Groundwater Monitoring System Report

Ash Disposal Area
Big Stone Plant
Big Stone City, South Dakota

Prepared for
Otter Tail Power Company

December 2016

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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.

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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
Drain	A subsurface drain located along the western edge of the Holding Pond and south western edge of the Evaporation Pond.
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 near Big Stone City, South Dakota. The Site location is shown on Figure 1. Among other Site facilities are the 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. The Slag Pond Area is a multiunit groundwater monitoring system as allowed by § 257.91 (d) and is described in a separate report.

The Ash Disposal Area (ADA) vicinity consists of the landfill and the area around the landfill in which the groundwater monitoring system is located. The ADA vicinity is shown on Figure 2.

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

- Field activities during July, August, and September 2016
- 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 systems for the Big Stone Plant ADA Landfill 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 each 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 network.
- Identify gaps in the existing data and perform additional field tasks to establish a monitoring network as required by the CCR Rule.
- Observe field investigation consisting of the following subtasks:
    - Installation of monitoring wells H8 and H9 and a pilot boring was completed near monitoring well H6 (SB H6 DEEP) at the Ash Disposal Area. Three (3) temporary

    piezometers (T1, T2, and T3) were installed and abandoned. The temporary piezometers were installed to properly identify the placement of monitoring wells H8 and H9.
    - Monitoring wells proposed to become part of the CCR monitoring system were developed.
    - Collect geotechnical samples for analysis of parameters such as grain size analysis, vertical hydraulic conductivity, and horizontal hydraulic conductivity.
    - Water level elevation data were collected to document groundwater flow directions.
    - Perform 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 Ash Disposal 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. 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) shown on Figure 2.

2.1.1 Ash Disposal Area History and Construction

The ADA is an ash monofill positioned between the Cooling Pond and Evaporation/Holding Pond areas to the south of the Reclaim Pond. Ash contact storm water is contained in a depression on the north side of the ADA. This area is part of the ADA and separated from the North Reclaim Pond (Figure 2). The bottom or base of the ADA is estimated to be at an elevation of 1090 ft. MSL on the south side and ~1070 ft. MSL on the north side, based on pre-landfill surface elevations. It is unlined and built on native clay till material. Construction drawings include a 1974 topographic map with a conceptual design for an earthen dike on the south and east sides of the ADA. OTP provided available final cover engineering construction design drawings.

A subsurface drain (Drain) is shown on Figure 2 along the western edge of the Holding Pond and south western edge of the Evaporation Pond. The location of the Drain is inferred from engineering construction design drawings that were provided by OTP. The Drain is believed to be a toe drain that was incorporated in the design of the Holding Pond and Evaporation Pond prior to construction. It is shown to slope south towards a pump manhole located south of the Holding Pond, where groundwater is collected and pumped into the Holding 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 till. Alluvium deposits are mapped to the south and east of the Site. End moraine deposits are shown southwest of the ADA. End moraine deposits consist of 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 shows the presence of shale with gravel and a lignite lens from 177 to 227 ft. bgs, which is inferred to be glacial till. The well log shows a white coarse sand underlying the gray till.

Soil borings completed at the Site in July 2016 did not reach depths greater than 177 ft. bgs and geological features described by the deeper 1977 log were not verified. It is possible the white coarse sand may be a remnant of Cretaceous Dakota Sandstone or possibly an erroneous classification for weathered granite. The shallower glacial till was observed elsewhere at the Site and is described below.

Glacial Till Unit (GTU)

The surficial geology is composed of Late Wisconsin Des Moines Lobe 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 or zones of 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 upper-most material encountered at the Site. The Brown Till unit consists of oxidized yellow to brown sandy lean clay with discontinuous seams and lenses of sand and clayey sand. 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 dictates 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 first occurrence of coarser-grained sediments, such as seams and lenses of sand and silt, in the Brown Till generally defines the uppermost aquifer.

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 has a "pre-bomb" tritium signature, indicating that the water in it was recharged prior to 1953.

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 Grey 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 Ash Disposal Area Geology and Hydrogeology

The geology at the ADA is comprised of the geology discussed in Section 2.2.3 and the hydrogeology at the ADA is comprised of the more permeable saturated geology discussed in Section 2.2.3.

2.3.1 Geology

The geology at the ADA consists of the GTU as described above. Generally, the sand and silt lenses within the uppermost Brown Till generally do not form continuous horizons between adjacent borings. The Brown Till progressively transitions to the Gray Till occurs at an elevation of around 1060 ft. MSL, or 30 to 40 ft. bgs. Soil borings did not extend to a depth to reach 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:

- Soil boring and monitoring well completion logs for monitoring system wells discussed in Section 4.0.

- Soil boring and well logs for H8 and H9, a pilot boring near monitoring well H6 called SB H6 DEEP, and 3 temporary piezometers (completed in July 2016). The 3 temporary piezometers (T1, T2, and T3) were used to optimize monitoring well placement during the installation of monitoring wells H8 and H9.

- Available soil logs and monitoring well completion logs used to create cross-sections presented in Section 3.0, except there is no boring log for the Bonus Well.

2.3.2 Site Hydrogeology

The movement of groundwater within the geologic formations occurs within more permeable material (e.g., seams or lenses of sand or silty 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 to the north, precipitation, and seepage from the water retention ponds.

Groundwater Flow

The upper water table aquifer for the Ash Disposal Area is locally higher-permeability seams and lenses observed within the Brown Till. Groundwater is relatively shallow and occurs at 10 to 20 ft. bgs in the Brown Till. Sandy zones reported on boring logs generally do not appear to form continuous horizons between adjacent borings.

A downward vertical gradient is apparent when comparing monitoring wells screened at different elevations, especially when comparing wells screened within the Brown Till and Gray Till. 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 limited groundwater elevation data for monitoring wells H8 and H9 because these wells were newly installed (July 2016).

The Drain located near the western edge of the Holding Pond and southwest edge of the Cooling Pond influences the groundwater flow direction near the ADA. Figure 5 shows groundwater flow north of the Cooling Pond and Evaporation Pond is generally in a south-southeasterly direction. Figure 5 shows groundwater flow near the North Reclaim Pond is from the larger ponds (Cooling Pond and the Evaporation) towards the North Reclaim Pond. From the North Reclaim Pond, groundwater flows under the ADA east towards the Drain, which serves as a groundwater discharge feature.

Laboratory Permeability and Hydraulic Conductivity

Table 1 and Table 2 summarize laboratory permeability test results from the Ash Disposal Area. Geotechnical laboratory data are available in Appendix C.

Table 1 **Ash Disposal Area Laboratory Values (Glacial Till Unit)**

Boring/ Well	Depth (ft.)	Sample Description	GTU	USCS	Test Type	Hydraulic Conductivity (cm/s)
H8	16-18	Sandy Lean Clay w/ a little gravel	Brown	CL	Vertical	$6.8x10^{-8}$
H8	16-18	Sandy Lean Clay w/ a little gravel	Brown	CL	Horizontal	$3.6x10^{-8}$
SB H6 DEEP	47-49	Sandy Lean Clay	Gray	CL	Vertical	$2.8x10^{-8}$
SB H6 DEEP	47-49	Sandy Lean Clay	Gray	CL	Horizontal	$4.8x10^{-8}$

As mentioned above, the upper water table aquifer is the locally higher-permeability seams and lenses observed within the Brown Till. Due to the thinness of the sand and silt seams (<2 inches) such as the thin sand and silt seams observed at 11.5 ft. and 18.7 ft. bgs within soil boring H8, laboratory tests were not conducted on them.

Slug test analyses are summarized in Table 2 and additional details pertaining to the data analysis are included in Appendix D. Slug Tests were performed at H3OX and H6 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 Level Troll 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 H3OX and H6; however the slug-in test data for H6 was not analyzed due to significant noise in the data.

Table 2 **Ash Disposal Area Slug Test Values (Brown Till)**

Well	Monitored Unit	Hydraulic Conductivity Slug-In (cm/s)	Hydraulic Conductivity Slug-Out (cm/s)
H3OX	Water Table, upgradient	6.6×10^{-5}	6.6×10^{-5}
H6	Water Table, downgradient	--	2.2×10^{-3}

The hydraulic conductivity of the Brown Till ranges from 2.2×10^{-3} to 6.6×10^{-5} cm/s based on single-well slug tests, with a geometric mean of 2.1×10^{-4} cm/s. The geometric mean was estimated from available conductivity values shown in Table 2. Hydraulic conductivity values are anticipated to vary within the Brown Till due to variability and thickness of more permeable seams and lenses of sand and silt.

Two sets of slug-in/out test pairs were performed at monitoring well H1UN, within the Gray Till; however the data was not analyzed due to lack of a measurable response during the 6.5-hour testing period. The lack of a measurable response is due to the very low permeability, which is estimated to be lower than 4.8×10^{-8} cm/s. This estimate was derived by assuming the Kh value is lower than the geotechnical laboratory Kh value determined for SB H6 DEEP (Table 1).

Groundwater Flow Rates in Brown Till

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

$$V_t = Kh * i/n = 0.0015 \text{ ft/day or } 5.3 \text{ ft/yr}$$

Where: V_t = average linear velocity
Kh = horizontal hydraulic conductivity (2.1×10^{-4} cm/s)
i = gradient (H3OX to H9 = 0.006; calculated from water levels)
n = effective porosity (0.25)

Porosity of sands range 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 effective porosity of the GTU aquifer is 0.25.

The actual groundwater flow in the vicinity of ADA 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 Gray Till appears to be a confining unit relative to the Brown Till. As mentioned above, due to the thinness of the sand and silt seams (<2 inches) such as the thin sand and silt seams observed at 11.5 ft. and 18.7 ft. bgs within soil boring H8, laboratory tests were not conducted on them. The main difference between the Brown Till and Gray Till is that the Kh slug test values for the Brown Till were higher (Kh =2.1×10^{-4} cm/s) compared to the lower Kh slug test values at H1UN estimated to be lower than 4.8×10^{-8} cm/s. Therefore, groundwater is expected to travel primarily in the horizontal direction within the more permeable seams or lenses within the Brown Till because Kh value for the Gray Till is much lower than the Brown Till.

2.4 Potential Groundwater Receptors

As mentioned in Section 2.3.2, Figure 5 shows groundwater flow near the North Reclaim Pond is from the larger ponds (Cooling Pond and the Evaporation) towards the North Reclaim Pond. From the North Reclaim Pond, groundwater flows under the ADA east towards the Drain, which serves as a groundwater discharge feature. No downgradient receptors are believed to be downgradient of the ADA since the Drain is ultimately pumped to the Holding Pond.

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 ensure that an adequate hydraulic connection exists between the well screen and the filter pack. Monitoring wells were surged several times initially by moving 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 amount purged, and the approximate well recharge rate field measurements.

Table 3 Ash Disposal Area 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]
H2OX	16.1	7	5 hours to recharge 8 ft. [7/28/16]
H3OX	4.2	12	7 minutes to recharge 14.5 ft. [7/27/16]
H4OX	6.3	5	12.5 minutes to recharge 2.5 ft. [7/27/16]
H6	6.2	6	9 minutes to recharge 1 ft. [7/28/16]
H8	6.2	25	16 minutes to recharge 10 ft. [8/8/16]
H9	6.9	52	10.5 minutes to recharge 24.5 ft. [8/8/16]

NA – Not Available

Table 3 also shows the approximate recharge rate measured by pumping the well dry and then measuring the recovery.

3.0 Conceptual Models

3.1 Ash Disposal Area Conceptual Model

Cross section locations for the ADA are shown on Figure 6 and include the locations of cross section A-A' and B-B'. Cross section A-A' is shown on Figure 7; cross section B-B' is shown on Figure 8. Groundwater elevation measurements collected on August 8, 2016 from monitoring wells screened in the Brown Till are displayed on the figures.

In Summary, Figure 7 and Figure 8 show the following features about the hydrogeology of the ADA:

- The surface materials consist primarily of the Brown Till.
- As mentioned in Section 2.3.2, the upper water table aquifer for the Ash Disposal Area is within locally higher-permeability seams and lenses observed within the Brown Till.
- As mentioned in Section 2.3.2, laboratory tests were not conducted on sand and silt seams due to the thinness of the seams (<2 inches), such as the thin sand and silt seams observed at 11.5 ft. and 18.7 ft. bgs within soil boring H8. Similarly, due to scale, the thin sand and silt seams are not shown on Figure 7 and Figure 8.
- Groundwater occurs at elevations of approximately 1070 ft. to 1010 ft. MSL, as observed in monitoring wells.
- A downward vertical gradient is apparent when comparing monitoring wells screened within the Brown Till and Gray Till (see water level shown for H1UN on Figure 7).
- As mentioned in Section 2.3.2, Figure 5 shows groundwater flow near the North Reclaim Pond is from the larger ponds (Cooling Pond and the Evaporation) towards the North Reclaim Pond. From the North Reclaim Pond, groundwater flows under the ADA east towards the Drain, which serves as a groundwater discharge feature.
- The transition from the Brown Till to the Gray Till is not abrupt, but occurs roughly at an elevation of 1060 ft. MSL.
- Soil borings did not extend to a depth to reach bedrock, which is anticipated at depths greater than 227 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 would travel so that a monitoring system can be positioned properly to intercept it.

A hypothetical release at the ADA would likely be transported east, 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 9 shows and Table 4 describes the CCR groundwater monitoring system for the ADA.

Table 4 Monitoring Well System Summary

Well ID	Well Placement	Rationale
H2OX, H3OX, and H4OX	Upgradient	To account for geologic and hydrogeologic variability upgradient of the Ash Disposal 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)).
H6, H8, and H9	Downgradient	To detect a release from the Ash Disposal Area and to account for geologic and 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 capable of providing representative groundwater samples. The monitoring well completion logs show that 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 ensure detection of any contaminants from a hypothetical release from the ADA.

As stated in Section 2.3.2, the Drain located near the western edge of the Holding Pond and southwest edge of the Cooling Pond influences the groundwater flow direction near the ADA. The monitoring wells located downgradient of the ADA are spaced approximately 400 ft. apart, with little downgradient zone located north of the north well or south of the south well. A typical downgradient monitoring system spacing might space wells at about 500 ft. By comparison, the down gradient monitoring wells meet industry monitoring system standards and provide the minimum number of downgradient wells require by the CCR Rule.

In summary, the groundwater monitoring system identified in Table 4 and on Figure 9 is deemed to be adequate for groundwater monitoring under the CCR Rule. Table 5 provides construction details of the proposed 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
H2OX	5/9/1994	1103.86	32.57	5/2.0	PVC/PVC/#10
H3OX	5/11/1994	1095.26	22.45	5/2.0	PVC/PVC/#10
H4OX	5/12/1994	1108.25	27.13	5/2.0	PVC/PVC/#10
H6	11/10/2011	1097.76	17.69	10/2.0	PVC/PVC/#6
H8	7/29/2016	1081.23	22.05	10/2.0	PVC/PVC/#6
H9	7/30/2016	1086.21	30.20	10/2.0	PVC/PVC/#6

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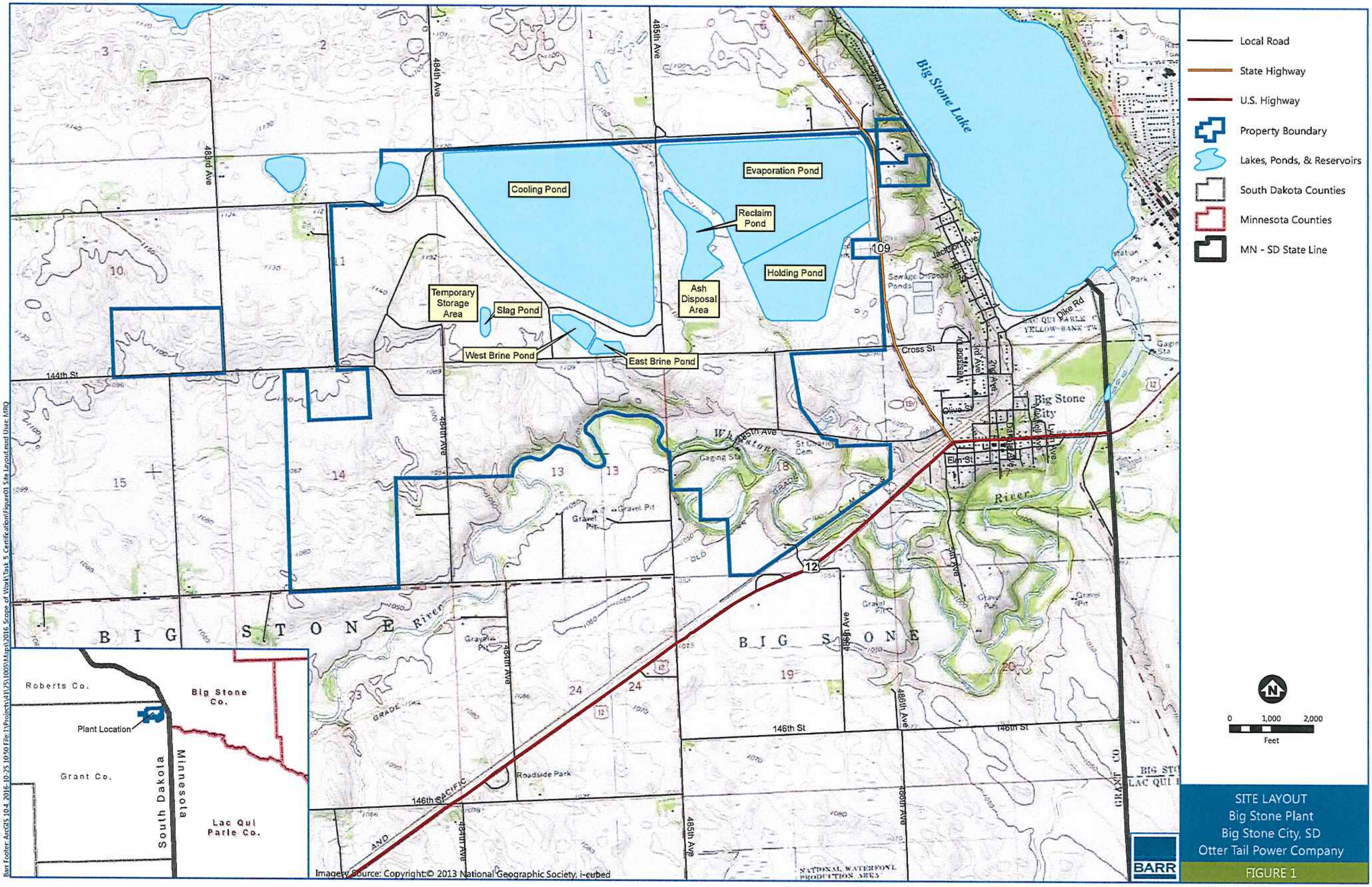
US EPA, 2015. Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals From Electric Utilities; Final Rule, Federal Register vol. 80, no. 74.

Figures



Imagery Source: Copyright:© 2013 National Geographic Society, i-cubed

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

FIGURE 1

Barr Footer: ArcGIS 10.4, 2016-10-25 10:50 File: I:\Projects\41\25\1005\Maps\2016 Scope of Work\Task 5 Certification\Figure01 Site Layout.mxd User: MRQ

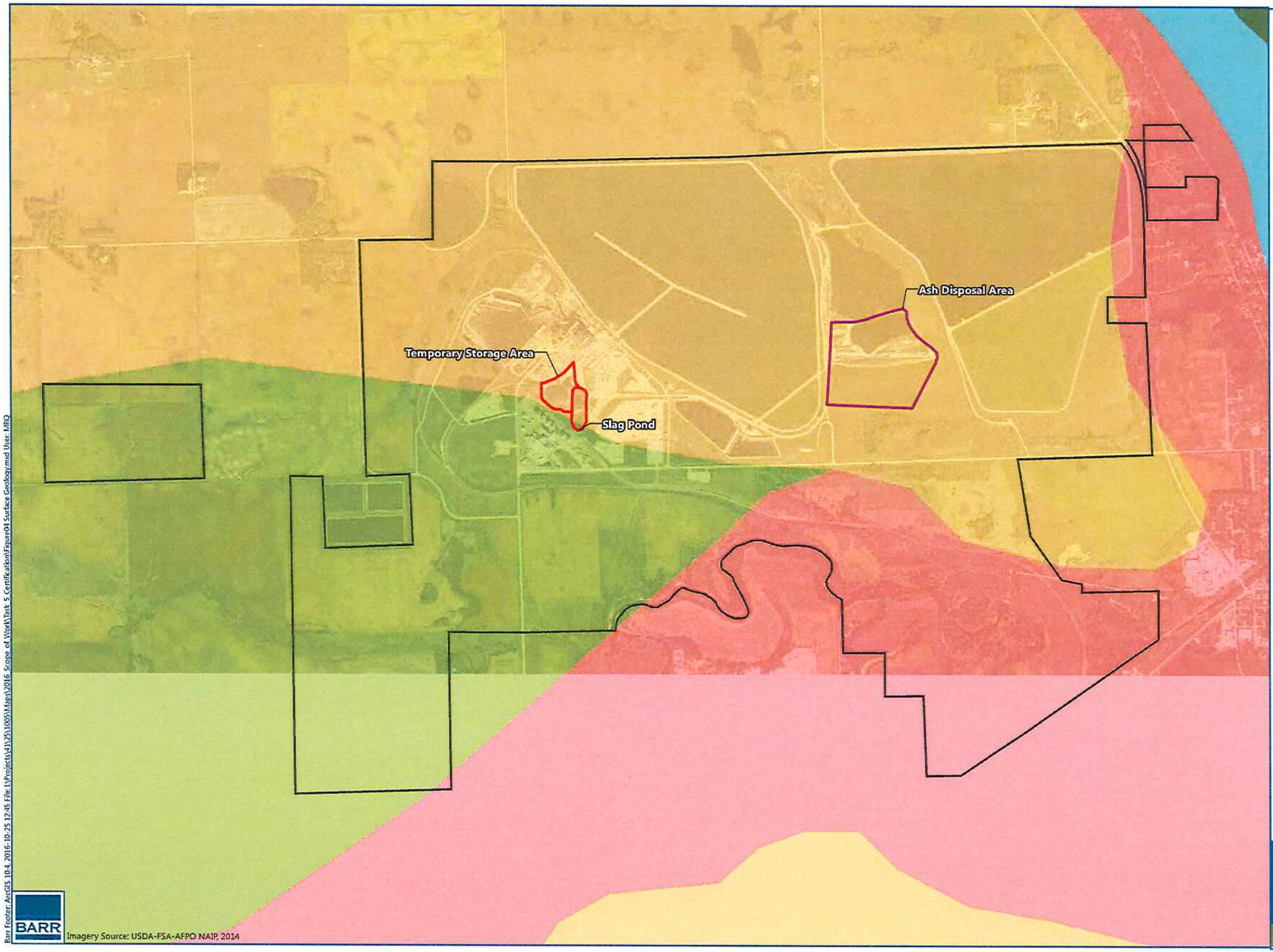
Note: Staff Gage locations provided by Otter Tail Power

Imagery Source: USDA-FSA-AFPO NAIP, 2014

ASH DISPOSAL AREA
Big Stone Plant
Big Stone City, SD
Otter Tail Power Company

FIGURE 2

Barr Footer: ArcGIS 10.4, 2016-10-25 12:30 File: I:\Projects\41\25\1005\Maps\2016 Scope of Work\Task 5 Certification\Figure03 Ash Disposal Area.mxd User: MRO



Geologic Terms

Alluvium - Gravel, sand, silt, and clay deposited along streams, as overbank material during floods, and in older, undifferentiated terrace deposits

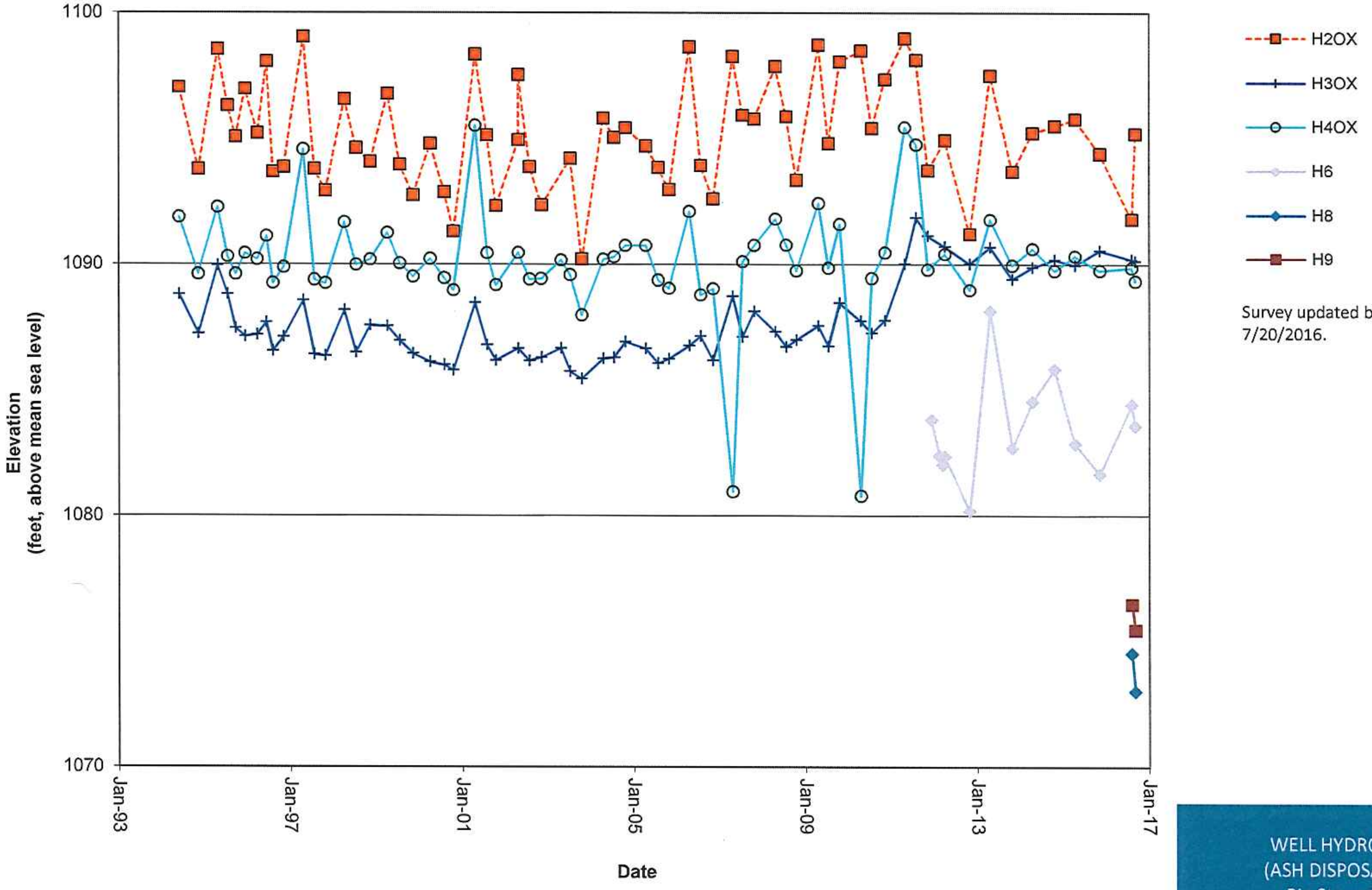
Till, End Moraine - Heterogeneous, clay with silt to boulder-size clasts of glacial origin. A geomorphic feature that is characterized by elevated linear ridges with hummocky terrain locally at former ice sheet margins. Composite thickness of all Upper Wisconsin till may be up to 300 ft (91 m).

Till, Ground Moraine - Heterogeneous, clay with silt to boulder-size clasts of glacial origin. A geomorphic feature that is characterized by smooth, rolling terrain. Composite thickness of all Upper Wisconsin till may be up to 300 ft (91 m).

Geology Source: 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

SURFACE GEOLOGY
Big Stone Plant
Big Stone City, SD
Otter Tail Power Company

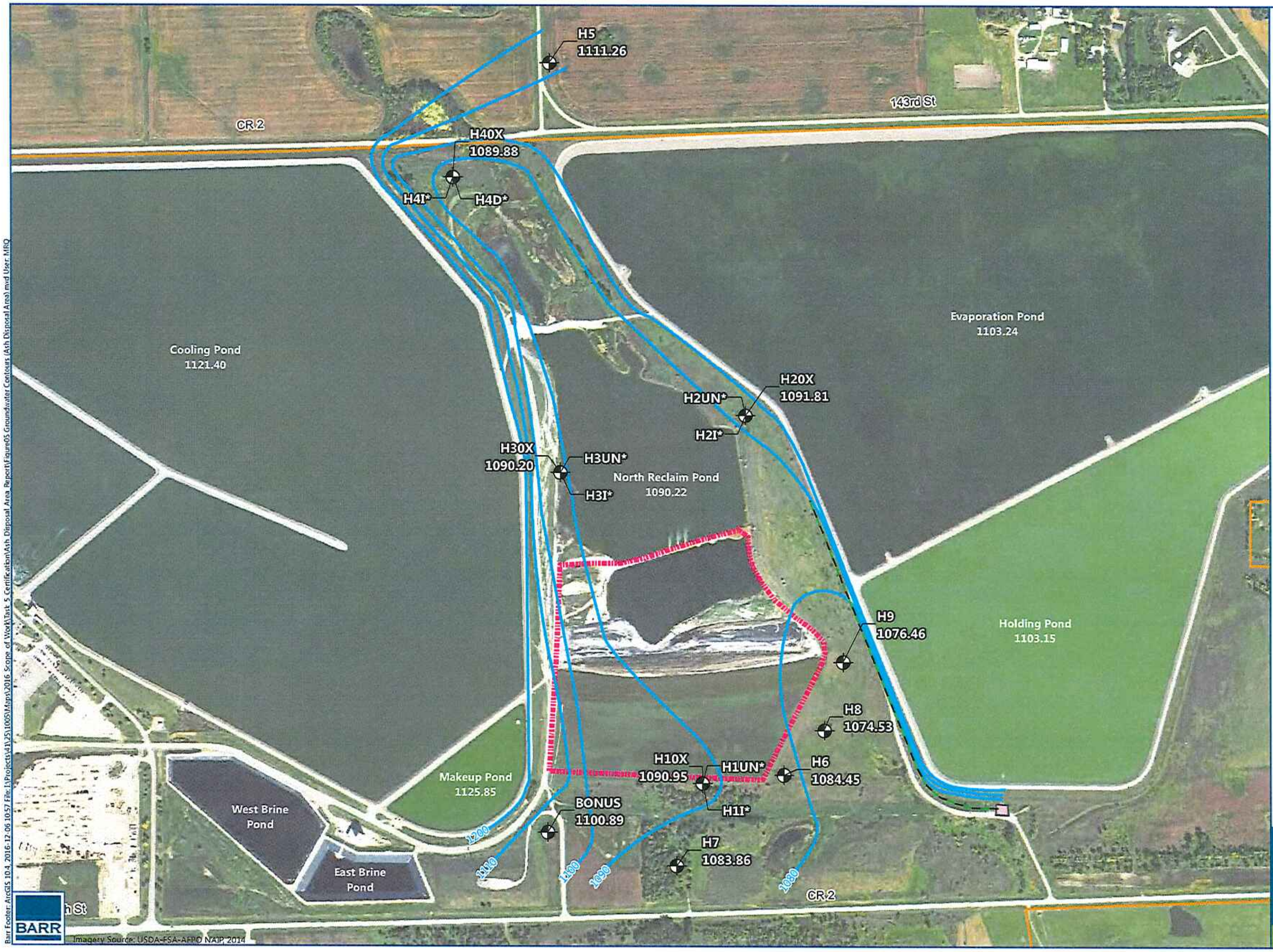
FIGURE 3



Survey updated by OTP on
7/20/2016.

WELL HYDROGRAPH
(ASH DISPOSAL AREA)
Big Stone Station
Big Stone, SD
Otter Tail Power Company

FIGURE 4



⊕ Monitoring Well Location

Groundwater Contour - August 2016 (ft MSL)

Drain

Pump

Ash Disposal Area

Property Boundary

1105.12 Groundwater Elevation (ft. MSL)

Note:
* Monitoring wells not included in groundwater contouring

Groundwater elevations collected on 8/1/2016, 8/8/2016, and 8/10/2016.

Pond elevations collected on 7/20/2016

N

0 350 700
Feet

GROUNDWATER CONTOURS
ASH DISPOSAL AREA
Big Stone Plant
Big Stone City, SD
Otter Tail Power Company

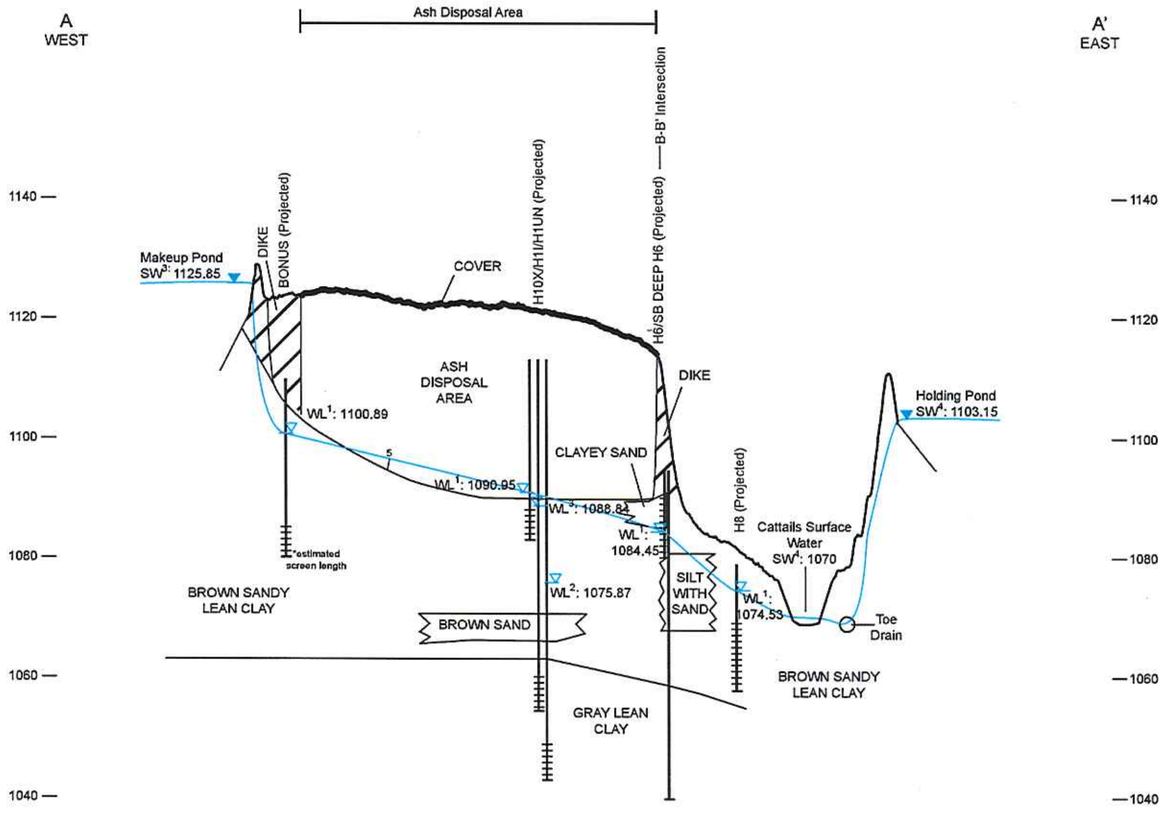
FIGURE 5

Barr Footer: ArcGIS 10.4, 2016-12-06 10:57 File: I:\Projects\41\25\1005\Maps\2016 Scope of Work\Task 5 Certification\Ash Disposal Area Report\Figure05 Groundwater Contours (Ash Disposal Area).mxd User: MRQ

CROSS SECTION LOCATION
ASH DISPOSAL AREA
Big Stone Plant
Big Stone City, SD
Otter Tail Power Company

FIGURE 6

Imagery Source: USDA-FSA-APFO NAIP, 2014



Approximate Horizontal Scale in Feet
25X Vertical Exaggeration

LEGEND

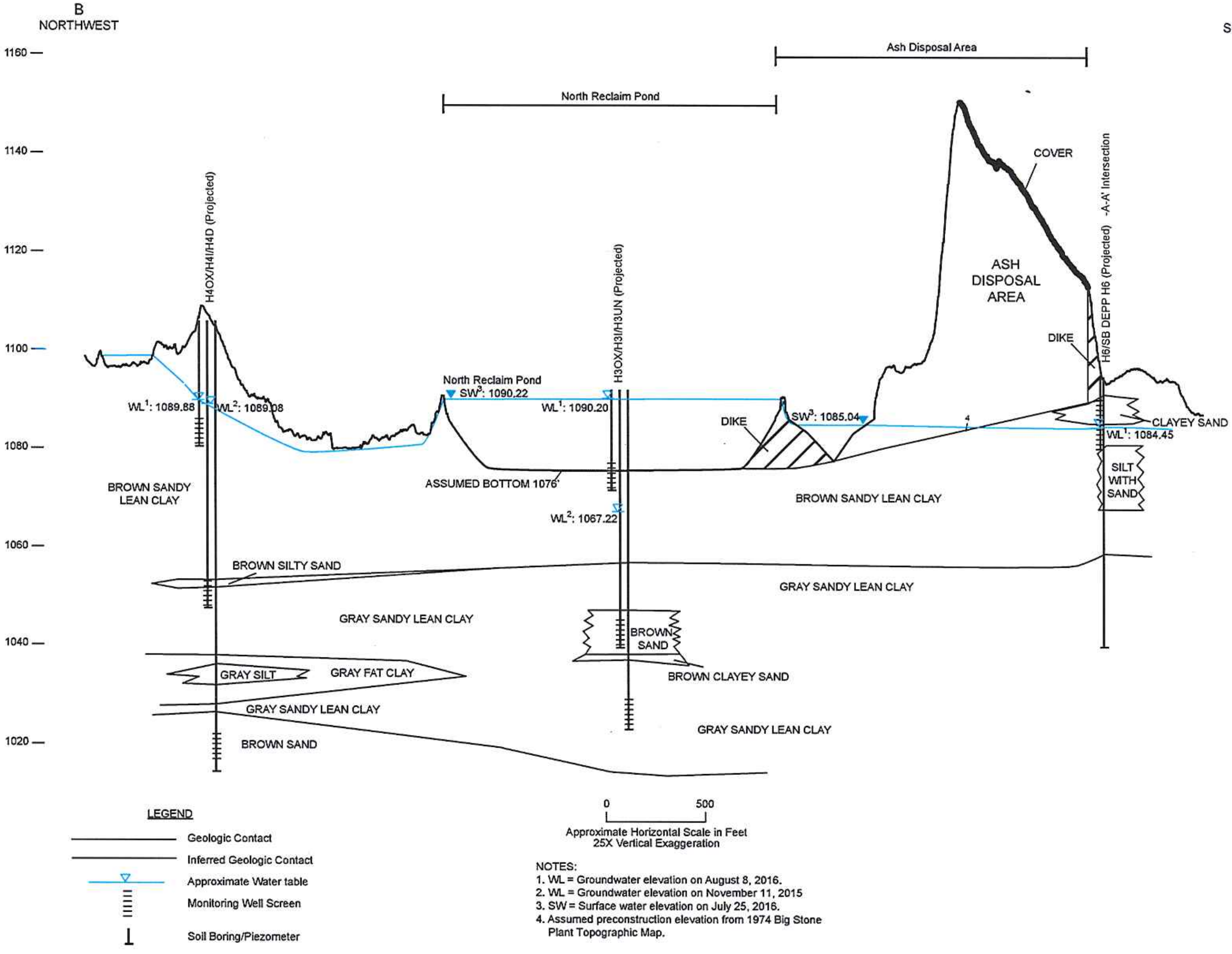
———	Geologic Contact
———	Inferred Geologic Contact
—▽—	Approximate Water table
☰	Monitoring Well Screen
⊥	Soil Boring/Piezometer

NOTES:
1. WL = Groundwater elevation on August 8, 2016.
2. WL = Groundwater elevation on August 12, 2016.
3. WL = Groundwater elevation on November 11, 2015
4. SW = Surface water elevation on July 25, 2016.
5. Assumed preconstruction elevation.1974 Big Stone Plant Topographic Map.

BARR

Figure 7

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



NOTES:
1. WL = Groundwater elevation on August 8, 2016.
2. WL = Groundwater elevation on November 11, 2015
3. SW = Surface water elevation on July 25, 2016.
4. Assumed preconstruction elevation from 1974 Big Stone Plant Topographic Map.

BARR

Figure 8

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

MONITORING WELL SYSTEM
ASH DISPOSAL AREA
Big Stone Plant
Big Stone City, SD
Otter Tail Power Company

FIGURE 9

Imagery Source: USDA-FSA-AFPO NAIP, 2014

Barr Footer: ArcGIS 10.4, 2016-10-25 15:17 File: I:\Projects\41\25\1005\Maps\2016 Scope of Work\Task 5 Certification\Figure18 Monitoring Well Network (Ash Disposal 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

~~11-T-121-N R-46-W~~ JOB NUMBER ______

FORMATION LOG

Surface elev = 1110'

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			
40	51	Br. clay	150	177	Blue sand clean
51	67	Blue clay			
67	73	Blue medium fine sand	177	227	Blk. shale w/gravel &
73	75	Blue clayey sand			
75	90	Br. sand (dirty)			lignite lenses
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		YIELD	WATER LEVEL BELOW SURFACE	DRAWDOWN	REMARKS
FROM	TO				
		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

22
&

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

TEST PUMP - 200' COLUMN & 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 shal
	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, 19 77 DRILLER: Neil Rollie

Grant

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

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, 19 77 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 (Ash Disposal Area)

F.8.A.1.i

LOG OF TEST BORING

JOB NO. 6600 94-354 VERTICAL SCALE 1" = 6' BORING NO. H-1UN

PROJECT OTTER TAIL POWER COMPANY, BIG STONE CITY, SOUTH DAKOTA

SURFACE ELEVATION 1113.1

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N or CR	WL	SAMPLE NO.	SAMPLE TYPE	TESTS W	TESTS D	ORGANIC VAPOR hNu (ppm)	ORGANIC VAPOR bkgd (ppm)
	FILL, mixture of SANDY LEAN CLAY and LEAN CLAY, with a little gravel, brown and dark brown	FILL			1	SB				
					2	SB				
					3	SB				
					4	SB				
19.0	**SANDY LEAN CLAY**, with a little gravel, brown, a 2" lens of waterbearing sand at 39' (CL)	TILL			5	SB				
					6	SB				
					7	3T*				
	* Shelby tube obtained from 25' to 27'.				8	SB				
					9	SB				
					10	SB				
				▽	11	SB				
42.5	**SAND**, medium to coarse grained, with gravel, brown, waterbearing (SP)	COARSE ALLUVIUM			12	SB				

BORING CONTINUED ON NEXT PAGE

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
5-10	6:01	75'	75'	75'		50'
5-11	8:00	75'	75'	75'		41.5'

START 5-10-94 COMPLETE 5-10-94 @ 6:00

METHOD 3 1/4" HSA 0-75'

CREW CHIEF R. Hanson

LOG OF TEST BORING

JOB NO. 6600 94-354 VERTICAL SCALE 1" = 6' BORING NO. H-1UN CONTINUED

PROJECT OTTER TAIL POWER COMPANY, BIG STONE CITY, SOUTH DAKOTA

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N or CR	WL	SAMPLE NO.	SAMPLE TYPE	TESTS W	TESTS D	ORGANIC VAPOR hNu (ppm)	ORGANIC VAPOR bkgd (ppm)
46	SAME AS PREVIOUS PAGE	*			13	SB				
47.0	**SANDY LEAN CLAY,** with a little gravel, brown (CL)	TILL			14	SB				
50.0	**LEAN CLAY,** with a little gravel, gray, a lens of waterbearing sand at 55' (CL)				15	SB				
					16	SB				
					17	SB				
					18	SB				
					19	3T				
					20	SB				
75.0	END OF BORING									

* COARSE ALLUVIUM

LOG OF TEST BORING

JOB NO. 6600 94-354 VERTICAL SCALE 1" = 6' BORING NO. **H-3UN**

PROJECT **OTTER TAIL POWER COMPANY, BIG STONE CITY, SOUTH DAKOTA**

DEPTH IN FEET	DESCRIPTION OF MATERIAL SURFACE ELEVATION 1092.0	GEOLOGIC ORIGIN	N or CR	WL	SAMPLE NO.	SAMPLE TYPE	TESTS W	TESTS D	ORGANIC VAPOR hNu (ppm)	ORGANIC VAPOR bkgd (ppm)
	FILL, mixture of **LEAN CLAY, SAND** and **CLAYEY SAND**, with a little gravel, brown and black	FILL								
4.5	**SANDY LEAN CLAY**, with a little gravel, brown mottled, limonite staining in fractures from 5' to 10', fractures from 10' to 15', no fractures below 15' (CL)	TILL			1	SB				
					2	SB				
					3	SB				
				▽						
					4	SB				
					5	SB				
					6	SB				
35.0	**SANDY LEAN CLAY**, with a little gravel, gray mottled (CL)				7	SB				
					8	SB				
					9	SB				
45.0	**BORING CONTINUED ON NEXT PAGE**									

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
4-21	11:00	40'	35'	40'		17'

START 4-21-94 COMPLETE 4-21-94 @ 4:00

METHOD
4 1/4" HSA 0-60', 3 1/4" HSA 60'-68 1/2'

CREW CHIEF R. Hanson

LOG OF TEST BORING

JOB NO. 6600 94-354 VERTICAL SCALE 1" = 6' BORING NO. H-3UN CONTINUED

PROJECT OTTER TAIL POWER COMPANY, BIG STONE CITY, SOUTH DAKOTA

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N or CR	WL	SAMPLE NO.	SAMPLE TYPE	TESTS W	TESTS D	ORGANIC VAPOR hNu (ppm)	ORGANIC VAPOR bkgd (ppm)
45	SAME AS PREVIOUS PAGE **SAND**, fine to medium grained, with a little gravel, brown, waterbearing (SP)	COARSE ALLUVIUM			10 11	SB SB				
53.5	**CLAYEY SAND**, fine grained, with a little gravel, brown, waterbearing (SC)	MIXED ALLUVIUM			12	SB				
55.0	**SANDY LEAN CLAY**, with a little gravel, gray, a 2' layer of reddish brown sandy lean clay at 60' (CL)	TILL			13 14 15 16 17	SB SB SB 3T SB				
68.5	**OBSTRUCTION**									

LOG OF TEST BORING

JOB NO. 6600 94-354 VERTICAL SCALE 1" = 6' BORING NO. H-4D

PROJECT OTTER TAIL POWER COMPANY, BIG STONE CITY, SOUTH DAKOTA

DEPTH IN FEET	DESCRIPTION OF MATERIAL SURFACE ELEVATION 1105.9	GEOLOGIC ORIGIN	N or CR	WL	SAMPLE		TESTS		ORGANIC VAPOR	
					NO.	TYPE	W	D	hNu (ppm)	bkgd (ppm)
	FILL, mostly SANDY LEAN CLAY, with a little gravel, black and brown	FILL			1	SB				
					2	SB				
7.5	**SANDY LEAN CLAY**, with a little gravel, brown mottled, lenses of waterbearing sand at 24', 25' and 39 1/2', limonite staining in fractures from 10' to 20', no fractures below 20' (CL)	TILL			3	SB				
					4	SB				
				▽	5	SB				
					6	SB				
					7	SB				
					8	SB				
					9	SB				
					10	SB				
41.7	**SANDY LEAN CLAY**, with a little gravel, gray (CL)				11	SB				

BORING CONTINUED ON NEXT PAGE

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
4-18	5:00	25'	3'	25'		24.6'
4-19	8:30	45'	45'	45'		14.8'

START 4-18-94 COMPLETE 4-19-94 @ 5:30

METHOD 6 1/4" HSA 0-4', 3 1/4" HSA 4'-91 1/2'

CREW CHIEF R. Hanson

Huntingdon

LOG OF TEST BORING

JOB NO. 6600 94-354 VERTICAL SCALE 1" = 6' BORING NO. H-4D CONTINUED

PROJECT OTTER TAIL POWER COMPANY, BIG STONE CITY, SOUTH DAKOTA

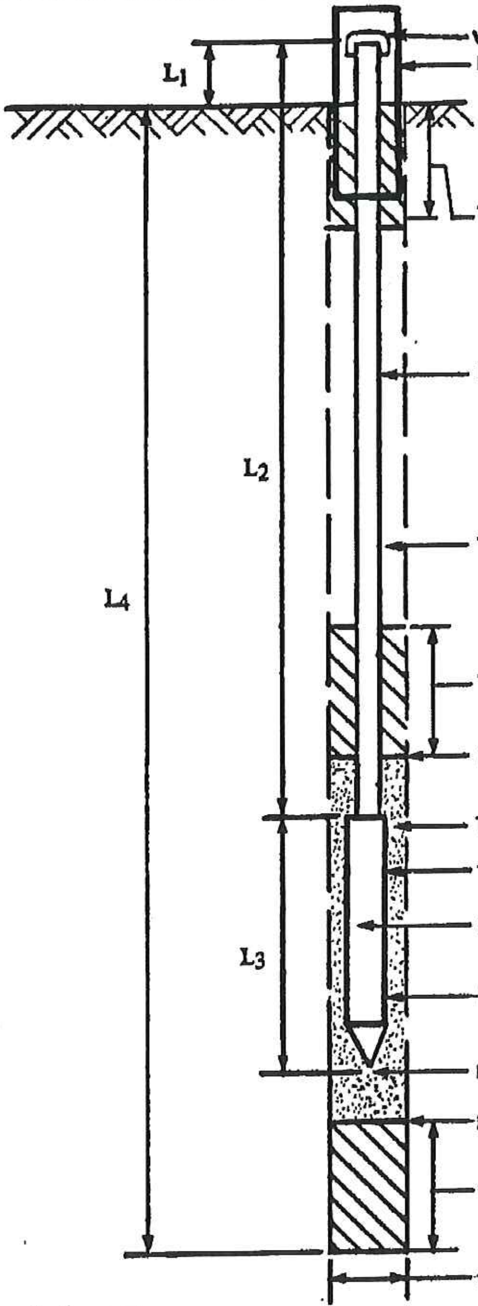
DEPTH IN FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N or CR	WL	SAMPLE NO.	SAMPLE TYPE	TESTS W	TESTS D	ORGANIC VAPOR hNu (ppm)	ORGANIC VAPOR bkgd (ppm)
45	SAME AS PREVIOUS PAGE	TILL			12	3T				
					13	SB				
49.0	**SANDY LEAN CLAY,** with a little gravel, brown mottled (CL)				14	SB				
50.7	**SANDY LEAN CLAY,** with a little gravel, gray (CL)				15	SB				
					16	SB				
53.1	**SILTY SAND,** fine grained, brown, waterbearing (SM)	*			17	SB				
54.2	**SANDY LEAN CLAY,** with a little gravel, gray, a cobble at 66' (CL)	TILL			18	SB				
					19	SB				
					20	SB				
					21	NSR				
68.0	**FAT CLAY,** gray (CH)	FINE ALLUVIUM			22	SB				
70.0	**SILT,** gray (ML)				23	SB				
					24	SB				
74.0	**FAT CLAY,** gray (CH)				25	SB				
78.0	**SANDY LEAN CLAY,** with a little gravel, gray (CL)	TILL			26	SB				
79.5	**SAND,** medium to coarse grained, with a little gravel, brown, waterbearing (SP)	COARSE ALLUVIUM			27	SB				
					28	SB				
	* MIXED ALLUVIUM									
					29	SB				
91.5	END OF BORING									

INSTALLATION OF MONITORING WELL

JOB NO. 6600 94-354 **MONITORING WELL NO.** H-lox

Otter Tail Power Company, Big Stone City, South Dakota

GROUND SURFACE ELEVATION 1113.07' **TOP OF RISER PIPE ELEVATION** (with cap removed) 1115.51'



VENTED CAP

PROTECTIVE CASING

Diameter and Type 4" steel tubing

Total Length 5'

Length Above Ground 3'

THICKNESS AND TYPE OF SEAL 3' cement

DIAMETER AND TYPE OF RISER PIPE 2" PVC

TYPE OF BACKFILL AROUND RISER cement and bentonite grout

THICKNESS AND TYPE OF SEAL 2' bentonite

DEPTH TO TOP OF FILTER SAND 23'

TYPE OF FILTER AROUND SCREEN silica sand

TYPE OF MONITORING WELL PVC

SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.) 0.010"

DIAMETER AND LENGTH OF SCREEN 2" X 5'

DEPTH TO BOTTOM OF MONITORING WELL 30'

DEPTH TO BOTTOM OF FILTER SAND 30'

THICKNESS AND TYPE OF SEAL —

DIAMETER OF BOREHOLE 7¼"

L_1= 2.5 FT

L_2= 27.5 FT

L_3= 5 FT

L_4= 30 FT

INSTALLATION COMPLETED:
Date 5/11/94 Time 4:30

MONITORING WELL WATER LEVEL MEASUREMENTS

DATE	TIME	BAILED DEPTHS	WATER LEVEL *
			**

* DEPTH BELOW TOP OF RISER PIPE
** See report for water level information.

twin city testing corporation

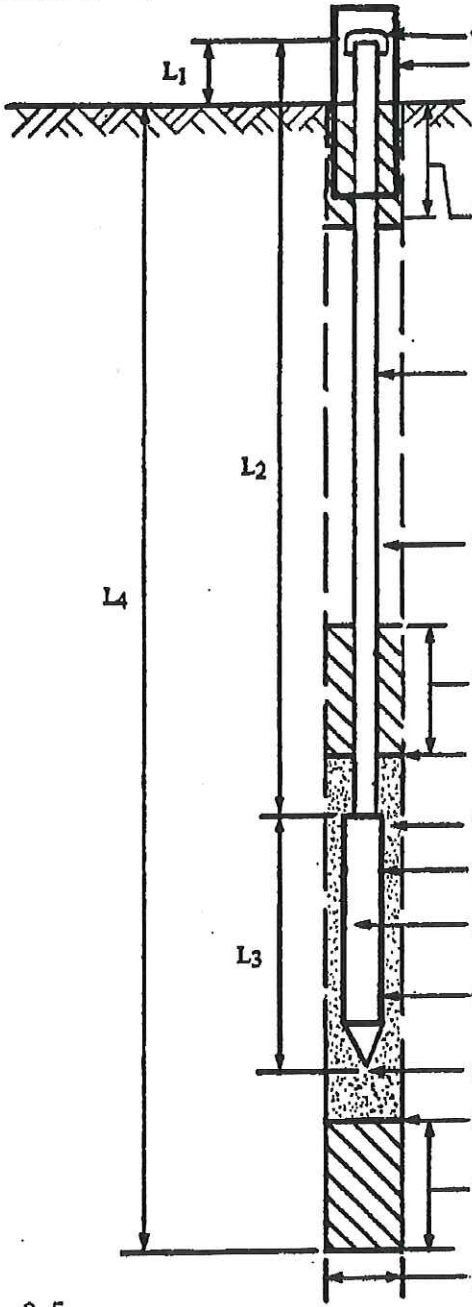
SE-29 (83-B)

INSTALLATION OF MONITORING WELL

JOB NO. 6600 94-354 **MONITORING WELL NO.** H-1i

Otter Tail Power Company, Big Stone City, South Dakota

GROUND SURFACE ELEVATION 1113.07' **TOP OF RISER PIPE ELEVATION** (with cap removed) 1115.48'



VENTED CAP

PROTECTIVE CASING

Diameter and Type 4" steel tubing

Total Length 5'

Length Above Ground

THICKNESS AND TYPE OF SEAL 3' cement

DIAMETER AND TYPE OF RISER PIPE 2" PVC

TYPE OF BACKFILL AROUND RISER cement and bentonite grout

THICKNESS AND TYPE OF SEAL 2' bentonite

DEPTH TO TOP OF FILTER SAND 52'

TYPE OF FILTER AROUND SCREEN silica sand

TYPE OF MONITORING WELL PVC

SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.) 0.010"

DIAMETER AND LENGTH OF SCREEN 2" X 5'

DEPTH TO BOTTOM OF MONITORING WELL 58'

DEPTH TO BOTTOM OF FILTER SAND 58½'

THICKNESS AND TYPE OF SEAL —

DIAMETER OF BOREHOLE 8¼"

L1= 2.5 FT

L2= 55.5 FT

L3= 5 FT

L4= 58.5 FT

INSTALLATION COMPLETED:
Date 6/02/94 Time 9:30

MONITORING WELL WATER LEVEL MEASUREMENTS

DATE	TIME	BAILED DEPTHS	WATER LEVEL *
			**

* DEPTH BELOW TOP OF RISER PIPE

** See report for water level information.

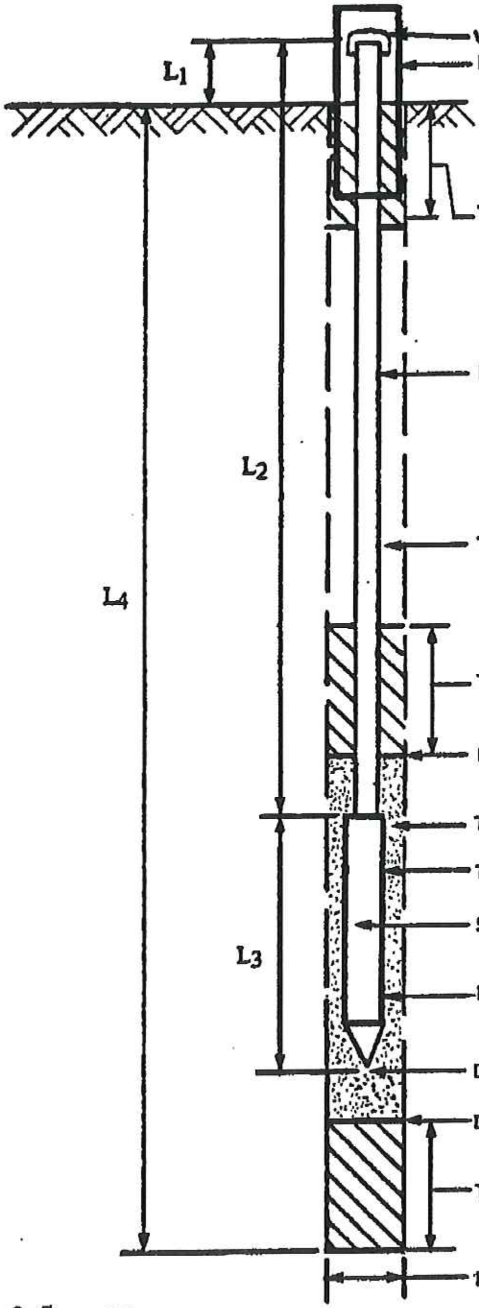
twin city testing corporation

INSTALLATION OF MONITORING WELL

JOB NO. 6600 94-354 **MONITORING WELL NO.** H-2ox

Otter Tail Power Company, Big Stone City, South Dakota

GROUND SURFACE ELEVATION 1100.55' **TOP OF RISER PIPE ELEVATION** (with cap removed) 1103.11'



VENTED CAP

PROTECTIVE CASING

Diameter and Type 4" steel tubing

Total Length 5'

Length Above Ground 2.8'

THICKNESS AND TYPE OF SEAL 3' cement

DIAMETER AND TYPE OF RISER PIPE 2' PVC

TYPE OF BACKFILL AROUND RISER cement and bentonite grout

THICKNESS AND TYPE OF SEAL 2' bentonite

DEPTH TO TOP OF FILTER SAND 23'

TYPE OF FILTER AROUND SCREEN silica sand

TYPE OF MONITORING WELL PVC

SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.) 0.010"

DIAMETER AND LENGTH OF SCREEN 2" X 5'

DEPTH TO BOTTOM OF MONITORING WELL 30'

DEPTH TO BOTTOM OF FILTER SAND 30'

THICKNESS AND TYPE OF SEAL —

DIAMETER OF BOREHOLE 8¼"

L_1= 2.5 FT

L_2= 27.5 FT

L_3= 5 FT

L_4= 30 FT

INSTALLATION COMPLETED:
Date 5/12/94 Time 12:00

MONITORING WELL WATER LEVEL MEASUREMENTS

DATE	TIME	BAILED DEPTHS	WATER LEVEL *
			**

* DEPTH BELOW TOP OF RISER PIPE

** See report for water level information.

twin city testing corporation

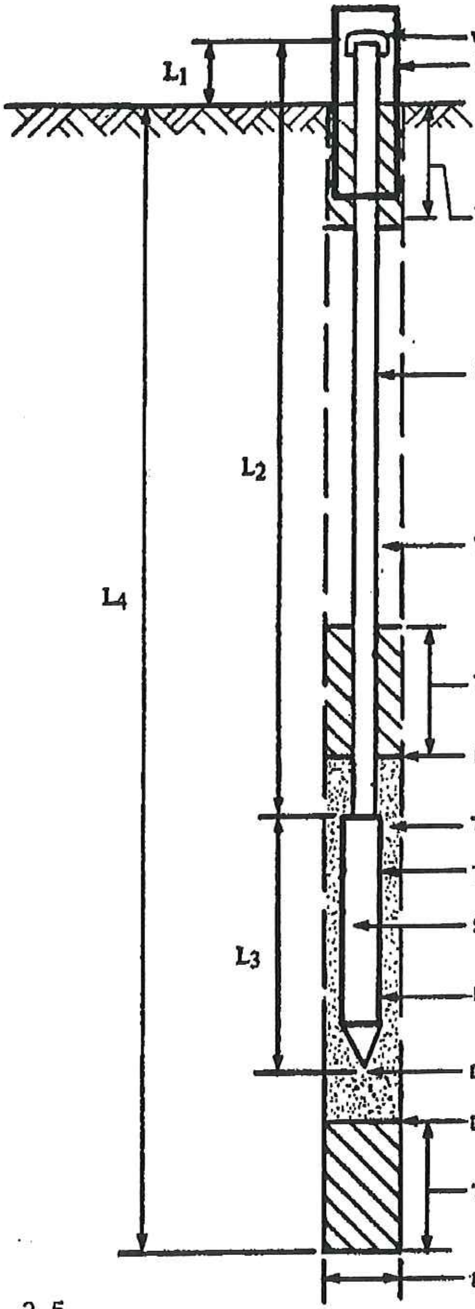
SE-28 (83-B)

INSTALLATION OF MONITORING WELL

JOB NO. 6600 94-354 **MONITORING WELL NO.** H-3ox

Otter Tail Power Company, Big Stone City, South Dakota

GROUND SURFACE ELEVATION 1092.19' **TOP OF RISER PIPE ELEVATION** (with cap removed) 1094.56'



VENTED CAP

PROTECTIVE CASING

Diameter and Type 4" steel tubing

Total Length 5'

Length Above Ground 2.8'

THICKNESS AND TYPE OF SEAL 3' cement

DIAMETER AND TYPE OF RISER PIPE 2" PVC

TYPE OF BACKFILL AROUND RISER cement and bentonite grout

THICKNESS AND TYPE OF SEAL 2' bentonite

DEPTH TO TOP OF FILTER SAND 13'

TYPE OF FILTER AROUND SCREEN silica sand

TYPE OF MONITORING WELL PVC

SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.) 0.010"

DIAMETER AND LENGTH OF SCREEN 2" X 5'

DEPTH TO BOTTOM OF MONITORING WELL 20'

DEPTH TO BOTTOM OF FILTER SAND 20½'

THICKNESS AND TYPE OF SEAL --

DIAMETER OF BOREHOLE 8¼"

L_1= 2.5 FT

L_2= 17.5 FT

L_3= 5 FT

L_4= 20.5 FT

INSTALLATION COMPLETED:
Date 5/11/94 Time 6:30

MONITORING WELL WATER LEVEL MEASUREMENTS			
DATE	TIME	BAILED DEPTHS	WATER LEVEL *
			**

* DEPTH BELOW TOP OF RISER PIPE
** See report for water level information.

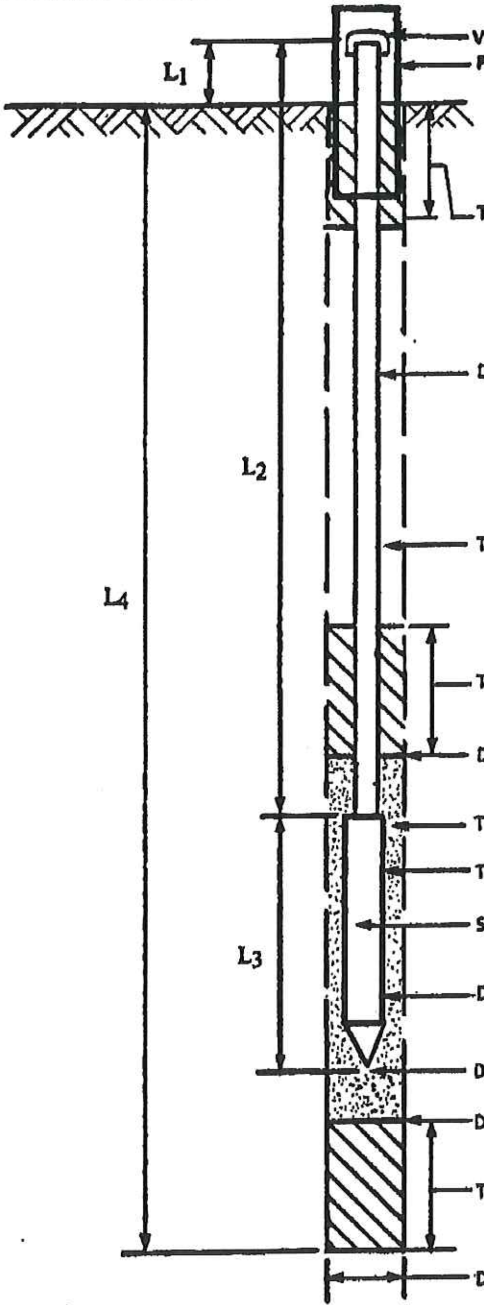
twin city testing corporation

INSTALLATION OF MONITORING WELL

JOB NO. 6600 94-354 **MONITORING WELL NO.** H-3i

Otter Tail Power Company, Big Stone City, South Dakota

GROUND SURFACE ELEVATION 1092.25' **TOP OF RISER PIPE ELEVATION** (with cap removed) 1094.69'



VENTED CAP	
PROTECTIVE CASING	
Diameter and Type	4" steel tubing
Total Length	5'
Length Above Ground	3.2'
THICKNESS AND TYPE OF SEAL	3' cement
DIAMETER AND TYPE OF RISER PIPE	2" PVC
TYPE OF BACKFILL AROUND RISER	cement and bentonite grout
THICKNESS AND TYPE OF SEAL	1' bentonite
DEPTH TO TOP OF FILTER SAND	44'
TYPE OF FILTER AROUND SCREEN	silica sand and natural sand
TYPE OF MONITORING WELL	PVC
SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.)	0.010"
DIAMETER AND LENGTH OF SCREEN	2" X 5'
DEPTH TO BOTTOM OF MONITORING WELL	52'
DEPTH TO BOTTOM OF FILTER SAND	52½'
THICKNESS AND TYPE OF SEAL	--
DIAMETER OF BOREHOLE	8¼"

L_1= 2.5 FT

L_2= 49.5 FT

L_3= 5 FT

L_4= 52.5 FT

INSTALLATION COMPLETED:
Date 5/25/94 Time 8:50

MONITORING WELL WATER LEVEL MEASUREMENTS

DATE	TIME	BAILED DEPTHS	WATER LEVEL *
			**

* DEPTH BELOW TOP OF RISER PIPE
** See report for water level information.

twin city testing corporation

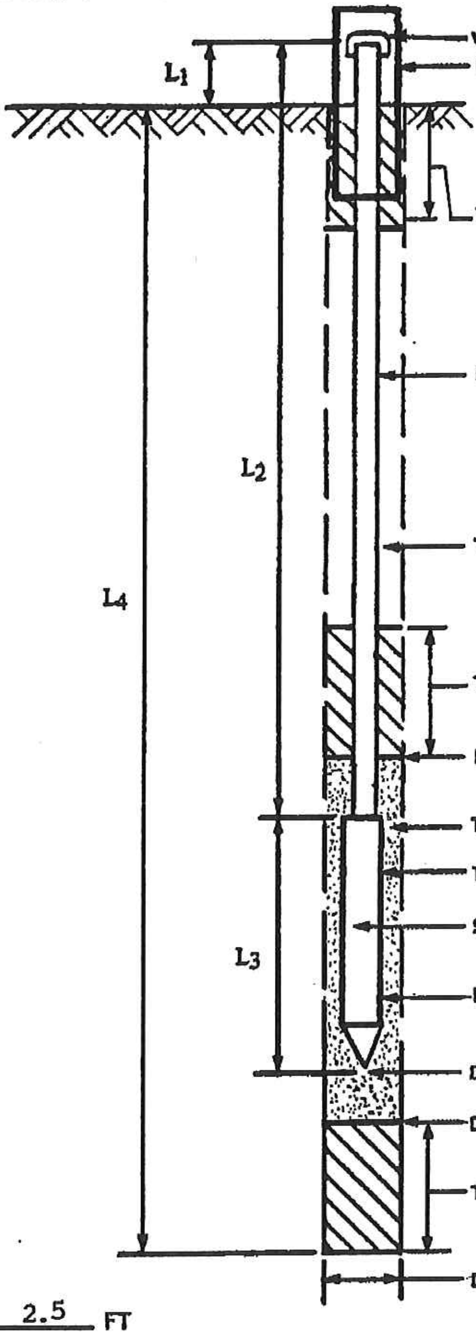
SE-29 (83-8)

INSTALLATION OF MONITORING WELL

JOB NO. 6600 94-354 **MONITORING WELL NO.** H-4ox

Otter Tail Power Company, Big Stone City, South Dakota

GROUND SURFACE ELEVATION 1105.69' **TOP OF RISER PIPE ELEVATION** (with cap removed) 1108.01'



VENTED CAP

PROTECTIVE CASING

Diameter and Type 4" steel tubing

Total Length 5'

Length Above Ground 2.8'

THICKNESS AND TYPE OF SEAL 3' cement

DIAMETER AND TYPE OF RISER PIPE 2" PVC

TYPE OF BACKFILL AROUND RISER cement and bentonite grout

THICKNESS AND TYPE OF SEAL 2' bentonite

DEPTH TO TOP OF FILTER SAND 18'

TYPE OF FILTER AROUND SCREEN silica sand

TYPE OF MONITORING WELL PVC

SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.) 0.010"

DIAMETER AND LENGTH OF SCREEN 2" X 5'

DEPTH TO BOTTOM OF MONITORING WELL 25'

DEPTH TO BOTTOM OF FILTER SAND 25½'

THICKNESS AND TYPE OF SEAL —

DIAMETER OF BOREHOLE 8¼"

L_1 = 2.5 FT

L_2 = 22.5 FT

L_3 = 5 FT

L_4 = 25.5 FT

INSTALLATION COMPLETED:
Date 5/12/94 Time 2:45

MONITORING WELL WATER LEVEL MEASUREMENTS

DATE	TIME	BAILED DEPTHS	WATER LEVEL *
			**

* DEPTH BELOW TOP OF RISER PIPE

** See report for water level information.

twin city testing corporation

INSTALLATION OF MONITORING WELL

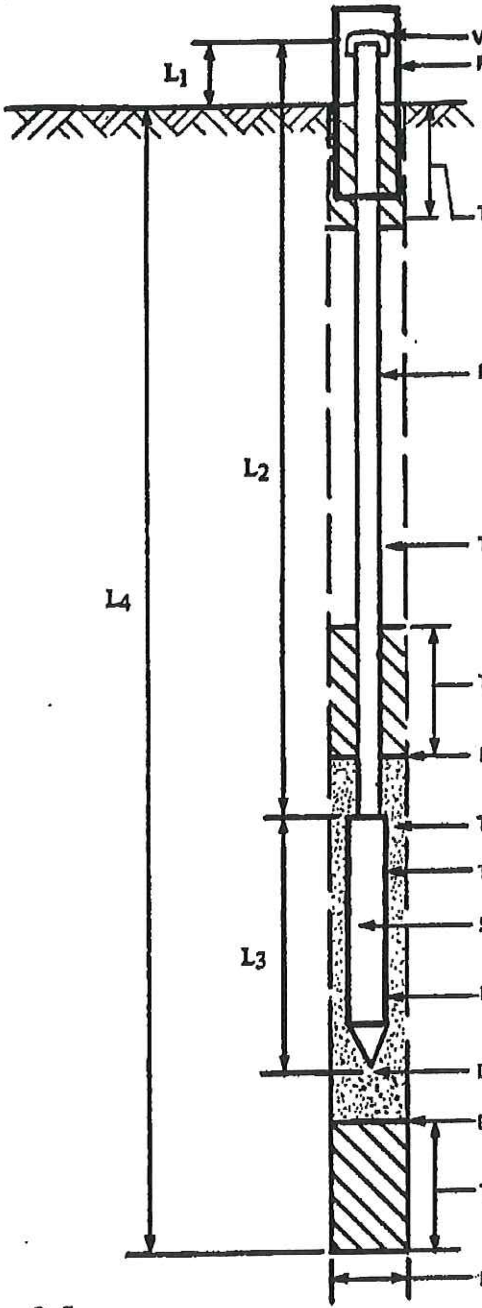
JOB NO. 6600 94-354

MONITORING WELL NO. H-4i

Otter Tail Power Company, Big Stone City, South Dakota

GROUND SURFACE ELEVATION 1105.96'

TOP OF RISER PIPE ELEVATION (with cap removed) 1108.36'



VENTED CAP

PROTECTIVE CASING

Diameter and Type	4" steel tubing
Total Length	5'
Length Above Ground	3'
THICKNESS AND TYPE OF SEAL	3' cement
DIAMETER AND TYPE OF RISER PIPE	2" PVC
TYPE OF BACKFILL AROUND RISER	cement and bentonite grout
THICKNESS AND TYPE OF SEAL	1.8' bentonite
DEPTH TO TOP OF FILTER SAND	51'
TYPE OF FILTER AROUND SCREEN	silica sand
TYPE OF MONITORING WELL	PVC
SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.)	0.010"
DIAMETER AND LENGTH OF SCREEN	2" X 5'
DEPTH TO BOTTOM OF MONITORING WELL	58'
DEPTH TO BOTTOM OF FILTER SAND	58½'
THICKNESS AND TYPE OF SEAL	--
DIAMETER OF BOREHOLE	8¼"

L_1= 2.5 FT

L_2= 55.5 FT

L_3= 5 FT

L_4= 58.5 FT

INSTALLATION COMPLETED:
Date 5/24/94 Time 10:00

MONITORING WELL WATER LEVEL MEASUREMENTS

DATE	TIME	BAILED DEPTHS	WATER LEVEL *
			**

* DEPTH BELOW TOP OF RISER PIPE

** See report for water level information.

twin city testing corporation

SE-29 (83-B)

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

LOG OF WELL H8

SHEET 1 OF 1

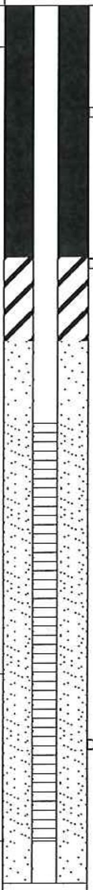
Project:Big Stone Station
Project No.:41251005
Location:Big Stone City, SD
Coordinates:N 554,702.0 ft E 2,872,096.6 ft
Datum:SD North State Plane NAD83

Surface Elevation:1078.9 ft
Drilling Method:HSA
Sampling Method:SS
Completion Depth:20.0 ft

Top of Casing Elev.: 1081.2 ft

Depth, feet	Blows/6in.	USCS	LITHOLOGIC DESCRIPTION	Elevation, feet
0		OL/OH	TOPSOIL (OL/OH): black (10YR 2/1); moist; 0% gravel, 10% sand, 90% fines.	
	2-2-1-1.	CL	LEAN CLAY (CL): yellowish brown to dark yellowish brown (10YR 5/6 to 10YR 4/4); moist; 5% gravel, 5% sand, 90% fines, with very fine to medium grain sand, oxidized seams, light gray clumps of silt (ML) becoming sandier with depth.	
	2-2-3-1.			1075
5	4-4-5-4.		5.5': Trace gravel.	
	5-6-6-7.			
	3-3-4-3.			1070
10	4-5-7-10.		11.5': SILTY SAND (SM) seam, very fine grain, oxidized.	
	5-11-11-15.			1065
15	4-7-9-10.			
			16': SILTY SAND (SM), dark yellowish brown (10YR 4/4), wet, medium to coarse grain, 20% gravel, 50% sand, 30% fines.	
	5-6-5-9.		18.7': SILTY SAND (SM) seam, dark yellowish brown (10YR 4/4), very fine grain.	1060
20			End of well 20.0 feet	
25				
30				

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: 6"
Type: Steel
Interval:

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

GROUT
Type: Neat Cement
Interval: 0-6' bgs

SEAL
Type: Bentonite
Interval: 6-8' bgs

SANDPACK
Type: Silica #50-80
Interval: 8-21' bgs

SCREEN
Diameter:
Type: #6 Sch 40
Interval: 10-20' bgs

Date Boring Started:	7/29/16 1:45 pm
Date Boring Completed:	7/29/16
Logged By:	JWJ
Drilling Contractor:	SDE
Drill Rig:	Truck

Remarks:

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

LOG OF WELL H9

SHEET 1 OF 1

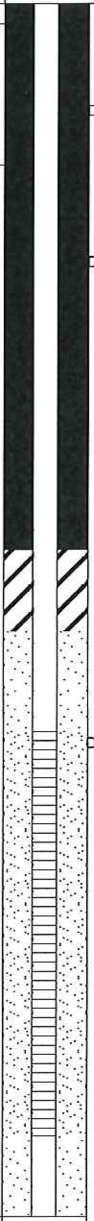
Project:Big Stone Station
Project No.:41251005
Location:Big Stone City, SD
Coordinates:N 555,166.2 ft E 2,872,218.3 ft
Datum:SD North State Plane NAD83

Surface Elevation:1083.8 ft
Drilling Method:HSA
Sampling Method:SS
Completion Depth:30.0 ft

Top of Casing Elev.: 1086.2 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
0				OL/OH		TOPSOIL (OL/OH): dark brown (10YR 3/3); moist; 0% gravel, 15% sand, 85% fines.	
			1-2-1-1.	ML		SILT WITH SAND (ML): very fine to fine grained; dark yellowish brown (10YR 4/6); moist; 0% gravel, 30% sand, 70% fines, trace gravel.	
			3-2-3-3.				1080
5			3-3-5-6.	CL		LEAN CLAY (CL): yellowish brown to dark yellowish brown (10YR 5/6 to 10YR 4/4); moist; 0% gravel, 10% sand, 90% fines, with very fine to medium grain sand and trace gravel throughout, reddish orange oxidation throughout.	
			5-6-6-8.				
			5-7-7-9.				1075
10						9.4': CLAYSTONE, dark gray, 1.2" thick.	
			6-8-10-12.				
			6-6-7-9.				1070
15			5-6-6-11.				
			4-6-7-9.				
			7-9-9-11.				1065
20			4-5-6-6.				
			5-6-9-12.				1060
25			4-6-5-7.			24': SILTY SAND (SM), dark brown (10YR 3/3), wet, very fine to medium grain, 0% gravel, 90% sand, 10% fines, 1.3' thick.	
			5-6-6-8.			29': SILTY SAND (SM), dark yellowish brown (10YR 4/4), wet, very fine to medium grain, 0% gravel, 90% sand, 10% fines, 9.6" thick.	1055
30						End of well 30.0 feet	

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: 6"
Type: Steel
Interval:

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

GROUT
Type: Neat Cement
Interval: 0-13.5' bgs

SEAL
Type: Bentonite
Interval: 13-15.5' bgs

SANDPACK
Type: Silica #50-80
Interval: 15.5-30' bgs

SCREEN
Diameter:
Type: #6 Sch 40
Interval: 18-28' bgs

Date Boring Started:	7/30/16 8:50 am
Date Boring Completed:	7/30/16 8:45 pm
Logged By:	NJS2
Drilling Contractor:	SDE
Drill Rig:	Truck

Remarks:

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

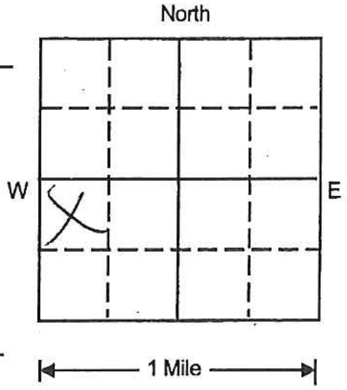
WCEC Job 8472

SOUTH DAKOTA WATER WELL COMPLETION REPORT

11-02

Location NW ¼ SW ¼ Sec 7 Twp 121N Rg 47W

County Grant



Please mark well location with an "X"

Well completion Date 11/2/11

Distance from nearest potential pollution source (Septic tank, abandoned well, feed lot, etc.)

? NA ft. from Unknown (identify source)

PROPOSED USE:
☐ Domestic/Stock ☐ Municipal ☐ Business ☐ Test Holes
☐ Irrigation ☐ Industrial ☐ Institutional ☒ Monitoring well

METHOD OF DRILLING:
Augers Hollow Stem

CASING DATA: ☐ Steel ☑ Plastic ☐ Other

If other describe

PIPEWEIGHT	DIAMETER	FROM	TO	HOLE DIAMETER
LB/FT	2 IN	0 FT	5 FT	12 IN
LB/FT	IN	FT	FT	IN
LB/FT	IN	FT	FT	IN

GROUTING DATA:

Grout Type	No. of Sacks	Grout Weight	From	To
Env. Grout/Bentonite		Lb/gal	0 Ft	4 Ft
		Lb/gal	Ft	Ft

Describe grouting procedure

SCREEN: ☐ Perforated pipe ☒ Manufactured

Diameter 2 Inches Length 10 Feet

Material PVC

Slot Size 10 Set From 5 Feet to 15 Feet

Other information Sch 40

WAS A PACKER OR SEAL USED? ☐ Yes ☒ No

If so, what material?

Describe packer(s) and location

DISINFECTION: Was well disinfected upon completion?

☐ Yes, How?

☒ No, Why Not?

Lab sample sent to for water quality analysis

Well Owner: Otter Tail Power Company
Business Name: OTPC Big Stone Plant
Address1: 48450 144th St
Address2:
City, State, Zip: Big Stone City, SD 57216

WELL LOG:

FORMATION	DEPTH FROM	DEPTH TO
Top Soil	0	2
Sandy Clay	2	4
Clayey Sand	4	10
Sandy clay	10	15

STATIC WATER LEVEL 10.5 FEET

If flowing: closed in pressure PSI

GPM flow through Inch pipe

Controlled by ☐ Valve ☐ Reducers ☐ Other

Reduced flow rate GPM

Can well be completely shut in?

WELL TEST DATA:

☐ Pumped Describe: NA

☐ Bailed

☐ Other

Pumping Level Below Land Surface

Ft. After Hrs. pumped GPM

Ft. After Hrs. pumped GPM

If pump installed, pump rate: GPM

REMARKS

MW2 Was Renamed H-6

This well was drilled under license # 769

And this report is true and accurate.

Drilling firm: WCEC

Signature of License Representative:

Signature of Well Owner or Equitable Property Holder: (agent)

Date: 11/16/2011

Please return White Copy to DENR Water Rights 523 E. Capitol Ave., Pierre SD 57501

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

LOG OF BORING SB DEEP H6

SHEET 1 OF 1

Project:Big Stone Station
Project No.:41251005
Location:Big Stone City, SD
Coordinates:N 554,399.9 ft E 2,871,848.1 ft
Datum:SD North State Plane NAD83

Surface Elevation:1094.7 ft
Drilling Method:HSA
Sampling Method:SS
Completion Depth:55.0 ft

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
0				OL/OH		TOPSOIL (OL/OH): black (10YR 2/1); moist; 0% gravel, 10% sand, 90% fines, trace roots.	
			3-2-1-1.			LEAN CLAY (CL): dark yellowish brown (10YR 3/6); moist; 0% gravel, 15% sand, 85% fines, with very fine to fine grain sand, little oxidization, some oxidized mottling, trace gravel througout, some cobbles, becomes sandier with depth.	
			3-3-3-5.				
5			6-7-6-9.				1090
			4-7-7-8.	CL		6.7': SANDSTONE/SAND inclusion, whitish.	
			5-8-7-9.				
10							1085
			7-9-11-9.			10.5': Sand gravel mix, wet. 11.7': Sand gravel mix.	
15			5-8-11-12.			SILTY WITH SAND (ML): fine to medium grained; dark yellowish brown (10YR 3/6); moist to wet; 5% gravel, 20% sand, 75% fines, trace gravel, some heavy oxidization, becomes sandier with depth. 14.4' & 14.8': Sand lense.	1080
			7-8-10-12.				
			8-8-10-13.				
20				ML			1075
25			11-18-23-28.				1070
			8-9-11-14.			LEAN CLAY (CL): dark brown (10YR 3/3); moist; 0% gravel, 10% sand, 90% fines, some cobbles, oxidization and black inclusions.	
30			9-12-15-19.				1065
			15-21-22-28.			33.5': Black organic inclusion.	
35							1060
			6-9-13-16.				
40			15-25-21-36.				1055
			4-6-8-5.	CL			
45			5-4-6-7.				1050
50							1045
			6-5-7-8.				
55			12-15-18-17.			End of boring 55.0 feet	1040
60							

Date Boring Started: 7/31/16 8:22 am
Date Boring Completed: 7/31/16 3:45 pm
Logged By: NJS2
Drilling Contractor: SDE
Drill Rig: Truck

Remarks:

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

LOG OF PIEZOMETER T-1

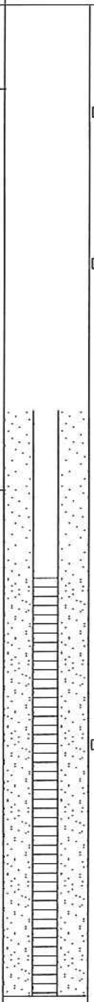
SHEET 1 OF 1

Project:Big Stone Station
Project No.:41251005
Location:Big Stone City, SD
Coordinates:N 554,209.8 ft E 2,870,671.0 ft
Datum:SD North State Plane NAD83

Surface Elevation:1107.5 ft
Drilling Method:HSA
Sampling Method:SS
Completion Depth:24.0 ft

Unique Well No.: T-1

Depth, feet	Blows/6in.	USCS	LITHOLOGIC DESCRIPTION
0	4-5-5-7.	OL/OH	TOPSOIL (OL/OH): very dark brown (10YR 2/2); moist; 5% gravel, 10% sand, 85% fines.
	5-5-6-9.	CL	SANDY CLAY (CL): yellowish borwn (10YR 5/4); moist; 10% gravel, 20% sand, 70% fines, with very fine grain to medium grain sand and coarse grain, subrounded gravel.
5	4-5-5-7.		
	4-4-5-5.		
	3-3-5-4.		
10	7-10-10-12.		
			11.5': CLAYEY SAND LENSE (SC), moist, 10% gravel, 60% sand, 30% fines, 1.2" thick.
	4-7-7-8.	CL	LEAN CLAY (CL): yellowish brown (10YR 5/4); moist; 5% gravel, 15% sand, 80% fines, with rusty cracks/seams,.
			13.5': Small inclusion of black organic material.
15	6-6-8-8.		
	5-5-7-8.		17': Trace coarse grain gravel.
	7-10-11-13.		19': Coarse grain gravel, subangular.
20			
	6-8-10-14.		
			End of piezometer 24.0 feet
25			
30			



WELL OR PIEZOMETER CONSTRUCTION DETAIL

PRO. CASING
Diameter:
Type:
Interval:

RISER CASING
Diameter: 1"
Type: PVC
Interval:

GROUT
Type:
Interval:

SEAL
Type:
Interval:

SANDPACK
Type: Silica #10
Interval:

SCREEN
Diameter:
Type: PVC #10 Slot
Interval: 13.7-23.7' bgs

Elevation, feet: 1105, 1100, 1095, 1090, 1085

Date Boring Started:	7/18/16 5:50 pm
Date Boring Completed:	7/19/16 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.

BARR

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

LOG OF PIEZOMETER T-2

SHEET 1 OF 1

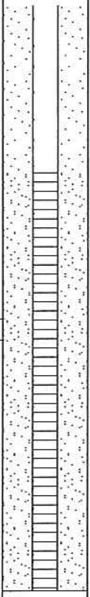
Project:Big Stone Station
Project No.:41251005
Location:Big Stone City, SD
Coordinates:N 554,277.9 ft E 2,871,572.0 ft
Datum:SD North State Plane NAD83

Surface Elevation:1094.4 ft
Drilling Method:HSA
Sampling Method:SS
Completion Depth:28.0 ft

Unique Well No.: T-2

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
0			2-1-1-1.	OL/OH		TOPSOIL (OL/OH): very dark brown (10YR 2/2); moist; 5% gravel, 10% sand, 85% fines.	
			2-1-2-2.	CL		LEAN CLAY (CL): brown to dark brown (10YR 4/3 - 5YR 3/4); moist; 20% gravel, 10% sand, 70% fines, very fine grain to medium grain, subangular sand with fine to coarse grain gravel.	1090
5			2-3-5-9.				
			3-3-3-5.				
			10-8-5-5.				1085
10			2-4-7-11.				
			2-4-4-7.				1080
15			7-9-9-12.				
			4-6-6-7.				
			6-8-8-10.				1075
20				ML		SILT (ML): yellowish brown (10YR 5/4); wet; 20% gravel, 10% sand, 70% fines.	
			5-6-8-11.	CL		LEAN CLAY (CL): brown to dark brown (10YR 4/3 - 5YR 3/4); wet; 20% gravel, 10% sand, 70% fines, very fine grain to medium grain, subangular sand with fine to coarse grain gravel.	
			6-10-13-17.				1070
25			5-6-8-11.			25.5': CLAYEY SAND LENSE (SC), yellowish brown (10YR 5/4), fine grain, subangular sand, wet, 3.6" thick.	
						End of piezometer 28.0 feet	
30							

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter:
Type:
Interval:

RISER CASING
Diameter: **1"**
Type: **PVC**
Interval:

GROUT
Type:
Interval:

SEAL
Type:
Interval:

SANDPACK
Type: **Silica #10**
Interval: **12-26' bgs**

SCREEN
Diameter:
Type: **PVC #10 Slot**
Interval: **16-26' bgs**

Date Boring Started:	7/18/16 2:00 pm
Date Boring Completed:	7/18/16 5:35 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.

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

LOG OF PIEZOMETER T-3

SHEET 1 OF 1

Project:Big Stone Station
Project No.:41251005
Location:Big Stone City, SD
Coordinates:N 554,728.9 ft E 2,872,107.4 ft
Datum:SD North State Plane NAD83

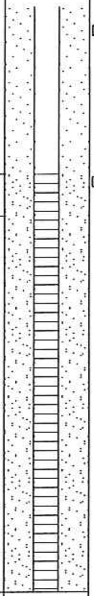
Surface Elevation:1076.9 ft
Drilling Method:HSA
Sampling Method:SS
Completion Depth:16.0 ft

Unique Well No.: T-3

Depth, feet	Blows/6in.	USCS	Elevation, feet
0	1-1-1-1.	CL	
	2-2-3-5.	CL	1075
5	5-6-7-10.	CL	
	7-8-8-10.	SM / CL	1070
10	4-2-2-7.	CL	
	7-4-9-9.	CL	1065
15	4-5-6-6.	CL	
20			
25			
30			

USCS	LITHOLOGIC DESCRIPTION
CL	LEAN CLAY (CL): brown (10YR 4/3); moist; 5% gravel, 5% sand, 90% fines, trace fine grain sand.
SM	SILTY SAND (SM): brown (10YR 4/3); wet; 5% gravel, 75% sand, 20% fines, trace gravel and clay clumps.
CL	SANDY CLAY (CL): brown (10YR 4/3); wet; 15% gravel, 40% sand, 55% fines, very fine grain to medium grain, subrounded to subangular sand, oxidized stains, light brownish gray clumps, sand clay becomes sandy lean clay with depth.
	End of piezometer 16.0 feet

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter:
Type:
Interval:

RISER CASING
Diameter: 1"
Type: PVC
Interval:

GROUT
Type:
Interval:

SEAL
Type:
Interval:

SANDPACK
Type: Silica #10
Interval: 2-16' bgs

SCREEN
Diameter:
Type: PVC #10 Slot
Interval: 6-16' bgs

Date Boring Started:	7/19/16 10:50 am
Date Boring Completed:	7/16/16 12:45 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.

Appendix C

Geotechnical Laboratory Results

Grain Size Distribution ASTM D422

Job No. : **10490**

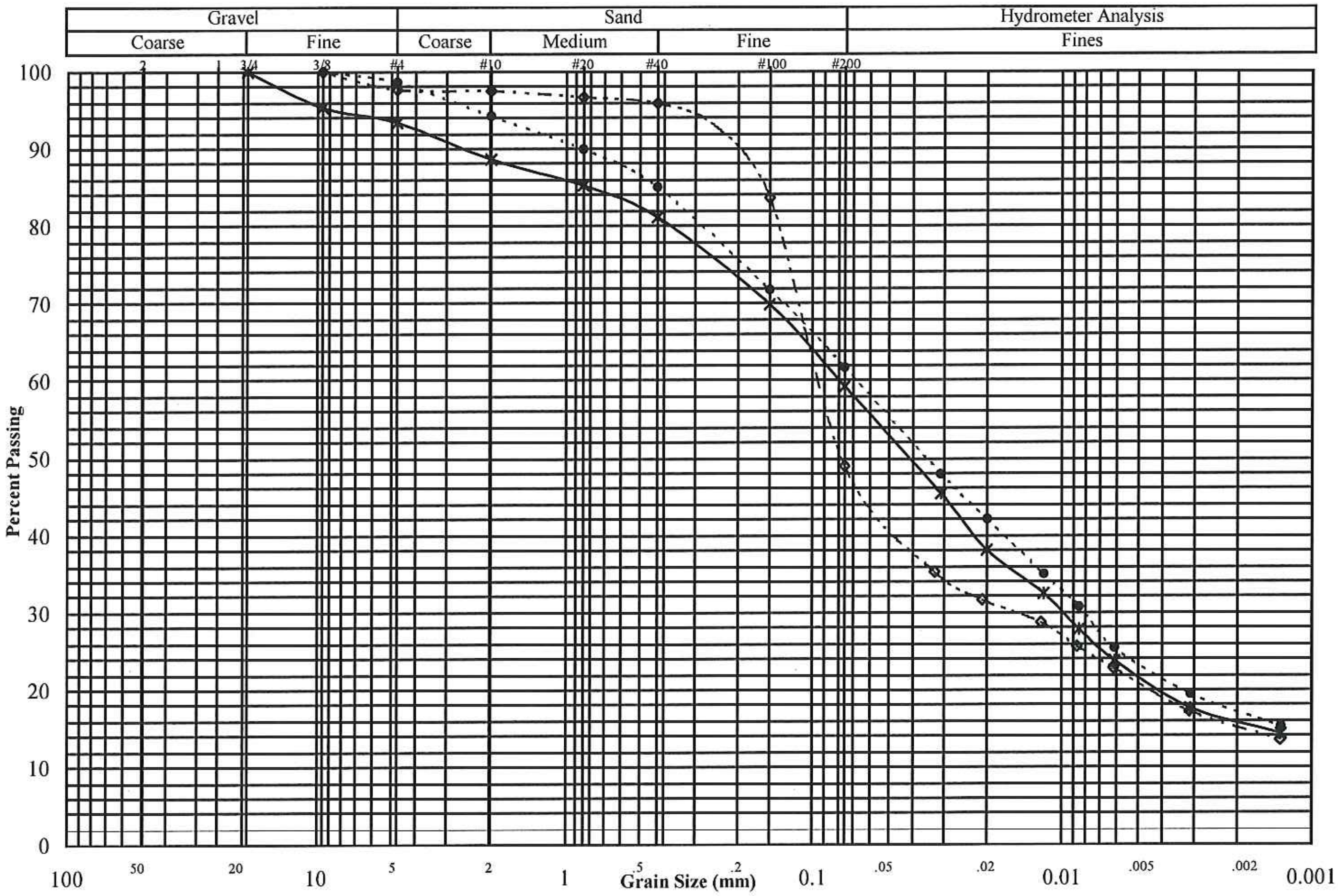
Project: Big Stone

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
∗	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:

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.

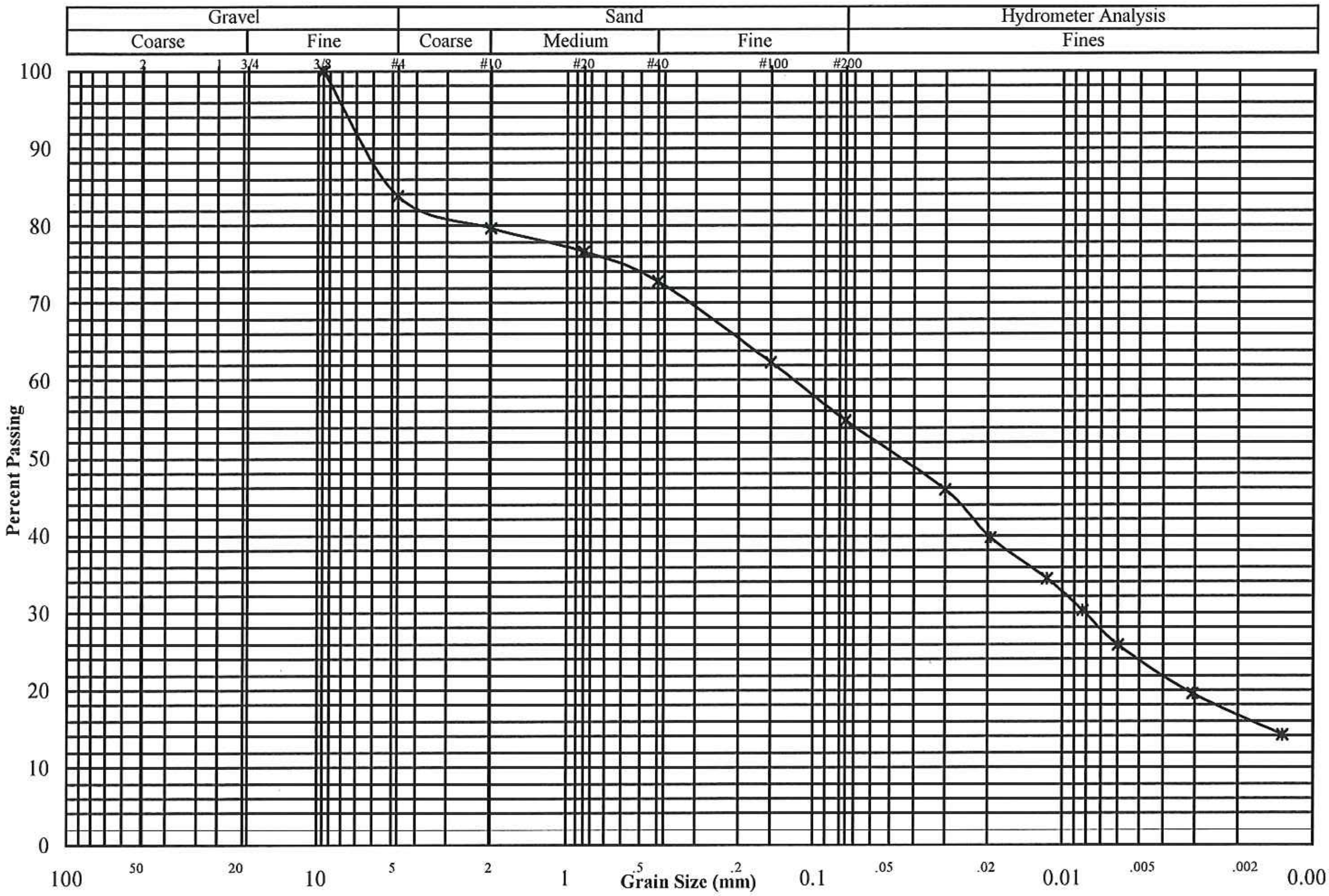
Bloomington, MN 55431

Grain Size Distribution ASTM D422

Job No. : **10490**

Project:	Big Stone	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
*	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:

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

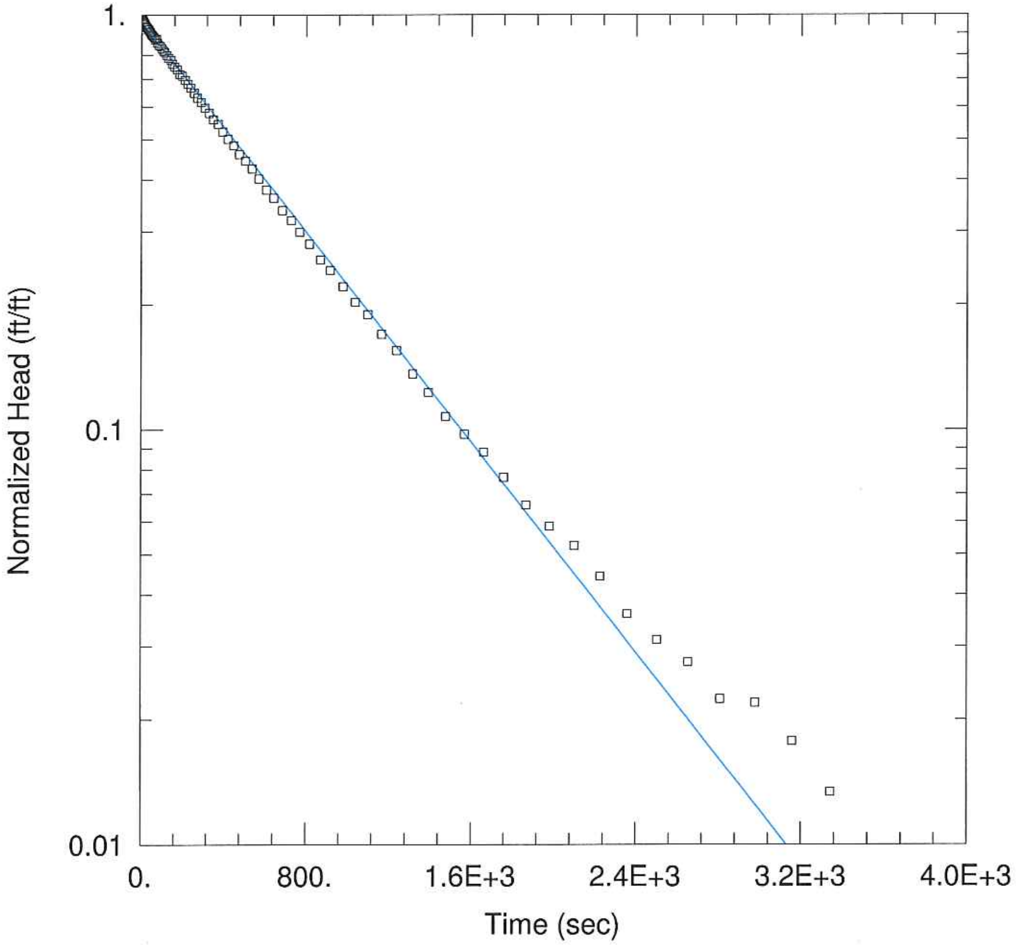
Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.030	45.9				
0.020	39.7				
0.012	34.4				
0.008	30.3				
0.006	25.9				
0.003	19.6				
0.001	14.2				

Remarks

Specimen 1	Specimen 2	Specimen 3

Appendix D

Slug Test Results



H3OX FALLING HEAD SLUG TEST (SLUG-IN)

Data Set: \...\H3ox Slug In.aqt
Date: 09/23/16
Time: 12:09:44

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: OtterTail Power Company
Project: 41251005
Location: Big Stone, SD
Test Well: H3ox
Test Date: July 29, 2016

AQUIFER DATA

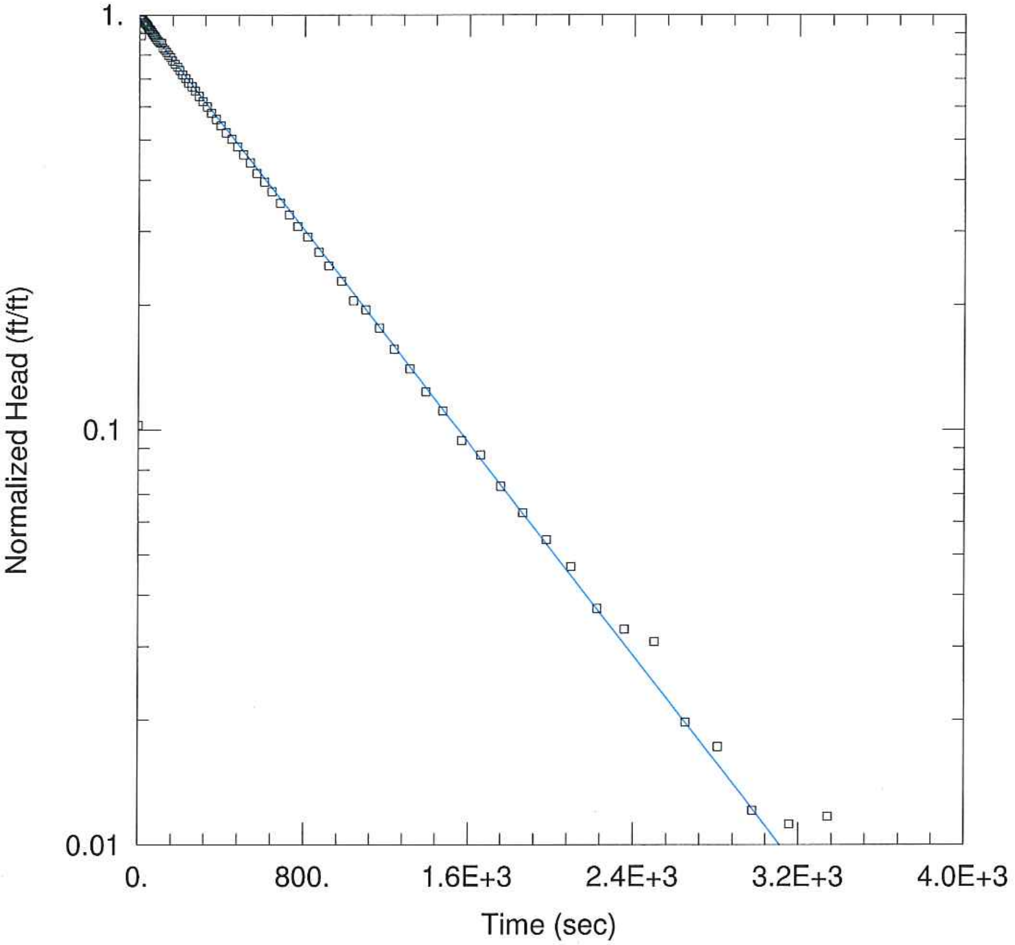
Saturated Thickness: 7. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (H3OX)

Initial Displacement: 1.379 ft
Static Water Column Height: 16.67 ft
Total Well Penetration Depth: 7. ft
Screen Length: 5. ft
Casing Radius: 0.083 ft
Well Radius: 0.344 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice
K = 6.561E-5 cm/sec
y0 = 1.329 ft



H3OX RISING HEAD SLUG TEST (SLUG-OUT)

Data Set: \...\H3ox Slug Out.aqt
Date: 09/23/16 Time: 12:10:32

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: OtterTail Power Company
Project: 41251005
Location: Big Stone, SD
Test Well: H3ox
Test Date: July 29, 2016

AQUIFER DATA

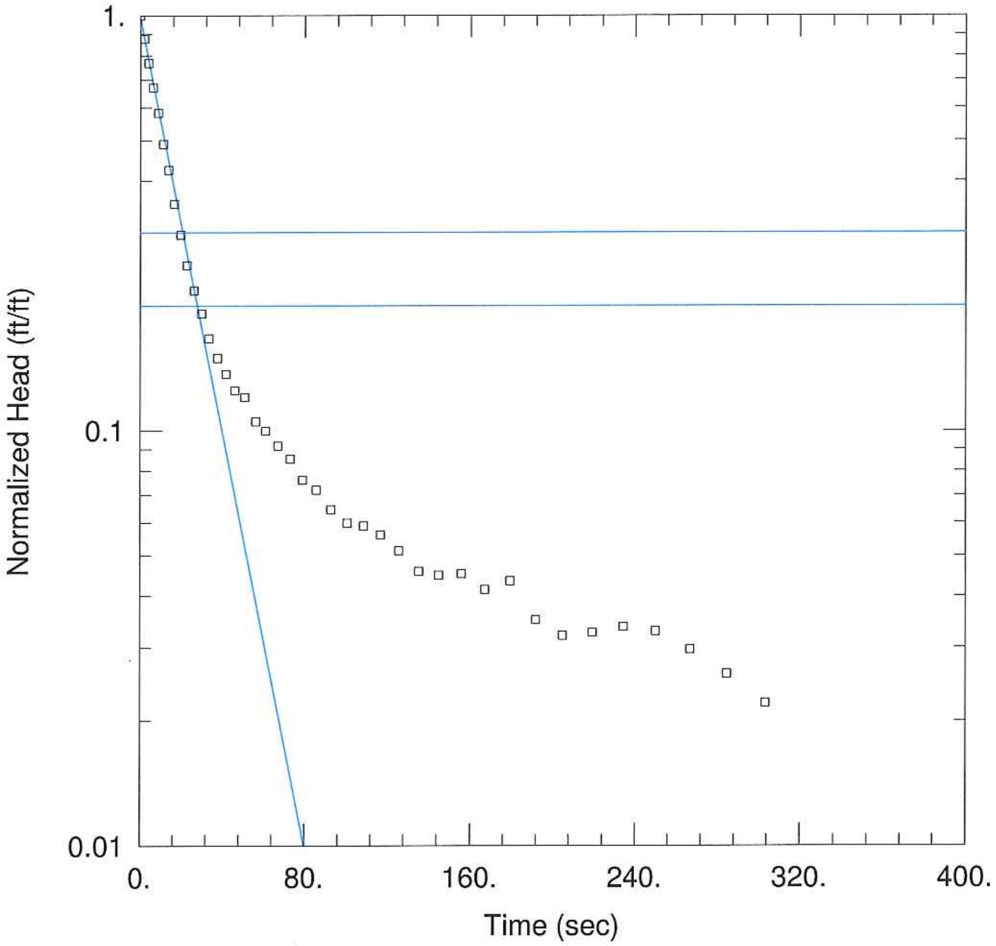
Saturated Thickness: 7. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (H3OX)

Initial Displacement: 1.464 ft
Total Well Penetration Depth: 7. ft
Casing Radius: 0.083 ft
Static Water Column Height: 16.67 ft
Screen Length: 5. ft
Well Radius: 0.344 ft

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice
K = 6.637E-5 cm/sec
y0 = 1.445 ft



H6 RISING HEAD SLUG TEST (SLUG-OUT)

Data Set: \...\H6 Slug Out.aqt
Date: 09/23/16 Time: 12:16:23

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: OtterTail Power Company
Project: 41251005
Location: Big Stone, SD
Test Well: H6
Test Date: July 29, 2016

AQUIFER DATA

Saturated Thickness: 4.06 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (H6)

Initial Displacement: 1.176 ft
Total Well Penetration Depth: 4.06 ft
Casing Radius: 0.083 ft
Static Water Column Height: 4.06 ft
Screen Length: 4.06 ft
Well Radius: 0.5 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.002227 cm/sec
y0 = 1.159 ft