Hayden Station CCR Landfill

Notification of Completion of Assessment of Corrective Measures

Public Service Company of Colorado (PSCo), an Xcel Energy Company, is the operator of Hayden Station, a coal-fired, steam turbine electric generating station. Hayden currently operates one CCR unit on site, a landfill that is used for final disposal of CCRs generated at Hayden Station, and that is subject to requirements of the Disposal of Coal Combustion Residuals from Electrical Utilities Rule (Federal CCR Rule), finalized on April 17, 2015. The CCR landfill has sufficient capacity for CCR disposal through the operating life of the station, after which it will be closed with installation of a final cover that is compliant with 257.102(d) and State of Colorado solid waste regulations, as described in the Written Closure Plan (Burns & McDonnell, 2018).

Protecting the environment is a priority for Xcel Energy

PSCo conducts all of its business in an environmentally responsible manner and that includes regularly monitoring our operations and taking steps to protect our air, water and other natural resources. Pursuant to 257.95(g), PSCo previously made a determination that one constituent listed in Appendix IV has been detected at Statistically Significant Levels (SSLs) above the Groundwater Protection Standards (GPS) established for the site pursuant to 257.95(h). This result does not indicate there is any impact on local drinking water. The downgradient monitoring wells evaluate groundwater in the alluvial aquifer adjacent to the CCR landfill, and measure groundwater conditions within the Hayden Station property boundary. PSCo will continue to monitor groundwater at the site in accordance with the assessment monitoring program as specified in 257.95.

PSCo also previously initiated an Assessment of Corrective Measures to identify and evaluate potential corrective measures to address this SSL over GPS. The assessment is complete, and the results are presented in the attached document, *Conceptual Site Model and Assessment of Corrective Measures*. The assessment includes preliminary analysis of the feasibility of seven potential corrective measures in meeting the requirements and objectives of the remedy as described in the CCR Rule. It also documents progress on a dewatering program that was implemented beginning in 2020 as a state approved corrective action pursuant to the Colorado solid waste regulations (6 CCR 1007-2 Part 1, Section 2.2 and Appendix B). This state corrective measure was initiated in response to groundwater monitoring results under the state program, prior to identification of SSLs under the CCR program. However, the dewatering corrective measure is consistent with the CCR source control requirement and is included as an alternative in the Assessment of Corrective Measures which also includes evaluation of whether any other corrective measures are necessary.

Conceptual Site Model and Assessment of Corrective Measures

for Compliance with the Coal Combustion Residuals (CCR) Rule

Hayden Station

Public Service Company of Colorado

October 14, 2021

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Certification

Hayden Landfill Assessment of Corrective Measures Report

I hereby certify to the best of my knowledge that this assessment of corrective measures for the Hayden Station Landfill is an accurate demonstration of the potential corrective measures under consideration for the landfill and is in compliance with 40 CFR Part 257 of the Federal Coal Combustion Residuals (CCR) Rule.

I am duly licensed Professional Engineer under the laws of the State of Colorado.

Megan Seymour, PE
Colorado PE License 0057276
License renewal date October 31, 2023

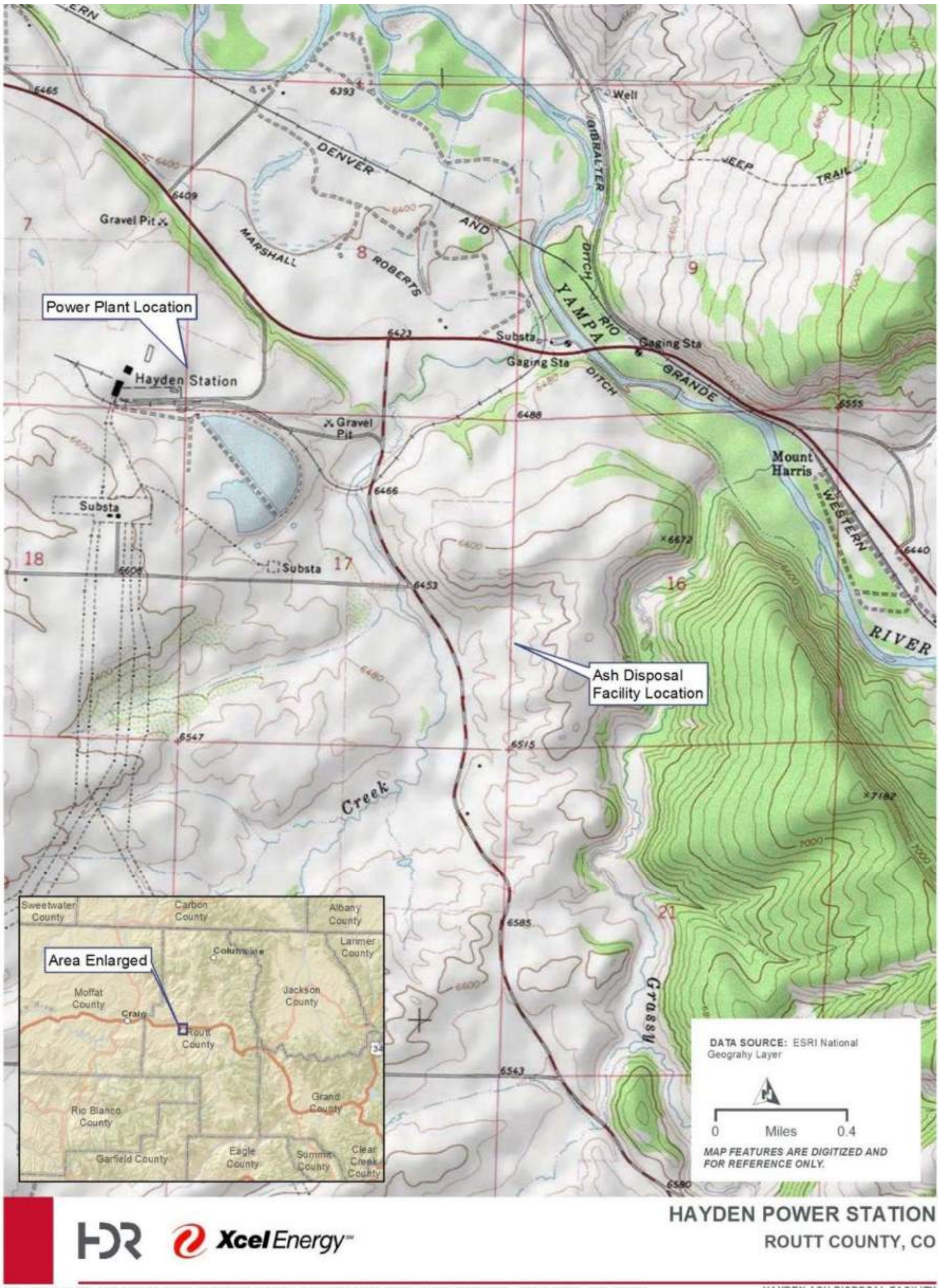
1 Introduction

This assessment of corrective measures (ACM) was performed for groundwater conditions at the Public Service Company of Colorado (PSCo) Hayden Generating Station CCR landfill site in Hayden, Colorado (Figure 1-1). The purpose of the assessment was to identify and evaluate potential groundwater corrective measures for the landfill, showing benefits and limitations associated with each alternative. The corrective measure alternatives were evaluated with the goal of reducing groundwater concentrations to levels below the groundwater protection standards (GPS) developed for the site. This ACM was initiated following the determination that was made and documented in a July 16, 2021 memorandum *Hayden Groundwater Protection Standards* that documented cobalt was present at a statistically significant level (SSL) above the GPS in one downgradient monitoring well at the landfill. The GPS values for each constituent of interest are either the 1) federal Maximum Concentration Limits (MCLs), as established under 40 CFR §141.62 and 141.66; or 2) background concentrations developed in accordance with 40 CFR §257.91, whichever is greater.

In accordance with 40 CFR §257.96(c), this assessment of corrective measures includes a preliminary analysis of the feasibility of potential corrective measures in meeting all of the requirements and objectives of the remedy as described under § 257.97. Seven potential corrective measure alternatives were evaluated for the landfill. The ACM table included herein provides a visual evaluation of the relative effectiveness of each corrective measure alternative. Criteria in the table were selected based on remedy selection criteria in §257.97.

This report also documents progress on implementation of a corrective action pursuant to the state of Colorado solid waste regulations (6 CCR 1007-2 Part 1, Section 2.2 and Appendix B). In 2020, PSCo began implementing a corrective action plan approved by the Colorado Department of Public Health and Environment (CDPHE) to dewater leachate that had previously infiltrated the landfilled ash, thereby removing the source of water causing the impacts observed in the state groundwater monitoring program. This state corrective action plan is described further in Section 5 of this ACM. Landfill dewatering and improved stormwater controls were implemented prior to identifying the SSL under the federal CCR Rule triggering requirements for corrective measures.

Figure 1-1. Hayden Station Vicinity Map



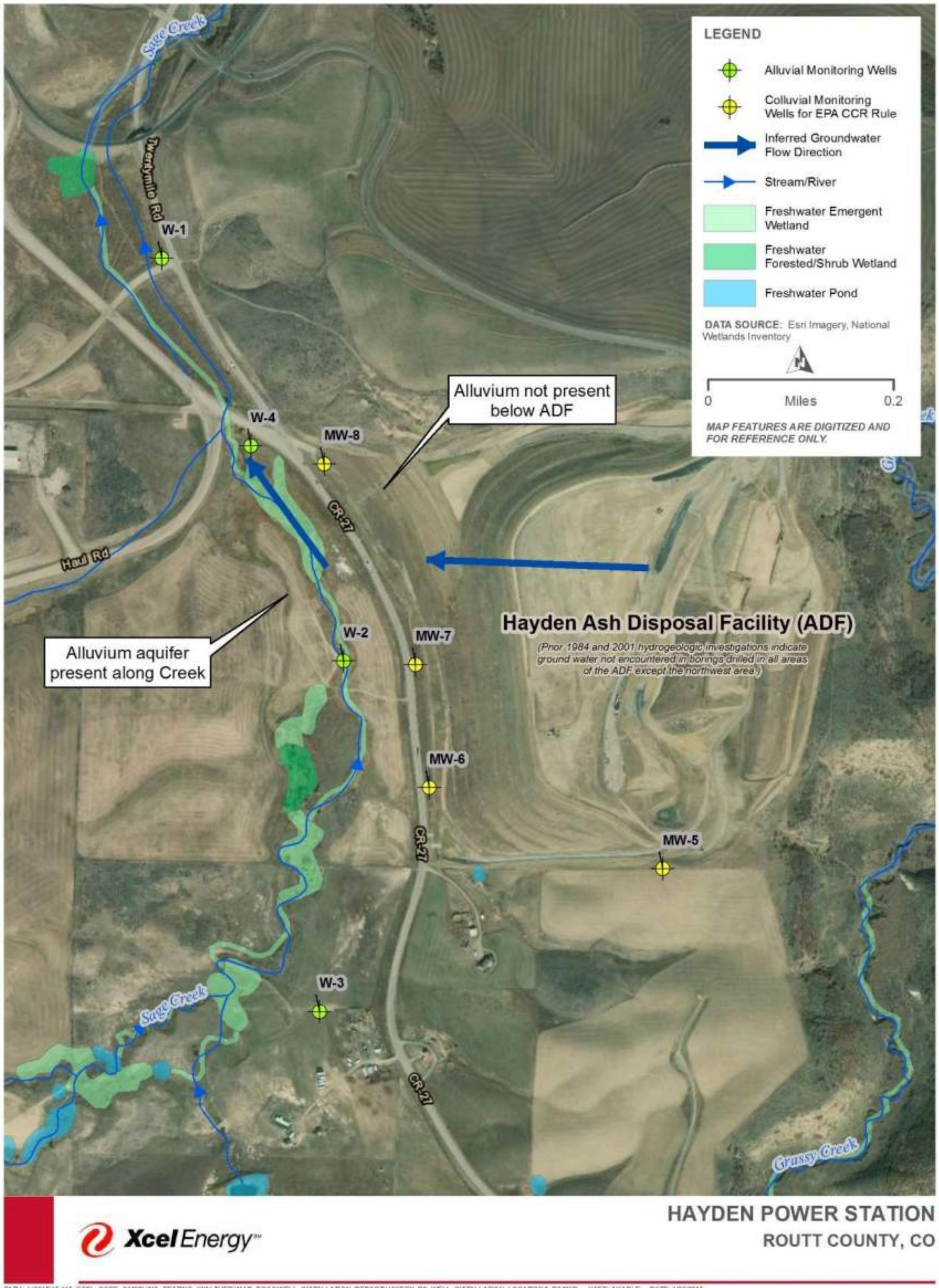
2 Background

Hayden Station has one CCR unit that is the subject of this assessment, the landfill (**Error! Reference source not found.**). Hayden Station is a coal-fired, steam turbine electric generating station; the fuel source for the existing coal-fired units is sub-bituminous, low-sulfur coal supplied by several mines in western Colorado. Hayden Station uses water from the Yampa River and does not discharge water offsite, other than stormwater. Hayden Station began operating in 1965 (Unit 1), with the addition of Unit 2 in 1976. CCR generated at the Station is permanently disposed in the landfill (**Error! Reference source not found.**). Wastes disposed at the landfill consist of coal ash, air emission control byproducts, water intake silt, excavation soils, and coal impurities. Approximately 230,000 cubic yards of ash are disposed annually at the ADF with 75 percent fly ash containing flue gas desulphurization (FGD) sorbets and 25 percent being bottom ash (Burns & McDonnell, 2019b). The area inside the permitted boundary of the ADF consists of approximately 154 acres of which approximately 136 acres is used for ash disposal and approximately 18 acres for stormwater control structures, access roads, and borrow area (Burns & McDonnell, 2019b). The landfill does not have an engineered liner, but is underlain by the Lewis Shale formation, which acts as an aquitard and confining layer (Burns & McDonnell, 2019b). The Lewis Shale can be as thick as 1,900 feet; however, at the Hayden site it is likely between 100 and 200 feet thick (Robson and Stewart, 1990).

The original certified CCR monitoring well network for the landfill consisted of four wells completed in the colluvium that underlies the landfill: one upgradient of the landfill and three at the downgradient waste boundary. Upgradient colluvial monitoring well, MW-5, has continued to be dry since program implementation and comparison of upgradient and downgradient groundwater chemistry in the colluvial wells has not been possible. If present, groundwater in the colluvium under the landfill would discharge to the adjacent alluvial aquifer of Sage Creek. Therefore, four existing monitoring wells in the adjacent alluvial aquifer that are part of the state approved groundwater monitoring program were added to the certified CCR monitoring network for the landfill. These four alluvial wells are located both upgradient and downgradient of the CCR landfill and are used to supplement the colluvial landfill monitoring wells. It is not appropriate to compare alluvial water quality to colluvial water quality; however, collecting samples from the alluvial well network will provide background groundwater that has not been impacted by the CCR unit, as well as groundwater downgradient of the CCR unit that has the potential to be impacted by the CCR unit. The colluvial wells were sampled for CCR constituents of interest (COIs) background water quality between December 2, 2015 and July 11, 2017. The alluvial wells were sampled for background water quality between April 11, 2018 and April 15, 2019 and background threshold values (BTVs) were developed. Results of the detection monitoring samples were compared against the BTVs as specified under CCR Rule §257.94, statistically significant increases (SSIs) were identified, and assessment monitoring was initiated September 25, 2019 as specified under §257.95.

In accordance with CCR Rule §257.95(h), GPS were established for each detected Appendix IV COI and documented in the *2020 Annual Groundwater Monitoring and Corrective Action Report* and the July 16, 2021 memorandum *Groundwater Protection Standards and Determination of SSLs*. One downgradient well was found to have concentrations of cobalt at SSLs above the GPS. PSCo will select, design, and implement a remedy for the landfill based upon the corrective measures assessment herein compliant with §257.96-97.

Figure 2-1. Hayden Station—CCR Units and Certified Monitoring Well System



3 Conceptual Site Model

The Conceptual Site Model (CSM) is a narrative description of the groundwater flow system. The purpose of the CSM is to identify all relevant hydrogeologic components of the local groundwater system to understand the physical processes within the groundwater system at the CCR unit.

3.1 Climate

The climate of the station location can be described as continental subarctic.

Annual total precipitation is 16.83 inches per year in Hayden, with annual mean snowfall of 107.8 inches (Western Regional Climate Center (WRCC, 2021). The wettest month is April, with an average of 1.61 inches of total precipitation. The warmest month is July with an average high of 83°F and an average low of 52°F. The coldest month is January with an average high of 29°F and an average low of 11°F. Table 3-1 summarizes key characteristics.

3.2 Surface Water

Surface water features adjacent to the landfill are illustrated on Figure 2-1. The two streams near the landfill are Sage Creek, directly west of the facility, and Grassy Creek, to the east of the facility. Both drainages flow in a northerly direction toward the Yampa River, one mile north of the landfill. There are no other significant, natural surface water bodies within two miles of the landfill.

Table 3-1. Key Climate Characteristics at Hayden Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Monthly Average Temperature (°F) (Hayden 1909-2016)	17.70	21.95	30.90	42.40	51.75	60.10	66.7	64.95	56.40	46.65	31.75	20.85	42.55
Monthly Average Precipitation (Inches) (Hayden 1909-2016)	1.47	1.24	1.30	1.61	1.52	1.17	1.29	1.39	1.53	1.54	1.29	1.50	16.83
Monthly Average Pan Evaporation (Inches) (Climax 1949-2005)	0.00	0.00	0.00	0.00	0.00	5.36	5.32	4.44	3.41	0.00	0.00	0.00	18.53

3.3 Geology

Investigation have been performed at the landfill over the years and are summarized in the text below:

- Eight borings and monitoring wells (HD-1 to HD-8) were first installed at the site in 1984. The logs for these borings are presented in the 2001 *Environmental Monitoring System (EMS) Installation Report* by Xcel (Xcel, 2001).
- The 2001 *EMS Installation Report* documents installation of three new monitoring wells (W-1 to W-3) to the west of the landfill along Sage Creek and two soil borings on the landfill (to characterize landfill waste types) and groundwater quality monitoring (Xcel, 2001).
- Groundwater monitoring wells W-4, W-5, and W-6 were installed in March of 2017 by AECOM.
- The 2019 *Engineering Design and Operation Plan* (EDOP) describes the physical characteristics of the landfill and landfill closure design plans (Burns & McDonnell, 2019b).
- A field investigation of the landfill performed by Burns & McDonnell in 2017-2019 encountered saturated ash within the landfill footprint and resulted in saturated ash zone delineation, volume estimation, evaluation of potential ash dewatering rates, and preparation of a dewatering plan that was approved by CDPHE (Burns & McDonnell, 2019a).

The ash landfill is located on a west-facing hillslope that drains to Sage Creek (Figure 2-1). The top of the slope is the east side of the landfill, which forms a drainage divide between Grassy Creek and Sage Creek. Sage Creek and Grassy Creek flow to the north.

Early hydrogeologic investigations conducted in 1984 reported that the soil underlying the landfill is colluvium consisting of silty clay or clay to a depth of 9 to 24 feet and generally increased from east to west across the site, which is underlain by shale bedrock of the Lewis Shale Formation (Xcel, 2001). The Lewis Shale Formation surface slopes down to the west/northwest towards Sage Creek (Xcel, 2001). The Lewis Shale Formation is several hundred feet thick in the area and is recognized as an aquiclude that inhibits vertical movement of water (Xcel, 2001). The landfill wells described in Xcel (2001) were dry and monitoring well MW-5 screened in colluvium at the upgradient end of the landfill is also dry. These dry wells indicate that the background condition of the colluvium was dry. These colluvial soils were then excavated under the landfill ahead of ash placement. Several geologic cross sections through the landfill were prepared in Burns & McDonnell (2019a) and are included in **Error! Reference source not found.** of this document. Cross section A-A' provides the geology under the landfill and illustrates the current condition with the colluvium having been removed under the landfill and illustrating that any infiltrated water in the landfill flows along the Lewis Shale contact and is discharged to the alluvium of Sage Creek (Burns & McDonnell, 2019b). The colluvial removal was confirmed in fall 2017 when seven borings penetrated through the ash and into the underlying Lewis Shale without encountering the unconsolidated materials (Burns & McDonnell, 2019a). Several of these borings were advanced up to 40 feet into the Lewis Shale and also through the shale and into the underlying Dakota Sandstone, and the results support the previous investigations that found the Lewis Shale to be dry (Appendix A, Cross Section A-A').

Monitoring wells MW-6, MW-7, and MW-8 are screened in colluvium at the landfill's western waste boundary. Groundwater believed to be landfill leachate was encountered in monitoring wells MW-6, MW-7, and MW-8 from 11 to 21 feet below grade (Figure 2-1). These well completions show that the material immediately west of the landfill at the waste boundary is colluvium, and the cross section developed by Burns and McDonnell (Appendix A, Cross Section A-A') has been annotated to reflect this data. The transition from colluvium to alluvium occurs somewhere between monitoring wells MW-6, MW-7, and MW-8 and the alluvial wells discussed below.

To the west of the ash landfill, the uppermost aquifer is within the alluvium deposited along the Sage Creek valley. Monitoring wells W-1, W-2, W-3, and W-4 were drilled to depths of 15 to 20 feet in sand and gravel alternating with finer-grained layers of sand, silt, and clay. Groundwater was encountered from 5 to 10 feet below grade (Xcel, 2001).

The hydraulic conductivities of these alluvial materials have been measured from in-situ slug tests to range from 10^{-3} to 10^{-4} centimeters per second (cm/s) (Burns & McDonnell, 2019b).

3.4 Groundwater Flow System

A regional water table does not exist in the Lewis Shale formation, the bedrock unit encountered beneath the landfill. The Lewis Shale Formation is relatively impermeable and acts as a confining layer to the underlying Mesaverde Formation aquifers (Robson and Stewart, 1990). The contribution of groundwater from the Lewis Shale to the adjacent Sage Creek alluvial aquifer is expected to be small due to the limited recharge area, climatic data, and low-permeability characteristics of the formation. Vertical infiltration rates to underlying aquifers are expected to be very low due to the thickness of the Lewis Shale and its low permeability.

In 1984, Woodward-Clyde Consultants installed a total of eight monitoring wells (HD 1-8) around the perimeter of the landfill to characterize lithology and groundwater flow at the facility (Xcel 2001). Monitoring wells were constructed within the borings to screen the upper portion of the Lewis Shale and, in some cases, the interface of the unconsolidated materials and the Lewis Shale. The wells were dry and were subsequently abandoned but demonstrate the limited potential for groundwater occurrence within the unconsolidated clays at the landfill (colluvium) and the general absence of groundwater within the Lewis Shale bedrock under the landfill.

The uppermost regional bedrock aquifer beneath the landfill is the Twentymile Sandstone (Robson and Stewart, 1990). Wells completed in this formation yield up to 100 gallons per minute (gpm), but typically average less than 10 gpm (Brogden and Giles, 1977). This aquifer is separated from the landfill by the Lewis Shale formation. The groundwater elevation for the Twentymile Sandstone differs from that of the unconfined groundwater in the colluvial CCR wells and the Sage Creek alluvium. Although the Twentymile Sandstone is the uppermost regional aquifer beneath the landfill, the Sage Creek alluvial aquifer that flows offsite to the north into the Yampa River located immediately adjacent to the landfill has a greater potential as the receiving aquifer of water from the landfill.

As part of an update to the EDOP under the state regulatory program, PSCo implemented a site hydrogeologic investigation in 2017 the results of which were incorporated into the approved EDOP (Burns & McDonnell, 2019b). The investigation and subsequent field work in 2017-2019 conducted by Burns & McDonnell (2019a) identified saturated conditions within the landfill. The zone of saturated ash within the landfill is perched on the Lewis Shale and migrates topographically downslope to the west until it leaves the ash landfill and moves through the colluvium and into the alluvial groundwater of the Sage Creek aquifer (Appendix A cross sections). The saturated ash zone is thought to be due to past operational conditions of stormwater ponding in a concentrated area on the ash and infiltrating. The previously impounded stormwater on the landfill was eliminated in 2013 and in 2018 PSCo implemented new grading plans that direct contact water to a newly constructed, lined retention pond. Daily soil and intermediate soil cover also are used to minimize infiltration of direct precipitation into the ash. Therefore, implementation of these corrective measures is predicted to eliminate additional leachate generation that would add to the saturated ash zone. Direct precipitation that is insufficient to run off to the lined pond will be minimal and limited to the soil cover. In addition to the stormwater controls, PSCo developed and is implementing a corrective action plan approved by the state to dewater the ash.

The Sage Creek alluvial aquifer is generally limited to the Sage Creek valley. Wells screened in the coarser deposits may yield 900 gpm, but typical yields are much less and dependent upon the well intercepting a layer of coarse material (Burns & McDonnell, 2019a). Depths to water are typically less than 10 feet below ground surface. Groundwater flow within the aquifer has been documented to generally be north/northwest toward the Yampa River.

The CCR Rule requires, at a minimum, one upgradient and three downgradient monitoring wells per CCR unit to be completed in the uppermost aquifer. In addition, the CCR Rule states that downgradient monitoring wells should be installed to: “accurately represent the quality of groundwater passing the waste boundary of the CCR unit. The downgradient monitoring system must be installed at the waste boundary that ensures detection of groundwater contamination in the uppermost aquifer.”

Based on the CCR requirements, hydrogeological data, and site visits, four wells were originally sited for CCR compliance to serve as one upgradient and three downgradient monitoring wells at the waste boundary (MW-5 through MW-8, Figure 2-1).

The original upgradient well (MW-5) is located to the southeast of the ash landfill (Figure 2-1). This location is upgradient from the landfill. This location did not encounter groundwater during drilling and has remained dry. The potential flow of groundwater is perpendicular to the length of the landfill. Therefore, downgradient monitoring wells to evaluate potential impacts to groundwater from the landfill are located to the west of the landfill, at the waste boundary. All three original downgradient wells (MW-6, 7 and 8) are located immediately west of the landfill and east of CR-27. The three downgradient wells are spaced along the length of the landfill at the waste boundary of the CCR unit to ensure the water quality from these three locations will detect constituents from the CCR unit, if present. All three downgradient wells are completed below the water table.

These original four monitoring wells (MW-5 through MW-8) were completed in the colluvium that underlies the landfill and above the Lewis Shale. The upgradient colluvial monitoring well MW-5 has continued to be dry since program implementation and comparison of upgradient and downgradient groundwater chemistry in the colluvial wells has not been possible.

As described above, the ash landfill is located above the westerly dipping, dry, Lewis Shale, such that any water in the ash would flow along the shale contact and discharges to the adjacent alluvial aquifer of Sage Creek. Based on the site hydrogeology and westerly sloping bedrock surface, impacts to groundwater from the landfill should be observable in the alluvial aquifer downgradient of the landfill waste boundary. Therefore, existing monitoring wells in the adjacent alluvial aquifer (W-1, W-2, W-3, and W-4) are included in the certified monitoring network for the landfill to supplement the colluvial monitoring wells. These four wells are screened in the alluvial aquifer west of the waste boundary (Figure 2-1). One upgradient well (W-3) is located southwest of the landfill to represent background water quality conditions that have not been impacted by the CCR unit. Three downgradient wells (W-1, W-2, and W-4) are located west and northwest of the landfill waste boundary and are capable of detecting impacts in groundwater as a result of water that has passed the waste boundary.

Table 3-2. Groundwater Elevations Collected in CCR Monitoring Wells

Well ID	December 15, 2020 (ft amsl)	June 22, 2021 (ft amsl)
W-1	6434.74	6435.69
W-2	6448.77	6448.85
W-3	6459.06	6459.87
W-4	6442.99	6444.32
MW-5	6592.57	6592.64
MW-6	6462.26	6462.09
MW-7	6460.05	6460.05
MW-8	6442.97	6443.8

Groundwater elevations for the CCR monitoring network wells are provided in Table 3-2 from the last two CCR groundwater monitoring dates, and groundwater contours are provided in Figure 3-1and Figure 3-2 for the same dates (December 2020 and June 2021). The groundwater flow direction in the alluvial aquifer is to the north towards the Yampa River. Contour maps illustrate W-3 as upgradient relative to the landfill and an appropriate location to serve as a background well for the alluvial aquifer wells. The colluvial well water quality will not be compared to the alluvial background groundwater because the wells are not completed in the same lithology therefore water quality may differ naturally. Further, the water in the downgradient colluvial wells is believed to be landfill leachate and the flow direction and water quality in the downgradient alluvial wells do reflect an influence from the landfill based on the detection monitoring SSIs, indicating they are effective at detecting releases from the CCR unit.

Field hydraulic conductivity (slug) testing was performed at monitoring wells MW-6, MW-7, MW-8. Monitoring wells MW-6 through MW-8 are screened in the colluvium and slug testing indicates hydraulic conductivity was between 8.66E-04 and 2.47E-03 cm/s with a geometric mean of 6.48E-04 cm/s (HDR, 2016). Field hydraulic conductivity (slug) testing was performed at monitoring wells W-1 through W-3. Monitoring wells W-1 through W-3 are screened in the alluvium and slug testing indicates hydraulic conductivity was between 0.28 and 145 ft/day with a mean of 92 ft/day (Xcel, 2001).

Using the hydraulic conductivity value of 92 feet per day (ft/day) and a representative effective porosity of 25%, an average groundwater travel velocity of 1.4 to 1.9 ft/day was calculated using Darcy's law (Xcel, 2001). This travel velocity reflects the sand and gravel beds found in the alluvial aquifer.

As described above, saturated ash fill was discovered in the southern portion of the landfill during the 2017 ash investigation (Burns & McDonnell, 2019a). Multiple piezometers were installed to delineate the extent of saturated conditions, and to potentially be used to dewater the saturated ash and thus control the migration of potentially impacted water from within the ash fill to the alluvial aquifer. Appendix A shows the locations of the lines of geologic cross section and the potentiometric surface measured within the landfill where saturated ash fill was observed. Geologic cross sections B-B', C-C', and D-D' depict the subsurface conditions and the potentiometric surface observed within the area of saturated ash fill (Burns & McDonnell, 2019a). Burns & McDonnell (2019a) estimated approximately 7 million gallons of water in the saturated ash zone. The dewatering currently being implemented is further described in Section 5.1.1.

Figure 3-1. Groundwater potentiometric surface from December 2020

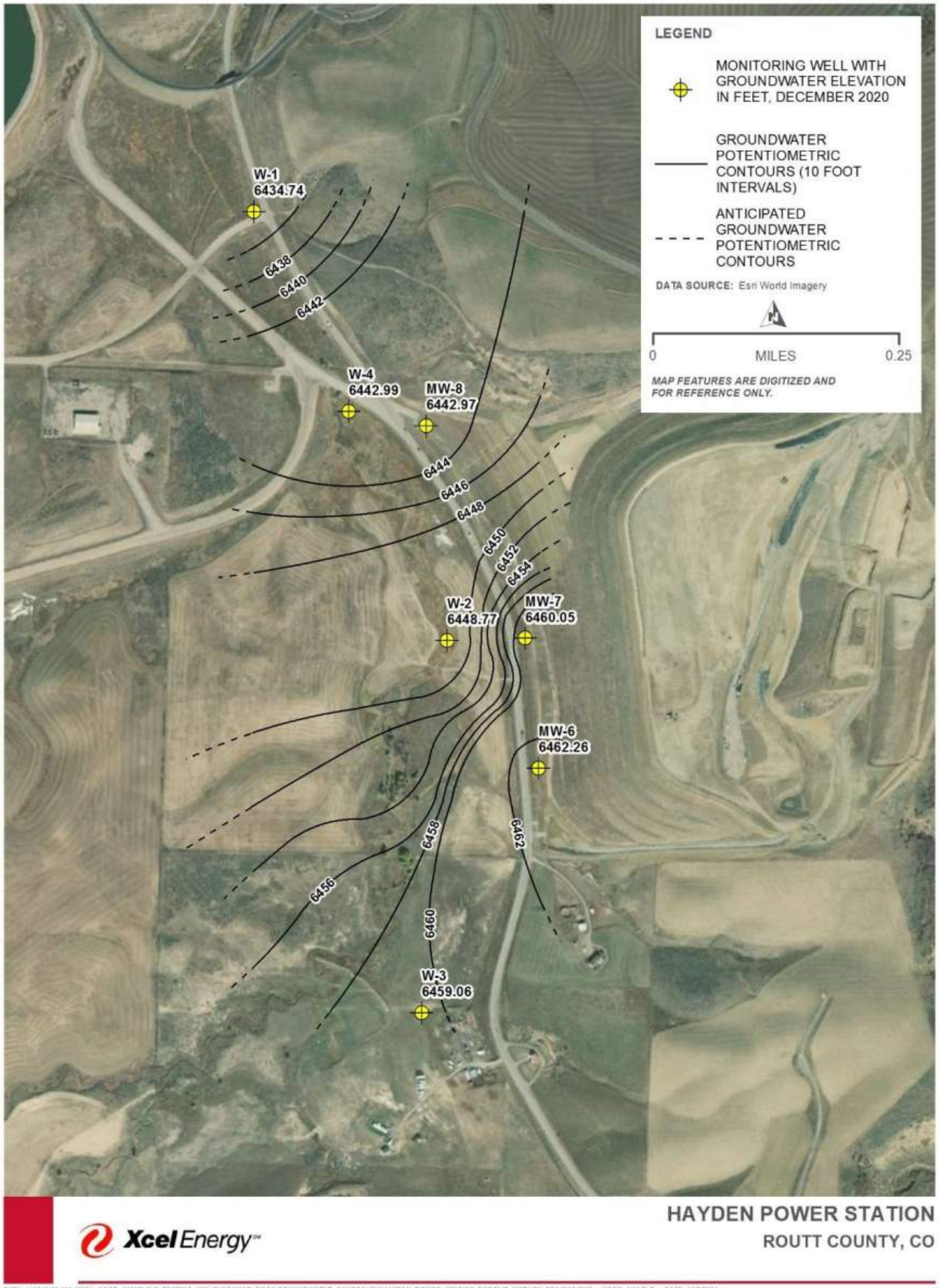
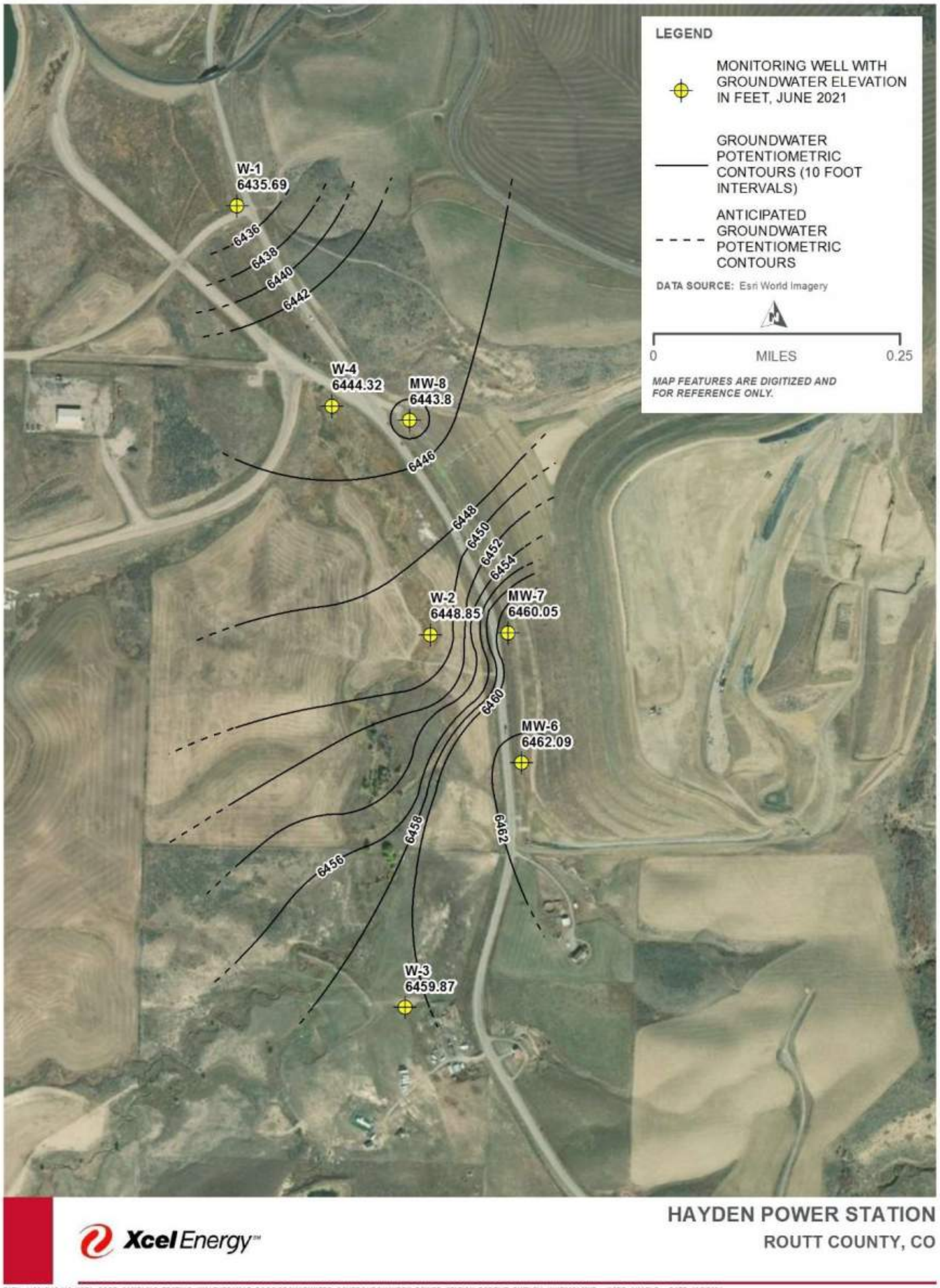


Figure 3-2. Groundwater potentiometric surface from June 2021



3.5 Water Quality

As stipulated in the CCR Rule, eight rounds of background groundwater sampling and detection monitoring were completed in 2019 for the landfill alluvial wells. The background sampling was described in detail in the Background Water Quality Statistical Certification (HDR, 2021). In the August 20, 2019 PSCo memorandum, Determination of Statistically Significant Increases over Background per §257.93(h)(2), concentrations of Appendix III COIs from each downgradient monitoring well at the landfill were compared against the BTVs and several COIs were shown to have SSIs over BTVs (upper prediction limit). Well W-2 has SSIs for boron and W-4 has SSIs for chloride, sulfate, and total dissolved solids. These SSIs triggered the assessment monitoring program for the landfill. In accordance with CCR Rule §257.95(h), GPS were established for each detected Appendix IV COI.

In accordance with CCR Rule §257.95(e), downgradient well concentrations from the December 2019 assessment monitoring event were compared against background values, and some concentrations were found to be above background values. In accordance with CCR Rule 257.95(f), detected Appendix IV COI concentrations in downgradient wells were compared against GPS and one well had a single slight exceedance of GPS. Therefore, in accordance with CCR Rule §257.95(g), statistical evaluation was completed to determine if any concentrations are at an SSL over GPS. No SSLs were observed, and assessment monitoring status continued.

In accordance with CCR Rule §257.95(e), downgradient well concentrations from the June 2020 assessment monitoring event were compared against background values, and some concentrations were found to be above background values. In accordance with CCR Rule 257.95(f), detected Appendix IV COI concentrations in downgradient wells were compared against GPS and none were found to exceed GPS. Therefore, in accordance with CCR Rule 257.95(f), assessment monitoring status continued.

In accordance with CCR Rule §257.95(e), downgradient well concentrations from the December 2020 assessment monitoring event were compared against background values, and some concentrations were found to be above background values. In accordance with CCR Rule §257.95(f), detected Appendix IV COI concentrations in downgradient wells were compared against GPS some concentrations were found to exceed GPS. Therefore, in accordance with CCR Rule §257.95(g), statistical evaluation was completed to determine if any concentrations are at an SSL over GPS, and cobalt was found to have a minor statistical exceedance of GPS in well W-4.

4 Constituents of Concern in Groundwater

4.1 Constituents Exceeding the Groundwater Protection Standard

Table 4-1 lists the EPA established MCL, the BTV, and the GPS for cobalt. Since there is no EPA established MCL for cobalt from 40 CFR §141.62, the MCL value is the EPA adopted health-based value for cobalt, per the amended rule. In accordance with CCR Rule §257.95(f), downgradient well concentrations from the assessment monitoring events were compared against GPS and found to exceed GPS. Therefore, following CCR Rule §257.95(g), downgradient well concentrations were compared against GPS to determine "if one or more constituents in Appendix IV to this part are detected at statistically significant levels above the groundwater protection standard." To determine if an exceedance of a GPS was statistically significant, the lower confidence limit (LCL) was calculated for each of the downgradient wells at the landfill for each of the detected Appendix IV COIs. Downgradient well W-4 had concentrations of cobalt at an SSL above the GPS. All other detected Appendix IV COIs are below the GPS. Therefore, the constituent that will be evaluated moving forward for assessment of corrective measures is cobalt (this constituent is referred to herein as the constituent of concern (COC)). It should be noted that the GPS exceedance is so slight that if the LCL were rounded down to the same significant figures as the MCL it would be the same value as the MCL; and therefore, would not trigger an ACM. However, although rounding is standard procedure in some regulatory programs (e.g., air quality), for the purposes of CCR Rule program compliance, Xcel is not rounding. Additionally, PSCo is already implementing corrective action at the landfill under Colorado regulations.

Table 4-1. Groundwater Protection Standard and LCL for Appendix IV COI with SSLs above the GPS at the Landfill §257.95(d)(3)

Constituent	Unit	Maximum Contaminant Level	Background Concentration (UTL)	Groundwater Protection Standard	Well W-4 LCL
Cobalt	mg/l	0.006*	0.00616	0.00616	0.00646**

*USEPA adopted health-based value in place of MCL
**Note the USEPA WSG-21 states reported data should be rounded to significant figures in the MCL; this may apply to rounding BTV and LCL values.

4.2 Constituents of Concern Source Areas

Fly ash and bottom ash have been deposited in the landfill since the early 1980's. By design, the landfill was constructed with the base cut to the Lewis Shale bedrock. The bedrock has low permeability and acts as a natural barrier to seepage; therefore, no engineered liner was constructed on the landfill bottom.

As described above and illustrated in the cross sections prepared by Burns& McDonnell (2019a) (Appendix A), a zone of saturated ash within the landfill was identified by PSCo. The saturated ash is at the base of the landfill, above the consolidated Lewis Shale bedrock. This leachate flow follows the bedrock slope to the west and discharges into the alluvial aquifer of Sage Creek. Therefore, there is potential for the source of any CCR program compliance COC in the alluvial downgradient wells to be from the saturated ash leachate contribution to the alluvial aquifer. That said, monitoring wells MW-6 and MW-7, located between the saturated zone of the landfill and the alluvial aquifer, have concentrations of cobalt (maximum concentration of 0.001 mg/L) that are much lower than the concentration of cobalt at W-4 where the GPS exceedance was observed. Therefore, there is some potential for another source; however, because another source has not yet been identified, PSCo is proceeding with this ACM.

4.3 Source Characterization

The landfill is built upon the low permeability Lewis Shale Formation. Historically, run-on stormwater and contact water runoff ponded in a low area of the landfill and infiltrated the ash surface forming a sub-surface saturated mound on top of the Lewis Shale within the ash on the south side of the landfill. PSCo installed wells located on and adjacent to the landfill to monitor the sub-surface water levels of this saturated zone. PSCo completed a field investigation to map and estimate the volume of the saturated ash zone and evaluate the potential dewatering pumping rates (Burns & McDonnell, 2019a). The water level measurements collected during the field investigations were used to generate a saturated zone surface in AutoCAD Civil 3D, which was used as the upper boundary of the saturated zone. The lower boundary was generated using historic bottom-of-landfill elevations and bedrock elevations encountered during piezometer installation. The saturated volume was multiplied by a porosity factor to estimate the volume of water in the pore space. Burns & McDonnell (2019a) estimated slightly over 7 million gallons of water in the saturated zone and located on the south side of the landfill (Appendix A map and cross section). After the field investigation, PSCo developed a Dewatering Plan as the corrective action under the state program, which is currently being implemented to address the impact to the alluvial aquifer adjacent to the landfill.

4.4 Potential Receptors

There is no primary or secondary drinking water standard for cobalt. The agricultural water quality standard for dissolved cobalt in Colorado is 0.05 mg/L. Therefore, the locations where groundwater concentrations of cobalt exceed the CCR Rule GPS, all of which are on Hayden Station property meet agricultural standards for cobalt.

There is one well permit close to 1 mile northwest of the landfill in the downgradient direction. State Engineer's Office records indicate this is a domestic well permit (I.D. number 13 on the map and table included in Appendix B, permit number 292002) mapped just inside the PSCo Hayden Station property, which is an inaccurate map siting. According to Hayden Station personnel, there is not a well at this location and the referenced domestic well permit is understood to be located father north across Highway 40 on the adjacent property.

4.5 Plume Evaluation

Based on the current understanding of the site hydrogeology, groundwater appears to be impacted by cobalt within the alluvial aquifer of Sage Creek immediately west of the landfill. Based on groundwater results from the state monitoring program, the plume is limited in the east west direction to within the alluvial aquifer. Based on CCR monitoring results, the plume is limited in the north south direction to between the south end of the landfill and to the north between W-4 and W-1 (W-1 is downgradient of W-4 and has low concentrations of cobalt (LCL of 0.0008 mg/L)), less than the GPS. The vertical extent of impacted groundwater is limited to the saturated portion of the alluvial aquifer above the Lewis Shale because of the well documented low permeability of the Lewis Shale as an aquiclude (Burns & McDonnell, 2019a).

4.6 Potential for Offsite Transport

All downgradient monitoring wells are located on PSCo property. However, during the state EDOP revision in 2018, it was determined that County Road 27 (CR27) between the landfill and the station property is County deeded property, and not a right-of-way or easement across PSCo's property. The state and county are aware that the impacted groundwater passes beneath CR27 and noted that the primary intent of the state regulations is to protect drinking water wells, and there are none within CR 27 footprint adjacent to the landfill. PSCo owns the parcel immediately west of CR27 and the alluvial wells have bounded the nature and extent of groundwater impacts to within PSCo property. The potential for offsite transport further downgradient will continue to be monitored in assessment monitoring completed by PSCo. Water quality sampling demonstrates that the furthest extent of the SSL in the downgradient direction was observed in W-4 and the furthest downgradient well, W-1, located on PSCo property, has low concentrations of cobalt (LCL of 0.0008 mg/L), less than the GPS. The potential for offsite transport will continue to be monitored in assessment monitoring completed by PSCo.

5 Corrective Measure Alternatives

Corrective measure alternatives are described for the landfill to address CCR-related impacts to groundwater. The alternatives are listed and compared with respect to their anticipated effectiveness, ease of implementation, institutional requirements, and timetable for implementation per §257.96(c). Additional data inputs are also identified. Results of ash dewatering and associated monitoring and final alternative selection will be compiled in a Remedy Selection Report. Per the CCR Rule a public meeting will be held at last 30 days prior to remedy selection.

5.1 Landfill Corrective Measure Alternatives

Table 5-1 provides brief descriptions of seven potential corrective measure alternatives for consideration at the landfill to address CCR-related impacts to groundwater. The selection of the remedy will take into consideration the COC cobalt identified at the alluvial aquifer well W-4. The alternatives are briefly discussed in the sections below.

5.1.1 Alternative 1—Landfill Dewatering

Description. The landfill is built upon the low permeability Lewis Shale. Historically, run-on stormwater and contact water ponded in a low area of the landfill and infiltrated the ash forming a saturated mound within the ash landfill on top of the Lewis Shale. As described earlier in this report, PSCo completed a field investigation that included installation of piezometers in the landfill to delineate and estimate the volume of the saturated ash zone and evaluate the potential dewatering pumping rates. The saturated ash is located on the south side of the landfill and is estimated to contain approximately 7 million gallons of leachate from stormwater historically ponded at the landfill. After the field investigation, PSCo developed a Dewatering Plan, which was approved by the state and is currently being implemented to eliminate the impact to the alluvial aquifer adjacent to the landfill.

Dewatering at the landfill is accomplished using two RPS-400 submersible solar pumps with associated piping, flow totalizers, sensors, and controllers installed in wells PZ-9 and PZ-10 (Burns & McDonnell, 2020). Pumping at each location was accomplished using an array of photovoltaic solar panels and a battery bank to allow for pumping outside of daylight hours. Both pumps are equipped with flow totalizers and were run between May and October in 2020 and 2021. Total flow was recorded daily. Produced water is transferred to the lined contact water pond and used as needed for dust suppression within the active area of the landfill. Produced water not used for dust suppression evaporates within the lined pond. Dewatering was initiated in 2020 and approximately 647,000 gallons have been removed to date (Burns & McDonnell, 2020; Xcel, 2021). Improvements were made to the system in 2021 that are expected to enable year-round pumping beginning in 2022.

Considerations. At the estimated pumping rate, pumping season duration (May to October), operation schedule, and the leachate volume estimated from the field investigation completed by Burns & McDonnell, it is believed that the saturated zone may be dewatered in 2.5 to 3.5 years. However, pumping rates will likely diminish over time as the water level drops and/or wells become plugged, which could extend the dewatering time to 5 to 7 years with seasonal operation (Burns & McDonnell, 2019a). Year-round pumping would decrease this time. Consideration may also be given to dewatering from wells at the toe of the landfill, which may be more efficient and reduce the time for completion of leachate removal. Depending on the volume and rate of water extraction in the future, it may be possible to manage the water in the lined pond at the landfill, similar to how leachate from the current dewatering program is managed, or it may require treatment and discharge as discussed in 5.1.5.

Additional Data Needs. Continued operation and monitoring to evaluate effectiveness of implemented corrective measure.

5.1.2 Alternative 2—Monitored Natural Attenuation

Description. Monitored natural attenuation (MNA) is well accepted as an appropriate mitigation factor that should be considered when evaluating passive and active remedial options (USEPA, 1999, 2007a, b). The USEPA has established a tiered series of steps to determine whether MNA would sufficiently lower concentrations of COIs on an appropriate timescale, and whether there is sufficient system capacity and stability for MNA mechanisms (USEPA, 1999, 2007a, b). Natural attenuation mechanisms include adsorption of COIs, ion exchange, precipitation of COI-containing minerals, and dilution/dispersion. In addition to adsorption to soil, clay particles, and organic matter, iron and manganese oxides that commonly precipitate downgradient of CCR disposal sites will, in turn, remove other COIs by adsorption. Modeling can be used to simulate long-term attenuation, but natural conditions will dictate how COCs migrate through the strata and how much is removed en route. Empirical data are the best indicator of natural attenuation mechanisms, but long-term groundwater monitoring is required (EPRI, 2015; USEPA, 1999, 2007a, b). Current groundwater monitoring conditions appear to show cobalt attenuation between downgradient wells W-4 and W-1.

Considerations. MNA as an alternative is carried forward to address the groundwater that has already been impacted in the alluvial aquifer but should be used in conjunction with leachate dewatering, as is currently being implemented and described in Alternative 1.

Additional Data Needs. This alternative requires continued assessment monitoring.

5.1.3 Alternative 3—Landfill Cover

Description. The Hayden landfill closure plan describes a final cover system that includes the use of a standard water balance cover (WBC) for the top deck of the landfill, and a modified WBC for the side slope perimeter berms. Water balance covers are designed based on site specific climatologic conditions and function to prevent infiltration into the ash by alternately containing precipitation within the soil cover pore spaces and releasing the moisture back to the atmosphere via evapotranspiration. CDPHE developed a statewide guidance document with support from USEPA and its contractor The Cadmus Group, Inc. to identify and model discrete geographic areas of the state based on climatologic conditions (ecozones) and develop WBC designs for each ecozone (Final Guidance Document, Water Balance Covers in Colorado (CDPHE, 2011)). The WBC for the landfill will follow the requirements for Ecozone 1 as described in the guidance. The landfill top deck will be constructed with material placed in a single loose lift with a minimum 3-foot thickness to function as a standard WBC. The top of the landfill will have a slope of approximately five percent to direct storm water toward the side slopes and away from the landfill. The perimeter berms will be constructed using lightly compacted WBC material for slope stability, with a minimum 3-foot thickness and an outside slope of approximately three horizontal to one vertical (3:1). The final cover will be vegetated with a mixture of native and hybrid seeds commonly used in the semi-arid western mountain states.

The cover system will be installed to prohibit vertical migration of precipitation into ash to prevent leaching of cobalt or other constituents to groundwater. After the ash is dewatered and the cover is installed at closure, groundwater monitoring will continue to evaluate the predicted decrease in the COC in groundwater by MNA.

Considerations. Use of a WBC for final landfill cover has been demonstrated to effectively retain infiltration of precipitation in the WBC with very minimal to no infiltration into the uppermost layer of the underlying ash, and virtually eliminate associated leaching of the COC into groundwater. This alternative would not address the existing saturated ash zone. Therefore, this alternative would be implemented in conjunction with the ash dewatering currently being implemented.

Additional Data Needs. No additional data needs.

5.1.4 Alternative 4—Ash Removal

Description. The ash removal alternative assumes that all or a large portion of ash from the landfill will be excavated and moved offsite for disposal or beneficial use.

Considerations. This alternative would provide source control through ash removal and elimination of the potential for leaching of the COC to groundwater. However, based on the site hydrogeologic investigation, once the existing leachate has been removed and the final WBC is installed to prevent future infiltration, the ash is anticipated to remain dry and not continue to be a source of leachate to groundwater. After completion of source control by ash removal, groundwater monitoring will continue to evaluate the predicted decrease in the COC in groundwater by MNA. Implementation of ash removal will take longer than other alternatives and extend the period of time that the landfill would be active. However, the practice of reclaiming ash from landfills is increasing due to demand for encapsulated beneficial uses, such as in concrete, and with appropriate run-on and stormwater controls, ash removal for beneficial use could be a viable alternative.

Additional Data Needs. Efforts to determine an appropriate disposal location or beneficial use of the ash would be required if this alternative were carried forward, which is not currently recommended based on the availability of better corrective measure options but could be reconsidered in the future.

5.1.5 Alternative 5—Groundwater Extraction and Treatment

Description. As an alternative to in-situ groundwater treatment methods, impacted groundwater could be pumped to the surface and treated above grade (pump-and-treat) in order to provide hydraulic containment and prevent the COC from migrating. Following treatment, the water could be discharged directly to a surface water body or reinjected underground, depending on the site conditions and permitting requirements. Active treatment systems are generally costly to construct and operate but can be designed to effectively lower the concentration of cobalt.

Considerations. Use of sorbents for chemical fixation of the COC or use of reverse osmosis (RO) is a well-established method to reduce COC concentrations in groundwater. Operation of a groundwater extraction system would effectively provide hydraulic containment of impacted groundwater, and in conjunction with other alternatives, could be accomplished within a finite period of time.

Additional Data Needs. Geochemical modeling to evaluate reduction in COC concentrations. Bench-scale screening and treatability testing would be required if this alternative were further evaluated.

5.1.6 Alternative 6—Permeable Reactive Barrier

Description. Form of in-situ groundwater treatment that can be constructed to remove contaminants. Constructed by excavating a trench that penetrates the saturated zone perpendicular to the direction of groundwater flow, which is keyed into an underlying barrier to groundwater movement such as bedrock. The trench is then backfilled with reactive material while maintaining a transmissivity greater than the surrounding subsurface so that groundwater continues to flow through, rather than around the PRB. The reactive material would likely be media that adsorbs the COC or precipitates the COC to reduce downgradient concentrations. The design of a PRB can involve the use of multiple types of reactive material depending on the target COC. Depending on the COC, multiple types of reactive material may be mixed together to create a single reactive zone or sequentially so that the groundwater passes through several different reactive zones. Example reagents include manganese-oxide, zero valent iron (ZVI), and apatite (phosphate) to precipitate cobalt.

A variation of the conventional PRB is a trenchless PRB, which involves the injection of reactive components, in a starch medium that subsequently breaks down, leaving the reactive components behind. The reactive components are injected at the desired depth(s) using a series of wells.

Considerations. A trenchless PRB can be installed to depths greater than that achievable using traditional trenching technologies. A funnel-and-gate system can be used to channel the contaminant plume into a gate that contains the reactive material (Obiri-Nyarko et al., 2014). The funnels are non-permeable (e.g., slurry wall), and the simplest design consists of a single gate with walls extending from both sides. The main advantage of the funnel-and-gate system is that a smaller reactive zone can be used to treat the plume, thereby, potentially reducing costs. This alternative treats groundwater downgradient of the landfill; however, this alternative will not remove or control the source of the COC to groundwater.

Additional Data Needs. Geochemical, bench-scale, and possible pilot-scale testing would be required to evaluate the optimal reactive media composition, PRB lifespan, selection of the most appropriate reagent(s), and to evaluate potential additional contaminant mobilization.

5.1.7 Alternative 7—In-Situ Solidification

Description. Injection of Portland cement or other binding agent to physically bind ash via creation of a monolith in the saturated ash zone if leachate is unable to be removed by ash dewatering. The mixture is intended to encapsulate the source material resulting in the COC becoming inert. This is accomplished through bench testing of the ash with potential binding agents to determine the effectiveness of the mixture in immobilizing the COC. Multiple injection techniques are available depending on the binding agent used.

Considerations. In-situ solidification is a potential option to immobilize the COC in the source where leachate is unable to be removed by ash dewatering rendering it inert.

Additional Data Needs. Geochemical, bench-scale, and possible pilot-scale testing will be required to evaluate the optimal binding agent.

5.2 Next Steps

PSCo will continue assessment monitoring at the landfill to evaluate concentration trends of cobalt and to assess if the implemented corrective measures (stormwater management and ash leachate dewatering, combined with MNA) appear to be an effective remedy. Current data in downgradient monitoring well W-1 appears to demonstrate limited extent of groundwater impacts and that MNA may be effective. The groundwater chemistry is expected to improve over time in response to ash dewatering. Additional data points are needed to evaluate for decreasing trends.

The following activities are proposed to be completed in the next 6-month period:

- Continued ash dewatering, including year-round dewatering if feasible.
- Continued semiannual groundwater assessment monitoring.
- Continued evaluation of cobalt concentration trends in all CCR monitoring wells.

Table 5-1. Summary of the Corrective Measure Alternatives at the Landfill

Alternative	Description	Performance and Reliability	Additional Data Needs	Relative Ease of Implementation 1 = easy 2 = moderately easy 3 = moderate 4 = moderately difficult 5 = difficult)	Potential Impacts of the Remedy (Safety, cross-media impacts, exposure to residual contamination)	Relative Time Required for Implementation/ Completion of Remedy 0 = Already implemented 1 = 1-5 yrs 2 = 5-10 yrs 3 = 10-50 yrs 4 = 50-100 yrs 5 = 100+ yrs	Institutional Requirements (Permits or other environmental or public health requirements	Recommended for Further Evaluation
Landfill Dewatering	Extraction of water from the saturated ash zone within the landfill on the Lewis Shale. Dewatering is being accomplished using two submersible solar pumps with associated piping, flow totalizers, sensors, and controllers installed in two wells. Pumps are equipped with flow totalizers and are run between May and October to avoid freezing conditions. Produced water is transferred piped to the lined contact water pond and used as needed for dust suppression or is evaporated. Dewatering was initiated in 2020 and approximately 647,000 gallons have been removed to date.	• Recharge to groundwater and leaching of the COC is reduced or eliminated from the ash. • At the estimated pumping rate, pumping season duration, and operation schedule, based on the estimated aquifer water volume, it is believed that the saturated zone can be dewatered in 2.5 to 3.5 years. However, pumping rates will diminish over time as the water level drops and/or wells become plugged. Based on this, the dewater time could take as long as 5 to 7 years. • Dewatered water placed in a lined pond and evaporated and used for dust suppression.	As dewatering continues, timeframe for the dewatering duration will continue to be refined.	1 (dewatering currently ongoing)	No additional impacts	0/2	PSCo has received approval from the CDPHE on the design and implementation of the dewatering project, PSCo reports to the State.	Yes – currently implemented approach
Monitored Natural Attenuation (MNA)	Well accepted by state and federal regulators as an appropriate mitigation factor that should be considered when evaluating passive and active remedial options (USEPA, 1999, 2007a, b). Natural attenuation mechanisms include adsorption of COIs, ion exchange, precipitation of COI-containing minerals, and dilution/dispersion. In addition to adsorption to soil, clay particles, and organic matter, iron and manganese oxides that commonly precipitate downgradient of CCR disposal sites will, in turn, remove other COIs by adsorption.	• Requires a determination of the existence of sufficient aquifer materials downgradient of the landfill to attenuate the COC in groundwater within the property boundary. This appears to be the condition based on water quality monitoring at W-1, downgradient alluvial well located 1,200 feet north of the northern end of the landfill and well W-4. Well W-1 does not have any SSLs of COIs over the GPS. • Accepted as a valid remedial approach. COC concentrations in groundwater should decrease over time if leaching of the COC is reduced or eliminated by leachate control and dewatering. • O&M is limited to performance monitoring and would not be reliant on operation or periodic maintenance of engineered systems.	This alternative requires it is paired with leachate control and dewatering. Continued monitoring of groundwater to ensure that the COC does not extend to the farthest downgradient well W-1 (as is the current condition).	1	No additional impacts	1/3 with effective leachate control (dewatering)	Landfill will continue to be monitored per CCR Rule and State regulations.	Yes – this approach is currently being implemented and monitored paired with the dewatering.
Landfill Cover	Closure plan for the landfill has designed a WBC for the landfill top and slopes to limit infiltration into the ash, thus limiting the ash leachate to groundwater.	• Recharge to groundwater and leaching of the COC is reduced or eliminated from the ash. • Transport modeling with slow groundwater flow velocities on site may predict long term presence of elevated COC in groundwater. Model simulations may show ash below the water table continuing to be a source of COC to groundwater.	None	2	No additional impacts	1/3	Landfill will continue to be monitored per state regulations. Will require approval from the State.	Yes – remains an alternative for further evaluation if the landfill dewatering approach is found insufficient as sole remedy
Ash Source Removal (partial or complete)	Removal of landfill ash.	• Ash removal will result in elimination of the COC to be able to leach to groundwater. • COC concentrations in groundwater should decrease over time after removal of the source.	Studies to determine an appropriate disposal location or beneficial use of the ash	4	No additional impacts	1/3-4	Landfill will continue to be monitored per state regulations. Will require approval from the State.	No – ash dewatering, stormwater controls, and final cover are significantly easier to

Table 5-1. Summary of the Corrective Measure Alternatives at the Landfill

Alternative	Description	Performance and Reliability	Additional Data Needs	Relative Ease of Implementation 1 = easy 2 = moderately easy 3 = moderate 4 = moderately difficult 5 = difficult)	Potential Impacts of the Remedy (Safety, cross-media impacts, exposure to residual contamination)	Relative Time Required for Implementation/ Completion of Remedy 0 = Already implemented 1 = 1-5 yrs 2 = 5-10 yrs 3 = 10-50 yrs 4 = 50-100 yrs 5 = 100+ yrs	Institutional Requirements (Permits or other environmental or public health requirements	Recommended for Further Evaluation
		• Complete or partial source control, including saturated ash zones. • Semi-remoteness of the site would make transport of the ash difficult and expensive.						implement
Pump and Treat	Extraction of groundwater from areas with COC discharging offsite, or newly installed extraction wells targeting the weathered bedrock, and above-ground treatment of COCs.	• Does not remove the source therefore required into perpetuity, or until the COC was completely leached out of the ash.	Geochemical, modeling and bench-scale testing to evaluate the optimal treatment train/reagents (e.g., RO), operational lifespan. This alternative requires it is paired with leachate control and dewatering.	5	No additional impacts	1/3 with leachate control	Landfill will continue to be monitored per state regulations. Will require approval from the State.	Yes – remains an alternative for further evaluation if the landfill dewatering approach is found insufficient as sole remedy
Permeable Reactive Barrier (PRB)	A form of in-situ groundwater treatment that can be constructed to remove contaminants. Constructed by excavating a trench that penetrates the saturated zone perpendicular to the direction of groundwater flow, which is keyed into an underlying barrier to groundwater movement such as bedrock. The trench is then backfilled with reactive material while maintaining a transmissivity greater than the surrounding subsurface so that groundwater continues to flow through, rather than around the PRB.	• Remedial alternative that, once installed, will prevent discharge of the COC beyond the landfill or beyond the PRB location. • Has been successfully implemented at other sites nationwide. • Effectiveness and frequency of reactive material recharge unknown without laboratory bench-scale testing. • Conventional PRB design life is commonly based on decades.	Geochemical, bench-scale and possible pilot-scale testing to evaluate the optimal reactive media composition, PRB lifespan, select the most appropriate reagent(s), and evaluate potential additional contaminant mobilization. Geotechnical study for design. Availability and quantity of material required for the respective application locations will drive feasibility.	3-4	Addition of reagents or adjustment of pH/redox conditions may mobilize other contaminants in groundwater.	1-2/3	EPA application may be required. Landfill will continue to be monitored per state regulations. Will require approval from the State.	Yes – remains an alternative for further evaluation if the landfill dewatering approach is found insufficient as sole remedy
In-situ solidification	Injection of Portland cement or other mixture to physically bind saturated ash in the landfill that is unable to be dewatered via creation of a monolith. Encapsulates source material and immobilizes the COC.	• Encapsulates the source of the COC and limits further migration. • One time implementation with no ongoing O&M. • Ease of implementation when compared to some other remedial alternatives, e.g., ash removal. • Contaminants are not destroyed or removed.	Geotechnical studies of the saturated ash to determine feasibility of injection of cement mixture into pore space.	3	No additional impacts	1/2	Landfill will continue to be monitored per state regulations. Will require approval from the State.	Yes – remains an alternative for further evaluation if the landfill dewatering approach is found insufficient as sole remedy

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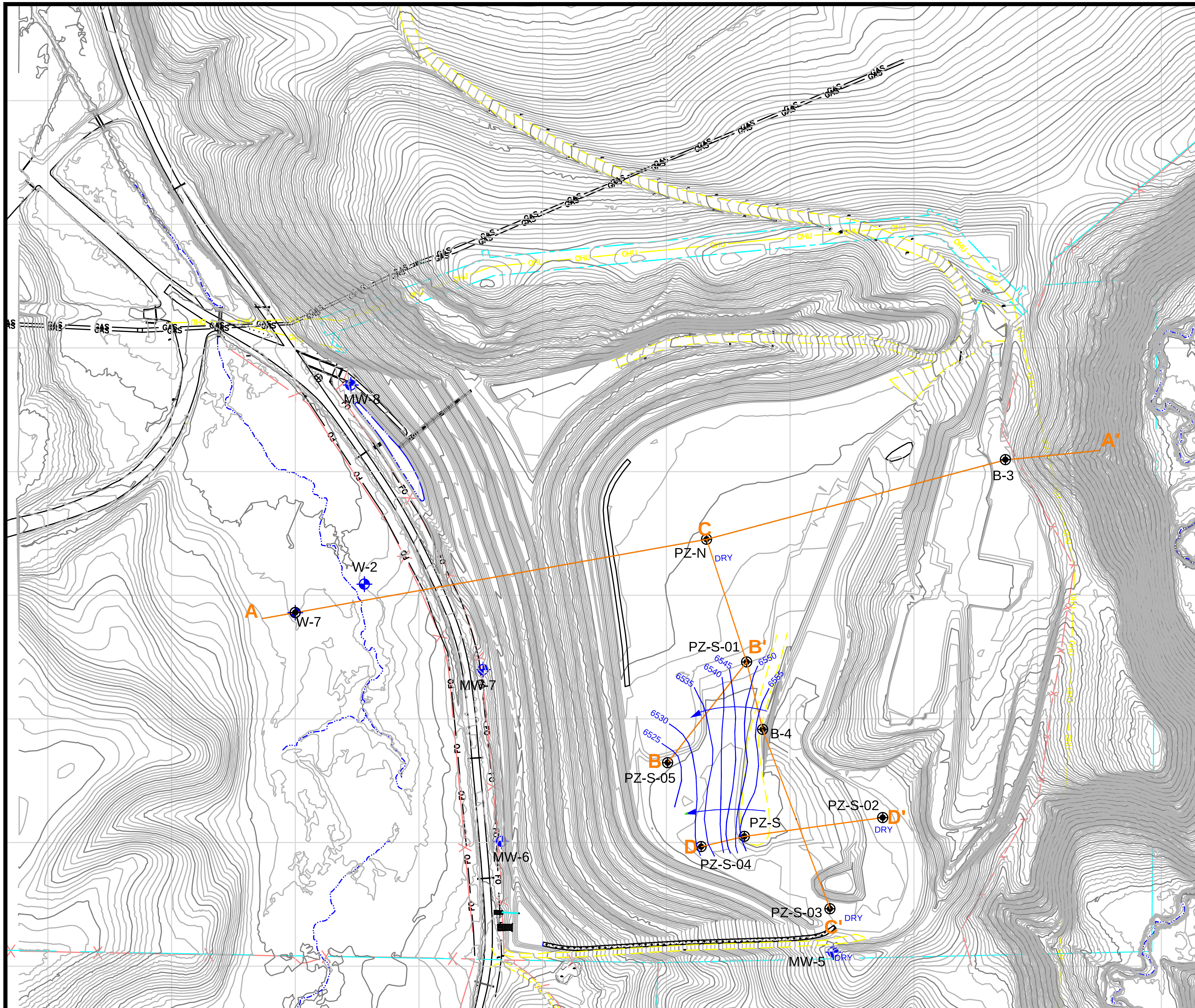
Appendix A

Landfill Geologic Cross-Sections



LEGEND

- PROPERTY BOUNDARY
- OHU — EXISTING OVERHEAD UTILITY LINE
- EXISTING FENCELINE
- EXISTING HAUL ROADS
- EXISTING FLOWLINE
- EXISTING ROADS
- FO — EXISTING FIBER OPTIC LINE
- EXISTING ELECTRICAL EASMENT
- GAS — EXISTING GAS LINE
- APPROXIMATE AREA OF ASH PLACEMENT
- EXISTING MONITORING WELL/ PIEZOMETER
- PIEZOMETRIC SURFACE IN ASH FILL
- APPROXIMATE GROUNDWATER FLOW DIRECTION

N

0 400' 800'

SCALE IN FEET

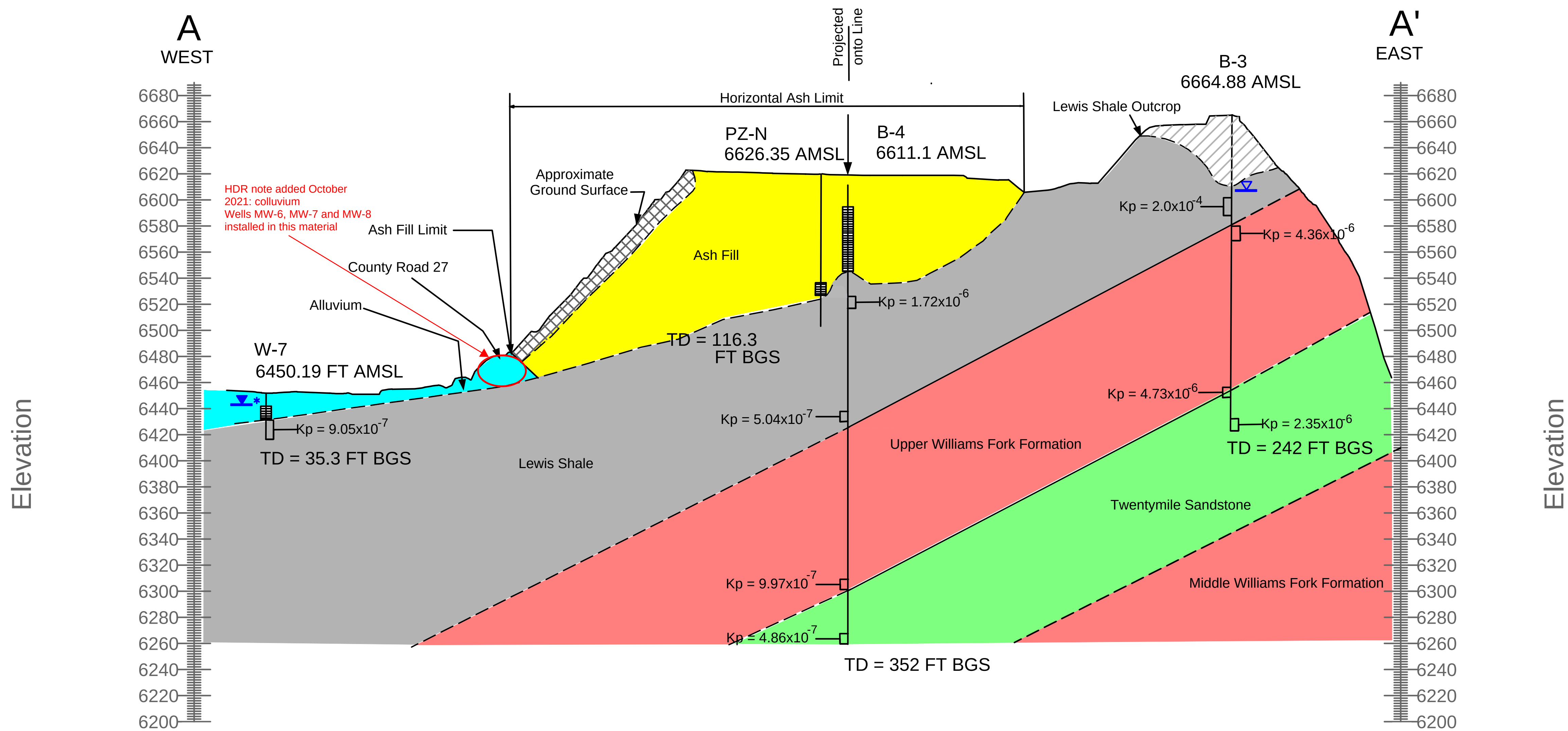
BURNS McDONNELL

Figure 3-2

HAYDEN ASH LANDFILL
GEOLOGIC CROSS-SECTION
PROFILE LINES

XCEL ENERGY

HAYDEN, COLORADO



LEGEND

	Soil Berm		Potentiometric Head Williams Fork Formation/Twentymile Sandstone
	Alluvium		Water Level in Ash Fill
	Lewis Shale Residuum		Water Level in Alluvium
	Lewis Shale		Well Screen
	Upper and Middle Williams Fork Formation	Kp = 9.05x10-7	Hydraulic Conductivity from Packer Test (cm/s)
	Twentymile Sandstone		
	Ash Fill		Geologic Contact (dashed where inferred)

FT AMSL = Feet Above Mean Sea Level

BGS = Below Ground Surface

NOTES:

1. CORRELATION OF UNITS IS AN INTERPRETATION AND NOT NECESSARILY A DELINEATION OF ACTUAL EXTENT AND THICKNESS OF INDIVIDUAL UNITS.
2. NEWLY INSTALLED WELLS LOGGED BY BURNS & MCDONNELL GEOLOGISTS IN ACCORDANCE WITH UNIFIED SOIL CLASSIFICATION SYSTEM.
3. WELL LOCATIONS APPROXIMATE

0 400' 800'
HORIZONTAL SCALE IN FEET

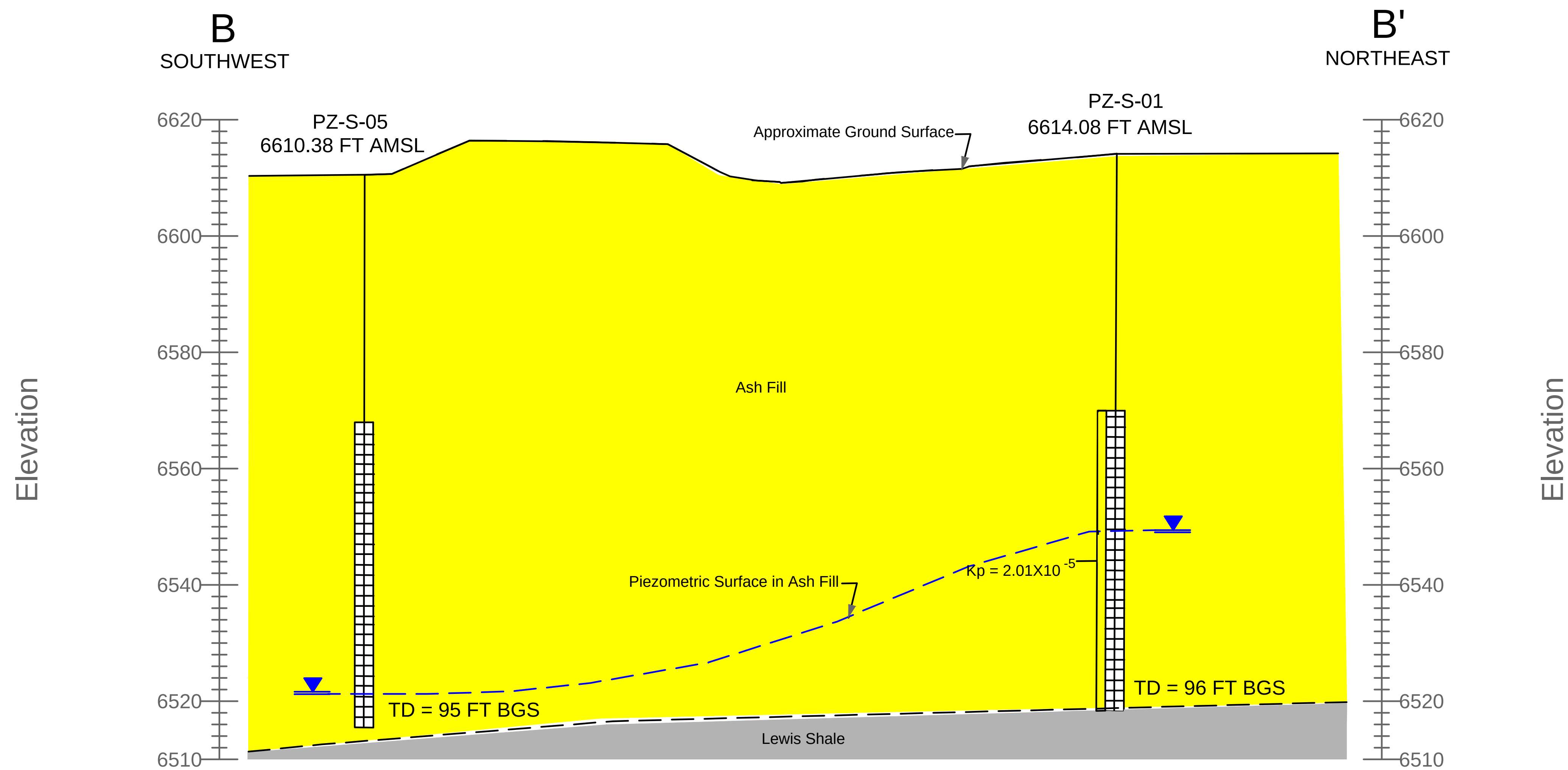
0 100' 200'
VERTICAL SCALE IN FEET

BURNS McDONNELL

Figure 3-3

GEOLOGIC CROSS SECTION A-A'
WEST TO EAST

XCEL ENERGY
HAYDEN, CO



LEGEND

(yellow box)	Ash Fill
(gray box)	Lewis Shale
(symbol)	Water Level in Ash Fill
(solid line)	Geologic Contact (dashed where inferred)
(dashed line)	Piezometric Surface in Ash Fill (inferred)
(symbol)	Well Screen
Kp = 9.05×10^{-7}	Hydraulic Conductivity from Packer Test (cm/s)

FT AMSL = Feet Above Mean Sea Level

BGS = Below Ground Surface

NOTES:

1. CORRELATION OF UNITS IS AN INTERPRETATION AND NOT NECESSARILY A DELINEATION OF ACTUAL EXTENT AND THICKNESS OF INDIVIDUAL UNITS.
2. NEWLY INSTALLED WELLS LOGGED BY BURNS & MCDONNELL GEOLOGISTS IN ACCORDANCE WITH UNIFIED SOIL CLASSIFICATION SYSTEM.
3. WELL LOCATIONS APPROXIMATE

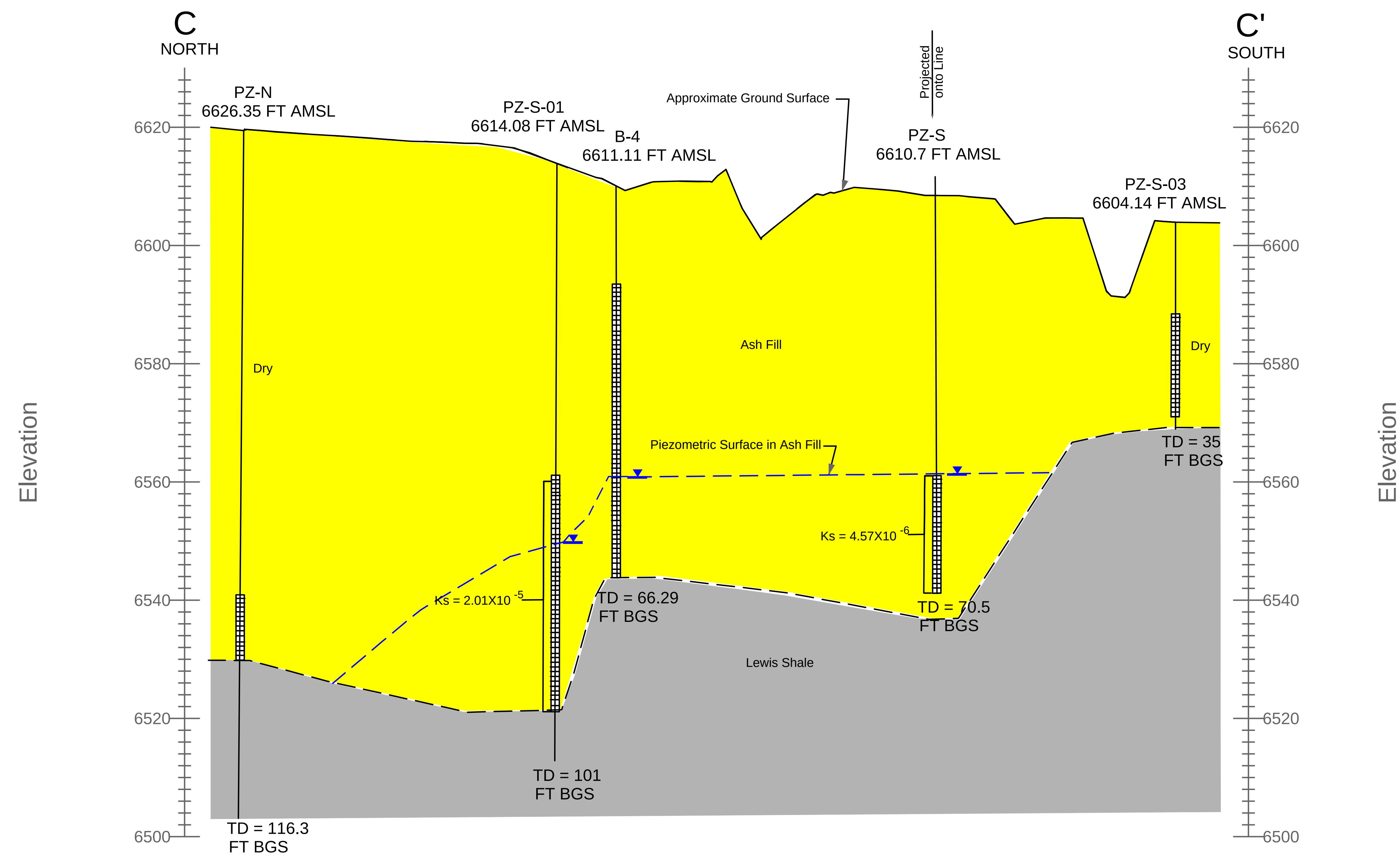
0 100' 200'
HORIZONTAL SCALE IN FEET

0 20' 40'
VERTICAL SCALE IN FEET

Figure 3-4

GEOLOGIC CROSS SECTION B-B'
SOUTHWEST TO NORTHEAST

XCEL ENERGY
HAYDEN, CO



LEGEND

- Ash Fill
- Lewis Shale
- Water Level in Ash Fill
- Geologic Contact (dashed where inferred)
- Piezometric Surface in Ash Fill (inferred)
- Well Screen
- Ks = 9.05x10^{-7} Hydraulic Conductivity from SlugTest (cm/s)

FT AMSL = Feet Above Mean Sea Level

BGS = Below Ground Surface

NOTES:

1. CORRELATION OF UNITS IS AN INTERPRETATION AND NOT NECESSARILY A DELINEATION OF ACTUAL EXTENT AND THICKNESS OF INDIVIDUAL UNITS.
2. NEWLY INSTALLED WELLS LOGGED BY BURNS & MCDONNELL GEOLOGISTS IN ACCORDANCE WITH UNIFIED SOIL CLASSIFICATION SYSTEM.
3. WELL LOCATIONS APPROXIMATE

0 200' 400'
HORIZONTAL SCALE IN FEET

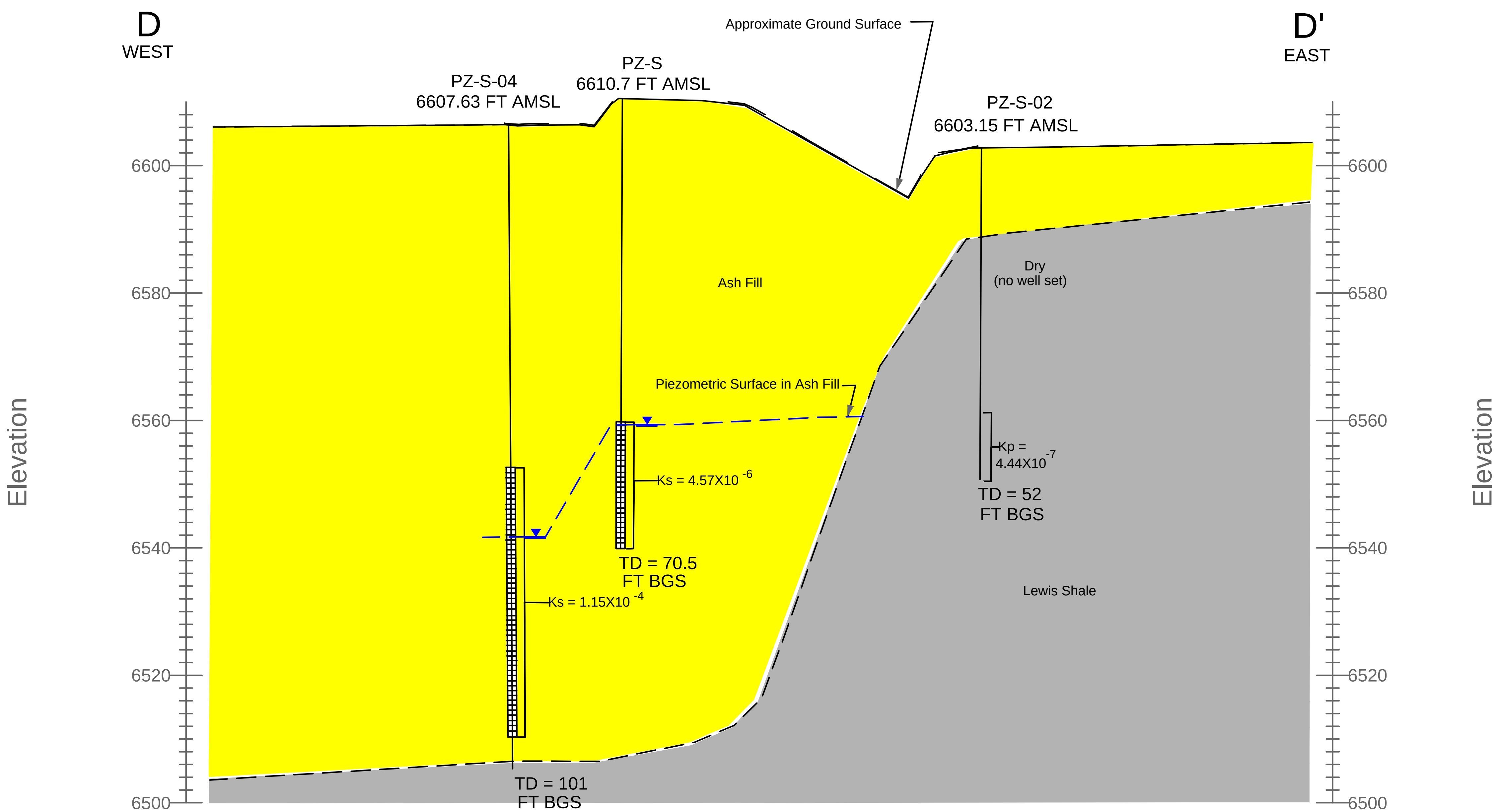
0 20' 40'
VERTICAL SCALE IN FEET

BURNS McDONNELL

Figure 3-5

GEOLOGIC CROSS SECTION C-C'
NORTH TO SOUTH

XCEL ENERGY
HAYDEN, CO



LEGEND

- Ash Fill
- Lewis Shale
- Water Level in Ash Fill
- Geologic Contact (dashed where inferred)
- Piezometric Surface in Ash Fill (inferred)
- Well Screen
- Ks = 9.05x10-7 Hydraulic Conductivity from Slug Test (cm/s)

FT AMSL = Feet Above Mean Sea Level

BGS = Below Ground Surface

Hydraulic Conductivity from Packer Test (cm/s) Kp = 9.05x10-7

NOTES:

1. CORRELATION OF UNITS IS AN INTERPRETATION AND NOT NECESSARILY A DELINEATION OF ACTUAL EXTENT AND THICKNESS OF INDIVIDUAL UNITS.
2. NEWLY INSTALLED WELLS LOGGED BY BURNS & MCDONNELL GEOLOGISTS IN ACCORDANCE WITH UNIFIED SOIL CLASSIFICATION SYSTEM.
3. WELL LOCATIONS APPROXIMATE

0 200' 400'
HORIZONTAL SCALE IN FEET

0 20' 40'
VERTICAL SCALE IN FEET

BURNS McDONNELL

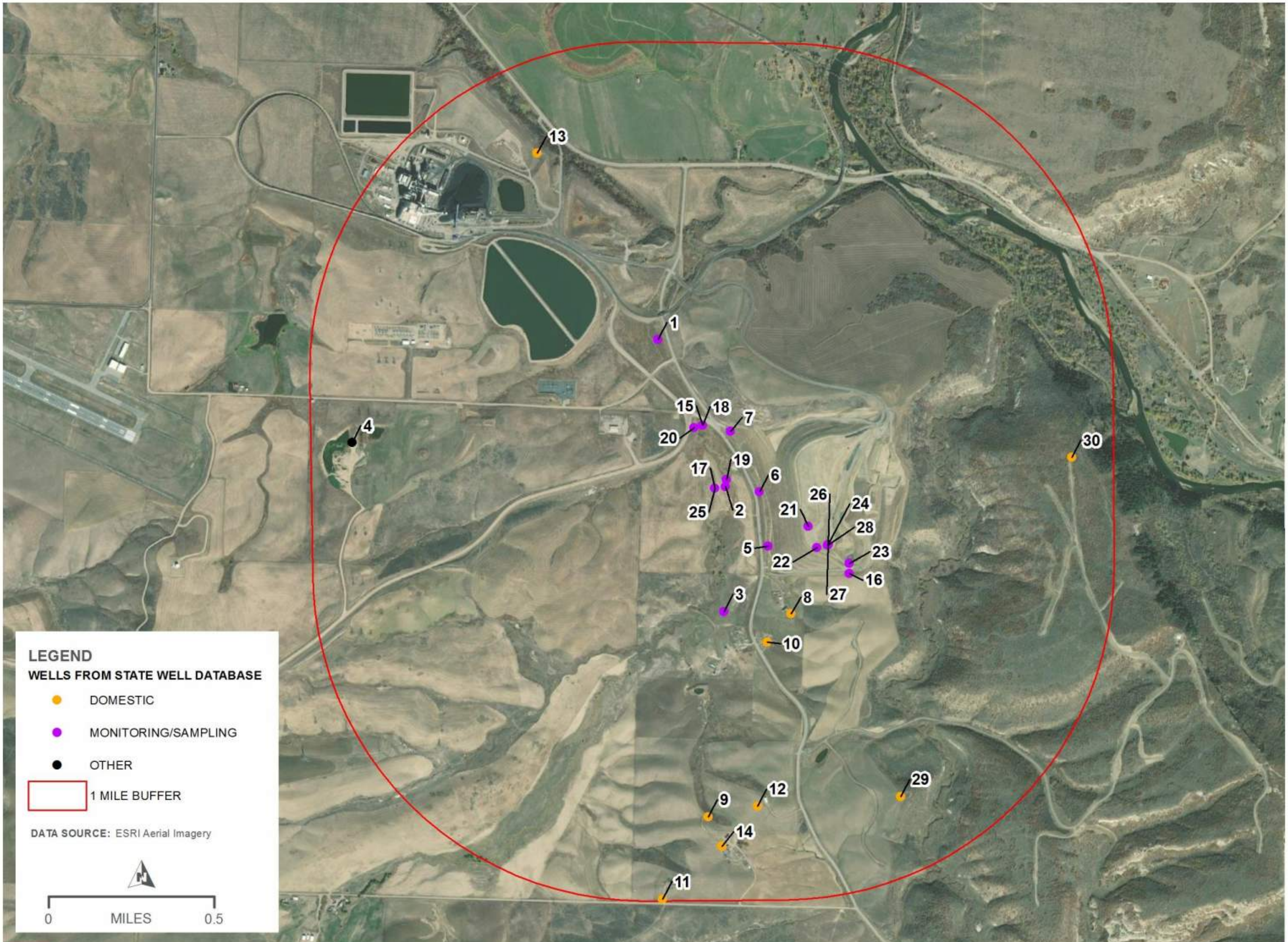
Figure 3-6

GEOLOGIC CROSS SECTION D-D'
WEST TO EAST

XCEL ENERGY
HAYDEN, CO

Appendix B

Well permits within 1-mile of the Ash Disposal Facility



HDR

WATER WELL LOCATION - HAYDEN POWER STATION
OVERVIEW MAP

Hayden Station - Colorado Well Permits within 1-mile of the Ash Disposal Facility

Well_Num	Permit	UTMX	UTMY	LocAccurac	LatDecDeg	LongDecDeg	Use1	WellDepth	TopPerfCas	BotPerfCas	Yield	StaticWL	ApplicantN
1	245503-	315951	4483362.3	Spotted from section lines	40.48057	-107.17139	Monitoring	0	0	0	0	0	XCEL, ENERGY
2	245504-	316279.5	4482644.7	Spotted from section lines	40.474188	-107.1673	Monitoring	0	0	0	0	0	XCEL, ENERGY
3	245505-	316270.9	4482038.2	Spotted from section lines	40.468722	-107.16723	Monitoring	0	0	0	0	0	XCEL, ENERGY
4	75506-F	314460.9	4482861.4	Spotted from quarters	40.475733	-107.18881	Monitoring	25	0	0	0	0	PEABODY SAGE CREEK MINING LLC
5	299817-	316488	4482355.4	Spotted from section lines	40.471624	-107.16476	Monitoring	25	14	24	0	0	PUBLIC SERVICE COMPANY OF COLORADO
6	299819-	316444.2	4482620.2	Spotted from section lines	40.474	-107.16536	Monitoring	31	19	29	0	0	PUBLIC SERVICE COMPANY OF COLORADO
7	299820-	316303.2	4482915.1	Spotted from section lines	40.476624	-107.16711	Monitoring	36	25	35	0	0	PUBLIC SERVICE COMPANY OF COLORADO
8	263762-	316598.4	4482028.6	Spotted from section lines	40.468713	-107.16337	Domestic	400	300	400	6	20	MAYHAN BLISS & DORIS
9	271066-	316195.8	4481039.2	Spotted from section lines	40.459712	-107.16782	Domestic	575	475	575	0	150	WILLIAMS RICHARD & BRENDA
10	271067-	316482	4481890	User supplied	40.467436	-107.1647	Domestic	420	240	420	0	15	MARSHALL III, WILLARD B.
11	274598-	315974	4480639	User supplied	40.456062	-107.17032	Domestic	410	360	420	0	30	WILLIAMS, BENJAMIN M.
12	277930-	316434	4481091	User supplied	40.460232	-107.16503	Domestic	600	500	600	0	91	BINETTI, SERGIO
13	292002-	315363	4484270	User supplied	40.488614	-107.17858	Domestic	14	0	0	0	0	IDLER ROSEMARIE & ARMBRUST ERIC DEAN
14	305032-	316263	4480895	User supplied	40.45843	-107.16699	Domestic	400	357	397	0	39	BAKER, RUSTY
15	56532-MH	316167.6	4482945.8	GPS	40.476873	-107.16871	Monitoring	20	0	0	0	4	PUBLIC SERVICE CO OF COLORADO
16	299818-	316882	4482224	User supplied	40.470531	-107.16008	Monitoring	21	10	20	0	0	PUBLIC SERVICE COMPANY OF COLORADO
17	57067-MH	316227.9	4482638.2	User supplied	40.474114	-107.16791	Monitoring	35	0	0	0	7	PUBLIC SERVICE OF COLORADO DBA XCEL ENERGY (STEWART, MARK)
18	312148-	316167.6	4482945.8	User supplied	40.476873	-107.16871	Monitoring	20	0	0	0	3	PUBLIC SERVICE COMPANY OF COLORADO (MCCARTER, JENNIFER)
19	312149-	316283.3	4482680.7	User supplied	40.474513	-107.16727	Monitoring	20	0	0	0	3	PUBLIC SERVICE COMPANY OF COLORADO (MCCARTER, JENNIFER)
20	312150-	316125.5	4482932.2	User supplied	40.476738	-107.1692	Monitoring	20	0	0	0	4	PUBLIC SERVICE COMPANY OF COLORADO (MCCARTER, JENNIFER)
21	312477-	316683.2	4482452.8	GPS	40.472549	-107.16249	Monitoring	101	0	0	0	93	PUBLIC SERVICE COMPANY DBA XCEL ENERGY
22	312478-	316724	4482349	User supplied	40.471622	-107.16198	Monitoring	101	0	0	0	78	PUBLIC SERVICE COMPANY DBA XCEL ENERGY
23	312479-	316882	4482272	User supplied	40.470963	-107.16009	Monitoring	36	0	0	0	0	PUBLIC SERVICE COMPANY DBA XCEL ENERGY
24	312480-	316777	4482362	User supplied	40.47175	-107.16136	Monitoring	71	0	0	0	56	PUBLIC SERVICE COMPANY DBA XCEL ENERGY
25	312481-	316227	4482638	User supplied	40.474114	-107.16792	Monitoring	35	0	0	0	7	PUBLIC SERVICE COMPANY DBA XCEL ENERGY
26	317469-	316778	4482363	User supplied	40.47176	-107.16135	Monitoring	86	0	0	0	51	PUBLIC SERVICE COMPANY DBA XCEL ENERGY
27	317470-	316779	4482363	User supplied	40.47176	-107.16133	Monitoring	81	0	0	0	63	PUBLIC SERVICE COMPANY DBA XCEL ENERGY
28	317471-	316781	4482364	User supplied	40.471769	-107.16131	Monitoring	81	0	0	0	63	PUBLIC SERVICE COMPANY DBA XCEL ENERGY
29	318765-	317132.9	4481137.9	User supplied	40.46081	-107.15681	Domestic	1000	940	1000	0	750	HUBER, DANIEL P.
30	321551-	317966.2	4482789.4	User supplied	40.475856	-107.14746	Domestic	900	800	860	0	710	OP ADVENTURE PROPERTIES LLC