Assessment of Corrective Measures

Lewis & Clark Station

Prepared for
Montana-Dakota Utilities Co.

August 2019

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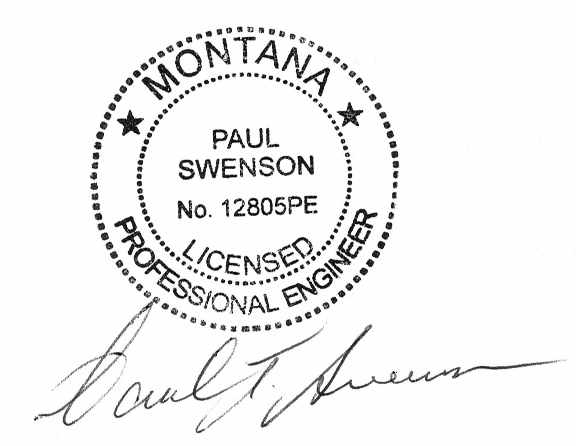
Certifications

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



	August 29, 2019
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Barr Engineering Co.	
MT License Number 12805PE	

1 Introduction

Montana-Dakota Utilities Co. (MDU) operates the Lewis & Clark Station (Lewis & Clark), a coal-fired steam-electric generating plant, near Sidney, Montana (Site). Operation of Lewis & Clark produces coal combustion residuals (CCR) as a by-product. CCR management is subject to the requirements of 40 CFR 257 Subpart D, Standards for Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments (CCR Rule).

1.1 Background

The United States Environmental Protection Agency (EPA) published the CCR Rule on April 17, 2015, to implement national minimum criteria for existing and new CCR landfills and existing and new CCR surface impoundments and all lateral expansions. The CCR Rule included location restrictions; design and operating criteria; groundwater monitoring and corrective action requirements; closure and post-closure care requirements; and recordkeeping, notification, and internet posting requirements.

A groundwater monitoring program was implemented at Lewis & Clark in accordance with the CCR Rule. A statistically significant increase (SSI) of appendix III constituents was determined on January 15, 2018. Assessment monitoring was established as required by § 257.94(e)(3) on April 15, 2018.

On July 30, 2018, the EPA issued a revision (Phase I) to the CCR Rule that, among other things, established default groundwater protection standards (GWPS) for cobalt, lead, lithium, and molybdenum, which do not have published maximum contaminant levels (MCLs). The default GWPS for lithium under the revised CCR Rule is 40 micrograms per liter (µg/L).

In compliance with CCR Rule § 257.95 (d)(2), GWPS were established for all appendix IV constituents detected in groundwater. GWPS are defined as the highest of the following values: the applicable MCL; in the case of cobalt, lead, lithium and molybdenum, the default GWPS values established under the CCR Rule; or, for any constituent, a site-specific background concentration established from baseline sampling. Background levels of lithium at the site are demonstrated to be higher than the default GWPS. Thus, a site-specific GWPS has been adopted for lithium in accordance with § 257.95(h)(3). The initial assessment monitoring and resample monitoring events showed detections of lithium and selenium (Constituents of Potential Concern, COPC) at statistically significant concentrations above GWPS.

In compliance with the CCR Rule, this report provides an assessment of corrective measures (ACM) to prevent further releases, to remediate any releases, and to restore affected areas to original conditions.[1] MDU also continues to evaluate whether other potential sources may contribute to contamination at the site.

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[1] A demonstration for 60-day extension for preparation of the ACM was completed on June 28, 2019, allowing for additional investigation to better understand site conditions.

1.2 Report Organization

Section 1 provides a brief history of the groundwater quality monitoring program at the site, including dates of transition between different phases of the program, and an overview of report organization.

Section 2 provides an overview description of the site, geology, and hydrogeology.

Section 3 summarizes the additional characterization of the site completed.

Section 4 details the criteria used when assessing each potential corrective measure.

Section 5 describes the potential corrective measures being assessed in this ACM.

Section 6 provides the results of the assessment.

2 Site Description

The Property (Figure 1) includes a 50 megawatt, coal-fired steam-electric generating plant and supporting facilities, located along the north bank of the Yellowstone River. The focus for this ACM is on the area surrounding the CCR units (the Scrubber Ponds and the former Temporary Storage Pad [TSP]) and associated groundwater monitoring system (Site - Figure 1). The groundwater monitoring system was established as a multiunit system due to the proximity of the two CCR units, making separate monitoring systems for each CCR unit infeasible.

The Scrubber Ponds are a single, multi-unit CCR unit, classified as an existing CCR surface impoundment (§ 257.53), that receives sluiced flue-gas desulfurization (FGD) sludge and fly ash material. FGD solids (excavated from the Scrubber Ponds) were stored and allowed to dewater on the TSP prior to loading and hauling for disposal at an off-site landfill. MDU voluntarily conducted TSP interim closure construction in accordance with the Closure Plan for Existing CCR Units, East and West Scrubber Ponds, and CCR Temporary Storage Pad (Barr, 2016). Interim closure construction activities were conducted from May 14 through June 6, 2018. The Facility includes the Scrubber Ponds and the former TSP, as shown on Figure 1.

2.1 Site Geology

Figure 2 shows the surficial geology at the Site as mapped by the Montana Bureau of Mines and Geology 1:500,000 Geologic Map (Vuke et. al., 2007). Due to the scale of this map, the geologic contacts shown when enlarged to the Site scale are not accurate. However, the map does show the general geological context. The Fort Union Formation (Tftr) is shown to the southeast of the Site. Areas mapped as gravel (Qgr) and alluvium (Qal) are a result of fluvial processes or of river origin.

Lithologic logs for the Site indicate that the uppermost subsurface materials are unconsolidated alluvial deposits of clays, silts, sands, and gravels. These deposits are typically coarsest and have the greatest permeability near their basal erosional contacts with the underlying consolidated bedrock unit (Smith et al., 2000). Bedrock is a dark gray claystone or siltstone interbedded with thin layers of coal. The bedrock unit is the Fort Union Formation, which was deposited by easterly-flowing streams that drained ancestral ranges of the northern Rocky Mountains between 55 and 65 million years ago (Smith et al., 2000).

Cross section locations for the Site are shown on Figure 3 and include the locations of cross sections A-A′, B-B′, C-C′, D-D′, and E-E′. Cross section A-A′ is shown on Figure 4; cross section B-B′ is shown on Figure 5; cross section C-C′ is shown on Figure 6, cross section D-D′ is shown on Figure 7; and cross section E-E′ is shown on Figure 8.

2.2 Site Hydrology and Hydrogeology

Groundwater is generally found at 8 to 10 feet below ground surface (bgs) at the Site depending on surface and groundwater elevations, with estimated groundwater elevations ranging from the elevation of the Yellowstone River to 1918 feet above mean sea level (MSL) within the fine- and coarse-grained alluvial deposits. Groundwater flow is generally from the west toward the CCR units and then radially outward to the north, south, and east toward Richland County Irrigation Ditch #12 and the Yellowstone River. The more permeable unconsolidated alluvial deposits allow for the movement of groundwater more readily compared to the less permeable underlying consolidated Fort Union Formation.

2.3 Surface Water Flow

A USGS stream gage (06329500) in the Yellowstone River and a stream gage installed in Irrigation Ditch #12 were used to determine the range of water elevations in the river and in the ditch, respectively (Figure 1).

3 Additional Site and Plume Characterization

Field work and site investigations were conducted during the first half of 2019 to gather additional site information. This assessment considers the historical information collected on the site and the additional information resulting from the 2019 investigation.

3.1 Groundwater and Contaminant Transport Modeling

A groundwater model was developed to simulate groundwater flow at the Site using existing information compiled from historical and current site data and publically available datasets to understand the potential effectiveness of the potential corrective actions included in this assessment.

The model was used to understand potential preferential groundwater flow paths and comparative travel times at the Site, and to estimate constituent concentrations and mass in Site groundwater through time. Lithium, as a non-sorbing contaminant, is transported at a rate approximately equal to the groundwater flow velocity. Selenium, as a sorbing contaminant, moves through the groundwater system at a rate that is slower than the groundwater flow velocity.

The results of the transport simulation were used as a preliminary screening-level tool to assess the effectiveness of potential corrective measures. Due to hydrogeologic conditions at the site, the preliminary modeling showed that the time required for groundwater to traverse the Site was very slow.

3.2 Potential Impacts to Downstream Receptors

The percent increase of lithium and selenium concentrations within the Yellowstone River due to groundwater flow from the site was calculated to evaluate potential impacts to river water quality. The groundwater flow rate and COPC concentrations discharging to the river were determined using results of the preliminary groundwater model. The flow rate and COPC concentration data for the Yellowstone River were determined from laboratory and literature data. For added conservatism, Yellowstone River flow rates of 10 percent and 20 percent of the 7 day, 10 year low flow were used for mixing calculations.

The following equations were used to evaluate the percent increase due to mixing:

<u>Mass Flux Rate</u> = average concentration (μg/L) x river flow rate (m^3/d) x 1,000

<u>River Flow Mixed</u> = river flow rate (m^3/d) + site drainage (m^3/d)

<u>River Concentration</u> with site drainage = Mass Flux Rate (μg/L) / Flow Mixed (m^3/d) / 1,000

Slow groundwater travel times combined with relatively low COPC concentration in site drainage result in low mass flux rates to the two groundwater outlets at the Site, resulting in negligible changes in COPC concentrations in the Yellowstone River, as shown in Table 1. The increase due to mixing (for the 10 percent and 20 percent flow rate reductions) are all less than a percent (lithium in the thousandths of a percent, selenium in the tenths of a percent).

4 Assessment Criteria

When assessing the effectiveness of the potential corrective measures, the CCR Rule (§ 257.96(c)) specifies that an analysis of the effectiveness of a potential measure must address the following:

1. Performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to any residual contamination;
2. Time required to begin and complete the remedy; and
3. Institutional requirements, such as state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy(s).

4.1 Performance

When evaluating a potential remedy's performance, groundwater and contaminant transport computer models were used to assess whether the remedy is expected to be effective in returning the site to meet GWPS. Factors limiting the remedy's effectiveness, such as low groundwater flow rates, flooding impacts, reduction in available treatment technology or supplies, or weather, were considered. Given the site layout, use, operational situation, and history, the evaluation included whether the proposed remedy would be an appropriate treatment method to use.

4.2 Reliability

When evaluating a potential remedy's reliability, operational and maintenance requirements for the life of the remedy were assessed, such as site specific testing, equipment cleaning, replacement needs, monitoring, ongoing sampling, etc. The evaluation considered whether the remedy has been used in other similar situations and if it was successful, if the remedy is able to adapt should site or groundwater conditions change, and if there may be impacts to downstream receptors if the treatment method is unsuccessful or fails.

4.3 Ease of Implementation

When evaluating a potential remedy's ease of implementation, standard construction means and methods were used to assess the degree of difficulty associated with the implementation. Factors such as site restrictions or limitations, the need for additional site characterization and studies, and availability of technology were assessed.

4.4 Safety Impacts

When evaluating a potential remedy's safety impacts, physical safety hazards and exposure risks for human health and the community associated with implementation of the remedy, such as during excavation, removal, storage, treatment, or transportation of contaminant, were assessed.

4.5 Cross-Media Impacts

The potential environmental exposure risks associated with implementation of the remedy were evaluated, such as potential for a cross-media impact during excavation, removal, storage, or transportation of contaminant. The potential for release to surface water from groundwater or other potential exposure routes were assessed, including impacts to potential receptors.

4.6 Control of Exposure to Residual Contamination

When evaluating a potential remedy's exposure control of residual contamination, potential controls needed to protect human health and the environment were assessed.

4.7 Time Required to Begin and Complete Remedy

When evaluating a potential remedy's timeline, discussions on design, testing, and construction durations were considered. Groundwater and contaminant transport computer models were used to project the relative timeframe for groundwater quality to meet GWPS.

4.8 Institutional Requirements

When evaluating a potential remedy's institutional requirements, local or state review process, permits, approval timelines and restrictions that could substantially affect implementation of a potential remedy were assessed. Evaluation included how the remedy will be conducted in compliance with all applicable requirements. Consideration was given to whether institutional controls would be required subsequent to implementation of the remedy.

5 Potential Corrective Measures

To address the impacts to groundwater identified during assessment monitoring, the following potential corrective measures have been considered:

- No further action beyond 2018 interim corrective measures
- Aquifer flushing
- Groundwater pump-and-treatment
- In situ chemical treatment
- Material solidification
- Full source removal of regulated CCR material

This list of potential corrective measures was developed during the scoping process to provide a wide range of options for the assessment phase. The following subsections provide a conceptual description of how each of these potential corrective measures could be implemented.

5.1 No Further Action beyond 2018 Interim Corrective Measures

The no further action (NFA) corrective measure was developed as a basis for assessing potential site conditions if no further action is taken to further reduce potential infiltration from the CCR Units and to compare to other potential correction measures. This remedy includes interim corrective measures that have already been implemented at the Site to better manage CCR materials. The Scrubber Ponds were reconstructed in 1993 with a 3-foot-thick clay liner, and then reconstructed again in 2018 with a composite liner. Interim closure construction activities were conducted in 2018 for the TSP, after which it was reconstructed as a new TSP facility with a paved base and runoff collection. The interim measures may begin to show improvements in affected areas prior to implementation of any additional potential corrective measures.

5.2 Aquifer Flushing

To reduce the time until GWPS is reached, the effectiveness of aquifer flushing to increase groundwater flow rates was evaluated. To introduce water into the aquifer, an infiltration gallery could be used to increase upgradient groundwater head and enhance groundwater flow. An infiltration gallery could consist of a system of perforated conduits in gravel or a series of injection wells.

An infiltration gallery was assumed upgradient of the CCR units with an assumed input flow rate required to maintain a small increase in the upgradient groundwater elevation. Groundwater modeling assumed the quality of the water introduced would be equal to the upgradient background water quality for the constituents of concern.

5.3 Groundwater Pumping with Treatment

Groundwater pumping would be conducted to intercept groundwater near the downgradient extent of the plume. The groundwater might need to be treated before it can be returned to the environment, depending on concentrations in the water that is collected and regulatory requirements for water quality for discharge to receiving waters.

5.3.1 Groundwater Capture

The preliminary groundwater modeling results (Section 3.1) suggest that groundwater at the site moves slowly. The slow rate of groundwater movement and shallow groundwater present challenges for conventional groundwater collection methods using wells. Due to the dense and varying geology over the site, placement of the wells to fully capture the impacted portions of the aquifer would be inefficient and/or ineffective. Based on this, the following collection options were evaluated in the modeling to preliminarily understand the effectiveness of reaching the GWPS for this corrective measure. Further refinement of model assumptions and predictive uncertainty analysis would be needed to better understand this potential corrective measure.

Collection Trench

To maximize groundwater capture, a collection trench (drain tile or French drain) would be located along the downstream perimeter of the impacted groundwater perpendicular to the direction of flow. The trench would be designed to intercept the full depth of the plume. Groundwater would be pumped from the collection trench at selected locations. Pumping would be controlled to avoid capturing water from the Yellowstone River.

Enhanced Collection Trench

In addition to the collection trench defined above, an infiltration gallery (as described in Section 5.2) would be implemented upgradient of the CCR Units in an attempt to improve groundwater flow rates by flushing the aquifer.

Partial Barrier Wall

To restrict movement of the plume, a barrier wall, such as a slurry wall, cement/bentonite grout curtain, or similar feature, would be constructed along the downstream perimeter of the CCR Units perpendicular to the direction of flow. Groundwater would be pumped from selected locations to reduce groundwater elevation on the upstream face of the wall.

Full Barrier Wall

In this scenario, the barrier wall would extend not just along the downstream perimeter of the CCR Units (as described in the half barrier wall section above), but would fully surround the CCR Units. The upstream barrier wall would restrict groundwater flow through the impacted plume by diverting the groundwater flow around the CCR Units.

5.3.2 Groundwater Treatment

Captured groundwater would need to be sampled and tested to monitor water quality compared to applicable standards. If water quality concentrations exceed standards, treatment may need to be implemented before it can be returned to the environment. Any treatment would need to also be compared to surface water quality criteria and Site discharge requirements if discharge will be to surface water. Potential locations for returning treated water to the environment include the irrigation ditch, the Yellowstone River, re-infiltration as groundwater, or evaporation to the atmosphere. The exact treatment required would be dependent on which of these locations is selected for returning the treated water to the environment, as well as the chemistry of the constituents that may need to be removed or treated. Several potential treatment options are described in the following paragraphs, with a focus on the chemistry that would be used to remove lithium or selenium, in particular. For the purposes of this evaluation, it is assumed that these technologies could, in fact, be employed for treatment of the extracted groundwater. However, further studies and testing would be needed to verify if each technology is feasible and appropriate for this Site.

Membrane Separation – Lithium and Selenium

To perform membrane separation, water is forced through membranes that prevent particles and some solutes from passing through. The membrane system would be designed to prevent lithium and selenium from passing through with the clean water (permeate), which could then be returned to the environment. Both lithium and selenium would remain in the concentrated waste stream (brine), which would require further treatment or disposal.

Chemical Precipitation – Selenium

Chemical precipitation potentially can be used to convert selenium into a solid form that can be removed from water using conventional treatment processes such as coagulation and flocculation, clarification, and filtration. Selenium in water is typically present as an oxyanion, either selenite (SeO_3^{2-}) or selenate (SeO_4^{2-}), which correspond to the $Se^{6+} or\ Se^{4+}$redox states, respectively. Potential precipitates that can be formed from selenium include:

- Selenium-iron hydroxide co-precipitate
- Elemental selenium
- Selenium sulfide

Selenite can be co-precipitated by adding a ferric salt, such as ferric chloride. Insoluble ferric hydroxides form, as shown in the following equation, which precipitate out of solution and entrap selenite in the process.

$$(Fe^{2+} or\ Fe^{3+}) + H_2O \rightarrow (Fe(OH)_2\ or\ Fe(OH)_3) + H^+$$

Additional operation considerations for this technology include a reduced pH of about 4. This technology also generates a large quantity of solids that will need to be dewatered and disposed.

Another method of co-precipitation is to use nano zero valent iron (NZVI), which can reduce selenate and selenite to elemental selenium, as shown in the following equation. Another benefit of this process is the production of insoluble ferric hydroxide after the iron has been dissolved. This additional solid material will help to entrap the colloidal selenium, promoting removal.

$$Fe^0 + (Se^{6+} or\ Se^{4+}) \rightarrow (Fe^{2+} or\ Fe^{3+}) + Se^0$$

$$(Fe^{2+} or\ Fe^{3+}) + H_2O \rightarrow (Fe(OH)_2\ or\ Fe(OH)_3) + H^+$$

Sodium sulfide can also potentially be used to precipitate selenite from solution as selenium sulfide (Geoffrey, 2011). However if mercury is present, this method may be less effective (Sandy, 2011).

Biological Reduction – Selenium

Selenium is a requirement for most organisms as a trace nutrient, however, for some microorganisms it can be used in respiration as an electron acceptor. When selenium is present as the oxidized selenium oxyanions, the addition of an organic substrate to the system can promote selenium-reducing microbiological activity. Selenium-reducing microorganisms convert soluble selenium oxyanions to elemental selenium or selenide that will precipitate and can be removed with the biological solids.

5.4 In Situ Chemical Treatment

The technology used for this alternative would be redox manipulation. Redox manipulation has the potential to immobilize selenium in situ. This treatment is performed by alternating between the injection of reducing agents, such as NZVI, and oxidizing agents, such as air, oxygen or peroxide. During redox manipulation, NZVI (see Section 5.3.2) is injected into the aquifer at an injection well to reduce selenium oxyanions to elemental selenium. Next, oxygen is injected into the same aquifer and the reduced iron present precipitates as iron hydroxides, entrapping and immobilizing selenium.

Redox manipulation has the potential to mobilize other constituents, possibly requiring further treatment. Constituents that tend to be redox sensitive are those that have multiple valence states such as iron and manganese (as well as arsenic, antimony, and some of the lesser known transitions metals). Iron is the primary issue, which has the further potential to release other constituents that sorb to iron in oxidized environments but are released in reduced environments (phosphorous, arsenic). Depending on the oxidant used, many of the reactions that occur during the reducing stage would be reversible in the oxidizing stage. Laboratory testing should be completed prior to injecting any chemicals in the field.

Implementation could follow two main options: target the whole area of the plume with numerous injection points dispersed over the area of the plume, or create a zone (near the downstream edge of the plume) to treat groundwater as it drains through that treatment zone. Several uncertainties about the potential effectiveness of in situ chemical treatment at the Site exist. Ongoing or additional treatments may be needed depending on how much of the COPC is in the groundwater compared to the mass sorbed or otherwise associated with the solid phase. While, as a preliminary assumption, it is expected that little of the selenium is sorbed to the soil, this would need to be verified with sorption/equilibrium testing prior to implementation. Additionally, given the nature of the slow groundwater flow rate at the Site, ongoing or multiple treatments may be needed before GWPS are achieved.

5.5 Material Solidification

In situ material solidification can potentially be used to decrease permeability of the aquifer material and slow the release of COPC. In this process, a large auger is used to mix the soil while introducing a mixing agent, such as Portland cement or bentonite. Solidification can be used as a standalone remedial approach or potentially combined with the in situ addition of other treatments to further limit the transport of contaminants. For example, NZVI, described in Section5.3.2, could also be introduced during mixing to reduce and co-precipitate selenite and selenate.

5.6 Full Source Removal of Regulated CCR Materials

Closure of the scrubber ponds would be accomplished through removal of CCR material and decontamination of the CCR Unit. Prior to excavation, free liquids would be removed from the scrubber ponds to provide access to the CCR material. CCR materials in the scrubber ponds would be removed and placed in an off-site disposal facility. Visual inspection of the scrubber pond area would be conducted to verify that CCR and liner materials have been removed from the site. Once the CCR material removal has been verified, clean fill would be imported and the pond location regraded to promote site drainage. The impacted area would be stabilized to prevent off-site sediment erosion.

6 Results of Assessment

The list of potential corrective measures described in Section 5 were assessed using the criteria specified in the CCR Rule (§ 257.96(c)) and summarized in Section 4. The results of the assessment are provided in the Corrective Measures Evaluation Summary (Table 2). The corrective measures and technologies are presented as an initial assessment. Further evaluation of these potential remedies, including pilot testing, bench testing, site investigations and further studies, as appropriate, are necessary to verify if the technology is feasible and appropriate for this Site.

7 References

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Tables

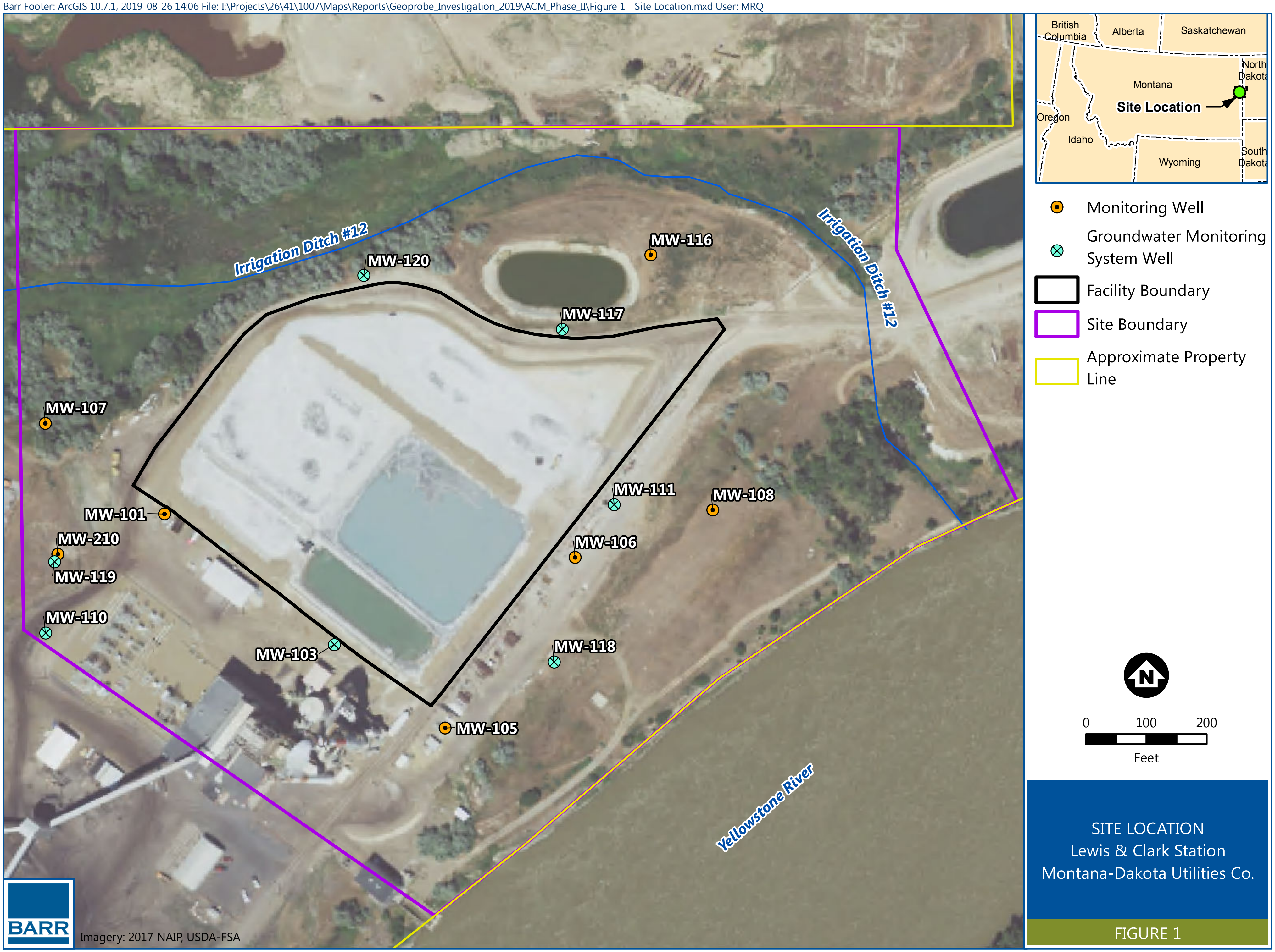
Table 1 Mixing Calculations

River Flow Scenario	Lithium			Selenium		
	Upstream River Concentration (µg/L)	River Concentration w/ Site Drainage (µg/L)	Percent Increase after Mixing	Upstream River Concentration (µg/L)	River Concentration w/ Site Drainage (µg/L)	Percent Increase after Mixing
10% of 7-Day, 10-Year Low Flow	34.0000	34.0011	0.003	0.5000	0.5014	0.278
20% of 7-Day, 10-Year Low Flow	34.0000	34.0005	0.002	0.5000	0.5007	0.139

Table 2
Preliminary Corrective Measures Evaluation
Lewis Clark Station
Montana-Dakota Utilities Co.

Evaluation Criteria	No Further Action beyond the 2018 Interim Corrective Measures	Aquifer Flushing	Pump and Treat	In-situ Chemical Treatment	Material Solidification	Full Source Removal of Regulated CCR Material
Performance §257.96(c)(1)	Measures implemented in 2018 reduce leakage from the Scrubber Ponds and removed a source of potential contamination at the TSP. GWPS will be achieved over a long timeframe due to slow rate of groundwater movement at the site.	GWPS would likely be achieved over a long timeframe due to slow rate of groundwater movement at the site, even with enhanced flushing.	GWPS would likely be achieved over a long timeframe due to slow rate of groundwater movement at the site. Further evaluation is necessary to understand the effectiveness of horizontal drains versus wells in capturing the impacted groundwater for this potential remedy, as well as whether infiltration gallery or capture trench additions may be beneficial.	There is less certainty whether constituent levels would reach GWPS due to the variability and potential limitation of effectiveness of this option at the site. COPC would be converted to a solid phase or sorbed to fix them in place, however chemicals remaining within the aquifer could resolubilize if the right conditions occurred. Geologic conditions may limit ability to inject reagents, though the slow rate of groundwater flow could help maintain the effectiveness of the remedy. Variability of existing geology may limit application of treatment over the extent of the plume.	Solidification could achieve GWPS by immobilizing COPC in place. Without additional site investigation, potential to reach GWPS is somewhat uncertain.	Removal of regulated CCR would eliminate the source of the COPC. GWPS will be achieved over a long timeframe due to slow rate of groundwater movement at the site.
Reliability §257.96(c)(1)	O&M could include routine maintenance, inspections, and periodic sampling to verify plume decrease and achievement of GWPS.	O&M could include cleaning, disposing of, and replacing infiltration material (sand) if pores get clogged limiting its effectiveness. Pumping systems to introduce flow into the infiltration areas could require maintenance and replacement of pumps and electrical systems.	O&M could include maintaining and replacing pumps and electrical system, removing pipe scaling, trench reconstruction as needed, periodic cleaning and disposal of any generated waste, and ongoing sampling to verify COPC concentrations are decreasing. Treatment system maintenance could include filter changes, mechanical repairs, or even system upgrades due to technology changes.	Site specific testing would be needed to design and implement the remedy to meet the specific geologic and hydrogeologic conditions of the site. Minimal O&M following completion of treatment would be expected, though, periodic follow-up treatments may be needed until GWPS are achieved.	Site specific testing would be needed to design and implement the remedy to meet the specific geologic and hydrogeologic conditions of the site. Minimal O&M following completion of treatment would be expected. May require periodic follow-up treatments. Additional wells may be needed at the extent of the plume to verify groundwater quality as monitoring wells within the Site may no longer be available with this remedy.	O&M could include routine maintenance, inspections, and periodic sampling to verify COPC concentrations are decreasing. Additional site specific testing and O&M may be required if other remedies are combined with this alternative to address the plume.
Ease of Implementation §257.96(c)(1)	Except monitoring groundwater quality to verify performance, no additional implementation actions would need to be undertaken.	Infiltration areas are commonly used to introduce flow into the groundwater system, though additional borings and site investigations may be needed to verify infiltration rates and the system feasibility.	Treatment system design could require bench and/or pilot testing to confirm site-specific treatment requirements and equipment requirements. Membrane separation is possible with this option, which would require the expenditure of considerable energy to force the water through the membranes and to evaporate the residual concentrate.	Site specific bench and pilot testing could be needed to evaluate and design an in-situ treatment remedy. Geologic conditions may limit ability to inject reagents. Implementation could be hindered by spacing of injection holes required due to geologic conditions. The large area of the plume and variability of existing geology may limit application of treatment. Due to the slow rate of groundwater flow, multiple treatments may be needed over many years until GWPS is achieved.	The influence zone would be adjacent to the ponds to the extent of the plume. Geologic conditions may limit ability to inject cementing agents. Site-specific bench and pilot testing could be needed to evaluate and design the treatment.	Implementing remedy would require the Scrubber Ponds to close, and may potentially require decommissioning of the power plant.
Safety Impacts §257.96(c)(1)	Minimal impacts - normal operation and maintenance safety concerns.	Typical construction safety hazards from drilling, excavation of trenches and construction of above-ground facilities.	Typical construction safety hazards from drilling, excavation of trenches and construction of above-ground facilities. Potential risk of staff exposure to chemicals used for treatment.	Typical construction safety hazards from drilling, and other above-ground activities. Potential risk of staff exposure to chemicals used for treatment.	Typical construction safety hazards from drilling, and other above-ground activities. Potential risk of staff exposure to chemicals used for treatment.	Typical construction safety hazards from material excavation and disposal.
Cross-Media Impacts §257.96(c)(1)	Potential risk of low-level COPC being discharged into the river by not intercepting the plume. However, mass flux of COPC is negligible compared with river mass flux and COPC concentrations present in upstream river conditions.	Potential risk of COPC being discharged into the river by not intercepting the plume. However, mass flux of COPC is negligible compared with river mass flux and COPC concentrations present in upstream river conditions.	Potential risk of release to surface water or groundwater due to leakage or pipeline breaks, such as due to freezing conditions common to the region.	Potential risk of contaminants being discharged into the river if the treatment isn't successful and the plume isn't intercepted. However, mass flux of COPC is negligible compared with river mass flux and COPC concentrations present in upstream river conditions. Additional impacts could occur from spills of chemicals used in the process to treat groundwater contaminants.	Potential risk of contaminants being discharged into the river if the treatment isn't successful and the plume isn't intercepted. However, mass flux of COPC is negligible compared with river mass flux and COPC concentrations present in upstream river conditions. Additional impacts could occur from potential spills of the grouting material or during removal of CCR material in the pond while implementing treatment.	Potential risk of contaminants being discharged into the river by not intercepting the plume and from spills and runoff during the construction removal. However, mass flux of COPC is negligible compared with river mass flux and COPC concentrations present in upstream river conditions.
Control of Exposure to Residual Contamination §257.96(c)(1)	While interim corrective measures reduced contribution of COPC from the source, the remedy would not limit exposure to COPC in the groundwater until GWPS is achieved. While depth to groundwater would protect workers within the facility boundary, seeps and wetlands located on the river slope could expose workers to COPC within this area. COPC do not pose an inhalation or dermal exposure concern. Drinking water wells are not present onsite and potable water is supplied by a rural water distribution system.	Remedy would not limit exposure to COPC in the groundwater until GWPS is achieved. While depth to groundwater would protect workers within the facility boundary, seeps and wetlands located on the river slope could expose workers to COPC within this area. COPC do not pose an inhalation or dermal exposure concern. Drinking water wells are not present onsite and potable water is supplied by a rural water distribution system.	Remedy would be designed to remove COPC to levels below the GWPS. Standard engineering controls should limit exposure to COPC during pumping activities. Institutional controls would be implemented to limit risk of exposure to COPC in the groundwater after remedy is implemented. Once GWPS are met, there should be no exposure concern with concentrations remaining in the groundwater. COPC do not pose an inhalation or dermal exposure concern. Drinking water wells are not present onsite and potable water is supplied by a rural water distribution system.	Remedy would be designed to change the COPC chemical make-up or reduce their mobility through groundwater. Depending on the chemical treatment used, residual concentrations may be present in groundwater and soil. Redox manipulation has the potential to mobilize other constituents, possibly requiring further treatment. While depth to groundwater would protect workers within the facility boundary, seeps and wetlands located on the river slope could expose workers to COPC within this area. COPC do not pose an inhalation or dermal exposure concern. Drinking water wells are not present onsite and potable water is supplied by a rural water distribution system.	Remedy would be designed to bind the COPC to prevent mobility through groundwater. While depth to groundwater solidification zone would protect workers within the facility boundary, potential risk still present if the solidified material is exposed or excavated. COPC do not pose an inhalation or dermal exposure concern. Drinking water wells are not present onsite and potable water is supplied by a rural water distribution system.	The removal of regulated CCR material would eliminate the source of the COPC, but the remedy does not limit exposure to constituents in the groundwater until GWPS is achieved. While depth to groundwater would protect workers within the facility boundary, seeps and wetlands located on the river slope could expose workers to COPC within this area. COPC do not pose an inhalation or dermal exposure concern. Drinking water wells are not present onsite and potable water is supplied by a rural water distribution system.
Time to Begin §257.96(c)(2)	Immediately (no further action needed with remedy).	Remedy may require a year or more of bench testing, design, and construction prior to introducing water into infiltration gallery.	Remedy may require a year or more of bench testing, design, and installation/construction prior to start of pumping and treating.	Remedy may require a year or more of bench testing, design, and construction prior to start of chemical treatment.	Remedy may require a year or more of bench testing, design, and construction prior to start of solidification treatment.	Remedy could be implemented once engineering design and any permitting is obtained, if required.
Time to Complete §257.96(c)(2)	This alternative would be among the longest to reach GWPS due to slow rate of groundwater movement, though additional design evaluation and groundwater model updates may be conducted in the future to better estimate the timeframe to completion.	Aquifer flushing is expected to increase the hydraulic gradient, which should decrease the time until GWPS is achieved. GWPS would likely take less time to achieve than the "No Further Action" alternative. Additional design evaluation and groundwater model updates may be conducted in the future to better estimate the timeframe to completion.	Collection methods, such as a trench, along the edge of the plume may prevent COPC from leaving the property. The addition of aquifer flushing in combination with collection methods is expected to increase the hydraulic gradient, which should decrease the time until GWPS is achieved when compared to either the "No Further Action" or "Aquifer Flushing" alternatives. though the duration would still likely be a long time due to the slow rate of groundwater movement. Additional design evaluation and groundwater model updates may be conducted in the future to better estimate-the timeframe to completion.	Implementation of the initial in situ treatment can likely be completed within a few years. Due to the slow rate of groundwater flow at the Site, it is likely that repeat yearly treatments may be necessary to achieve GWPS. Variability of existing geology may limit application of treatment over some areas of the plume, causing the duration until GWPS is achieved to increase. Compared with other alternatives, it is anticipated that the time to complete would be moderate for this alternative.	Implementation of the initial in situ treatment can likely be completed within a few years. It is likely that repeat treatments may be necessary to achieve GWPS. Variability of existing geology may limit application of treatment over extent of the plume, causing the time until GWPS is achieved to increase. Compared with other alternatives, it is anticipated that the time to complete would be moderate for this alternative.	Completion of the material removal can likely be accomplished within a few years. Returning Site groundwater quality to GWPS within the plume under this alternative would be relatively slow due to slow rate of groundwater movement, but the source is removed and no longer contributes to the plume. Additional design evaluation and groundwater model updates may be conducted in the future to better estimate the timeframe to completion.
Institutional Requirements §257.96(c)(3)	Remedy is not affected by institutional requirements.	Injection of water through an infiltration gallery may require state regulatory permitting. Other than permitting injection to groundwater, minimal impact to potential remedy by institutional requirements is expected.	Construction limitations within the floodplain may restrict where the collection system can be located. Other potential restrictions may be identified and evaluated during treatment system design. Montana industrial wastewater permit (MPDES) permit modifications may be needed depending on discharge location. A permit from the Army Corps of Engineers or Montana Department of Natural Resources and Conservation may be required, potentially among other permits.	Construction limitations within the floodplain may restrict where the treatment method can be implemented, though temporary above grade construction equipment and features would most likely not be restricted within this area. Other potential restrictions may be identified and evaluated during treatment system design. A permit from the Army Corps of Engineers or Montana Department of Natural Resources and Conservation may be required, potentially among other permits.	Construction limitations within the floodplain may restrict where the treatment method can be implemented, though temporary above grade construction equipment and features would most likely not be restricted within this area. Other potential restrictions may be identified and evaluated during treatment system design. A permit from the Army Corps of Engineers or Montana Department of Natural Resources and Conservation may be required, potentially among other permits.	CCR Unit removal could require state regulatory permitting. This alternative would likely require construction stormwater discharge permitting and closure of the facility under the Montana industrial wastewater permit (MPDES), requiring state regulatory approval.

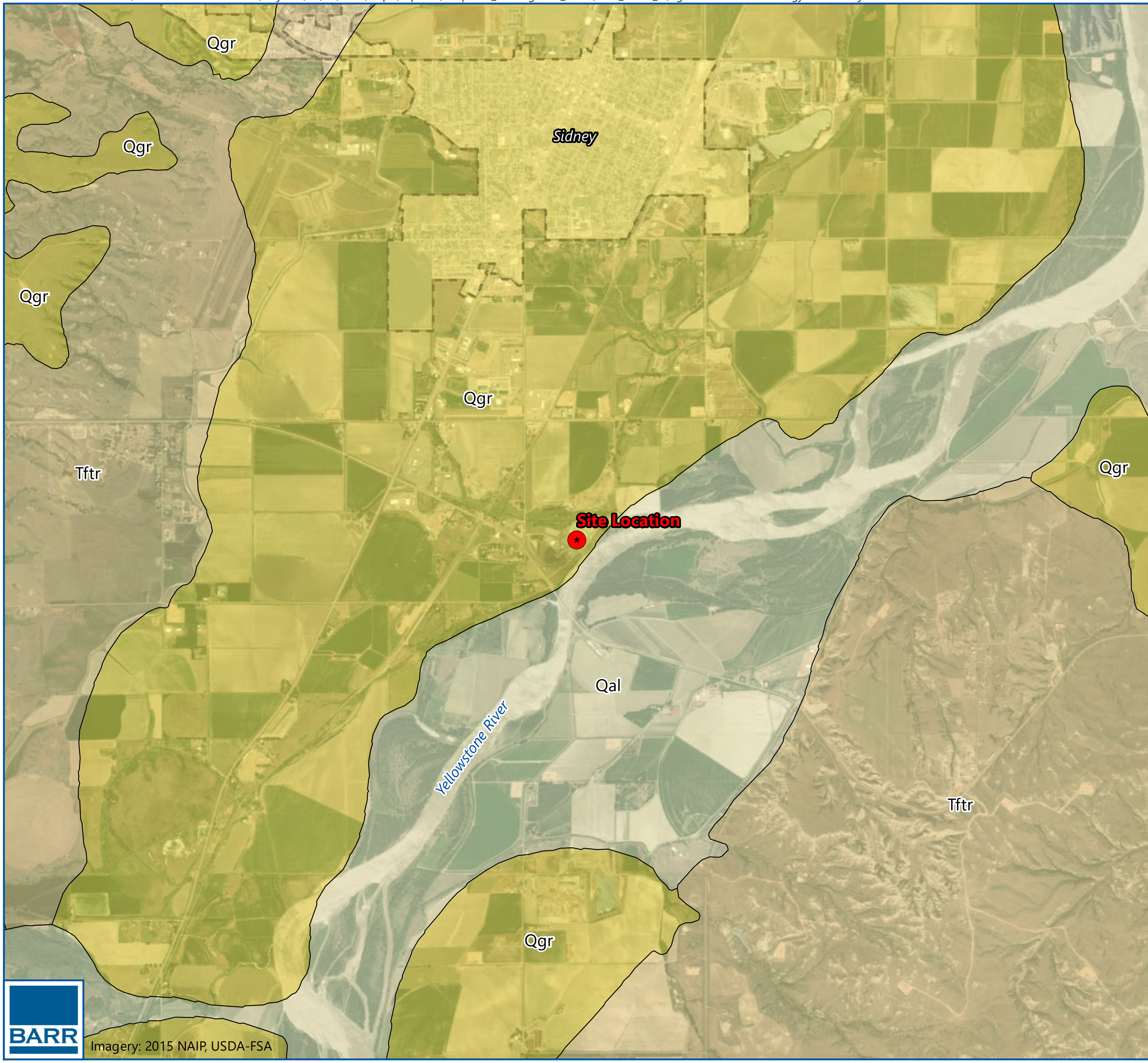
Figures



SITE LOCATION
Lewis & Clark Station
Montana-Dakota Utilities Co.

FIGURE 1

Barr Footer: ArcGIS 10.6.1, 2019-08-07 10:06 File: I:\Projects\26\41\1007\Maps\Reports\Geoprobe_Investigation_2019\ACM_Phase_II\Figure 2 - Surficial Geology.mxd User: jrv



Site Location

Geology Unit

Qal - Alluvium

Qgr - Gravel

Tftr - Tongue River Member of Fort Union Formation

Geology data received from Montana Bureau of Mines and Geology

Vuke, S.M., Porter, K.W., Lonn, J.D., and Lopez, D.A., 2007, Geologic Map of Montana (digital data) : Montana Bureau of Mines and Geology, scale 1:500,000

N

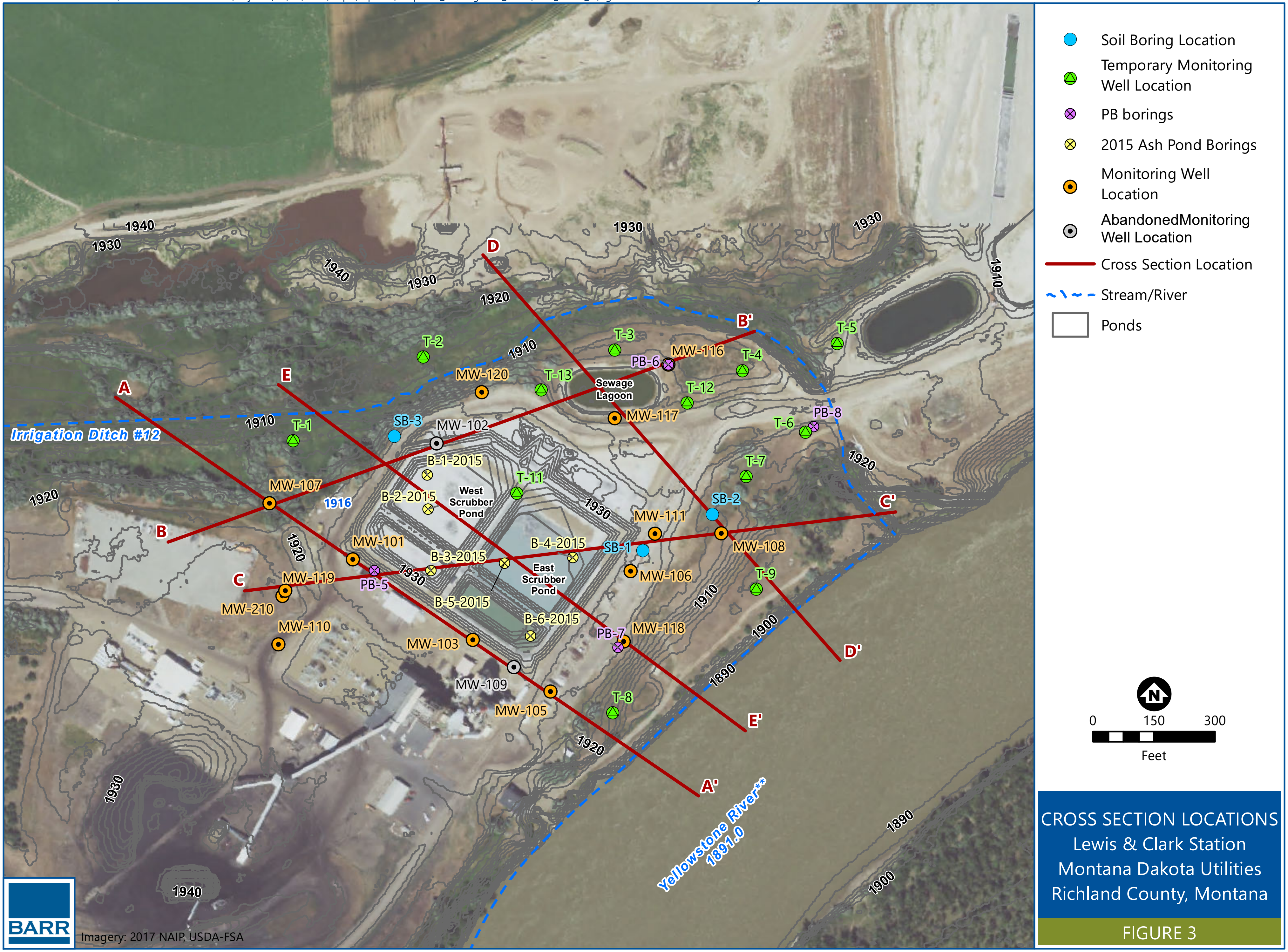
0 2,000 4,000 6,000

Feet

SURFICIAL GEOLOGY
Lewis & Clark Station
Montana-Dakota Utilities Co.

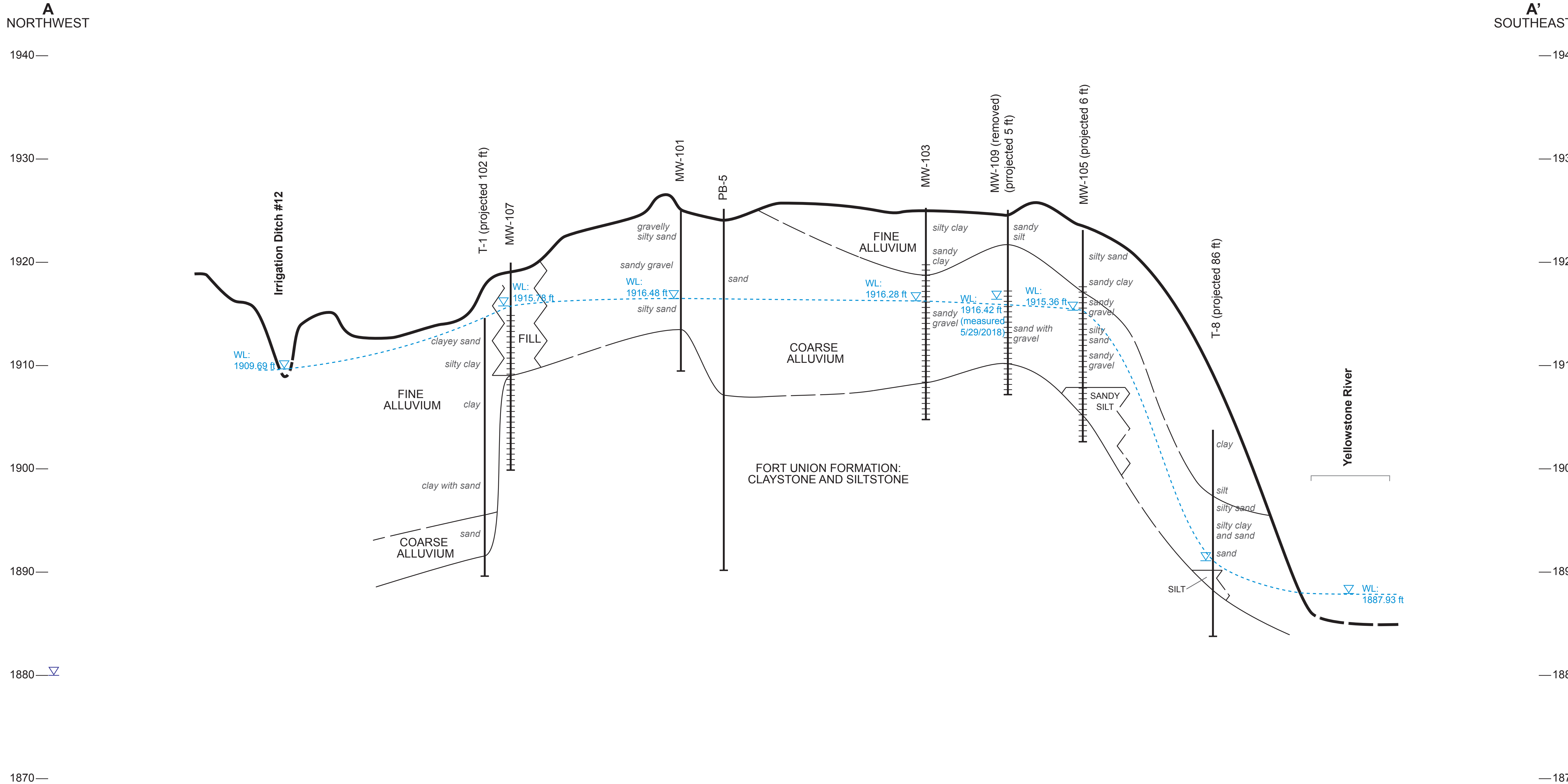
FIGURE 2

Barr Footer: ArcGIS 10.6.1, 2019-08-07 10:58 File: I:\Projects\26\41\1007\Maps\Reports\Geoprobe_Investigation_2019\ACM_Phase_II\Figure 3 - Cross Sections.mxd User: jrv



CROSS SECTION LOCATIONS
Lewis & Clark Station
Montana Dakota Utilities
Richland County, Montana

FIGURE 3



LEGEND

Geologic Contact

Inferred Geologic Contact

Approximate Water Table
(water levels measured 1/31/2019 to 2/1/2019 except where noted)

Monitoring Well Screen

Soil Boring/Piezometer

0 150

Approximate Horizontal Scale in Feet
15X Vertical Exaggeration

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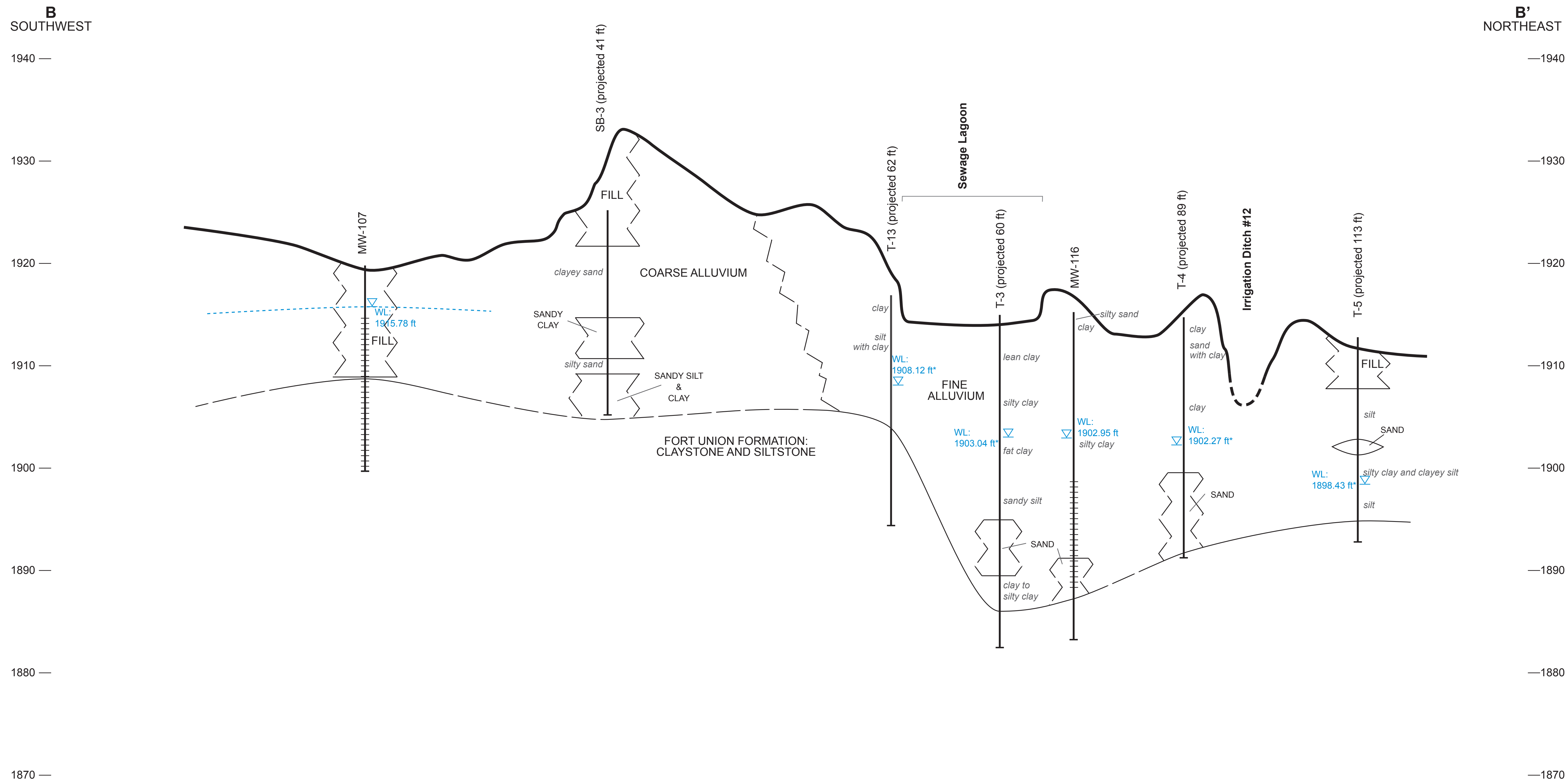
Figure 4

CROSS-SECTION A-A'
Montana-Dakota Utilities
Lewis & Clark Station



LEGEND

Geologic Contact

Inferred Geologic Contact

Approximate Water Table
(water levels measured 1/31/2019 to 2/1/2019 except where noted)

Monitoring Well Screen

Soil Boring/Piezometer

0 150

Approximate Horizontal Scale in Feet
15X Vertical Exaggeration

NOTES

* Water levels recorded for temporary monitoring (TM) wells T-3, T-4, T-5, and T-13 were not at equilibrium at the time of measurement. Therefore, water level elevations are not contoured for these TM wells.

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Figure 5

CROSS-SECTION B-B'
Montana-Dakota Utilities
Lewis & Clark Station

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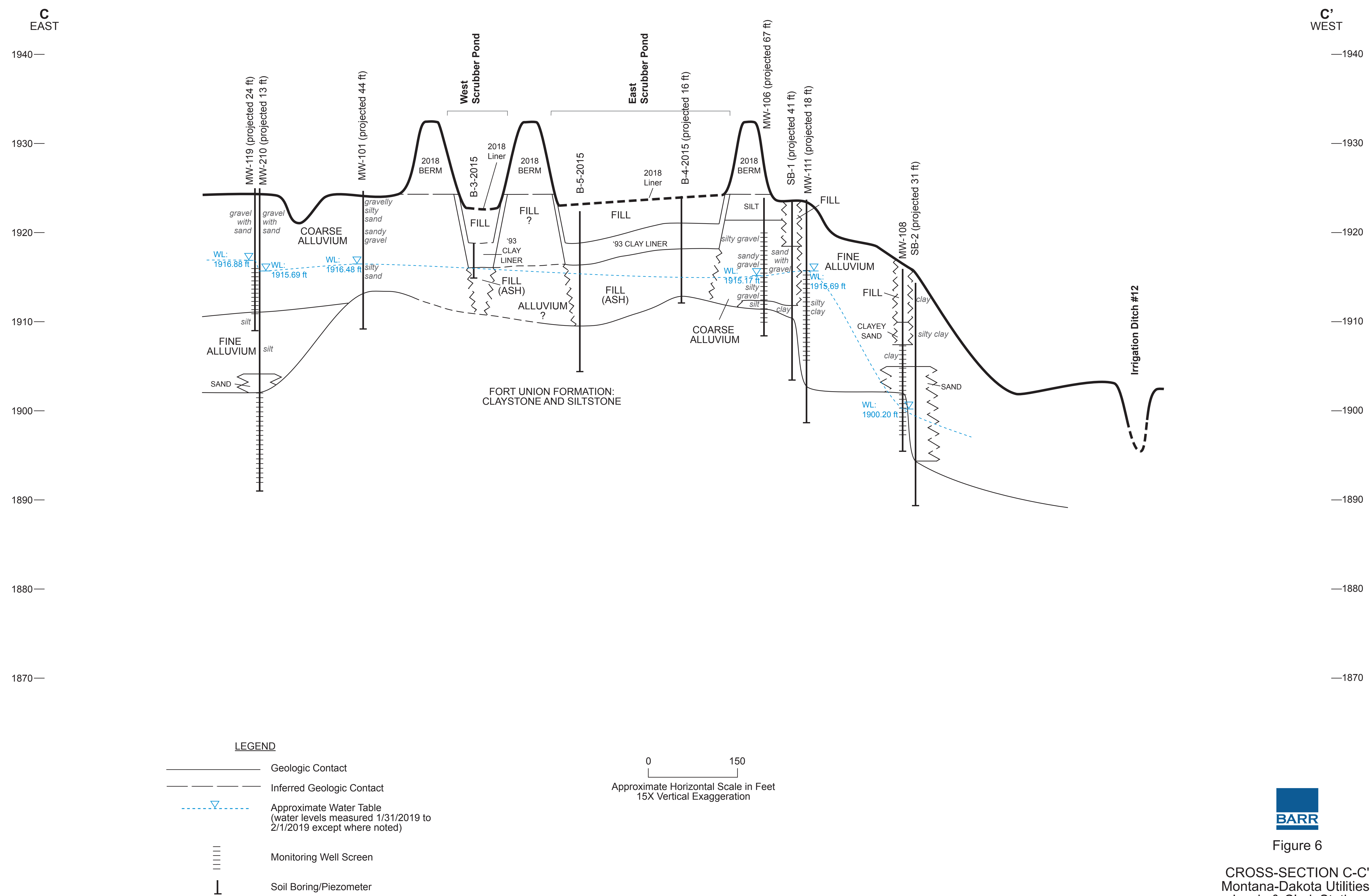

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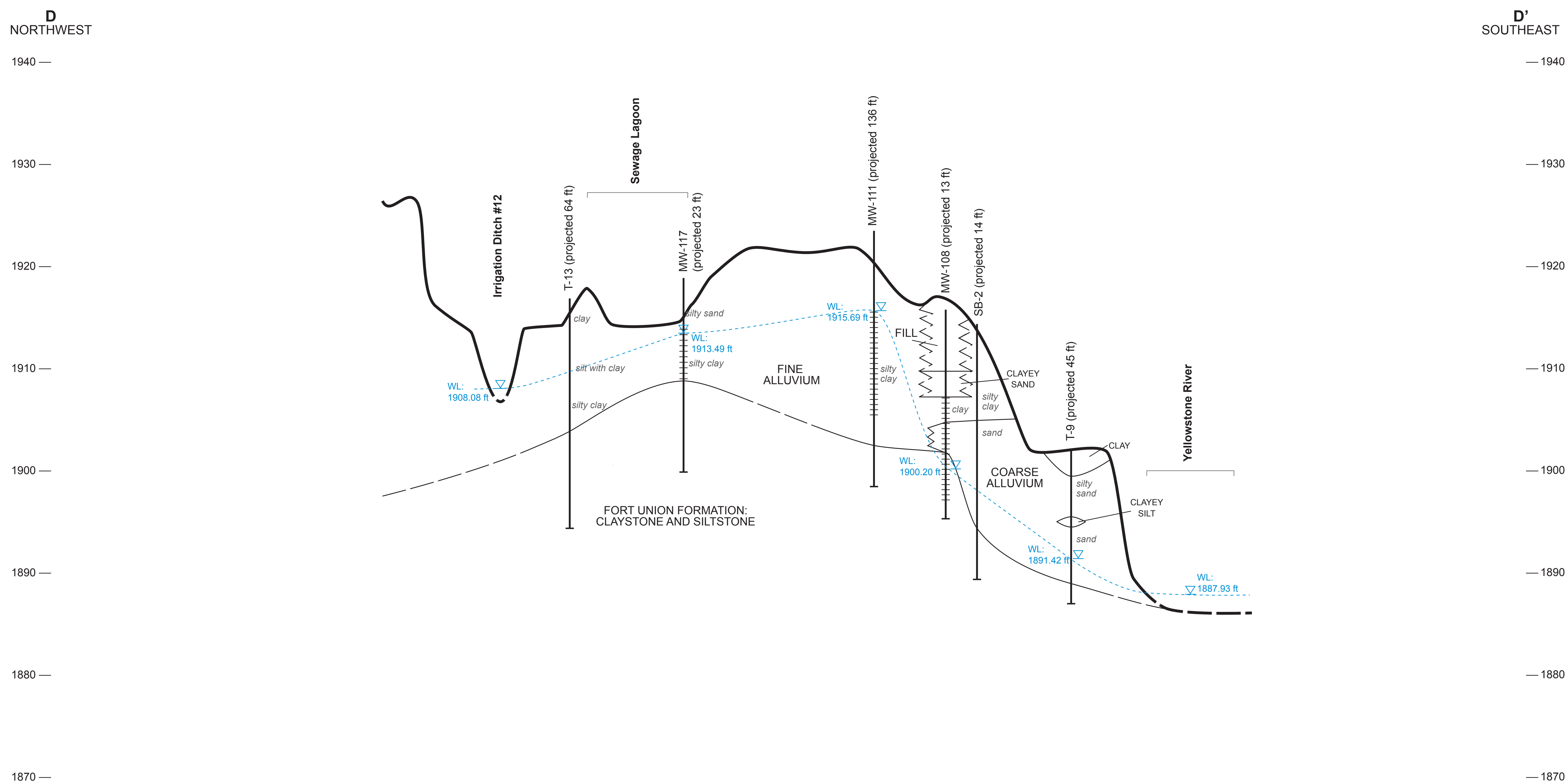
Figure 6

CROSS-SECTION C-C'
Montana-Dakota Utilities
Lewis & Clark Station



LEGEND

Geologic Contact

Inferred Geologic Contact

Approximate Water Table (water levels measured 1/31/2019 to 2/1/2019 except where noted)

Monitoring Well Screen

Soil Boring/Piezometer

0 150

Approximate Horizontal Scale in Feet
15X Vertical Exaggeration

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Figure 7

CROSS-SECTION D-D'
Montana-Dakota Utilities
Lewis & Clark Station

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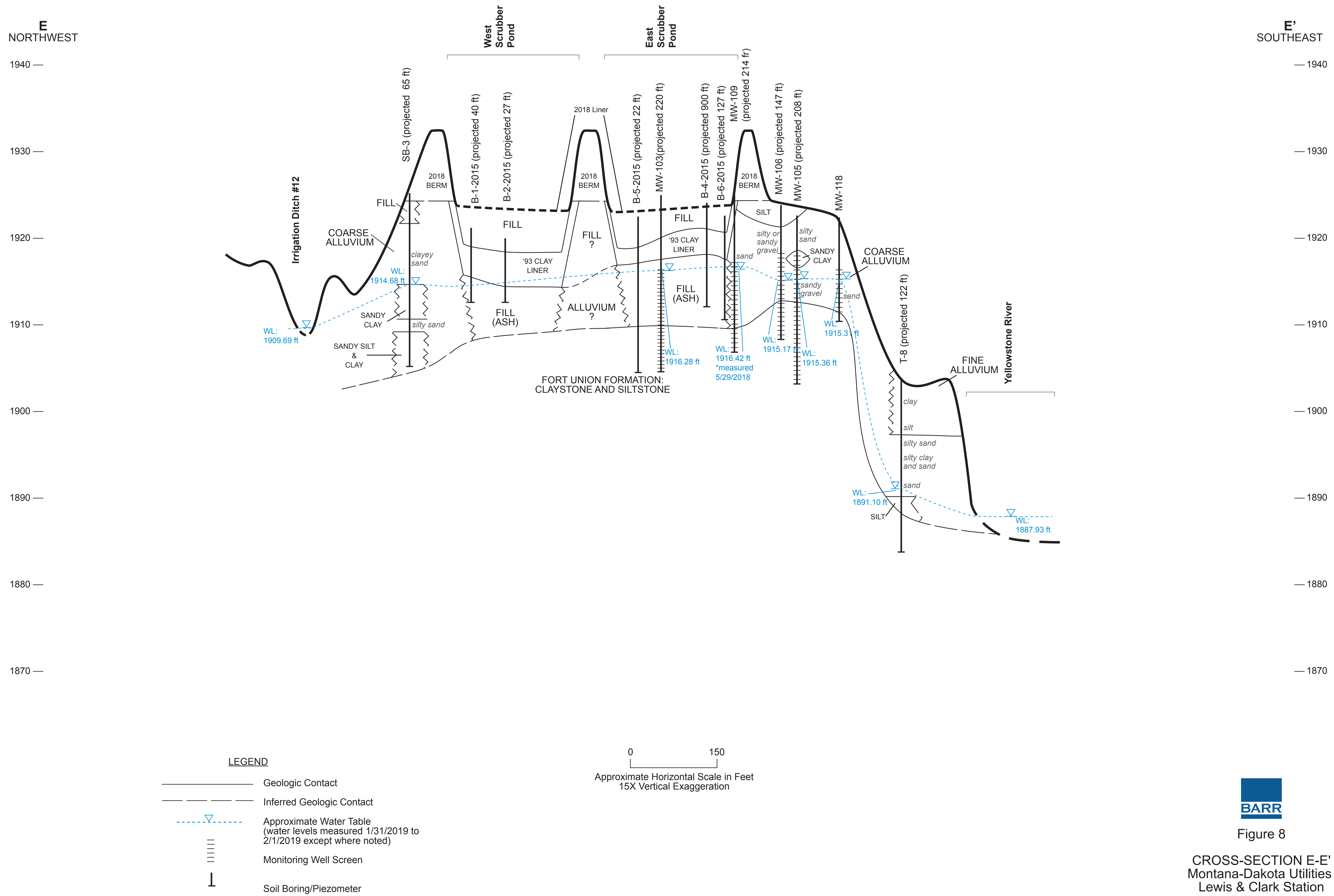

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Figure 8

CROSS-SECTION E-E'
Montana-Dakota Utilities
Lewis & Clark Station

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