Alternative Liner Demonstration at a CCR Surface Impoundment at Rainbow Energy Center's Coal Creek Station

Craig Schuettpelz[1], Todd Stong[1], Jennifer Charles[2], Shane Stockdill[2]

[1]Golder Associates USA Inc., 7245 W Alaska Drive, Suite 200, Lakewood, CO 80226

[2]Rainbow Energy Center, Coal Creek Station, 2875 Third Street SW, Underwood, ND 58576

1.0 INTRODUCTION

Golder Associates USA Inc. (Golder), a member of WSP, prepared an alternative liner demonstration for the Upstream Raise 91 coal combustion residual (CCR) surface impoundment (Upstream Raise 91) at Coal Creek Station (CCS). CCS is a 1,200-megawatt coal-fired electric generation facility located in McLean County, approximately 10 miles northwest of Washburn, North Dakota. Upstream Raise 91 is located in the south-central portion of the plant site east of the plant buildings (Figure 1) and is used as a combined dewatering and storage facility for CCR including fly ash, bottom ash, economizer ash, and flue gas desulfurization (FGD) material and is planned to be closed with CCR in-place.

Figure 1. Coal Creek Station and Upstream Raise 91 CCR Surface Impoundment.

The original United States Environmental Protection Agency (USEPA) CCR Rule was promulgated in April 2015 under Title 40 of the Code of Federal Regulations (40 CFR) Part 257 (USEPA 2015). Part 257.71(a)(1)(i) of this rule originally allowed for an existing CCR surface impoundment to have a liner constructed of two feet of low permeability soil with a hydraulic conductivity less than 1 x 10^{-7} centimeters per second (cm/sec). In 2018, a District of Columbia circuit court judge redressed the liner requirements for existing CCR surface impoundments, requiring these facilities to have a composite liner system (including a geomembrane and low permeability soil layer). As a result of this decision, the USEPA revised the original 2015 CCR Rule with a revision entitled "A Holistic Approach to Closure Part B: Alternate Demonstration for Unlined Surface Impoundments" (the Part B Rule), which was published in the Federal Register on November 12, 2020 (USEPA 2020). As described in the CCR Rule (40 CFR

257.70(b)), the prescriptive liner system requires a compacted soil layer at least two feet thick with an installed hydraulic conductivity of 1 x 10^{-7} cm/sec or less overlain by a geomembrane having a minimum thickness of 30 mils (minimum thickness of 60 mils if the geomembrane is high density polyethylene [HDPE]).

As a part of the revised rule, an allowance was included for utilities to be able to perform an alternative liner demonstration (ALD) to justify that an existing liner will be protective and will not lead to exceeded groundwater protection standards at the waste boundary. An ALD is required to be completed in two primary phases:

- Phase 1 – Alternative Liner Demonstration Application due at the end of 2020
- Phase 2 – Alternative Liner Demonstration due at the end of 2021

The intention was that the USEPA review the ALD Application, which included a discussion of background information regarding the existing CCR surface impoundment, documentation regarding the design and construction of the liner system installed, documentation of current facility compliance with the CCR Rule, and information regarding the current groundwater monitoring network and statistical results. After approval of the ALD Application, a utility could then pursue a formal ALD report. Due to scheduling constraints, the USEPA was unable to review the ALD Application, but Coal Creek Station elected to pursue and submit an ALD report in 2021 as written in the revised 2020 CCR Rule language.

The following paper presents site background information and a summary of the ALD completed for Upstream Raise 91.

2.0 UPSTREAM RAISE 91 SITE HISTORY

CCRs were originally managed in the South Ash Pond, which is a legacy facility at CCS. The South Ash Pond CCR and process water containment area was created by constructing a clay core dike around the perimeter and relying on in situ low permeability soil to act as a soil liner across the floor. This facility was put into operation in 1979 and operated intermittently from 1979 through 1990. Due to the identification of leakage from the facility, the South Ash Pond was removed from service in 1990. In the early 1990s, as part of the site corrective action to address the groundwater impacts, the South Ash Pond was closed by removal of CCRs. In-place CCRs and a portion of the underlying subsoil were excavated from the South Ash Pond and transported to an offsite landfill. After CCRs were removed from the South Ash Pond, that facility ceased to exist.

A portion of the remaining clay core dikes was salvaged, and additional soil embankments were constructed to outline the footprint of both Upstream Raise 91 and the adjacent Upstream Raise 92. A new composite liner was completed over the regraded Upstream Raise 91 floor and embankments in 1993, the specifics of which are discussed below. In addition, a composite liner was installed in the area between Upstream Raise 91 and Upstream Raise 92 in 2016. This additional liner completes a continuous composite-lined area between Upstream Raise 91 and Upstream Raise 92.

1.1 Upstream Raise 91 Liner Design

The majority of Upstream Raise 91 was constructed with a composite liner system in 1993 consisting of an upper component of HDPE geomembrane having a minimum thickness of 40 mils and a lower component consisting of a compacted soil layer at least two feet thick with a hydraulic conductivity less than 1 x 10^{-7} cm/sec. Construction Quality Assurance (CQA) monitoring was performed during installation of the Upstream Raise 91 composite liner system in 1993. Both the low permeability soil layer and geomembrane layer were monitored as part of these CQA programs.

A small area of Upstream Raise 91 that was originally outside of the surface impoundment limits was lined with a composite liner system in 2016 to more efficiently use the surface impoundment footprint. This liner system consists of an upper component of HDPE geomembrane having a minimum thickness of

60 mils and a lower component of Geosynthetic Clay Liner (GCL) and was also subject to and monitored by a CQA program.

3.0 ALTERNATIVE LINER DEMONSTRATION

The Alternative Liner Demonstration included the following:

- Characterization of Site Hydrogeology
- Characterization of the Potential for Infiltration
- Mathematical Model to Estimate the Potential for Releases

These components of the ALD will be discussed in the following sections.

2.1 Site Characterization

As part of the ALD, 40 CFR 257.71(d)(ii)(A) requires:

> *“A characterization of the variability of site-specific soil and hydrogeology surrounding the surface impoundment that will control the rate and direction of contaminant transport from the impoundment.”*

The following sections will discuss previous hydrogeologic studies, and detailed site subsurface investigation and results completed as a part of the ALD.

Previous Studies and Site Geologic and Hydrogeologic Conditions

Golder reviewed information from the operating record documenting the design, installation, and development of the monitoring wells and/or describing hydrogeologic conditions at the site. The area surrounding CCS is primarily characterized by the presence of mixed glacial deposits. Geologic conditions are heterogeneous, with soils varying from silty clay and sandy clay till to interbedded sand lenses and discontinuous coal seams (CPA/UPA 1989).

Regional groundwater flow of the uppermost water bearing zone in the vicinity of CCS is a subtle expression of the surface topography, which is influenced by the configuration of the eroded bedrock. Based on site groundwater elevations, the shallow groundwater at the CCR facilities generally follows surface topography, flowing to the east and north at Upstream Raise 91. Paired wells (shallow and deep) located north, and northeast of Upstream Raise 91 indicate that an upward gradient is common across the site. Therefore, the horizontal gradient beneath Upstream Raise 91 is likely to be the primary component to groundwater flow.

Subsurface Site Investigation

As part of the ALD, the CCR Rule requires measurements of the variability of subsurface soil characteristics from around the perimeter of the impoundment, using recognized and generally accepted methods, along with a justification of the sample spacing and depth.

In support of the demonstration, a drilling program was executed in September 2021 to meet the requirements of the rule. Approximately thirty borings were placed approximately 200 feet apart on center around the north, west, and south sides of the facility perimeter to capture potential variability in the glacial outwash underlying Upstream Raise 91. Borings could not be placed along the east side as drilling could not be done without compromising the liner system. The depths of the borings were selected to extend a minimum of 20 feet beneath the bottom of the nearest surface water body, which is Samuelson Slough located north of Upstream Raise 91. Five monitoring wells were also installed to complement the existing monitoring well network and provide additional locations for in situ hydraulic conductivity testing required as part of the demonstration.

Each of the borings around the perimeter of Upstream Raise 91 were advanced via hollow-stem augers and were documented via logging. Standard penetration testing and collection of split-spoon samples were completed at 5-foot intervals within the borings as a means of classifying subsurface soils. Logging and in-situ testing and sampling were completed in general accordance with industry practices.

Split-spoon samples were collected every five feet within the borings and were used to classify materials according to American Society for Testing and Materials (ASTM) standards via geotechnical index testing (grain size distributions per ASTM D422 and Atterberg limits per ASTM D4318). Index testing was performed in accordance with accepted ASTM standards and allows for classification of soils via the widely used Unified Soil Classification System (USCS).

Boreholes completed in September 2021 serve as a basis for detailed understanding of the geologic conditions around Upstream Raise 91. Detailed stratigraphic cross sections were compiled based on boring information from current CCR monitoring wells, the boring program conducted in support of this demonstration, and historical monitoring wells and boreholes (an example section is included as Figure 2).

The results of drilling generally indicated the following:

- A relatively consistent zone of low permeability soil used to construct the perimeter berm surrounding Upstream Raise 91. Some zones of sandier soil were noted in this berm; however, the majority of this berm consists of the clayey glacial till common at CCS.
- A relatively consistent zone of low permeability soil (i.e., clayey soil) of varying thickness directly underlying the facility. This zone appears to have a thickness of at least approximately 10 feet before reaching a zone of higher permeability underlying soil. Some zones of sandier soils were noted within this low permeability soil, but were not found to be extensive or continuous.
- A relatively consistent layer of sandy soil was observed in the lower portions of the boreholes.

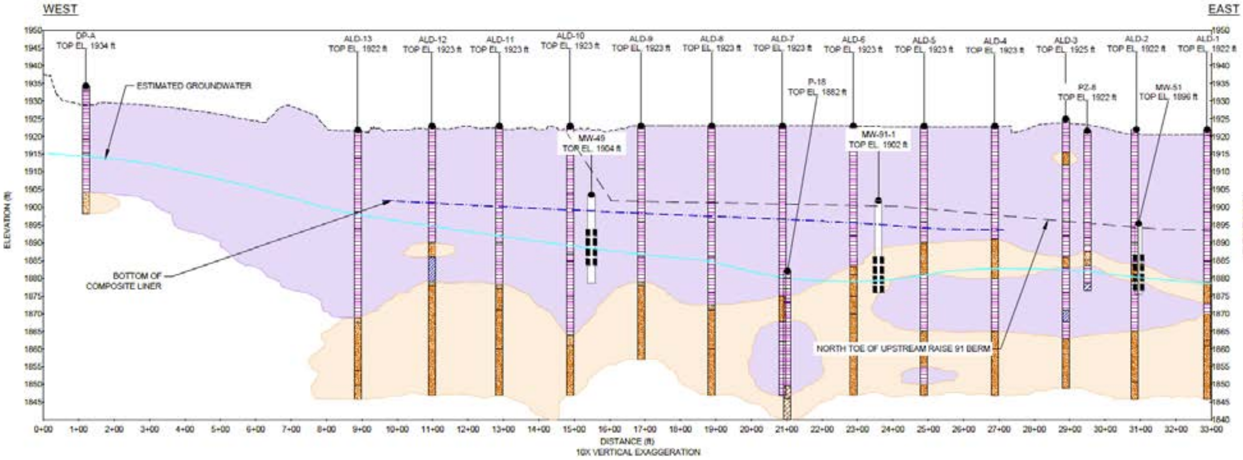

Figure 2. Subsurface Site Investigation Cross Section Along the North Side of Upstream Raise 91.

Site Hydraulic Conductivity

As part of the characterization of the site, in situ hydraulic conductivity testing was performed in 2021. In situ hydraulic conductivity testing completed in 2021 supplements previously completed laboratory hydraulic conductivity testing.

As a part of the work, variable-head hydraulic (i.e., slug) testing was performed at ten wells surrounding Upstream Raise 91. The data resulting from the 2021 slug tests is used to evaluate the range in in-situ horizontal hydraulic conductivity of geologic materials isolated by the screened intervals (i.e., the uppermost water bearing unit) in support of mathematical modeling.

The variable lithologies within well screened intervals was confirmed by review of the borehole logs and well completion diagrams available for each monitoring well that was tested. The presence of variable lithologies within a well screen interval, and between wells, resulted in hydraulic conductivities ranging from 4 x 10^{-6} cm/sec to 2 x 10^{-2} cm/sec. With wells screened across multiple lithologies, the resulting hydraulic conductivity is considered a bulk value and is most representative of the lithology with the highest hydraulic conductivity within the saturated zone of each well.

Laboratory tests to measure saturated hydraulic conductivity have been conducted on nine relatively undisturbed (i.e., Shelby tube) samples obtained from relevant depths in boreholes drilled in and around the area occupied by Upstream Raise 91 to characterize the hydraulic conductivity of the near-surface native soils. The results of the hydraulic conductivity tests performed on Shelby tube samples obtained from relevant depths in boreholes drilled near Upstream Raise 91 are characterized by hydraulic conductivity values ranging from 5 x 10^{-8} cm/sec to 2 x 10^{-6} cm/sec (geometric mean of 2 x 10^{-7} cm/sec).

In the early 2000s, an alternative cover demonstration project was completed at GRE's CCS to evaluate the use of site soils for use in an evapotranspiration cover system in the semi-arid North Dakota climate. As a part of this work, soil water characteristic curve (SWCC) laboratory testing was completed on site soils of varying density. This information was used to develop properties for the soil modeled as a part of the vadose zone (unsaturated soil zone).

Conceptual Site Model

A conceptual site model was developed to outline the stratigraphy underlying Upstream Raise 91. The site conceptual model is presented as Figure 3 and is generally based on site groundwater elevation measurements and the more generalized understanding of the geologic and hydrogeologic setting discussed above. As shown in Figure 3, Upstream Raise 91 generally has a stratigraphic sequence that consists primarily of silty clay and sandy clay till (primarily fine-grain soils, more than 50% of soil particles passing the Number 200 sieve) near the surface, with isolated interbedded sand lenses and discontinuous coal seams. Coarse-grain soils (less than 50% of soil particles passing the Number 200 sieve) are more prevalent at depths of between 5 feet and 20 feet below the Upstream Raise 91 composite liner system.

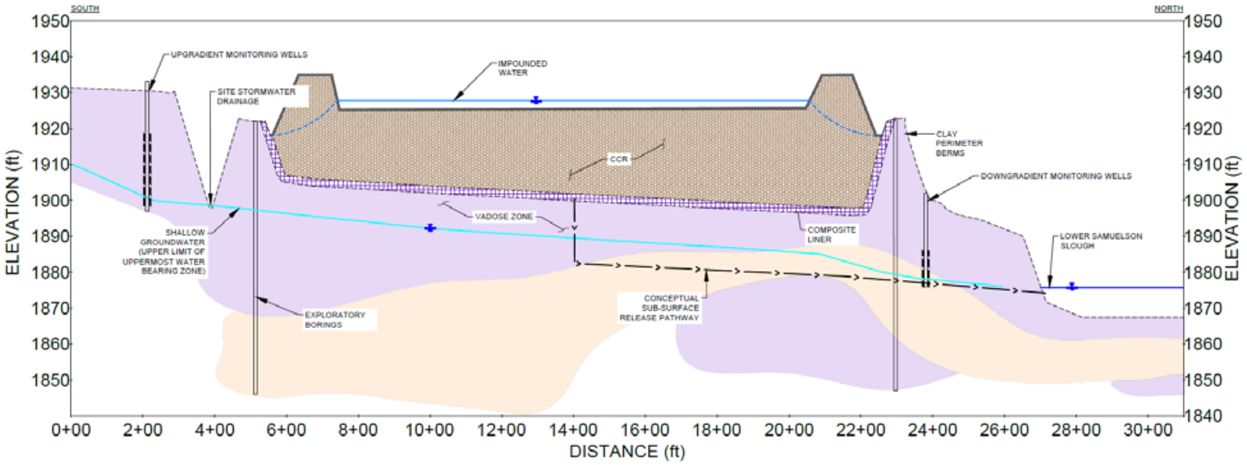

Figure 3. Conceptual Site Model.

The conceptual site model described above and shown in Figure 3 indicates that a theoretical subsurface release from Upstream Raise 91 would be expected to migrate vertically downward through the unsaturated zone to the uppermost groundwater, approximately 5 to 15 feet below the bottom of the composite liner system, before flowing downgradient. The downgradient wells that monitor Upstream Raise 91 are positioned along the downgradient edges of the CCR facility to detect a release if it was to occur.

3.1 Potential For Infiltration

As part of the ALD, 40 CFR 257.71(d)(ii)(B) requires:

> *"A characterization of the potential for infiltration through any soil-based liner components and/or naturally occurring soil that control release and transport of leachate."*

The characterization of the potential for infiltration from Upstream Raise 91 focused on the engineered and constructed composite liner system. Soils beneath the composite liner system that are a part of the vadose zone or saturated zone are included as a part of the modeling efforts discussed later. The following sections will discuss the alternative composite liner at Upstream Raise 91, the method proposed for evaluating composite liner infiltration, sampling and testing of the soil layer component of the composite liner, modeling properties of the geomembrane component of the composite liner, and resulting infiltration rate estimates.

The alternative liner for Upstream Raise 91 consists of a compacted low hydraulic conductivity soil layer at least two feet thick with an installed hydraulic conductivity of 1 x 10^{-7} cm/sec or less overlain by a HDPE geomembrane having a minimum thickness of 40 mils. As stated earlier, the prescriptive liner for existing CCR surface impoundments from the CCR Rule (40 CFR 257.70(b)) requires a compacted soil layer at least two feet thick with an installed hydraulic conductivity of 1 x 10^{-7} cm/sec or less overlain by a geomembrane having a minimum thickness of 30 mils (minimum thickness of 60 mils if the geomembrane is HDPE). Thus, the only difference between the alternative liner and the prescriptive liner is the thickness of the HDPE geomembrane component (see Figure 4).

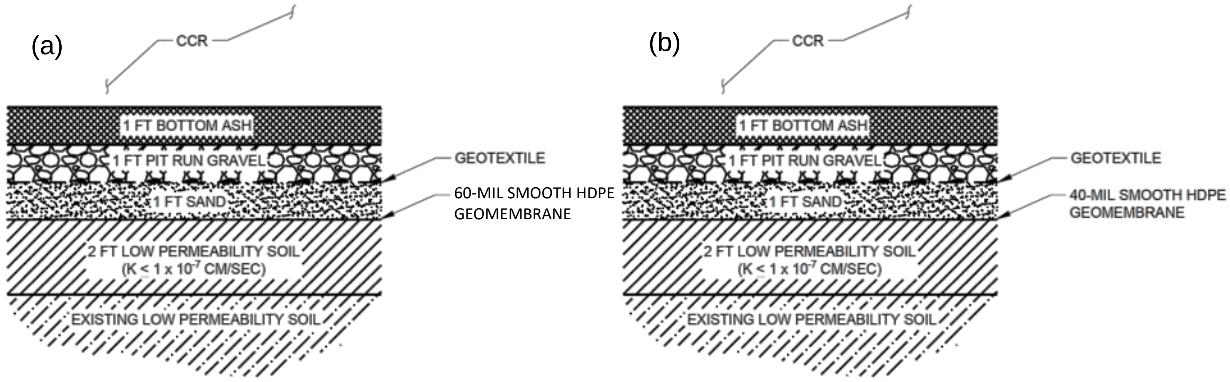

Figure 4. (a) Prescriptive Liner System per the CCR Rule and (b) the Proposed Alternative Liner System at Upstream Raise 91.

Composite Liner Infiltration

The composite liner at Upstream Raise 91 consists of a geomembrane overlying a compacted soil layer. The flow of water through a geomembrane liner is primarily advective flow through defects in the geomembrane rather than diffusive flow through the geomembrane. Defects occur primarily due to installation damage that is not identified and corrected as part of the CQA program. Infiltration through a composite liner occurs when flow passes through a defect. This infiltration rate is controlled by the size of the defect, the contact between the geomembrane and underlying soil layer of the composite liner, the properties of that underlying soil layer, and the head of water on the geomembrane.

Several studies have been performed, and equations developed to estimate infiltration rates through composite liners. The method selected to estimate infiltration rates through the composite liner at Upstream Raise 91 is that proposed by Rowe (1998), which includes a set of equations using theoretical principles that can accommodate the expected conditions at Upstream Raise 91. The following sections summarize the applicable aspects required to complete the infiltration calculations.

Soil Layer

Both the CCR Rule's prescriptive composite liner and the existing alternative composite liner at Upstream Raise 91 include a compacted soil layer at least two feet thick with an installed hydraulic conductivity of 1×10^{-7} cm/sec or less.

Two sources of information were used to establish soil layer inputs for modeling the potential for infiltration from Upstream Raise 91: soil layer testing from CQA monitoring and current hydraulic conductivity testing with site-specific soil layer samples and leachate:

- As a part of CQA monitoring during original construction of the composite liner system, 170 thin-walled tube samples (Shelby tubes samples) were collected across the Upstream Raise 91 footprint for hydraulic conductivity testing.
  - The hydraulic conductivity from these tests ranged from approximately 5×10^{-9} cm/sec to 1×10^{-7} cm/sec with a geometric mean hydraulic conductivity of 2×10^{-8} cm/sec. All tests met the design hydraulic conductivity of 1×10^{-7} cm/sec or less.
  - The thickness of the soil layer of the composite liner system ranged between approximately 2 and 4.5 feet with an average thickness of 2.4 feet.
- To augment the original testing, Shelby tube samples of the soil layer component of the composite liner system at Upstream Raise 91 were collected in 2021 for use in chemical equilibrium hydraulic conductivity tests performed with site-specific leachate.
  - In 2021, Shelby tubes (24-inch long, 3-inch diameter) from the soil layer of the composite liner system were collected near the top of side slopes at three locations within Upstream Raise 91.
  - Sampling of liquid from the Upstream Raise 91 sump representative of liquid in direct contact with the composite liner system was collected from an existing sump riser.
  - Samples were set up for chemical equilibrium hydraulic conductivity testing using site-specific leachate. The tests are being conducted in accordance with ASTM D5084 "Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials using a Flexible Wall Permeameter."
  - Some of the tests have been running for approximately eight months and have not yet reached chemical equilibrium. The current estimated hydraulic conductivities of the samples with reliable hydraulic data (flow in equals flow out) is on the order of approximately 4×10^{-9} cm/sec. Figure 5 shows a graphical representation of hydraulic conductivity and pore volumes of flow that have passed through one of the samples that has reached steady state flow conditions.
  - Based on the current estimates for chemical equilibrium hydraulic conductivity, it may take between one and five years to pass just one pore volume of permeant through the samples, and chemical equilibrium may require that between one and ten pore volumes of permeant pass through the samples (Benson et al. 2018). Because of the long projected test durations and the initial low hydraulic conductivity of the samples,

composite liner infiltration rates for ALD modeling will be based on the 170 hydraulic conductivity tests performed during liner construction.

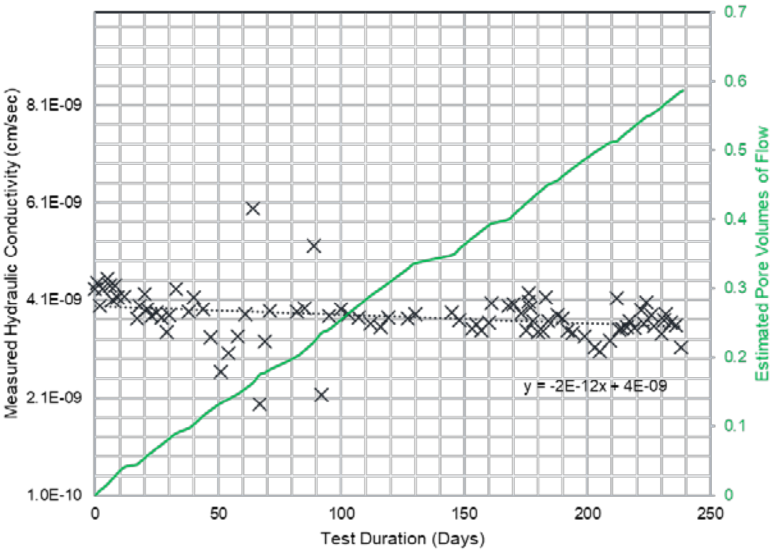

Figure 5. Chemical Equilibrium Permeability Testing Results.

The inputs used in the infiltration calculation are described below:

- L_s = thickness of the soil layer (m)
  - A value of 2 feet (0.6096 m) representing the minimum thickness required and minimum thickness measured based on CQA activities at Upstream Raise 91 will be used. Using this minimum value represents a conservative assumption of soil layer thickness.
- K_{sat} = saturated hydraulic conductivity of the soil layer (m/sec)
  - The hydraulic conductivity results from 170 tests conducted during composite liner construction will be increased conservatively by a factor of 10 applied to reflect the potential increase in hydraulic conductivity over time due to the chemical composition of leachate from Upstream Raise 91 (although no increase in hydraulic conductivity has been observed to-date in tests using site leachate).

Geomembrane

Both the CCR Rule's prescriptive composite liner and the existing alternative composite liner at Upstream Raise 91 include HDPE geomembrane over a soil layer component. The prescriptive composite liner has a 60-mil HDPE geomembrane, and the alternative liner has a 40-mil HDPE geomembrane.

The HDPE geomembrane inputs (and associated references) used in the infiltration calculation are described below:

- r_d = radius of defect (m)
  - A defect area of 6 square millimeters (radius of 1.4 x 10^{-3} m) based on the middle of a range of hole sizes reported by Rollin et al. (1999).
- T = Transmissivity of the interfacial zone

    - 1.6×10^{-8} m^2/s for good contact reflective of the CQA oversight associated with the installation of the geomembrane at Upstream Raise 91.
- n = density of defects (# per hectare)
    - The defect frequency measured from 26 sites (USEPA 2002) will be used to reflect the range in potential defects in the prescriptive geomembrane.
    - For the alternative liner with a 40-mil HDPE geomembrane, the defect frequency from the 26 sites will be increased by 25% to reflect the potential for more defects in a 40-mil HDPE geomembrane versus a 60-mil HDPE geomembrane.

Based on the piezometric surface conditions over the operational life of the facility, the time-weighted average head on the liner was estimated to be 19 feet.

Infiltration Rate Calculations

The information described above was used to evaluate the range in infiltration rates through the composite liner system at Upstream Raise 91. To capture the input variability, the 26 possible defect frequency rates were coupled with the 170 possible soil layer saturated hydraulic conductivity values from original CQA testing performed during composite liner construction to create 4,420 possible scenarios. Percentile distributions were developed from these scenarios and are used as inputs into the mathematical modeling (Table 1).

Table 1. Calculated Infiltration Rate Distributions.

Percentile	Infiltration Rate (m/year)	
	Alternative Composite Liner (40-mil HDPE Geomembrane Overlying a Compacted Soil Layer)	Prescriptive Composite Liner (60-mil HDPE Geomembrane Overlying a Compacted Soil Layer)
0%	0	0
10%	0	0
25%	0	0
50%	3.0×10^{-4}	2.4×10^{-4}
75%	1.1×10^{-3}	8.4×10^{-4}
80%	1.3×10^{-3}	1.1×10^{-3}
85%	1.4×10^{-3}	1.1×10^{-3}
90%	1.7×10^{-3}	1.3×10^{-3}
95%	1.9×10^{-3}	1.5×10^{-3}
100%	4.6×10^{-3}	3.6×10^{-3}

4.1 Mathematical Model to Estimate the Potential for Releases

As part of the ALD, 40 CFR 257.71(d)(ii)(C) requires:

> *“Mathematical model to estimate the potential for releases. Owners or operators must incorporate the data collected for paragraphs (d)(1)(ii)(A) and (d)(1)(ii)(B) of this section into a mathematical model to calculate the potential groundwater concentrations that may result in downgradient wells as a result of the impoundment.”*

Mathematical modeling was performed to predict peak groundwater concentrations at the downgradient waste boundary assuming a potential contaminant release from Upstream Raise 91 from operation through the post-closure period.

The following sections describe the conceptual model, modeling approach, input parameters, and predicted results and conclusions from the mathematical model.

Modeling Approach

The purpose of mathematical modeling is to predict peak groundwater concentrations at the downgradient waste boundary assuming a potential contaminant release from Upstream Raise 91. To conduct this contaminant fate and transport modeling, Golder used the USEPA Composite Model for Leachate Migration with Transformation Products (EPACMTP). This model was developed and validated by the USEPA to simulate fate and transport of constituents leaching from waste management units through the underlying unsaturated and saturated zones. The EPACMTP was the modeling package used for the USEPA's CCR Risk Assessment (USEPA 2014) and is generally described below.

The EPACMTP accounts for the following processes which are important for contaminant fate and transport: advection, dispersion, sorption, decay, and recharge dilution in the saturated zone. The EPACMTP was used to simulate one-dimensional (vertically downward) unsaturated flow, three-dimensional groundwater flow, along with constituent transport in the area beneath and surrounding Upstream Raise 91. The estimated infiltration rates summarized in Section 3.1 act as a source leaching rate term for the unsaturated flow module of EPACMTP. Simulations were run for each of the fifteen Appendix IV constituents to predict respective peak groundwater concentrations at a hypothetical receptor well located at the downgradient waste boundary and within a contaminant plume centerline.

Given the heterogeneous hydrogeologic setting characterized for the site, simulations were run in probabilistic, Monte Carlo mode to incorporate site variability. Simulations include an assumed leaching source duration to account for the initial operation through post-closure period of Upstream Raise 91 and were run over a total exposure period of 10,000 years, consistent with USEPA (2014).

Simulations in EPACMTP were used to predict probability distributions of downgradient groundwater concentrations attributed to the Upstream Raise 91 surface impoundment in isolation. The peak groundwater concentrations were evaluated for each constituent based on the Upstream Raise 91 impoundment in isolation and in addition to background groundwater concentrations. For each constituent, the cumulative distribution function (CDF) of the model-predicted concentration (from Upstream Raise 91 in isolation) was added to the upgradient background groundwater concentration CDF to calculate a combined distribution of each constituent concentration for model results plus background. The addition of the CDFs was conducted using GoldSim Technology Group (GoldSim) (2021) by probabilistically sampling each distribution and adding them together for 10,000 realizations.

Simulation results were evaluated with a particular focus on the predicted concentrations of the probability distribution between the 10th and 90th percentiles, as this range is the most representative of overall scenario behavior. This is consistent with the USEPA's guidance for conducting probabilistic risk assessments and evaluating probabilistic data distributions (USEPA 2001).

Model Inputs

The site-specific geologic, hydrogeologic, and impoundment characteristics were generally described in the above sections and were used to develop the model input parameters required for the simulations where possible. If site-specific properties were not available, conservative values were used from the USEPA or from literature.

The input parameters required for the modeling include contaminant source parameters, physical parameters, and chemical constituent parameters. Contaminant source parameters were based on the Upstream Raise 91 surface impoundment design, operational information, site sump leachate and national-scale impoundment porewater chemistry data, and liner infiltration calculations. Physical parameters were based on the Upstream Raise 91 surface impoundment design and site-specific geologic and hydrogeologic data collected from site investigations. Chemical constituent parameters were based on the sorption characteristics of each Appendix IV constituent. Empirical distributions were developed and input in the model for select site-specific parameters and constituent parameters to account for site variability. These model inputs are not described in detail here but are included with the original ALD report (Golder 2021).

Model Results and Conclusions

As described above, probabilistic Monte Carlo simulations were completed using the EPACMTP to evaluate a hypothetical contaminant release from Upstream Raise 91. Simulations were run for each of the fifteen Appendix IV constituents to predict respective peak groundwater concentrations at the downgradient waste boundary.

Illustrative model results for Lead and Lithium are presented in Figures 6 and 7. Model results are presented in comparison to their corresponding site-specific GWPS. The original ALD report contains results for all Appendix IV constituents (Golder 2021). Note that the model results represent predictions for a hypothetical contaminant release from the alternative liner of Upstream Raise 91 and are best compared to predictions for relative performance of a prescriptive liner.

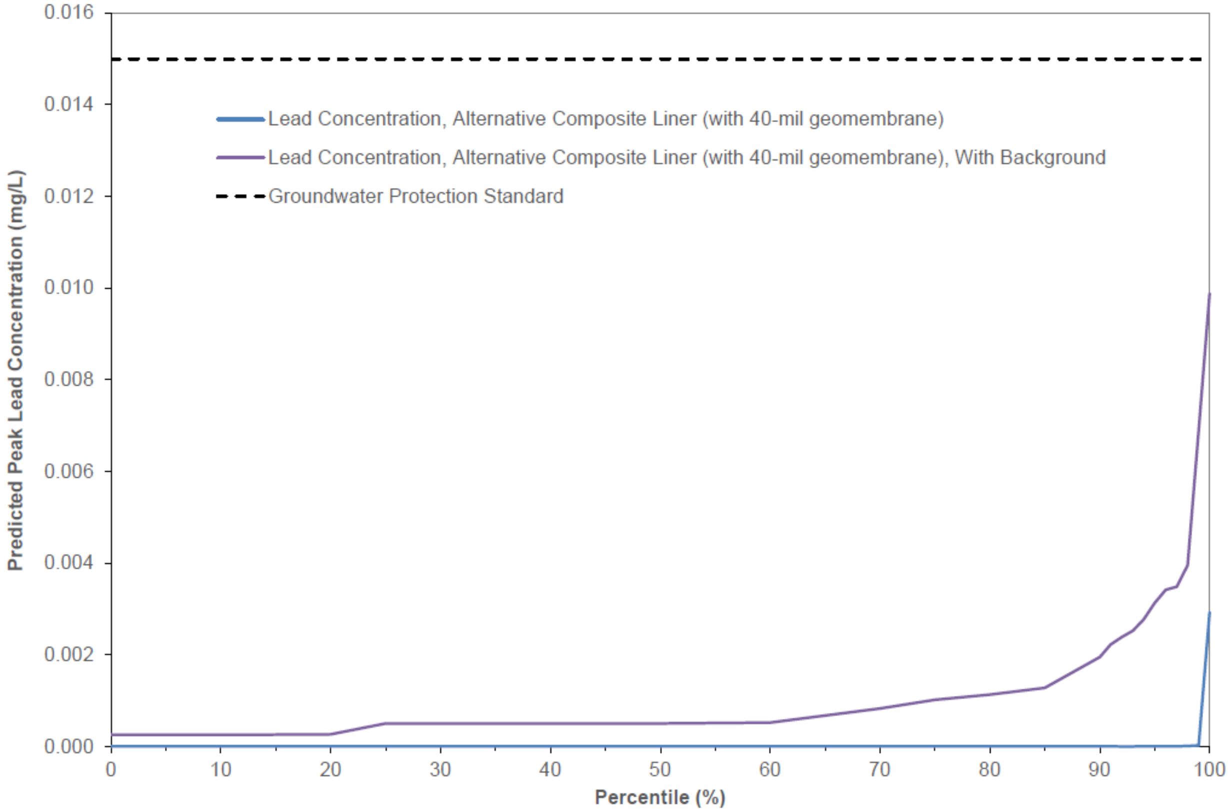

Figure 6. Mathematical Modeling Results - Lead.

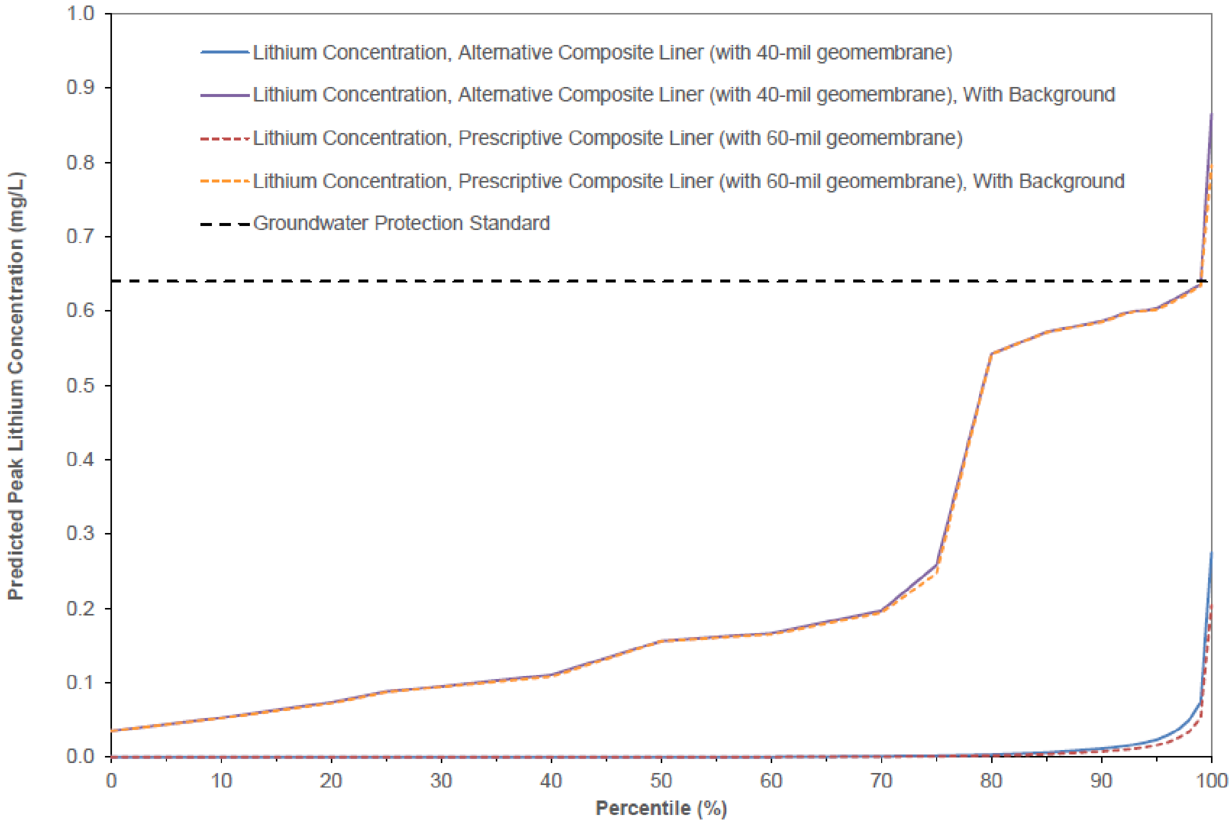

Figure 7. Mathematical Modeling Results - Lithium.

Conclusions based on the model results are summarized below. The conclusions focus on the results of the probability distributions between the 10th and 90th percentiles, as this range is the most representative of overall scenario behavior. This is consistent with the USEPA's guidance for conducting probabilistic risk assessments and evaluating probabilistic data distributions (USEPA 2001). The simulation results indicate that the Upstream Raise 91 alternative liner will perform similar to a prescriptive liner, even with conservative modeling assumptions for the alternative liner associated with a 25% higher defect density. There was negligible difference in peak concentration predicted at the downgradient waste boundary when comparing the predicted fate and transport of select constituents for the two liner scenarios. Furthermore, the modeling results indicate there is no reasonable probability that peak groundwater concentrations of each Appendix IV constituent will exceed their corresponding site GWPS at the downgradient waste boundary.

4.0 CONCLUSIONS

Per 40 CFR 257.71(d)(1)(ii), the ALD "must present evidence to demonstrate that, based on the construction of the unit and surrounding site conditions, there is no reasonable probability that operation of the surface impoundment will result in concentrations of constituents listed in Appendix IV to this part in the uppermost aquifer at levels above a GWPS." This is done through three lines of evidence:

- Characterization of Site Hydrogeology
    - The geologic and hydrogeologic conditions around Upstream Raise 91 that control the rate and transport of constituents potentially leaking from the surface impoundment were characterized by reviewing previous information (including regional and local information), performing a detailed site investigation to evaluate subsurface conditions, and developing a site conceptual model of the potential release pathway.
- Characterization of the Potential for Infiltration
    - Due to the engineered composite liner at Upstream Raise 91, the characterization of the potential for infiltration focused on the geomembrane and soil layer components of the composite liner and a calculation of infiltration through that composite liner.
- Mathematical Model to Estimate the Potential for Releases
    - The EPACMTP was used to predict peak groundwater concentrations at the downgradient waste boundary assuming a potential contaminant release from Upstream Raise 91. Model inputs were developed from the site hydrogeological characterization, estimates of potential infiltration, and site-specific and national-scale data on leachate. The model was run in probabilistic, Monte Carlo mode, to incorporate the range in site and source conditions.

Based on the lines of evidence discussed above, there is no reasonable probability that peak groundwater concentrations at the Upstream Raise 91 waste boundary will exceed the site-specific GWPS. Furthermore, the alternative liner at Upstream Raise 91 is determined to be equally protective of human health and the environment as the prescriptive liner for CCR surface impoundments.

5.0 REFERENCES

Benson CH, Chen JN, Edil TB, Likos WJ. 2018. Hydraulic Conductivity of Compacted Soil Liners Permeated with Coal Combustion Product Leachates. Journal of Geotechnical and Geoenvironmental Engineering. Volume 144, Issue 4. April 2018.

CPA/UPA (Cooperative Power and United Power Associations). 1989. Application to Renew Permit SU-033 – Coal Creek Station, McLean County, North Dakota. Submitted to the North Dakota State Department of Health. February 1989.

Golder (Golder Associates Inc.). 2021. Alternative Liner Demonstration for the Upstream Raise 91 CCR Surface Impoundment, Great River Energy - Coal Creek Station. November 30, 2021.

Goldsim (Goldsim Technology Group) 2020. Goldsim Version 12.1. Issaquah, WA, Release Date: July 15, 2000.

Rollin AL, Marcotte M, Jacquelin T, Chaput L. 1999. Leak Location in Exposed Geomembrane Liners Using an Electrical Leak Detection Technique. Geosynthetics ‘99: Specifying Geosynthetics and Developing Design Details, Vol. 2, pp 615-626.

Rowe RK. 1998. Geosynthetics and the Minimization of Contaminant Migration Through Barrier Systems Beneath Solid Waste. Proc., 6th Int. Conf. on Geosynthetics, International Geosynthetics Society, Minneapolis, 27-102.

USEPA (United States Environmental Protection Agency). 2001. Risk Assessment Guidance for Superfund (RAGS). Volume III: Part A, Process for Conducting Probabilistic Risk Assessment. Office of Emergency and Remedial Response. EPA 540-R-02-002; Publication 9285.7-45; PB2002-963302. 385p., December.

USEPA. 2002. Industrial Waste Management Evaluation Model (IWEM) Technical Background Document. EPA530-R-02-012. August.

USEPA. 2014. Human and Ecological Risk Assessment of Coal Combustion Residuals (Final). Office of Solid Waste and Emergency Response, Office of Resource Conservation and Recovery. EPA-HQ-OLEM-2019-0173-008. 1237p., December.

USEPA. 2015. Code of Federal Regulations Title 40 Part 257: Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities. April 17.

USEPA. 2020. Code of Federal Regulations Title 40 Part 257: Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; A Holistic Approach to Closure Part B: Alternate Demonstration for Unlined Surface Impoundments. November 12.