Groundwater Monitoring Plan

R.M. Heskett Station

Prepared for
Montana-Dakota Utilities Co.

January 2021

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Certifications

I hereby certify that this report was prepared by me or under my direct supervision, and that I am a duly registered Professional Engineer under the laws of the State of North Dakota.

Thomas J. Radue

Thomas J. Radue, P.E.
PE #: 3632

January 27, 2021
Date

THOMAS J RADUE
PE-3632
DATE 01/27/2021

Thomas J. Radue

I certify that this report was prepared by me or under my direct supervision and that I am a geologist possessing academic training and professional experience in the field of hydrogeology.

James S. Aiken

James S. Aiken, M.S., P.G. (MN)
Hydrogeologist

January 27, 2021
Date

1.0 Introduction

This Monitoring Plan outlines the proposed groundwater monitoring system update at the Montana-Dakota Utilities' (MDU) R.M. Heskett Station (Site) located in Mandan, North Dakota. Groundwater monitoring is required to comply with the North Dakota Administrative Code, Article 33.1-20 (Solid Waste Management and Land Protection; ND Code), specifically -07.1 (Small Volume Industrial Waste Landfills and Special Waste Landfills), -08 (Disposal of Coal Combustion Residuals [CCR] in Landfills and Surface Impoundments), and -13 (Water Protection Provisions) which went into effect on July 1, 2020. The Site location is shown on Figure 1.

The CCR unit at the Site is a CCR landfill (ash landfill) with the north and southwest portions capped and active landfill activities to the southeast. MDU is planning to cease operation of the coal-fired units at the Site in about late March 2022, with final closure of the landfill planned to occur thereafter. The ash landfill features an existing monitoring well network shown on Figure 1.

1.1 Purpose

The purpose of this Monitoring Plan is to describe a monitoring network that will provide representative samples of groundwater so that a release from the facility can be detected and, if necessary, corrective action initiated to protect water resources.

1.2 Background

The ash landfill at the Site previously has been permitted both as a CCR unit under the federal rule, as well as a Special Waste Landfill under ND Code under permit No. SP-087. The state permit included both the ash landfill and the Evaporation Pond at the Site. Due to differing regulatory requirements, the facility has had separate state and federal monitoring plans, with different well networks, parameter lists, reporting requirements and timelines. North Dakota adopted the federal CCR Rule into North Dakota Administrative Code Title 33.1 (Article 33.1-20, Chapter 33.1-20-08) in 2020. Therefore, this Monitoring Plan proposes a single network, parameter list, and reporting requirements.

1.3 Scope of Work

This Monitoring Plan provides:

- An evaluation of the existing Site conditions and background information on the existing monitoring network
- A description of the proposed monitoring network based on those conditions and requirements of the ND Code
- Additional activities needed to certify the monitoring network under the ND Code including parameters, frequency, and statistical methods for groundwater quality sampling

Where appropriate, this Monitoring Plan references methods and industry practice that demonstrate that the work will be conducted in accordance with applicable industry standards, methods, and established standard operating procedures. In addition, a Sampling and Analysis Plan (SAP) is included that outlines the approach to collection of groundwater and other media for analytical sample analysis.

Specific details regarding the groundwater sampling procedures, laboratory analytical procedures, and groundwater statistical analysis methods are included in the Sampling and Analysis Plan (Appendix C).

2.0 Site Characterization

R.M. Heskett Station facility includes a 100 megawatt lignite coal-fired electric generating station and an 88 megawatt gas fired combustion turbine located along the west bank of the Missouri River in Mandan, North Dakota (Figure 1). This facility consumes around 500,000 tons of lignite annually (LEC, 2015). The active facility features consist of a power block, coal handling areas, offices, and the landfill that connects to the facility via a haul road. The landfill is considered an "existing CCR landfill" as defined by 40 CFR 257.53 and in ND Code Chapter 33.1-20-08. The power block consists of an approximate 25 MW Riley spreader stoker unit (Unit1) and an approximate 75 MW atmospheric bubbling fluidized bed unit (Unit 2).

2.1 Site Setting

The ash landfill is bounded by Rock Haven Creek to the north and west. The creek flows eastward and discharges to the Missouri River several hundred feet downgradient of the ash landfill. Surrounding topography slopes generally to the north and surface drainage from off-site areas to the south flow into a drainage ditch that transects the property to the east of the landfill. Several single-family dwellings are located along the southern boundary of the ash landfill and are separated from the facility by a vegetated buffer and screening berm.

Beyond these residences, the Site is generally located in an industrial area bounded by a refinery to the south and open areas to the north and west consisting of farmsteads and agricultural land. Further to the west, there is significant commercial and residential development. Water quality in Rock Haven Creek and the drainage ditch to the east of the ash landfill are assumed to be typical of developed areas and are believed to be influenced by urban runoff, particularly chlorides and trace metals.

The ash landfill is constructed on land that is located above the 100-year floodplain of both Rock Haven Creek and the Missouri River. The FEMA (2020) classification of the area is "Area of Minimal Flood Hazard". Elevations on the Missouri River are controlled by flow from the Garrison Dam located approximately 60 miles upriver from the Site. Flooding has occurred along the river and periodic high-water conditions can occasionally inundate lower elevation areas where some downgradient monitoring wells are located. There are no other significant surface water features within 1 mile of the Site.

2.1.1 Regional Geology

The Site geology and hydrogeology is compiled from prior site documents including the 1989 MDU permit (1989) and is summarized below.

The Tertiary (Paleocene) Cannonball Formation underlies the entire Site and outcrops over a large portion of eastern Morton County. The Cannonball Formation is named for the boulder-sized carbonate concretions that are sporadically found in weathered exposures. The Cannonball Formation interfingers laterally with the Ludlow Formation. The two formations are consistent with deposition of the Cannonball occurring in a marine environment and the Ludlow in a freshwater environment. The Cannonball Formation consists of discontinuous lithostratigraphic units or beds composed of sand, silt, and clay that tend to lack continuous lithostratigraphic units or beds (Cvancara, 1976). Some of the sand units are partially cemented and are resistant to erosion.

Regional soils have developed from climatic and biotic interactions with poorly consolidated sand, silt, and clay of the upper Cretaceous and Tertiary Formations. Glacial till of the Coleharbor Formation appears preserved on some upland surfaces and lowland outwash terraces (Bluemle, 1971; Carlson, 1983).

2.1.2 Site Geology

Lithologic and geophysical logs for the Site completed as part of the permitting process indicated that the uppermost 100 feet of the subsurface materials lie within the Cannonball Formation. Historical boring logs and cross sections (MDU, 1989) are included in Appendix A. Glacial till is present in small patches throughout the Site and, when encountered, is typically less than 5 feet thick (Wells 33, 40, 43, 55; Appendix A).

The dominant lithology observed at the Site is unconsolidated silt in a clay matrix with interspersed fine to medium-grained sand. Thin sand lenses with limited extent have also been observed. Small gypsum crystals occur throughout approximately the upper 30 feet of the surface soils and have been presumed to be the result of diagenetic processes which occur above the water table during alternating wetting and drying cycles (Groenewold et al, 1983). Typical porosity of these geologic materials is approximately 20 to 30% (Freeze and Cherry, 1979).

2.1.3 Regional and Site Hydrogeology

Regionally, groundwater enters the flow system from infiltration in upland areas to the west and/or from Rock Haven Creek and flows under the Site and discharges to Rock Haven Creek, downgradient of the Site, which ultimately discharges into the Missouri River. Flow is generally under unconfined conditions within the Cannonball Formation.

Existing monitoring wells at the Site are shown on Figure 1. Monitoring wells MW2, MW8, and MW4B are associated with a non-CCR ash pile that no longer requires monitoring. These wells are shown for completeness but are proposed for decommissioning pending NDDEQ approval.

Groundwater flow at the Site (Figure 2) has been consistent historically and is from the southwest to northeast toward Rock Haven Creek and the Missouri River. Depth to groundwater is 10.5 to 40 feet bgs depending on surface elevation, with estimated groundwater elevations ranging from 1,665 to 1,695 feet above mean sea level (MSL) as shown on Figure 3.

Public water supplies for Bismarck and Mandan are derived from the Missouri River. The developed areas near the Site are connected to city-supplied sewer and water service. No alluvial aquifers are present below the Site due to the erosional truncation by the modern Missouri River channel into the Cannonball Formation (Groenenwald, 1980). According to the North Dakota State Water Commission Mapservice (ND Water Commission, 2020), up to 15 domestic water supply wells and several groundwater monitoring wells are mapped within 1-mile of the Site. These wells are located upgradient or sidegradient of the Site. There are no water supply wells downgradient of the Site.

As part of a previous investigation, grain size and falling head permeability testing was completed for a clayey to silty sand unit within the Cannonball Formation that corresponds to the uppermost saturated portion of the formation at the Site. The falling head permeability lab test results on Shelby tubes pushed into the unit ranged from approximately 2 x 10^{-7} to 2.7 x 10^{-9} cm/sec. Slug tests completed in monitoring wells screened in the same interval as the falling head permeability lab results showed between 10^{-4} to 10^{-5} cm/sec or about 0.3 to 0.03 feet/day (MDU, 1989). The falling head permeability lab tests measure the vertical hydraulic conductivity of the sample tested, whereas the slug tests provide results more representative of horizontal hydraulic conductivity. Storage coefficient for the unconfined conditions are assumed to be equivalent to the specific yield or approximately the same as the estimated porosity.

2.1.4 Ambient Groundwater Quality

Elevated concentrations of Appendix I and II parameters (parameter lists required to be monitored at CCR units per in ND Code Chapter 33.1-20-08) have been observed in historical and regional groundwater quality data. These parameters include, at a minimum, chloride, fluoride, TDS, and sulfate.

Groundwater samples collected in 1986 (prior to construction of the CCR unit; an aerial photograph from March 30, 1988 shows the area of the CCR unit, which appears to be undisturbed) were included in the 1989 Special Use Disposal Site Permit Application (Permit Application, MDU, 1989). Chloride concentrations in these groundwater samples were measured as high as 558 mg/L (Well 44, 11/21/1986), indicating that high chloride concentrations at the Site pre-date construction of the CCR unit. Additionally, the North Dakota State Water Commission conducted a groundwater study in Morton County (Ackerman, 1980); 45 wells screened in the Cannonball and Ludlow Formations were sampled for various parameters including chloride. Chloride concentrations ranged from 0 to 500 mg/L (37% of which had concentrations greater than 250 mg/L).

Analyses of groundwater samples collected prior to construction of the CCR unit included in the Permit Application notes that high sulfate and TDS was observed at the Site. Maximum sulfate and TDS concentrations reported in 1986 were 11,632 mg/L and 14,917 mg/L, respectively, in Well 60, with similar concentrations observed two years later. Additionally, small gypsum crystals are documented discontinuously throughout the upper 30 feet of the surface materials, which have been presumed to be the result of diagenetic processes which occur above the water table during alternating wetting and drying cycles (Groenewold et al, 1983). Gypsum is a hydrated calcium sulfate mineral that can be a source of high sulfate concentrations in groundwater. Dissolution of gypsum will occur until equilibrium concentrations are attained in the groundwater or until all the minerals are consumed.

Fluoride concentrations have been observed in several regional groundwater quality studies on the Cannonball Formation and associated units. See summary table below (Table 1).

Table 1 Fluoride Concentrations in the Cannonball Formation and Associated Units

Reference	Fluoride Conc. Range	Formation/Units	Data Source Location
Ackerman, D.J., 1980. Ground-Water Resources of Morton County, North Dakota. North Dakota Geological Survey Bulletin 72, Part III. 51 p.	0.0 to 4.0 mg/L	Cannonball and Ludlow formations, undifferentiated	Morton County
Crosby, O.A. and Klausing, R.L., 1984. Hydrology of Area 47, Northern Great Plains and Rocky Mountain Coal Provinces, North Dakota, South Dakota, and Montana. USGS Water-Resources Investigations Open-File Report 83-221, 93 p.	0.1 to 6.3 mg/L	Entire Fort Union Formation (includes Cannonball Formation)	Morton County

The Ackerman study provides summary statistics for the fluoride concentrations observed in Morton County. Forty-six samples were analyzed for fluoride; of those, 20 (or 43%) had concentrations greater than 1.3 mg/L (Ackerman, 1980).

2.1.5 Travel Time Estimates and Dispersion

Several factors related to monitoring networks are determined by reference to the average travel time of a non-reactive dissolved particle. For the highest hydraulic conductivity of 10^{-4} cm/sec (0.28 feet/day) presented in Section 2.1.3, an approximate gradient (from Figure 2) of 0.02, and an effective porosity estimate of 0.25 for silty sandstone, the average linear groundwater flow velocity where $V = KI/e = (0.28 * 0.02)/0.25 = 0.023$ feet/day. This relatively low velocity means that, when considering dispersion and travel time, a release from the Site would not likely impact off-site water resources, at least not in the near term. For example, the average time required for a release to travel from the midpoint of the Site to the downgradient edge (approximately 400 feet) would be about 50 years.

2.2 Conceptual Site Model

The Conceptual Site Model (CSM) provides a framework to understand how a hypothetical release would flow through the groundwater monitoring system (see Figure 4).

The objective of groundwater detection monitoring is to detect a release from the facility within the uppermost saturated zone immediately below the solid waste facility. A release from the center of the landfill area would migrate vertically downward though the compacted clay subgrade and unsaturated clay of the Cannonball Formation, then slowly disperse laterally to the waste boundary. There is localized heterogeneity in the Cannonball Formation therefore making it likely that the movement of a release through the matrix and these inhomogeneities would increase the dispersion of the release within the aquifer compared to a uniform homogenous aquifer. Downgradient monitoring wells are offset from the waste boundary to allow for dispersion of the hypothetical release passing the waste boundary so that it is more likely to be detected, while avoiding allowing the hypothetical plume to bypass the monitoring network. On this basis monitoring of the uppermost saturated thickness of the Cannonball Formation downgradient of the CCR unit is adequate to detect a release from the Site.

3.0 Monitoring Plan

This section presents the groundwater monitoring network, analytical parameters, sampling frequency, data analysis, and reporting requirements for the Heskett Landfill per the ND Code.

3.1 Groundwater Monitoring Network

Figure 1 shows the monitoring wells located at the Site. For the new Heskett Landfill groundwater monitoring network, there will be one upgradient monitoring well (MW-13) and four downgradient monitoring wells (MW1-90, MW2-90, MW3-90, and MW80R).

The remaining wells on the Site shown on Figure 2 will be used for water level measurements and/or supplemental data collection as needed and as they remain open; five upgradient (MW-33, MW-101, MW-70, MW-102, and MW-103), two downgradient (MW-104, and MW-105) and), and one side-gradient (MW-44R).

3.1.1 Compliance with ND Code

ND Code requires a minimum of one upgradient well and three downgradient wells, screened in the uppermost aquifer beneath the monitored unit. The monitoring network described herein includes 4 wells, screened in the uppermost saturated unit located below the base of the landfill that is the target of detection monitoring at the Site. The monitoring network therefore exceeds the well quantity requirements NDAC 33-1-20-08-06. Well construction details of existing monitoring wells are provided on Large Table 2.

3.2 Parameter List and Sampling Frequency

Groundwater samples will be collected semi-annually, per ND Code. Depending on the monitoring program (detection or assessment), groundwater samples will be analyzed for Appendix I and/or Appendix II parameters (Large Table 1). Additional parameters namely major cations and anions have been added to the analytical list to allow for regular charge balance error calculations and standard data evaluations.

3.2.1 Dataset Limitations and Baseline

The historical dataset is valuable in understanding the geochemical evolution of water quality at the Site, but due to the inconsistent data collection and review practices relative to today (due to technology limitations, changes in monitoring requirements, and changes to site conditions), there is potential for error if the dataset is used in whole to conduct statistical evaluations of the Site.

Therefore, Future data analysis will use the data collected at the Site starting in February 2016 through present. Data collected prior to this date will be preserved for comparison but will not be used as part of the initial statistical evaluations for determining the potential presence of a statistically significant increase over baseline.

Additionally, one of the downgradient wells, MW1-90, was not monitored as part of the CCR unit network and therefore groundwater samples from MW1-90 have not been analyzed for all the parameters included in Appendix I and II of the ND Code. Therefore, this well presently lacks a baseline dataset and Appendix I and II parameters will be collected on a semiannual basis until a baseline dataset of 8 samples are collected for any parameters, prior to conducting a statistical evaluation of this well's data (i.e. check for statistically significant increasing concentrations or SSIs).

3.3 Data Analysis

Statistical data analysis will be conducted in accordance with the certified statistical plan on record (Barr, 2017).

3.4 Reporting Requirements

Data will be reported annually and will include water levels, water quality results, and SSI analysis results.

For the preceding calendar year, the annual report will document the status of the ground water monitoring and corrective action program for the CCR unit, summarize key actions completed, describe any problems encountered, discuss actions to resolve the problems, and project key activities for the upcoming year.

The annual report must be completed by January 31 after the monitoring year and is considered completed when the report is placed in the facility's operating record. However, the annual report must be submitted to the department for approval and placed on the facility's publicly accessible internet site by March first of each year.

The annual groundwater monitoring and corrective action report will contain the following information, to the extent available:

1. A map, aerial image, or diagram showing the CCR unit and all background (or upgradient) and downgradient monitoring wells, to include the well identification numbers, that are part of the ground water monitoring program for the CCR unit;
2. Identification of any monitoring wells that were installed or decommissioned during the preceding year, along with a narrative description of why those actions were taken;
3. In addition to all the monitoring data, a summary including the number of ground water samples that were collected for analysis for each background and downgradient well, the dates the samples were collected, and whether the sample was required by the detection monitoring or assessment monitoring programs; and
4. A narrative discussion of any transition between monitoring programs (e.g., the date and circumstances for transitioning from detection monitoring to assessment monitoring, in addition to identifying the constituents detected at a statistically significant increase over background levels).

4.0 References

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Large Tables

Table 1
Groundwater Sampling Parameter List
R.M. Heskett Station
Montana-Dakota Utilities Co.

Sampling Type:

General	**Sampling Parameter List**[1]			**Method**	**RL**	**Unit**
	I	**II**	**Cations / Anions**			
Alkalinity, total (as CaCO3)			x	SM 2320 B-2011 Modified	20	mg/l
Chloride	x		x	SM 4500 Cl-E-2011	1	mg/l
Dissolved Solids, total	x			USGS I-1750-85	5	mg/l
Fluoride	x	x		SM 4500 F-C-1997	0.1	mg/l
pH	x			SM 4500-H$^+$B-2011	1	unit
Sulfate	x		x	ASTM D516-07 Modified	5	mg/l
Metals[2]						
Antimony		x		EPA 6020A (ICP-MS)	0.001	mg/l
Arsenic		x		EPA 6020A (ICP-MS)	0.002	mg/l
Barium		x		EPA 6020A (ICP-MS)	0.002	mg/l
Beryllium		x		EPA 6020A (ICP-MS)	0.0005	mg/l
Boron	x			EPA 6010C (ICP)	0.1	mg/l
Cadmium		x		EPA 6020A (ICP-MS)	0.0005	mg/l
Calcium	x			EPA 6010C (ICP)	1	mg/l
Chromium		x		EPA 6020A (ICP-MS)	0.002	mg/l
Cobalt		x		EPA 6020A (ICP-MS)	0.002	mg/l
Lead		x		EPA 6020A (ICP-MS)	0.0005	mg/l
Lithium		x		EPA 6010C (ICP) - New Ulm	0.1	mg/l
Magnesium			x	EPA 6010C (ICP)	1	mg/l
Mercury		x		EPA 7470A (CVAA)/Leachate EPA 245.1	0.0002	mg/l
Molybedenum		x		EPA 6020A (ICP-MS)	0.002	mg/l
Potassium			x	EPA 6010C (ICP)	1	mg/l
Selenium		x		EPA 6020A (ICP-MS)	0.002	mg/l
Sodium			x	EPA 6010C (ICP)	1	mg/l
Thallium		x		EPA 6020A (ICP-MS)	0.0005	mg/l
Others						
Radium 226 and 228, combined		x		Radium 226 - SM7500 RA_B/Radium 228 Ga-Tech	Radium 226 0.2 / Radium 228 1	pCi/L

[1] - Sample parameter list represents (1) Appendix I to Chapter 33.1-20-08 - Constituents for Detection Monitoring, (2) Appendix II Chapter 33.1-20-08 - Constituents f
anions.

[2] - Total metals to comply with North Dakota Administrative Code, Chapter 33.1-20-08-06 3(i).

One duplicate per 10 samples and one field blank per sampling event per sample type

Table 2
Monitoring Well Construction Details
R.M. Heskett Station
Montana-Dakota Utilities Co.

Well ID	Placement from monitored unit	Installation Date	Ground Surface Elevation (feet, MSL)[1]	Constructed Depth (feet, BGS)	2015-2016 Measured Depth (feet, BGS)	Dedicated Pump Intake Depth from BOW (feet, BGS)[3]	Bottom of Screen Elevation (feet, MSL)	TOR Elevation (feet, MSL)	Screen interval (feet, BGS)	Casing	Screen	Sand Pack
Network Monitoring Wells												
MW-13	Upgradient	11/13/1986	1721.90	41	39.4	5.0	1681.53	1724.27	20.37-40.37	2" Sch 40 PVC	20 slotted PVC	19-41 Washed Sand
MW1-90	Downgradient	2/5/1990	1673.86	15	17.0	unknown	1658.86	1675.86	5-15	2" SDR-21	10 slotted PVC	4-15 160# Silica Sand Pack
MW2-90	Downgradient	2/5/1990	1684.83	23	22.6	2.0	1661.83	1687.08	13-23	2" SDR-21	10 slotted PVC	9-20 160# Silica Sand Pack
MW3-90	Downgradient	2/5/1990	1684.62	20	20.1	2.0	1663.6	1686.46	10-20	2" SDR-21	10 slotted PVC	12-23 160# Silica Sand Pack
MW-80R	Downgradient	10/20/2014	1683.73	27	27.1	10.0	1656.73	1686.78	7-27	2" Sch 40 PVC	10 slotted PVC	5-27 Granusil Industrial Quartz
Water Level Only												
MW-70	Upgradient	8/21/1986	1703.41	40	40.2	10.0	1663.41	1706.34	20-40	2" Sch 40 PVC	10 slotted PVC	18-41
MW-33[2]	Upgradient	11/13/1986	1715.92	45	45.4	3.0	1671.26	1717.95	25.65-45.65	2" Sch 40 PVC	20 slotted PVC	24-45 Washed Sand
MW-101	Upgradient	8/19/2015	1716.55	60	54.2	10.0	1662.55	1719.53	34-54	2" Sch 80 PVC	No. 6 slotted PVC	40-70 Silica
MW-102	Upgradient	8/19/2015	1703.79	30	30.4	5.0	1673.79	1706.64	20-30	2" Sch 80 PVC	No. 6 slotted PVC	40-70 Silica
MW-103	Upgradient	8/20/2015	1714.74	44	44.4	5.0	1670.74	1717.53	24-44	2" Sch 80 PVC	No. 6 slotted PVC	40-70 Silica
MW-44R	Cross-gradient	10/20/2014	1708.71	46	43.1	10.0	1665.71	1711.57	23-43	2" Sch 40 PVC	10 slotted PVC	21-46 Granusil Industrial Quartz
MW-104	Downgradient	8/20/2015	1681.45	30	29.9	10.0	1652.45	1684.51	9-29	2" Sch 80 PVC	No. 6 slotted PVC	40-70 Silica
MW-105	Downgradient	8/17/2015	1686.0	30	29.3	10.0	1656.0	1689.14	10-30	2" Sch 80 PVC	No. 6 slotted PVC	40-70 Silica

MSL - Mean Sea Level

BGS - Below Ground Surface

TOR - Top of Riser

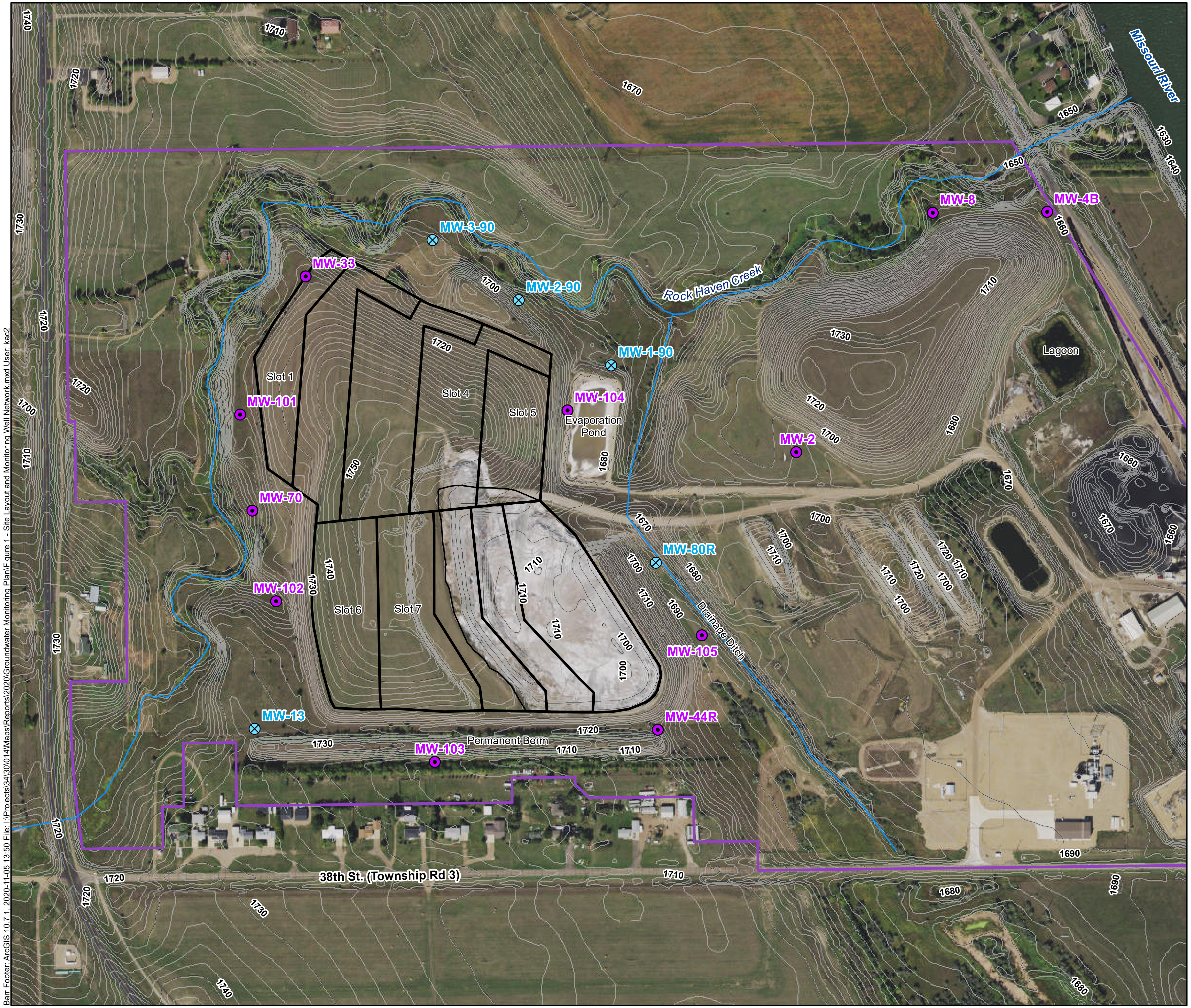
[1] Survey completed by Interstate Engineering October 8, 2015

[2] Well was damaged and resurveyed by Barr Engineering Co. on September 20, 2016.

[3] Recommended intake depths recommended by Barr Engineering Co.; actual depths may vary slightly

\\Barr.com\projects\Mpls\34 ND\30\3430014 Heskett Station Ash Management\WorkFiles\2020 Application for Permit Modification\17-GW Monitoring Plan with SAP and Stats\MP_Attach\Table 2 - Well Construction Table.xlsx

Figures



⊗ Monitoring Well Location

⦿ Monitoring Well Location - Water Level Only

Existing Slot Boundaries

Streams

Property Line

10ft Contours

2ft Contours

Image Source: 2017 Statewide Imagery (ND GIS Hub)

CAD Data Source: Slot Linework.dwg

N

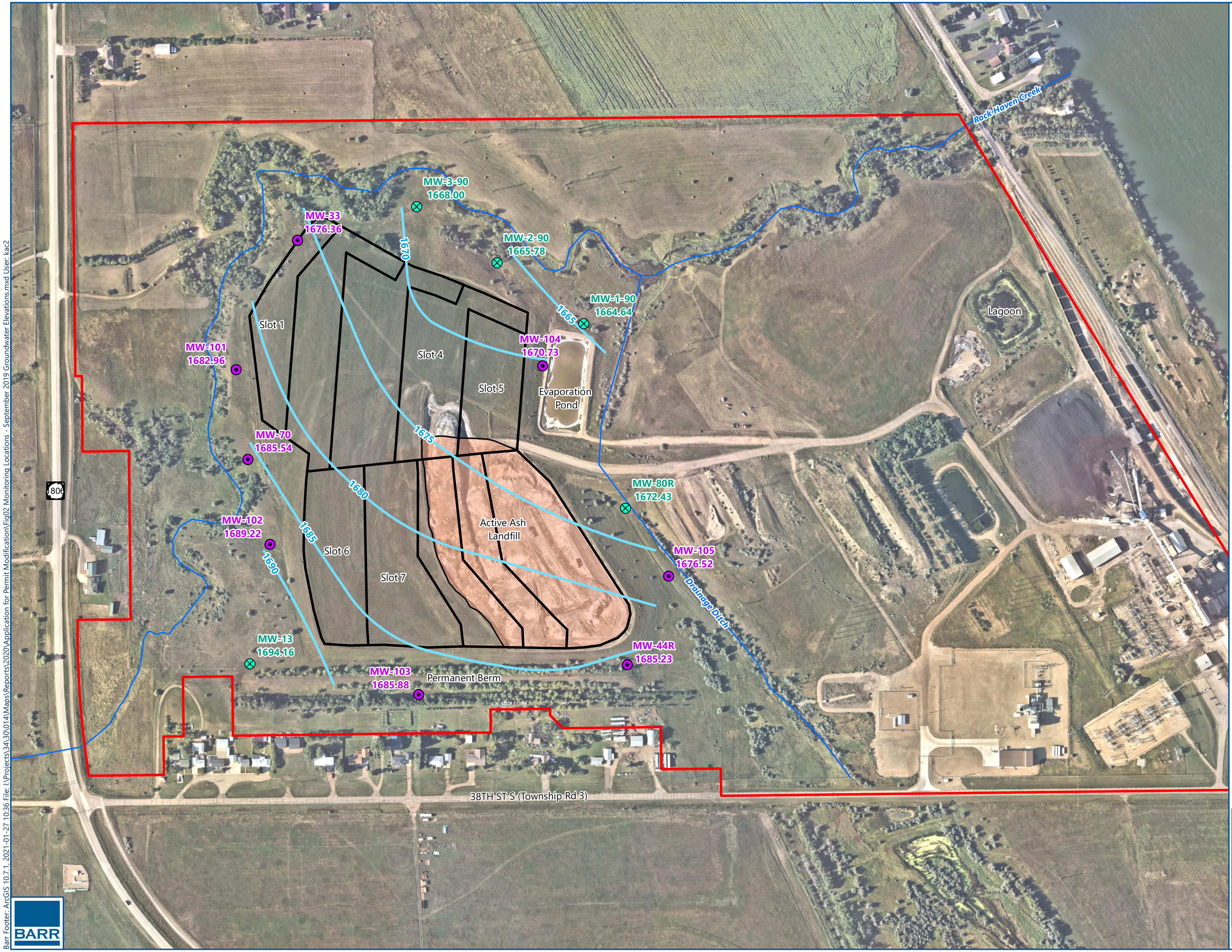
Feet

350 0 350

BARR

Figure 1

SITE LAYOUT AND MONITORING WELL NETWORK
R. M. Heskett Station
Groundwater Monitoring Plan
Montana Dakota Utilities
Mandan, North Dakota



⊗ Monitoring Well Location

● Monitoring Well Location - Water Level Only

Groundwater Elevation Contour (ft MSL)

Property Boundary

Existing Slot Boundaries

🟧 Active Portion of Landfill

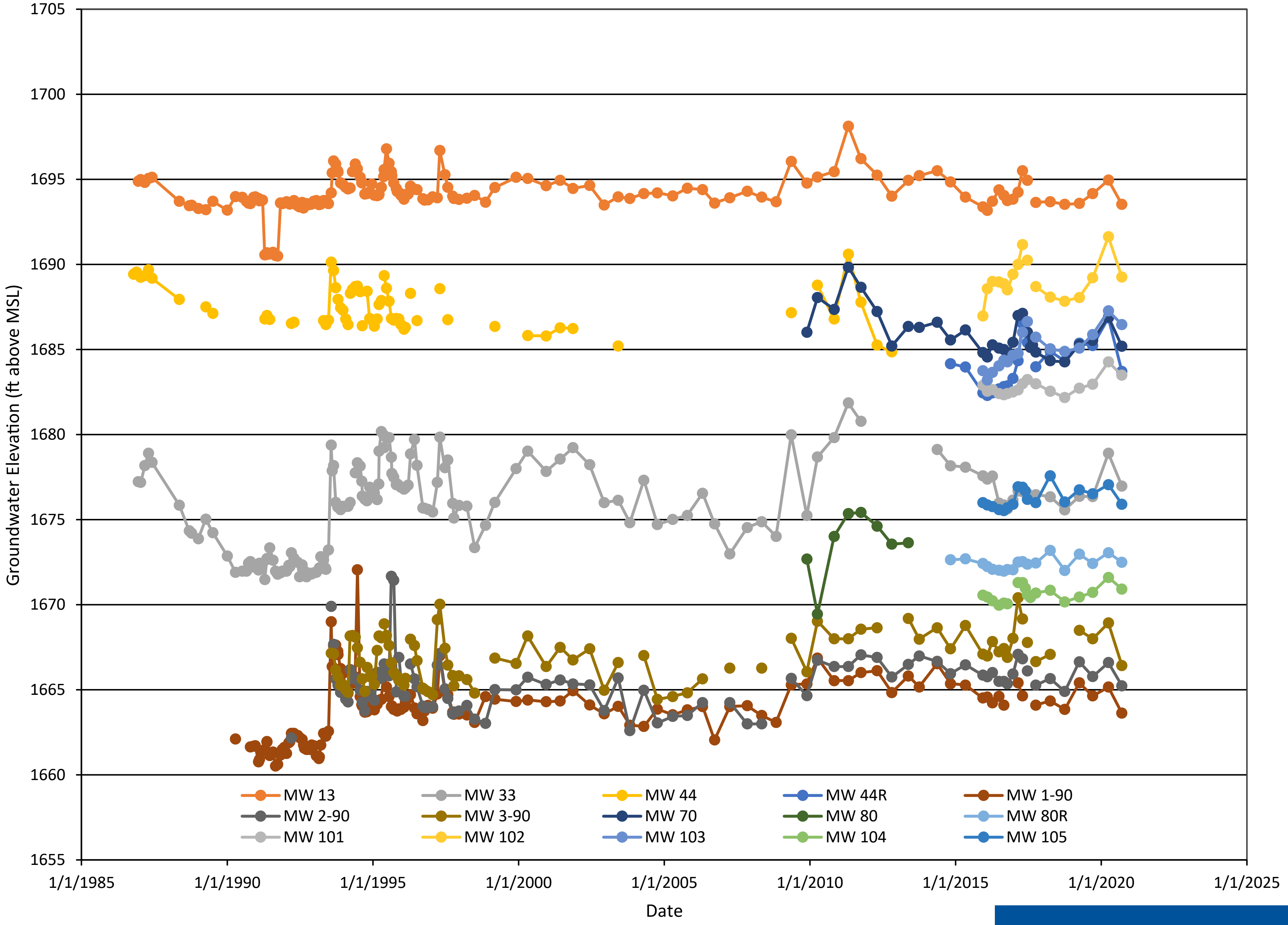
Imagery Source: NearMap Imagery (8/21/2019)

0 350 700

Feet

SEPTEMBER 2019 GROUNDWATER ELEVATIONS
Heskett Station
2019 Annual Monitoring Report
Montana Dakota Utilities
Mandan, North Dakota

FIGURE 2

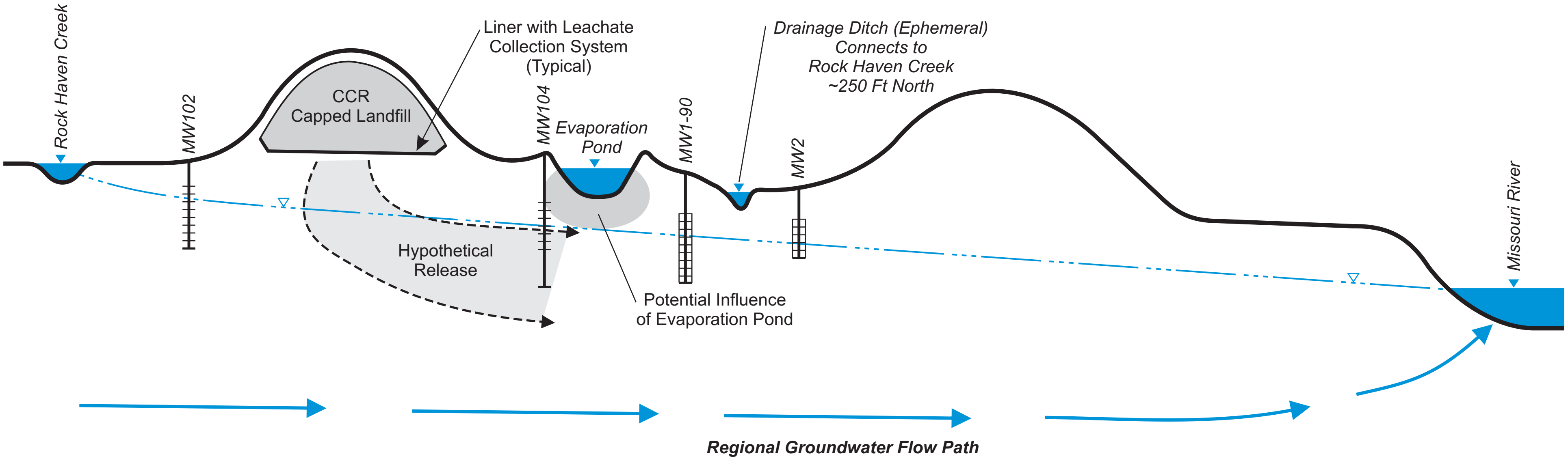


HYDROGRAPH
Heskett Station
Groundwater Monitoring Plan
Montana Dakota Utilities
Mandan, North Dakota

FIGURE 3

BARR

P:\Mpls\34 ND\30\34300014\Workfiles\Figures_Graphics\Site Conceptual Model.CDR RLG 08-12-15



Not To Scale

LEGEND

-▽- —— Approximate Water Table

Monitoring Well Screen

Proposed Groundwater Monitoring Well
(Collect Analytical Sample and Water Level Measurements)

Existing Groundwater Monitoring Well

Figure 4

SITE CONCEPTUAL MODEL
Heskett Station
Groundwater Monitoring Plan
Montana Dakota Utilities
Mandan, North Dakota

Appendices

Appendix A

Historical Geologic Information

Barr Engineering Company
4300 MarketPointe Drive Suite 200
Minneapolis, MN 55435
Telephone: 952-832-2600

LOG OF BORING MW-101
DRAFT

SHEET 1 OF 3

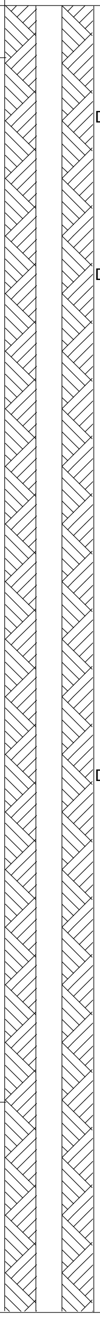
Project:R.M. Haskett Station CCR Monitoring Network
Project No.:34300014.12
Location:Mandan, ND
Coordinates:Lat: 438844.919° Long: 1868647.777°
Datum:NAD 83

Surface Elevation:1716.6 ft
Drilling Method:HSA
Sampling Method:SPT
Completion Depth:58.0 ft

Unique Well No.:

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
0						TOPSOIL: Brown (5/4 7.5YR).	
		1	4-4-4-6.			SANDY LEAN CLAY WITH GRAVEL (CL): fine to medium grained; Brown (5/3 7.5YR); moist; thinly laminated; some mottling; low plasticity; [Cannonball Formation].	1715
						At 2': Start to see gravel inclusions.	
		2	4-6-6-7.				
						At 4': Oxidized staining.	
5		3	7-9-14-16.			At 5': Oxidized staining.	
		4	8-9-12-15.			At 7': Oxidized staining and white staining.	1710
		5	10-15-21-26.				
10							
		6	7-18-24-27.	CL		At 11': Oxidized staining.	1705
		7	8-12-19-23.				
15		8	8-14-18-23.			At 15': Gypsum.	
						16-20': No recovery.	1700
20							
						At 20.5': Gypsum.	
		9	7-10-13-15.			LEAN CLAY (CL): Dark Brown (3/2 7.5YR); oxidized staining, some mottling; medium to high plasticity; [Cannonball Formation].	
						At 22': Color change to Brown (4/2 7.5YR).	1695
		10	7-9-13-15.	CL			
						At 24': Interbedded sand, fine grained.	
25							

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: **4"**
Type: **Steel pipe**
Interval: **3.5' ags - 1.5' bgs**

RISER CASING
Diameter: **2"**
Type: **PVC SCH 80**
Interval: **2.98' ags - 34' bgs**

GROUT
Type: **Neat cement**
Interval: **0 - 29' bgs**

SEAL
Type: **Bentonite chips**
Interval: **29 - 32' bgs**

SANDPACK
Type: **Silica 40-70**
Interval: **32 - 56' bgs**

SCREEN
Diameter: **2"; No.6 slot**
Type: **PVC SCH 80**
Interval: **34 - 54' bgs**

Date Boring Started:	8/18/15
Date Boring Completed:	8/19/15
Logged By:	JEG3
Drilling Contractor:	Terracon
Drill Rig:	Rig mounted HSA

Remarks: Hole caved in from 56 - 58' bgs.
DTW = 36.66' TOR on 9/23/2015 (elev. 1682.87)

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

Barr Engineering Company
4300 MarketPointe Drive Suite 200
Minneapolis, MN 55435
Telephone: 952-832-2600

LOG OF BORING MW-101
DRAFT

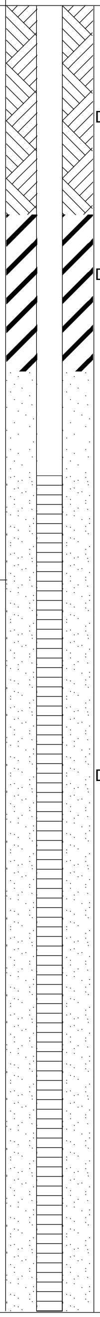
Project:R.M. Haskett Station CCR Monitoring Network
Project No.:34300014.12
Location:Mandan, ND
Coordinates:Lat: 438844.919° Long: 1868647.777°
Datum:NAD 83

Surface Elevation:1716.6 ft
Drilling Method:HSA
Sampling Method:SPT
Completion Depth:58.0 ft

Unique Well No.:

Depth, feet	Sample No.	Blows/6in.	USCS	LITHOLOGIC DESCRIPTION	Elevation, feet
25	11	7-11-13-15.	CL	LEAN CLAY (CL): Dark Brown (3/2 7.5YR); oxidized staining, some mottling; medium to high plasticity; [Cannonball Formation]. *(continued)* At 25' and 25.5': Gypsum.	
	12	8-11-15-19.		At 26.5': Gypsum.	1690
	13	8-11-13-15.		At 29.5': Gypsum.	
30	14	6-11-14-17.			1685
	15	8-13-17-22.		At 33': Gypsum.	
35	16	8-14-19-21.		At 34.5': Gypsum. At 35.5-36': Color change to Black (2.5/1 7.5YR), turns back to brown.	
	17	11-16-20-27.	CH	FAT CLAY (CH): Black (2.5/1 7.5YR); very stiff; hight plasticity; wet at 43'; [Cannonball Formation].	1680
				At 38': Oxidized staining.	
40	18	9-13-20-25.			
	19	7-14-23-26.		At 41': Oxidized staining.	1675
	20	9-16-23-26.			
45					
					1670
50					

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: **4"**
Type: **Steel pipe**
Interval: **3.5' ags - 1.5' bgs**

RISER CASING
Diameter: **2"**
Type: **PVC SCH 80**
Interval: **2.98' ags - 34' bgs**

GROUT
Type: **Neat cement**
Interval: **0 - 29' bgs**

SEAL
Type: **Bentonite chips**
Interval: **29 - 32' bgs**

SANDPACK
Type: **Silica 40-70**
Interval: **32 - 56' bgs**

SCREEN
Diameter: **2"; No.6 slot**
Type: **PVC SCH 80**
Interval: **34 - 54' bgs**

Date Boring Started:	8/18/15
Date Boring Completed:	8/19/15
Logged By:	JEG3
Drilling Contractor:	Terracon
Drill Rig:	Rig mounted HSA

Remarks: Hole caved in from 56 - 58' bgs.
DTW = 36.66' TOR on 9/23/2015 (elev. 1682.87)

Weather:

Barr Engineering Company
4300 MarketPointe Drive Suite 200
Minneapolis, MN 55435
Telephone: 952-832-2600

LOG OF BORING MW-101
DRAFT

SHEET 3 OF 3

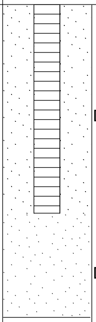
Project:R.M. Haskett Station CCR Monitoring Network
Project No.:34300014.12
Location:Mandan, ND
Coordinates:Lat: 438844.919° Long: 1868647.777°
Datum:NAD 83

Surface Elevation:1716.6 ft
Drilling Method:HSA
Sampling Method:SPT
Completion Depth:58.0 ft

Unique Well No.:

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
50				CH	▨	FAT CLAY (CH): Black (2.5/1 7.5YR); very stiff; hight plasticity; wet at 43'; [Cannonball Formation]. *(continued)*	
							1665
55							
							1660
						End of boring 58.0 feet	
60							
65							
70							
75							

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: **4"**
Type: **Steel pipe**
Interval: **3.5' ags - 1.5' bgs**

RISER CASING
Diameter: **2"**
Type: **PVC SCH 80**
Interval: **2.98' ags - 34' bgs**

GROUT
Type: **Neat cement**
Interval: **0 - 29' bgs**

SEAL
Type: **Bentonite chips**
Interval: **29 - 32' bgs**

SANDPACK
Type: **Silica 40-70**
Interval: **32 - 56' bgs**

SCREEN
Diameter: **2"; No.6 slot**
Type: **PVC SCH 80**
Interval: **34 - 54' bgs**

Date Boring Started: 8/18/15
Date Boring Completed: 8/19/15
Logged By: JEG3
Drilling Contractor: Terracon
Drill Rig: Rig mounted HSA

Remarks: Hole caved in from 56 - 58' bgs.
DTW = 36.66' TOR on 9/23/2015 (elev. 1682.87)

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

Barr Engineering Company
4300 MarketPointe Drive Suite 200
Minneapolis, MN 55435
Telephone: 952-832-2600

LOG OF BORING MW-102
DRAFT

SHEET 1 OF 2

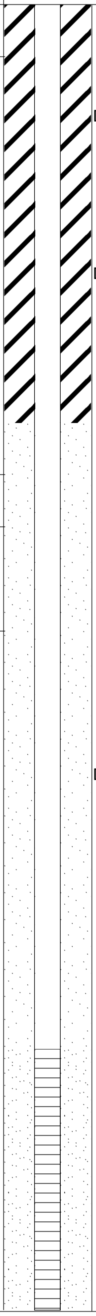
Project:R.M. Haskett Station CCR Monitoring Network
Project No.:34300014.12
Location:Mandan, ND
Coordinates:Lat: 438161.145° Long: 1868782.871°
Datum:NAD 83

Surface Elevation:1703.8 ft
Drilling Method:HSA
Sampling Method:SPT
Completion Depth:46.0 ft

Unique Well No.:

Depth, feet	Sample No.	Blows/6in.	USCS	LITHOLOGIC DESCRIPTION	Elevation, feet
0				TOPSOIL: Brown (5/4 7.5YR).	
	1	3-3-3-2.		LEAN CLAY (CL): medium grained; Brown (4/3 7.5YR); moist; low to medium plasticity; with gravel to 4'; [Cannonball Formation].	
	2	3-2-2-3.			1700
5	3	3-3-4-5.	CL		
	4	3-4-5-7.			
	5	4-8-7-4.			1695
			ML	SANDY SILT WITH GRAVEL (ML): Strong Brown (5/6 7.5YR); fine to coarse sand, fine to medium gravel, unconsolidated; [Cannonball Formation].	
10	6	4-3-5-9.	CL	LEAN CLAY WITH GRAVEL (CL): fine to medium grained; Brown (5/3 7.5YR); some mottling; medium plasticity; [Cannonball Formation].	
	7	3-5-7-9.		LEAN CLAY (CL): Dark Brown (3/2 7.5YR); medium to high plasticity; [Cannonball Formation].	1690
15	8	6-8-12-14.			
	9	6-10-12-16.			
	10	5-9-14-16.	CL		1685
20	11	5-12-15-18.		At 21': Color changes to Black (2.5/1).	
	12	9-15-18-22.			1680
25					

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: **4"**
Type: **Steel pipe**
Interval: **3.5' ags - 1.5' bgs**

RISER CASING
Diameter: **2"**
Type: **PVC SCH 80**
Interval: **2.85' ags - 10' bgs**

GROUT
Type: **None**
Interval: **None**

SEAL
Type: **Bentonite chips**
Interval: **0 - 8' bgs**

SANDPACK
Type: **Silica 40-70**
Interval: **8 - 31' bgs**

SCREEN
Diameter: **2"; No.6 slot**
Type: **PVC SCH 80**
Interval: **20 - 30' bgs**

Date Boring Started: 8/18/15
Date Boring Completed: 8/18/15
Logged By: JEG3
Drilling Contractor: Terracon
Drill Rig: Rig mounted HSA

Remarks: Lithological descriptions for a hole that was abandoned. Monitoring well blind drilled and installed next to abandoned hole.
DTW = 17.09' TOR on 8/21/2015 (elev. 1689.51

Weather:

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Barr Engineering Company
4300 MarketPointe Drive Suite 200
Minneapolis, MN 55435
Telephone: 952-832-2600

LOG OF BORING MW-102

DRAFT

SHEET 2 OF 2

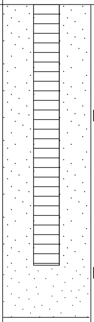
Project: R.M. Haskett Station CCR Monitoring Network
Project No.: 34300014.12
Location: Mandan, ND
Coordinates: Lat: 438161.145° Long: 1868782.871°
Datum: NAD 83

Surface Elevation: 1703.8 ft
Drilling Method: HSA
Sampling Method: SPT
Completion Depth: 46.0 ft

Unique Well No.:

Depth, feet	Sample No.	Blows/6in.	USCS	LITHOLOGIC DESCRIPTION	Elevation, feet
25	13	9-14-19-22.		LEAN CLAY (CL): Dark Brown (3/2 7.5YR); medium to high plasticity; [Cannonball Formation]. *(continued)*	
	14	10-17-18-24.			
	15	6-15-18-26.		At 29': Gypsum.	1675
30					
	16	7-14-18-22.			
	17	11-16-20-27.		At 33.5' and 34': Gypsum.	1670
35	18	10-14-15-24.	CL		
	19	13-19-25-35.			
	20	8-17-26-31.			1665
40					
	21	10-20-27-38.			
	22	13-20-27-37.			1660
				SILTY SAND (SM): fine to medium grained; Dark Gray (4/1 7.5YR); wet; [Cannonball Formation].	
45	23	15-27-27-32.	SM		
				End of boring 46.0 feet	
50					

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: **4"**
Type: **Steel pipe**
Interval: **3.5' ags - 1.5' bgs**

RISER CASING
Diameter: **2"**
Type: **PVC SCH 80**
Interval: **2.85' ags - 10' bgs**

GROUT
Type: **None**
Interval: **None**

SEAL
Type: **Bentonite chips**
Interval: **0 - 8' bgs**

SANDPACK
Type: **Silica 40-70**
Interval: **8 - 31' bgs**

SCREEN
Diameter: **2"; No.6 slot**
Type: **PVC SCH 80**
Interval: **20 - 30' bgs**

Date Boring Started: 8/18/15
Date Boring Completed: 8/18/15
Logged By: JEG3
Drilling Contractor: Terracon
Drill Rig: Rig mounted HSA

Remarks: Lithological descriptions for a hole that was abandoned. Monitoring well blind drilled and installed next to abandoned hole.
DTW = 17.09' TOR on 8/21/2015 (elev. 1689.51

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

BARR

Barr Engineering Company
4300 MarketPointe Drive Suite 200
Minneapolis, MN 55435
Telephone: 952-832-2600

LOG OF BORING MW-103
DRAFT

SHEET 1 OF 2

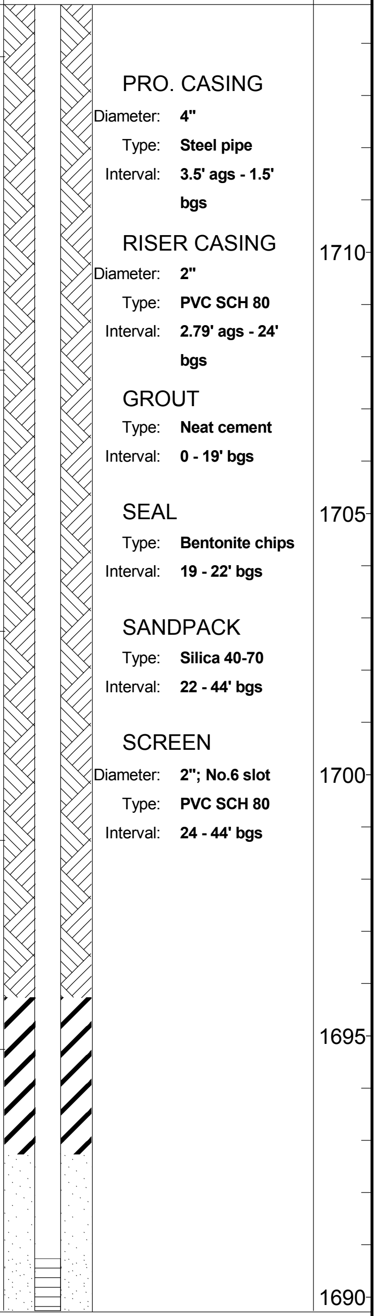
Project:R.M. Haskett Station CCR Monitoring Network
Project No.:34300014.12
Location:Mandan, ND
Coordinates:Lat: 437578.205° Long: 1869355.992°
Datum:NAD 83

Surface Elevation:1714.7 ft
Drilling Method:HSA
Sampling Method:SPT
Completion Depth:44.0 ft

Unique Well No.:

Depth, feet	Sample No.	Blows/6in.	USCS	LITHOLOGIC DESCRIPTION
0	1	3-4-5-5.	OL/OH	TOPSOIL (OL/OH): Brown (5/4 7.5YR).
5	2 3 4	5-5-8-8. 5-8-10-11. 6-9-15-15.	CL	LEAN CLAY (CL): Very Dark Gray (3/1 7.5YR); moist; stiff; medium to high plasticity; [Cannonball Formation].
10	5 6	5-6-5-4. 4-5-5-7.	SP	POORLY GRADED SAND WITH GRAVEL (SP): fine to coarse grained; Brown (5/4 7.5YR); some oxidized staining, some mottling; [Cannonball Formation].
15	7 8	2-2-2-3. 3-3-3-3.	SP-SM	POORLY GRADED SAND WITH SILT (SP-SM): fine to medium grained; Brown (5/4 7.5YR); [Cannonball Formation].
				NO RECOVERY (16 - 20').
20 25	9	3-3-5-5.	CL	SANDY LEAN CLAY (CL): fine to medium grained; Light Brown (6/4 7.5YR); wet; some mottling and oxidized staining, cohesive; low to medium plasticity; [Cannonball Formation].

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: 4"
Type: Steel pipe
Interval: 3.5' ags - 1.5' bgs

RISER CASING
Diameter: 2"
Type: PVC SCH 80
Interval: 2.79' ags - 24' bgs

GROUT
Type: Neat cement
Interval: 0 - 19' bgs

SEAL
Type: Bentonite chips
Interval: 19 - 22' bgs

SANDPACK
Type: Silica 40-70
Interval: 22 - 44' bgs

SCREEN
Diameter: 2"; No.6 slot
Type: PVC SCH 80
Interval: 24 - 44' bgs

Date Boring Started:	8/19/15
Date Boring Completed:	8/20/15
Logged By:	JEG3
Drilling Contractor:	Terracon
Drill Rig:	Rig mounted HSA

Remarks: DTW = 33.24' TOR on 8/20/2015 (elev. 1684.29)

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

LOG OF BORING MW-103
DRAFT

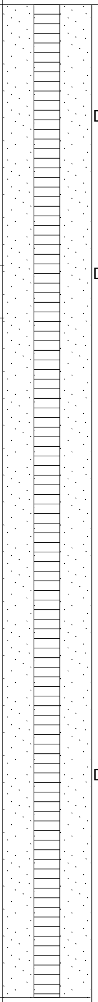
SHEET 2 OF 2

Project:R.M. Haskett Station CCR Monitoring Network
Project No.:34300014.12
Location:Mandan, ND
Coordinates:Lat: 437578.205° Long: 1869355.992°
Datum:NAD 83

Surface Elevation:1714.7 ft
Drilling Method:HSA
Sampling Method:SPT
Completion Depth:44.0 ft

Unique Well No.:

Depth, feet	Sample No.	Blows/6in.	USCS	LITHOLOGIC DESCRIPTION	Elevation, feet
25	10	2-2-4-4.	CL	SANDY LEAN CLAY (CL): fine to medium grained; Light Brown (6/4 7.5YR); wet; some mottling and oxidized staining, cohesive; low to medium plasticity; [Cannonball Formation]. *(continued)*	
30			SM	SILTY SAND WITH GRAVEL (SM): wet; [Cannonball Formation].	1685
	11	10-10-7-9.	CL	LEAN CLAY (CL): Brown (4/4 7.5YR); moist; oxidized staining; medium to high plasticity; [Cannonball Formation].	
	12	8-15-17-22.		At 32.5': Sand lens, color changes to Black (2.5/1 7.5YR). At 33.5': Sand lens. At 34': Interbedded sand with oxidized staining.	
35	13	7-19-15-25.			1680
	14	11-16-21-50 for 5".		At 36.5': Sand lens. At 37': Sand lens. At 37.5': Color change to Gray (5/1 7.5YR). At 38-38.5': 6" thick layer of hard material.	
	15	50 for 2"`-.			
40	16	12-17-22-30.		At 42-42.5': Silt layer.	1675
	17	9-18-24-50.		At 43.5-44': Silt layer.	
				End of boring 44.0 feet	
45					
50					



WELL OR PIEZOMETER CONSTRUCTION DETAIL

PRO. CASING
Diameter: **4"**
Type: **Steel pipe**
Interval: **3.5' ags - 1.5' bgs**

RISER CASING
Diameter: **2"**
Type: **PVC SCH 80**
Interval: **2.79' ags - 24' bgs**

GROUT
Type: **Neat cement**
Interval: **0 - 19' bgs**

SEAL
Type: **Bentonite chips**
Interval: **19 - 22' bgs**

SANDPACK
Type: **Silica 40-70**
Interval: **22 - 44' bgs**

SCREEN
Diameter: **2"; No.6 slot**
Type: **PVC SCH 80**
Interval: **24 - 44' bgs**

Date Boring Started:	8/19/15
Date Boring Completed:	8/20/15
Logged By:	JEG3
Drilling Contractor:	Terracon
Drill Rig:	Rig mounted HSA

Remarks: DTW = 33.24' TOR on 8/20/2015 (elev. 1684.29)

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

BARR
Barr Engineering Company
4300 MarketPointe Drive Suite 200
Minneapolis, MN 55435
Telephone: 952-832-2600

LOG OF BORING MW-104

DRAFT

SHEET 1 OF 2

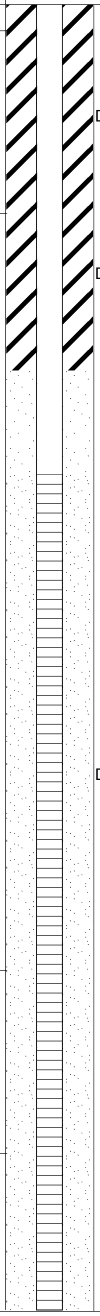
Project:R.M. Haskett Station CCR Monitoring Network
Project No.:34300014.12
Location:Mandan, ND
Coordinates:Lat: 438853.542° Long: 1869832.72°
Datum:NAD 83

Surface Elevation:1681.5 ft
Drilling Method:HSA
Sampling Method:SPT
Completion Depth:32.0 ft

Unique Well No.:

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
0						TOPSOIL: Brown (5/4 7.5YR).	
		1	4-5-5-5.	CL		LEAN CLAY WITH SAND (CL): fine to medium grained; Brown (5/4 7.5YR); moist; gravel; medium plasticity; [Cannonball Formation].	1680
		2	3-5-6-8.				
				CL		LEAN CLAY (CL): Brown (4/4 7.5YR); oxidized staining and mottling; medium to high plasticity; with gypsum throughout; [Cannonball Formation].	
5		3	3-7-9-10.				1675
		4	5-7-9-10.				
		5	5-9-9-10.				
10 ▼							▼
		6	5-7-9-10.				1670
						At 12': Heavily oxidized.	
		7	5-8-8-12.				
15		8	5-9-11-15.			At 15': Start seeing black staining.	1665
		9	6-9-11-13.			At 17': Heavily oxidized.	
				SM		SILTY SAND (SM): Strong Brown (5/6 7.5YR); wet; [Cannonball Formation].	
		10	4-7-16-19.			At 19.5': Color change to Brown (5/4 7.5YR).	
20							
		11	5-16-22-26.			At 21': Oxidized layer.	1660
				CH		FAT CLAY (CH): Dark Gray (4/1 7.5YR); moist; stiff; high plasticity; with interbedded sand layers below 27'; [Cannonball Formation].	
		12	7-11-14-16.				
25							

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: **4"**
Type: **Steel pipe**
Interval: **3.5' ags - 1.5' bgs**

RISER CASING
Diameter: **2"**
Type: **PVC SCH 80**
Interval: **3.06' ags - 9' bgs**

GROUT
Type: **None**
Interval: **None**

SEAL
Type: **Bentonite chips**
Interval: **0 - 7' bgs**

SANDPACK
Type: **Silica 40-70**
Interval: **7 - 32' bgs**

SCREEN
Diameter: **2"; No.6 slot**
Type: **PVC SCH 80**
Interval: **9 - 29' bgs**

Date Boring Started: 8/20/15
Date Boring Completed: 8/20/15
Logged By: JEG3
Drilling Contractor: Terracon
Drill Rig: Rig mounted HSA

Remarks: DTW = 13.25' TOR on 8/21/2015 (elev. 1671.26)

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

LOG OF BORING MW-104
DRAFT

SHEET 2 OF 2

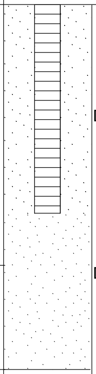
Project:R.M. Haskett Station CCR Monitoring Network
Project No.:34300014.12
Location:Mandan, ND
Coordinates:Lat: 438853.542° Long: 1869832.72°
Datum:NAD 83

Surface Elevation:1681.5 ft
Drilling Method:HSA
Sampling Method:SPT
Completion Depth:32.0 ft

Unique Well No.:

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
25	☒	13	6-12-16-17.	CH	▨	FAT CLAY (CH): Dark Gray (4/1 7.5YR); moist; stiff; high plasticity; with interbedded sand layers below 27'; [Cannonball Formation]. *(continued)*	
	☒	14	8-12-16-21.				1655
	☒	15	8-12-16-20.				
30	☒	16				Driller notes: sluff.	1650
						End of boring 32.0 feet	
35							
40							
45							
50							

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: **4"**
Type: **Steel pipe**
Interval: **3.5' ags - 1.5' bgs**

RISER CASING
Diameter: **2"**
Type: **PVC SCH 80**
Interval: **3.06' ags - 9' bgs**

GROUT
Type: **None**
Interval: **None**

SEAL
Type: **Bentonite chips**
Interval: **0 - 7' bgs**

SANDPACK
Type: **Silica 40-70**
Interval: **7 - 32' bgs**

SCREEN
Diameter: **2"; No.6 slot**
Type: **PVC SCH 80**
Interval: **9 - 29' bgs**

Date Boring Started:	8/20/15
Date Boring Completed:	8/20/15
Logged By:	JEG3
Drilling Contractor:	Terracon
Drill Rig:	Rig mounted HSA

Remarks: DTW = 13.25' TOR on 8/21/2015 (elev. 1671.26)

Weather:

BARR
Barr Engineering Company
4300 MarketPointe Drive Suite 200
Minneapolis, MN 55435
Telephone: 952-832-2600

LOG OF BORING MW-105
DRAFT

SHEET 1 OF 2

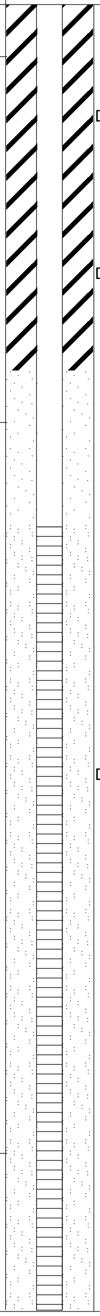
Project:R.M. Haskett Station CCR Monitoring Network
Project No.:34300014.12
Location:Mandan, ND
Coordinates:Lat: 438042.079° Long: 1870325.657°
Datum:NAD 83

Surface Elevation:1686.0 ft
Drilling Method:HSA
Sampling Method:SPT
Completion Depth:30.0 ft

Unique Well No.:

Depth, feet	Sample No.	Blows/6in.	USCS	LITHOLOGIC DESCRIPTION	Elevation, feet
0				TOPSOIL: Brown (5/4 7.5YR).	
	1	6-7-6-5.		SANDY LEAN CLAY (CL): fine to medium grained; Brown (4/2 7.5YR); moist; gravel; medium plasticity; [Cannonball Formation].	1685
	2	5-5-5-6.			
5	3	3-2-4-5.	CL		
	4	2-2-2-3.			1680
	5	2-1-2-2.		LEAN CLAY (CL): Brown (4/2 7.5YR); soft; high plasticity; wet at 16'; [Cannonball Formation].	
10 ▼					
	6	2-1-2-1.		At 10.5': Color change to Reddish-Yellow (6/6 7.5YR).	1675
	7	2-1-1-3.			
15	8	4-3-5-5.	CL	At 14.5-15.5': Gravel inclusions. At 15.5': Color change to Brown (4/3 7.5YR).	1670
	9	7-9-11-13.			
	10	7-9-11-13.		At 18': Color change to Brown (5/3 7.5YR).	
20					
	11	7-9-13-15.			1665
	12	19-26-28-30.	SP-SM	POORLY GRADED SAND WITH SILT (SP-SM): medium to coarse grained; Brown (5/4 7.5YR); [Cannonball Formation].	
25					

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: **4"**
Type: **Steel pipe**
Interval: **3.5' ags - 1.5' bgs**

RISER CASING
Diameter: **2"**
Type: **PVC SCH 80**
Interval: **3.16' ags - 10' bgs**

GROUT
Type: **None**
Interval: **None**

SEAL
Type: **Bentonite chips** ▼
Interval: **0 - 7' bgs**

SANDPACK
Type: **Silica 40-70**
Interval: **7 - 30' bgs**

SCREEN
Diameter: **2"; No.6 slot**
Type: **PVC SCH 80**
Interval: **10 - 30' bgs**

Date Boring Started: 8/17/15
Date Boring Completed: 8/17/15
Logged By: JEG3
Drilling Contractor: Terracon
Drill Rig: Rig mounted HSA

Remarks: DTW = 13.22' TOR on 8/21/2015 (elev. 1675.92)

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

Barr Engineering Company
4300 MarketPointe Drive Suite 200
Minneapolis, MN 55435
Telephone: 952-832-2600

LOG OF BORING MW-105

DRAFT

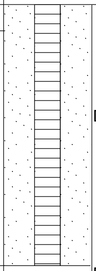
SHEET 2 OF 2

Project:R.M. Haskett Station CCR Monitoring Network
Project No.:34300014.12
Location:Mandan, ND
Coordinates:Lat: 438042.079° Long: 1870325.657°
Datum:NAD 83

Surface Elevation:1686.0 ft
Drilling Method:HSA
Sampling Method:SPT
Completion Depth:30.0 ft

Unique Well No.:

Depth, feet	Sample Type & Recovery	Sample No.	Blows/6in.	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation, feet
25	☒	13	15-25-31-40.				
				CL	▨	FAT CLAY (CL): Dark Brown (3/4 7.5YR); high plasticity; sand lens at 26.5'; [Cannonball Formation]. At 26': Color change to Gray (5/1 7.5YR).	1660
	☒	14	10-15-18-30.				
	☒	15	11-16-22-32.				
30						End of boring 30.0 feet	
35							
40							
45							
50							



WELL OR PIEZOMETER CONSTRUCTION DETAIL

PRO. CASING
Diameter: **4"**
Type: **Steel pipe**
Interval: **3.5' ags - 1.5' bgs**

RISER CASING
Diameter: **2"**
Type: **PVC SCH 80**
Interval: **3.16' ags - 10' bgs**

GROUT
Type: **None**
Interval: **None**

SEAL
Type: **Bentonite chips**
Interval: **0 - 7' bgs**

SANDPACK
Type: **Silica 40-70**
Interval: **7 - 30' bgs**

SCREEN
Diameter: **2"; No.6 slot**
Type: **PVC SCH 80**
Interval: **10 - 30' bgs**

Date Boring Started: 8/17/15
Date Boring Completed: 8/17/15
Logged By: JEG3
Drilling Contractor: Terracon
Drill Rig: Rig mounted HSA

Remarks: DTW = 13.22' TOR on 8/21/2015 (elev. 1675.92)

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

EXHIBIT 5-E

LITHOLOGIC LOGS

Wells 10, 11, 12 and 13

MW13 Screen

0-1	Top soil, silty, clayey, sandy, brown, calcareous; with some limestone pebbles.
1-11	Silt, clayey, brownish-tan, slightly indurated, very dry, calcareous; with thin coarse-grained, clean silt lenses and a few small (less than .5 in.) iron oxide concretions. Abundant small gypsum crystals (less than .13 in. long). Some small, black flakes of organic plant material. Cannonball-Ludlow Formations.
11-14	Silt, as above, with some (less than 20%) very fine- to fine-grained sand interspersed.
14-30	Silt, as above, clayey, less sand than above interval, oxidized; with very fine-grained silty sand lenses and very few gypsum crystals.
30-41	Silt, very clayey, with some (less than 20%) very fine-grained sand interspersed, steel-gray (color change), moderately indurated; with fewer small gypsum crystals than above intervals.
41-59	Silt, as above, very clayey, with some (less than 20%) fine- to medium-grained sand interspersed in a silt and clay matrix.
59-65	Silt, as above, with abundant (more than 20%) fine- to medium-grained sand interspersed.
65-81	Silt, clayey, steel-gray to bluish, moderately indurated; with thin coarse-grained silt to very fine-grained sand lenses in an otherwise fine silt to clay matrix.
81-84	Clay, silty, steel-gray to bluish, moderately indurated, dense.
84-91	Siltstone, sandy, clayey, steel-gray to bluish, slightly indurated; with small fine-grained sand lenses and abundant (more than 20%) sand interspersed in the matrix.
91-110	Silt, clayey, bluish-gray, moderately indurated; with thin (less than 1 foot) mudstone lenses.
110-120	Silt, very clayey, steel-gray to bluish, moderately indurated, very dense. Cannonball-Ludlow Formations.

Well Number: 13

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CCD

Elevation: Ground; 1721.88 ft. Casing top; 1724.90 ft.
Well Bottom; 1681.88 ft.

Completion: Date drilled; 11-13-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry

Boring: Diameter; 5 5/8 in. Depth drilled; 40 ft.
Encountered water (below surface); ? ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +3.02-20.37 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC Depths (from ground); 20.37-40.37 ft.
Elevation of interval; 1681.51-1701.51 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 19-41 ft.

Grout Seal: Depths (from ground); 0-19 ft.
Date sealed; 1-27-87

Additional Data:

Static Water Level: Date; 12-15-86
Depth; 30.09 ft. below top of casing
Elevation; 1694.81 ft.

Chemistry: Date; NA
pH; NA Sp. cond; NA
Temp; NA

Wells 20 and 21

0-1	Top soil, silty, sandy, clayey, dark-brown, calcareous; with some limestone and granite pebbles.
1-21	Silt, clayey, with minor amounts (less than 10%) of very fine-grained sand interspersed, brownish-tan, slightly indurated, calcareous, oxidized; with small iron oxide concretions and abundant small gypsum crystals. Cannonball-Ludlow Formations.
21-26	Silt, as above, steel-gray (color change).
26-49	Silt, clayey, with some (less than 20%) very fine- to medium-grained sand interspersed, steel-gray to bluish, slightly indurated; with very few small gypsum crystals and some thin (less than 1 foot) siltstone lenses.
49-53	Silt, as above, with abundant (more than 20%) fine- to medium-grained sand interspersed.
53-63	Silt, as above, clayey, less sand, with thin (less than 1 foot) siltstone to mudstone lenses.
63-80	Silt, very clayey, steel-gray to bluish, moderately indurated, very dense. Cannonball-Ludlow Formations.

Wells 30, 31, 32 and 33

0-1	Top soil, silty, sandy, brownish, calcareous; with some granite and limestone pebbles.
1-2	Pebble-loam (glacial till), silty, sandy, clayey, yellowish-brown, dry, calcareous.
2-31	Silt, clayey, with minor amounts (less than 10%) of very fine-grained sand interspersed, brownish-tan, slightly indurated, calcareous, oxidized; with small iron oxide concretions. Some small, black flakes organic plant material. Cannonball-Ludlow Formations.
31-44	Silt, clayey, steel-gray (color change), slightly indurated, calcareous; with small iron oxide concretions, thin coarse silt lenses, small gypsum crystals and gray to reddish-brown mottling.

MW 30
46 Screen 26

Well Number: 33

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CBA

Elevation: Ground; 1715.34 ft. Casing top; 1717.79 ft.
Well Bottom; 1672.79 ft.

Completion: Date drilled; 11-13-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry

Boring: Diameter; 5 5/8 in. Depth drilled; 45 ft.
Encountered water (below surface); ? ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.45-25.65 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 25.65-45.65 ft.
Elevation of interval; 1669.69-1689.69 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 24-45 ft.

Grout Seal: Depths (from ground); 0-24 ft.
Date sealed; 1-27-87

Additional Data:
Static Water Level: Date; 12-15-86
Depth; 40.68 ft. below top of casing
Elevation; 1677.11 ft.

Chemistry: Date; NA
pH; NA Sp. cond; NA
Temp; NA

44-61	Silt, as above, with some (less than 20%) fine- to medium-grained sand interspersed.
61-65	Silt, as above, with abundant (more than 20%) fine- to medium-grained sand interspersed, dense.
65-76	Silt, as above, clayey, less sand, some thin (less than 1 foot) lenses of siltstone to mudstone.
76-80	Siltstone, sandy, clayey, steel-gray to bluish, slightly indurated; with small fine-grained sand lenses and abundant (more than 20%) fine-grained sand interspersed in the matrix.
80-92	Silt, clayey, steel-gray to bluish, moderately indurated, with some (less than 20%) very fine- to fine grained sand interspersed.
92-120	Silt, very clayey, steel-gray to bluish, moderately indurated, very dense. Cannonball-Ludlow Formations.

Well 40

0-1	Top soil, sandy, silty, brownish-tan, calcareous; with some granite and limestone pebbles.
1-5	Pebble-loam (glacial till), sandy, silty, with detrital lignite and organic matter, yellowish-brown, very dry, calcareous.
5-22	Sand, very fine- to medium-grained, unconsolidated, with thin lenses of clay and detrital lignite, brownish-yellow, calcareous.
22-40	Silt, clayey, with minor amounts (less than 10%) very fine-grained sand interspersed, brownish-tan, slightly indurated, calcareous, oxidized; with small iron oxide concretions and small gypsum crystals; Cannonball-Ludlow Formations.
40-51	Silt, clayey, with minor amounts (less than 10%) of very fine-grained sand interspersed, steel-gray (color change), moderately indurated; with some reddish-brown mottling and some very thin (less than 6 inches) mudstone lenses.
51-58	Silt, as above, with abundant (more than 20%) fine-grained sand and thin silty-clay lenses.

70-80	Silt, as above, very clayey, some (less than 10%) fine-grained sand interspersed; less sand than above interval.

Wells 43 and 44

0-2	Top soil, clayey, silty, some sand, brownish-tan to light-gray, calcareous.
2-20	Silt, clayey, with some (less than 20%) fine-grained sand interspersed, brownish-tan, slightly indurated, very dry, calcareous; with small iron oxide concretions, abundant small gypsum crystals and occasional thin silt lenses. Cannonball-Ludlow Formations.
20-25	Silt, as above, very clayey, oxidized, with minor amounts (less than 10%) of fine-grained sand.
25-35	Silt, as above, dark-brownish-tan to bluish-gray (color change), with thin very fine-grained sand lenses.
35-60	Silt, clayey, with some (less than 20%) fine- to medium-grained sand interspersed, steel-gray to bluish, moderately indurated; with some indurated silty sand lenses. Cannonball-Ludlow Formations.

Wells 50, 51 and 52

0-4	Top soil, clayey, silty, very dark-brown.
4-10	Clay, silty, with some (less than 20%) fine-grained sand, dark-brownish-tan, soft, cohesive, wet, sticky; with some pebbles.
10-22	Silt, very clayey, with some (less than 20%) very fine-grained sand interspersed, brownish-tan, slightly indurated, calcareous, dense; with abundant small gypsum crystals and very thin silt and sand lenses; Cannonball-Ludlow Formations.
22-23	Sandstone, fine-grained, silty, indurated, oxidized, dark-brown.
23-30	Silt, very clayey, with some (less than 20%) very fine-grained sand interspersed, steel-gray (color change), moderately indurated; with thin medium grained sand lenses.

58-62	Siltstone, sandy, clayey, steel-gray to bluish, moderately indurated; with small fine-grained sand lenses and abundant (more than 20%) sand interspersed in the matrix.
62-70	Silt, clayey, with some (less than 20%) fine- to medium-grained sand interspersed, steel-gray to bluish, moderately indurated; with thin (less than 2 feet) sandy lenses.
70-80	Silt, as above, very clayey, some (less than 10%) fine-grained sand interspersed; less sand than above interval.
80-120	Silt, as above, dark-steel-gray. Cannonball-Ludlow Formations.

Wells 41, 42 and 43

0-1	Top soil, sandy, silty, dark-brown, calcareous; with some granite and limestone pebbles.
1-4	Pebble-loam (glacial till), sandy, silty, clayey, yellowish-brown, very dry, calcareous.
4-40	Silt, clayey, with some (less than 20%) very fine-grained sand interspersed, brownish-tan, unconsolidated, noncompacted, calcareous to 25 feet, oxidized; with small iron oxide concretions and abundant small gypsum crystals. Cannonball-Ludlow Formations.
40-51	Silt, clayey, with minor amounts (less than 10%) of very fine-grained sand interspersed, steel-gray (color change), moderately indurated; with some reddish-brown mottling and some very thin (less than 6 inches) mudstone lenses.
51-58	Silt, as above, with abundant (more than 20%) fine-grained sand and thin silty-clay lenses.
58-62	Siltstone, sandy, clayey, steel-gray to bluish, moderately indurated; with small fine-grained sand lenses and abundant (more than 20%) sand interspersed in the matrix.
62-70	Silt, clayey, with some (less than 20%) fine- to medium-grained sand interspersed, steel-gray to bluish, moderately indurated; with thin (less than 2 feet) sandy lenses.

30-40	Silt, as above, very clayey, less sand than above interval, dark-steel-gray. Cannonball-Ludlow Formations.

Wells 53 and 54

0-4	Top soil, clayey, silty, very dark-brown, wet, sticky.
4-15	Clay, silty, with some (less than 20%) fine- to medium-grained sand interspersed, brownish-tan, slightly indurated, dry, calcareous; with small iron oxide concretions, small gypsum crystals and occasional reddish-brown mottling; Cannonball-Ludlow Formations.
15-20	Sand, very fine-grained to medium-grained, silty, clayey, unconsolidated, yellowish-brown, oxidized.
20-30	Silt, clayey, with some (less than 20%) fine-grained sand interspersed, steel-gray (color change), slightly indurated; with clay and sand lenses, some small concretions and some small gypsum crystals.
30-45	Silt, as above, very clayey.
45-60	Silt, as above, clayey, brownish-gray, moderately indurated, some reddish-brown mottling. Cannonball-Ludlow Formations.

Wells 55 and 56

0-5	Sandy-loam (glacial), with fine- to medium-grained sand, silty, calcareous; with small granite and limestone pebbles.
5-26	Clay, silty, with minor amounts (less than 10%) of very fine-grained sand, dark-brownish-tan, moderately indurated, brittle, very dry, calcareous; with small iron oxide concretions, small gypsum crystals and occasional thin sandstone laminae. Some small, black flakes of organic plant material. Cannonball-Ludlow Formations.
26-35	Clay, as above, very silty, sandy, brownish-tan, oxidized.

35-40	Silt, clayey, with some (less than 20%) very fine- to fine-grained sand interspersed, steel-gray (color change) moderately indurated; with small gypsum crystals and occasional clay lenses.
40-60	Silt, as above, with minor amounts (less than 10%) of fine-grained sand interspersed.
60-85	Silt, as above, clayey, less sand than above interval.
85-100	Silt, as above, very clayey, with minor amounts (less than 10%) of sand interspersed, light-gray. Cannonball-Ludlow Formations.

Wells 60, 61 and 62

0-2	Top soil, silty, clayey, dark-brown to tanish-brown, calcareous.
2-25	Silt, very clayey, with some minor amounts (less than 10%) of very fine- to fine-grained sand interspersed, brownish-tan, slightly indurated, dry, calcareous; with abundant small gypsum crystals and thin silt and sand lenses; Cannonball-Ludlow Formations.
25-29	Silt, as above, with abundant (more than 20%) fine- to medium-grained sand interspersed.
29-36	Silt, as above, clayey, less sand than above interval, dark-brownish-tan, oxidized.
36-60	Silt, very clayey, with some (less than 20%) very fine-grained sand interspersed, steel-gray (color change), moderately indurated; with thin (less than 1 foot) sandy-silt lenses. Cannonball-Ludlow Formations.

Well 70 0-2	Pebble-loam (glacial till), clayey, sandy, yellowish-brown, unconsolidated, damp, calcareous.
2-21	Silty, clayey, with some (less than 20%) fine-grained sand interspersed, brownish-tan, moderately indurated, very dry, calcareous, oxidized; with small iron oxide concretions and abundant small gypsum crystals. Cannonball-Ludlow Formations.

21-24	Shale, silty, steel- to dark-gray (color change), indurated, fissile, very dry; with occasional thin silt and sand lenses.
24-31	Silt, clayey, with abundant (more than 30%) sand, steel-gray, moderately indurated.
31-62	Silt, clayey, with some (less than 20%) very fine- to fine- grained sand interspersed, steel-gray, moderately indurated; with some small gypsum crystals and small iron oxide concretions.
62-76	Silt, as above, with some (less than 20%) fine-grained sand interspersed.
76-82	Silt, as above, with abundant (more than 20%) fine- to medium-grained sand.
82-100	Silt, as above, clayey, with some (less than 20%) fine-grained sand interspersed, dark-gray. Cannonball-Ludlow Formations.

The litnologic logs for wells 1-4 were described by personal from Water Supply Incorporated (WS), Bismarck, North Dakota. The wells were installed during a previous ground water investigation at Heskett Station.

Well WS 2

0-1	Top soil, silty, black.
1-4	Pebble-loam (glacial till), silty, clayey, some cobbles, yellowish-brown.
4-7	Gravel, sand and rocks.
7-21	Sand, fine- to coarse-grained, some pebbles.
21-39	Clay, silty, sandy, yellowish-brown to gray.
39-52	Clay, silty, sandy, gray.
52-67	Sand, fine-grained, bluish, with some clay layers.
67-89	Clay, silty, sandy, brown to gray.

Wells WS 1, 1A and 1B

0-1	Top soil, silty, black
1-4	Clay, (glacial), silty, with pebbles, yellowish-brown.
4-21	Sand, fine- to medium-grained, yellowish-brown; with clay and silt lenses.
21-25	Clay, silty, yellowish-brown.
25-30	Sand, fine-grained, yellowish-brown, some indurated layers.
30-35	Clay, silty, yellowish-brown.
35-45	Sand, fine-grained, yellowish-brown.
45-50	Clay, silty, sandy, gray, about 50 percent shale.
50-56	Sand, fine-grained, with clay layers.
56-73	Clay, silty, sandy, gray.

WElls WS 4, 4A and 4B

0-13	Pebble-loam (glacial till), silty, sandy, with some cobbles, yellowish-brown.
13-23	Sand, fine- to medium-grained, yellowish-brown.
23-25	Slay, silty, sandy, yellowish-brown.
25-27	Sandstone, indurated.
27-30	Clay, sandy, silty, gray.
30-36	Sand, fine-grained, gray.
36-52	Clay, silty, sandy, gray; with some sand layers.

Wells WS 3 and 3A

0-1	Top soil, silty, black.
1-12	Pebble-loam, clayey, silty, with some cobbles, yellowish-brown.
12-16	Clay, silty, gray; with some shale layers.
16-18	Limestone, indurated.
18-23	Clay, silty, yellowish-brown; with some sand layers.
23-44	Sand, fine- to medium-grained, gray; with some clay layers.
44-50	Clay, silty, medium-gray.

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

LOG OF BORING MW-44 R

SHEET 1 OF 2

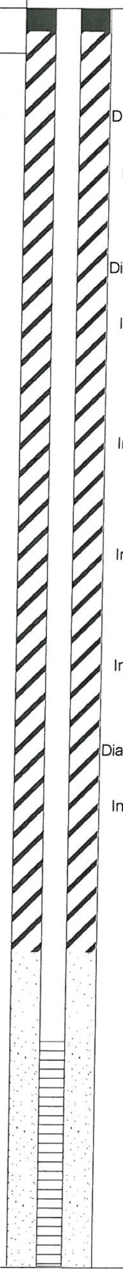
Project:Heskett Station
Project No.:34301012
Location:Mandan, ND
Coordinates:Lat: 46.86620° Long: -100.89313°
Datum:

Surface Elevation:
Drilling Method:HSA
Sampling Method:Split Spoon
Completion Depth:46.0 ft

Unique Well No.:MW-44 R

Depth, feet	Sample No.	Blows/6in.	USCS	LITHOLOGIC DESCRIPTION
0	1	3-3-5-8.	OL/OH	0-1': TOPSOIL (OL/OH): Very Dark Brown (2.5/2 7.5YR); low to medium plasticity; roots, fine to medium grained sand.
				1-46': SANDY CLAY (CL): Brown (5/4 7.5YR) to Dark Gray (4/1 7.5YR); medium to high plasticity; massive; fine to medium grained sand. Moist; 20% gravel, 30% sand, 50% fines. At 1-5': Gravel sized inclusions.
	2	9-9-7-7.		Moist; 10% gravel, 20% sand, 70% fines.
5	3	7-5-5-7.		Moist; 0% gravel, 30% sand, 70% fines.
	4	7-9-11-13.		Moist; 0% gravel, 20% sand, 80% fines. At 8': Oxidized staining.
	5	7-9-12-13.		
10				
	6	6-7-11-13.		
	7	7-10-12-14.	CL	
15	8	6-10-14-14.		
20	9	10-10-13-16.		At 20': Interbedded layer of sand.
				(CL): At 24': Color change to dark brown (3/3 7.5YR). Moist; 0% gravel, 20% sand, 80% fines.
25	10	10-10-12-16.		At 25': Sand lens.
			CL	

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: **4" by 4"**
Type: **Steel**
Interval: **3' up & 3' down**

RISER CASING
Diameter: **2"**
Type: **Schd 40 PVC**
Interval: **Stick up to screen (23')**

GROUT
Type: **Cement**
Interval: **0-0.5' BGS**

SEAL
Type: **Bentonite**
Interval: **Chips 0.5-21' BGS**

SANDPACK
Type: **Granusil**
Interval: **21-46' BGS**

SCREEN
Diameter: **2"**
Type: **No. 10 Slot**
Interval: **23-43' BGS**

Elevation, feet

Date Boring Started:	10/20/14
Date Boring Completed:	10/20/14
Logged By:	JEG3
Drilling Contractor:	Midwest Testing (Terracon)
Drill Rig:	

Remarks: Water encountered at 28.7' BGS in MW-44R while drilling on 10/2014

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

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

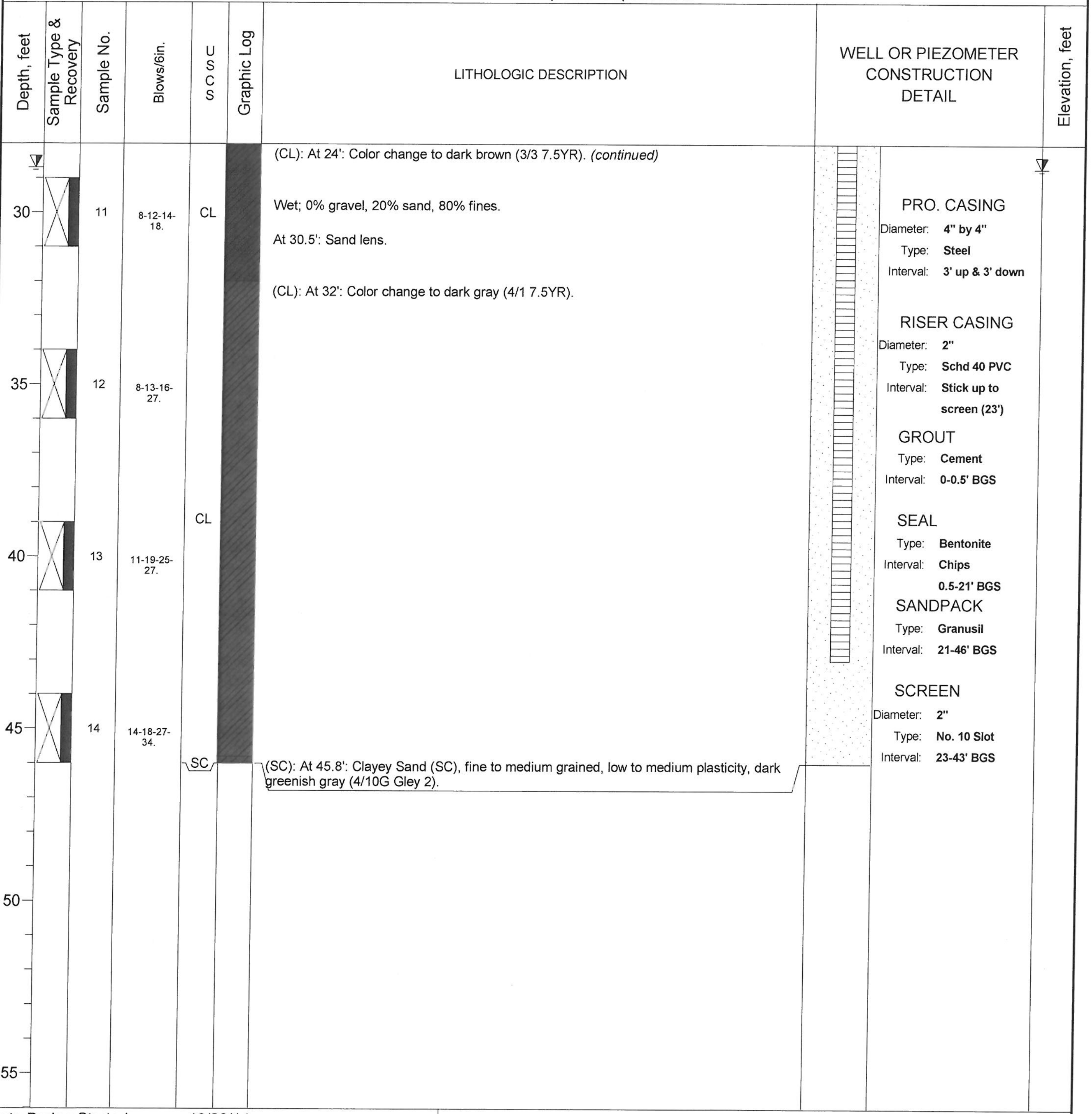
LOG OF BORING MW-44 R

SHEET 2 OF 2

Project:Heskett Station
Project No.:34301012
Location:Mandan, ND
Coordinates:Lat: 46.86620° Long: -100.89313°
Datum:

Surface Elevation:
Drilling Method:HSA
Sampling Method:Split Spoon
Completion Depth:46.0 ft

Unique Well No.:MW-44 R



Depth, feet	Sample No.	Blows/6in.	USCS
30	11	8-12-14-18.	CL
35	12	8-13-16-27.	
40	13	11-19-25-27.	CL
45	14	14-18-27-34.	SC

LITHOLOGIC DESCRIPTION

(CL): At 24': Color change to dark brown (3/3 7.5YR). *(continued)*

Wet; 0% gravel, 20% sand, 80% fines.

At 30.5': Sand lens.

(CL): At 32': Color change to dark gray (4/1 7.5YR).

(SC): At 45.8': Clayey Sand (SC), fine to medium grained, low to medium plasticity, dark greenish gray (4/10G Gley 2).

WELL OR PIEZOMETER CONSTRUCTION DETAIL

PRO. CASING
Diameter: **4" by 4"**
Type: **Steel**
Interval: **3' up & 3' down**

RISER CASING
Diameter: **2"**
Type: **Schd 40 PVC**
Interval: **Stick up to screen (23')**

GROUT
Type: **Cement**
Interval: **0-0.5' BGS**

SEAL
Type: **Bentonite**
Interval: **Chips 0.5-21' BGS**

SANDPACK
Type: **Granusil**
Interval: **21-46' BGS**

SCREEN
Diameter: **2"**
Type: **No. 10 Slot**
Interval: **23-43' BGS**

Date Boring Started: 10/20/14
Date Boring Completed: 10/20/14
Logged By: JEG3
Drilling Contractor: Midwest Testing (Terracon)
Drill Rig:

Remarks: Water encountered at 28.7' BGS in MW-44R while drilling on 10/2014

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

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

LOG OF BORING MW-80 R

SHEET 1 OF 1

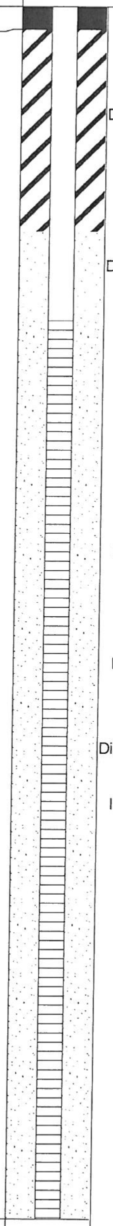
Project:Heskett Station
Project No.:34301012
Location:Mandan, ND
Coordinates:Lat: 46.86789° Long: -100.89320°
Datum:

Surface Elevation:
Drilling Method:HSA
Sampling Method:Split Spoon
Completion Depth:27.0 ft

Unique Well No.:MW-80 R

Depth, feet	Sample No.	Blows/6in.	USCS	LITHOLOGIC DESCRIPTION
0			OL/OH	0-0.5': TOPSOIL (OL/OH): Black; organic roots.
	1	4-4-4-5.		0.5-27': SANDY CLAY (CL): Brown (4/4 7.5 YR) to Black (2.5/1 7.5YR); medium to high plasticity; fine to medium grained sand. Moist; 0% gravel, 30% sand, 70% fines. At 2': Gravel inclusions.
	2	4-5-7-9.		Moist; 10% gravel, 30% sand, 60% fines.
			CL	
5	3	4-4-5-8.		Moist; 0% gravel, 20% sand, 80% fines.
	4	4-4-6-6.		
			CL	(CL): At 8': Color change to 2.5/1 7.5YR black, no odor.
	5	3-4-5-6.		(CL): At 9': Color change to 2.5/2 7.5YR very dark brown. Moist; 0% gravel, 20% sand, 80% fines.
10			CL	
	6	1-3-3-4.		(CL): At 11': Color change to 3/3 7.5YR dark brown. Moist; 0% gravel, 20% sand, 80% fines.
			CL	
	7	1-1-2-1.		(CL): At 13': Color change to 4/4 7.5YR brown. Wet; 0% gravel, 20% sand, 80% fines.
15	8	1-2-2-1.		
20			CL	
	9	7-11-12-17.		At 21': Thin sand lens less than 0.1" thick. Wet; 0% gravel, 20% sand, 80% fines. At 21.5': Thin sand lens less than 0.1" thick.
25				
	10	7-11-17-17.		Wet; 0% gravel, 20% sand, 80% fines. At 26.5': Thin sand lens less than 0.1" thick.

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: 4" by 4"
Type: Steel
Interval: 3' up & 3' down

RISER CASING
Diameter: 2"
Type: Schd 40 PVC
Interval: Stick up to screen (7')

GROUT
Type: Cement
Interval: 0-0.5' BGS

SEAL
Type: Bentonite
Interval: Chips 0.5-5' BGS

SANDPACK
Type: Granusil
Interval: 5-27' BGS

SCREEN
Diameter: 2"
Type: No 10 Slot
Interval: 7-27' BGS

Elevation, feet

Date Boring Started: 10/20/14
Date Boring Completed: 10/20/14
Logged By: JEG3
Drilling Contractor: Midwest Testing (Terracon)
Drill Rig:

Remarks: Water encountered at 11.8' BGS in MW-80R while drilling on 10/20/14

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

EXHIBIT 5-C

WELL COMPLETION REPORTS

Well Number: 10

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CCD

Elevation: Ground; 1722.06 ft. Casing top; 1725.01 ft.
Well Bottom; 1604.01 ft.

Completion: Date drilled; 8-12-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 120 ft.
Encountered water (below surface); 65 ft.
Geophysical log recorded

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.90-115.30 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 115.30-119.30 ft.
Elevation of interval; 1604.01-1608.01 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 114-120 ft.

Grout Seal: Depths (from ground); 0-114 ft.
Date sealed; 8-13-86

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 51.97 ft. below top of casing
Elevation; 1673.04 ft.

Chemistry: Date; 8-21-86
pH; 7.75 Sp. cond; 11050 micromhos/cm
Temp; 8.9 oC

Well Number: 11

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CCD

Elevation: Ground; 1722.10 ft. Casing top; 1725.01 ft.
Well Bottom; 1642.81 ft.

Completion: Date drilled; 8-12-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 80 ft.
Encountered water (below surface); 65 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.90-78.20 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 78.20-82.20 ft.
Elevation of interval; 1642.81-1646.81 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 77-79 ft.

Grout Seal: Depths (from ground); 0-77 ft.
Date sealed; 8-13-86

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 43.83 ft. below top of casing
Elevation; 1681.18 ft.

Chemistry: Date; 8-21-86
pH; 7.75 Sp. cond; 9840 micromhos/cm
Temp; 8.6 oC

Well Number: 12

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CCD

Elevation: Ground; 1721.88 ft. Casing top; 1724.90 ft.
Well Bottom; 1643.51 ft.

Completion: Date drilled; 8-12-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 80 ft.
Encountered water (below surface); 65 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +3.02-58.37 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 58.37-78.37 ft.
Elevation of interval; 1643.51-1663.51 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 57-79 ft.

Grout Seal: Depths (from ground); 0-57 ft.
Date sealed; 8-13-86

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 43.60 ft. below top of casing
Elevation; 1681.30 ft.

Chemistry: Date; 8-21-86
pH; 7.60 Sp. cond; 11440 micromhos/cm
Temp; 8.5 oC

Well Number: 13

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CCD

Elevation: Ground; 1721.88 ft. Casing top; 1724.90 ft.
Well Bottom; 1681.88 ft.

Completion: Date drilled; 11-13-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry

Boring: Diameter; 5 5/8 in. Depth drilled; 40 ft.
Encountered water (below surface); ? ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +3.02-20.37 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC Depths (from ground); 20.37-40.37 ft.
Elevation of interval; 1681.51-1701.51 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 19-41 ft.

Grout Seal: Depths (from ground); 0-19 ft.
Date sealed; 1-27-87

Additional Data:

Static Water Level: Date; 12-15-86
Depth; 30.09 ft. below top of casing
Elevation; 1694.81 ft.

Chemistry: Date; NA
pH; NA Sp. cond; NA
Temp; NA

Well Number: 20

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CAC

Elevation: Ground; 1707.04 ft. Casing top; 1709.48 ft.
Well Bottom; 1627.48 ft.

Completion: Date drilled; 8-12-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry

Boring: Diameter; 5 5/8 in. Depth drilled; 80 ft.
Encountered water (below surface); 45 ft.
Geophysical log recorded

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.44-75.56 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 75.56-79.56 ft.
Elevation of interval; 1627.48-1631.48 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 74-80 ft.

Grout Seal: Depths (from ground); 0-74 ft.
Date sealed; 8-13-86

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 37.96 ft. below top of casing
Elevation; 1671.52 ft.

Chemistry: Date; 8-21-86
pH; 7.98 Sp. cond; 4970 micromhos/cm
Temp; 8.7 oC

Well Number: 21

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CAC

Elevation: Ground; 1707.22 ft. Casing top; 1709.40 ft.
Well Bottom; 1661.90 ft.

Completion: Date drilled; 8-12-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;

Boring: Diameter; 5 5/8 in. Depth drilled; 50 ft.
Encountered water (below surface); 45 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.66-21.32 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 21.32-45.32 ft.
Elevation of interval; 1661.90-1685.90 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 20-46 ft.

Grout Seal: Depths (from ground); 0-20 ft.
Date sealed; 8-13-86

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 29.33 ft. below top of casing
Elevation; 1680.07 ft.

Chemistry: Date; 8-21-86
pH; 6.95 Sp. cond; 13920 micromhos/cm
Temp; 8.5 oC

Well Number: 30

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CBA

Elevation: Ground; 1715.55 ft. Casing top; 1717.64 ft.
Well Bottom; 1595.64 ft.

Completion: Date drilled; 8-12-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 120 ft.
Encountered water (below surface); 60 ft.
Geophysical log recorded

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.90-115.91 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 115.91-119.91 ft.
Elevation of interval; 1595.64-1599.64 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 114-120 ft.

Grout Seal: Depths (from ground); 0-114 ft.
Date sealed; 8-13-86

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 49.41 ft. below top of casing
Elevation; 1668.23 ft.

Chemistry: Date; 8-21-86
pH; 7.95 Sp. cond; 1993 micromhos/cm
Temp; 8.6 oC

Well Number: 31

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CBA

Elevation: Ground; 1715.24 ft. Casing top; 1717.58 ft.
Well Bottom; 1635.58 ft.

Completion: Date drilled; 8-12-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 80 ft.
Encountered water (below surface); 60 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.34-75.66 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 75.66-79.66 ft.
Elevation of interval; 1635.58-1639.58 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 74-80 ft.

Grout Seal: Depths (from ground); 0-74 ft.
Date sealed; 8-13-86

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 43.54 ft. below top of casing
Elevation; 1674.04 ft.

Chemistry: Date; 8-21-86
pH; 7.96 Sp. cond; 1993 micromhos/cm
Temp; 7.8 oC

Well Number: 32

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CBA

Elevation: Ground; 1715.34 ft. Casing top; 1717.79 ft.
Well Bottom; 1641.69 ft.

Completion: Date drilled; 8-12-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 80 ft.
Encountered water (below surface); 60 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.45-53.65 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 53.65-73.65 ft.
Elevation of interval; 1641.69-1661.69 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 52-75 ft.

Grout Seal: Depths (from ground); 0-52 ft.
Date sealed; 8-13-86

Additional Data:

Static Water Level: Date; 8-21-86
Depth; 42.03 ft. below top of casing
Elevation; 1675.76 ft.

Chemistry: Date; 8-21-86
pH; 7.22 Sp. cond; 3000 micromhos/cm
Temp; 8.0 oC

Well Number: 33

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CBA

Elevation: Ground; 1715.34 ft. Casing top; 1717.79 ft.
Well Bottom; 1672.79 ft.

Completion: Date drilled; 11-13-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry

Boring: Diameter; 5 5/8 in. Depth drilled; 45 ft.
Encountered water (below surface); ? ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.45-25.65 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 25.65-45.65 ft.
Elevation of interval; 1669.69-1689.69 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 24-45 ft.

Grout Seal: Depths (from ground); 0-24 ft.
Date sealed; 1-27-87

Additional Data:
Static Water Level: Date; 12-15-86
Depth; 40.68 ft. below top of casing
Elevation; 1677.11 ft.

Chemistry: Date; NA
pH; NA Sp. cond; NA
Temp; NA

Well Number: 40

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CDB

Elevation: Ground; 1708.02 ft. Casing top; 1710.15 ft.
Well Bottom; 1592.25 ft.

Completion: Date drilled; 8-13-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 120 ft.
Encountered water (below surface); 50 ft.
Geophysical log recorded

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.13-111.77 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 111.77-115.77 ft.
Elevation of interval; 1592.25-1596.25 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 110-117 ft.

Grout Seal: Depths (from ground); 0-117 ft.
Date sealed; 8-13-86

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 63.72 ft. below top of casing
Elevation; 1646.43 ft.

Chemistry: Date; 8-21-86
pH; 7.58 Sp. cond; 6260 micromhos/cm
Temp; 8.2 oC

Well Number: 41

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CDB

Elevation: Ground; 1708.03 ft. Casing top; 1710.07 ft.
Well Bottom; 1626.77 ft.

Completion: Date drilled; 8-13-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 82 ft.
Encountered water (below surface); 50 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.04-77.26 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 77.26-81.26 ft.
Elevation of interval; 1626.77-1630.77 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 76-82 ft.

Grout Seal: Depths (from ground); 0-76 ft.
Date sealed; 8-13-86

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 36.58 ft. below top of casing
Elevation; 1673.49 ft.

Chemistry: Date; 8-21-86
pH; 7.57 Sp. cond; 5480 micromhos/cm
Temp; 8.4 oC

Well Number: 42

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CDB

Elevation: Ground; 1708.12 ft. Casing top; 1710.31 ft.
Well Bottom; 1652.61 ft.

Completion: Date drilled; 8-13-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 60 ft.
Encountered water (below surface); 50 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.19-35.51 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 35.51-55.51 ft.
Elevation of interval; 1652.61-1672.61 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 34-56 ft.

Grout Seal: Depths (from ground); 0-34 ft.
Date sealed; 8-13-86

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 32.88 ft. below top of casing
Elevation; 1677.43 ft.

Chemistry: Date; 8-21-86
pH; 7.22 Sp. cond; 5060 micromhos/cm
Temp; 8.6 oC

Well Number: 43

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CDD

Elevation: Ground; 1708.92 ft. Casing top; 1711.03 ft.
Well Bottom; 1650.14 ft.

Completion: Date drilled; 9-18-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry

Boring: Diameter; 5 5/8 in. Depth drilled; 60 ft.
Encountered water (below surface); 25 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.11-54.78 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 54.78-58.78 ft.
Elevation of interval; 1650.14-1654.14 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 53-59 ft.

Grout Seal: Depths (from ground); 0-53 ft.
Date sealed; 9-18-86

Additional Data:
Static Water Level: Date; 10-4-86
Depth; 25.85 ft. below top of casing
Elevation; 1685.18 ft.

Chemistry: Date; 10-4-86
pH; 6.70 Sp. cond; 6950 micromhos/cm
Temp; 8.5 oC

Well Number: 44

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CDD

Elevation: Ground; 1709.09 ft. Casing top; 1711.40 ft.
Well Bottom; 1685.88 ft.

Completion: Date drilled; 9-18-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry

Boring: Diameter; 5 5/8 in. Depth drilled; 25 ft.
Encountered water (below surface); 25 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.31-3.21 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 3.21-23.54 ft.
Elevation of interval; 1685.88-1705.88 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 2.5-24.0 ft.

Grout Seal: Depths (from ground); 0-2.5 ft.
Date sealed; 9-18-86

Additional Data:
Static Water Level: Date; 10-4-86
Depth; 21.92 ft. below top of casing
Elevation; 1689.48 ft.

Chemistry: Date; 10-4-86
pH; 6.72 Sp. cond; 10270 micromhos/cm
Temp; 9.1 oC

Well Number: 45

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CDB

Elevation: Ground; 1708.12 ft. Casing top; 1710.31 ft.
Well Bottom; 1668.12 ft.

Completion: Date drilled; 11-13-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;

Boring: Diameter; 5 5/8 in. Depth drilled; 40 ft.
Encountered water (below surface); ? ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.19-20.51 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 20.51-40.51 ft.
Elevation of interval; 1667.61-1687.61 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 19-41 ft.

Grout Seal: Depths (from ground); 0-19 ft.
Date sealed; 1-27-86

Additional Data:
Static Water Level: Date; 12-15-86
Depth; 28,71 ft. below top of casing
Elevation; 1681.60 ft.

Chemistry: Date; NA
pH; NA Sp. cond; NA
Temp; NA

Well Number: 50

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CAD

Elevation: Ground; 1674.58 ft. Casing top; 1677.01 ft.
Well Bottom; 1647.51 ft.

Completion: Date drilled; 8-13-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 30 ft.
Encountered water (below surface); 17 ft.
Geophysical log recorded

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.43-7.07 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 7.07-27.07 ft.
Elevation of interval; 1647.51-1667.51 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 6-29 ft.

Grout Seal: Depths (from ground); 0-6 ft.
Date sealed; 8-13-86

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 5.45 ft. below top of casing
Elevation; 1671.56 ft.

Chemistry: Date; 8-21-86
pH; 7.56 Sp. cond; 6480 micromhos/cm
Temp; 10.8 oC

Well Number: 51

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CAD

Elevation: Ground; 1674.47 ft. Casing top; 1676.70 ft.
Well Bottom; 1637.33 ft.

Completion: Date drilled; 9-18-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 40 ft.
Encountered water (below surface); 18 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.23-32.14 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 32.14-37.14 ft.
Elevation of interval; 1637.33-1642.33 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 31-38 ft.

Grout Seal: Depths (from ground); 0-31 ft.
Date sealed; 9-18-86

Additional Data:
Static Water Level: Date; 10-4-86
Depth; 5.77 ft. below top of casing
Elevation; 1670.93 ft.

Chemistry: Date; 10-4-86
pH; 7.46 Sp. cond; 3700 micromhos/cm
Temp; 8.2 oC

Well Number: 52

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CAD

Elevation: Ground; 1674.45 ft. Casing top; 1676.71 ft.
Well Bottom; 1658.01 ft.

Completion: Date drilled; 9-18-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 20 ft.
Encountered water (below surface); 18 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.26-6.44 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 6.44-16.44 ft.
Elevation of interval; 1658.01-1668.01 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 5-18 ft.

Grout Seal: Depths (from ground); 0-5 ft.
Date sealed; 9-18-86

Additional Data:
Static Water Level: Date; 10-4-86
Depth; 4.13 ft. below top of casing
Elevation; 1672.58 ft.

Chemistry: Date; 10-4-86
pH; 7.29 Sp. cond; 6300 micromhos/cm
Temp; 9.4 oC

Well Number: 53

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10DCC

Elevation: Ground; 1685.71 ft. Casing top; 1688.17 ft.
Well Bottom; 1665.70 ft.

Completion: Date drilled; 9-18-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry

Boring: Diameter; 5 5/8 in. Depth drilled; 21 ft.
Encountered water (below surface); 15 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.46-5.01 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 5.01-20.01 ft.
Elevation of interval; 1665.70-1680.70 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 4-21 ft.

Grout Seal: Depths (from ground); 0-4 ft.
Date sealed; 9-18-86

Additional Data:
Static Water Level: Date; 10-4-86
Depth; 6.30 ft. below top of casing
Elevation; 1681.87 ft.

Chemistry: Date; 10-4-86
pH; NA Sp. cond; NA micromhos/cm
Temp; NA oC

Well Number: 54

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10DCC

Elevation: Ground; 1685.71 ft. Casing top; 1688.10 ft.
Well Bottom; 1633.11 ft.

Completion: Date drilled; 9-18-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry

Boring: Diameter; 5 5/8 in. Depth drilled; 60 ft.
Encountered water (below surface); 15 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.39-47.60 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 47.60-52.60 ft.
Elevation of interval; 1633.11-1638.11 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 46-54 ft.

Grout Seal: Depths (from ground); 0-46 ft.
Date sealed; 9-18-86

Additional Data:
Static Water Level: Date; 10-4-86
Depth; 15.16 ft. below top of casing
Elevation; 1672.94 ft.

Chemistry: Date; 10-4-86
pH; 9.55 Sp. cond; 1100 micromhos/cm
Temp; 9.8 oC

Well Number: 55

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10DCA

Elevation: Ground; 1693.86 ft. Casing top; 1696.10 ft.
Well Bottom; 1636.95 ft.

Completion: Date drilled; 9-18-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry

Boring: Diameter; 5 5/8 in. Depth drilled; 60 ft.
Encountered water (below surface); 45 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.24-31.91 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 31.91-56.91 ft.
Elevation of interval; 1636.95-1661.95 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 30-58 ft.

Grout Seal: Depths (from ground); 0-30 ft.
Date sealed; 9-18-86

Additional Data:

Static Water Level: Date; 10-4-86
Depth; 29.46 ft. below top of casing
Elevation; 1666.64 ft.

Chemistry: Date; 10-4-86
pH; 6.81 Sp. cond; 10840 micromhos/cm
Temp; 8.5 oC

Well Number: 56

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-80-10DCA

Elevation: Ground; 1693.86 ft. Casing top; 1696.42 ft.
Well Bottom; 1597.99 ft.

Completion: Date drilled; 9-18-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry

Boring: Diameter; 5 5/8 in. Depth drilled; 100 ft.
Encountered water (below surface); 45 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.56-91.87 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 91.87-96.87 ft.
Elevation of interval; 1597.99-1601.99 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 90-98 ft.

Grout Seal: Depths (from ground); 0-90 ft.
Date sealed; 9-18-86

Additional Data:
Static Water Level: Date; 10-4-86
Depth; 42.03 ft. below top of casing
Elevation; 1654.39 ft.

Chemistry: Date; 10-4-86
pH; 8.44 Sp. cond; 4160 micromhos/cm
Temp; 8.3 oC

Well Number: 60

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-18-10CDB

Elevation: Ground; 1714.23 ft. Casing top; 1716.42 ft.
Well Bottom; 1662.02 ft.

Completion: Date drilled; 8-13-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 60 ft.
Encountered water (below surface); 45 ft.
Geophysical log recorded

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.19-22.21 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 22.21-52.21 ft.
Elevation of interval; 1662.02-1692.02 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 21-54 ft.

Grout Seal: Depths (from ground); 0-21 ft.
Date sealed; 8-13-86

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 31.01 ft. below top of casing
Elevation; 1685.41 ft.

Chemistry: Date; 8-21-86
pH; 6.94 Sp. cond; 15760 micromhos/cm
Temp; 8.5 oC

Well Number: 61

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CDA

Elevation: Ground; 1714.23 ft. Casing top; 1716.53 ft.
Well Bottom; 1670.89 ft.

Completion: Date drilled; 9-18-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry

Boring: Diameter; 5 5/8 in. Depth drilled; 46 ft.
Encountered water (below surface); 37 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.30-13.34 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 13.34-43.34 ft.
Elevation of interval; 1670.89-1700.89 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 12-45 ft.

Grout Seal: Depths (from ground); 0-12 ft.
Date sealed; 9-18-86

Additional Data:
Static Water Level: Date; 10-4-86
Depth; 32.58 ft. below top of casing
Elevation; 1683.95 ft.

Chemistry: Date; 10-4-86
pH; 6.83 Sp. cond; 12750 micromhos/cm
Temp; 8.4 oC

Well Number: 62

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10CDB

Elevation: Ground; 1714.32 ft. Casing top; 1716.67 ft.
Well Bottom; 1681.40 ft.

Completion: Date drilled; 9-18-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry

Boring: Diameter; 5 5/8 in. Depth drilled; 35 ft.
Encountered water (below surface); 35 ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.35-12.92 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 12.92-32.91 ft.
Elevation of interval; 1681.40-1701.40 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 11-34 ft.

Grout Seal: Depths (from ground); 0-11 ft.
Date sealed; 9-18-86

Additional Data:
Static Water Level: Date; 10-4-86
Depth; 32.74 ft. below top of casing
Elevation; 1683.93 ft.

Chemistry: Date; 10-4-86
pH; 6.71 Sp. cond; 13170 micromhos/cm
Temp; 9.3 oC

Well Number: 70

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-16ABA

Elevation: Ground; 1733.18 ft. Casing top; 1735.67 ft.
Well Bottom; 1634.57 ft.

Completion: Date drilled; 8-13-86
Driller; Mohl Drilling, Beulah, ND
Method of drilling; Air rotary, dry;
some air-mist

Boring: Diameter; 5 5/8 in. Depth drilled; 102 ft.
Encountered water (below surface); 45 ft.
Geophysical log recorded

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.49-94.61 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 94.61-98.61 ft.
Elevation of interval; 1634.57-1638.57 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 93-99 ft.

Grout Seal: Depths (from ground); 0-93 ft.
Date sealed; 8-13-86

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 54.20 ft. below top of casing
Elevation; 1681.47 ft.

Chemistry: Date; 8-21-86
pH; 7.85 Sp. cond; 13000 micromhos/cm
Temp; 10.1 oC

Well Number: (WS1)

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-DBB

Elevation: Ground; 1679.61 ft. Casing top; 1681.71 ft.
Well Bottom; 1606.73 ft.
Repaired casing top (1-13-86); 1683.67 ft.

Completion: Date drilled; 9-22-81
Driller; Water Supply, Inc.
Method of drilling; NA

Boring: Diameter; NA in. Depth drilled; 73 ft.
Encountered water (below surface); NA ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +2.7-40, 45-73 ft.
(as of 1-13-87); +4.7-40, 45-73 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 40-45 ft.
Elevation of interval; 1634.61-1639.61 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 37-47 ft.

Grout Seal: Depths (from ground); 0-37 ft.
Date sealed; NA

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 24.61 ft. below top of casing
Elevation; 1657.10 ft.

Chemistry: Date; 8-21-86
pH; 7.47 Sp. cond; 1899 micromhos/cm
Temp 7.0 oC

Well Number: (WS1A)

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-DBB

Elevation: Ground; 1679.10 ft. Casing top; 1682.23 ft.
Well Bottom; 1657.10 ft.

Completion: Date drilled; 8-5-85
Driller; Water Supply, Inc.
Method of drilling; NA

Boring: Diameter; NA in. Depth drilled; 23 ft.
Encountered water (below surface); NA ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +3.2-17 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 17-22 ft.
Elevation of interval; 1657.10-1662.10 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 15-23 ft.

Grout Seal: Depths (from ground); 0-15 ft.
Date sealed; NA

Additional Data:
Static Water Level: Date; 8-21-86
Depth; DRY ft. below top of casing
Elevation; ft.

Chemistry: Date: 8-21-86
pH; NA Sp. cond; NA micromhos/cm
Temp; NA oC

Well Number: (WS1B)

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10DBB

Elevation: Ground; 1678.80 ft. Casing top; 1682.07 ft.
Well Bottom; 1648.80 ft.

Completion: Date drilled; 8-6-85
Driller; Water Supply, Inc.
Method of drilling; NA

Boring: Diameter; NA in. Depth drilled; 30 ft.
Encountered water (below surface); NA ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +3.3-25 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 25-30 ft.
Elevation of interval; 1648.80-1653.80 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 23-30 ft.

Grout Seal: Depths (from ground); 0-22 ft.
Date sealed; NA

Additional Data:
Static Water Level: Date; 8-21-86
Depth; 24.48 ft. below top of casing
Elevation; 1657.59 ft.

Chemistry: Date; 8-21-86
pH; 7.07 Sp. cond; 3940 micromhos/cm
Temp; 8.5 oC

Well Number: (WS2)

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10DCC

Elevation: Ground; 1696.00 ft. Casing top; 1698.64 ft.
Well Bottom; 1607.00 ft.

Completion: Date drilled; 9-23-81
Driller; Water Supply, Inc.
Method of drilling; NA

Boring: Diameter; NA in. Depth drilled; 90 ft.
Encountered water (below surface); NA ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +3-56, 61-89 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 56-61 ft.
Elevation of interval; 1635.00-1640.00 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 53-62 ft.

Grout Seal: Depths (from ground); 0-52 ft.
Date sealed; NA

Additional Data:
Static Water Level: Date; 10-4-86
Depth; 33.86 ft. below top of casing
Elevation; 1664.78 ft.

Chemistry: Date; 8-21-86
pH; 7.04 Sp. cond; 3760 micromhos/cm
Temp; 8.6 oC

Well Number: (WS3)

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10DBA

Elevation: Ground; 1658.00 ft. Casing top; 1661.00 ft.
Well Bottom; 1608.00 ft.

Completion: Date drilled; 9-21-81
Driller; Water Supply, Inc.
Method of drilling; NA

Boring: Diameter; NA in. Depth drilled; 50 ft.
Encountered water (below surface); NA ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +3-25, 30-50 ft.

Screen: Diameter; 2 in. Slot size; 20

Material; Factory slotted PVC
Depths (from ground); 25-30 ft.
Elevation of interval; 1628.00-1633.00 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 24-32 ft.

Grout Seal: Depths (from ground); 0-23 ft.
Date sealed; NA

Additional Data:
Static Water Level: Date; 9-4-86
Depth; 14.67 ft. below top of casing
Elevation; 1646.33 ft.

Chemistry: Date; NA
pH; NA Sp. cond; NA micromhos/cm
Temp; NA oC

Well Number: (WS3A)

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10DBA

Elevation: Ground; 1657.70 ft. Casing top; 1660.81 ft.
Well Bottom; 1645.31 ft.

Completion: Date drilled; 8-5-85
Driller; Water Supply, Inc.
Method of drilling; NA

Boring: Diameter; NA in. Depth drilled; 13 ft.
Encountered water (below surface); NA ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +3.1-7.5 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 7.5-12.5 ft.
Elevation of interval; 1645.31-1650.31 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 6-13 ft.

Grout Seal: Depths (from ground); 0-6 ft.
Date sealed; NA

Additional Data:
Static Water Level: Date; 10-4-86
Depth; 8.37 ft. below top of casing
Elevation; 1652.44 ft.

Chemistry: Date; NA
pH; NA Sp. cond; NA micromhos/cm
Temp; NA oC

Well Number: (WS4)

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10DBA

Elevation: Ground; 1659.61 ft. Casing top; 1662.61 ft.
Well Bottom; 1607.60 ft.

Completion: Date drilled; 9-24-81
Driller; Water Supply, Inc.
Method of drilling; NA

Boring: Diameter; NA in. Depth drilled; 52 ft.
Encountered water (below surface); NA ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +3-30, 35-52 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 30-35 ft.
Elevation of interval; 1624.60-1629.60 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 27-36 ft.

Grout Seal: Depths (from ground); 0-26 ft.
Date sealed; NA

Additional Data:
Static Water Level: Date; 9-4-86
Depth; 19.62 ft. below top of casing
Elevation; 1642.99 ft.

Chemistry: Date; NA
pH; NA Sp. cond; NA micromhos/cm
Temp; NA oC

Well Number: (WS4A)

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10DBA

Elevation: Ground; 1659.49 ft. Casing top; 1662.49 ft.
Well Bottom; 1641.50 ft.

Completion: Date drilled; 9-24-81
Driller; Water Supply, Inc.
Method of drilling; NA

Boring: Diameter; NA in. Depth drilled; 18 ft.
Encountered water (below surface); NA ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +3-13 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 13-18 ft.
Elevation of interval; 1641.50-1646.50 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 11-18 ft.

Grout Seal: Depths (from ground); 0-11 ft.
Date sealed; NA

Additional Data:
Static Water Level: Date; 9-4-86
Depth; 17.29 ft. below top of casing
Elevation; 1645.20 ft.

Chemistry: Date; NA
pH; NA Sp. cond; NA micromhos/cm
Temp; NA oC

Well Number: (WS4B)

Project: MDU Ash Disposal Program

Construction Data:

Location: 139-81-10DBA

Elevation: Ground; 1659.75 ft. Casing top; 1662.75 ft.
Well Bottom; 1635.80 ft.

Completion: Date drilled; 8-5-85
Driller; Water Supply, Inc.
Method of drilling; NA

Boring: Diameter; NA in. Depth drilled; 25 ft.
Encountered water (below surface); NA ft.

Casing: Diameter; 2 in. Material; Sch. 40 PVC
Depths (from ground); +3.1-19.0 ft.

Screen: Diameter; 2 in. Slot size; 20
Material; Factory slotted PVC
Depths (from ground); 19-24 ft.
Elevation of interval; 1635.80-1640.80 ft.

Sand Pack: Type of sand; Washed sand
Depths (from ground); 18-25 ft.

Grout Seal: Depths (from ground); 0-18 ft.
Date sealed; NA

Additional Data:
Static Water Level: Date; 9-4-86
Depth; 17.39 ft. below top of casing
Elevation; 1645.36 ft.

Chemistry: Date; NA
pH; NA Sp. cond; NA micromhos/cm
Temp; NA oC

EXHIBIT 5-E

LITHOLOGIC LOGS

Wells 10, 11, 12 and 13

0-1	Top soil, silty, clayey, sandy, brown, calcareous; with some limestone pebbles.
1-11	Silt, clayey, brownish-tan, slightly indurated, very dry, calcareous; with thin coarse-grained, clean silt lenses and a few small (less than .5 in.) iron oxide concretions. Abundant small gypsum crystals (less than .13 in. long). Some small, black flakes of organic plant material. Cannonball-Ludlow Formations.
11-14	Silt, as above, with some (less than 20%) very fine- to fine-grained sand interspersed.
14-30	Silt, as above, clayey, less sand than above interval, oxidized; with very fine-grained silty sand lenses and very few gypsum crystals.
30-41	Silt, very clayey, with some (less than 20%) very fine-grained sand interspersed, steel-gray (color change), moderately indurated; with fewer small gypsum crystals than above intervals.
41-59	Silt, as above, very clayey, with some (less than 20%) fine- to medium-grained sand interspersed in a silt and clay matrix.
59-65	Silt, as above, with abundant (more than 20%) fine- to medium-grained sand interspersed.
65-81	Silt, clayey, steel-gray to bluish, moderately indurated; with thin coarse-grained silt to very fine-grained sand lenses in an otherwise fine silt to clay matrix.
81-84	Clay, silty, steel-gray to bluish, moderately indurated, dense.
84-91	Siltstone, sandy, clayey, steel-gray to bluish, slightly indurated; with small fine-grained sand lenses and abundant (more than 20%) sand interspersed in the matrix.
91-110	Silt, clayey, bluish-gray, moderately indurated; with thin (less than 1 foot) mudstone lenses.
110-120	Silt, very clayey, steel-gray to bluish, moderately indurated, very dense. Cannonball-Ludlow Formations.

Wells 20 and 21

0-1	Top soil, silty, sandy, clayey, dark-brown, calcareous; with some limestone and granite pebbles.
1-21	Silt, clayey, with minor amounts (less than 10%) of very fine-grained sand interspersed, brownish-tan, slightly indurated, calcareous, oxidized; with small iron oxide concretions and abundant small gypsum crystals. Cannonball-Ludlow Formations.
21-26	Silt, as above, steel-gray (color change).
26-49	Silt, clayey, with some (less than 20%) very fine- to medium-grained sand interspersed, steel-gray to bluish, slightly indurated; with very few small gypsum crystals and some thin (less than 1 foot) siltstone lenses.
49-53	Silt, as above, with abundant (more than 20%) fine- to medium-grained sand interspersed.
53-63	Silt, as above, clayey, less sand, with thin (less than 1 foot) siltstone to mudstone lenses.
63-80	Silt, very clayey, steel-gray to bluish, moderately indurated, very dense. Cannonball-Ludlow Formations.

Wells 30, 31, 32 and 33

0-1	Top soil, silty, sandy, brownish, calcareous; with some granite and limestone pebbles.
1-2	Pebble-loam (glacial till), silty, sandy, clayey, yellowish-brown, dry, calcareous.
2-31	Silt, clayey, with minor amounts (less than 10%) of very fine-grained sand interspersed, brownish-tan, slightly indurated, calcareous, oxidized; with small iron oxide concretions. Some small, black flakes organic plant material. Cannonball-Ludlow Formations.
31-44	Silt, clayey, steel-gray (color change), slightly indurated, calcareous; with small iron oxide concretions, thin coarse silt lenses, small gypsum crystals and gray to reddish-brown mottling.

44-61	Silt, as above, with some (less than 20%) fine- to medium-grained sand interspersed.
61-65	Silt, as above, with abundant (more than 20%) fine- to medium-grained sand interspersed, dense.
65-76	Silt, as above, clayey, less sand, some thin (less than 1 foot) lenses of siltstone to mudstone.
76-80	Siltstone, sandy, clayey, steel-gray to bluish, slightly indurated; with small fine-grained sand lenses and abundant (more than 20%) fine-grained sand interspersed in the matrix.
80-92	Silt, clayey, steel-gray to bluish, moderately indurated, with some (less than 20%) very fine- to fine grained sand interspersed.
92-120	Silt, very clayey, steel-gray to bluish, moderately indurated, very dense. Cannonball-Ludlow Formations.

Well 40

0-1	Top soil, sandy, silty, brownish-tan, calcareous; with some granite and limestone pebbles.
1-5	Pebble-loam (glacial till), sandy, silty, with detrital lignite and organic matter, yellowish-brown, very dry, calcareous.
5-22	Sand, very fine- to medium-grained, unconsolidated, with thin lenses of clay and detrital lignite, brownish-yellow, calcareous.
22-40	Silt, clayey, with minor amounts (less than 10%) very fine-grained sand interspersed, brownish-tan, slightly indurated, calcareous, oxidized; with small iron oxide concretions and small gypsum crystals; Cannonball-Ludlow Formations.
40-51	Silt, clayey, with minor amounts (less than 10%) of very fine-grained sand interspersed, steel-gray (color change), moderately indurated; with some reddish-brown mottling and some very thin (less than 6 inches) mudstone lenses.
51-58	Silt, as above, with abundant (more than 20%) fine-grained sand and thin silty-clay lenses.

58-62	Siltstone, sandy, clayey, steel-gray to bluish, moderately indurated; with small fine-grained sand lenses and abundant (more than 20%) sand interspersed in the matrix.
62-70	Silt, clayey, with some (less than 20%) fine- to medium-grained sand interspersed, steel-gray to bluish, moderately indurated; with thin (less than 2 feet) sandy lenses.
70-80	Silt, as above, very clayey, some (less than 10%) fine-grained sand interspersed; less sand than above interval.
80-120	Silt, as above, dark-steel-gray. Cannonball-Ludlow Formations.

Wells 41, 42 and 43

0-1	Top soil, sandy, silty, dark-brown, calcareous; with some granite and limestone pebbles.
1-4	Pebble-loam (glacial till), sandy, silty, clayey, yellowish-brown, very dry, calcareous.
4-40	Silt, clayey, with some (less than 20%) very fine-grained sand interspersed, brownish-tan, unconsolidated, noncompacted, calcareous to 25 feet, oxidized; with small iron oxide concretions and abundant small gypsum crystals. Cannonball-Ludlow Formations.
40-51	Silt, clayey, with minor amounts (less than 10%) of very fine-grained sand interspersed, steel-gray (color change), moderately indurated; with some reddish-brown mottling and some very thin (less than 6 inches) mudstone lenses.
51-58	Silt, as above, with abundant (more than 20%) fine-grained sand and thin silty-clay lenses.
58-62	Siltstone, sandy, clayey, steel-gray to bluish, moderately indurated; with small fine-grained sand lenses and abundant (more than 20%) sand interspersed in the matrix.
62-70	Silt, clayey, with some (less than 20%) fine- to medium-grained sand interspersed, steel-gray to bluish, moderately indurated; with thin (less than 2 feet) sandy lenses.

30-40	Silt, as above, very clayey, less sand than above interval, dark-steel-gray. Cannonball-Ludlow Formations.

Wells 53 and 54

0-4	Top soil, clayey, silty, very dark-brown, wet, sticky.
4-15	Clay, silty, with some (less than 20%) fine- to medium-grained sand interspersed, brownish-tan, slightly indurated, dry, calcareous; with small iron oxide concretions, small gypsum crystals and occasional reddish-brown mottling; Cannonball-Ludlow Formations.
15-20	Sand, very fine-grained to medium-grained, silty, clayey, unconsolidated, yellowish-brown, oxidized.
20-30	Silt, clayey, with some (less than 20%) fine-grained sand interspersed, steel-gray (color change), slightly indurated; with clay and sand lenses, some small concretions and some small gypsum crystals.
30-45	Silt, as above, very clayey.
45-60	Silt, as above, clayey, brownish-gray, moderately indurated, some reddish-brown mottling. Cannonball-Ludlow Formations.

Wells 55 and 56

0-5	Sandy-loam (glacial), with fine- to medium-grained sand, silty, calcareous; with small granite and limestone pebbles.
5-26	Clay, silty, with minor amounts (less than 10%) of very fine-grained sand, dark-brownish-tan, moderately indurated, brittle, very dry, calcareous; with small iron oxide concretions, small gypsum crystals and occasional thin sandstone laminae. Some small, black flakes of organic plant material. Cannonball-Ludlow Formations.
26-35	Clay, as above, very silty, sandy, brownish-tan, oxidized.

35-40	Silt, clayey, with some (less than 20%) very fine- to fine-grained sand interspersed, steel-gray (color change) moderately indurated; with small gypsum crystals and occasional clay lenses.
40-60	Silt, as above, with minor amounts (less than 10%) of fine-grained sand interspersed.
60-85	Silt, as above, clayey, less sand than above interval.
85-100	Silt, as above, very clayey, with minor amounts (less than 10%) of sand interspersed, light-gray. Cannonball-Ludlow Formations.

Wells 60, 61 and 62

0-2	Top soil, silty, clayey, dark-brown to tanish-brown, calcareous.
2-25	Silt, very clayey, with some minor amounts (less than 10%) of very fine- to fine-grained sand interspersed, brownish-tan, slightly indurated, dry, calcareous; with abundant small gypsum crystals and thin silt and sand lenses; Cannonball-Ludlow Formations.
25-29	Silt, as above, with abundant (more than 20%) fine- to medium-grained sand interspersed.
29-36	Silt, as above, clayey, less sand than above interval, dark-brownish-tan, oxidized.
36-60	Silt, very clayey, with some (less than 20%) very fine-grained sand interspersed, steel-gray (color change), moderately indurated; with thin (less than 1 foot) sandy-silt lenses. Cannonball-Ludlow Formations.

Well 70 0-2	Pebble-loam (glacial till), clayey, sandy, yellowish-brown, unconsolidated, damp, calcareous.
2-21	Silty, clayey, with some (less than 20%) fine-grained sand interspersed, brownish-tan, moderately indurated, very dry, calcareous, oxidized; with small iron oxide concretions and abundant small gypsum crystals. Cannonball-Ludlow Formations.

21-24	Shale, silty, steel- to dark-gray (color change), indurated, fissile, very dry; with occasional thin silt and sand lenses.
24-31	Silt, clayey, with abundant (more than 30%) sand, steel-gray, moderately indurated.
31-62	Silt, clayey, with some (less than 20%) very fine- to fine- grained sand interspersed, steel-gray, moderately indurated; with some small gypsum crystals and small iron oxide concretions.
62-76	Silt, as above, with some (less than 20%) fine-grained sand interspersed.
76-82	Silt, as above, with abundant (more than 20%) fine- to medium-grained sand.
82-100	Silt, as above, clayey, with some (less than 20%) fine-grained sand interspersed, dark-gray. Cannonball-Ludlow Formations.

R.M. HESKETT STATION

S. 1/2 SECTION 10, LOT 1 SECTION 11
TOWNSHIP 139 NORTH - RANGE 81 WEST
MORTON COUNTY, NORTH DAKOTA

LEGEND

- - - - SETBACK LINE
- · - · - BUFFER ZONE
00○ OBSERVATION WELL
(0000) - GROUND ELEVATION (Feet above MSL)

0 100 200 400 Feet

CONTOUR INTERVAL = 10 Feet

North

EXHIBIT 5-A

MONTANA - DAKOTA UTILITIES CO.
R.M. HESKETT STATION SITE

VERTICAL EXAGGERATION x 10
WATER LEVELS FROM 10/16/86

PLATE - A

EXHIBIT 5—B

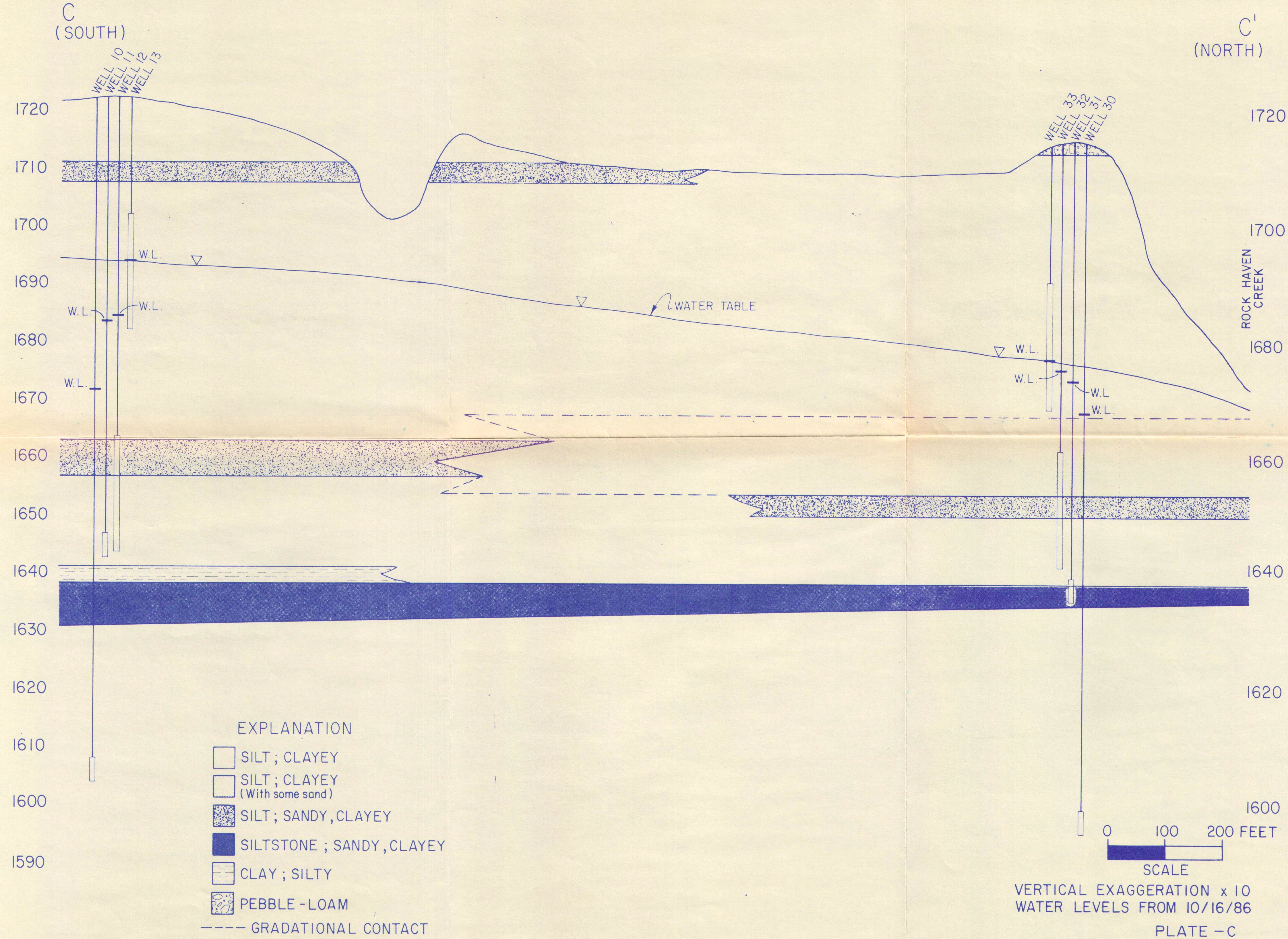
MONTANA - DAKOTA UTILITIES CO
R.M. HESKETT STATION SITE

VERTICAL EXAGGERATION x 10
WATER LEVELS FROM 10/16/86

PLATE – B

EXHIBIT 5–B

MONTANA–DAKOTA UTILITIES CO.
R.M. HESKETT STATION SITE



VERTICAL EXAGGERATION x 10
WATER LEVELS FROM 10/16/86

PLATE – C

EXHIBIT 5–B

MONTANA – DAKOTA UTILITIES CO.
R.M. HESKETT STATION SITE

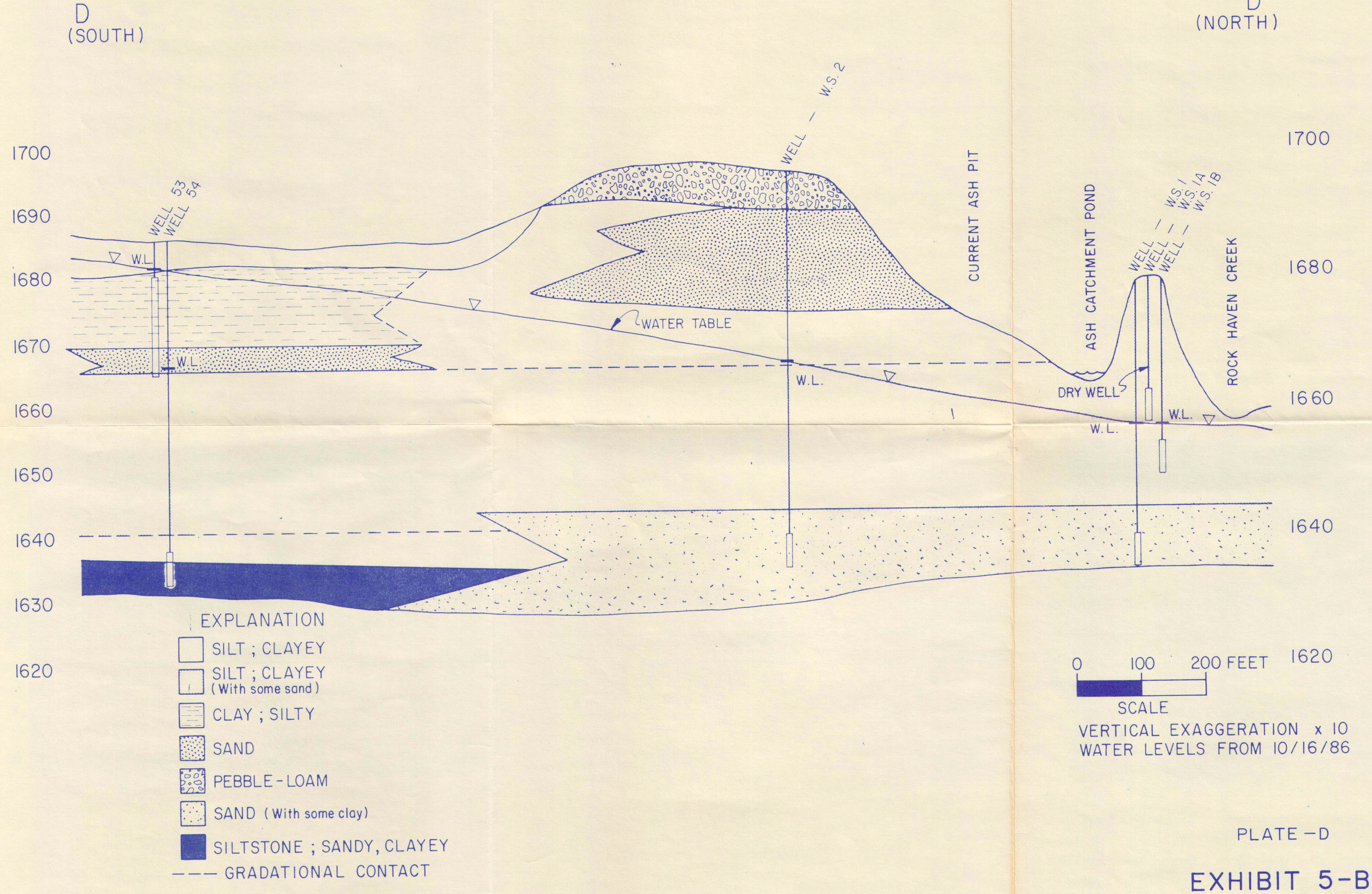
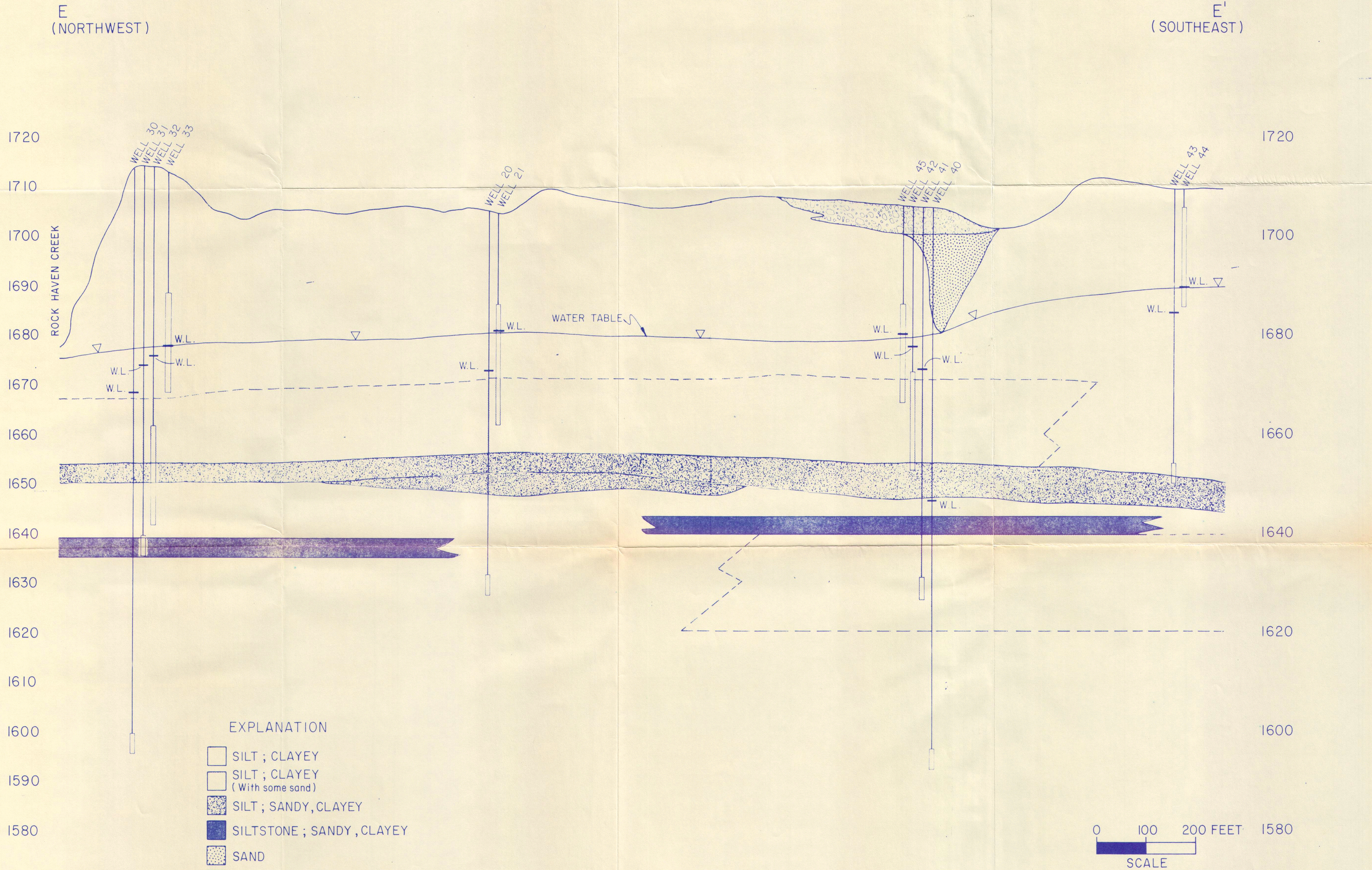


PLATE -D

EXHIBIT 5-B

MONTANA-DAKOTA UTILITIES CO.
R.M. HESKETT STATION SITE

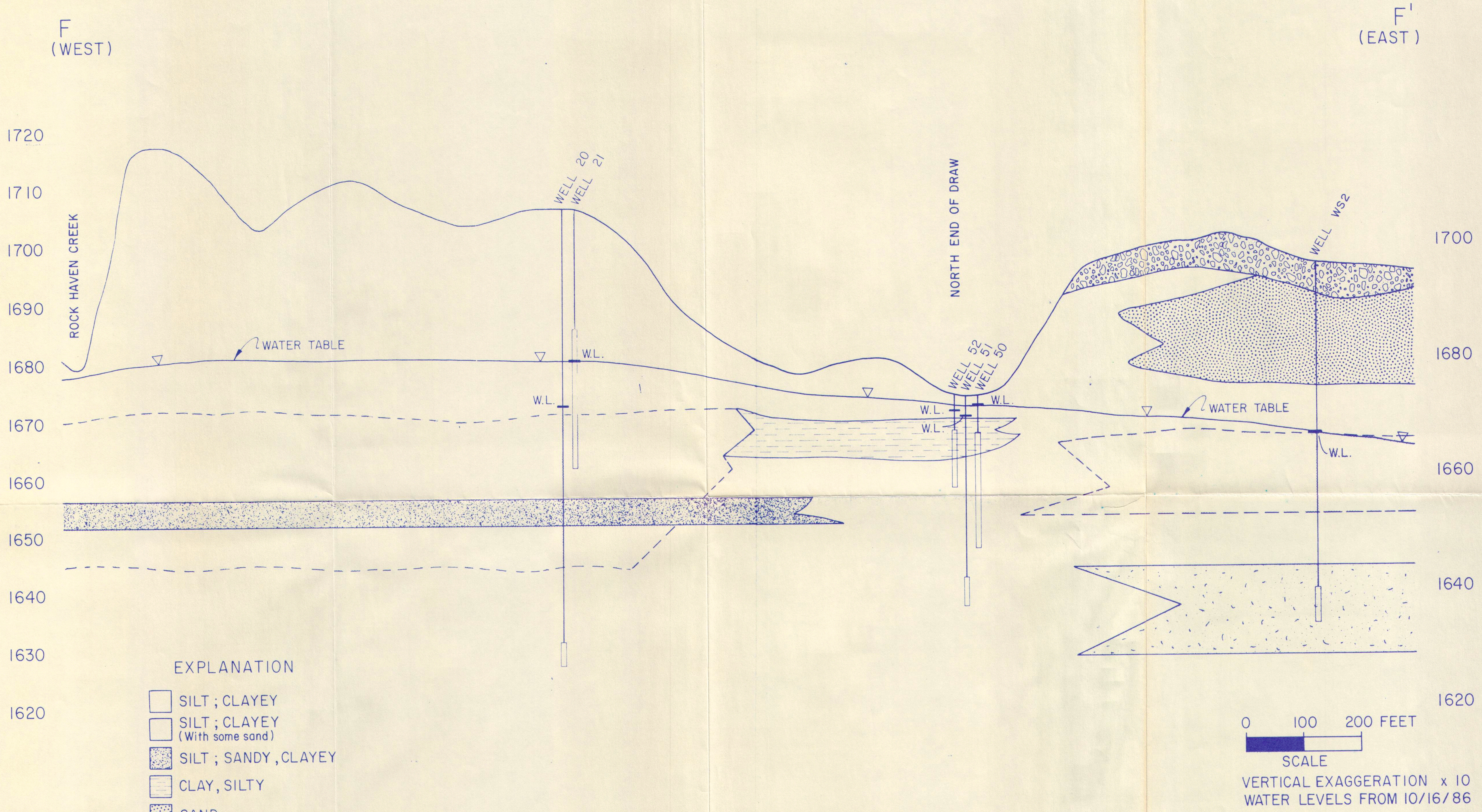


VERTICAL EXAGGERATION x 10
WATER LEVELS FROM 10/16/86

PLATE - E

EXHIBIT 5-B

MONTANA - DAKOTA UTILITIES CO.
R.M. HESKETT STATION SITE



EXPLANATION

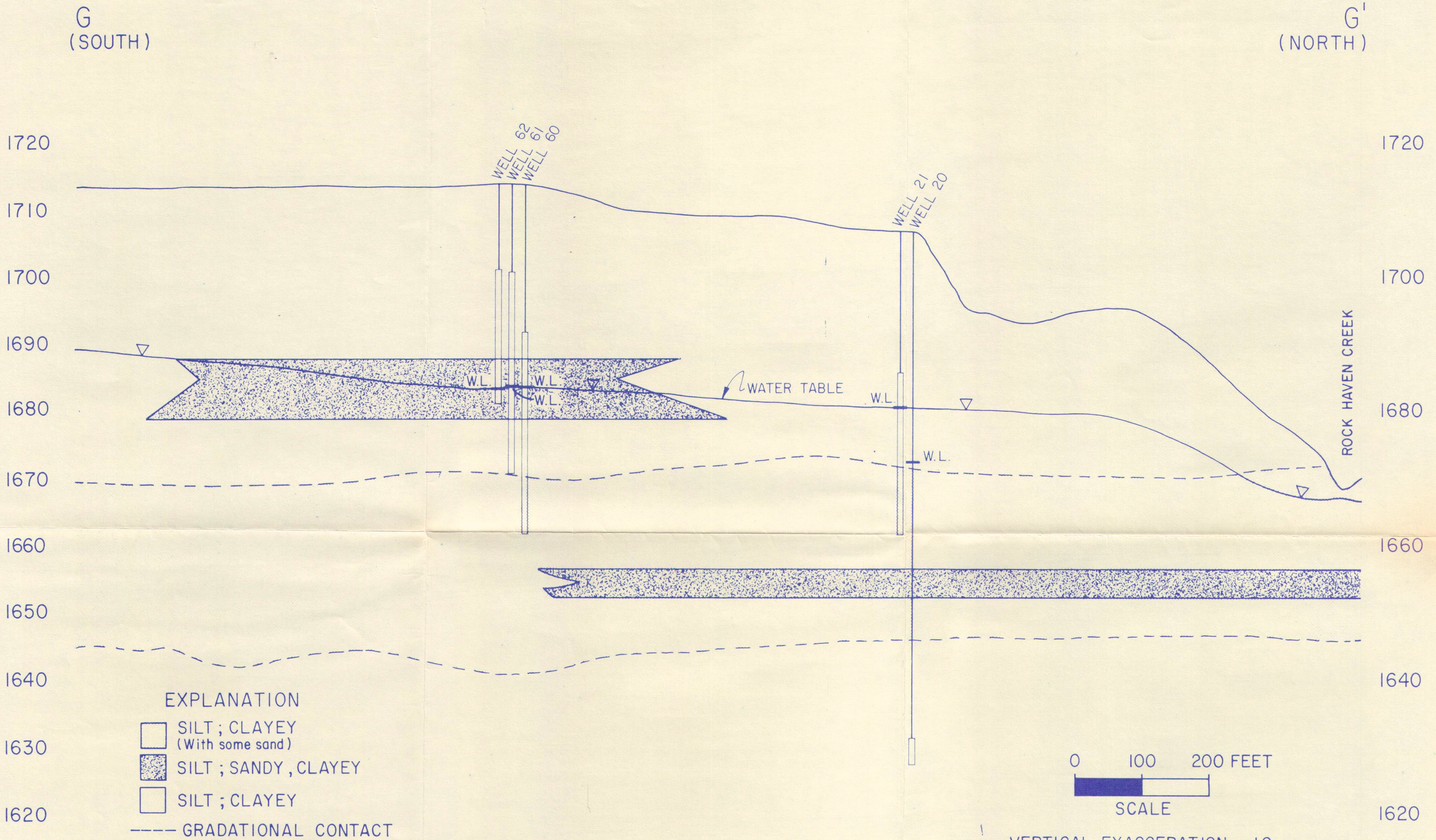
- ☐ SILT ; CLAYEY
- ☐ SILT ; CLAYEY (With some sand)
- ▨ SILT ; SANDY , CLAYEY
- ▤ CLAY, SILTY
- ▨ SAND
- ▨ PEBBLE - LOAM
- ▨ SAND (With some clay)
- ---- GRADATIONAL CONTACT

VERTICAL EXAGGERATION x 10
WATER LEVELS FROM 10/16/86

PLATE - F

EXHIBIT 5-B

MONTANA - DAKOTA UTILITIES CO.
R.M. HESKETT STATION SITE



VERTICAL EXAGGERATION x 10
WATER LEVELS FROM 10/16/86

PLATE – G

EXHIBIT 5 – B

MONTANA – DAKOTA UTILITIES CO.
R.M. HESKETT STATION SITE

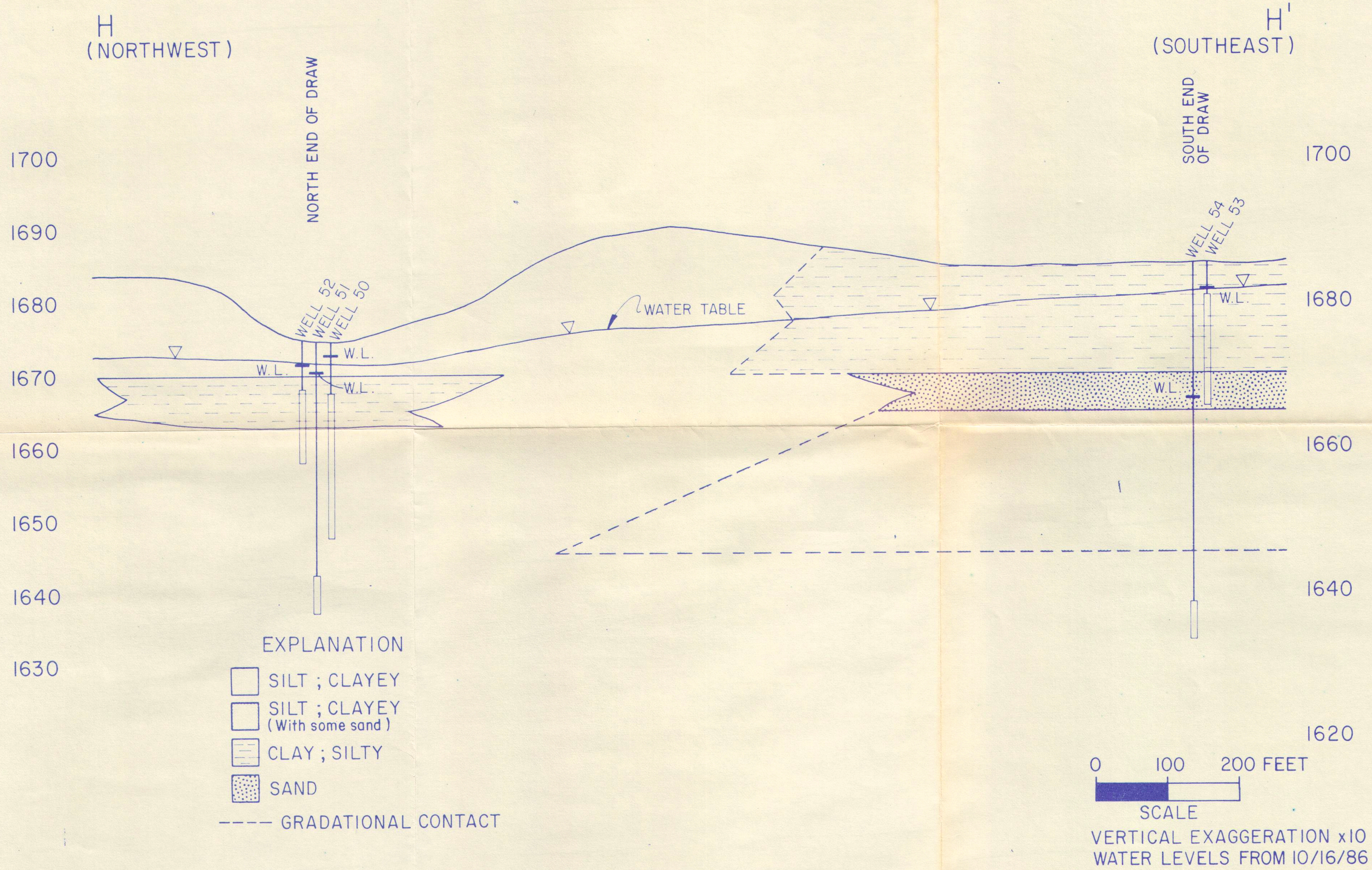


PLATE – H

EXHIBIT 5-B

MONTANA – DAKOTA UTILITIES CO.
R.M. HESKETT STATION SITE

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

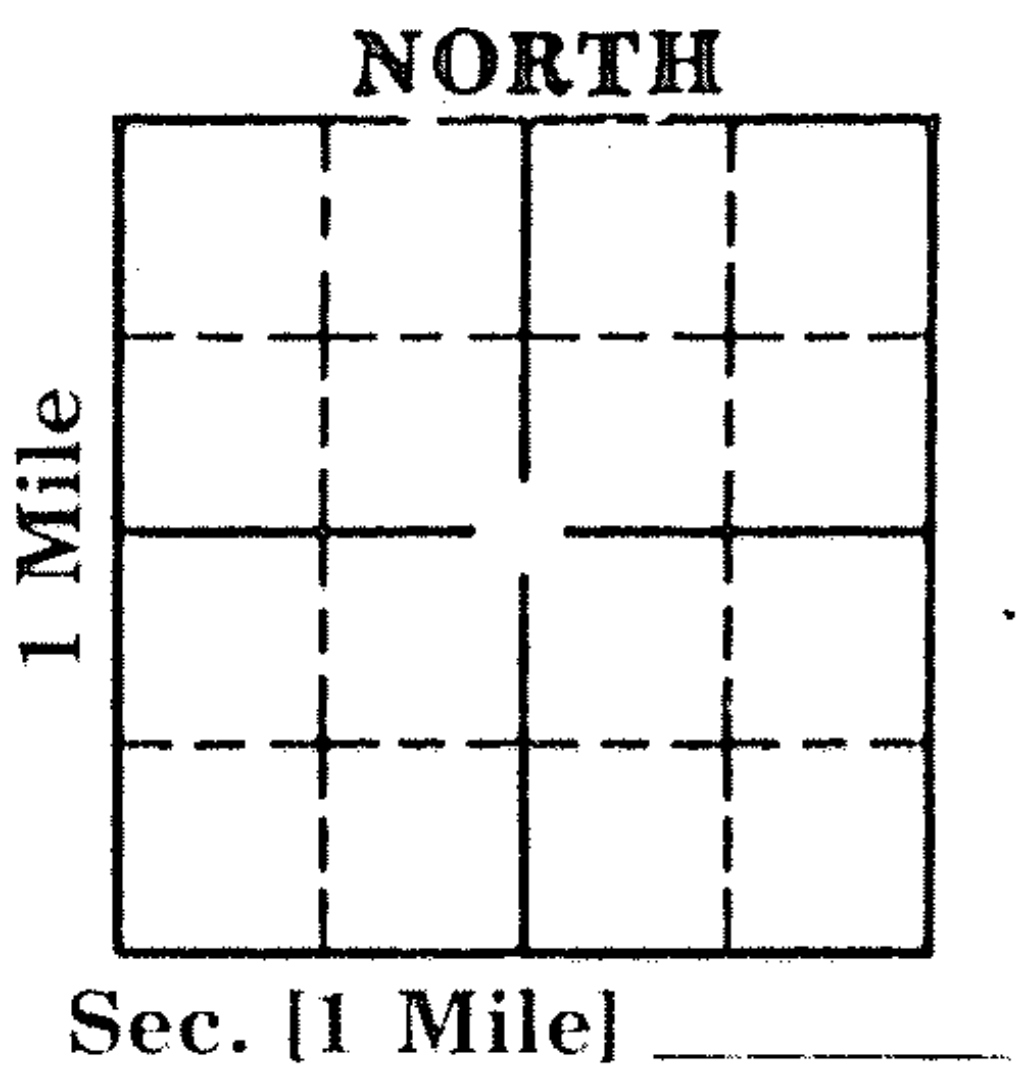
Name Montana Dakota Utilities

Address Bismarck, ND

2. WELL LOCATION

Sketch map location must agree with written location.

Heskett Ash
Dispoal Site
#1-90
139-81-10CAD
Top nof pipe
1675.54
Ground level
1673.6



County Morton

SE ¼ NE ¼ SW ¼ Sec. 10 Twp. 139 N. Rg. 81 W.

3. PROPOSED USE

☐ Domestic
☐ Stock
☐ Geothermal
☐ Irrigation
☐ Municipal
☒ Monitoring
☐ Industrial
☐ Test Hole

4. METHOD DRILLED

☐ Cable
☒ Forward Rotary
☐ Reverse Rotary
☐ Jetted
☐ Bored
☐ Auger

If other, specify

5. WATER QUALITY

Was a water sample collected for:

Chemical Analysis? ☐ Yes ☐ No

Bacteriological Analysis? ☐ Yes ☐ No

If so, to what laboratory was it sent

6. WELL CONSTRUCTION

Diameter of hole 5 inches. Depth 15 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☐ Other

If other, specify

Pipe Weight:	Diameter:	From:	To:
SDR-21 lb/ft.	2 inches	±2.0 feet	5 feet
lb/ft.	inches	feet	feet
lb/ft.	inches	feet	feet

Was perforated pipe used? ☐ Yes ☒ No

Perforated pipe set from ft to feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material PVC Diameter 2 inches
(stainless steel, bronze, etc.)

Slot size 10 set from 5 feet to 15 feet

Slot size set from feet to feet

Was a packer or seal used? ☒ Yes ☐ No

If so, what material cse bentonite Depth 3 to 4 Ft.

Type of well: Straight screen ☐ Gravel packed ☒

Depth grouted: From 3 To surface

Grouting Material: Cement X Other

If other explain: w/bentonite

Well head completion: Pitless unit

12" above grade X Other

If other, specify

Was pump installed: ☐ Yes ☒ No

Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level 12.3 feet below land surface

If flowing: closed-in pressure psi

GPM flow through inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

ft. after hrs. pumping gpm

ft. after hrs. pumping gpm

ft. after hrs. pumping gpm

9. WELL LOG

Formation	Depth (ft.) From	Depth (ft.) To
Clay, fill	0	3
Sand, fine to medium, yellowish brown	3	6
Clay, silty, yellowish brown, bedrock	6	13
Clay, silty, medium gray	13	15

(Use separate sheet if necessary.)

10. DATE COMPLETED 2/5/90

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how

12. REMARKS:

2" PVC cap on bottom of screen
160# of silica sand pack

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply, Inc. 46
Driller's or Firm's Name Certificate No
Box 1191 - Bismarck, ND 58502
Address

Signed by Lewis Knutson 2/5/90
Date

WHITE—DRILLER'S COPY YELLOW—BOARD'S COPY PINK—CUSTOMER'S COPY

STATE OF NORTH DAKOTA
BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

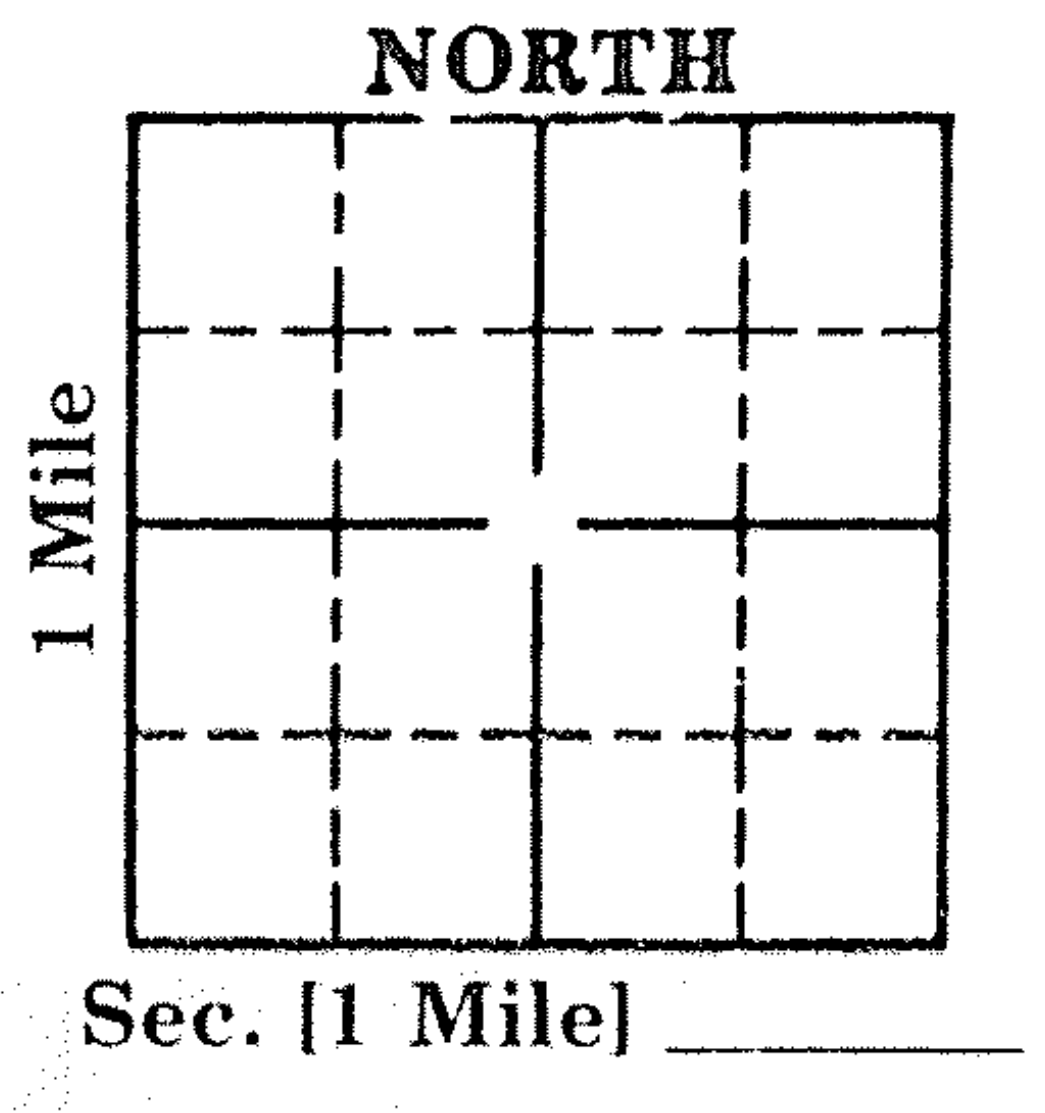
Name Montana Dakota Utilities

Address Bismarck, ND

2. WELL LOCATION

Sketch map location must agree with written location.

Heskett Ash
Disposal Site
#2-90
139-81-10CAB1
Top of pipe
1686.54
Ground level
1684.3



County Morton

SW ¼ NE ¼ NW ¼ Sec. 10 Twp. 139 N. Rg. 81 W.

3. PROPOSED USE

☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal ☒ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☒ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☐ Auger

If other, specify

5. WATER QUALITY

Was a water sample collected for:

Chemical Analysis? ☐ Yes ☐ No

Bacteriological Analysis? ☐ Yes ☐ No

If so, to what laboratory was it sent

6. WELL CONSTRUCTION

Diameter of hole 5 inches. Depth 23 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☐ Other

If other, specify

Pipe Weight:	Diameter:	From:	To:
SDR-21 ~~lb/~~ft.	2 inches	+2.3 feet	13 feet
lb/ft.	inches	feet	feet
lb/ft.	inches	feet	feet

Was perforated pipe used? ☐ Yes ☒ No

Perforated pipe set from ft to feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material PVC Diameter 2 inches
(stainless steel, bronze, etc.)

Slot size 10 set from 13 feet to 23 feet

Slot size set from feet to feet

Was a packer or seal used? ☒ Yes ☐ No

If so, what material cse bentonite Depth 11 to 12 Ft.

Type of well: Straight screen ☐ Gravel packed ☒

Depth grouted: From 11 To surface

Grouting Material: Cement X Other

If other explain: w/bentonite

Well head completion: Pitless unit

12" above grade X Other

If other, specify

Was pump installed: ☐ Yes ☒ No

Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level dry feet below land surface

If flowing: closed-in pressure psi

GPM flow through inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

ft. after hrs. pumping gpm

ft. after hrs. pumping gpm

ft. after hrs. pumping gpm

9. WELL LOG

Formation	Depth (ft.) From	Depth (ft.) To
Topsoil, silty, black	0	1
Sand, fine, yellowish gray	1	6.5
Clay, silty, yellowish brown, till	6.5	11
Clay, silty, medium gray	11	13
Sand	13	15.5
Clay, silty, medium gray, bedrock	15.5	23

(Use separate sheet if necessary.)

10. DATE COMPLETED 2/5/90

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how

12. REMARKS:

2" PVC cap on bottom of screen
160# silica sand pack

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply, Inc. 46
Driller's or Firm's Name Certificate No.
Box 1191 - Bismarck, ND 58502
Address
2/5/90
Signed by Lewis Knutson Date

WHITE—DRILLER'S COPY YELLOW—BOARD'S COPY PINK—CUSTOMER'S COPY

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

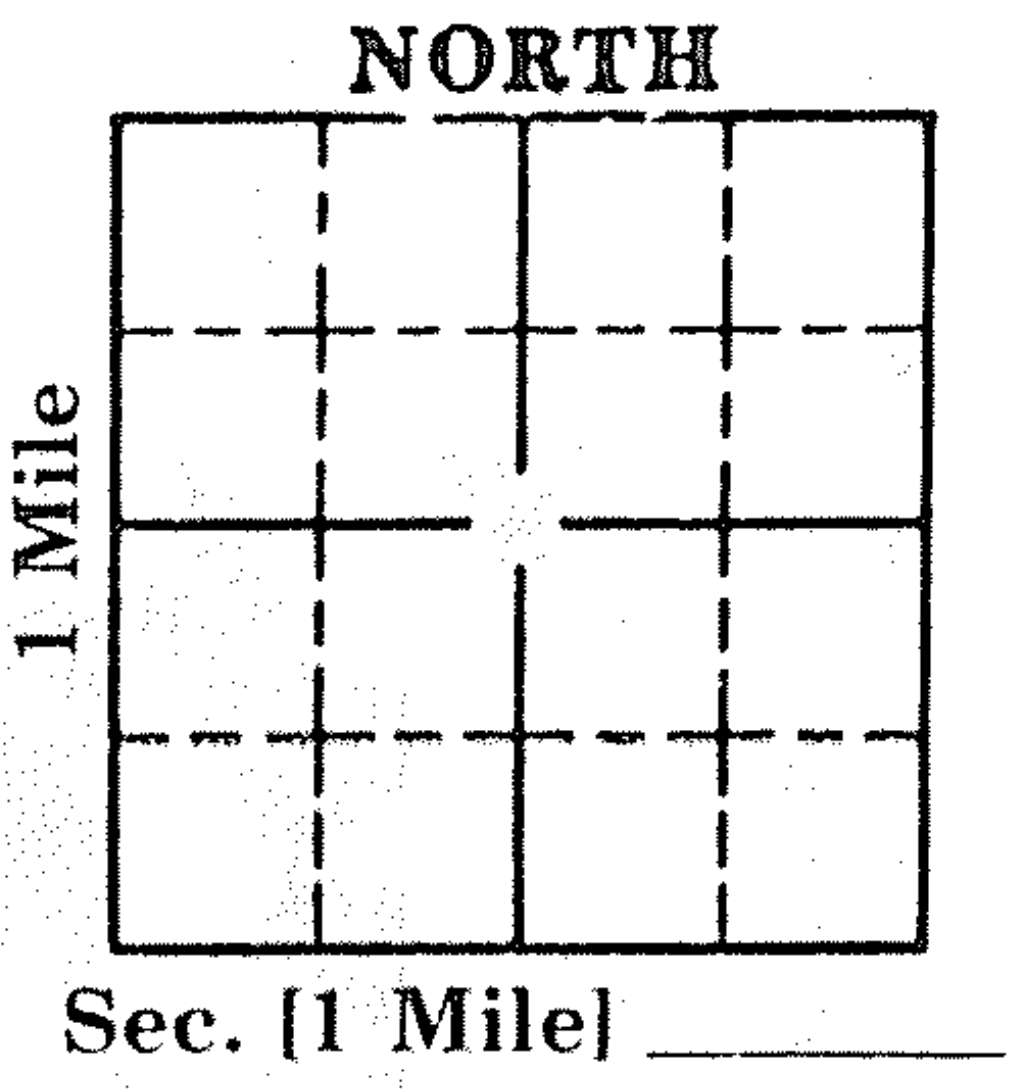
Name Montana Dakota Utilities

Address Bismarck, ND

2. WELL LOCATION

Sketch map location must agree with written location.

Heskett Ash
Disposal Site
#3-90
139-81-10CAB2
Top of pipe
1685.92
Ground level
1683.6



County Morton

SW ¼ NE ¼ NW ¼ Sec. 10 Twp. 139 N. Rg. 81 W.

3. PROPOSED USE

☐ Geothermal ☒ Monitoring
☐ Domestic ☐ Irrigation ☐ Industrial
☐ Stock ☐ Municipal ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Reverse Rotary ☐ Bored
☒ Forward Rotary ☐ Jetted ☐ Auger

If other, specify

5. WATER QUALITY

Was a water sample collected for:
Chemical Analysis? ☐ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent

6. WELL CONSTRUCTION

Diameter of hole 5 inches. Depth 20 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete
☐ Threaded ☐ Welded ☐ Other

If other, specify

Pipe Weight:	Diameter:	From:	To:
SDR-21 xxxx/ft.	2 inches	+2.3 feet	10 feet
lb/ft.	inches	feet	feet
lb/ft.	inches	feet	feet

Was perforated pipe used? ☐ Yes ☒ No

Perforated pipe set from ft to feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material PVC Diameter 2 inches
(stainless steel, bronze, etc.)

Slot size 10 set from 10 feet to 20 feet

Slot size set from feet to feet

Was a packer or seal used? ☒ Yes ☐ No

If so, what material cse bentonite Depth 7.5 to 9 Ft.

Type of well: Straight screen ☐ Gravel packed XX

Depth grouted: From 7.5 To surface

Grouting Material: Cement X Other

If other explain: w/bentonite

Well head completion: Pitless unit

12" above grade X Other

If other, specify

Was pump installed: ☐ Yes ☒ No

Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level dry feet below land surface

If flowing: closed-in pressure psi

GPM flow through inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

ft. after hrs. pumping gpm
ft. after hrs. pumping gpm
ft. after hrs. pumping gpm

9. WELL LOG

Formation	Depth (ft.) From	Depth (ft.) To
Topsoil, silty, black	0	1
Clay, silty, yellowish brown, till	1	7
Sand, fine, yellowish brown	7	8
Clay, silty, medium gray, till	8	15
Clay, silty to sandy, medium gray, abt 40% sand	15	20

(Use separate sheet if necessary.)

10. DATE COMPLETED 2/5/90

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how

12. REMARKS:

2" PVC cap on bottom of screen
160# silica sand pack

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply, Inc. 46
Driller's or Firm's Name Certificate No.

Box 1191 - Bismarck, ND 58502
Address

2/5/90
Signed by Lewis Knutson Date

State of North Dakota

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58505

MONITORING WELL REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

Name MDU-Heskett Station

Address 2025 38th Street

Mandan, North Dakota

2. WELL LOCATION (MW-44R)

Address (if in city) (see attached drawing)

County Morton

SE ¼ SE ¼ SW ¼ Sec. 10 Twp. 139 N. Rge. 81 W.

Lat. 46.86620 Long.: -100.89313

Altitude:

3. METHOD DRILLED

☒ Auger Other

4. WELL CONSTRUCTION

Diameter of Hole 8 inches Depth 46 feet

Riser: ☒ PVC ☐ Other

☒ Threaded ☐ Solvent ☐ Other

Riser rating SDR Schedule 40

Diameter 2.0 inches

From +2 ft. to 23 ft.

Was a well screen installed? ☒ Yes ☐ No

Material Schedule 40 PVC Diameter 2.0 inches

Slot Size #10 set from 23 feet to 43 feet

Sand packed from 21 ft to 46 ft

Depth grouted from 1 ft to 21 ft

Grouting Material

Bentonite x Other

If other explain:

One foot concrete collar at surface

Well head completion:

24" above grade Other x

If other, specify 4" x 4" x 5' steel cover

Was protective casing installed? ☒ Yes ☐ No

Was well disinfected upon completion? ☐ Yes ☒ No

5. WATER LEVEL

Static water level 28.5 feet below surface

If flowing: closed in pressure psi or ft. above land surface

6. WELL LOG

Formation	Depth (Ft.) From	To
Topsoil	0	0.5
Sandy lean clay	0.5	5
Sandy fat clay	5	46

(Use separate sheet if necessary)

7. WAS THE HOLE PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how?

8. REMARKS

3 steel bumpers installed around well head

9. DATE COMPLETED 10-21-14

10. CONTRACTOR CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Midwest Testing Laboratory, Inc. 444

Monitoring Well Contractor Certificate No.

P.O. Box 2084, Bismarck, ND 58502-2084

Address

10-22-14

Signature Date

State of North Dakota

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58505

MONITORING WELL REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

Name MDU-Heskett Station
Address 2025 38th Street
Mandan, North Dakota

2. WELL LOCATION (MW-80R)

Address (if in city) (see attached drawing)

County Morton

NE ¼ SE ¼ SW ¼ Sec. 10 Twp. 139 N. Rge. 81 W.

Lat. 46.86789 Long.: -100.89320

Altitude:

3. METHOD DRILLED

■ Auger Other

4. WELL CONSTRUCTION

Diameter of Hole 8 inches Depth 27 feet

Riser: ■ PVC ☐ Other

■ Threaded ☐ Solvent ☐ Other

Riser rating SDR Schedule 40

Diameter 2.0 inches

From +2.5 ft. to 7 ft.

Was a well screen installed? ■ Yes ☐ No

Material Schedule 40 PVC Diameter 2.0 inches

Slot Size #10 set from 7 feet to 27 feet

Sand packed from 5 ft to 27 ft

Depth grouted from 1 ft to 5 ft

Grouting Material

Bentonite x Other

If other explain:

One foot concrete collar at surface

Well head completion:

24" above grade Other x

If other, specify 4" x 4" x 5' steel cover

Was protective casing installed? ■ Yes ☐ No

Was well disinfected upon completion? ☐ Yes ■ No

5. WATER LEVEL

Static water level 12 feet below surface

If flowing: closed in pressure psi or ft. above land surface

6. WELL LOG

Formation	Depth (Ft.) From	To
Topsoil	0	0.5
Sandy lean clay	0.5	27

(Use separate sheet if necessary)

7. WAS THE HOLE PLUGGED OR ABANDONED?

☐ Yes ■ No

If so, how?

8. REMARKS

3 steel bumpers installed around well head

9. DATE COMPLETED 10-21-14

10. CONTRACTOR CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Midwest Testing Laboratory, Inc. 444
Monitoring Well Contractor Certificate No.

P.O. Box 2084, Bismarck, ND 58502-2084
Address

10-22-14
Signature Date

Appendix B

Historical Groundwater Contour Map

R.M. HESKETT STATION

S. 1/2 SECTION 10, LOT 1 SECTION 11
TOWNSHIP 139 NORTH - RANGE 81 WEST
MORTON COUNTY, NORTH DAKOTA

LEGEND

- - - - - -	SETBACK LINE
— - — - —	BUFFER ZONE
oo—o	OBSERVATION WELL
(0000)	GROUND ELEVATION (Feet above MSL)
—0000—	WATER TABLE ELEVATION (Feet above MSL) CONTOUR LINE

R.M. HESKETT STATION
WATER TABLE ELEVATION 10-16-86
CONTOUR INTERVAL 5 FEET

EXHIBIT 5-H

MONTANA - DAKOTA UTILITIES CO.
R.M. HESKETT STATION SITE

Appendix C

Sampling and Analysis Plan

Groundwater Sampling and Analysis Plan

R.M. Heskett Station

Prepared for
Montana-Dakota Utilities Co.

January 2021

4300 MarketPointe Drive, Suite 200
Minneapolis, MN 55435
952.832.2600
www.barr.com

Groundwater Sampling and Analysis Plan
R.M. Heskett Station

January 2021

Contents

List of Tables

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Laboratory Certification

I certify that all sampling and laboratory staff have read this document and that Montana-Dakota Utilities Co. may rely on the results of sample data, and that it was collected and analyzed in accordance with this plan and appendices, and that I am an officer with authority to ensure that the provisions of the plan have been carried out.

Name: ______________________________ Title: _______________________________ Company: ___________________________	Date

Acronyms

Acronym	Description
CCR	coal combustion residual
COC	chain of custody
DQO	data quality objectives
EDD	electronic data deliverable
LCS/LCSD	laboratory control sample data
MS/MDS	matrix spike/matrix duplicate spike
ND	non-detect
NDDEQ	North Dakota Department of Environmental Quality
NTU	nephelometric turbidity unit
QA	quality assurance
QC	quality control
RPD	relative percent difference
SAP	samplings and analysis plan
SOP	standard operating procedure
SSI	statistically significant increase
US DOT	United States Department of Transportation
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey

1.0 Introduction

This sampling and analysis plan (SAP) describes the Sampling and Analysis program (Program) required by the ND Administrative Code 33.1-20-08-06 (ND Code), Ground water monitoring and corrective action. The SAP provides a description of the monitoring system for the Heskett Landfill (which encompasses both the defined CCR unit and the permitted Special Waste Landfill) at the R.M. Heskett Station (Site) located in Mandan, North Dakota (Figure 1).

1.1 Purpose and Scope

The purpose of this SAP is to provide methods and procedures for collecting and analyzing groundwater data so that the results are representative of groundwater conditions at the Site.

The scope includes a description of the methods and procedures that will be utilized for the collection, preservation and shipment, analysis, chain of custody control, quality assurance and quality control, and reporting of groundwater quality data in accordance with the ND Code. Statistical analysis methods are described in the Statistical Method Selection Certification (Barr, 2017)

1.2 Data Quality Objectives

The table below is a detailed discussion of the groundwater sampling and analysis requirements outlined in ND Code 33.1-20-08-06, subchapter 3, paragraphs (a), (b), (c), (e), and (i), and this Site's compliance with the ND Code. These requirements will be utilized to define the data quality objectives (DQOs) of this project. The other paragraphs ((f) through (h)) relate to the statistical methods and are covered in the Statistical Method Selection Certification (Barr, 2017).

Table 1 ND Code Requirements and Compliance

ND Code Requirements (33.1-20-08-06 subchapter 3)	Compliance with ND Code
Sampling and Analysis Plan (a): The groundwater monitoring program must include consistent sampling and analysis procedures that are designed to ensure monitoring results that provide an accurate representation of groundwater quality at the background and downgradient wells. The owner or operator of the CCR unit must develop a sampling and analysis program that includes procedures and techniques for: (1) Sample collection; (2) Sample preservation and shipment; (3) Analytical procedures; (4) Chain of custody control; and (5) Quality assurance and quality control	Yes, see Sections 2.2-2.5 and SOPs in Appendix B and C.
Appropriate Methodology (b): The groundwater monitoring program must include sampling and analytical methods that are appropriate for groundwater sampling and that accurately measure hazardous constituents and other monitoring parameters in groundwater samples. For the purpose of this section, the term *constituent* refers to both hazardous constituents and other monitoring parameters listed in either appendix I or II of this chapter.	Yes, see Sections 2.2.5 and 2.3 as well as Table 2.

ND Code Requirements (33.1-20-08-06 subchapter 3)	Compliance with ND Code
Groundwater Elevations (c): Groundwater elevations must be measured in each well prior to purging, each time groundwater is sampled. The owner or operator of the CCR unit must determine the rate and direction of groundwater flow each time groundwater is sampled. Groundwater elevations in wells which monitor the same CCR management area must be measured within a period of time short enough to avoid temporal variations in groundwater flow which could preclude accurate determination of groundwater flow rate and directions.	Yes, see Section 2.2.1.
Number of Samples (e): The number of samples collected when conducting detection monitoring and assessment monitoring (for both downgradient and background wells) must be consistent with the statistical procedures chosen under subdivision f of this section and the performance standards under subdivision g of this section. The sampling procedures must be those specified under subsection 4 for detection monitoring, subsection 5 for assessment monitoring, and subsection 6 for corrective action monitoring.	Yes, at least eight events of data will be collected from each monitoring well to establish an appropriate background dataset; see the Statistical Method Selection Certification (Barr, 2017).
Total Recoverable Metals (i): The owner or operator must measure "total recoverable metals" concentrations in measuring groundwater quality. Measurements of total recoverable metals captures both the particulate fraction and dissolved fraction of metals in natural waters. Groundwater samples shall not be filed-filtered prior to analysis.	Yes, see Sections 2.2.4 and 2.2.5.

2.0 Routine Water Monitoring

This section presents the proposed monitoring well system, sampling methods, parameters for analysis, and analytical methods.

2.1 Monitoring System

The monitoring well system around the CCR unit and special waste landfill consists of one upgradient well (MW-13) and four downgradient wells (MW1-90, MW-2-90, MW-3-90, and MW80R). The remaining wells on the Site will be used for water level measurements and/or supplement data collection, as needed and as they remain open; five upgradient (MW-33, MW-101, MW-70, MW-102, and MW-103), two downgradient (MW-104 and MW-105), and one side-gradient (MW-44R). Well locations are shown on Figure 1.

2.2 Field Procedures

This section describes basic monitoring procedures and information that will be recorded during each monitoring event at each well location. All data shall be recorded in the field and dated notes shall be kept for each event. Staff contracted to collect samples under the ND Code shall provide all field collection information identified on the example log along with field notes **to Barr within 10 business days** of the completion of each sampling event.

The ND Code requires total metals sampling, but acknowledges that artificially high concentrations of total metals due to excess colloidal material in the well (high turbidity) should be avoided through proper well construction and development techniques. Due to the fine grained and heterogeneous geology at the Site, avoiding high turbidity samples may be difficult for some or all of the monitoring wells even though these wells were constructed in accordance with the North Dakota Department of Environmental Quality (NDDEQ) regulations. Therefore, all well purging and sampling activities should avoid surging the well just prior to sampling, which may mobilize solids from the filter pack and beyond. If sampling yields high-turbidity samples in one or more wells, then the corresponding well(s) should be repeatedly surged and purged just after completing the sampling event in an effort to reduce turbidity in samples retrieved in subsequent sampling event.

2.2.1 Water Level Measurements

Water level measurements will be taken at each of the monitoring wells to the nearest 0.01 foot using an electronic water level indicator two times during each sampling event (prior to purging and during sampling).

2.2.2 Well Evaluation

Prior to purging and sampling, the well depth and static water level will be measured and recorded on a Field Sampling Data Sheet for each well and the volume of water in the well will then be calculated and recorded. After purging, the water depth will be recorded again. Additional observations regarding any issues with the well will be noted, including sediment at the bottom (soft bottom), obstructions, broken riser cap or lock, gaps in surface seal, etc. All such issues will be brought to Barr and MDU's attention immediately so they may be addressed promptly.

2.2.3 Well Development, Stabilization Criteria, and Purge Water Handling

Monitoring wells shall be developed in accordance with the *Collection of Groundwater Samples from a Temporary or Permanent Monitoring Well (Includes Well Purging and Stabilization)* SOP (see Appendix A) after initial installation. Groundwater monitoring well purging and sampling techniques will be used and stabilization parameters will be recorded prior to sampling. Turbidity of samples is a potential complication when collecting total metals samples in accordance with the ND Code because total metals data are subject to higher concentration bias from suspended sediment particles in the sample. In general, lower turbidity in the sample will result in lower metals concentrations. Therefore, groundwater quality sampling should not occur until turbidity values have stabilized below 5 NTU or as determined in consultation with Barr's project manager. In the event turbidity values do not stabilize to a sufficiently low level after removal of four well volumes, then sampling for the current event shall proceed, but re-development or further evaluation of well construction may be considered, especially for monitoring wells with low recharge rates. Such issues should be brought to Barr's attention immediately. SOPs required for well development and stabilization are included in Appendix A.

2.2.4 Groundwater Sampling and Handling

Groundwater samples will be collected in accordance with methods described in Barr's SOP for *Collection of Groundwater Samples from a Temporary or Permanent Monitoring Well* (see Appendix A). Samples will be collected from monitoring wells in accordance with the frequency outlined by the ND Code. Groundwater sampling will be conducted by personnel selected by MDU. Contracted personnel will follow the SOP for groundwater sample collection, including completing the appropriate documentation and daily safety sheets. Groundwater monitoring wells will be analyzed for detection (Appendix I) and/or assessment (Appendix II) parameters. Depending on the monitoring conducted, one or both lists may be analyzed in case a statistically significant increase (SSI) is encountered. Additional parameters, such as dissolved metals and major cations and anions may also be collected. A detailed list of the Site-specific parameters are in Table 2.

2.2.5 Purging and Metals Analysis

Field personnel will perform and document field stabilization criteria (pH, redox, temperature, dissolved oxygen, conductivity, and turbidity) prior to sample collection. All field stabilization methods will be selected to allow for real-time data collection, while meeting data quality objectives. Field personnel ensure the production of quality field data using overall quality assurance systems that are supported by documented quality control checks. These checks include instrument calibration standards and field blanks and adherence to consistent sampling techniques. Field sheets, including stabilization logs for each well, will be provided **to Barr within 10 business days** following each sampling event.

2.2.6 Sample Shipping

Analytical samples to be transported will be marked with a permanent marker directly on the container or on adhesive labels that will remain on the container during shipping and handling. A chain-of-custody (COC) form will accompany all samples and remain with the samples from collection to the final testing facility. Each shipping container will be marked with a proper US Department of Transportation (DOT) transportation description, if necessary, the sample designation, as well as names and addresses of the sender and receiver. Proper shipping papers will accompany each shipment of samples.

All samples will be transported via courier service or delivered by field staff to the laboratory within the specified holding time requirements. The laboratory will ship any necessary aliquots to the respective testing facilities for tests the primary laboratory does not perform. Samples will be shipped via overnight delivery to alternate test facilities.

2.3 Analytical Procedures

Analytical methods have been selected to provide adequate reporting limits for Appendix I, Appendix II, and major cation and anion constituents, and for the final intended data usage. A list of anticipated laboratory methods and their corresponding reporting limits can be found in Table 2.

2.3.1 Combined Radium Calculation

Analysis and reporting of radium 226 and 228 are unique compared to other analytes because the analysis and equipment are based on detection of a physical property of radioactive decay (alpha and beta particle emission) rather than the chemical properties of the sample solution chemistry. The individual radium isotope results are reviewed per Barr's SOP for Routine Level Radium 226 and 228 Data Evaluation (Appendix B) which includes the determination of whether reported results are 'detected' or 'not detected (ND)'. Some challenges of the data can include negative results or uncertainties greater than the sample result. Based on these, several important assumptions are required to report the results and uncertainty of both these parameters to achieve a combined value as shown below:

After individually verifying results as detected or non-detect (ND) and addressing any blanks contamination, add the results for each radium isotope together and report as follows:

- Replace negative results with zero when adding numerical results together and do not combine the counting uncertainty of a negative result.
- Both results detected – add the numerical results.
- Both results ND – add the numerical results and qualify as ND with a < symbol indicating the upper bound of uncertainty reported by the lab and ignoring negative values (<).
- One result detected and the other result ND – add the numerical results (no substitution) and qualify 'a' (estimated value, calculated using some or all values that are estimates).
- Combine counting uncertainties as follows:

$$Combined\ Counting\ Uncertainty = \sqrt{U_{226}^2 + U_{228}^2}$$

Where:

U = Uncertainty expressed as a positive or negative count value

2.4 Data Validation/Verification

The overall quality assurance (QA) objective for this work is to meet the requirements of the DQOs (as defined in Section 1.2), which include developing and implementing procedures for sampling, sample custody, laboratory analysis, and reporting that will support decisions made for subsequent stages of investigation, Site sampling activities, and/or feasibility studies.

For the purposes of this Program, **data validation** is defined as the evaluation of the technical usability of the data. **Data verification** is defined as the determination of adherence to SOPs, the field sampling plan, and the laboratory(s) quality assurance plan. Data verification will be performed in accordance with Barr's (SOPs) for data evaluation.

A brief overview of procedures for evaluating and reviewing the data include:

- **Holding Times:** Compare the time and date the sample was collected (on the chain-of-custody) to the date analyzed in the laboratory data package. Verify the dates are within the recommended holding times for the particular method.

- **Method Blank Data:** Verify through the method blank sample data results that no significant laboratory contamination issues exist.

- **Laboratory Control Sample Data:** Verify the percent recovery of the spiked compounds is within acceptable laboratory criteria included in each laboratory report, or the Barr SOP presented in Appendix B.1 and B.2.

- **Matrix Spike Data:** Verify the percent recovery of the spiked compounds is within acceptable laboratory criteria included in each laboratory report, or the Barr SOP presented in Appendix B.1 and B.2.

- **Field Duplicate Analysis Data:** Calculate the relative percent difference of target compounds where both the native and field duplicate sample concentrations are greater than five times the reporting limit and compare them to the acceptance criteria included in the Barr SOP presented in Appendix B.1 and B.2 to demonstrate acceptable precision and reproducibility of the field and laboratory procedures.

- **Field Blank:** Verify through the field blank sample data results that no significant contamination exists from sampling activities, sample transport, and storage at the sampling site.

- **Overall Data Assessment:** Examine the data package as a whole and compare it to (1) the chain-of-custody to verify completeness, (2) the historical data to verify representativeness, and (3) the other Site data to verify comparability is being achieved.

Qualification of the data may result if the evaluation criteria are not met. Data qualification(s) will be presented in the data tables.

Field data is reviewed in real-time by the appropriate field personnel. Additionally, during preparation of the final field report, technical field personnel members need to document their records for accuracy and completeness. Appropriate Barr staff may additionally check for completeness, representativeness, and any transcription errors. If errors are detected, the field personnel will be contacted, and corrections will be initiated as necessary.

2.5 Laboratory Data Deliverable

Laboratory analyses reports will be submitted to Barr and MDU within four weeks of the receipt of samples for all parameters except for the Rad Chem data which will be submitted to Barr and MDU within six weeks of the receipt of samples. The Laboratory Project Manager performs a final review of the report summaries and case narratives to determine whether the report meets project requirements. In addition to the record of chain-of-custody, the report format shall consist of:

- Date of issuance
- Project name and number
- Condition of samples upon receipt at the laboratory
- Cross referencing of laboratory sample to project sample identification numbers
- Sample collection and receipt date
- Laboratory analysis performed
- Reference method used for analysis
- Laboratory batch number
- Sample preparation and analysis dates
- Sample results (including units and percent moisture and/or solids data used in dry weight corrections, if applicable)
- Laboratory reporting limit for each analyte
- Quality control data and acceptance criteria (including method blank results, laboratory control sample recoveries, matrix spike and matrix spike duplicate recoveries and RPDs, and/or laboratory duplicate RPDs, if applicable)

- Discussion and/or qualification of any laboratory quality control data which failed to meet acceptance criteria
- Discussion and/or qualification of any holding times that were not met
- Data qualifier definitions
- Discussion of technical problems or other observations which may have created analytical difficulties
- Any deviations from intended analytical strategy
- Signature of the laboratory project manager

Data will be received in an electronic format compatible with Barr’s EQuIS data management system. Any data received in non-electronic form will be manually entered into the EDD format and uploaded into the EQuIS system.

2.6 Data Sufficiency

The data will be compiled from each sampling event and summarized in tabular and/or graphical form. The data quality assessment process will involve multiple steps depending on the results of the data verification process. Data that has been qualified, by the laboratory or by Barr, will be assessed for the particular circumstances surrounding the sample.

This treatment also applies to qualifications based on failure to meet matrix spike/matrix spike duplicate criteria if the sample or contaminant affected is critical to the project decision-making, in which case correction to the data may result. Corrections may include resampling and/or reanalysis of the sample. Detection limits may be elevated above appropriate criteria due to dilutions or matrix interferences. In this case, the necessity of the data will be evaluated as with the previous examples and potential corrections may include either, (a) reporting the data result as equal to the method detection limits and using the qualified data, or (b) resampling of critical samples.

Additional considerations when evaluating the data include the following statistical factors:

- Data time-series or historical trends.
- Spatial distributions of results such as similar and dissimilar results from adjacent sample locations.
- Outlier analysis (when statistical sampling protocols are used).
- Statistical interpretation of large data sets (sample sizes) when statistical sampling protocols are used.

3.0 Statistical Evaluation

A discussion of the statistical evaluation methods are included in the CCR Groundwater Statistical Analysis Plan (Barr, 2017), with specific details to be outlined in each annual report.

4.0 Reporting

An annual groundwater monitoring report will be uploaded to the facility's operating record by January 31 of the following year. The report will summarize the results of the year's groundwater monitoring, describe any modifications to the monitoring system, and propose changes to the monitoring system, parameters, or frequency of monitoring activities based on the evaluation of the annual data. The annual reports will also note the occurrence of any SSI's and proposed actions to resolve the SSI. Demonstration data, if required due to a confirmed SSI, will be submitted within 90 days of the verified SSI (e.g., confirmed by a resample), within a report certified by a qualified professional engineer.

This Program will be reviewed on an annual basis and, when appropriate, will be updated in the facility's operating record along with the rationale for the proposed change(s) as applicable.

5.0 References

Barr, 2017. CCR Groundwater Statistical Analysis Plan R.M. Heskett Station. Prepared for Montana-Dakota Utilities Co. October 2017.

EPA, 2015a. Hazardous and Solid Waste Management Systems; Management of Coal Combustion Residuals From Electric Utility, CFR Parts 257 and 261, Federal Register, Vol. 80, No. 74, April 17, 2015.

Tables

Table 2
Groundwater Sampling Constituent List
R.M. Heskett Station
Montana-Dakota Utilities Co.

Sampling Type:

General	Sampling Parameter List[1]			Method	RL	Unit
	I	II	Cations / Anions			
Alkalinity, total (as CaCO3)			x	SM 2320 B-2011 Modified	20	mg/l
Chloride	x		x	SM 4500 Cl-E-2011	1	mg/l
Dissolved Solids, total	x			USGS I-1750-85	5	mg/l
Fluoride	x	x		SM 4500 F-C-1997	0.1	mg/l
pH	x			SM 4500-H$^+$B-2011	1	unit
Sulfate	x		x	ASTM D516-07 Modified	5	mg/l
Metals[2]						
Antimony		x		EPA 6020A (ICP-MS)	0.001	mg/l
Arsenic		x		EPA 6020A (ICP-MS)	0.002	mg/l
Barium		x		EPA 6020A (ICP-MS)	0.002	mg/l
Beryllium		x		EPA 6020A (ICP-MS)	0.0005	mg/l
Boron	x			EPA 6010C (ICP)	0.1	mg/l
Cadmium		x		EPA 6020A (ICP-MS)	0.0005	mg/l
Calcium	x			EPA 6010C (ICP)	1	mg/l
Chromium		x		EPA 6020A (ICP-MS)	0.002	mg/l
Cobalt		x		EPA 6020A (ICP-MS)	0.002	mg/l
Lead		x		EPA 6020A (ICP-MS)	0.0005	mg/l
Lithium		x		EPA 6010C (ICP) - New Ulm	0.1	mg/l
Magnesium			x	EPA 6010C (ICP)	1	mg/l
Mercury		x		EPA 7470A (CVAA)/Leachate EPA 245.1	0.0002	mg/l
Molybedenum		x		EPA 6020A (ICP-MS)	0.002	mg/l
Potassium			x	EPA 6010C (ICP)	1	mg/l
Selenium		x		EPA 6020A (ICP-MS)	0.002	mg/l
Sodium			x	EPA 6010C (ICP)	1	mg/l
Thallium		x		EPA 6020A (ICP-MS)	0.0005	mg/l
Others						
Radium 226 and 228, combined		x		Radium 226 - SM7500 RA_B/Radium 228 Ga-Tech	Radium 226 0.2 / Radium 228 1	pCi/L

---

[1] - Sample parameter list represents (1) Appendix I to Chapter 33.1-20-08 - Constituents for Detection Monitoring, (2) Appendix II Chapter 33.1-20-08 - Constituents f
anions.

[2] - Total metals to comply with North Dakota Administrative Code, Chapter 33.1-20-08-06 3(i).

One duplicate per 10 samples and one field blank per sampling event per sample type

Figures

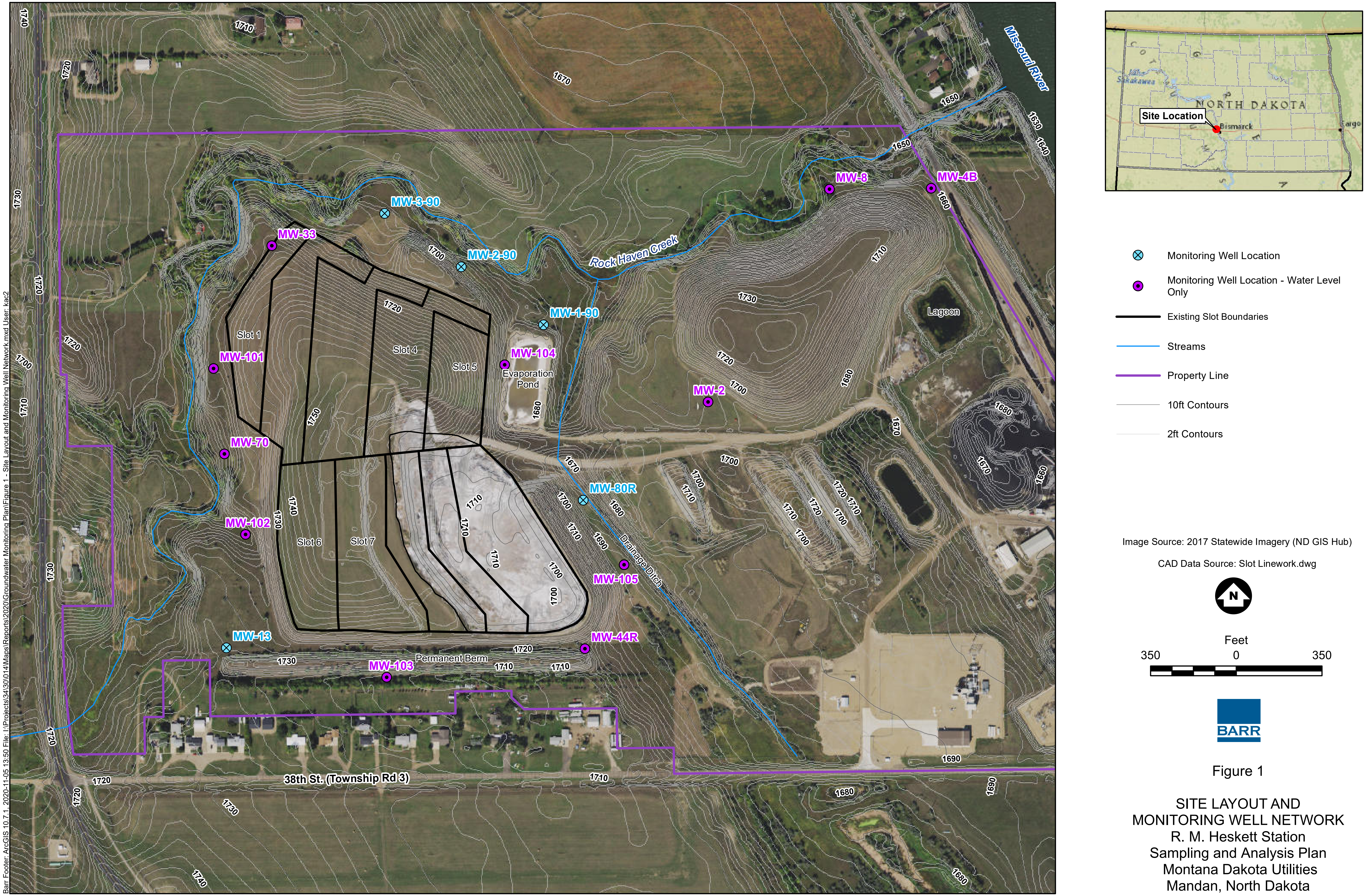


Image Source: 2017 Statewide Imagery (ND GIS Hub)

CAD Data Source: Slot Linework.dwg

Figure 1

SITE LAYOUT AND
MONITORING WELL NETWORK
R. M. Heskett Station
Sampling and Analysis Plan
Montana Dakota Utilities
Mandan, North Dakota

Appendices

Appendix A

Field SOPs

Appendix A.1

Monitoring Well Development Oversight SOP

Standard Operating Procedure

Monitoring Well Development Oversight

Revision 6

October 22, 2019

Approved By:

John W. Juntilla	John W. Juntilla	10/22/19
Print Technical Reviewer	Signature	Date
Terri A. Olson	Terri A. Olson	10/22/19
Print QA Manager	Signature	Date

Review of the SOP has been performed and the SOP still reflects current practice.

Initials: ____________________ Date: ____________________

Initials: ____________________ Date: ____________________

Initials: ____________________ Date: ____________________

Initials: ____________________ Date: ____________________

Monitoring Well Development Oversight

1.0 Scope and Applicability

The purpose of this Standard Operating Procedure (SOP) is to describe oversight provided on monitoring well development or redevelopment. These procedures are performed with the objective of obtaining representative groundwater information and water quality samples from aquifers.

The recommended procedures in this SOP should be followed unless conditions make it impractical or inappropriate to do so. Modifications should be noted in the applicable documentation and communicated to appropriate personnel. Significant changes may result in a revision or newly created SOP.

2.0 Limitations

- Well development should be completed by an appropriately licensed or registered well contractor unless allowed by rules governing wells and borings.
- Best practice is to have a minimum of one week pass between monitoring well development and monitoring well sampling unless there are other project requirements.
- If well will be sampled for per- and polyfluorinated alkyl substances (PFAS), special consideration must be taken to avoid accidental contamination of the well during the development process - see Barr's SOP 'Collection of Per- and Polyfluorinated Alkyl Substances (PFAS) Samples'.

3.0 Responsibilities

Experienced Field Technicians are responsible for overseeing the well development, quality control procedures, and documentation.

The role of the Field Safety Representative is to oversee on-site safety activities.

The well drilling contractors are typically responsible for the development of monitoring wells at the time of installation and have the necessary tools, equipment, chemicals, applicable licenses or registrations that may be required to perform the development work. Successful development of a new well may be a requirement of the drilling specifications.

4.0 Safety

Barr staff is responsible for conducting the aspects of the job safely. When applicable, refer to the appropriate Project Health and Safety Plan (PHASP) to understand the hazards associated with suspected contamination, symptoms of exposure, methods to minimize exposure, personal protective equipment (PPE), and personal air monitoring required when using this SOP. Minimum protection of one pair of chemical resistant gloves (e.g., nitrile) and safety glasses with side shields should be worn to prevent sample contact with the skin and eyes. When working with liquids contaminated with corrosive materials, emergency eye flushing facilities should be available.

5.0 Equipment, Reagents, and Supplies

- Pumps^ (e.g., submersible or peristaltic)
- Pump discharge hose/tubing
- Chemical resistant gloves (e.g., nitrile)
- Surge block (optional)
- Turbidimeter (optional)
- Water level indicator or interface probe
- Bailers
- Water quality meter (optional)
- Items listed in Section 8.0 Records
- Decontamination supplies (see Decon SOP)

* See Barr's PFAS SOP for a list of prohibited and acceptable items.

6.0 Procedure

These procedures are used to remove the fine-grained materials from a well or well bore as a result of boring or well construction. Monitoring wells must be developed to provide water free of suspended solids and to yield representative samples. Well development should result in a well that yields visibly clear groundwater.

6.1 Calibration

If used, the water quality meter and turbidimeter will be calibrated as per the applicable Barr SOP. The meters will undergo calibration checks, at a minimum, before and after sampling. The calibration check will be documented on a calibration form (as appropriate) and/or in the field notebook. Any significant issues found during the calibration check will be noted in the field notebook and the Equipment Technicians will be notified.

6.2 Development

Successful development methods include bailing, surging, pumping/over-pumping, and jetting with water. The basic principle behind each method is to create reversals of water flow into and out of the well screen (and/or bore hole) to break-down any potential mud cake or disturbed zones where fine-grained particles may be concentrated at the borehole-formation interface, and to draw the finer materials into the well or borehole for removal. This process also helps remove fine fraction formation materials in proximity to the borehole wall, leaving behind a "natural" pack of coarser-grained materials.

6.2.1 Bailing

In relatively clean, permeable formations where water flows freely into the borehole, bailing is an effective development technique. Let the bailer fall down the well until it strikes the surface of the groundwater which produces an outward surge. Rapidly withdraw the bailer to create a drawdown and/or after the bailer hits the groundwater lower it to the bottom of the well and agitate it with rapid short strokes. Continue bailing with repeated up and down "surging motions" until water bailed from the well is free from suspended particles.

Note: During this process, if the well goes dry, stop bailing and let the well recharge before continuing.

6.2.2 Surge Block

A surge block is a tool used to break up bridging of fine grained material by inducing agitation and inducing flow into and out of the well and aquifer formation. Bridging is the tendency for particles moving towards a well under unidirectional flow (pumping) to develop a blockage that restricts subsequent particles to move into a well. Surge block is used alternately with either a pump or bailer. Let the surge block fall down the well until it strikes the groundwater surface. This creates a vigorous outward surge; rapidly retrieve the surge block. Lower the surge block to the top of the well intake and begin a pumping action with a typical stroke of approximately 3 feet and gradually work downward through the screened interval. Remove the surge block at regular intervals to discard the loosened suspended particles by either bailing or pumping. Continue the cycle of surging/bailing/pumping until satisfactory development has been attained.

6.2.3 Pumping/Over-pumping

In both pumping techniques, the groundwater flow is induced to flow into the well and the fine particulate material moves into the well and is discharged by the pump. In the case of over-pumping, the pump is operated at a capacity that substantially exceeds the ability of the formation to deliver water. Once pumping has begun, start the surging action by lowering and raising the hose/pumping apparatus through the screened interval. Bailing or bailing and surging may be combined with pumping for efficient well development. Continue pumping until such time as satisfactory development has been attained based on field observation of visibly clear water produced. If an analytical measure is needed, use turbidity meter readings to document initial turbidity and final turbidity readings. Well stabilization parameters may also be measured and documented pre- and post-development.

If pumping/over-pumping is completed by air lifting, the air compressor must be of an oil-less type or fitted with an oil trap capable of removing compressor oil from the air stream to avoid contaminating the well or boring.

Note: The types of pumps used are described in Barr's SOPs 'Collection of Groundwater Samples from a Temporary or Permanent Monitoring Well (Includes Well Purging and Stabilization)' or 'Collection of Groundwater Samples using Low-Flow Purging and Sampling'.

6.2.4 High Velocity Jetting

Development by high velocity jetting may be completed with either water or air. In practice, jetting with water is typically followed by or simultaneously occurring air-lift pumping/over pumping to remove the fine materials. The jetting procedure consists of operating a horizontal water jet(s) inside of the well screen so high velocity streams of water shoot through the screen openings into the sand pack/formation. The jetting tool is worked similar to a surge block. The jetting tool ideally will have four openings located 90 degrees apart and should be worked up and down the screened interval while being rotated. At a minimum, the amount of water introduced during jetting and, if feasible, an additional 10 well volumes of water should be purged from the well.

6.3 Data Reduction/Calculations

The calculations for well volume and volume of water to be purged are included in Barr's SOP '*Collection of Groundwater Samples from a Temporary or Permanent Monitoring Well (Includes Well Purging and Stabilization)'*.

6.4 Disposal

Waste generated by this process will be disposed of in accordance with Federal, State and Local regulations and Barr's SOP 'Investigative Derived Waste'. Where reasonably feasible, technological changes have been implemented to minimize the potential for environmental pollution.

7.0 Quality Control and Quality Assurance (QA/QC)

QA/QC objectives (e.g., turbidity, well recovery rate, water quality parameters) are specific to each project and/or well. Discuss QA/QC procedures with the project team prior to well development.

8.0 Records

The field technician(s) will document the method of development, any deviations from this SOP, volume of water purged, and any volume of water introduced to the well (e.g., high velocity jetting, flushing).

Examples of common field documentation are available in Barr's "Compendium of Field Documentation". Field documentation specific to this SOP are listed below:

- Field Log Cover Sheet
- Field Log Data Sheet

The field documents are provided to a Barr Data Management Administrator for storage on the internal Barr network.

Additional records information can be found in Barr's "Records Management System Manual".

Other Barr SOP subjects referenced within this SOP: water quality meter, turbidimeter, well recovery rate testing, collection of PFAS samples, decontamination of sampling equipment, groundwater purging/sampling, low-flow purging/sampling, and investigative derived waste.

9.0 References

American Society for Testing and Materials (ASTM), D5521/D5521M-13. 2013. *Standard Guide for Development of Groundwater Monitoring Wells in Granular Aquifers.*

Environmental Protection Agency, Offices of Waste Programs Enforcement and Solid Waste and Emergency Response. 1986. *RCRA Ground-Water Monitoring Technical Enforcement Document.*

Johnson Filtration Systems. 1986. *Groundwater and Wells.*

National Water Well Association. *Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells.*

Appendix A.2

Collection of Groundwater Samples from a Temporary or Permanent Monitoring Well (includes well purging and stabilization) SOP

BARR

Standard Operating Procedure

Collection of Groundwater Samples from a Temporary or Permanent Monitoring Well (Includes Well Purging and Stabilization)

Revision 2

March 14, 2019

Approved By:

Kristen Jung ____________________ ____________________ 03/14/19
Print Technical Reviewer Signature Date

Terri Olson Terri A. Olson 03/14/19
Print QA Manager Signature Date

Review of the SOP has been performed and the SOP still reflects current practice.

Initials: ____________________ Date: ____________________
Initials: ____________________ Date: ____________________
Initials: ____________________ Date: ____________________
Initials: ____________________ Date: ____________________

Minneapolis, MN ● Hibbing, MN ● Duluth, MN ● Ann Arbor, MI ● Jefferson City, MO ● Bismarck, ND ● Calgary, AB, Canada ● Grand Rapids, MI ● Salt Lake City, UT

Collection of Groundwater Samples from a Monitoring Well (Includes Well Purging and Stabilization)

1.0 Scope and Applicability

The purpose of this Standard Operating Procedure (SOP) is to describe the methods used for monitoring well purging, stabilization, and sampling (excluding residential/water supply systems). The SOP also provides details regarding the calculation of purge volumes and measurement of groundwater stabilization criteria and identifies the common container, preservative, and holding times for typical groundwater sample analyses.

The recommended procedures in this SOP should be followed unless conditions make it impractical or inappropriate to do so. Modifications should be noted in the applicable documentation and communicated to appropriate personnel. Significant changes may result in a revision or newly created SOP.

2.0 Limitations

- Sample collection methods can vary by project. If not specified in the project scope of work and/or documentation (e.g., Work Plan, Sampling Analysis Plan (SAP), or Quality Assurance Project Plan (QAPP)), consult with the appropriate regulatory agency for guidance.
- Collection of groundwater samples from residential/water supply systems are not discussed within this SOP.
- Dedicated sampling equipment and/or decontamination of sampling equipment is required to prevent cross-contamination.
- Low-flow sampling methods are not discussed within this SOP.
- Sample collection using 'clean hands/dirty hands' methods is not discussed within this SOP.
- If sampling for per- and polyfluorinated alkyl substances (PFAS), special consideration must be taken to avoid accidental contamination of environmental samples - see Barr's SOP 'Collection of Per- and Polyfluorinated Alkyl Substances (PFAS) Samples'.

3.0 Responsibilities

The Project Manager, in conjunction with the client, develops the site specific scope of work (e.g., Work Plan, SAP, etc.).

Experienced Field Technician(s) are responsible for the measurement of well pumping rates, calculation of well purge volume, field screening procedures, field equipment and calibration, proper sample identification, collection of samples, quality control procedures, and documentation.

Equipment Technicians are responsible for maintaining equipment in working order and aiding in troubleshooting equipment issues.

The role of the Field Safety Representative is to oversee on-site safety activities.

Project staff are responsible for ordering sample containers prior to the sampling event.

4.0 Safety

Barr staff is responsible for conducting the aspects of the job safely. When applicable, refer to the appropriate Project Health and Safety Plan (PHASP) to understand the hazards associated with suspected contamination, symptoms of exposure, methods to minimize exposure, personal protective equipment (PPE), and personal air monitoring required when using this SOP. Minimum protection of one pair of chemical resistant gloves (e.g., nitrile) and safety glasses with side shields should be worn to prevent sample contact with the skin and eyes. When sampling waters contaminated with corrosive materials, emergency eye flushing facilities should be available.

Some of the sample containers may require the use of preservatives. Consult the applicable Safety Data Sheet to review hazards and appropriate PPE to minimize exposure.

5.0 Equipment, Reagents, and Supplies*

- Water quality meter (e.g., YSI, or equivalent)
- Polyethylene bailer and rope
- Sample tubing and fittings
- Turbidimeter (optional)
- Coolers
- Ice
- Chemical resistant gloves (e.g., nitrile)
- Calculator
- Locks/keys
- Pump (peristaltic or submersible), power source, and appropriate drive tubing
- Cord reel (optional)
- Graduated measuring container
- Plastic bags
- Waterproof ink pen or pencil
- Clock or stopwatch
- Sample containers (method specific)
- Items listed in Section 8.0 Records
- Decontamination supplies (see Decon SOP)

* See Barr's PFAS SOP for a list of prohibited and acceptable items.

6.0 Procedure

This section describes the procedure(s) for calibrating field equipment, measuring pumping rates, calculating purge volumes, well purging, measuring well stabilization, and the sampling, handling, and delivery of groundwater samples. Best practices include setting up the purging, stabilization, and sampling equipment in an upwind direction from any potential source of contamination.

This SOP describes the groundwater collection from a bore hole, temporary well, or permanent monitoring well. Typically, a direct-push (Geoprobe® or equivalent) will be used to create the bore hole or temporary well by advancing the direct-push sampler to the desired sampling interval (sampling depth). When the sampling depth is reached, small diameter extension rods are inserted through the steel probe rods to hold the groundwater sampler screen in place while the rods and screen sheath are retracted, exposing the screen. The groundwater sampler screen can typically be exposed up to 41 inches, but can be exposed a shorter length depending on project requirements. Alternately, a small diameter PVC well screen and riser pipe may be installed in the bore hole for use as a temporary well. Polyethylene (or project specified) tubing is placed into the bore hole or temporary well, and a peristaltic pump (or equivalent) or project specified pump is used to draw water samples to the surface for collection. Well stabilization is not always necessary for temporary wells but if required by the project, see Section 6.2.6 of this SOP.

After each borehole or temporary well is constructed, the probe rods are decontaminated by the drilling contractor in accordance with project requirements. The polyethylene (or project specified) tubing is discarded after each sample is collected and new tubing is used for the collection of the next sample. The borehole and temporary well locations will be permanently sealed following applicable state and local regulations.

6.1 Calibration

The water quality meter and turbidimeter will be calibrated as per the applicable Barr SOP. The meters will undergo calibration checks, at a minimum, before and after sampling. The calibration check will be documented on a calibration form (as appropriate) and/or in the field notebook. Any significant issues found during the calibration check will be noted in the field notebook and the Equipment Technicians will be notified.

6.2 Purging/Well Stabilization/Sampling

Prior to sampling, purging of the monitoring well is performed to remove stagnant water from within the well and to stabilize the well to allow for representative groundwater sample collection. The term ‘purge volume’ refers to the amount of water removed from a well before groundwater sample collection occurs.

Purging well volumes and stabilizing to remove stagnant water from a temporary well may not be necessary due to the short time frame between well installation and sampling. Purging and well stabilization procedure for temporary wells may vary by project or by well. Recommended practice is to purge a temporary well until the water clears, if possible, prior to sampling; however, purging prior to sampling may not be possible at all if water is limited (as it might be in a perched water zone), or water recharge is slow (as it would be in a clayey or silty water bearing zone).

6.2.1 Purge Volume

The volume of standing water in the well is calculated to determine the purge volume that needs to be removed from the well. The water level must be measured in order to determine the volume (see applicable Barr SOP). Calculation of the purge volume is addressed in Section 6.3, Data Reduction/Calculation of this SOP and Table 1. If a well is pumped dry, this constitutes an adequate purge and the well can be sampled following recovery. Refer to project documentation for volumes required to be purged.

6.2.2 Bailer Purging

A bailer can be used for slowly recovering wells with minimal water volume and a depth to groundwater greater than 25 feet. A new disposable polyethylene bailer with a check valve can be attached to a cord reel or a downrigger and support assembly. Polyethylene bailers can be hauled using stainless steel wire or new nylon line (rope).

- Put on gloves for skin protection and to prevent sample contamination.

- Secure the bailer and lower slowly into the water column until the bailer is submerged. Avoid rapid movements of the bailer to minimize turbidity. A cord reel can be used to aid in the lowering of the bailer.
- Raise the bailer and empty the water collected from the bailer into a graduated measuring container.
- Sampling may begin once desired volume is purged and the well has stabilized (see Section 6.2.6, Well Stabilization of this SOP).

6.2.3 Peristaltic Pump Purging

A peristaltic pump is used when the water level is within suction lift (e.g., within about 25 feet of the ground surface but may be less at higher altitudes). It usually is a low-volume suction pump with low pumping rates suitable for sampling shallow, small-diameter wells.

- Put on gloves for skin protection and to prevent sample contamination.
- Lower tubing into the well water to the desired depth (typically near the middle of the water column within the well screen interval) and cut to the desired length.
- Connect the well tubing to the drive tubing entering the pump.
- Connect the drive tubing exiting the pump to the short section of tubing entering the flow-through cell or graduated measuring container.
- Turn on pump and set the speed at the desired rate of flow.
- Sampling may begin once desired volume is purged and the well has stabilized (see Section 6.2.6, Well Stabilization of this SOP).

6.2.4 Submersible Pump Purging

A submersible pump is used when the water level is greater than the suction lift associated with a peristaltic pump. It is commonly used in conjunction with a control box to achieve the desired pumping rate (low to high). Variable rate submersible pumps are available to fit inside 2 inch or larger wells.

6.2.4.1 1.5-inch Submersible Pump

This is a type of submersible pump that can be used in 2-inch or larger diameter wells. It can purge water from depths down to 200 feet or greater, depending on pump model and manufacturer.

- Put on gloves for skin protection and to prevent sample contamination.
- Attach appropriate diameter tubing to pump intake, secure the tubing to the pump using a hose clamp or zip tie, lower pump, and secure at desired depth (typically near the middle of the water column within the well screen interval).
- Cut off tubing, allowing additional tubing length for discharge.
- Plug the pump into the controller. Pump will begin pumping using the variable speed controller. There are varieties of speed controllers available, typically designed for a specific pump.
- Attach the controller to the power supply (e.g., car battery, generator).
- Attach the tubing to the flow-through cell for the water quality meter.

  Note: If water is considerably turbid after initial pump start-up, the flow-through cell may be connected after purge water has cleared visually.

Turn on the controller and dial the speed control to the desired flow rate. The controller can slow the purge rate down to the optimum rate.

Note: If the submersible pump is not running, turn off the pump and then disconnect from the power supply. Check connections and try again.

- Sampling may begin once desired volume is purged and the well has stabilized (see Section 6.2.6, Well Stabilization of this SOP).

6.2.4.2 3 or 4-inch Submersible Pump

This pump may be used to purge water samples from any depth.

- Put on gloves for skin protection and to prevent sample contamination.
- Attach purging hose to the pipe connected on the top of the submersible pump.
- Lower the submersible pump slowly into the well until it is completely submersed into the water and secure at desired depth (typically near the middle of the water column within the well screen interval).
- Connect the pump to a sufficiently sized generator with an extension cord.
- Attach the flow-through cell for the water quality meter.

  Note: If water is considerably turbid after initial pump start-up, the flow-through cell may be connected after purge water has cleared visually.
- Turn on pump and if it does not start, check connections to generator.
- Adjust flow rate to desired rate with the valve and measure the flow rate with the graduated measuring container.
- Sampling may begin once desired volume is purged and the well has stabilized (see Section 6.2.6, Well Stabilization of this SOP).

6.2.5 Well Purging with In-place Plumbing

In-place plumbing consists of dedicated, submersible pumps that are permanently installed in a well.

- Put on gloves for skin protection and to prevent sample contamination.
- Turn switch to start the generator, put choke on, pull recoil rope, and let generator idle until it is running smooth.
- Connect the pump to the generator with an extension cord.
- Connect the pipe, elbow, and valve to the discharge pipe of the submersible pump (located at the top of the well) and turn on the generator.

  Note: If the pump does not start, check the connection from the generator to the pump.
- When water flows from discharge of the pump, adjust the flow according to desired flow rate and measure the flow rate with the graduated measuring container.
- Attach the flow-through cell for the water quality meter.

  Note: If water is considerably turbid after initial pump start-up, the flow-through cell may be connected after purge water has cleared visually.
- Sampling may begin once desired volume is purged and the well has stabilized (see Section 6.2.6, Well Stabilization of this SOP).

  Note: Each dedicated pump has its own pipe, elbow, and valve. These pieces are left at each well.

6.2.6 Well Stabilization

Well stabilization is typically conducted to help verify that the groundwater sample is representative of aquifer conditions. A well is considered 'stabilized' after the well purge volume has been met and the groundwater (or well) stabilization parameter measurements are within acceptable limits for three consecutive readings. Well stabilization parameters may vary by project or regulatory agency but at a minimum typically include pH, temperature, and specific conductance (temperature corrected electrical conductivity). Dissolved oxygen (DO) and oxidation-reduction potential (ORP) may also be used as stabilization parameters.

The procedure to stabilize a well includes recording well stabilization parameter measurements collected with the water quality meter at the beginning of the well purging process and after subsequently purged well volumes. A well volume is measured as the volume of water present inside a well screen and/or casing (i.e., from the base of the well to the water level measurement) and is defined in the footnotes of Table 1. Groundwater aliquots used for stabilization parameter measurements are typically collected by either directing the purge water discharge line through a flow-through cell or by pouring groundwater from a bailer into a container holding the water quality meter probe (depending on the purging method used).

Documentation of the well stabilization process typically includes recording pertinent information such as the pump type, pumping rate, volume pumped, and well stabilization measurements on the field log data sheets or field notebook. If only the minimum parameters are used for stabilization, the DO and ORP should still be measured and recorded as they may be needed to interpret other chemical parameter results. Turbidity is measured with a standalone turbidimeter but is typically not used as a stabilization parameter. A qualitative determination of turbidity may also be noted (e.g. clear, cloudy, very cloudy, etc.).

The well may be sampled after three consecutive measurements (typically one well volume per measurement), collected at the intervals described above, are within specific project criteria or the criteria presented in Section 7.2, Measurement Criteria of this SOP.

If field parameters do not stabilize after five well volumes have been purged, then the field technician will verify that the probes and related equipment are functioning properly and that operator error is not an issue. They will also re-evaluate whether or not water is being withdrawn from the appropriate depth to effectively evacuate the well. If the checks produce no new insight, a decision will need to be made by the project team on whether to collect samples for laboratory analysis. When samples are collected, it will be clearly documented that stabilization was not achieved; at a minimum, this fact will be reported on the field log data sheets and in the Field Sampling Report.

If the well was purged dry, it shall be allowed to recharge and the samples should then be collected. If there is insufficient sample volume for the analyses being sampled, the project team will need to decide if sampling should be carried out or if a reduced prioritized list of analyses should be collected.

6.2.7 Sampling

The project team will determine the order for sampling the wells but general guidelines are below:

- Where water quality data are available, the least contaminated wells would be sampled first, proceeding to increasingly contaminated wells.

- Where the distribution of contaminants is not known, wells considered to be up gradient from likely sources of contamination would be sampled first and downgradient wells closest to the suspected contamination would be last.
- Make certain to keep records of the order in which wells were sampled.

Similar to purging, sampling requires the use of pumps or bailers. It may be appropriate to use a different device to sample than that which was used to purge. The most common example of this is the use of a pump to purge and a bailer to sample. There are several factors to take into consideration when choosing a sampling device. The experience of the project team will be used to determine which is appropriate and care should be taken when reviewing the advantages or disadvantages of any one device.

To reduce potential contamination, samples for PFAS should be collected first. See Barr's SOP 'Collection of Per- and Polyfluorinated Alkyl Substances (PFAS) Samples'. To prevent the possible loss of some volatile organic compounds (VOCs), samples for volatile parameters should be collected second with as little agitation and disturbance as possible, then proceed in order towards the least volatile parameter as listed in Barr's 'Water Sampling Guidelines' form. The 40 mL vials used to collect the VOC samples should be checked for air bubbles. Air bubbles may be caused by insufficient meniscus when sealing the vial, degassing after sample collection or during sample shipment, or reaction between the sample and preservative (HCl). If air bubbles > 6 mm (pea-sized) are observed during sampling, discard the vial and recollect the sample using a new vial. If air bubbles are believed to be due to the sample reacting with the preservative, the sample should be collected in an unpreserved vial if possible.

Put on new sampling gloves at each sampling site to reduce the risk of sample cross-contamination and exposure to skin. Never reuse gloves.

Prepare sampling containers by filling out the label, using an indelible permanent pen, with the following information at a minimum:

- Sample ID
- Date and time of sample collection
- Preservative
- Sample analysis (if required by the lab)

When filling the containers, do not insert the tubing into the containers and do not overfill preserved containers. When samples are containerized, place the filled sample containers in a sampling cooler with ice, turn off any equipment, disassemble the sampling apparatus, dispose of one-time use (disposable) equipment, and decontaminate reusable equipment per Barr's SOP 'Decontamination of Sampling Equipment'.

6.2.7.1 Bailer Sampling

After the well has been purged and stabilized, secure the bailer and slowly lower into the top of the water column making certain not to stir up the water with the bailer, which could result in volatizing the samples. Keep the bailer in the top portion of the water column when collecting the sample.

When the bailer is filled, slowly raise the bailer out of the well. A clean tarp may be used to cover the ground to minimize the contact of the rope with the ground. Fill containers in the order listed in Barr's 'Water Sampling Guidelines' form.

6.2.7.2 Peristaltic / Submersible Pump Sampling

After the well has been purged and stabilized, disconnect the tubing exiting the pump from the flow-through cell, if used and fill containers as listed in Barr's 'Water Sampling Guidelines' form.

6.2.7.3 Check Valve Sampling

Sampling temporary wells through tubing with a check valve may be conducted following a drilling subcontractor's procedure.

6.2.8 Preservation

Container volume, type, and preservative are important considerations in sample collection. Container volume must be adequate to meet laboratory requirements for quality control, split samples, or repeat analyses. The container type varies with the analysis required. Typically, the analytical laboratory will preserve the container before shipment. Preservation and shelf life vary; contact the laboratory to determine if an on-hand container is still useful. Barr's 'Water Sampling Guidelines' form lists the parameter, container type, container volume, and preservative for many of the most common parameters collected.

6.2.9 Handling

The samples will be bubble wrapped or bagged after collection, stored in a sample cooler, and packed on double bagged wet ice. Samples will be kept cold (≤ 6 °C, but not frozen), until receipt at the laboratory (where applicable).

Note: Samples may need to be stored indoors in winter to prevent freezing.

6.2.10 Shipment/Delivery

Once the cooler is packed to prevent breaking of bottles, the proper chain-of-custody (COC) documentation is signed and placed inside a plastic bag then added to the cooler.

Samples will be kept secured to prevent tampering. If sample coolers are left in a vehicle or field office for temporary storage, the area will be locked and secured.

Custody seals may be present, but at a minimum, the coolers must be taped shut to prevent the lid from opening during shipment.

The coolers must be delivered to the laboratory via hand or overnight delivery courier, if possible, in accordance with Federal, State and Local transportation regulations and Barr's SOP 'Domestic Transport of Samples to the Laboratory'.

6.3 Data Reduction/Calculations

Table 1 provides the volume of water (per foot or meter of depth) based on the diameter of the casing or hole. The following are two examples of calculations used in Table 1:

<u>Volume of Standing Water (V), cubic feet</u>

$$V = (\pi)(r^2)(h)$$

Where: π = 3.1416

r = Well radius (ft)

h = Total well depth (ft) – depth to static water (ft) = Water column height (ft)

Note: For the table calculations, 'h' is equal to one foot.

<u>*Well Volume (WV), gallons*</u>

$$WV = (V)(7.48)$$

Where: V = Volume of standing water, cubic feet

7.48 = Cubic foot to US Gallons conversion factor

Calculate the volume of water to be purged using the equation below:

$$VP = (WV)(NWV)$$

Where: VP = Volume of water to be purged

WV = Well volume in gallons

NMV = Number of well volumes to be purged per project requirements

6.4 Disposal

Waste generated by this process will be disposed of in accordance with Federal, State and Local regulations and Barr's SOP 'Investigative Derived Waste'. Where reasonably feasible, technological changes have been implemented to minimize the potential for environmental pollution.

7.0 Quality Control and Quality Assurance (QA/QC)

The QC activities described below allow the self-verification of the quality and consistency of the work.

7.1 QA/QC Samples

QA/QC samples are defined in Barr's SOP 'Collection of Quality Control Samples'. The sampling frequency should be performed at the frequency noted in the project scope of work and/or documentation (e.g., Work Plan, SAP, or QAPP).

7.2 Well Stabilization Criteria

Well stabilization criteria to be used if there are no project specific criteria:

- pH ± 0.1 standard units
- Temperature ± 0.5 °C
- Specific conductance ± 5%
- Optional Criteria:
    - ORP ± 10 mV
    - Dissolved oxygen ± 10% (> 0.5 mg/L)

      Note: Three consecutive readings ≤ 0.5 mg/L can be considered stabilized.
    - Turbidity ± 10% (> 5 Nephelometric Turbidity Units (NTU))

      Note: Three consecutive readings ≤ 5 NTU can be considered stabilized.

8.0 Records

The field technician will document the pumping flow rate, well volume, time purged, volume purged, water level, total well depth and stabilization test measurements on the field log data sheet and/or field notebook. They will also document the type and number of bottles on the chain-of-custody record, as appropriate. The analysis for each container and the laboratory used will be documented on the chain-of-custody record. Refer to Barr's SOP 'Documentation on a Chain-of-Custody (COC)' for further information.

Examples of common field documentation are available in Barr's "Compendium of Field Documentation". Field documentation specific to this SOP are listed below:

- Chain-of-custody (COC)
- Sample label
- Custody seal (if applicable)
- Water Level Data Sheet
- Field Log Data Sheet
- Field Log Cover Sheet
- Field Sampling Report
- Water Sampling Guidelines (includes sampling order, container, preservation, and holding time)

The field documents and COCs are provided to a Barr Data Management Administrator for storage on the internal Barr network.

Additional records information can be found in Barr's "Records Management System Manual".

Other Barr SOP subjects referenced within this SOP: water level measurement, water quality meter, turbidimeter, collection of QC samples, collection of PFAS samples, decontamination of sampling equipment, investigative derived waster, domestic transport of samples, and documentation on a COC.

9.0 References

Environmental Protection Agency. *Title 40 of the Code of Federal Regulations, Part 136.3.*

Environmental Protection Agency, EPA/540/P-91/007. 1999. *Compendium of ERT Groundwater Sampling Procedures.*

Minnesota Pollution Control Agency, Water Quality Division. 2006. *Sampling Procedures for Groundwater Monitoring Wells.*

Table 1

Volume of Water in Casing or Hole

Diameter of Casing or Hole (In)	Gallons per Foot of Depth (WV)	Cubic Feet per Foot of Depth (V)	Liters per Meter of Depth	Cubic Meters per Meter of Depth
1	0.041	0.0055	0.509	0.509 x 10^{-3}
1½	0.092	0.0123	1.142	1.142 x 10^{-3}
2	0.163	0.0218	2.024	2.024 x 10^{-3}
2½	0.255	0.0341	3.167	3.167 x 10^{-3}
3	0.367	0.0491	4.558	4.558 x 10^{-3}
3½	0.500	0.0668	6.209	6.209 x 10^{-3}
4	0.653	0.0873	8.110	8.110 x 10^{-3}
4½	0.826	0.1104	10.26	10.26 x 10^{-3}
5	1.020	0.1364	12.67	12.67 x 10^{-3}
5½	1.234	0.1650	15.33	15.33 x 10^{-3}
6	1.469	0.1963	18.24	18.24 x 10^{-3}
7	2.000	0.2673	24.84	24.84 x 10^{-3}
8	2.611	0.3491	32.43	32.43 x 10^{-3}
9	3.305	0.4418	41.04	42.04 x 10^{-3}
10	4.080	0.5454	50.67	50.67 x 10^{-3}
11	4.937	0.6600	61.31	61.31 x 10^{-3}
12	5.875	0.7854	72.96	72.96 x 10^{-3}
14	8.000	1.069	99.35	99.35 x 10^{-3}
16	10.44	1.396	129.65	129.65 x 10^{-3}
18	13.22	1.767	164.18	164.18 x 10^{-3}
20	16.32	2.182	202.68	202.68 x 10^{-3}
22	19.75	2.640	245.28	245.28 x 10^{-3}
24	23.50	3.142	291.85	291.85 x 10^{-3}
26	27.58	3.687	342.52	342.52 x 10^{-3}
28	32.00	4.276	397.41	397.41 x 10^{-3}
30	36.72	4.909	456.02	456.02 x 10^{-3}
32	41.78	5.585	518.87	518.87 x 10^{-3}
34	47.16	6.305	585.68	585.68 x 10^{-3}
36	52.88	7.069	656.72	656.72 x 10^{-3}

1 gallon = 3.7854 liters
1 liter = 0.26417 gallons
1 meter = 3.281 feet
1 gallon water weighs 8.33 lbs. = 3.785 kilograms
1 liter water weighs 1 kilogram = 2.205 lbs.
1 gallon per foot of depth = 12.419 liters per foot of depth
1 gallon per meter of depth = 12.419 x 10^{-3} cubic meters per meter of depth

Appendix B

Data Verification SOPs

Appendix B.1

Routine Level General Chemistry Data Evaluation SOP

Standard Operating Procedure

Routine Level General Chemistry Data Evaluation

Revision 8

January 2, 2020

Approved By:

Michael Dupay 01/02/20

Print Technical Reviewer Signature Date

Terri Olson Terri A. Olson 01/02/20

Print QA Manager Signature Date

Review of the SOP has been performed and the SOP still reflects current practice.

Initials: ____________________ Date: ____________________

Initials: ____________________ Date: ____________________

Initials: ____________________ Date: ____________________

Initials: ____________________ Date: ____________________

Routine Level General Chemistry Data Evaluation

1.0 Scope and Applicability

This SOP is intended as a guidance document for the routine level evaluation of general chemistry data provided by laboratories to be used in Barr Engineering Company (Barr) projects.

This SOP is based on the recommendations of the associated approved analytical methods from USEPA, ASTM, and *Standard Methods for the Examination of Water and Wastewate*r and applies to routine general chemistry data evaluation including a variety of approved methods not limited to the following parameters:

Alkalinity (Total, Bicarbonate, Carbonate)
Ammonia, Total (NH_3 + NH_4^-)
Biological Oxygen Demand (BOD)
Chemical Oxygen Demand (COD)
Chloride
Chromium VI (Hexavalent Chromium)
Conductance, Specific – *in lab*
Cyanide (as CN^-)
Fluoride
Hardness
Nitrate (or Nitrite) only
Nitrate + Nitrite
Oil and Grease (as HEM)
Orthophosphate
pH – *in lab*
Phosphorus, Total
Sulfate
Sulfide
Surfactants
Total Dissolved Solids (TDS)
Total Kjeldahl Nitrogen (TKN)
Total Organic Carbon (TOC)
Total Phenolics
Total Suspended Solids (TSS)
Turbidity

In the case of specific parameters not listed above, the guidelines within this document will provide the basis upon which to make adequate professional judgment in the evaluation of data submitted for review. Laboratories may not provide all the review elements in this SOP, review only those that are provided.

The recommended procedures in this SOP should be followed unless conditions make it impractical or inappropriate to do so. Modifications should be noted in the applicable documentation and communicated to appropriate personnel. Significant changes may result in a revision or newly created SOP.

2.0 Limitations

- Level IV data evaluation is not covered in this SOP and should be performed in accordance with project specific requirements.

3.0 Responsibilities

The laboratory is responsible for generating data from the samples submitted for analysis. In instances where QC criteria are not met for the analysis of samples, the laboratory is responsible for reanalysis of the samples, provided reanalysis is possible (considering matrix interference, holding times and sample volume, etc.), or documenting the impact to the data.

The Data Quality Specialist is responsible for evaluating the data in accordance with this document, in addition to using professional judgment where necessary or appropriate. Project specific requirements, such as those specified in a Quality Assurance Project Plan (QAPP) or Sampling and Analysis Plan (SAP), may differ from these recommendations and professional judgment should be applied before qualifying any data.

4.0 Procedure

The Quality Assurance/Quality Control (QA/QC) data detailed below are the most typical found in a routine level laboratory report evaluation. Other QA/QC data may be provided by the laboratory within the laboratory report case narrative, data qualifiers, or cover sheet and should be evaluated using professional judgment (e.g., initial calibration, calibration verification, internal standards, post digestion, serial dilution).

Definitions to common QA/QC terms and terms used within this SOP along with a list of Barr 'Data Qualifiers/Footnotes' that may be applied during review can be found in Barr's "Compendium of Data Quality Assessment Documentation".

4.1 Holding Time and Preservation

The purpose of holding time and preservation evaluation is to ascertain the validity of the analytical results based on the sample condition, preservation, and time elapsed between the date of sample collection and date of analysis.

40 CFR Part 136 and the *Test Methods for Evaluating Solid Waste (SW-846)* are used as guidance for the recommended holding time and preservation acceptance criteria listed in *Table 1*. Further information may be found in the water and soil sampling guidelines in Barr's "Compendium of Field Documentation".

Table 1 - Recommended Holding Times and Preservation

Parameter	**Recommended Hold Time**						**Preservation**					
	24 Hour	48 Hour	7 Day	14 Day	28 Day	180 Day	Ice (≤ 6 °C)	HCl	HNO_3	H_2SO_4	NaOH	ZnAc + NaOH
Alkalinity, as $CaCO_3$				X			X					
Ammonia as N					X		X			X		
Biochemical Oxygen Demand (BOD)		X					X					
Chemical Oxygen Demand (COD)					X		X			X		
Chloride					X		None required					
Chromium, Hexavalent	X				x[a]		X					
Conductance, Specific					X		X					
Cyanide				X			X				X	
Fluoride					X		None required					
Hardness						X			X[b]	X[b]		

(Table 1 continued on next page)

Table 1 - Recommended Holding Times and Preservation

Parameter	Recommended Hold Time						Preservation					
	24 Hour	48 Hour	7 Day	14 Day	28 Day	180 Day	Ice ($\leq 6\,^\circ C$)	HCl	HNO_3	H_2SO_4	NaOH	ZnAc + NaOH
Nitrate or Nitrite		X[c]					X					
Nitrate + Nitrite as N					X		X			X		
Oil & Grease, HEM					X		X	X[d]		X[d]		
Orthophosphate (field filter w/in 15 min)		X					X					
pH			X[e]				None required					
Phenolics, total					X		X			X		
Phosphorus, total					X		X			X		
Sulfate					X		X					
Sulfide			X				X					X
Surfactants		X					X					
Total Dissolved Solids (TDS)			X				X					
Total Kjeldahl Nitrogen (TKN)					X		X			X		
Total Organic Carbon (TOC)					X		X	X[d]		X[d]		
Total Suspended Solids (TSS)			X				X					
Turbidity		X					X					

a = Per 40 CFR Part 136.3, a 28-day holding time may be achieved if the ammonium sulfate buffer solution specified in EPA Method 218.6 is used. This footnote supersedes preservation and holding time requirements in approved hexavalent chromium methods, unless this would compromise the measurement and then the method must be followed.
b = Either preservative may be used for the titration method; if calculated from Ca and Mg, HNO_3.
c = Holding time for nitrate is NA when calculated from Nitrate + Nitrite minus Nitrite.
d = Either preservative may be used (pH < 2).
e = Method recommends pH should be measured in the field, holding time is 15 minutes.; however, for confirmation measurements in the laboratory, a maximum holding time of 7 days from sample collection may be used as a guideline for qualification.

If samples do not meet holding time, preservation and analysis recommendations in *Table 1*, consider qualification with an ‘H’ (“Recommended sample preservation, extraction or analysis holding time was exceeded.”). Other matrices, such as product samples (e.g. oil, waste rock, drill cores) may not be subject to the same holding time recommendations.

If the sample was stored on ice upon collection and delivered to the laboratory the same day, the sample may exceed recommended temperature at the time of laboratory receipt. Professional judgment should be applied (considering temperature, matrix, magnitude of the exceedance, etc.) when evaluating the application of qualifiers when criteria are not met.

4.2 Blank Samples

Blank sample evaluation is conducted to determine the existence and magnitude of target analyte contamination as a result of activities in the field during collection and transport or from inter-laboratory sources.

- While not required for all methods, method blanks are recommended for all but the pH analysis. Evaluation pertains to the batch of samples analyzed with the method blank.
- Field or equipment blank collection and analysis frequency is project specific. Evaluation pertains to the field samples associated with the field or equipment blank.
- Blank analyses may not have involved the same weights, volumes, or dilution factors as the associated samples. Data reviewers may have to obtain raw data and/or convert the data to the same units for comparison purposes.

Table 2 – Guidelines for Blank Contamination

Sample Result	Recommended Action for Associated Data
Non-detect	No action required
< 5x blank concentration	Qualify with 'UB'
≥ 5x blank concentration	Use professional judgment

UB = The analyte is detected in one of the associated laboratory, equipment, field or trip blank samples and is considered non-detect at the concentration reported by the laboratory.

Note: Other multipliers of the blank contamination may be used based on professional judgment (reporting to the MDL, common lab contaminant, etc.)

Professional judgment regarding the usability of the data should be used in cases where gross detections of target analytes are found in the blank sample. A number of factors may be considered including historical data, prior knowledge of the site conditions, target analytes involved, type of blank sample, etc. In such cases, it may be appropriate to qualify the affected data with 'J' ("Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory's detection and quantitation limits.") or 'R' ("The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.").

4.3 Laboratory Control Samples (LCS) and Laboratory Control Sample Duplicate Samples (LCSD)

The laboratory control sample is used to monitor the overall performance of each step during analysis, including sample preparation. The LCS should be analyzed:

- Once every preparation batch (typically 20 or less samples of the same matrix).
- Once for each matrix.

Laboratory control samples contain a known amount of each target compound and the percent recoveries are evaluated based on the criteria within the laboratory report or project specific requirements. Percent recoveries are calculated for accuracy and the relative percent difference (RPD) is calculated for precision (when an LCSD was analyzed). Accuracy and precision equations can be found in 'Definitions' from Barr's "Compendium of Data Quality Assessment Documentation".

Table 3 – Guidelines for Laboratory Control Samples		
Criteria	**Recommended Action for Associated Data**	
	Detect	**Non-Detect**
%R > Upper Limit	Qualify with 'J+' or use professional judgment	No qualification
%R < Lower Limit	Qualify with 'J-' or 'R', use professional judgment	
RPD > Upper Limit	Qualify with 'J' or use professional judgment	
%R and RPD within Limits	No qualification	

J+ = The result is an estimated quantity and may be biased high.
J- = The result is an estimated quantity and may be biased low.
J = Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory's detection and quantitation limits.
R = The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.

4.4 Laboratory Duplicate Samples

Laboratory duplicate samples are separate aliquots of field samples analyzed to demonstrate acceptable method precision by the laboratory at the time of analysis. Ideally, blanks and proficiency testing (PT) samples should not be used for duplicate analysis. The MS/MSD duplicate pairs may be substituted for laboratory duplicates. The RPDs are calculated using the equation as provided in 'Definitions' from Barr's "Compendium of Data Quality Assessment Documentation" and are not calculated where data are already qualified with U, UB, <, or R. RPD results are dependent on the homogeneity of the samples.

Duplicates should be analyzed (whichever is more frequent):

- One from each matrix (soil or water)
- One from each SDG

Laboratory acceptance criteria or project specific requirement are used to evaluate RPDs. If criteria are not available, use professional judgment when considering qualification of associated results.

Higher RPDs are expected when results are at or near the reporting limits and are not always indicative of poor precision. RPDs are typically only evaluated for samples where both the native and duplicate sample concentrations are greater than five times (>5x) the RL. In cases where either of the samples (native or duplicate) is non-detect for a parameter and the other corresponding sample has detectable concentrations much greater than five times (>5x) the RL, professional judgment should be used to determine if qualification is appropriate.

Table 4 – Guidelines for Laboratory Duplicates	
% RPD	**Recommended Action for Associated Data**
RPD < Upper Limit	No action is required
RPD > Upper Limit	Both results are ≤ 5x RL, no action is required
RPD > Upper Limit	Both results are > 5x RL, consider qualifying with ‘J’

J = Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory’s detection and quantitation limits.

4.5 Field Duplicate Samples

Field duplicate samples (also known as “masked” or “blind” duplicate samples) are used to demonstrate acceptable precision and reproducibility of the field and laboratory procedures. Frequency of collection is project specific. The RPDs are calculated using the equation as provided under precision in ‘Definitions’ from Barr’s “Compendium of Data Quality Assessment Documentation” and are not calculated where data is already qualified with U, UB, <, or R. RPD results are dependent on the homogeneity of the samples.

Acceptance criteria for field duplicate samples are subject to the professional judgment of the Data Quality Specialist but typically RPDs ≤ 30% for aqueous samples and ≤ 40% for soil and sediment samples are considered acceptable unless other project specific requirements are defined.

Higher RPDs are expected when results are at or near the reporting limits and are not always indicative of poor precision. RPDs are typically only evaluated for samples where both the native and duplicate sample concentrations are greater than five times (>5x) the RL. In cases where either of the samples (native or field duplicate) is non-detect for a parameter and the other corresponding sample has detectable concentrations much greater than five times (>5x) the RL, professional judgment should be used to determine if qualification is appropriate.

Table 5 – Guidelines for Field Duplicates	
% RPD	**Recommended Action for Associated Data**
RPD < Upper Limit	No action is required
RPD > Upper Limit	Both results are ≤ 5x RL, no action is required
RPD > Upper Limit	Both results are > 5x RL, consider qualifying with ‘J’

J = Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory’s detection and quantitation limits.

4.6 Matrix Spikes (MS) and Matrix Spike Duplicate (MSD) Samples

Matrix spike samples contain a known amount of a target compound and provide information about the effect of each samples’ matrix on the sample preparation procedures and analytical results. Matrix spikes are typically analyzed at the following frequencies:

- 1 (MS/MSD pair) in every 20 samples
- 1 per preparation batch per matrix
- 1 per SDG

However, the frequency may be project specific and the documents outlining the needs of the project (SAP, QAPP, etc.) should be reviewed. In some cases, MS/MSD analysis is not required.

The percent recoveries are evaluated based on the criteria within the laboratory report or project specific requirements. If a matrix spike recovery does not meet acceptance criteria and is not associated with a project sample, no further action is required unless other systematic evidence warrants qualification.

If the native concentration of a spiked sample is significantly greater than the spike added (>4x), spike recovery cannot be accurately evaluated, therefore the criteria do not apply. Professional judgment should be used for percent recoveries nominally outside laboratory acceptance criteria prior to qualifying data.

If criteria are not available, use guidance found in the NFG. Percent recoveries of matrix spike (and matrix spike duplicate) samples should be calculated using the equation provided under accuracy in 'Definitions' from Barr's "Compendium of Data Quality Assessment Documentation".

Solid samples may have highly variable concentrations of target analytes and percent recoveries (%R) may be influenced by the sampling precision and inherent sample homogeneity. Professional judgment should be used for difficult matrices and the acceptance criteria adjusted accordingly.

Table 6 – Guidelines for Matrix Spikes

Criteria	**Recommended Action for Associated Data**	
	Detect	**Non-Detect**
%R > Upper Limit	Qualify with 'J+' or use professional judgment	No qualification
%R < Lower Limit	Qualify with 'J-' or 'R', use professional judgment	
RPD > Upper Limit	Qualify with 'J' or use professional judgment	
%R and RPD within Limits	No qualification	

J+ = The result is an estimated quantity and may be biased high.
J- = The result is an estimated quantity and may be biased low.
J = Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory's detection and quantitation limits.
R = The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.

While matrix spike duplicates are not required by all methods, if results for MSD analyses are reported, evaluate the RPD for MS and MSD pairs using the equation as provided under precision in 'Definitions' from Barr's "Compendium of Data Quality Assessment Documentation".

4.7 Overall Assessment

The chain-of-custody should be reviewed to determine if the laboratory report matches the requested analyses and that project specific parameters were analyzed as requested. The narrative and other supporting documentation should be evaluated to ensure that sample condition was appropriately documented by the laboratory upon receipt. If available, historical data should be used to assist with data evaluation. Any additional anomalies should be documented and evaluated, if necessary.

5.0 Quality Control and Quality Assurance (QA/QC)

Depending on the project objectives, the data evaluation may include the completion of a Routine Level Quality Control Report. This may be a report produced via EQuIS DQM (Environmental Quality Information System Data Quality Module) or a hardcopy as found in Barr's "Compendium of Data Quality Assessment Documentation". Within each QC data section, the reviewer should include references to whether the QC data met or exceeded the acceptance criteria. The qualifiers, added, removed, or retained, should be documented. If using EQuIS DQM, reason codes will also be applied. The reason codes are defined in the software. Where multiple qualifiers may be applicable to a sample/analyte result, professional judgment should be used to determine if all qualifiers are necessary or if one qualifier would be sufficient to represent the deviations. A statement as to whether the data are acceptable as reported or acceptable with qualification(s) should also be included. If revised reports are required and the revision affects the sample results, notification should be given to the appropriate data management personnel and/or project team members.

6.0 Records

The Routine Level Quality Control Report should be saved to the appropriate internal Barr file and the link uploaded to the tracking system. Periodically, Data Quality staff should check for missing Routine Level Quality Control Reports in the tracking system to help maintain the most current information. Documentation of the data evaluation may include but is not limited to an email to the project team, data evaluation summary report, technical memo, or section within a project report.

Documentation specific to this SOP are listed below and are available in Barr's "Compendium of Data Quality Assessment Documentation".

- Definitions
- Barr Qualifiers/Footnotes
- Routine Level Quality Control Report

Additional records information can be found in Barr's "Records Management System Manual".

7.0 References

Environmental Protection Agency. *Title 40 of the Code of Federal Regulations, Part 136.3.*

Environmental Protection Agency, *National Functional Guidelines for Inorganic Superfund Data Review.*

Analytical methods listed under the 'Scope and Applicability' section of this SOP.

Attachment 1

Revision History

Revision Number	Date of Revision	Section	Revision Made
5.0	06/17/13	Cover page	Added Calgary office
		Applicability	Added US to EPA reference
		I	Added waste rock and drill cores to examples of product sample
		III	Added LCSD information
		III, IV, V, VI	Added 'project specific requirements' as possible criteria source
		V	Added 'field and laboratory procedures' to clarify that it's not only a laboratory item
		V	Clarified field duplicate criteria as < one value and not a range
		VIII	Added statement regarding multiple qualifiers
6	01/07/16	Document Wide	SOP restructuring, new format
7	04/24/18	1.0	Added laboratories may not provide all the review elements in this SOP, review only those that are provided.
		4.2, third bullet	Clarified that data reviewers would have to obtain raw data since not provided with Level II report.
8	01/02/20	Document wide	Updated for new qualifiers

Appendix B.2

Routine Level Metals Data Evaluation SOP

BARR

Standard Operating Procedure

Routine Level Metals Data Evaluation

Revision 8

January 2, 2020

Approved By:

Michael Dupay — 01/02/20
Print — Technical Reviewer — Signature — Date

Terri Olson — Terri A. Olson — 01/02/20
Print — QA Manager — Signature — Date

Review of the SOP has been performed and the SOP still reflects current practice.

Initials: ____________ Date: ____________
Initials: ____________ Date: ____________
Initials: ____________ Date: ____________
Initials: ____________ Date: ____________

Routine Level Metals Data Evaluation

1.0 Scope and Applicability

This SOP is intended as a guidance document for the routine level evaluation of metals data provided by laboratories to be used in Barr Engineering Company (Barr) projects.

This SOP is based on quality assurance elements, not the specific criteria, of *USEPA Contract Laboratory Program National Functional Guidelines (NFG) for Inorganic Data* and applies to routine metals data evaluation for analyses by the following technologies:

- Inductively Coupled Plasma/Atomic Emission Spectroscopy (ICP/AES)
  - Method examples: EPA 200.7, EPA 6010
- Inductively Coupled Plasma/Mass Spectrometry (ICP/MS)
  - Method examples: EPA 200.8, EPA 6020
- Cold Vapor Atomic Absorption (CVAA)
  - Method examples: EPA 245.1, EPA 7470, EPA 7471, SM 3112 B
- Cold Vapor Atomic Fluorescence Spectrometry (CVAF)
  - Method examples: EPA 245.7, EPA 1631 (low-level mercury), EPA 7474
- Thermal Decomposition / Atomic Absorption Spectrophotometer
  - EPA 7473
- Graphite Furnace Atomic Absorption (GFAA)
  - Method examples: EPA 7010, SM 3113 B
- Methods above in conjunction with Toxicity Characteristic Leachate Procedure (TCLP), EPA 1311
- Methods above in conjunction with Synthetic Precipitation Leachate Procedure (SPLP), EPA 1312

The letter indicator for the various EPA method revisions have been intentional omitted. Multiple versions of the approved methods would be applicable for review under this SOP. In the case of specific technologies and/or methods not listed above, the guidelines within this document will provide the basis upon which to make adequate professional judgment in the evaluation of data submitted for review. Laboratories may not provide all the review elements in this SOP, review only those that are provided.

The recommended procedures in this SOP should be followed unless conditions make it impractical or inappropriate to do so. Modifications should be noted in the applicable documentation and communicated to appropriate personnel. Significant changes may result in a revision or newly created SOP.

2.0 Limitations

- Level IV data evaluation is not covered in this SOP and should be performed in accordance with NFG or project specific requirements.

3.0 Responsibilities

The laboratory is responsible for generating data from the samples submitted for analysis. In instances where QC criteria are not met for the analysis of samples, the laboratory is responsible for reanalysis of the samples, provided reanalysis is possible (considering matrix interference, holding times and sample volume, etc.), or documenting the impact to the data.

The Data Quality Specialist is responsible for evaluating the data in accordance with this document, in addition to using professional judgment where necessary or appropriate. Project specific requirements, such as those specified in a Quality Assurance Project Plan (QAPP) or Sampling and Analysis Plan (SAP), may differ from these recommendations and professional judgment should be applied before qualifying any data.

4.0 Procedure

The Quality Assurance/Quality Control (QA/QC) data detailed below are the most typical found in a routine level laboratory report. Other QA/QC data may be provided by the laboratory within the laboratory report case narrative, data qualifiers, or cover sheet and should be evaluated using professional judgment (e.g., initial calibration, calibration verification, internal standards, post digestion, serial dilution).

Definitions to common QA/QC terms and terms used within this SOP along with a list of Barr 'Data Qualifiers/Footnotes' that may be applied during review can be found in Barr's "Compendium of Data Quality Assessment Documentation".

4.1 Holding Time and Preservation

The purpose of holding time and preservation evaluation is to ascertain the validity of the analytical results based on the sample condition, preservation, and time elapsed between the date of sample collection and date of analysis.

40 CFR Part 136 and the *Test Methods for Evaluating Solid Waste (SW-846)* are used as guidance for the recommended holding time and preservation acceptance criteria listed in *Table 1*.

Table 1 – Recommended Holding Times and Preservation

Compound	Matrix	Temp.	Preservative	Maximum Holding Time
Mercury	Aqueous	--	HNO_3 < 2 pH	28 days
	Aqueous (low level)	--	Pre-tested hydrochloric acid or bromine chloride	48 hours preserve or analyze if not oxidized in sample bottle/28 days preserve if oxidized in sample bottle 90 days analysis (from collection) if preserved
	Sediment/Soil	Cool, ≤ 6 °C	Ice	28 days
	Wipe/Air	--	NA	28 days

(Table 1 continued on next page)

Table 1 – Recommended Holding Times and Preservation

Compound	Matrix	Temp.	Preservative	Maximum Holding Time
Mercury	TCLP	--	NA	28 days TCLP Extraction/ 28 days analysis
All other metals	Aqueous	--	HNO_3 < 2 pH	180 days
	Sediment/Soil	Cool, ≤ 6 °C	Ice	180 days
	Wipe/Air	--	NA	180 days
	TCLP	--	NA	180 days TCLP Extraction/ 180 days analysis

Note: When analyzing boron or silica, do not collect samples in borosilicate glass bottles.

If samples do not meet holding time, preservation and analysis recommendations in *Table 1*, consider qualification with an 'H' ("Recommended sample preservation, extraction or analysis holding time was exceeded."). Other matrices, such as product samples (e.g. oil, waste rock, drill cores) may not be subject to the same holding time recommendations.

If the sample was stored on ice upon collection and delivered to the laboratory the same day, the sample may exceed recommended temperature at the time of laboratory receipt. Professional judgment should be applied (considering temperature, matrix, magnitude of the exceedance, etc.) when evaluating the application of qualifiers when criteria are not met.

Special considerations for low-level mercury

Low-level mercury must be collected directly into a specially cleaned, pretested, fluoropolymer or glass bottle using sample handling techniques specially designed for collection of mercury at trace levels and preserved with pre-tested hydrochloric acid (required for methyl mercury) or bromine chloride. Samples not collected in the correct type of container may be qualified with an 'H' ("Recommended sample preservation, extraction or analysis holding time was exceeded."). These samples may be shipped unpreserved provided:

- Sample is collected in a fluoropolymer or glass bottle.
- Bottle contains no headspace and is capped tightly.
- Sample temperature was maintained at ≤ 6 °C.
- Samples are preserved or analyzed within 48 hours or oxidized in the bottle within 28 days.

4.2 Blank Samples

Blank sample evaluation is conducted to determine the existence and magnitude of target analyte contamination as a result of activities in the field during collection and transport or from inter-laboratory sources.

- For each matrix, at least one method blank should be prepared and analyzed with each sample delivery group (SDG), or each batch digested (whichever is more frequent). Evaluation pertains to the batch of samples analyzed with the method blank.

- Field or equipment blank collection and analysis frequency is project specific. Evaluation pertains to the field samples associated with the field or equipment blank.
- Blank analyses may not have involved the same weights, volumes, or dilution factors as the associated samples. It may be easier to work with the raw data and/or convert the data to the same units for comparison purposes.
- Low-level mercury method requires *at least* three method blanks per run per analytical batch.

Table 2 – Guidelines for Blank Contamination

Sample Result	Recommended Action for Associated Data
Non-detect	No action required
< 5x blank concentration	Qualify with 'UB'
≥ 5x blank concentration	Use professional judgment

UB = The analyte is detected in one of the associated laboratory, equipment, field or trip blank samples and is considered non-detect at the concentration reported by the laboratory.

Note: Other multipliers of the blank contamination may be used based on professional judgment (reporting to the MDL, common lab contaminant, etc.)

Professional judgment regarding the usability of the data should be evaluated in cases where gross detections of target analytes are found in the blank sample. A number of factors may be considered including historical data, prior knowledge of the site conditions, target analytes involved, type of blank sample, etc. In such cases, it may be appropriate to qualify the affected data with 'J' ("Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory's detection and quantitation limits.") or 'R' ("The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.").

4.3 Laboratory Control Samples (LCS) and Laboratory Control Sample Duplicate Samples (LCSD)

The laboratory control sample is used to monitor the overall performance of each step during analysis, including sample preparation. The LCS should be analyzed:

- Once every preparation batch (typically 20 or less samples of the same matrix).
- Once for each matrix.
- For low-level mercury, ongoing precision and recovery (OPR) samples are run before and after each analytical batch - quality control samples (QCS) should be from a different source and analyzed once per analytical batch.

Laboratory control samples contain a known amount of each target compound and the percent recoveries are evaluated based on the criteria within the laboratory report or project specific requirements. If criteria are not available, use guidance found in the NFG. Percent recoveries are calculated for accuracy and the relative percent difference (RPD) is calculated for precision (when an LCSD was analyzed). Accuracy and precision equations can be found in 'Definitions' from Barr's "Compendium of Data Quality Assessment Documentation".

Table 3 – Guidelines for Laboratory Control Samples		
Criteria	**Recommended Action for Associated Data**	
	Detect	**Non-Detect**
%R > Upper Limit	Qualify with 'J+' or use professional judgment	No qualification
%R < Lower Limit	Qualify with 'J-' or 'R', use professional judgment	
RPD > Upper Limit	Qualify with 'J' or use professional judgment	
%R and RPD within Limits	No qualification	

J+ = The result is an estimated quantity and may be biased high.
J- = The result is an estimated quantity and may be biased low.
J = Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory's detection and quantitation limits.
R = The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.

4.4 Laboratory Duplicate Samples

Laboratory duplicate samples are separate aliquots of field samples analyzed to demonstrate acceptable method precision by the laboratory at the time of analysis. Ideally, blanks and proficiency testing (PT) samples should not be used for duplicate analysis. The MS/MSD duplicate pairs may be substituted for laboratory duplicates. The RPDs are calculated using the equation as provided in 'Definitions' from Barr's "Compendium of Data Quality Assessment Documentation" and are not calculated where data are already qualified with U, UB, <, or R. RPD results are dependent on the homogeneity of the samples.

Duplicates should be analyzed (whichever is more frequent):

- One from each matrix (soil or water)
- One from each SDG

Laboratory acceptance criteria or project specific requirement are used to evaluate RPDs. If criteria are not available, use guidance found in NFG or use professional judgment when considering qualification of associated results.

Higher RPDs are expected when results are at or near the reporting limits and are not always indicative of poor precision. RPDs are typically only evaluated for samples where both the native and duplicate sample concentrations are greater than five times (>5x) the RL. In cases where either of the samples (native or duplicate) is non-detect for a parameter and the other corresponding sample has detectable concentrations much greater than five times (>5x) the RL, professional judgment should be used to determine if qualification is appropriate.

Table 4 – Guidelines for Laboratory Duplicates	
% RPD	**Recommended Action for Associated Data**
RPD < Upper Limit	No action is required
RPD > Upper Limit	Both results are ≤ 5x RL, no action is required
RPD > Upper Limit	Both results are > 5x RL, consider qualifying with 'J'

J = Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory's detection and quantitation limits

4.5 Field Duplicate Samples

Field duplicate samples (also known as "masked" or "blind" duplicate samples) are used to demonstrate acceptable precision and reproducibility of the field and laboratory procedures. Frequency of collection is project specific. The RPDs are calculated using the equation as provided under precision in 'Definitions' from Barr's "Compendium of Data Quality Assessment Documentation" and are not calculated where data are already qualified with U, UB, <, or R. RPD results are dependent on the homogeneity of the samples.

Acceptance criteria for field duplicate samples are subject to the professional judgment of the Data Quality Specialist but typically RPDs ≤ 30% for aqueous samples and ≤ 40% for soil and sediment samples are considered acceptable unless other project specific requirements are defined.

Higher RPDs are expected when results are at or near the reporting limits and are not always indicative of poor precision. RPDs are typically only evaluated for samples where both the native and duplicate sample concentrations are greater than five times (>5x) the RL. In cases where either of the samples (native or field duplicate) is non-detect for a parameter and the other corresponding sample has detectable concentrations much greater than five times (>5x) the RL, professional judgment should be used to determine if qualification is appropriate.

Table 5 – Guidelines for Field Duplicates	
% RPD	**Recommended Action for Associated Data**
RPD < Upper Limit	No action is required
RPD > Upper Limit	Both results are ≤ 5x RL, no action is required
RPD > Upper Limit	Both results are > 5x RL, consider qualifying with 'J'

J = Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory's detection and quantitation limits.

4.6 Matrix Spikes (MS) and Matrix Spike Duplicate (MSD) Samples

Matrix spike samples contain a known amount of a target compound and provide information about the effect of each samples' matrix on the sample preparation procedures and analytical results. Matrix spikes are typically analyzed at the following frequencies:

- 1 (MS/MSD pair) in every 20 samples
- 1 per preparation batch per matrix
- 1 per SDG

However, the frequency may be project specific and the documents outlining the needs of the project (SAP, QAPP, etc.) should be reviewed. In some cases, MS/MSD analysis is not required.

The percent recoveries are evaluated based on the criteria within the laboratory report or project specific requirements. If a matrix spike recovery does not meet acceptance criteria and is not associated with a project sample, no further action is required unless other systematic evidence warrants qualification.

If the native concentration of a spiked sample is significantly greater than the spike added (>4x), spike recovery cannot be accurately evaluated, therefore the criteria do not apply. Professional judgment should be used for percent recoveries nominally outside laboratory acceptance criteria prior to qualifying data.

If criteria are not available, use guidance found in the NFG. Percent recoveries of matrix spike (and matrix spike duplicate) samples should be calculated using the equation provided under accuracy in 'Definitions' from Barr's "Compendium of Data Quality Assessment Documentation".

Solid samples may have highly variable concentrations of target analytes and percent recoveries (%R) may be influenced by the sampling precision and inherent sample homogeneity. Professional judgment should be used for difficult matrices and the acceptance criteria adjusted accordingly.

Table 6 – Guidelines for Matrix Spikes

Criteria	**Recommended Action for Associated Data**	
	Detect	**Non-Detect**
%R > Upper Limit	Qualify with 'J+' or use professional judgment	No qualification
%R < Lower Limit	Qualify with 'J-' or 'R', use professional judgment	
RPD > Upper Limit	Qualify with 'J' or use professional judgment	
%R and RPD within Limits	No qualification	

J+ = The result is an estimated quantity and may be biased high.
J- = The result is an estimated quantity and may be biased low.
J = Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory's detection and quantitation limits.
R = The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.

While matrix spike duplicates are not required by all methods, if results for MSD analyses are reported, evaluate the RPD for MS and MSD pairs using the equation as provided under precision in 'Definitions' from Barr's "Compendium of Data Quality Assessment Documentation".

4.7 Overall Assessment

The chain-of-custody should be reviewed to determine if the laboratory report matches the requested analyses and that project specific parameters were analyzed as requested. The narrative and other supporting documentation should be evaluated to ensure that sample condition was appropriately documented by the laboratory upon receipt. If available, historical data should be used to assist with data evaluation. Any additional anomalies should be documented and evaluated, if necessary.

4.8 Total vs. Dissolved

Occasionally, the measurements for dissolved metals are equivalent to or greater than the associated results reported for the total metals analysis. When this occurs, the variation between the total and dissolved results may indicate that the majority of the target metals present in the sample were in the dissolved phase and normal analytical variability may account for the difference. Professional judgment should be used to determine if the variation is significant enough to be qualified.

5.0 Quality Control and Quality Assurance (QA/QC)

Depending on the project objectives, the data evaluation may include the completion of a Routine Level Quality Control Report. This may be a report produced via EQuIS DQM (Environmental Quality Information System Data Quality Module) or a hardcopy as found in Barr's "Compendium of Data Quality Assessment Documentation". Within each QC data section, the reviewer should include references to whether the QC data met or exceeded the acceptance criteria. The qualifiers, added, removed, or retained, should be documented. If using EQuIS DQM, reason codes will also be applied. The reason codes are defined in the software. Where multiple qualifiers may be applicable to a sample/analyte result, professional judgment should be used to determine if all qualifiers are necessary or if one qualifier would be sufficient to represent the deviations. A statement as to whether the data are acceptable as reported or acceptable with qualification(s) should also be included. If revised reports are required and the revision affects the sample results, notification should be given to the appropriate data management personnel and/or project team members.

6.0 Records

The Routine Level Quality Control Report should be saved to the appropriate internal Barr file and the link uploaded to the tracking system. Periodically, Data Quality staff should check for missing Routine Level Quality Control Reports in the tracking system to help maintain the most current information. Documentation of the data evaluation may include but is not limited to an email to the project team, data evaluation summary report, technical memo, or section within a project report.

Documentation specific to this SOP are listed below and are available in Barr's "Compendium of Data Quality Assessment Documentation".

- Definitions
- Barr Qualifiers/Footnotes
- Routine Level Quality Control Report

Additional records information can be found in Barr's "Records Management System Manual

7.0 References

Environmental Protection Agency. *Title 40 of the Code of Federal Regulations, Part 136.3.*

Environmental Protection Agency, *National Functional Guidelines for Inorganic Superfund Data Review.*

Analytical methods listed under the 'Scope and Applicability' section of this SOP.

Attachment 1

Revision History

Revision Number	Date of Revision	Section	Revision Made
5.0	06/17/13	Cover page	Added Calgary office
		Applicability	Added US to EPA reference
		I	Added waste rock and drill cores to examples of product sample
		III, IV, V, VI	Added 'project specific requirements' as possible criteria source
		V	Added 'field and laboratory procedures' to clarify that it's not only a laboratory item
		V	Clarified field duplicate criteria as < one value and not a range
		VIII	Added statement regarding multiple qualifiers
6.0	01/07/16	Document Wide	SOP restructuring, new format
7	04/24/18	1.0	Added letter indicator for the various EPA method revisions was intentional omitted; multiple versions of the approved methods would be applicable for review under this SOP.
			Added laboratories may not provide all the review elements in this SOP, review only those that are provided.
		4.2, third bullet	Clarified that data reviewers would have to obtain raw data since not provided with Level II report.
8	01/02/20	Document wide	Updated for new qualifiers

Appendix B.3

Routine Level Radium 226 and 228 Data Evaluation SOP

BARR

Standard Operating Procedure

Routine Level Radium 226 and 228 Data Evaluation

Revision 1

January 8, 2020

Approved By:

Marta Nelson	M Nelson	01/08/20
Print Technical Reviewer	Signature	Date
Terri Olson	Terri A. Olson	01/08/20
Print QA Manager	Signature	Date

Review of the SOP has been performed and the SOP still reflects current practice.

Initials: ____________ Date: ____________

Initials: ____________ Date: ____________

Initials: ____________ Date: ____________

Initials: ____________ Date: ____________

Routine Level Radium 226 and Radium 228 Data Evaluation

1.0 Scope and Applicability

This SOP is intended as a guidance SOP for the routine level evaluation of Radium 226 and Radium 228 data provided by laboratories to be used in Barr Engineering Company (Barr) projects.

This SOP is based on quality assurance elements, not the specific criteria, of *USEPA Contract Laboratory Program National Functional Guidelines (NFG)* and applies to Radium 226 and Radium 228 data evaluation for analyses by the following methods:

- EPA 903.1, EPA 904.0, EPA 9315, EPA 9320, EPA EMSL-19, SM 7500-Ra B, SM7500-Ra D, Georgia Technical Research Institute

The letter indicator for the various EPA method revisions have been intentional omitted. Multiple versions of the approved methods would be applicable for review under this SOP. In the case of specific technologies and/or methods not listed above, the guidelines within this document will provide the basis upon which to make adequate professional judgment in the evaluation of data submitted for review. Laboratories may not provide all the review elements in this SOP, review only those that are provided.

The recommended procedures in this SOP should be followed unless conditions make it impractical or inappropriate to do so. Modifications should be noted in the applicable documentation and communicated to appropriate personnel. Significant changes may result in a revision or newly created SOP.

2.0 Limitations

- Level IV data validation is not covered in this SOP and should be performed in accordance with the method or project specific requirements.

3.0 Responsibilities

The laboratory is responsible for generating data from the samples submitted for analysis. In instances where QC criteria are not met for the analysis of samples, the laboratory is responsible for reanalysis of the samples, provided reanalysis is possible (considering matrix interference, holding times and sample volume, etc.), or documenting the impact to the data.

The Data Quality Specialist is responsible for evaluating the data in accordance with this document, in addition to using professional judgment where necessary or appropriate. Project specific requirements, such as those specified in a Quality Assurance Project Plan (QAPP) or Sampling and Analysis Plan (SAP), may differ from these recommendations and professional judgment should be applied before qualifying data.

4.0 Procedure

The Quality Assurance/Quality Control (QA/QC) data detailed below are the most typical found in a routine level laboratory report evaluation. Other QA/QC data may be provided by the laboratory within the laboratory report case narrative, data qualifiers, or cover sheet and should be evaluated using professional judgment (e.g., initial calibration, calibration verification, internal standards).

Definitions to common QA/QC terms and terms used within this SOP along with a list of Barr 'Data Qualifiers/Footnotes' that may be applied during review can be found in Barr's "Compendium of Data Quality Assessment Documentation".

4.1 Holding Time and Preservation

The purpose of holding time and preservation evaluation is to ascertain the validity of the analytical results based on the sample condition, preservation, and time elapsed between the date of sample collection and date of analysis.

40 CFR Part 136 and the *Test Methods for Evaluating Solid Waste (SW-846)* are used as guidance for the recommended holding time and preservation acceptance criteria listed in *Table 1*.

Table 1 – Recommended Holding Times and Preservation

Compound	Matrix	Temp.	Preservative	Maximum Hold Time
Radium 226, Radium 228	Aqueous	---	$HNO_3 < 2$ pH*	6 months
Radium 226, Radium 228	Solid	≤ 6 ° C	NA	14 days

* = Per SM 7010B, chemical preservative should be added at the time of collection but not delayed beyond 5 days from collection. At least sixteen (16) hours must elapse between acidification and analysis.

If samples do not meet holding time, preservation and analysis recommendations in *Table 1*, consider qualification with an 'H' ("Recommended sample preservation, extraction or analysis holding time was exceeded.").

Professional judgment should be applied (considering temperature, matrix, magnitude of the exceedance, etc.) when evaluating the application of qualifiers when criteria are not met.

4.2 Assessment of Detections

Prior to review of the QC data, determine if a result was detected or not detected by comparing the result to the Minimum Detectable Concentration (MDC) and the uncertainty.

The MDC is the minimum detectable activity (MDA) expressed in concentration units relative to the sample weight or volume and is the smallest concentration of radioactivity in a sample that can be detected with a 5 % probability of erroneously detecting radioactivity, when in fact none was present and also, a 5 % probability of not detecting radioactivity when in fact it is present.

Uncertainty is the degree of inaccuracy and imprecision associated with a measured quantity. It must be reported to determine if the result was detected or not detected. It may also be called counting uncertainty and is defined as the statistical sample standard deviation, which is an approximation of the population standard. Units for counting uncertainty should be the same as for the reported result and the MDC. The uncertainty is typically reported at 2 standard deviation (2s, 95% confidence level). If the uncertainty confidence level is not provided in the laboratory report, it should be confirmed with the lab. The uncertainty used below assumes 2s.

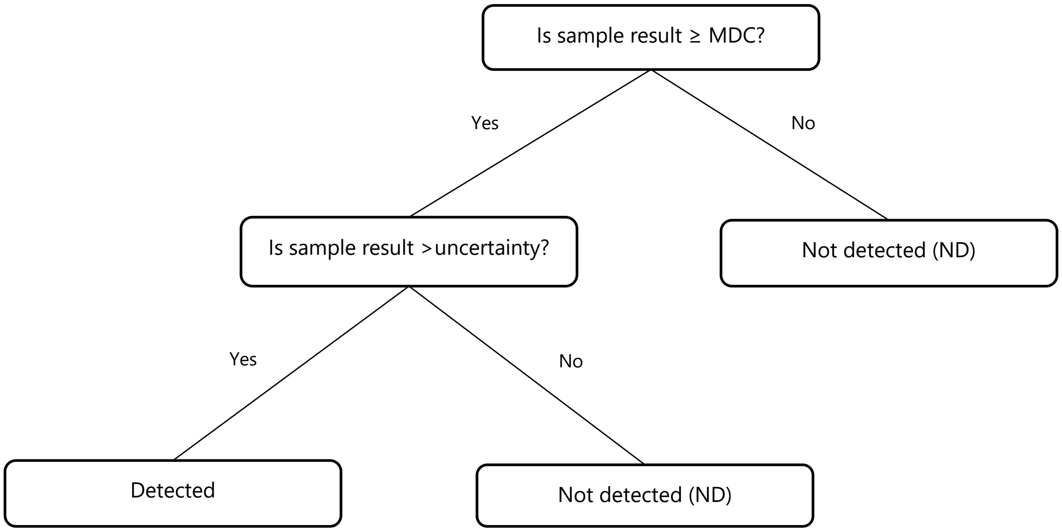
Reporting of results can vary by laboratory. The laboratory report should include:

- Minimum Detectable Concentration (MDC)
- Sample result concentration and sample result uncertainty
- QC data (e.g., method blank, laboratory control sample (LCS), matrix spike (MS), matrix spike duplicate (MSD), and/or laboratory duplicate sample results

The test for detection includes two distinct steps:

1. Is the sample result ≥ MDC?
2. Is the sample result > uncertainty?

See flow chart below:



- If the sample result is < MDC, accepting probability of a 5% false negative result (assuming MDC at 95%).
- If the sample result is < uncertainty, the radionuclide is not different than zero at the 95% confidence level.

Examples:

Sample Result ± Uncertainty	**MDC**	**Unit**	**Detected or Not Detected?**
0.5 ± 0.2	0.3	pCi/L	Detected
0.5 ± 0.6	0.3	pCi/L	Not detected
0.5 ± 0.2	0.6	pCi/L	Not detected

If the MDC was not included, but a sample report limit was provided, use this value to determine if the result was detected or not detected. Without this information, the determination of detected or not detected (ND) cannot be performed.

4.3 Blank Samples

Blank sample evaluation is conducted after assessment of detections to determine the existence and magnitude of target analyte contamination as a result of activities in the field during collection and transport or from inter-laboratory sources.

- For each matrix, at least one method blank should be prepared and analyzed with each batch. Evaluation pertains to the samples analyzed with the method blank.
- Field or equipment blank collection and analysis frequency is project specific. Evaluation pertains to the field samples associated with the field or equipment blank.
- Blank evaluation is performed by calculating the normalized absolute difference between the highest detected blank concentration associated with a group of samples and the detected sample concentration.

$$Normalized\ Absolute\ Difference\ (NAD) = \frac{|S - B|}{\sqrt{U_S^2 + U_B^2}}$$

Where:
S = Sample result
B = Blank result
U = Uncertainty

The method blank result should include the uncertainty. If any of the equation variables are missing, the NAD equation cannot be used. Qualify samples results < 2x the blank concentration.

Table 2 – Guidelines for Blank Contamination

Result	Recommended Action for Associated Data
Sample or MB not detected	No action required
NAD < 1.96 or < 2x blank concentration	Qualify with ‘UB’
NAD ≥ 1.96 or ≥ 2x blank concentration	No action required

UB = The analyte is detected in one of the associated laboratory, equipment, field or trip blank samples and is considered non-detect at the concentration reported by the laboratory.

Professional judgment regarding the usability of the data should be used in cases where gross detections of target analytes are found in the blank sample. A number of factors may be considered including historical data, prior knowledge of the site conditions, target analytes involved, type of blank sample, etc. In such cases, it may be appropriate to qualify the affected data with ‘J’ (“Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory’s detection and quantitation limits.”) or ‘R’ (“The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.”).

4.4 Laboratory Control Samples (LCS) and Laboratory Control Sample Duplicate Samples (LCSD)

The laboratory control sample is used to monitor the overall performance of each step during analysis, including sample preparation. The LCS should be analyzed:

- Once every preparation batch (typically 20 or less samples of the same matrix).

Laboratory control samples contain a known amount of each target compound and the percent recoveries are evaluated based on the criteria within the laboratory report or project specific requirements. Percent recoveries are calculated for accuracy and the relative percent difference (RPD) is calculated for precision (when an LCSD was analyzed). Accuracy and precision equations can be found in 'Definitions' from Barr's "Compendium of Data Quality Assessment Documentation".

Table 3 – Guidelines for Laboratory Control Samples

Criteria	**Recommended Action for Associated Data**	
	Detect	**Non-Detect**
%R > Upper Limit	Qualify with 'J+' or use professional judgment	No qualification
%R < Lower Limit	Qualify with 'J-' or 'R', use professional judgment	
RPD > Upper Limit	Qualify with 'J' or use professional judgment	
%R and RPD within Limits	No qualification	

J+ = The result is an estimated quantity and may be biased high.
J- = The result is an estimated quantity and may be biased low.
J = Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory's detection and quantitation limits.
R = The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.

4.5 Duplicate Samples

Laboratory duplicate samples are separate aliquots of field samples analyzed to demonstrate acceptable method precision by the laboratory at the time of analysis. Field blanks and proficiency testing (PT) samples should not be used for laboratory duplicate analysis. The MS/MSD duplicate pairs may be substituted for laboratory duplicates when evaluating precision.

Field duplicate samples (also known as "masked" or "blind" duplicate samples) are used to demonstrate acceptable precision and reproducibility of the field and laboratory procedures. Frequency of collection is project specific.

Duplicate evaluation is performed by calculating the RPD and/or NAD (sometimes referred to as Relative Error Ratio (RER) in laboratory reports). RPDs are calculated using the equation as provided in 'Definitions' from Barr's "Compendium of Data Quality Assessment Documentation" and NADs are calculated using the equation under the blank section of this SOP by substituting the duplicate data for the blank sample data. RPD is typically calculated for samples where both the native and duplicate sample concentrations are greater than five times (>5x) the sample report limit. NAD is typically calculated when results are at or near the sample report limit (< 5x). In cases where either of the samples (native or duplicate) is non-detect for a parameter and the other corresponding sample has a detectable concentration, the NAD may still be calculated but professional judgment should be used to determine if qualification is appropriate. The RPDs and NADs are not calculated where data are already qualified with U, UB, <, or R.

Duplicates should be analyzed (whichever is more frequent):

- One from each matrix (soil or water)
- One from each SDG

Laboratory acceptance criteria or project specific requirements are used to evaluate RPDs and/or NADs. If criteria are not available, use professional judgment when considering qualification of associated results.

Table 4 – Guidelines for Duplicates	
% RPD or NAD	**Recommended Action for Associated Data**
RPD or NAD < Upper Limit	No action is required
RPD or NAD > Upper Limit	Consider qualifying with 'J'

J = Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory's detection and quantitation limits.

4.6 Matrix Spikes (MS) and Matrix Spike Duplicate (MSD) Samples

Matrix spike samples may contain all target compounds or a subset and provide information about the effect of each samples' matrix on the sample preparation procedures and analytical results. Matrix spikes are typically analyzed at the following frequencies:

- 1 (MS/MSD pair) in every 20 samples
- 1 per preparation batch per matrix

However, the frequency may be project specific and the documents outlining the needs of the project (SAP, QAPP, etc.) should be reviewed. In some cases, MS/MSD analysis is not required.

The percent recoveries are evaluated based on the criteria within the laboratory report or project specific requirements. If a matrix spike recovery does not meet acceptance criteria and is not associated with a project sample, no further action is required unless other systematic evidence warrants qualification.

Table 5 – Guidelines for Matrix Spikes		
Criteria	**Recommended Action for Associated Data**	
	Detect	**Non-Detect**
%R > Upper Limit	Qualify with 'J+' or use professional judgment	No qualification
%R < Lower Limit	Qualify with 'J-' or 'R', use professional judgment	
RPD > Upper Limit	Qualify with 'J' or use professional judgment	
%R and RPD within Limits	No qualification	

J+ = The result is an estimated quantity and may be biased high.
J- = The result is an estimated quantity and may be biased low.
J = Estimated detected value. Either certain QC criteria were not met or the concentration is between the laboratory's detection and quantitation limits.
R = The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.

4.7 Overall Assessment

The chain-of-custody should be reviewed to determine if the laboratory report matches the requested analyses and that project specific parameters were analyzed as requested. The narrative and other supporting documentation should be evaluated to ensure that sample condition was appropriately documented by the laboratory upon receipt. If available, historical data should be used to assist with data evaluation. Any additional anomalies should be documented and evaluated, if necessary.

5.0 Quality Control and Quality Assurance (QA/QC)

Depending on the project objectives, the data evaluation may include the completion of a Routine Level Quality Control Report. This may be a report produced via EQuIS DQM (Environmental Quality Information System Data Quality Module) or a hardcopy as found in Barr's "Compendium of Data Quality Assessment Documentation". Within each QC data section, the reviewer should include references to whether the QC data met or exceeded the acceptance criteria. The qualifiers, added, removed, or retained, should be documented. If using EQuIS DQM, reason codes will also be applied. The reason codes are defined in the software. Where multiple qualifiers may be applicable to a sample/analyte result, professional judgment should be used to determine if all qualifiers are necessary or if one qualifier would be sufficient to represent the deviations. A statement as to whether the data are acceptable as reported or acceptable with qualification(s) should also be included. If revised reports are required and the revision affects the sample results, notification should be given to the appropriate data management personnel and/or project team members.

6.0 Records

The Routine Level Quality Control Report should be saved to the appropriate internal Barr file and the link uploaded to the tracking system. Periodically, Data Quality staff should check for missing Routine Level Quality Control Reports in the tracking system to help maintain the most current information. Documentation of the data evaluation may include but is not limited to an email to the project team, data evaluation summary report, technical memo, or section within a project report.

Documentation specific to this SOP are listed below and are available in Barr's "Compendium of Data Quality Assessment Documentation".

- Definitions
- Barr Qualifiers/Footnotes
- Routine Level Quality Control Report

Additional records information can be found in Barr's "Records Management System Manual".

7.0 References

J.G. Paar, University of TN, Knoxville/Oak Ridge National Laboratory and D. R. Porterfield, Chemical Science and Technology Division Los Alamos National Laboratory. April 1997. *Evaluation of Radiochemical Data Usability.*

Environmental Protection Agency, *National Functional Guidelines*.

Analytical methods listed under the 'Scope and Applicability' section of this SOP.