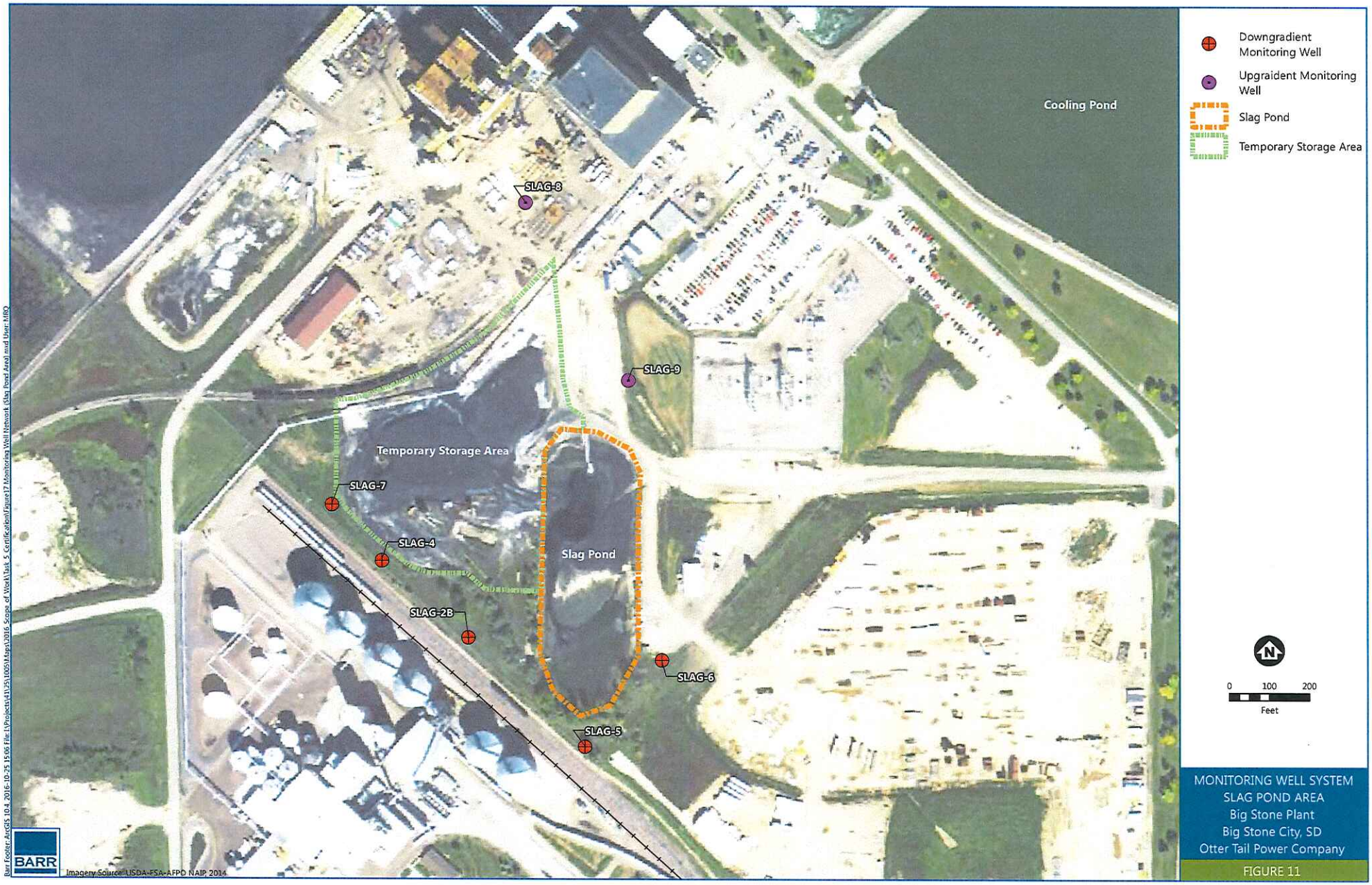
NOTES:
1. WL = Groundwater elevation on August 8, 2016.

LEGEND

- Geologic Contact
- Inferred Geologic Contact
- Monitoring Well Screen
- Soil Boring/Piezometer

Figure 10

CROSS SECTION D-D'
Slag Pond Area
Big Stone Plant
Otter Tail Power Company
Big Stone City, SD


Cooling Pond
SLAG-8
SLAG-9
Temporary Storage Area
SLAG-7
SLAG-4
Slag Pond
SLAG-2B
SLAG-6
SLAG-5
Downgradient Monitoring Well
Upgraidient Monitoring Well
Slag Pond
Temporary Storage Area
N
0
100
200
Feet
MONITORING WELL SYSTEM
SLAG POND AREA
Big Stone Plant
Big Stone City, SD
Otter Tail Power Company
FIGURE 11
BARR
Imagery Source: USDA-FSA-APFO NAIP 2014
Barr Footer: ArcGIS 10.4, 2016-10-25 15:56 File: I:\Projects\41\25\1005\Mxds\2016 Scope of Work\Task 5 Certification\Figure17 Monitoring Well Network (Slag Pond Area).mxd User: MRQ

Appendices

Appendix A

1977 Boing Log

Permit #1982-3 & 4881-3
SESW 12 T121N R47W

121-47-12 CDAD ?

Grant

LAYNE MINNESOTA COMPANY
3147 CALIFORNIA STREET, N.E.
MINNEAPOLIS MINNESOTA

WELL LOG

JOB NAME Ottertail Power Company STARTED _____, 19__

LOCATION Big Stone Plant COMPLETED August 24, 19 77

12-T-121-N R-46-W JOB NUMBER _____

FORMATION LOG

Surface elev = 1116'

FROM	TO	MATERIAL	FROM	TO	MATERIAL
0	20	Yellow silty clay			
20	32	Br. clayey sand	130	150	Blue sand with clay streaks
32	40	Br. coarse sand	150	177	Blue sand clean
40	51	Br. clay			
51	67	Blue clay	177	227	Blk. shale w/gravel &
67	73	Blue medium fine sand			lignite lenses
73	75	Blue clayey sand			
75	90	Br. sand (dirty)			
90	130	Blk. clay with boulders	227	252	White coarse sand

Reamed 17"

METHOD OF DRILLING mud RIG USED R14 Franks DIAMETER OF HOLE 12 IN.

WAS OUTER CASING CEMENTED yes METHOD pressure grout AMOUNT OF CEMENT 8 grout CY.

DEPTH OF WELL, -FROM GROUND LEVEL 250 FT. -FROM TOP OF CASING 254 FT. STATIC 85 FT.

UNDER REAMED FROM 227 FT. TO 252 FT. DIAMETER 22 IN. METHOD Hydraulic

SIZES OF GRAVEL 85 mm. to 125 m. AMOUNT 2 CY.

WELL SHOT AT ____ FT. TO ____ FT. NUMBER ____ SIZE ____ LBS. REMOVED ____ CY.

MATERIAL INSTALLED IN WELL

	OPENING	LENGTH	DIAMETER	MATERIAL
SCREEN	.030	25' "	6 "	Stainless steel
DRIVE CASING		227' "	12 "	Steel
LINER CASING		20' "	6 "	Stainless steel riser pipe

PUMPING TEST

HRS PUMPED FROM	HRS PUMPED TO	YIELD	WATER LEVEL BELOW SURFACE	DRAWDOWN	REMARKS
		GPM	' "	' "	
		GPM	' "	' "	
		GPM	' "	' "	
		GPM	' "	' "	

TIME TO CLEAR ____ HRS ____ MIN. SPECIFIC CAPACITY ____ GPM/FT OF DD.

DATE ____, 19____ DRILLER Neil Rollie

LAYNE MINNESOTA COMPANY
3147 CALIFORNIA STREET, N.E.
MINNEAPOLIS MINNESOTA

pumping test

Permit #1982-3 & 4881-3
SESW 12 T121N R47W

JOB Ottertail Power Company

LOCATION Big Stone Plant

WELL NO. 77-1 STATIC LEVEL 88' DATE August 22 & 23, 19 77

TEST Pump - 200' Columns & Shaft + 6' Bowl Section

DATE	HOUR	ORIF.	GPM WATER	DEPTH TO WATER	DRAWDOWN	SAND PPM	GPM/FT.	REMARKS
8/22	2:00PM	4"	234	190'	102'	.5		Mostly Shale
	3:00PM	4"	247	192'	104'	.3		Sand, some shale
	4:00PM	4"	239	193'	105'	.1		Pieces of shale
	5:00PM	4"	243	191'	103'	.0		Pieces of shale
	6:00PM	4"	243	191'	103'	.0		Traces of shale
	7:00PM	4"	243	192'	104'	.0		Traces of shale
	8:00PM	4"	239	193'	105'	.0		Traces of shale
	9:00PM	4"	230	193'	105'	.0		Traces of shale
	10:00PM	4"	234	195'	107'	.0		Traces of shale
	11:00PM	4"	230	195'-6"	107'-6"	.0		Traces of shale
	12:00	4"	225	195'-6"	107'-6"	.0		Traces of shale
8/23	1:00AM	4"	230	195'	107'-6"	.0		Traces of shale
	2:00AM	4"	230	196'	108'	.0		Traces of shale
	3:00AM	4"	230	195'-6"	107'-6"	.0		Traces of shale
	4:00AM	4"	225	196'	108'	.0		Traces of shale
	5:00AM	4"	225	195'-6"	107'-6"	.0		Traces of shale
	6:00AM	4"	225	195'-6"	107'-6"	.0		Traces of shale
	7:00AM	4"	225	195'-6"	107'-6"	0		Traces of shale
	8:00AM	4"	220	195'-6"	107'-6"	.0		Traces of shale
	9:00AM	4"	205	195'-6"	107'-6"	.0		Traces of shale
	10:00AM	4"	210	194'	106'	.0		Very small pieces
	11:00AM	4"	200	180'	92'	.0		Bigger pieces sha
	12:00	4"	200'	183'-6"	195'-6"	.0		Very small pieces
	1:00PM	4"	200	182'	94'	.0		
	2:00PM	4"	200	182'	94'	.0		

REMARKS 10:45 AM, 8/23/77, water became very cloudy, didn't clean up until 10:45, Lots of shale.

DATE: 8/23, 1977 DRILLER: Neil Rollie

LAYNE MINNESOTA COMPANY
3147 CALIFORNIA STREET, N.E.
MINNEAPOLIS MINNESOTA

pumping test

Plant

Permit #1982-3 & 4881-3
SESW 12 T121N R47W

RECOVERY

JOB Ottertail Power Company

LOCATION Big Stone

WELL NO. #1 STATIC LEVEL 88' DATE August 23, 1977

8 T-121-N R-46-W

DATE	HOUR	ORIF.	GPM WATER	DEPTH TO WATER	DRAWDOWN	SAND PPM	GPM/FT.	REMARKS
8/23	2:00PM		200	182'				Shut off
	2:01PM		200	116'				
	2:02PM			104'				
	2:04PM			102'-5"				
	2:06PM			101'				
	2:08PM			100'				
	2:10PM			100'				
	2:15PM			99'-6"				
	2:20PM			99'-6"				
	2:30PM			99'				
	2:40PM			99'				
	2:50PM			98'-8"				
	3:00PM			98'-4"				
	3:30PM			98'				
	5:30PM			97'				
	7:30PM			96'-6"				
8/24	12:00'							

REMARKS

DATE: August 23, 1977 DRILLER: Neil Rollie

LAYNE MINNESOTA COMPANY
3147 CALIFORNIA STREET, N.E.
MINNEAPOLIS MINNESOTA

pumping test

Permit #1982-3 & 4881-3
SESW 12 T121N R47W

JOB Ottertail Power Company

LOCATION Big Stone Plant

WELL NO Observation Well STATIC LEVEL 89' DATE August 23, 19 77
200' Distant

DATE	HOUR '	ORIF.	GPM WATER	DEPTH TO WATER	DRAWDOWN	SAND PPM	GPM/FT.	REMARKS
8/22	2:00PM			90'-6"				
	3:00PM			91'				
	4:00PM			92'				
	5:00PM			94'				
	6:00PM			94'				
	7:00PM			94'				
	8:00PM			94'				
	9:00PM			95'-6"				
	10:00PM			95'-6"				
	11:00PM			96'-0"				
	12:00			96'-6"				
8/23	1:00AM			97'-6"				
	2:00AM			98'				
	3:00AM			97'-6"				
	4:00AM			97'-6"				
	5:00AM			98'				
	6:00AM			98'-6"				
	7:00AM			99'				
	8:00AM			99'				
	9:00AM			99'				
	10:00AM			100'				
	11:00AM			100'				
	12:00			100'				
	1:00PM			100'				
	2:00PM			100'				

REMARKS

DATE: August 23, 1977 DRILLER: Neil Rollie

LAYNE MINNESOTA COMPANY
3147 CALIFORNIA STREET, N.E.
MINNEAPOLIS MINNESOTA

pumping test

Permit #1982-3 & 4881-3
SESW 12 T121N R47W

RECOVERY

JOB Ottertail Power Company

LOCATION Big Stone Plant

WELL NO. Observation STATIC LEVEL 89' DATE August 23, 1977

DATE	HOUR	ORIF.	GPM WATER	DEPTH TO WATER	DRAWDOWN	SAND PPM	GPM/FT.	REMARKS
8/23	2:00PM			100'				Shut off
	2:01PM			99'-6"				
	2:02PM			99'-4"				
	2:04PM			99'-4"				
	2:06PM			99'-2"				
	2:08PM			99'-0"				
	2:10PM			98'-9"				
	2:15PM			98'-9"				
	2:20PM			98'-5"				
	2:30PM			98'-4"				
	2:40PM			98'-4"				
	2:50PM			98'-1"				
	3:00PM			98'-0"				
	3:30PM			97'-9"				
	5:30PM			97'-8"				
	7:30PM			97'-3"				
8/24	12:00			96'				

REMARKS

DATE: August 23, 1977 DRILLER: Neil Rollie

Appendix B

Soil Boring Logs (Slag Pond Area)

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING B-1

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019402m, E:695243m
Datum:NAD83

Surface Elevation:1112.9 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:32.0 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
0		1	5-13-7-8.	SW-SM		WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM): 2.5Y 4/4 (olive brown); moist; 20% gravel, 70% sand, 10% fines, fine to coarse grained sand, 6 inch black sandy gravel fill, subangular.	
		2	3-3-5-5.	SM		SILTY SAND (SM): 2.5Y 4/3 (olive brown); moist; 0% gravel, 70% sand, 30% fines, nonplastic, very fine to medium grained sand, subangular, trace red oxidation, trace black organics, mottled light gray towards bottom, very low effercescence.	1110
5		3	4-5-8-8.	CL		SANDY LEAN CLAY (CL): 2.5Y 4/4 (olive brown); moist; 2% gravel, 48% sand, 50% fines, low plasticity, subrounded to subangular sand, more oxidized with depth, mottled light gray.	1105
10		4	5-8-9-12.	CL		LEAN CLAY (CL): 2.5Y 5/4 (light olive brown); moist; 0% gravel, 10% sand, 90% fines, low plasticity, very fine to fine grained sand, at 8': trace black organics, red/orange oxidation layers and inclusions, trace fine grained subangular sand within inclusions.	
		5	4-5-8-10.			Moist; 0% gravel, 5% sand, 95% fines, At 11' to 14': low to medium plasticity, very fine to medium grained sand, orange/red oxidization, increasing silt content, low effervescence.	1100
15		6	6-9-9-12.			Moist; 0% gravel, 5% sand, 95% fines, At 14' to 17': very fine to medium grained sand lenses approximately every 4 inches, sand lenses are oxidized on boundaries, increasing silt content.	
		7	5-4-6-6.			Moist; 0% gravel, 5% sand, 95% fines.	1095
20		8	3-3-7-10.	SP		Wet to saturated; 19 ft: less silt, two wet very fine grained sand seams, trace black organics, oxidation, low effervescence.	
				CL		POORLY GRADED SAND (SP): 2.5Y 4/3 (olive brown); saturated; 0% gravel, 95% sand, 5% fines, very fine to fine grained, subrounded to subangular - mostly subangular.	
25						LEAN CLAY (CL): 2.5Y 4/3 (olive brown); moist; 2% gravel, 5% sand, 93% fines, plastic, fine to medium grained sand, subangular, some silt, trace black organics, oxidized, mottled dark gray, low effervescence.	1090

Date Boring Started: 12/14/15
Date Boring Completed: 12/15/15
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks: WT @ 1084.54 ft. on 12/14/15
WT @ 1098.19 ft. on 12/15/15

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251001 BIG STONE\41251005 BIG STONE.GPJ BARR_LIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING B-1

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019402m, E:695243m
Datum:NAD83

Surface Elevation:1112.9 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:32.0 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
25		9	4-10-12-10.	CL		LEAN CLAY (CL): 2.5Y 4/3 (olive brown); moist; 2% gravel, 5% sand, 93% fines, plastic, fine to medium grained sand, subangular, some silt, trace black organics, oxidized, mottled dark gray, low effervescence. *(continued)*	
				SP-SM		POORLY GRADED SAND WITH SILT (SP-SM): wet; 0% gravel, 90% sand, 10% fines, very fine grained sand with silt.	
		10	6-7-8-11.				1085
				CL		LEAN CLAY WITH SAND (CL): moist; 0% gravel, 20% sand, 80% fines, low to medium plasticity, very fine grained to medium grained sand, subrounded to subangular, oxidization.	
30		11	6-7-13-21.			Wet; 31.5 ft: very fine grained subrounded and subangular sand with silt and oxidized layers, lense of well graded subangular sand at bottom, low effervesence.	
						End of boring 32.0 feet	
35							
40							
45							
50							

Date Boring Started: 12/14/15
Date Boring Completed: 12/15/15
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks: WT @ 1084.54 ft. on 12/14/15
WT @ 1098.19 ft. on 12/15/15

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251001 BIG STONE\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING B-2

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019299m, E:695253m
Datum:NAD83

Surface Elevation:1108.7 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:35.0 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
0				CL		LEAN CLAY (CL): 7.5YR 2.5/1 (black); topsoil, fine grained sand, subround to subangular, some gravel.	
		1	2-2-2-2.			LEAN CLAY (CL): 2.5Y 4/4 (olive brown); moist; 5% gravel, 5% sand, 90% fines.	
						At 2': fill, fine to medium grained sands, subrounded to subangular, slight red oxidation, low effervescence.	
		2	3-3-4-4.			Moist; 2% gravel, 3% sand, 95% fines, medium plasticity, fine to medium grained sand, At 4': trace gravels, subrounded to subangular, red oxidation spots.	1105
5							
		3	4-5-7-7.	CL		2.5Y 5/4 (light olive brown); moist; 4% gravel, 3% sand, 93% fines, At 7.5': thin very fine sand lense, subrounded to subangular.	
							1100
10		4	6-8-8-10.			Moist; 4% gravel, 3% sand, 93% fines, At 10 ft: thin very fine grained sand lense, subrounded to subangular, mottled.	
		5	7-9-8-12.			LEAN CLAY (CL): 2.5Y 5/4 (light olive brown); moist; 5% gravel, 5% sand, 90% fines, low plasticity, well graded fine to coarse grained sand lense, oxidation on outside edge/fracture.	1095
15		6	6-6-6-8.	CL		Moist; 5% gravel, 5% sand, 90% fines, fine to coarse grained sand, At 16': well graded small gravel with increasing mix of sand, subrounded to subangular, red oxidation.	
						LEAN CLAY (CL): 2.5Y 4/4 (olive brown); moist; 5% gravel, 5% sand, 90% fines, thin fine to medium grained sand seams, trace black organics.	
		7	8-8-9-10.				1090
20						Wet; At 19.5': 1" fine to coarse grained sand seam, subrounded to subangular. Wet; At 20': 1" well graded very fine to fine grained sand seam, subangular.	
		8	3-5-7-8.	CL		2.5Y 4/3 (olive brown); moist; 1% gravel, 3% sand, 96% fines, at 21': trace fine gravel, subrounded to subangular, thin very fine to fine grained sand lenses, trace red oxidation, increasing black organics.	
							1085
25							

Date Boring Started: 12/14/15
Date Boring Completed: 12/14/15
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks: WT @ 1080.32

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251001 BIG STONE\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING B-2

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019299m, E:695253m
Datum:NAD83

Surface Elevation:1108.7 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:35.0 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
25		9	4-6-8-9.	CL		LEAN CLAY (CL): 2.5Y 4/4 (olive brown); moist; 5% gravel, 5% sand, 90% fines, thin fine to medium grained sand seams, trace black organics. *(continued)* Moist; 2% gravel, 3% sand, 95% fines, AT 25': increased very fine to fine grained sand content, increasing moisture, oxidized orange and red layers, low effervescence.	
		10	3-5-9-11.	CL		LEAN CLAY (CL): 2.5Y 5/3 (light olive brown); moist; 0% gravel, 2% sand, 98% fines, trace very fine grained sand, subrounded to subangular, oxidized orange and red layers, trace black organics, low effervescence.	
				SC		CLAYEY SAND (SC): wet; 0% gravel, 80% sand, 20% fines, very fine to fine grained sand, subrounded to subangular, trace silt and clay, some oxidation, black spots, very low effervescence.	1080
30		11	7-7-7-9.	CL		LEAN CLAY (CL): 10YR 3/1 (very dark gray); wet; 6" layer mottled with fine to medium grained sand.	
				SC		CLAYEY SAND (SC): 0% gravel, 85% sand, 15% fines, some areas layered fine grained sand/clay.	1075
		12	6-7-9-11.				
35				CL		SANDY LEAN CLAY (CL): 10YR 3/1 (very dark gray); wet; very fine grained oxidized sand pockets within. End of boring 35.0 feet	
40							
45							
50							

Date Boring Started: 12/14/15
Date Boring Completed: 12/14/15
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks: WT @ 1080.32

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251001 BIG STONE\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING B-3

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019355m, E:695127m
Datum:NAD83

Surface Elevation:1111.1 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:50.0 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
0		1	4-5-5-6.	CL		LEAN CLAY (CL): frozen; trace topsoil, black ash runoff.	1110
						2.5Y 5/4 (light olive brown); moist; 0% gravel, 10% sand, 90% fines, At 2': low plasticity, very fine to fine with trace medium grained sand, subrounded to subangular, larger grains subangular, trace black vitreous bottom slag, low effervescence.	
		2	3-3-3-4.			2.5Y 2.5/1 (black); moist; 0% gravel, 2% sand, 98% fines, At 4': 6": trace oxidation, roots/ organics, no effervescence.	
5		3	5-5-6-8.			2.5Y 5/4 (light olive brown); 2% gravel, 8% sand, 90% fines, mottled with 2.5y 7/1 (light gray), very fine to fine with trace medium grained sand, subrounded to subangular, larger grains more subangular, oxidation, none to low effervescence.	1105
10		4	6-8-7-8.	SP		POORLY GRADED SAND (SP): 2.5Y 5/4 (light olive brown); moist; 0% gravel, 95% sand, 5% fines, very fine with some medium grained sand, subrounded to subangular, larger grains more subangular, trace red oxidation, little black spots within, some layering, no effervescence.	1100
		5	4-7-7-6.			0% gravel, 95% sand, 5% fines.	
						Wet at 13.8'.	
15		6	7-7-9-12.	CL		LEAN CLAY (CL): moist; 5% gravel, 10% sand, 85% fines, medium plasticity, very fine to medium grained sand, subrounded to subangular, few subangular gravel, some dark brown/black oxidation, trace black organic chunks.	1095
		7	3-5-7-10.			Moist; 0% gravel, 10% sand, 90% fines.	
20		8	4-4-6-7.	CL		LEAN CLAY (CL): moist; 0% gravel, 10% sand, 90% fines, medium plasticity, very fine to medium grained sand, subrounded to subangular, larger grains more subangular, trace black organics, some oxidation in thin very fine grained sand layers.	1090
25		9	3-3-3-6.	CL		LEAN CLAY (CL): moist; 0% gravel, 5% sand, 95% fines, increasing silt content, very fine grained sand lenses to larger fine grained to medium grained subangular sand, red and black oxidation.	

Date Boring Started: 12/15/15
Date Boring Completed: 12/15/15
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks:

Additional data may have been collected in the field which is not included on this log.

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING B-3

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019355m, E:695127m
Datum:NAD83

Surface Elevation:1111.1 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:50.0 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
		10	4-4-5-9.	CL		LEAN CLAY (CL): moist; 0% gravel, 5% sand, 95% fines, increasing silt content, very fine grained sand lenses to larger fine grained to medium grained subangular sand, red and black oxidation. *(continued)*	1085
30		11	2-3-5-5.				1080
				SM		SILTY SAND (SM): at 31.5': 6" thick.	
				SC		CLAYEY SAND (SC): 2.5Y 4/4 (olive brown); saturated; 0% gravel, 50% sand, 50% fines, transitioning.	
		12	3-3-4-4.	SM		SILTY SAND (SM): 2.5Y 4/4 (olive brown); saturated; no effervescence.	
35							1075
		13	3-3-4-5.	SC		CLAYEY SAND (SC): 2.5Y 4/4 (olive brown); very fine grained sand.	
				SC		CLAYEY SAND (SC): moist; 0% gravel, 50% sand, 50% fines, At 37.5': very fine to medium grained sand, subrounded to subangular, coarse grains more subangular, some dark brown/black oxidation - manganese, some saubangular gravels, trace black organic chunks. 2.5Y 4/3 (olive brown); moist; medium plasticity, very fine to medium grained sand, subrounded to subangular, larger grains more subangular, oxidation, trace black organics, low effervescence.	
40		14	4-4-6-8.			2.5Y 4/3 (olive brown); moist; medium plasticity, subrounded to subangular sand, larger grains more subangular, oxidation, trace black organics, low effervescence.	1070
		15	7-13-21-24.	SC		CLAYEY SAND (SC): 2.5Y 4/3 (olive brown); saturated; 0% gravel, 50% sand, 50% fines, very fine to fine grained sand, no effervescence, soupy.	
				CL		LEAN CLAY (CL): 2.5Y 3/1 (very dark gray); moist; medium plasticity, medium grained sand, 6", subrounded, oxidation.	
45		16	11-9-9-12.	SC		2.5Y 4/3 (olive brown); moist; medium plasticity, very fine to fine with trace medium grained sand, subrounded to subangular, larger grains more subangular, 9", oxidation, trace black organics, low effervescence. CLAYEY SAND (SC): wet; 3" sand seam, very fine to fine grained sand, subrounded to subangular.	1065
				CL		SANDY LEAN CLAY (CL): 2.5Y 3/1 (very dark gray); At 46.5': very fine to medium grained sand, subangular, soft, low effervescence.	
		17	6-7-10-10.				
50				CL		LEAN CLAY (CL): 2.5Y 3/1 (very dark gray); moist; 0% gravel, 5% sand, 95% fines, At 49.5': low plasticity, very fine to fine grained sand, mostly subrounded, no oxidation, soft, low effervescence. 2.5Y 4/1 (dark gray); medium plasticity.	
						End of boring 50.0 feet	

Date Boring Started: 12/15/15
Date Boring Completed: 12/15/15
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks:

Additional data may have been collected in the field which is not included on this log.

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING SLAG-1

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019487m, E:695191m
Datum:NAD83

Surface Elevation:1120.3 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:32.3 ft

Top of Casing Elev.: 1123.0 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION
0		1	30-9-10-10.	CL		SANDY LEAN CLAY (CL): 2.5Y 4/3 (olive brown); frozen; 10% gravel, 30% sand, 60% fines, fine to medium grained sand, subrounded to subangular, few subangular gravel.
		2	21-14-18-11.	CL		LEAN CLAY (CL): wet; 2% gravel, 5% sand, 93% fines, low plasticity, fine to medium grained sand, subrounded to subangular, trace subangular gravel, around 5' most likely bottom of a ditch & both sides of well, none to low effervescence.
5		3	6-5-5-7.			Medium plasticity; Wet at 6' bgs.
		4	4-5-8-9.	CL		LEAN CLAY (CL): 2.5Y 5/4 (light olive brown); moist; 0% gravel, 5% sand, 95% fines, medium plasticity, very fine to fine with trace medium grained sand, well graded, subrounded to subangular - mostly subangular, few sand lenses toward bottom, some lenses oxidized on boundaries, trace red oxidized spots, low effervescence.
10		5	5-4-5-9.			Moist; 1% gravel, 4% sand, 95% fines, at 14': thin (less than 1/4") sand lense.
		6	4-5-5-9.			Moist; 2% gravel, 4% sand, 94% fines, At 15': no sand lense, trace oxidation, no oxidized boundaries.
15		7	4-7-5-8.			Moist; 2% gravel, 4% sand, 94% fines, At 18': very fine to fine grained sand, sandy lean clay towards 20', oxidation, some red surrounded by black spots.
20		8	4-4-4-4.			2.5Y 5/3 (light olive brown); 0% gravel, 5% sand, 95% fines, medium plasticity, very fine to fine with trace mediun grained sand, subrounded to subangular with more subangular, red oxidation, low effervescence.
25						

WELL OR PIEZOMETER CONSTRUCTION DETAIL

PRO. CASING
Diameter: 6"
Type: Steel
Interval: Surface + 3'

RISER CASING
Diameter: 2"
Type: PVC SCH 40
Interval: 0-25' bgs

GROUT
Type: Neat cement
Interval: with 5% bentonite slurry

SEAL 3-17.5' bgs
Type: Bentonite chips
Interval: 0-20' bgs

SANDPACK
Type: AGSCO#1 Silica
Interval: 50-80
20-32' bgs

SCREEN
Diameter: Slot 6
Type: 2" PVC SCH 40
Interval: 22-32'

Elevation, feet: 1120, 1115, 1110, 1105, 1100

Date Boring Started: 12/17/15
Date Boring Completed: 12/17/15
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks:

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251001 BIG STONE\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING SLAG-1

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019487m, E:695191m
Datum:NAD83

Surface Elevation:1120.3 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:32.3 ft

Top of Casing Elev.: 1123.0 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	WELL OR PIEZOMETER CONSTRUCTION DETAIL	Elevation, feet
25						LEAN CLAY (CL): 0% gravel, 5% sand, 95% fines.		1095
						Moist; At 26': medium plasticity, silty, soft.	PRO. CASING Diameter: 6" Type: Steel Interval: Surface + 3'	
		9	3-4-4-4.					
				CL		SANDY LEAN CLAY: saturated; 0% gravel, 40% sand, 60% fines, very fine to fine grained sand.	RISER CASING Diameter: 2" Type: PVC SCH 40 Interval: 0-25' bgs	
30		10	2-2-4-2.					1090
						2.5Y 4/4 (olive brown); moist; 0% gravel, 5% sand, 95% fines, medium plasticity, very fine to fine with trace medium grained sand, subrounded to subangular, medium grained more subangular, oxidized red pockets, some larger areas, low effervescence.	GROUT Type: Neat cement Interval: with 5% bentonite slurry SEAL 3-17.5' bgs Type: Bentonite chips Interval: 0-20' bgs	
						End of boring 32.3 feet	SANDPACK Type: AGSCO#1 Silica Interval: 50-80 20-32' bgs SCREEN Diameter: Slot 6 Type: 2" PVC SCH 40 Interval: 22-32'	
35								
40								
45								
50								

Date Boring Started: 12/17/15
Date Boring Completed: 12/17/15
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks:

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251001 BIG STONE\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING SLAG-2

SHEET 1 OF 1

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019303m, E:695093m
Datum:NAD83

Surface Elevation:1108.3 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:21.0 ft

Top of Casing Elev.: 1111.0 ft

Depth, feet	Sample No.	Blows/6in.	USCS	LITHOLOGIC DESCRIPTION	Elevation, feet
0	1	4-4-3-4.	CL	LEAN CLAY (CL): 2.5Y 4/4 (olive brown); frozen; very fine grained to medium grained sand, subangular fill.	
				10YR 2/2 (very dark brown); moist; 0% gravel, 2% sand, 98% fines, At 1.5': plastic with roots.	
	2	3-4-5-4.		2.5Y 5/4 (light olive brown); moist; 0% gravel, 5% sand, 95% fines, nonplastic, very fine to medium grained sand, subrounded to subangular, medium grained more subangular, mottled with 2.5Y 7/1 (light gray), oxidized with red spots, low effervescence, increased silt.	1105
5					
	3	3-4-4-4.		Moist; At 7' and 7.5': thin sand lenses, black organics/ oxidation.	
					1100
	4	5-6-6-5.		Wet; 2% gravel, 8% sand, 90% fines, At 9': medium plasticity, thin sand lenses throughout, oxidized on boundaries and fractures, red mottles with gray, soft.	
10					
	5	4-6-6-8.		Wet; 0% gravel, 10% sand, 90% fines, At 12': sand lenses within.	
				At 12.8': clayey at bottom. At 12.9': silty clay fill.	1095
	6	3-5-4-5.	SC	CLAYEY SAND (SC): saturated; 2% gravel, 68% sand, 30% fines, fine to medium grained sand, well graded, subrounded to subangular- mostly subangular, low to no effervesence.	
15				Saturated; 5% gravel, 70% sand, 25% fines, very fine to coarse grained sand, very well graded, subrounded to subangular with mostly subangular, trace subangular gravel.	
	7	4-8-8-8.			
			CL	LEAN CLAY (CL): wet to saturated; nonplastic, trace medium grained sand, subangular, increased silt, oxidized.	
	8	7-5-7-7.		CLAYEY SAND (SC): saturated; 2% gravel, 60% sand, 38% fines, At 18': trace gravel.	1090
			SC	Saturated; 0% gravel, 90% sand, 10% fines, At 19': 6" bottom is a black/ black and white sand mix, subangular, clayey sand.	
20	6	7-7-6-8.		At 20': 6" subrounded to subangular sand, no effervescence.	
				2.5Y 4/4 (olive brown); moist; 0% gravel, 10% sand, 90% fines, At 20.5': 6" medium plasticity, fine to medium grained sand, subrounded to subangular, soft, trace red oxidation, trace black organics/ oxidation, low effervescence.	
				End of boring 21.0 feet	
25					

WELL OR PIEZOMETER CONSTRUCTION DETAIL

PRO. CASING
Diameter: 6"
Type: Steel
Interval: Surface + 3'

RISER CASING
Diameter: 2"
Type: PVC SCH 40
Interval: 0-13' bgs

GROUT
Type: Neat cement
Interval: with 5% bentonite slurry

SEAL 3-6' bgs
Type: Bentonite chips
Interval: 0-8' bgs

SANDPACK
Type: AGSCO#1 Silica
Interval: 50-80
8-20.5' bgs

SCREEN
Diameter: Slot 6
Type: 2" PVC SCH 40
Interval: 10-20'

Date Boring Started: 12/18/18
Date Boring Completed: 12/18/18
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks:

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251001 BIG STONE\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF WELL SLAG 2B

Project:Big Stone Station
Project No.:41251005
Location:Big Stone City, SD
Coordinates:N 554,108.7 ft E 2,865,827.2 ft
Datum:SD North State Plane NAD83

Surface Elevation:1108.5 ft
Drilling Method:HSA
Sampling Method:SS
Completion Depth:40.0 ft

Top of Casing Elev.: 1110.5 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION
0						
20			5-6-6-8.	CL		LEAN CLAY (CL): yellowish brown (10YR 5/6); moist; 0% gravel, 5% sand, 95% fines, with very fine to medium grain sand and fine to coarse grain, subrounded gravel increasing with depth.
			6-8-11-10.			
25			6-9-8-9.	CL		LEAN CLAY (CL): dark gray (10YR 4/1); moist; 15% gravel, 15% sand, 70% fines, with sand and gravel.
			3-3-5-8.			26.5': SILTY SAND (SM) seam, 1' thick.
				SC		CLAYEY SAND (SC): w/ gravel and large pockets of sand w/ silt, as logged by SET; dark gray (10YR 4/1).
30			10-9-10-16.	CL		LEAN CLAY (CL): dark gray (10YR 4/1); moist; 15% gravel, 15% sand, 70% fines, with sand and gravel.
			5-8-8-11.			
35			7-6-9-7.			
			3-4-4-6.			
			4-5-5-8.			
40						End of well 40.0 feet

WELL OR PIEZOMETER CONSTRUCTION DETAIL

PRO. CASING
Diameter:
Type:
Interval:

RISER CASING
Diameter: 2"
Type: PVC Sch 40
Interval:

GROUT
Type: Neat Cement
Interval: 0-29' bgs

SEAL
Type: Bentonite
Interval: 29-31' bgs

SANDPACK
Type: Silica #50-80
Interval: 31-38' bgs

SCREEN
Diameter:
Type: #6 Sch 40
Interval: 32.5-37.5' bgs

Elevation, feet: 1105, 1100, 1095, 1090, 1085, 1080, 1075, 1070

Date Boring Started: 7/29/16 7:20 am
Date Boring Completed: 7/29/16 9:30 am
Logged By: JWJ
Drilling Contractor: SDE
Drill Rig: Truck

Remarks:

Additional data may have been collected in the field which is not included on this log.

O:\GINT\PROJECTS\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING SLAG-3

SHEET 1 OF 1

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019452m, E:695252m
Datum:NAD83

Surface Elevation:1108.3 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:25.0 ft

Top of Casing Elev.: 1111.5 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	WELL OR PIEZOMETER CONSTRUCTION DETAIL	Elevation, feet
0		1	13-12-12-10.	CL		LEAN CLAY WITH SAND AND GRAVEL (CL): black (2.5Y 2.5/1) to dark olive brown (2.5Y 3/3); frozen; 10% gravel, 10% sand, 80% fines, low plasticity, sand and gravels subrounded to subangular, mostly subangular, low effervescence.	PRO. CASING Diameter: 6" Type: Steel Interval: Surface + 3'	
		2	5-3-3-4.			LEAN CLAY (CL): olive brown (2.5Y 4/4); moist; medium plasticity; 2% gravel, 8% sand, 90% fines, fine to medium grained sand, subrounded to subangular, trace red oxidation, low effervescence.		1105
5		3	5-9-7-9.	CL		Wet at 6' bgs. Moist to wet; 0% gravel, 10% sand, 90% fines, At 8': sandy clay, fine grained sand, subrounded to subangular, mottled gray. Wet; 2% gravel, 13% sand, 85% fines, At 9': LEAN CLAY WITH SAND	RISER CASING Diameter: 2" Type: PVC SCH 40 Interval: 0-13' bgs	
10		4	5-8-10-13.			At 10': Increasing coarse grained sand and small gravel, trace black organics.	GROUT Type: Neat cement Interval: with 5% bentonite slurry SEAL 3-6' bgs Type: Bentonite chips Interval: 0-8' bgs	1100
		5	10-10-11-10.			Wet; 2% gravel, 13% sand, 85% fines.		
		6	5-5-7-10.	SM		SILTY SAND (SM): wet; At 13': 4" SILTY SAND, very fine grained, subrounded to subangular, low to no effervescence.	SANDPACK Type: AGSCO#1 Silica Interval: 50-80 8-25' bgs	1095
15		7	3-5-9-11.			LEAN CLAY (CL): olive brown (2.5Y 4/4). 0% gravel, 5% sand, 95% fines, At 14.5': 4" Wet to saturated.	SCREEN Diameter: Slot 6 Type: 2" PVC SCH 40 Interval: 10-20'	
		8	5-6-6-11.	CL		Moist to wet; 0% gravel, 5% sand, 95% fines, At 18': Two thin sand seams, very fine to fine grained sand, subrounded to subangular, low to no effervescence.		1090
20		9	5-7-11-13.			Moist to wet; 0% gravel, 5% sand, 95% fines, At 20': Two thin sand lenses, very fine to fine grained sand, subrounded to subangular.		
		10	6-8-9-14.					
		11	6-7-7-11.	CL		LEAN CLAY (CL): olive brown (2.5Y 4/4); wet; 0% gravel, 10% sand, 90% fines, low plasticity, very fine to medium grained sand, subrounded to subangular, more subangular at larger grains, oxidized red, some thin sand lenses oxidized on boundaries, trace black oganics, low to no effervescence.		1085
25						End of boring 25.0 feet		

Date Boring Started: 12/21/15
Date Boring Completed: 12/22/15
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks:

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251001 BIG STONE\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING SLAG-4

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019390m, E:695003m
Datum:NAD83

Surface Elevation:1110.2 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:37.0 ft

Top of Casing Elev.: 1113.2 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	WELL OR PIEZOMETER CONSTRUCTION DETAIL	Elevation, feet
0		1	14-5-5-6.	CL		LEAN CLAY WITH SAND (CL): frozen; 0% gravel, 15% sand, 85% fines, fine to coarse grained sand, subrounded to subangular, mostly subangular, black vitreous fragments within top 1 foot, none to low effervescence.	PRO. CASING Diameter: 6" Type: Steel Interval: Surface + 3'	1110
		2	5-4-5-6.				RISER CASING Diameter: 2" Type: PVC SCH 40 Interval: 0-29' bgs	
5		3	6-9-8-12.			LEAN CLAY (CL): light olive brown (2.5Y 5/4); moist; 5% gravel, 10% sand, 85% fines, medium plasticity, mixed with very fine to coarse grained sand and fine gravel, subrounded to subangular, more subangular in coarser grains, red oxidation spots and dark orange oxidation layers with black spots, low effervescence. Moist; At 7': fine grained sand lense, not continuous.	GROUT Type: Neat cement Interval: with 5% bentonite slurry SEAL 3-22' bgs Type: Bentonite chips Interval: 0-24' bgs	1105
		4	13-6-9-9.			Moist; 2% gravel, 8% sand, 90% fines, At 9.5': 4" fine grained sandy clay, moist.		
10		5	9-10-10-12.			Wet; 5% gravel, 10% sand, 85% fines, medium plasticity, At 10': increased silt content Mottled gray, trace black organics Areas w/ more coarse sand, subangular, none to low effervescence.	SANDPACK Type: AGSCO#1 Silica Interval: 50-80 24-37' bgs SCREEN Diameter: Slot 6 Type: 2" PVC SCH 40 Interval: 26-36'	1100
		6	17-20-22-30.			5% gravel, 10% sand, 85% fines, At 12-14': No water in spoon Moist.		
15		7	31-22-25-27.	CL		At 14-16': no recovery, rock.		1095
		8	15-9-10-9.			CLAY: olive brown (2.5y 4/4); moist; 5% gravel, 10% sand, 85% fines, low effervescence.		
		9	6-9-13-15.			At 18-20': no recovery.		
20		10	7-11-11-16.			Moist; 2% gravel, 5% sand, 93% fines, At 20-22': rock blocking part of spoon.		1090
		11	6-7-7-10.			Moist; At 22': thin fine grained sand lense trace fine grained sand, black lenses and fragments, low to moderate effervescence.		
				CL		FAT CLAY (CL): dark gray (10YR 4/1); wet; 1% gravel, 2% sand, 97% fines, high plasticity, trace silt, dark orange/ brown oxidation, low to no effervescence.		
25				CL		LEAN CLAY WITH SAND (CL): saturated; 0% gravel, 20% sand, 80% fines, very fine to		

Date Boring Started: 12/22/15
Date Boring Completed: 12/23/15
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks:

Additional data may have been collected in the field which is not included on this log.

M:\GIN\PROJECTS\41251001 BIG STONE\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING SLAG-4

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019390m, E:695003m
Datum:NAD83

Surface Elevation:1110.2 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:37.0 ft

Top of Casing Elev.: 1113.2 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
25		12	4-4-4-6.	CL		fine grained, subrounded to subangular. LEAN CLAY (CL): very dark grayish brown (2.5Y 3/2); moist to wet; 0% gravel, 5% sand, 95% fines, high plasticity, trace silt, lean, oxidized, none to low effervescence. Wet to saturated; At 26.25': 2" wet to saturated sandy clay seam.	1085
		13	4-4-4-6.			CLAY (CL): moist; 0% gravel, 5% sand, 95% fines, high plasticity, several thin very fine to fine grained sand lenses, subrounded and subangular, trace black organics, mottled brown and dark gray, trace oxidation.	
		14	5-9-10-16.	CL			
30		15	18-13-13-19.			Moist; 0% gravel, 2% sand, 98% fines, At 30': fine grained sand lense.	1080
		16	2-1-1-1.	SP-SC		POORLY GRADED SAND WITH CLAY (SP-SC): saturated; 2% gravel, 88% sand, 10% fines, very fine to fine grained sand, subrounded to subangular.	
35		17	2-1-1-2.				1075
						End of boring 37.0 feet	
40							
45							
50							

WELL OR PIEZOMETER CONSTRUCTION DETAIL

PRO. CASING
Diameter: 6"
Type: Steel
Interval: Surface + 3'

RISER CASING
Diameter: 2"
Type: PVC SCH 40
Interval: 0-29' bgs

GROUT
Type: Neat cement
Interval: with 5% bentonite slurry

SEAL 3-22' bgs
Type: Bentonite chips
Interval: 0-24' bgs

SANDPACK
Type: AGSCO#1 Silica
Interval: 50-80
24-37' bgs

SCREEN
Diameter: Slot 6
Type: 2" PVC SCH 40
Interval: 26-36'

Date Boring Started: 12/22/15
Date Boring Completed: 12/23/15
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks:

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251001 BIG STONE\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING SLAG-5

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019219m, E:695184m
Datum:NAD83

Surface Elevation:1104.7 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:40.0 ft

Top of Casing Elev.: 1107.1 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION
0		1	2-2-2-6.	CL		LEAN CLAY (CL): black (2.5Y 2.5/1); frozen to moist; 0% gravel, 5% sand, 95% fines, medium plasticity, roots, no effervescence, topsoil.
				CL		SANDY LEAN CLAY (CL): light olive brown (2.5Y 5/4); very fine grained sand, subrounded to subangular.
5		2	9-8-7-7.	SC		CLAYEY SAND (SC): moist; 0% gravel, 60% sand, 40% fines, fine grained with some medium grained sand and clay, subrounded to subangular, oxidized red areas, mottled with gray sand toward bottom, 1" seam of fine to medium grained sand. At 5': gray sand, subangular, trace black oxidation, wet on top of spoon - most likely snow inside auger.
		3	8-10-10-12.	SP-SM		POORLY GRADED SAND WITH SILT (SP-SM): dry to moist; 5% gravel, 85% sand, 10% fines, very fine grained sand, subrounded to subangular, dark orange oxidation, no effervescence.
		4	8-5-5-7.	SP-SC		POORLY GRADED SAND WITH CLAY (SP-SC): moist; 0% gravel, 85% sand, 15% fines, At 8-10': slight increase in silt and clay content within sand, trace black oxidation.
10		5	4-7-8-6.	SP-SM		POORLY GRADED SAND WITH SILT (SP-SM): moist; 0% gravel, 85% sand, 15% fines, At 10-13': increasing moisture and silt with depth.
		6	9-6-6-7.			At 13': no recovery (1" shift), very tight/hard drilling with auger.
15		7	3-4-8-8.	CL		LEAN CLAY (CL): light olive brown (2.5Y 5/3); moist to wet; 0% gravel, 10% sand, 90% fines, medium plasticity, very fine to medium grained sand, subrounded to subangular, black oxidation spots, oxidized red spots and orange layers and boundaries.
		8	4-5-6-9.			Olive brown (2.5Y 4/3); At 16': trace black organics, mottled grays, orange oxidation along thin fractures and thin sand seams.
				SP		POORLY GRADED SAND (SP): wet; fine grained sand seam, subangular.
		9	7-6-7-12.	SW		WELL GRADED SAND (SW): wet; well graded fine to coarse grained sand seam, subrounded and subangular.
20		10	12-16-17-19.	CL		LEAN CLAY (CL): grayish brown (2.5Y 5/2); moist to wet; 3% gravel, 12% sand, 85% fines, medium plasticity, trace small subangular gravels, trace black organics, oxidized on boundaries and trace red oxidation, very low effervescence. At 20': minimal recovery.
		11	3-4-4-3.	ML		SILT (ML): wet; 0% gravel, 5% sand, 95% fines, At 30': low plasticity, very fine to fine grained thin sand lenses, silty, oxidized on boundaries, none to trace sand within clay and silt.
25						

WELL OR PIEZOMETER CONSTRUCTION DETAIL

PRO. CASING
Diameter: 6"
Type: Steel
Interval: Surface + 3'

RISER CASING
Diameter: 2"
Type: PVC SCH 40
Interval: 0-29' bgs

GROUT
Type: Neat cement
Interval: with 5% bentonite slurry

SEAL 3-22' bgs
Type: Bentonite chips
Interval: 0-24' bgs

SANDPACK
Type: AGSCO#1 Silica
Interval: 50-80
24-40' bgs

SCREEN
Diameter: Slot 6
Type: 2" PVC SCH 40
Interval: 26-36'

Elevation, feet: 1100, 1095, 1090, 1085, 1080

Date Boring Started: 12/23/15
Date Boring Completed: 12/23/15
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks:

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251001 BIG STONE\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF BORING SLAG-5

Project:Slag Pond Monitoring Well Network
Project No.:41251005
Location:Big Stone Plant
Coordinates:UTM 14N N:5019219m, E:695184m
Datum:NAD83

Surface Elevation:1104.7 ft
Drilling Method:Hollow Stem Auger
Sampling Method:Split Spoon
Completion Depth:40.0 ft

Top of Casing Elev.: 1107.1 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	WELL OR PIEZOMETER CONSTRUCTION DETAIL	Elevation, feet
25		12	5-4-4-6.	ML		SILT (ML): wet; 0% gravel, 5% sand, 95% fines, At 30': low plasticity, very fine to fine grained thin sand lenses, silty, oxidized on boundaries, none to trace sand within clay and silt. *(continued)* Wet; 0% gravel, 5% sand, 95% fines, At 25': very fine grained sand lenses, oxidized on boundaries, fractured, very wet at bottom. Wet; 0% gravel, 5% sand, 95% fines, At 27': low recovery.	PRO. CASING Diameter: 6" Type: Steel Interval: Surface + 3'	
		13	6-9-8-9.			Olive brown (2.5y 4/3); wet; 0% gravel, 5% sand, 95% fines, At 28': low plasticity.		
		14	4-5-6-5.				RISER CASING Diameter: 2" Type: PVC SCH 40 Interval: 0-29' bgs	1075
30		15	4-5-5-12.	CL		LEAN CLAY (CL): olive brown (2.5y 4/3); wet; 0% gravel, 10% sand, 90% fines, medium plasticity, fine to coarse grained sand, subrounded and subangular, more subangular coarse grains, thin sand lenses with orange and black oxidation on boundaries. At 31.75': fine grained, subrounded to subangular, red oxidation spots, 6" area of mottled clay with gray, very low effervescence, 1/2 inch saturated clayey sand.	GROUT Type: Neat cement Interval: with 5% bentonite slurry	
		16	4-3-12-8.	SM		SILTY SAND (SM): dark gray (2.5y 4/1); wet; 5% gravel, 20% sand, 75% fines, fine to coarse grained sand, mostly fine grained, well graded subrounded to subangular.	SEAL 3-22' bgs Type: Bentonite chips Interval: 0-24' bgs	1070
35		17	16-22-27-31.	CL		LEAN CLAY (CL): dark gray (2.5y 4/1); moist to wet; fine to coarse grained sand, subangular, trace subangular gravels, no oxidation, low effervescence. At 35': no recovery.	SANDPACK Type: AGSCO#1 Silica Interval: 50-80 24-40' bgs	
		18	15-16-21-25.			Moist to wet; 5% gravel, 10% sand, 85% fines, fine to coarse grained sand, subangular, trace subangular gravels, no oxidation, low effervescence.		
		19	4-5-5-8.			Moist to wet; 5% gravel, 5% sand, 90% fines, medium to high plasticity.	SCREEN Diameter: Slot 6 Type: 2" PVC SCH 40 Interval: 26-36'	1065
40						End of boring 40.0 feet		
45								
50								

Date Boring Started: 12/23/15
Date Boring Completed: 12/23/15
Logged By: DJZ
Drilling Contractor: Stevens Drilling
Drill Rig: SIMCO 7000

Remarks:

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251001 BIG STONE\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF WELL SLAG 6

Project:Big Stone Station
Project No.:41251005
Location:Big Stone City, SD
Coordinates:N 554,058.1 ft E 2,866,310.7 ft
Datum:SD North State Plane NAD83

Surface Elevation:1108.5 ft
Drilling Method:HSA
Sampling Method:SS
Completion Depth:34.5 ft

Top of Casing Elev.: 1111.5 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	WELL OR PIEZOMETER CONSTRUCTION DETAIL	Elevation, feet
0			3-2-2-2.	CL		FILL - SANDY CLAY (CL): black (10YR 2/1); moist; 5% gravel, 15% sand, 80% fines, with slag.	PRO. CASING Diameter: 6" Type: Steel Interval:	1105
			5-4-4-4.			LEAN CLAY (CL): yellowish brown (10YR 5/4); moist; 5% gravel, 0% sand, 95% fines, trace subrounded gravel.		
5			2-4-5-5.	CL			RISER CASING Diameter: 2" Type: PVC Sch 40 Interval:	1100
			4-5-7-5.					
			6-7-9-9.	SM		SILTY SAND (SM): dark yellowish brown (10YR 44/4); moist; 5% gravel, 70% sand, 25% fines.		
10			6-7-7-7.	CL		LEAN CLAY (CL): yellowish brown (10YR 6/2); moist; 10% gravel, 5% sand, 85% fines, with coarse grain, subangular gravel, rusty yellowish red oxidized seams.	GROUT Type: Neat Cement Interval: 0-17.5' bgs	1095
			5-7-6-7.					
15			3-3-5-5.	SM		SILTY SAND (SM): brown (10YR 6/2); moist; 0% gravel, 80% sand, 20% fines, very fine grain.	SEAL Type: Bentonite Interval: 17.5-20.5' bgs	
			5-5-7-10.			LEAN CLAY (CL): yellowish brown (10YR 5/6); moist; 10% gravel, 5% sand, 85% fines, with gravel, lean clay becomes sandy lean clay with depth.		1090
			12-7-10-14.					
20			6-6-6-9.				SANDPACK Type: Silica #50-80 Interval: 20.5-34.5' bgs	
			7-8-7-7.					
			5-6-6-11.	CL			SCREEN Diameter: Type: #6 Sch 40 Interval: 24.2-34.2' bgs	1085
25			8-11-10-15.					
			7-11-13-25.			28': CLAYEY SAND (SC), yellowish brown (10YR 5/6), wet, very fine grain sand with clay, 0% gravel, 80% sand, 20% fines, 1' thick.		1080
30			9-5-10-11.			30': CLAYEY SAND (SC) with gravel, yellowish brown (10YR 5/6), wet, 30% gravel, 40% sand, 30% fines, 1' thick.		
								1075
35			50/0-.			End of well 34.5 feet		
40								

Date Boring Started: 7/19/16 2:20 pm
Date Boring Completed: 7/20/16
Logged By: JWJ
Drilling Contractor: SDE
Drill Rig: Truck

Remarks:

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF WELL SLAG 7

Project:Big Stone Station
Project No.:41251005
Location:Big Stone City, SD
Coordinates:N 554,435.7 ft E 2,865,483.4 ft
Datum:SD North State Plane NAD83

Surface Elevation:1111.9 ft
Drilling Method:HSA
Sampling Method:SS
Completion Depth:46.0 ft

Top of Casing Elev.: 1114.4 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	WELL OR PIEZOMETER CONSTRUCTION DETAIL	Elevation, feet
0			3-3-4-5.	CL		TOPSOIL - LEAN CLAY (CL): black to olive brown (2.5Y 2.5/1); moist; 0% gravel, 5% sand, 95% fines, vegetation.		1110
			7-8-7-7.			LEAN CLAY (CL): olive brown (2.5U 4/4); moist; 0% gravel, 5% sand, 95% fines, with rusty colored seams, trace very fine grain to coarse grain sand throughout, trace subrounded gravel throughout, some <1" lenses of sand and silt mixture (SM), lean clay becoming sandy lean clay with depth.	PRO. CASING Diameter: 6" Type: Steel Interval:	
5			3-2-5-6.					1105
			6-6-9-11.					
			7-8-7-9.				RISER CASING Diameter: 2" Type: PVC Sch 40 Interval:	
10			6-7-7-9.			10': CLAYEY SAND (SC), olive brown (2.5Y 4/4), moist to saturated, alternating layers of sand/silt mixture and sand/clay mixture about 3" thick each, 0% gravel, 60% sand, 40% fines, 1' thick.		1100
			6-7-7-9.					
15			4-5-5-6.	CL		15': CLAYEY SAND (SC), olive brown (2.5Y 4/4), wet, 0% gravel, 60% sand, 40% fines, 1.5' thick.	GROUT Type: Neat Cement Interval: 0-30.8' bgs	1095
			5-4-5-5.					
			7-6-5-5.				SEAL Type: Bentonite Interval: 30.8-33' bgs	
20			9-5-6-8.					1090
			5-5-5-7.				SANDPACK Type: Silica #50-80 Interval: 33-47' bgs	
25			5-4-4-5.					1085
			5-4-4-4.				SCREEN Diameter: Type: #6 Sch 40 Interval: 36-46' bgs	
			4-4-4-4.			29': SILTY SAND (SM), dark grayish brown (2.5Y 4/2), moist, very fine grain, 0% gravel, 70% sand, 30% fines, 1.2" thick.		
30			5-4-6-8.	SC		CLAYEY SAND (SC): olive brown (2.5U 4/4); wet; 0% gravel, 70% sand, 30% fines, very fine grain.		1080
						SANDY LEAN CLAY (CL): olive brown (2.5U 4/3); wet to saturated; 10% gravel, 10% sand, 80% fines, very fine grain, becomes sandier with depth.		
35			5-4-3-3.			35.2': SILTY SAND (SM), olive brown (2.5Y 4/3), very fine grain to medium grain, 0% gravel, 80% sand, 20% fines, 9.6" thick.		1075
			7-8-10-11.	CL				
40			6-9-17-23.			40': CLAYEY SAND (SC), olive brown (2.5Y 4/3), wet, very fine grain to medium grain, 0% gravel, 60% sand, 40% fine, 2' thick.		1070
			10-13-19-18.					
45			8-8-14-21.	ML		SILT (ML): olive brown (2.5U 4/3); wet; 0% gravel, 0% sand, 100% fines, with trace very fine grain sand.		
						End of well 46.0 feet		
50								

Date Boring Started: 7/20/16 2:23 pm
Date Boring Completed: 7/21/16
Logged By: JWJ
Drilling Contractor: SDE
Drill Rig: Truck

Remarks:

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF WELL SLAG 8

Project:Big Stone Station
Project No.:41251005
Location:Big Stone City, SD
Coordinates:N 553,999.3 ft E 2,870,258.3 ft
Datum:SD North State Plane NAD83

Surface Elevation:1124.3 ft
Drilling Method:HSA
Sampling Method:SS
Completion Depth:55.0 ft

Top of Casing Elev.: 1127.3 ft
Unique Well No.: BONUS WELL

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
0							1120
5							
10			6-4-4-9.			LEAN CLAY (CL): dark yellowish brown (10YR 4/4); moist; 5% gravel, 15% sand, 80% fines, with sand, oxidization throughout.	1115
15			7-6-9-12.	CL			1110
			15-26-18-22.			17': 1" gravel layer with cobbles, subangular.	
20			14-13-19-23.			SILTY SAND (SM): fine to medium grained; dark yellowish brown (10YR 4/4); wet; 20% gravel, 50% sand, 30% fines, with gravel.	1105
			8-15-13-11.	SM		23': WELL GRADED SAND (SW) with gravel, dark yellowish brown (10YR 4/4), wet, 15% gravel, 85% sand, 5% fines, 3' thick.	1100
25			11-11-18-13.			26.2': CLAYSTONE/MUDSTONE, dark gray.	
30			8-8-11-13.			LEAN CLAY (CL): dark yellowish brown (10YR 4/4); moist; 0% gravel, 10% sand, 90% fines, with sand, oxidization throughout.	1095
			13-9-10-15.	CL		29.5': 1" fine to medium grain sand lense.	1090
35			5-6-11-12.				
			7-9-11-16.				1085
40			4-5-8-11.			LEAN CLAY (CL): very dark gray (10YR 3/1); moist; 0% gravel, 10% sand, 90% fines.	
			6-7-9-11.				1080
45			4-4-4-7.	CL			
			7-5-6-7.				1075
50							
				SM		SILTY SAND (SM): dark yellowish brown (10YR 4/4); moist; 0% gravel, 60% sand, 40% fines.	1070
55			11-15-18-21.	CL		LEAN CLAY (CL): very dark gray (10YR 3/1); moist; 0% gravel, 10% sand, 90% fines.	
						End of well 55.0 feet	
60							

Date Boring Started: 8/1/16 11:30 am
Date Boring Completed: 8/1/16 3:30 pm
Logged By: NJS2
Drilling Contractor: SDE
Drill Rig: Truck

Remarks:
Boring advancd next to existing SLAG 8 well

Additional data may have been collected in the field which is not included on this log.

O:\GINT\PROJECTS\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF WELL SLAG 9

Project:Big Stone Station
Project No.:41251005
Location:Big Stone City, SD
Coordinates:N 554,758.4 ft E 2,866,219.4 ft
Datum:SD North State Plane NAD83

Surface Elevation:1119.4 ft
Drilling Method:HSA
Sampling Method:SS
Completion Depth:48.0 ft

Top of Casing Elev.: 1122.4 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	WELL OR PIEZOMETER CONSTRUCTION DETAIL	Elevation, feet
0				CL		LEAN CLAY (CL): dark yellowish brown (10YR 4/5); moist; 10% gravel, 10% sand, 80% fines, with sand and coarse grain, subangular gravel throughout, gravel content increasing with depth.	PRO. CASING Diameter: 6" Type: Steel Interval:	1115
5								
10							RISER CASING Diameter: 2" Type: PVC Sch 40 Interval:	1110
15							GROUT Type: Neat Cement Interval: 0-31.5' bgs	1105
20							SEAL Type: Bentonite Interval: 31.5-35' bgs	1100
25							SANDPACK Type: Silica #50-80 Interval: 35-50' bgs	1095
30							SCREEN Diameter: Type: #6 Sch 40 Interval: 38-48' bgs	1090
35								1085
40			6-12-12-13.	SM		SILTY SAND (SM): very fine to fine grained; yellowish brown (10YR 5/4); wet; 0% gravel, 75% sand, 25% fines, gravel content increases with depth. 39': POORLY GRADED SAND WITH SILT (SP), yellowish brown (10YR 5/4), wet, very fine to fine grain, 0% gravel, 90% sand, 10% fines, 1' thick.		1080
45			7-7-14-18. 7-14-14-28. 8-13-20-29.			43': SILT (ML), yellowish brown (10YR 5/4), wet, 0% gravel, 10% sand, 90% fines, 2' thick.		1075
50						End of well 48.0 feet		

Date Boring Started: 7/27/16 2:45 pm
Date Boring Completed: 7/28/16 5:15 pm
Logged By: JWJ
Drilling Contractor: SDE
Drill Rig: Truck

Remarks:

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Barr Engineering Company
234 West Century Avenue
Bismarck, ND 58503
Telephone: 701-255-5460

LOG OF WELL SLAG 9 DEEP

SHEET 1 OF 1

Project:Big Stone Station
Project No.:41251005
Location:Big Stone City, SD
Coordinates:N 554,758.4 ft E 2,866,219.4 ft
Datum:SD North State Plane NAD83

Surface Elevation:1119.4 ft
Drilling Method:HSA
Sampling Method:SS
Completion Depth:68.0 ft

Top of Casing Elev.: 1121.9 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
0			4-3-3-4.	CL		LEAN CLAY (CL): dark yellowish brown (10YR 4/5); moist; 10% gravel, 10% sand, 80% fines, with sand and coarse grain, subangular gravel throughout, gravel content increasing with depth.	1115
5			15-13-12-10.				
			3-5-4-5.				
			7-6-9-11.				
			7-6-10-11.				1110
10			6-5-8-10.				
			7-9-10-10.				
			7-8-7-8.				1105
15			3-3-5-7.				
			5-7-7-10.				
			6-8-8-10.				1100
20			9-14-14-14.				
			6-7-9-12.				
			11-13-21-20.				1095
25			12-13-18-24.				
			14-18-20-22.	SC		CLAYEY SAND (SC): very fine to fine grained; dark yellowish brown (10YR 4/5); wet; 5% gravel, 75% sand, 20% fines, with coarse grain, subangular gravel.	1090
30			22-36-16-18.				
			15-10-24-32.	CL		LEAN CLAY (CL): dark yellowish brown (10YR 4/5); moist; 10% gravel, 20% sand, 70% fines, with sand and gravel.	1085
35			5-6-8-13.	SM		SILTY SAND (SM): wet; 0% gravel, 80% sand, 20% fines, very fine grain to medium grain, some fine grain gravel.	
			7-6-12-13.				1080
40			26-24-10-8.				
			8-9-9-10.				
			9-11-9-15.				1075
45			9-11-9-15.			47.8': CLAYEY SAND (SC), dark yellowish brown (10YR 4/6), wet, very fine grain, some gravel, 10% gravel, 70% sand, 20% fines, 2.4" thick.	
			9-8-14-16.			49': SILTY GRAVEL (GM) grades to CLAYEY GRAVEL (GC), dark yellowish brown (10YR 4/6), wet, 50% gravel, 30% sand, 20% fines, 3' thick.	1070
50			11-13-14-16.	CL		LEAN CLAY (CL): very dark gray (2.5Y 3/1); moist; 5% gravel, 5% sand, 95% fines, some coarse grain, subangular gravel, fine to medium grain sand lense.	
			12-14-11-16.				1065
55			8-8-7-10.				
			6-4-7-9.				
			9-10-10-14.				1060
60							
							1055
65			9-11-26-37.	ML		SILT (ML): gray (2.5Y 5/1); moist.	
70						End of well 68.0 feet	

WELL OR PIEZOMETER CONSTRUCTION DETAIL

PRO. CASING
Diameter:
Type:
Interval:

RISER CASING
Diameter: 2"
Type: PVC Sch 40
Interval:

GROUT
Type: Neat Cement
Interval: 0-58.5' bgs

SEAL
Type: Bentonite
Interval: 58.5-61' bgs

SANDPACK
Type: Silica #50-80
Interval: 61-68' bgs

SCREEN
Diameter:
Type: #6 Sch 40
Interval: 63-68' bgs

Date Boring Started: 7/22/16 8:50 am
Date Boring Completed: 7/22/16
Logged By: JWJ
Drilling Contractor: SDE
Drill Rig: Truck

Remarks:

Additional data may have been collected in the field which is not included on this log.

M:\GINT\PROJECTS\41251005 BIG STONE.GPJ BARRLIBRARY.GLB ENVIRO LOG BARR TEMPLATE.GDT

Appendix C

Geotechnical Laboratory Results

Hydraulic Conductivity Test Data ASTM D2434

Project: Big Stone Date: 8/29/2016

Client: Barr Engineering Company Job No.: 10490

Boring No.:	Slag 9 Deep						
Sample No.:							
Depth (ft):	38-40						
Location:							
Sample Type:	3T						
Soil Type:	Sand with silt (SP-SM)						
Atterberg Limits							
LL							
PL							
PI							
Permeability Test	Intact						
Before Test Conditions: Saturation %:							
Porosity:							
Ht. (in):	3.97						
Dia. (in):	2.88						
Dry Density (pcf):	111.7						
Water Content:	17.7%						
Test Type:	Constant						
Max Head (cm):	28.2						
Confining press. (Effective-psi):	None						
Trial No.:	6-10						
Water Temp °C:	21.0						
% Compaction							
% Saturation (After Test)							
Coefficient of Permeability							
K @ 20 °C (cm/sec)	**1.5×10^{-4}**						
K @ 20 °C (ft/min)	**3.0×10^{-4}**						
Notes:							

9530 James Ave South · SOIL ENGINEERING TESTING, INC. · Bloomington, MN 55431

Hydraulic Conductivity Test Data ASTM D5084

Project: Big Stone Date: 9/7/2016

Client: Barr Engineering Company Job No.: 10490

Boring No.:	H8		SB H6 DEEP		NEW SLAG 2		SLAG 6
Sample No.:					SLAG 2B		
Depth (ft):	16-18		47-49		28-30		32-34
Sample Orientation:	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
Sample Type:	3T		3T		3T		3T
Soil Type:	Sandy Lean Clay w/ a little gravel (CL)		Sandy Lean Clay (CL)		Clayey Sand w/ gravel and large pockets of sand w/ silt (SC)		Clayey Sand w/ a trace of gravel (SC)
Atterberg Limits							
LL							
PL							
PI							
Permeability Test	Intact	Intact	Intact	Intact	Intact	Intact	Intact
Before Test Conditions: Saturation %:							
Porosity:	0.339	0.358	0.331	0.346			0.352
Ht. (in):	2.95	2.13	2.91	2.07	2.86	1.59	3.03
Dia. (in):	2.87	1.94	2.88	1.94	2.90	1.94	2.88
Dry Density (pcf):	110.6	107.4	111.9	109.4	121.3	116.7	108.4
Water Content:	18.3%	19.0%	17.2%	18.1%	10.7%	13.9%	18.3%
Test Type:	Falling Head	Falling Head	Falling Head	Falling Head	Falling Head	Falling Head	Falling Head
Max Head (ft.):	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Confining press. (Effective-psi):	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Trial No.:	7-11	9-13	7-11	10-14	7-11	10-14	7-11
Water Temp °C:	22.0	22.0	22.0	22.0	22.0	22.0	22.0
% Compaction							
% Saturation (After Test)	97.8%	95.2%	95.6%	95.2%	95.1%	95.6%	95.1%
Coefficient of Permeability							
K @ 20 °C (cm/sec)	6.8×10^{-8}	3.6×10^{-8}	2.8×10^{-8}	4.8×10^{-8}	1.0×10^{-6}	1.2×10^{-6}	6.6×10^{-7}
K @ 20 °C (ft/min)	1.3×10^{-7}	7.1×10^{-8}	5.5×10^{-8}	9.5×10^{-8}	2.0×10^{-6}	2.4×10^{-6}	1.3×10^{-6}
Notes:							

9530 James Ave South
SOIL ENGINEERING TESTING, INC.
Bloomington, MN 55431

Hydraulic Conductivity Test Data ASTM D5084

Project: Big Stone Date: 9/7/2016

Client: Barr Engineering Company Job No.: 10490

Boring No.:	SLAG 9 DEEP						
Sample No.:							
Depth (ft):	64-66						
Sample Orientation:	Vertical						
Sample Type:	3T						
Soil Type:	Sandy Lean Clay w/ a little gravel (CL)						
Atterberg Limits							
LL							
PL							
PI							
Permeability Test							
Before Test Conditions: Saturation %:							
Porosity:	0.405						
Ht. (in):	2.56						
Dia. (in):	2.88						
Dry Density (pcf):	99.5						
Water Content:	25.0%						
Test Type:	Falling Head						
Max Head (ft.):	5.0						
Confining press. (Effective-psi):	2.0						
Trial No.:	7-11						
Water Temp °C:	22.0						
% Compaction							
% Saturation (After Test)	99.6%						
Coefficient of Permeability							
K @ 20 °C (cm/sec)	**3.7×10^{-8}**						
K @ 20 °C (ft/min)	**7.3×10^{-8}**						
Notes:							

9530 James Ave South

ET OIL ENGINEERING TESTING, INC.

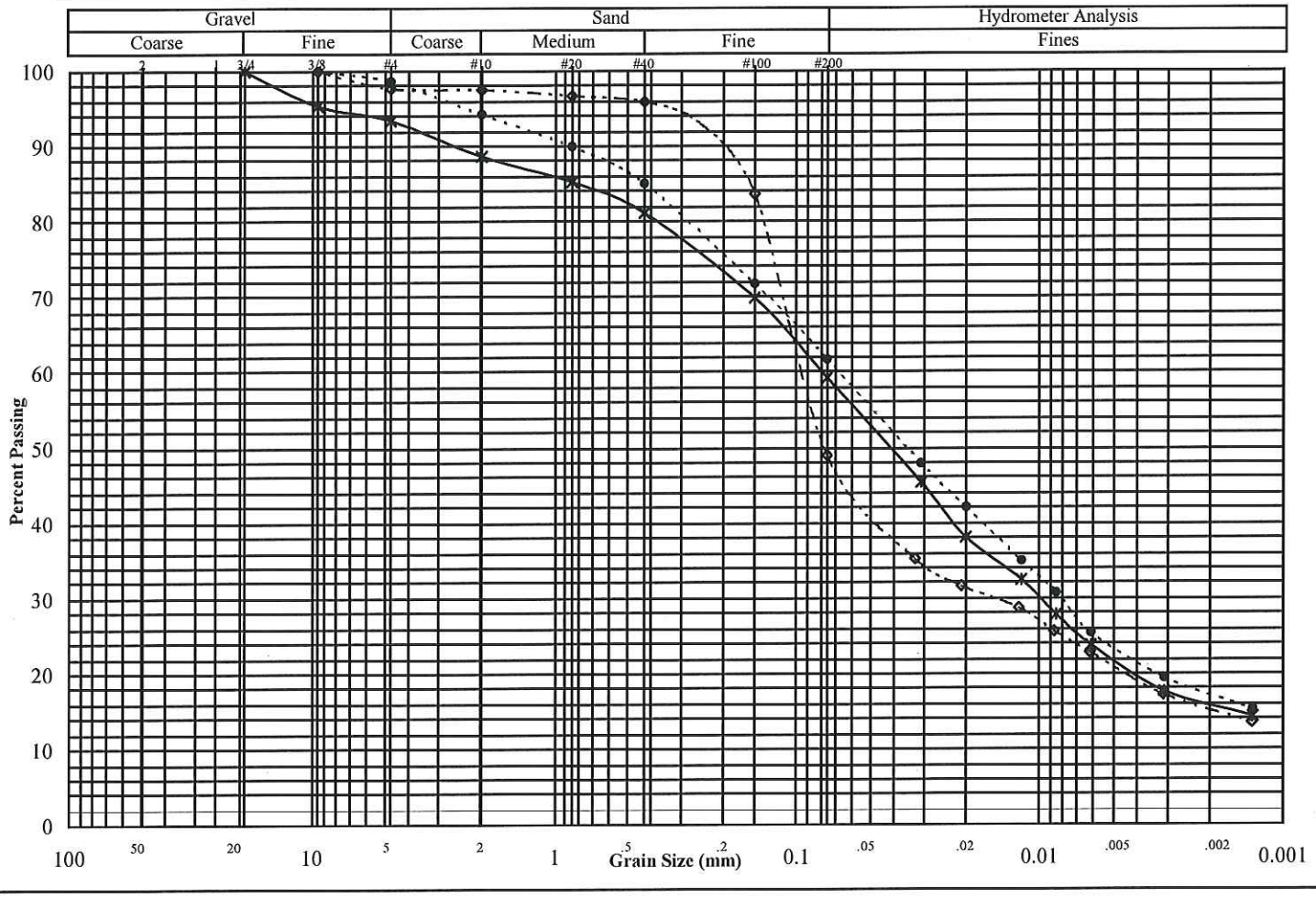
Bloomington, MN 55431

Grain Size Distribution ASTM D422

Job No. : **10490**

Project:	Big Stone
Reported To:	Barr Engineering Company
Test Date:	8/24/416
Report Date:	8/26/16

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	H8		16-18	3T	Sandy Lean Clay w/a little gravel (CL)
●	SB H6 Deep		47-49	3T	Sandy Lean Clay (CL)
◇	Slag 6		32-34	3T	Clayey Sand w/a trace of gravel (SC)



Other Tests

	*	●	◇
Liquid Limit			
Plastic Limit			
Plasticity Index			
Water Content			
Dry Density (pcf)			
Specific Gravity	2.67*	2.67*	2.67*
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	187.2	249.1	154.5
2"			
1.5"			
1"			
3/4"	100.0		
3/8"	95.4	100.0	100.0
#4	93.4	98.7	97.7
#10	88.7	94.3	97.5
#20	85.3	90.0	96.7
#40	81.2	85.1	95.9
#100	69.9	71.8	83.7
#200	59.3	61.8	49.0

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

9530 James Ave South

SOIL ENGINEERING TESTING, INC.

Bloomington, MN 55431

Grain Size Distribution ASTM D422

Job No. : **10490**

Project:	Big Stone	Test Date:	8/24/416
Reported To:	Barr Engineering Company	Report Date:	8/26/16

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	H8		16-18	3T	Sandy Lean Clay w/a little gravel (CL)
Spec 2	SB H6 Deep		47-49	3T	Sandy Lean Clay (CL)
Spec 3	Slag 6		32-34	3T	Clayey Sand w/a trace of gravel (SC)

Sieve Data

Specimen 1		Specimen 2		Specimen 3	
Sieve	% Passing	Sieve	% Passing	Sieve	% Passing
2"		2"		2"	
1.5"		1.5"		1.5"	
1"		1"		1"	
3/4"	100.0	3/4"		3/4"	
3/8"	95.4	3/8"	100.0	3/8"	100.0
#4	93.4	#4	98.7	#4	97.7
#10	88.7	#10	94.3	#10	97.5
#20	85.3	#20	90.0	#20	96.7
#40	81.2	#40	85.1	#40	95.9
#100	69.9	#100	71.8	#100	83.7
#200	59.3	#200	61.8	#200	49.0

Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.031	45.4	0.031	48.0	0.033	35.3
0.020	38.1	0.020	42.1	0.021	31.7
0.012	32.5	0.012	35.0	0.012	28.7
0.009	27.8	0.009	30.8	0.009	25.6
0.006	23.8	0.006	25.5	0.006	22.9
0.003	17.7	0.003	19.5	0.003	17.3
0.001	14.3	0.001	15.3	0.001	13.6

Remarks

Specimen 1	Specimen 2	Specimen 3

9530 James Ave South

SOIL ENGINEERING TESTING, INC.

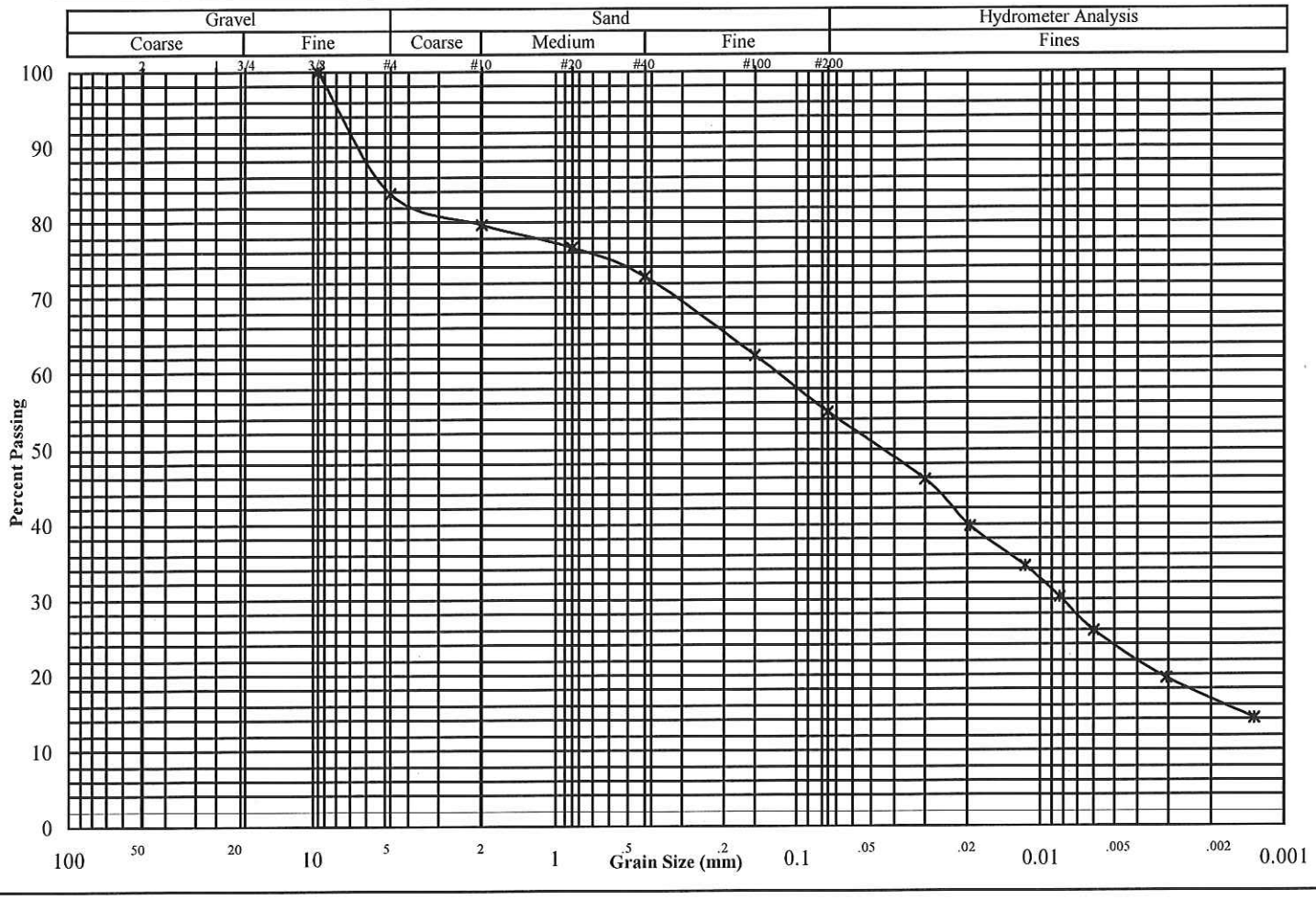
Bloomington, MN 55431

Grain Size Distribution ASTM D422

Job No. : **10490**

Project:	Big Stone
Reported To:	Barr Engineering Company
Test Date:	8/24/16
Report Date:	8/26/16

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	Slag 9 Deep		64-66	3T	Sandy Lean Clay w/gravel (CL)
●					
◇					



Other Tests

	*	●	◇
Liquid Limit			
Plastic Limit			
Plasticity Index			
Water Content			
Dry Density (pcf)			
Specific Gravity	2.67*		
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	467.8		
2"			
1.5"			
1"			
3/4"			
3/8"	100.0		
#4	83.9		
#10	79.7		
#20	76.7		
#40	72.9		
#100	62.4		
#200	54.9		

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

9530 James Ave South

SOIL ENGINEERING TESTING, INC.

Bloomington, MN 55431

Grain Size Distribution ASTM D422

Job No. : **10490**

Project:	Big Stone	Test Date:	8/24/16
Reported To:	Barr Engineering Company	Report Date:	8/26/16

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	Slag 9 Deep		64-66	3T	Sandy Lean Clay w/gravel (CL)
Spec 2					
Spec 3					

Sieve Data

Specimen 1		Specimen 2		Specimen 3	
Sieve	% Passing	Sieve	% Passing	Sieve	% Passing
2"		2"		2"	
1.5"		1.5"		1.5"	
1"		1"		1"	
3/4"		3/4"		3/4"	
3/8"	100.0	3/8"		3/8"	
#4	83.9	#4		#4	
#10	79.7	#10		#10	
#20	76.7	#20		#20	
#40	72.9	#40		#40	
#100	62.4	#100		#100	
#200	54.9	#200		#200	

Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.030	45.9				
0.020	39.7				
0.012	34.4				
0.008	30.3				
0.006	25.9				
0.003	19.6				
0.001	14.2				

Remarks

Specimen 1	Specimen 2	Specimen 3

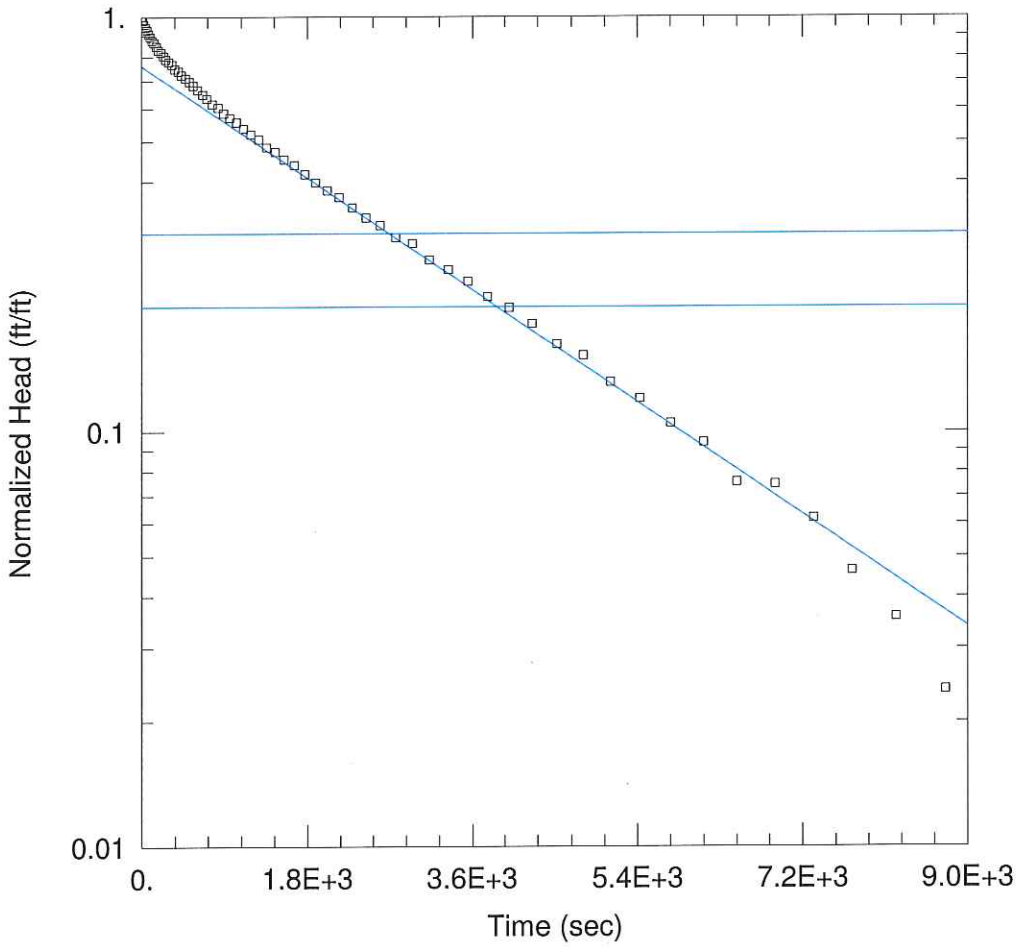
9530 James Ave South

SOIL ENGINEERING TESTING, INC.

Bloomington, MN 55431

Appendix D

Slug Test Results



SLAG 1 FALLING HEAD SLUG TEST (SLUG-IN)

Data Set: \...\Slag 1 Slug In.aqt
Date: 09/23/16 Time: 11:57:15

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: OtterTail Power Company
Project: 41251005
Location: Big Stone, SD
Test Well: Slag 2
Test Date: Aug 12, 2016

AQUIFER DATA

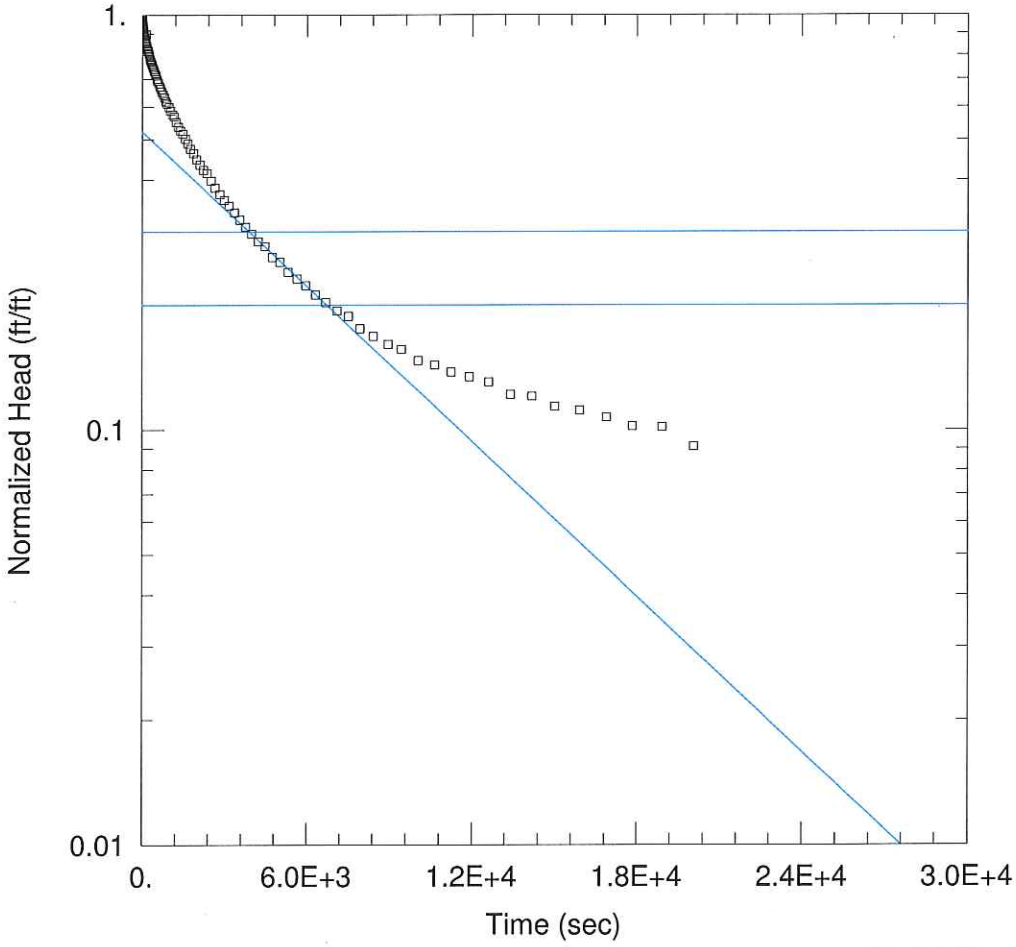
Saturated Thickness: 12. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (Slag 1)

Initial Displacement: 1.281 ft
Total Well Penetration Depth: 12. ft
Casing Radius: 0.083 ft
Static Water Column Height: 17.1 ft
Screen Length: 10. ft
Well Radius: 0.344 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice
K = 9.642E-6 cm/sec
y0 = 0.9758 ft



SLAG 1 RISING HEAD SLUG TEST (SLUG-OUT)

Data Set: \...\Slag 1 Slug Out.aqt
Date: 09/23/16 Time: 11:58:51

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: OtterTail Power Company
Project: 41251005
Location: Big Stone, SD
Test Well: Slag 2
Test Date: Aug 12, 2016

AQUIFER DATA

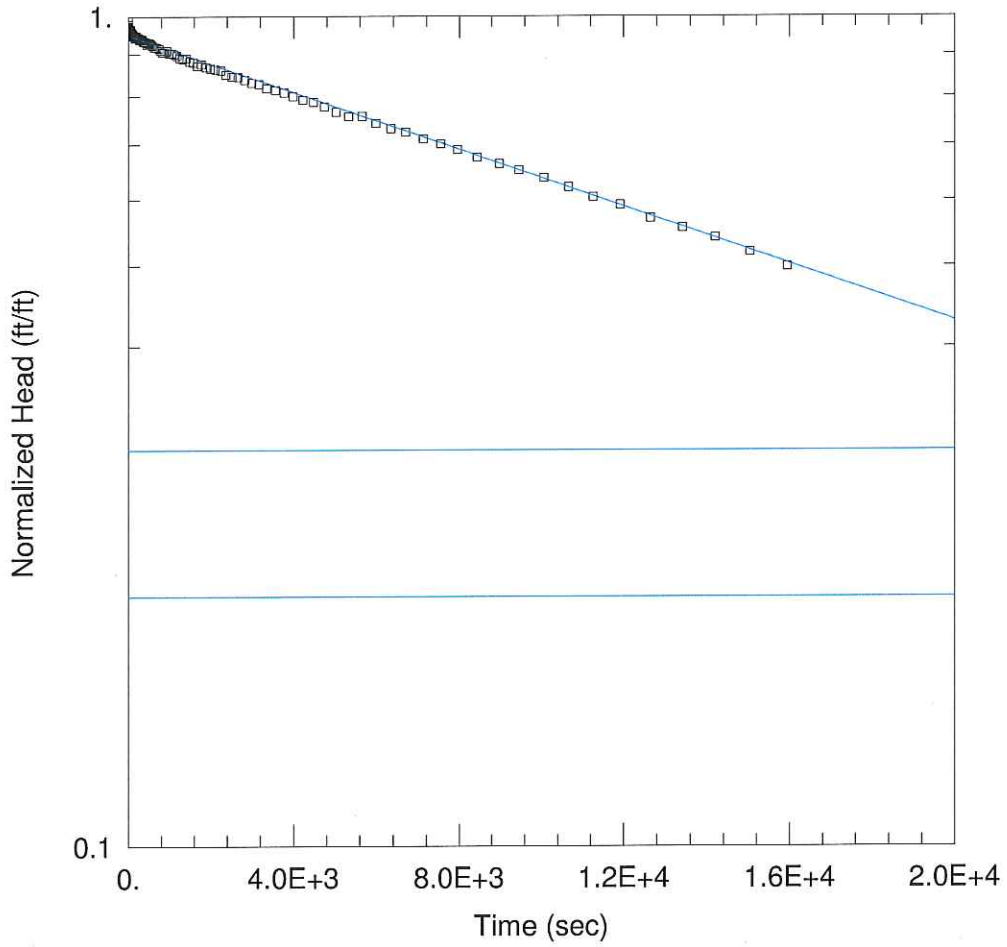
Saturated Thickness: 12. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (Slag 1)

Initial Displacement: 1.319 ft
Total Well Penetration Depth: 12. ft
Casing Radius: 0.083 ft
Static Water Column Height: 17.1 ft
Screen Length: 10. ft
Well Radius: 0.344 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice
K = 4.0E-6 cm/sec
y0 = 0.6908 ft



SLAG 2 DEEP RISING HEAD SLUG TEST (SLUG-OUT)

Data Set: \...\Slag 2 Deep Slug Out.aqt
Date: 12/15/16 SLUG 2B Time: 08:45:07

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: OtterTail Power Company
Project: 41251005
Location: Big Stone, SD
Test Well: Slag 2 Deep
Test Date: Aug 12, 2016

AQUIFER DATA

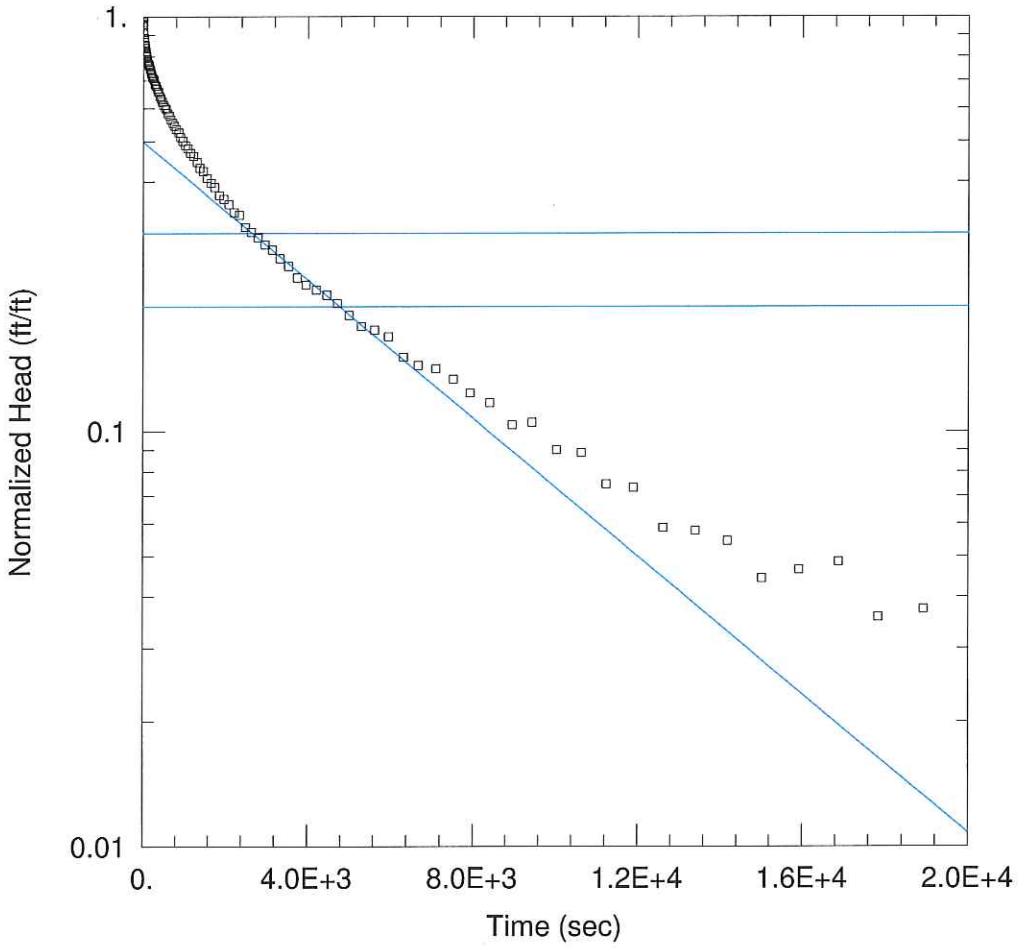
Saturated Thickness: 7. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (Slag 2 Deep)

Initial Displacement: 1.202 ft
Total Well Penetration Depth: 7. ft
Casing Radius: 0.083 ft
Static Water Column Height: 19.26 ft
Screen Length: 5. ft
Well Radius: 0.177 ft

SOLUTION

Aquifer Model: Confined
K = 2.264E-6 cm/sec
Solution Method: Bouwer-Rice
y0 = 1.14 ft



SLAG-5 FALLING HEAD SLUG TEST (SLUG-IN)

Data Set: \...\Slag-5 Slug In.aqt
Date: 09/23/16 Time: 12:04:53

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: OtterTail Power Company
Project: 41251005
Location: Big Stone, SD
Test Well: Slag-5
Test Date: July 29, 2016

AQUIFER DATA

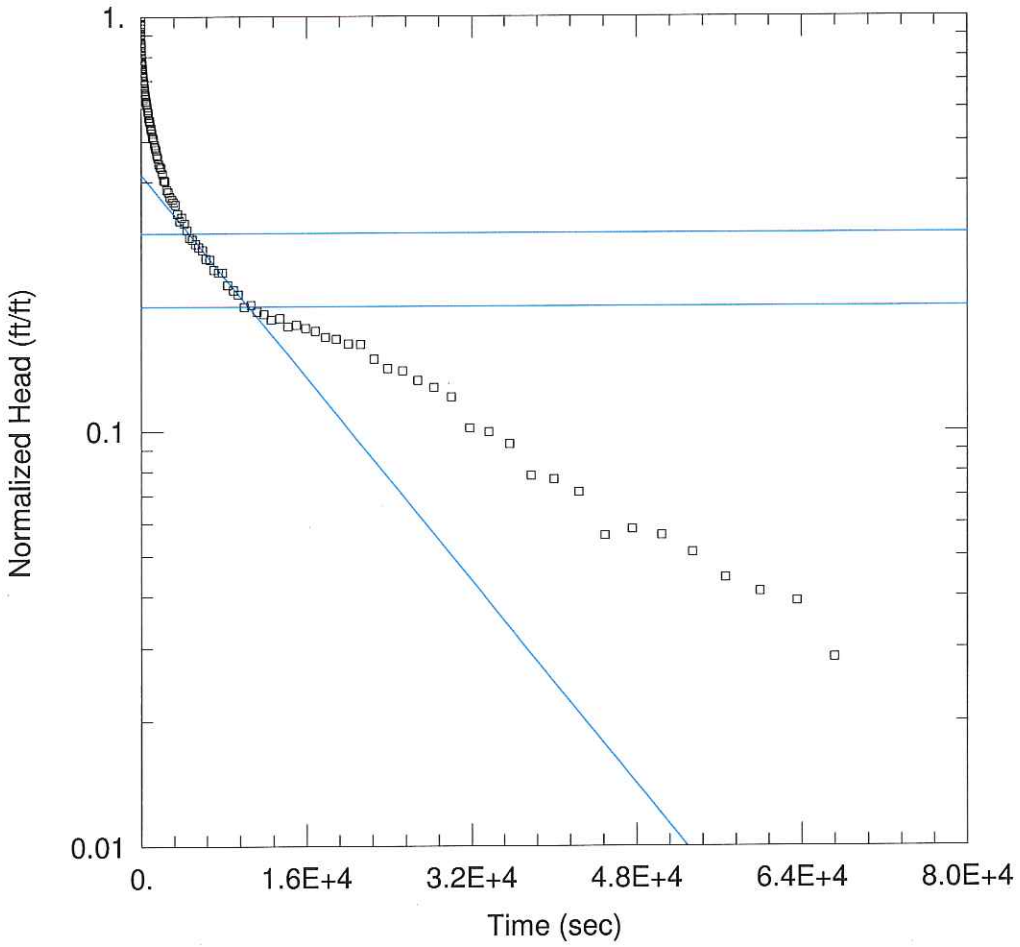
Saturated Thickness: 3. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (Slag 5)

Initial Displacement: 0.897 ft
Total Well Penetration Depth: 3. ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.43 ft
Screen Length: 3. ft
Well Radius: 0.344 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice
K = 1.038E-5 cm/sec
y0 = 0.4478 ft



SLAG-5 RISING HEAD SLUG TEST (SLUG-OUT)

Data Set: \...\Slag-5 Slug Out.aqt
Date: 09/23/16 Time: 12:05:50

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: OtterTail Power Company
Project: 41251005
Location: Big Stone, SD
Test Well: Slag-5
Test Date: July 30, 2016

AQUIFER DATA

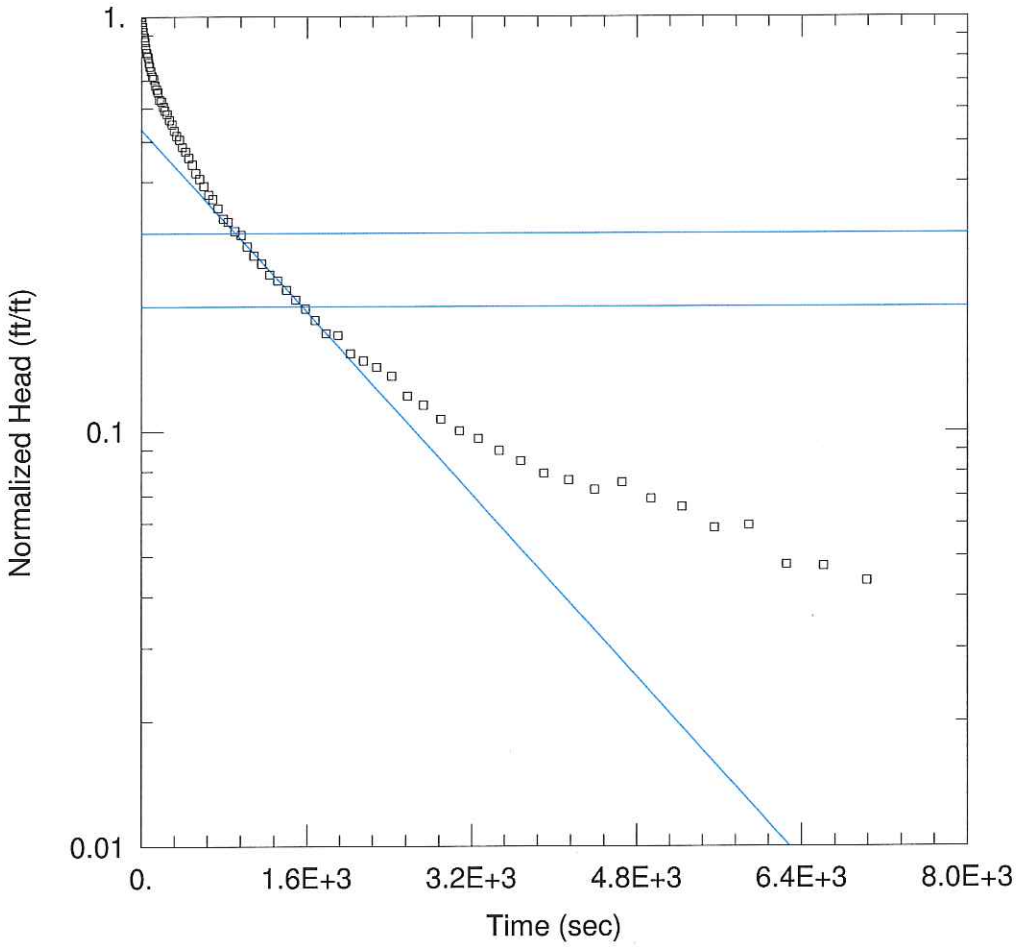
Saturated Thickness: 3. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (Slag 5)

Initial Displacement: 0.949 ft
Total Well Penetration Depth: 3. ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.43 ft
Screen Length: 3. ft
Well Radius: 0.344 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice
K = 3.817E-6 cm/sec
y0 = 0.3951 ft



SLAG 8 FALLING HEAD SLUG TEST (SLUG-IN)

Data Set: \...\Slag 8 Slug In.aqt
Date: 09/23/16 Time: 12:07:58

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: OtterTail Power Company
Project: 41251005
Location: Big Stone, SD
Test Well: Bonus Well
Test Date: July 27, 2016

AQUIFER DATA

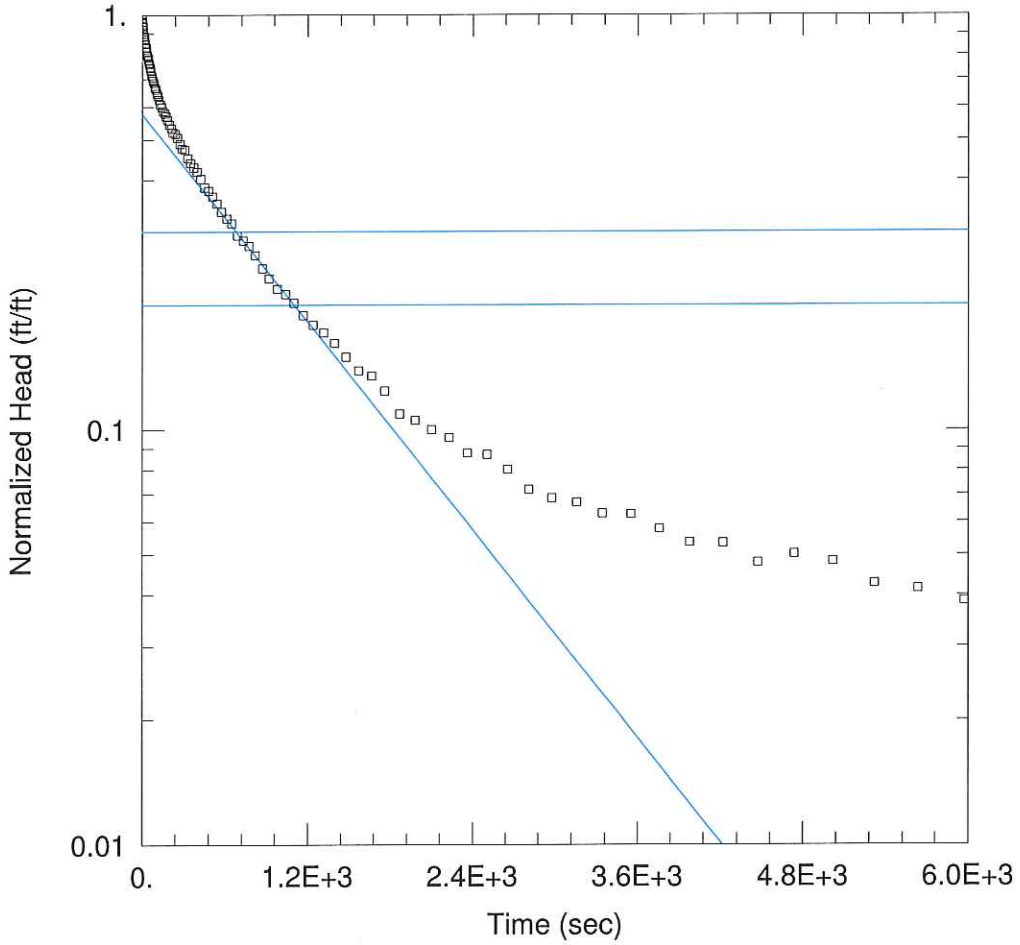
Saturated Thickness: 7. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (Slag 8)

Initial Displacement: 1.016 ft
Total Well Penetration Depth: 7. ft
Casing Radius: 0.083 ft
Static Water Column Height: 35.31 ft
Screen Length: 5. ft
Well Radius: 0.177 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice
K = 3.621E-5 cm/sec
y0 = 0.5422 ft



SLAG 8 RISING HEAD SLUG TEST (SLUG-OUT)

Data Set: \...\Slag 8 Slug Out.aqt
Date: 09/23/16 Time: 12:08:49

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: OtterTail Power Company
Project: 41251005
Location: Big Stone, SD
Test Well: Bonus Well
Test Date: July 27, 2016

AQUIFER DATA

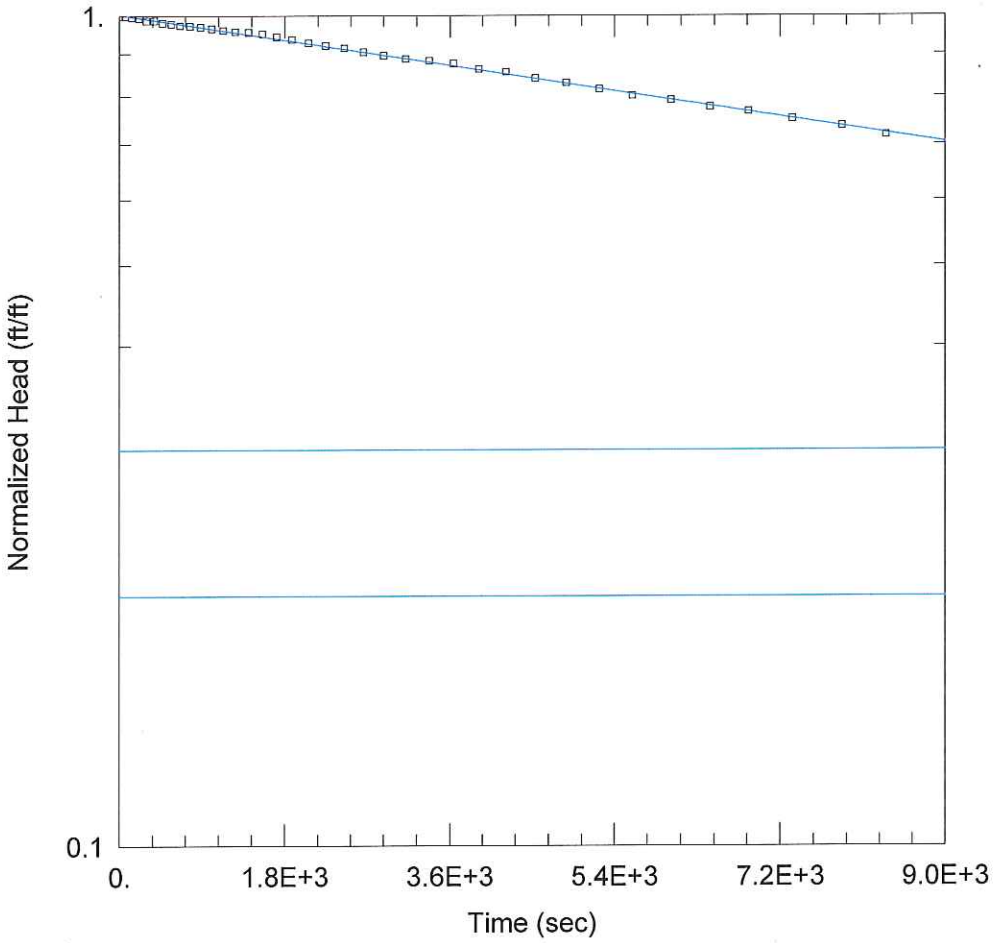
Saturated Thickness: 7. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (Slag 8)

Initial Displacement: 1.123 ft
Total Well Penetration Depth: 7. ft
Casing Radius: 0.083 ft
Static Water Column Height: 35.31 ft
Screen Length: 5. ft
Well Radius: 0.177 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice
K = 5.505E-5 cm/sec
y0 = 0.6481 ft



SLAG 9 DEEP RISING HEAD SLUG TEST (SLUG-OUT)

Data Set: \...\Slag 9 Deep Slug Out.aqt
Date: 10/26/16 Time: 16:22:44

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: OtterTail Power Company
Project: 41251005
Location: Big Stone, SD
Test Well: Slag 9 Deep
Test Date: Aug 12, 2016

AQUIFER DATA

Saturated Thickness: 7. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (Slag 9 Deep)

Initial Displacement: 1.466 ft
Total Well Penetration Depth: 7. ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.61 ft
Screen Length: 5. ft
Well Radius: 0.177 ft

SOLUTION

Aquifer Model: Confined
K = 2.247E-6 cm/sec
Solution Method: Bouwer-Rice
y0 = 1.47 ft