ATTACHMENT VIII – LEACHATE MANAGEMENT PLAN

LEACHATE MANAGEMENT PLAN

Bremo Bluff FFCP Management Facility
Solid Waste Permit 627
Fluvanna County, Virginia

Prepared for:

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CERTIFICATION

This Leachate Management Plan for the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility) was prepared by Schnabel Engineering (Schnabel). The document and Certification/Statement of Professional Opinion are based on and limited to information that Schnabel has relied on from Dominion Energy and others, but not independently verified.

On the basis of and subject to the foregoing, it is my professional opinion as a Professional Engineer licensed in the Commonwealth of Virginia that this document has been prepared in accordance with good and accepted engineering practices as exercised by other engineers practicing in the same discipline(s), under similar circumstances, at the same time, and in the same locale. It is my professional opinion that the document was prepared consistent with the requirements in the United States Environmental Protection Agency's "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments" (CCR Rule, 40 CFR §257 Subpart D) as well as the Virginia Department of Environmental Quality's Virginia Solid Waste Management Regulations (VSWMR, 9VAC20-81).

The use of the word "certification" and/or "certify" in this document shall be interpreted and construed as a Statement of Professional Opinion and is not and shall not be interpreted or construed as a guarantee, warranty, or legal opinion.

James R. DiFrancesco	Principal / Practice Leader Solid Waste
Name	Title
	November 15, 2024
Signature	Date

1.0 GENERAL

This Leachate Management Plan (Plan) has been prepared for the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility) located in Bremo Bluff, Virginia. The Facility will accept coal combustion residuals (CCR) previously generated at the Bremo Station (Station) and operate as a new, captive industrial landfill (CCR Unit) under the Virginia Department of Environmental Quality (DEQ) Solid Waste Permit (SWP) 627. Schnabel Engineering (Schnabel) has prepared this Plan on behalf of the Virginia Electric and Power Company d/b/a Dominion Energy Virginia (Dominion Energy).

The Facility is subject to the design requirements in the United States Environmental Protection Agency's "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments" (CCR Rule, 40 CFR §257 Subpart D) as well as the DEQ's Virginia Solid Waste Management Regulations (VSWMR, 9VAC20-81).

The goal of the leachate management system design is to provide for effective and efficient leachate minimization, containment, collection, and extraction for the operational life, closure, and post-closure period of the Facility. The objectives of the leachate management system design for the Facility include:

- Efficient collection of leachate by drainage layers and a perforated piping system (gravity flow) with engineered leachate extractions points;
- Minimize leachate head build-up on the liner system to a maximum of 30 centimeters (cm), specifically during the placement of CCR where leachate generation is greatest;
- Development of base grades at a post-settlement gradient to promote rapid leachate collection; and,
- Leachate system removal redundancy, as needed, to efficiently remove and extract collected leachate.

The principal elements of the leachate collection and removal system include the drainage materials; leachate collection pipes; leachate sump, sideslope riser, and associated extraction pumps; leachate forcemain; and the on-site leachate transfer tanks.

1.1 Facility Description

The Facility will be located along State Route 656 at 2134 Bremo Bluff Road in Bremo Bluff, Virginia on an approximately 214-acre parcel that is adjacent to the Station property (Tax Parcel 62-A-7). The Facility will be owned and operated by Dominion Energy. The Disposal Unit Boundary (DUB) of the Facility is approximately 47 acres.

2.0 LEACHATE ESTIMATE

2.1 Leachate Quantity

The Hydrologic Evaluation of Landfill Performance (HELP) Model Program Version 4.0.1, as developed by the U.S. Army Engineering Waterways Experiment Station in Vicksburg, Mississippi for the U.S. Environmental Protection Agency (USEPA), was used to evaluate various operational scenarios to estimate the leachate production rates for the Facility over a 20-year period.

Leachate generated in the CCR Unit includes precipitation that has collected and percolated through the CCR waste. Precipitation that contacts CCR is considered contact stormwater. Where feasible during operation of the CCR Unit, contact stormwater will be collected and managed separately from leachate;

however, for conservative leachate production calculations and leachate collection system designs, no contact stormwater runoff was allowed in the HELP models.

Calculations for the total leachate quantities assume that the CCR Unit will be operated with a maximum active area of 28 acres, with the remaining portion of the CCR Unit covered to allow clean stormwater run-on to be pumped to the on-site sediment basins and not collected as leachate, until average placed CCR waste mass heights exceed the perimeter berm elevation and allow for increasing areas of sideslope intermediate cover for clean stormwater runoff.

Under these anticipated operating conditions, monthly and annual average volume estimates were determined as well as the maximum annual leachate volume, which is estimated to be approximately 18,387,297 gallons and occurs in Year 3 of the CCR Unit's operational life. Attachment 1 presents the HELP modeling methodology, data sources, assumptions, and estimated leachate flows through the life of the CCR Unit.

2.2 Leachate Quality

The quality of leachate is expected to be similar to that of other CCR disposal units, and to the contact water previously treated by the Station. In general, the leachate is expected to be nonhazardous, inorganic, and may contain dissolved metals. The pH of the leachate is expected to vary from acidic (~4) to basic (~9) and lack strong odor.

3.0 LEACHATE COLLECTION SYSTEM

Leachate will be collected via header and lateral pipes, which drain by gravity to a collection sump at the southern limits of the disposal area. Leachate collected in the sump will be pumped from a sideslope riser system into a forcemain that will convey the leachate to two 500,000-gallon on-site transfer tanks prior to being pumped to a proposed Dominion Energy-owned, permitted wastewater treatment facility located at the Station.

The leachate collection system (geocomposite; aggregate drainage layer; leachate pipe size, perforations, spacing, etc.) is designed to convey the peak daily leachate generation flows generated during the life of the CCR Unit, discussed in detail in Attachment 1.

3.1 Drainage Layer Design

The proposed drainage layer for the CCR Unit includes a 250-mil double-sided drainage geocomposite overlain by an 18-inch-thick aggregate layer on both the floor and sideslopes [i.e., slopes equal to 3.5H:1V (horizontal to vertical)].

3.1.1 Aggregate Drainage Layer

In accordance with 9VAC20-81-130.J.2, the 18-inch-thick aggregate layer is composed of a 12-inch-thick drainage layer for leachate removal and a 6-inch-thick protective layer placed above the drainage layer, both consisting of materials with a hydraulic conductivity of 1×10^{-3} centimeters per second (cm/s) or greater. The options proposed for the bottom liner system aggregate, as depicted in Attachment III of the Part B Permit Application (Design Plans), consist of the following: a 12-inch-thick coarse aggregate drainage layer overlain by a 6-inch-thick fine aggregate protective layer (Option 1), an 18-inch-thick layer of coarse aggregate where coarse aggregate is used as the drainage layer and the protective layer

(Option 2A), or an 18-inch-thick layer of fine aggregate where fine aggregate is used as the drainage layer and the protective layer (Option 2B).

The aggregate drainage material shall contain no greater than 15 percent calcium carbonate equivalent and have a hydraulic conductivity greater than or equal to $1x10^{-3}$ cm/s, as required in Technical Specifications.

3.1.1.1 Bearing Capacity

A bearing capacity analysis, included in Attachment VI of the Part B Permit Application (Design Report), was performed to demonstrate that the bearing capacity of the underlying soils will not be exceeded by the anticipated loading from the CCR Unit. The proposed drainage layer material is aggregate, which typically consolidates immediately upon placement; thus, the drainage layer material has sufficient bearing capacity under the anticipated applied load of the CCR Unit.

3.1.1.2 Slope Stability

The maximum slope is approximately 29% for the base grade sideslopes. At this slope, the proposed aggregate layer has sufficient stability, and is further discussed in Section 3.1.2.2.

3.1.2 Geosynthetic Drainage Layer

To provide additional drainage, as well as protection for the geomembrane, the aggregate drainage layer will be underlain with a 250-mil geocomposite consisting of geonet core that is heat laminated on both sides with an 8 ounce per square yard (oz) non-woven geotextile fabric.

3.1.2.1 Transmissivity

A transmissivity of $9.0x10^{-4}$ square meters per second (m^2/s) under a loading of 1,000 pounds per square foot (psf) and the resulting hydraulic conductivity of 2.2 cm/s was used in HELP modeling for CCR loads representing less than an average waste height of 50 feet to reflect the upper bound of transmissivity for loaded geocomposites, which conservatively models higher peak leachate generation flows for leachate collection and removal system design during the initial stages of filling.

A transmissivity of $2.2x10^{-4}$ m^2/s under a loading of 10,000 psf and the resulting hydraulic conductivity of 0.4 cm/s was used in HELP modeling for CCR loads representing an average waste height of 50 feet and greater to reflect the lower bound of transmissivity for loaded geocomposites, which conservatively models higher long-term head on the bottom liner system.

Additional details for these transmissivities are provided in Attachment 1.

3.1.2.2 Side Slopes

A veneer stability calculation, included in the Design Report, was performed to analyze the bottom liner system slope stability. Veneer stability of the base liner system was evaluated for the 3.5H:1V sideslopes for the longest liner section, approximately 164 feet, as a series of interfaces where the liner system materials overlay one another. All interfaces of the proposed liner system, inclusive of the proposed 250-mil geocomposite drainage layer, must have a minimum peak friction angle of at least 22.7 degrees with no adhesion.

In addition, calculations for liner self-weight and liner stress during construction were performed for the bottom liner system. It was determined the liner system could support its own weight and equipment loads during construction at the 3.5H:1V design slopes.

3.2 Filter Layer and Pipe Protection Design

For the proposed aggregate options discussed in Section 3.1.1, where fine aggregate or CCR is to be placed atop coarse aggregate, a 10-oz geotextile is proposed for filtration/separation to prevent the finer material from migrating into the coarser material. In Option 1, a 10-oz non-woven geotextile is proposed between the 6-inch-thick fine aggregate and 12-inch-thick coarse aggregate to prevent the fine aggregate from migrating into the coarse aggregate. In Option 2A, a 10-oz non-woven geotextile is proposed above the 18-inch-thick coarse aggregate layer to prevent placed CCR from being deposited into the coarse aggregate. In the case of an 18-inch-thick layer of fine aggregate, Option 2B, and the 6-inch-thick fine aggregate in Option 1, a 10-oz non-woven geotextile is not proposed between the placed CCR and fine aggregate layers because the fine aggregate acts as a filter layer to prevent migration of the placed CCR. The aggregate layer will be underlain by a 250-mil geocomposite, double-sided with an 8-oz non-woven geotextile.

Additionally, leachate collection piping will be enveloped in Virginia Department of Transportation (VDOT) No. 57 stone. If fine aggregate is used (Option 2B), the VDOT No. 57 stone shall be wrapped with a 10-oz non-woven geotextile to provide separation and filtration capacity from the surrounding leachate drainage layer and prevent the fine aggregate from migrating into the stone and leachate collection piping.

3.2.1 Fine Aggregate Filter Layer

Filter compatibility between the fine aggregate and placed CCR was evaluated in accordance with Chapter 26, Gradation Design of Sand and Gravel Filters, of the National Engineering Handbook. A CCR gradation from site-specific sample data was used to develop the fine aggregate gradation restrictions included in Attachment VII of the Part B Permit Application (Technical Specifications). Calculations, included as Attachment 2, indicate that the adjoining materials are compatible and meet applicable filter criteria.

3.2.2 Geotextile Filter Layer

A calculation was performed to determine the appropriate maximum apparent opening size (AOS) of the 10-oz pipe wrap geotextile, 8-oz geocomposite geotextile, and 10-oz filter/separation geotextile. The non-woven geotextile wrap and geocomposite geotextile shall have an AOS of 0.21 millimeters (mm) or smaller. The filter/separation geotextile shall have a maximum AOS size 0.15 mm. AOS sizing calculations for the geotextiles are included as Attachment 3.

The leachate collection pipes will consist of 8-inch headers and 6-inch laterals. The velocity, computed in Attachment 4, is sufficient for self-cleaning. Cleanout access points for the leachate collection piping are located around the perimeter of the CCR Unit and are shown in the Design Plans.

3.3 Leachate Collection Pipe

3.3.1 Pipe Sizing and Capacity

The leachate collection lateral and header piping will consist of 6-inch and 8-inch SDR-11 perforated high-density polyethylene (HDPE), respectively. Leachate will flow by gravity. Calculations in Attachment 4 demonstrate the ability of the proposed leachate collection pipes to convey leachate from the drainage layer to the leachate collection sump. The calculations assume slopes after differential settlement of the foundation soils. The headers and laterals are sized for the maximum peak daily flow generated through the HELP Model Program. The pipe calculated to convey the most leachate will have an estimated peak flow depth at approximately 92 percent of its nominal inner diameter and a peak flowrate at approximately 98 percent of its potential capacity. The computed velocity in the pipe is approximately 6.94 feet per second (ft/s). The peak flow depths, flowrates, and velocities for the headers and laterals are summarized in Attachment 4.

The leachate collection pipes will have 4 rows of 3/8-inch diameter perforations spaced every 6 linear inches of pipe, as shown in the Design Plans. The leachate collection pipe perforation size and gravel gradation were checked to confirm the VDOT No. 57 stone does not migrate into the perforated piping. The d_{50} gradation point of VDOT No. 57 stone is approximately 0.5 inch. The U.S. Army Corps of Engineers Technical Letter ETL 1110-1-162 provides the following guidance on bedding stone size and perforation size for preventing infiltration of material into the perforated pipe:

$$\frac{50\%\ size\ of\ filter\ material}{hole\ diameter\ or\ slot\ width} \geq 1.0\ (holes)\ or\ \geq 1.2\ (slots)$$

The proposed pipe and stone results in a ratio of d_{50} to hole diameter of 1.3, which satisfies this criterion.

3.3.2 Pipe Strength

The leachate collection pipes were analyzed for compressive ring thrust, ring deflection, and wall buckling. Calculations presented in Attachment 5 demonstrate the pipes are structurally stable under the full loading of the CCR Unit; therefore, the leachate collection pipes within the aggregate are protected against stresses and disturbances from overlying CCR, cover materials, and equipment operations.

3.4 Leachate Collection System Design Standard

The HELP Model Program was used to calculate the maximum head on the bottom liner system. Based on the open condition model with 10 feet of CCR waste at 2.5% base grades, included in Attachment XVI of the Part B Permit Application (Alternate Final Cover Demonstration), the maximum head on the base liner system is 11.6341 inches, which is less than the regulatory maximum allowable head of 30 cm for bottom liner systems. The leachate collection system, as designed, can maintain less than 30 cm of head on the bottom liner.

4.0 LEACHATE REMOVAL SYSTEM

Leachate will flow by gravity through the leachate collection pipes to the sump where it will be removed through two 24-inch diameter SDR-11 HDPE sideslope riser pipes that extend atop the bottom liner and through the final cover into a sump house that will be accessible after closure.

The leachate sump pumps will direct leachate from the sump house into a dual-contained forcemain that conveys the leachate to two 500,000-gallon on-site transfer tanks prior to being pumped to a proposed Dominion Energy-owned, permitted wastewater treatment facility located at the Station. The leachate forcemain will be 6-inch diameter SDR-11 HDPE pipe within 10-inch diameter SDR-17 HDPE pipe from the sump house to the transfer tanks and will transition to 8-inch SDR-11 HDPE pipe within 12-inch SDR-17 HDPE pipe from the transfer tanks to Dominion Energy’s treatment facility. Details of the leachate collection sump, risers, sump house, and forcemain are included in the Design Plans.

Based on the maximum monthly leachate generation condition for the bottom liner system, calculated in Attachment 1, it is anticipated that the average leachate flow for the maximum month is approximately 95.8 gallons per minute (gpm). The leachate pumps are sized for more than the average flow rate for the maximum month by a factor of greater than 2 (approximately 200 gpm each), enabling the volume of the leachate sump to be removed within approximately one hour. The total dynamic head condition for the leachate sumps to the transfer tanks is approximately 225 feet, which includes 55 feet in elevation change, 162 feet in friction and minor losses, and 8 feet in velocity head losses.

5.0 COLLECTION AND STORAGE UNITS

Leachate will gravity drain to a sump within the limits of the lined disposal area. From the sump, leachate will be pumped and conveyed via forcemain to the on-site transfer tanks prior to being pumped to a proposed Dominion Energy-owned, permitted wastewater treatment facility located at the Station. The leachate transfer tanks will be double-walled and have a capacity of approximately 500,000 gallons each.

Although the two dedicated leachate transfer tanks are not considered on-site leachate storage because of the direct connection to the proposed Dominion Energy-owned, permitted wastewater treatment facility, the tanks were evaluated to ensure they meet the regulatory seven-day storage capacity. Based on the HELP model estimates in Appendix A, the two 500,000-gallon leachate transfer tanks (nominal capacity of 1,000,000 gallons) provide sufficient storage capacity and adequate flow equalization and surge capacity at least equal to the maximum expected projection of leachate for a seven-day period for the life of the CCR Unit, which was calculated to be 965,500 gallons.

6.0 LEACHATE TREATMENT OR DISPOSAL

Leachate from the Facility transfer tanks is pumped to a proposed Dominion Energy-owned, permitted wastewater treatment facility located on the adjacent Station property for treatment and discharge. Leachate will be managed at the treatment facility in accordance with the Station’s Virginia Pollutant Discharge Elimination System (VPDES) permit.

Alternative disposal of leachate will be via pump and haul to the Moores Creek Wastewater Treatment Plant located at 695 Moores Creek Ln, Charlottesville, VA 22902, which is owned and operated by the Rivanna Water and Sewer Authority.

7.0 LEACHATE RECIRCULATION

No leachate recirculation is proposed at the Facility.

ATTACHMENT 1

HELP MODEL ANALYSIS

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Calculations

PROJECT: Bremo Bluff FFCP Management Facility	**REFERENCE NO:** 22130437.031
SUBJECT: HELP Model Analysis	**DATE:** 06/01/2024

1.0 OBJECTIVE

The objective of this analysis is to evaluate the hydraulic performance of the bottom liner and leachate collection systems for the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility). The maximum drainage length, peak daily head, average monthly and annual leachate volumes, and the peak leachate volume for the life of the CCR Unit were determined through this analysis.

2.0 METHODOLOGY

The analysis was performed using the Hydrologic Evaluation of Landfill Performance (HELP) Model Program Version 4.0.1, as developed by the U.S. Army Engineering Waterways Experiment Station in Vicksburg, Mississippi for the U.S. Environmental Protection Agency (USEPA). The HELP Model uses climatological, soil, and CCR Unit design information to predict peak daily and annual values of precipitation, runoff, evapotranspiration, lateral drainage, percolation/leakage, and head on the bottom liner. The HELP Model was used to evaluate conditions throughout the operation of the CCR Unit to estimate the total leachate production rates for the Facility. The CCR Unit was evaluated for both opened and closed operational scenarios. The open condition was divided into 10-feet (ft), 25-ft, 40-ft, 50-ft, and 70-ft depths of CCR to analyze different average CCR waste depths during the filling cycle. The open CCR scenarios were modeled with varying percentages of allowable runoff to simulate sideslope intermediate cover areas at the increasing CCR waste mass height. No runoff was allowed in the model until the average depth of the CCR waste mass height exceeded the perimeter berm elevation. All conditions were modeled for 20 years to provide sufficient data to conduct the lifetime leachate volume analysis. Each iteration of the HELP Model was run for a one-acre area to develop per-acre values that were used to calculate leachate generation for each condition.

The initial moisture contents of the CCR and drainage layers were manually adjusted from the default values to simulate the saturation of CCR in each condition. The 10-ft open condition's moisture content was developed by the HELP Model for the nearly-steady-state condition of the CCR. Subsequent iterations were run with increasing CCR lift thickness using the previous iteration's final moisture contents for each CCR and drainage layer.

3.0 ASSUMPTIONS AND MODEL INPUTS

The climate data for the models consists of precipitation, temperature, solar radiation, and evapotranspiration. Precipitation and temperature data were generated by the HELP Model Program using historical data from Stations USC00440993 (Bremo Bluff, VA) and USC00446491 (Scottsville, VA), which are part of the National Oceanic and Atmospheric Administration's (NOAA) Global Historical Climatology Network (GHCN). Solar radiation and evapotranspiration data was synthetically generated by the HELP Model Program for a longitude of -78.27° N. Wind speed and relative humidity were generated by the HELP Model Program using historical data from the National Solar Radiation Database (NSRD) Station 724016 (Charlottesville, VA). The closed condition was assigned a leaf area index (LAI) of 4 for a good to excellent stand of vegetation, and the open conditions were assigned an LAI of 0 for bare earth. Values for the start and end of growing season were assigned based on average monthly temperature data for Bremo Bluff, VA.

Each model was assigned surface water runoff parameters based on the intended condition. The Natural Resource Conservation Service (NRCS) runoff curve numbers were selected based on guidance from Technical Release 55 (TR-55). Curve numbers of 91 and 61 were used for the open and closed conditions, respectively. Runoff in the model was not allowed for the 10-ft and 25-ft open CCR conditions to account for the CCR waste mass height being below the perimeter berm and the bottom liner system's collection of all precipitation as leachate. Alternatively, increasing percentages of runoff were allowed for the 40-ft, 50-ft, and 70-ft open CCR conditions to account for increasing areas of sideslope intermediate cover. Under the closed condition, 100% of precipitation was considered as runoff.

The high-density polyethylene (HDPE) and linear low-density polyethylene (LLDPE) geomembrane layers were modeled with no pinholes or installation defects and with excellent placement to generate more conservative model results for higher peak leachate generation flows and higher long-term head on the bottom liner system.

Based on laboratory testing performed by GSE Environmental, LLC, the 250-mil geocomposite has a measured transmissivity of 9.0×10^{-4} square meters per second (m^2/s) under a loading of 1,000 pounds per square foot (psf), which is approximately equal to the minimum CCR depth of 10 feet used for HELP modeling. After applying reduction factors for intrusion, creep, and chemical and biological clogging, the resulting hydraulic conductivity was calculated as 2.2 centimeters per second (cm/s). This hydraulic conductivity was used in the HELP models for CCR loads less than an average waste height of 50 feet to reflect the upper bound of transmissivity for loaded geocomposites, which conservatively models higher peak leachate generation flows for the leachate collection and removal system design during the initial stages of filling.

Based on the same laboratory testing performed by GSE Environmental, LLC, the 250-mil geocomposite has a measured transmissivity of 2.2×10^{-4} m^2/s under a loading of 10,000 psf, which is approximately equal to the maximum average CCR waste depth of 85 feet used for HELP modeling. After applying reduction factors for intrusion, creep, and chemical and biological clogging, the resulting hydraulic conductivity was calculated as 0.4 cm/s. This hydraulic conductivity was used in the HELP models for CCR loads equal to and greater than an average waste height of 50 feet to reflect the lower bound of transmissivity for loaded geocomposites, which conservatively models higher long-term head on the bottom liner system.

The options proposed for the bottom liner system aggregate (Options 1, 2A, and 2B), as depicted in Attachment III of the Part B Permit Application (Design Plans), were evaluated in the HELP Model Program for the assumed worst-case operational condition, i.e. 10-ft of open CCR, to determine the maximum leachate pipe spacing and resulting leachate head and flows at both the minimum 2.5% and 5% base grade slopes. The results are summarized below in Table 1.

Table 1: HELP Model Results for Bottom Liner System Aggregate Options

Option	Minimum Base Grade Slopes (%)					
	2.5	5	2.5	5	2.5	5
	Maximum Head on Liner (in)[1]		Peak Daily Leachate Flow (cf/ac)[2]		Average Annual Leachate Flow (cf/ac)[2]	
1	8.52	7.52	1270	1333	66121	66122
2A[3]	11.63	10.53	1276	1332	66299	66300
2B	0.79	0.65	1259	1330	66341	66341

Notes: [1] Inch (in)
[2] Cubic feet per acre (cf/ac).
[3] Bottom liner system aggregate resulting in the highest leachate head and flows. Higher average annual leachate flows for Option 2B were considered to be negligible.

As shown above, Option 2A (18 inches of coarse aggregate) produces the most leachate head and flow of the three options; therefore, this bottom liner system, specifically at the minimum 5% base grade slope where the most leachate flow is produced, was used for the open conditions in this analysis[1]. Model results for the minimum 2.5% base grade slope sections, though not used in leachate generation analysis, are included in the attached HELP Models (Attachments 5 through 10) for reference.

Similarly, as demonstrated in Attachment XVI of the Part B Permit Application (Alternate Final Cover Demonstration), Sideslope Final Cover System Option 2 produces a higher peak daily maximum head of the two sideslope final cover systems proposed; therefore, this final sideslope cover system was used to model the closed condition of the CCR Unit.

The composition of each modeled section is included in the tables below. The vegetative support soil and protective cover soil were assumed to be sandy loam (Unified Soil Classification System SM) in accordance with the silty sands and sand-silt mixtures on-site. The values used for these soils correspond with existing boring logs and laboratory testing completed for the Part A Permit Application (by others) and are assumed to be characteristic of on-site soils. Except in cases where the hydraulic conductivity can be estimated with some degree of certainty, such as the LLDPE geomembrane drainage studs discussed in Attachment XVI of the Part B Permit Application (Alternate Final Cover Demonstration), or in cases where a minimum or maximum hydraulic conductivity has been established, such as the geosynthetic clay liner (GCL) discussed in Attachment XIV of the Part B Permit Application (Alternate Liner Demonstration), the default HELP Model Program values were used. The hydraulic conductivity of the bottom drainage layer was set to $1x10^{-3}$ centimeters per second (cm/s) for all conditions, corresponding to the regulatory minimum listed in 9VAC20-81-130 J.2.

Table 2: Bottom Liner System at 5% – 10-ft CCR

Layer No.	Layer ID	Layer Type	Thickness (in)	Porosity (vol/vol)	Initial Soil Water Content (vol/vol)	Effective Saturated Hydraulic Conductivity (cm/s)
1	CCR	1	120.0	0.5410	0.3177	5.00E-05
2	Aggregate Layer	2	18.0	0.3900	0.1468	1.00E-03
3	250-mil Geocomposite	2	0.25	0.8500	0.1132	2.20E+00
4	60-mil HDPE Geomembrane	4	0.06	N/A	N/A	2.00E-13
5	GCL	3	0.28	0.7500	0.7500	3.40E-09

[1] Subsequent modeled open condition scenarios resulted in a higher peak daily leachate flow or maximum head on the liner than the values reported in Table 1; 3,333 cf/ac in the 40-ft open CCR condition at 2.5% base grades and 11.61 inch in the 70-ft open CCR condition at 5% base grades, respectively. These values were considered to be calculation outliers in the HELP Model Program Version 4.0.1 and not representative of anticipated leachate production conditions; however, the more conservative value is used where applicable, e.g. 3,333 cf/ac is used to demonstrate leachate collection pipe capacity, and all HELP Model outputs were confirmed to be in accordance with the proposed leachate collection system design and requirements.

Table 3: Bottom Liner System at 5% – 25-ft CCR

Layer No.	Layer ID	Layer Type	Thickness (in)	Porosity (vol/vol)	Initial Soil Water Content (vol/vol)	Effective Saturated Hydraulic Conductivity (cm/s)
1	CCR	1	300.0	0.5410	0.3731	5.00E-05
2	Aggregate Layer	2	18.0	0.3900	0.1563	1.00E-03
3	250-mil Geocomposite	2	0.25	0.8500	0.3088	2.20E+00
4	60-mil HDPE Geomembrane	4	0.06	N/A	N/A	2.00E-13
5	GCL	3	0.28	0.7500	0.7500	3.40E-09

Table 4: Bottom Liner System at 5% – 40-ft CCR

Layer No.	Layer ID	Layer Type	Thickness (in)	Porosity (vol/vol)	Initial Soil Water Content (vol/vol)	Effective Saturated Hydraulic Conductivity (cm/s)
1	CCR	1	480.0	0.5410	0.3315	5.00E-05
2	Aggregate Layer	2	18.0	0.3900	0.1237	1.00E-03
3	250-mil Geocomposite	2	0.25	0.8500	0.0311	2.20E+00
4	60-mil HDPE Geomembrane	4	0.06	N/A	N/A	2.00E-13
5	GCL	3	0.28	0.7500	0.7500	3.40E-09

Table 5: Bottom Liner System at 5% – 50-ft CCR

Layer No.	Layer ID	Layer Type	Thickness (in)	Porosity (vol/vol)	Initial Soil Water Content (vol/vol)	Effective Saturated Hydraulic Conductivity (cm/s)
1	CCR	1	600.0	0.5410	0.3152	5.00E-05
2	Aggregate Layer	2	18.0	0.3900	0.0519	1.00E-03
3	250-mil Geocomposite	2	0.25	0.8500	0.0331	0.40E+00
4	60-mil HDPE Geomembrane	4	0.06	N/A	N/A	2.00E-13
5	GCL	3	0.28	0.7500	0.7500	3.40E-09

Table 6: Bottom Liner System at 5% – 70-ft CCR

Layer No.	Layer ID	Layer Type	Thickness (in)	Porosity (vol/vol)	Initial Soil Water Content (vol/vol)	Effective Saturated Hydraulic Conductivity (cm/s)
1	CCR	1	840.0	0.5410	0.3082	5.00E-05
2	Aggregate Layer	2	18.0	0.3900	0.0515	1.00E-03
3	250-mil Geocomposite	2	0.25	0.8500	0.0313	0.40E+00
4	60-mil HDPE Geomembrane	4	0.06	N/A	N/A	2.00E-13
5	GCL	3	0.28	0.7500	0.7500	3.40E-09

Table 7: Closed Condition with Sideslope Final Cover System Option 2 – 85-ft CCR

Layer No.	Layer ID	Layer Type	Thickness (in)	Porosity (vol/vol)	Initial Soil Water Content (vol/vol)	Effective Saturated Hydraulic Conductivity (cm/s)
1	Vegetative Cover	1	6.0	0.4530	0.2249	7.20E-04
2	Protective Cover	1	18.0	0.4530	0.1036	7.20E-04
3	Geotextile and Drainage Studs	2	0.13	0.8500	0.0166	1.09E+01
4	50-mil LLDPE MicroDrain® or Super Gripnet®	4	0.05	N/A	N/A	4.00E-13
5	Prepared and Compacted Subgrade	1	12.0	0.4530	0.2239	7.20E-04
6	CCR	1	1020.0	0.5410	0.3005	5.00E-05
7	Aggregate Layer	2	18.0	0.3900	0.1202	1.00E-03
8	250-mil Geocomposite	2	0.25	0.8500	0.0344	0.40E+00
9	60-mil HDPE Geomembrane	4	0.06	N/A	N/A	2.00E-13
10	GCL	3	0.28	0.7500	0.7500	3.40E-09

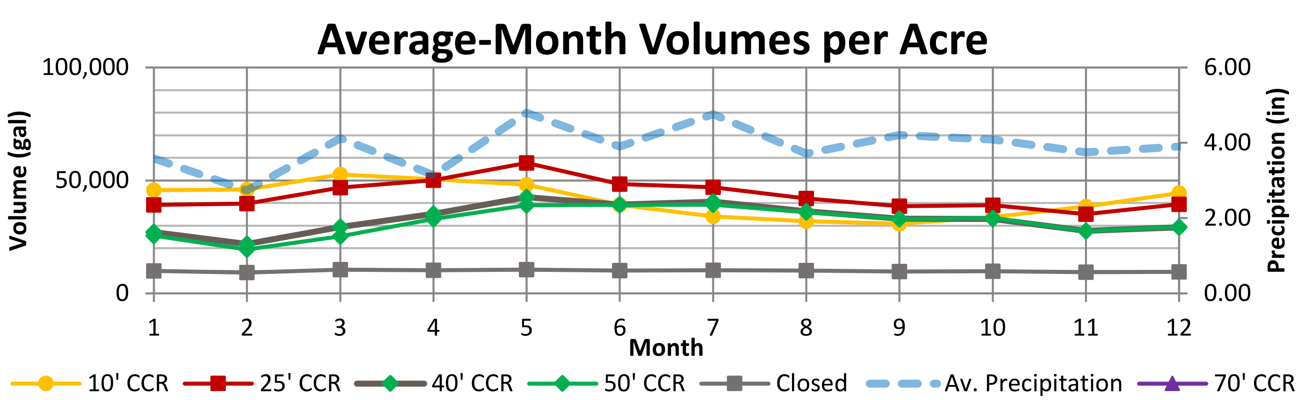
4.0 CALCULATIONS AND RESULTS

4.1 Maximum Drainage Length and Daily Head

As discussed in Section 3.0, the options for the bottom liner system were analyzed at both the minimum 2.5% and 5% base grade slopes to determine the maximum leachate pipe spacing and resulting leachate head. As demonstrated by these HELP models, drainage lengths of 225 ft and 425 ft yield less than the regulatory maximum allowable head of 30 centimeters (cm) at the 2.5% and 5% base grade slopes, respectively; therefore, the laterals in the leachate collection piping were spaced such that the maximum drainage length to a lateral collection pipe is 225 ft where base grade slopes are less than 5% and 425 ft where base grade slopes are greater than 5%. Figures showing maximum drainage lengths in the base grades and final grades are included in Attachment 11.

4.2 Average-Month and Average-Year Volumes

The average-month leachate generation volumes were calculated based on the daily "Lateral Drainage Collected" values from the leachate drainage layer in the HELP Model outputs. These values were averaged for each condition for all non-zero volumes. The average-year volumes were calculated by summing the average month volumes for each condition. The average-month and average-year volumes are contained in Attachment 2, and the average-month volumes per acre are shown in the graph below.

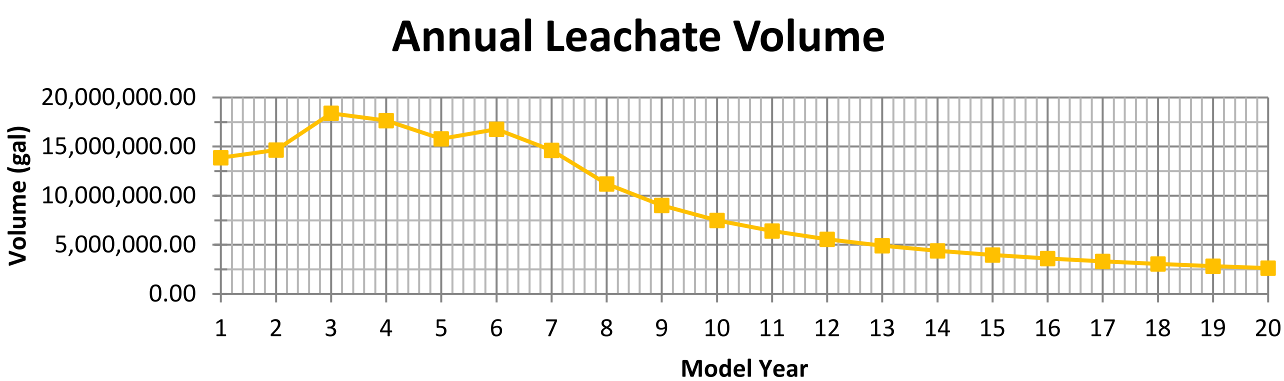


4.3 Annual and Maximum Leachate Volumes

A schedule of leachate volumes was developed (Attachment 3) to calculate the estimated annual leachate volumes produced by the CCR Unit. This schedule was used to determine the maximum expected leachate volume for the Facility, based on the anticipated operating schedule and conditions.

The period that the CCR Unit is expected to be in operation (open CCR) was divided into 10-ft, 25-ft, 40-ft, 50-ft, and 70-ft fill-depth periods of approximately equal time. The CCR Unit was then analyzed for closure conditions immediately following the open phase and for the remainder of CCR Unit's life. The per-acre HELP Model volumes were applied (on an annual basis) to the CCR Unit based on the time spent under each condition. Annual leachate volumes for open conditions were based on the monthly leachate volumes averaged over the entire 20-year HELP Model analysis. The annual leachate volumes for the closed condition varied based on the model year to best simulate the decrease in leachate production over time. The HELP Model volumes were multiplied by the appropriate total disposal area based on condition, which is further discussed in Section 4.4.

By comparing the annual leachate volumes, the maximum annual leachate volume was identified as 18,387,297 gallons during Year 3. Over the projected lifespan of the Facility, an average yearly precipitation rate of 46.7 inches was modeled. The total annual leachate volumes are shown in the graph below.



4.4 Seven-Day Peak Storage

The seven-day peak storage volume was calculated based on the maximum monthly collected leachate volume for each modeled condition. Each maximum was divided by the number of days in the corresponding month to get an average maximum daily that was converted into a seven-day leachate collection volume.

For the 10-ft and 25-ft open CCR conditions, runoff was not included in the model to account for the average CCR waste mass height being below the perimeter berm elevation and the bottom liner system's collection of all precipitation as leachate. By multiplying the per-acre leachate volume by an area, it was determined that the CCR Unit can operate with a maximum active area of 28 acres in these conditions to not exceed the site's leachate tank capacity of 1,000,000 gallons. Calculations for the total leachate volumes assume that the remaining portion of the CCR Unit will be covered to allow clean stormwater run-on to be pumped to the on-site sediment basins and not collected as leachate.

Alternatively, increasing percentages of runoff were allowed for the 40-ft, 50-ft, and 70-ft open CCR conditions to account for increasing areas of sideslope intermediate cover, and under the closed condition, 100% of precipitation was considered as runoff. The percentage of runoff from the intermediate cover is sufficient for these conditions to maintain a peak seven-day storage volume below 1,000,000 gallons.

The peak seven-day storage for the CCR Unit was calculated to be 965,500 gallons in the 10-ft open CCR condition. The seven-day storage volumes are shown in Attachment 4.

5.0 CONCLUSIONS

Based on the above results, the leachate collection system maintains less than 30 cm of head on the liner with the proposed drainage material and collection pipe spacing, and the tanks at the Facility have the capacity to handle the peak leachate flows.

Attachments:

(1) Monthly Collected Leachate Volumes
(2) Average Month and Year Leachate Flows
(3) Annual Leachate Production Under Anticipated Operational Conditions
(4) Seven-Day Storage Volumes
(5) HELP Models, 10-ft CCR
(6) HELP Models, 25-ft CCR
(7) HELP Models, 40-ft CCR
(8) HELP Models, 50-ft CCR
(9) HELP Models, 70-ft CCR
(10) HELP Models, Closed
(11) Maximum Drainage Length Figures
(12) Bottom Liner System Geocomposite Hydraulic Conductivity

References:

(1) Oh, H., Likos, W.J., Edil, T.B. 2021. *Drainability of Base Aggregate and Sand*, NRRA202107, Minnesota Department of Transportation, St. Paul, Minnesota
(2) The Hydrologic Evaluation of Landfill Performance (HELP) Model V4.0.1, January, 2020.
(3) United States Environmental Protection Agency. 2020. *Hydrologic Evaluation of Landfill Performance: HELP 4.0 User Manual*, EPA600/B-20/219, Office of Research and Development (8101R), Washington DC.

HELP Model Analysis Attachment 1

Monthly Collected Leachate Volumes

Attachment 1

		Monthly Collected Leachate Volumes (acre-in/acre)																					
		Year																				Monthly Average	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	ac-in/acre	CF/acre
10' CCR	January	1.4030	1.6238	0.5053	3.2620	4.2531	1.3511	1.8403	2.3339	1.9618	0.7062	0.8573	0.7855	0.6158	2.6775	1.5261	1.5055	1.7414	2.7312	1.3519	0.6189	1.6826	6,107.8
	February	0.9556	1.3266	1.2828	3.7345	2.9240	0.8520	2.3072	1.8396	2.8879	0.4449	0.9510	0.6624	0.4027	3.2211	2.0059	1.3638	2.6506	2.0846	0.8945	1.0793	1.6935	6,147.6
	March	2.2100	2.3563	1.4039	2.3199	5.5360	0.4428	4.5057	1.7044	**5.6237**	0.3445	0.5442	0.1763	0.1132	2.1301	1.2063	1.5625	2.1052	2.1112	0.7296	1.6358	1.9381	7,035.2
	April	1.5175	1.7049	1.4860	2.3924	5.2010	1.8063	2.9372	2.0153	4.3391	0.5792	1.1787	0.7372	0.8822	2.5342	1.6692	1.3292	1.7769	0.9462	0.7841	1.3535	1.8585	6,746.4
	May	1.9466	1.0745	1.6673	2.8996	3.9077	2.0829	2.2502	1.9865	2.7937	1.1755	0.7928	0.3856	0.8815	3.6292	1.1279	2.5130	1.4285	1.0568	0.7255	1.1377	1.7732	6,436.5
	June	1.4473	0.9971	2.7701	2.2047	2.3142	1.3682	1.6882	1.4097	2.0375	1.0328	0.8131	1.0476	0.7125	2.9014	1.0397	1.4596	1.0759	1.4070	0.5090	0.6423	1.4439	5,241.3
	July	1.9108	0.9172	2.5594	2.3786	1.3058	0.9083	1.3240	0.7730	1.2944	0.7350	1.7451	0.7135	0.5171	3.0300	0.6579	1.5710	0.9305	1.2071	0.2537	0.3637	1.2548	4,555.0
	August	1.0432	0.8008	1.7819	0.9922	1.4285	2.0965	1.1103	0.8069	1.4116	0.9757	1.5108	0.9389	0.6596	2.1774	1.5008	1.5524	0.2919	1.0178	0.6057	0.7936	1.1748	4,264.6
	September	1.1467	1.2704	1.2824	2.5244	1.4260	2.1155	0.4694	1.4075	1.0435	0.8683	1.0838	0.4056	0.4213	1.4269	1.3394	1.1542	0.7383	0.7871	0.7297	1.0852	1.1363	4,124.7
	October	1.6590	1.7607	1.0595	2.0854	1.5980	1.4989	2.6701	1.4828	0.9559	0.4549	0.9698	0.9946	0.2578	1.5960	1.1161	1.7994	1.0117	0.6737	0.2918	0.9628	1.2449	4,519.2
	November	1.0369	1.2938	0.3698	1.5233	2.2177	0.8982	2.7994	0.7494	0.7555	1.8022	0.3366	0.7769	0.8674	2.6504	1.5921	1.9151	4.3011	0.6779	1.1896	0.6117	1.4182	5,148.2
	December	1.4570	1.3137	0.7489	0.9416	1.7256	3.2489	2.0816	3.0706	0.6196	1.9013	0.6945	0.7910	2.1378	1.7464	0.8956	2.0133	4.9341	0.5959	1.2277	0.5290	1.6337	5,930.3
25' CCR	January	3.8092	1.8458	0.6142	0.7922	1.4060	2.2963	1.3025	1.8121	1.9383	1.2596	0.9588	1.1557	0.7620	0.6730	1.3551	0.9939	0.7143	3.0271	1.5150	0.6587	1.4445	5,243.5
	February	4.2041	0.8294	0.7027	1.8130	2.3691	1.1124	1.4357	1.9606	1.0511	0.5745	1.0958	0.8006	0.4950	1.4310	2.2101	0.9687	2.1415	2.7075	1.1482	0.1947	1.4623	5,308.1
	March	4.6620	2.4747	1.4196	2.0866	2.4109	0.6176	2.4062	1.6503	2.8445	0.6089	0.6253	0.3499	0.1226	1.3828	1.6297	1.5155	2.3553	3.0132	1.0881	1.2783	1.7271	6,269.4
	April	2.5777	2.1970	0.6996	2.3706	4.0536	1.2700	3.3306	2.2154	3.6567	0.6833	1.0502	0.9353	0.8596	1.1612	2.2282	0.9878	2.3770	1.5979	1.1768	1.4439	1.8436	6,692.3
	May	3.4987	1.7836	1.3920	2.4119	**5.1266**	2.3422	3.1537	2.5851	3.7706	1.3062	0.8199	0.3353	1.0181	2.5847	1.7558	2.1443	2.2107	1.8227	1.1096	1.3719	2.1272	7,721.7
	June	2.1911	1.6479	1.3505	2.4300	3.9721	1.8609	2.7005	1.9348	3.2457	1.1950	0.7773	1.0278	0.8424	1.7787	1.6167	1.7288	1.8000	2.1158	0.5445	0.8491	1.7805	6,463.2
	July	2.9088	1.5875	2.6037	3.2200	2.2779	1.3118	2.3602	1.5492	2.4404	1.0655	1.2718	0.7753	0.7524	3.1949	0.8966	1.9451	1.3291	1.9728	0.6858	0.4257	1.7287	6,275.3
	August	1.8469	1.2178	2.3489	1.2138	2.4177	1.2661	1.9436	1.1320	2.5152	1.3230	1.6526	1.0443	0.8637	2.9091	1.2062	1.4835	1.0350	1.7739	0.9631	0.8117	1.5484	5,620.7
	September	1.5661	0.6519	1.9700	2.4924	1.8894	2.3127	0.7438	1.6273	1.9732	1.2326	1.3973	0.4069	0.5675	2.3328	1.3034	1.1347	1.1047	1.4910	1.0020	1.2417	1.4221	5,162.1
	October	2.3951	1.7266	1.4854	2.7890	1.8027	2.0298	1.5052	1.8447	1.9142	0.6446	1.2257	1.0694	0.2693	1.2179	1.1904	2.0584	0.4903	1.3724	0.4881	1.1986	1.4359	5,212.3
	November	1.2622	1.5023	0.8648	2.2628	2.7465	1.0262	1.9349	0.9788	1.4845	0.5880	0.6526	0.9536	0.5814	2.8334	1.7453	1.3013	0.8864	1.0774	0.3022	0.8610	1.2923	4,691.0
	December	1.6599	1.5908	0.8788	1.4292	2.5520	1.4668	2.2728	1.3971	1.4607	1.7703	1.1422	1.0670	0.3959	2.2727	0.9885	2.0946	2.3899	0.6789	1.0157	0.5346	1.4529	5,274.1
40' CCR	January	2.2910	1.4597	0.4749	0.4590	0.4468	2.1583	0.7497	0.9384	1.3656	1.1829	0.9430	1.1491	0.7874	0.4126	0.6303	0.5689	0.4999	1.6733	1.2997	0.4589	0.9975	3,620.8
	February	1.3298	0.5289	0.4345	0.3596	1.3281	1.0108	0.8722	1.3690	0.7353	0.4326	0.9565	0.5402	0.3919	0.1668	1.5579	0.5183	1.0304	1.4171	1.0232	0.0986	0.8051	2,922.5
	March	2.2404	2.0125	0.9999	1.1124	0.8826	0.5086	0.9820	0.9670	1.1484	1.0338	0.4363	0.4397	0.1522	0.8876	1.2942	0.9642	1.6247	2.1973	1.0284	0.7834	1.0848	3,937.7
	April	1.7656	2.0011	0.4528	1.3005	1.7402	1.1387	2.1627	1.5854	1.8742	0.7180	0.9634	0.8483	0.8320	0.4703	1.7039	0.5731	1.9432	1.5900	1.1530	1.1330	1.2975	4,709.8
	May	2.2260	1.7988	0.9266	1.3803	**3.1711**	2.0429	2.2448	2.2423	2.7723	1.3468	0.7446	0.4418	0.9617	0.6123	1.4951	1.3372	1.9900	1.4342	1.0767	1.1285	1.5687	5,694.4
	June	1.5777	1.6851	0.7326	1.7593	2.8634	1.7811	2.2217	1.8319	2.6353	1.1953	0.5873	0.9177	0.7650	0.6443	1.4455	1.4866	1.7283	1.7101	0.6172	0.7776	1.4482	5,256.8
	July	2.3383	1.6537	1.7589	2.4711	2.2824	1.1920	2.1306	1.8261	2.2157	1.2101	1.0177	0.7656	0.7943	1.5478	0.7263	1.5037	1.4279	1.7409	0.8884	0.4099	1.4951	5,427.1
	August	1.9543	1.0767	1.7981	0.9001	1.9778	1.0003	1.8825	0.9319	2.3353	1.3265	1.3421	0.8461	0.8380	1.7881	0.8672	1.1859	1.3335	1.6599	1.0178	0.6765	1.3369	4,853.0
	September	1.3374	0.5040	1.6470	1.8074	1.3861	1.8835	0.6814	1.5673	1.9878	1.2149	1.3141	0.5108	0.7482	1.5657	0.9528	0.8341	1.0136	1.4612	0.9161	1.0061	1.2170	4,417.6
	October	2.1496	1.4655	1.2615	2.3050	1.4178	1.8260	0.9024	1.6715	1.9779	0.4664	1.0564	0.9867	0.2376	0.6437	1.0413	1.5594	0.4786	1.4286	0.3700	0.9921	1.2119	4,399.2
	November	0.9845	1.3332	0.7923	2.0226	2.1338	0.9020	0.9757	0.8014	1.6975	0.5078	0.7391	0.8900	0.5775	1.5462	1.3031	0.7671	0.5018	0.9262	0.2827	0.7352	1.0210	3,706.2
	December	1.4101	1.2750	0.6646	1.2198	2.2317	0.8168	1.6184	0.7955	1.6893	1.4283	1.1249	0.9953	0.2799	1.5182	0.7241	1.5306	0.4056	0.6541	0.7619	0.4294	1.0787	3,915.6
50' CCR	January	0.7511	1.3147	0.4973	0.4478	0.4918	2.2384	0.8282	0.8122	1.4220	1.3764	1.0511	1.2314	0.8804	0.4084	0.5390	0.5032	0.5582	1.5714	1.3928	0.5117	0.9414	3,417.2
	February	0.4462	0.2990	0.2995	0.2579	1.0667	1.1386	0.8281	1.3916	0.7764	0.4832	1.0433	0.6421	0.4218	0.1152	1.4406	0.5160	0.7552	1.1670	1.1018	0.1251	0.7158	2,598.2
	March	0.4140	1.4802	0.9719	0.9079	0.8356	0.5699	0.7956	0.8915	0.8792	1.0973	0.5177	0.4889	0.1878	0.8399	1.1875	0.9560	1.4991	2.1597	1.1220	0.7834	0.9292	3,373.1
	April	1.3634	1.7832	0.3504	0.9768	1.3139	1.0540	2.0882	1.5538	1.6827	0.8619	0.9308	0.9318	0.8769	0.4416	1.6181	0.5788	1.8742	1.5152	1.2440	1.1713	1.2106	4,394.3
	May	0.8050	1.5968	0.8126	1.1296	**2.9135**	2.1123	2.1782	2.2071	2.5660	1.4282	0.8506	0.4722	1.0074	0.4020	1.4954	1.0440	1.9800	1.4365	1.1716	1.1899	1.4399	5,227.0
	June	1.2389	1.5602	0.5918	1.5837	2.7273	1.8696	2.2902	1.8530	2.6018	1.3355	0.6773	0.9903	0.8534	0.6779	1.4684	1.4813	1.7777	1.7292	0.7409	0.8546	1.4452	5,245.9
	July	1.3606	1.5854	1.5998	2.2706	2.2777	1.3202	2.1162	1.8653	2.2144	1.3169	0.9874	0.8330	0.8565	1.1901	0.8062	1.5552	1.5458	1.7963	0.9775	0.4418	1.4458	5,248.4
	August	1.2605	1.1254	1.7353	1.0220	1.9327	0.9540	2.0240	1.0111	2.3294	1.4496	1.3937	0.9387	0.9076	1.6072	0.7476	1.0607	1.3550	1.7414	1.1138	0.7018	1.3206	4,793.7
	September	1.0186	0.3502	1.6282	1.5145	1.3352	1.9446	0.7731	1.5774	2.0470	1.3349	1.3800	0.5498	0.8178	1.4408	0.9315	0.8613	1.1406	1.5523	1.0017	1.0546	1.2127	4,402.1
	October	1.5397	1.3629	1.3207	2.2773	1.4394	1.9784	0.8583	1.7785	2.0871	0.5375	1.1726	1.0509	0.2498	0.7913	1.0991	1.5751	0.4923	1.5313	0.4192	1.0600	1.2311	4,468.8
	November	0.9294	1.2343	0.7714	1.9510	2.1186	0.9436	0.9083	0.8781	1.8395	0.5086	0.7848	0.9605	0.6407	1.2256	1.2575	0.6764	0.5085	1.0524	0.3090	0.7782	1.0138	3,680.1
	December	0.8469	1.3144	0.7124	1.2770	2.3287	0.7505	1.7003	0.7026	1.8315	1.4939	1.1882	1.0641	0.3275	1.4978	0.7862	1.5477	0.3081	0.6813	0.8611	0.4652	1.0843	3,935.9
70' CCR	January	1.2603	0.0353	0.6537	0.4419	0.6519	2.0073	0.8713	0.5455	1.2888	1.6418	1.1706	1.2551	1.0505	0.3810	0.5920	0.4018	0.7312	0.6944	1.2784	0.6627	0.8808	3,197.2
	February	0.4885	0.0569	0.2765	0.3646	0.4250	1.3229	0.6767	1.1637	0.7966	0.6257	1.0861	0.9349	0.5972	0.1994	0.7430	0.4325	0.2729	0.6372	1.0947	0.2523	0.6223	2,259.1
	March	0.8455	0.1579	0.7679	0.3743	0.8713	0.6271	0.7786	0.6846	0.5149	0.8160	0.7663	0.4022	0.1463	0.4746	1.0998	0.6816	0.8563	1.5968	1.0612	0.3651	0.6944	2,520.7
	April	1.6496	1.1262	0.4142	0.4969	0.6483	0.4697	1.4000	0.9038	0.6953	1.0078	0.5705	1.0547	0.7313	0.4390	1.2172	0.5481	1.4585	1.4179	1.2034	1.0555	0.9254	3,359.1
	May	1.5342	0.5582	0.5964	0.5495	1.4992	1.8577	1.6340	1.8824	2.0873	1.3351	1.0655	0.5103	1.0138	0.3109	1.3228	0.3070	1.6918	1.3032	1.1866	1.1546	1.1700	4,247.2
	June	1.5239	1.3198	0.5005	1.0679	2.0484	1.7451	1.9326	1.8531	**2.1371**	1.4761	0.8499	1.0258	0.9701	0.5792	1.3263	1.2715	1.6368	1.4626	0.9452	0.9641	1.3318	4,834.4
	July	1.5757	0.9227	1.1984	1.7537	1.9864	1.4551	1.9911	1.6545	2.1080	1.3880	0.7642	0.8518	0.8959	0.5048	1.0032	1.4227	1.5783	1.6339	0.9450	0.6338	1.3133	4,767.5
	August	1.3516	1.2429	1.5504	1.3135	1.9066	0.6216	2.0006	1.2554	2.1356	1.5341	1.3849	1.0664	0.9718	1.2199	0.3508	0.6600	1.2932	1.6215	1.1262	0.5225	1.2565	4,561.0
	September	0.3191	1.1897	1.5036	0.6772	0.9581	1.7025	0.8993	1.3211	2.0000	1.4504	1.3555	0.5407	0.9795	1.2255	0.7678	0.9738	1.2363	1.5205	1.1579	0.9860	1.1382	4,131.7
	October	1.1649	1.1404	1.4686	1.7954	1.4093	1.7721	0.6301	1.6842	2.0093	0.7979	1.3305	1.0201	0.3863	1.1484	1.0382	1.2726	0.5642	1.5091	0.5802	1.1134	1.1918	4,326.1
	November	1.1430	1.1859	0.8330	1.8462	1.4892	1.2319	0.6656	1.1257	1.8544	0.2495	0.8559	1.0065	0.7033	0.4814	0.9486	0.5712	0.4650	1.3109	0.2402	0.9035	0.9555	3,468.6
	December	1.4008	0.6492	0.8493	1.2918	1.9888	0.5597	1.4995	0.3871	1.8283	1.3466	1.1749	1.0846	0.4912	1.3137	0.9675	1.2428	0.4020	0.4510	0.8699	0.5981	1.0198	3,702.0
Closed	January	0.4911	1.1295	0.8405	0.6639	0.5452	0.4609	0.3979	0.3491	0.3103	0.2789	0.2529	0.2310	0.2124	0.1964	0.1825	0.1703	0.1595	0.1500	0.1414	0.1337	0.3649	1,324.5
	February	0.7131	0.9932	0.7434	0.5894	0.4854	0.4111	0.3554	0.3122	0.2778	0.2498	0.2267	0.2072	0.1906	0.1763	0.1639	0.1530	0.1433	0.1348	0.1271	0.1203	0.3387	1,229.5
	March	1.1204	1.0711	0.8063	0.6416	0.5297	0.4495	0.3891	0.3423	0.3048	0.2743	0.2491	0.2278	0.2096	0.1940	0.1804	0.1685	0.1579	0.1485	0.1401	0.1326	0.3869	1,404.4
	April	1.2028	1.0094	0.7642	0.6103	0.5052	0.4295	0.3724	0.3279	0.2923	0.2633	0.2392	0.2189	0.2015	0.1866	0.1736	0.1621	0.1520	0.1430	0.1350	0.1277	0.3758	1,364.3
	May	**1.2903**	1.0163	0.7736	0.6201	0.5145	0.4382	0.3805	0.3355	0.2993	0.2698	0.2453	0.2246	0.2069	0.1916	0.1783	0.1666	0.1563	0.1470	0.1388	0.1314	0.3862	1,402.0
	June	1.2475	0.9589	0.7337	0.5901	0.4909	0.4188	0.3642	0.3214	0.2870	0.2589	0.2356	0.2158	0.1989	0.1843	0.1716	0.1604	0.1504	0.1416	0.1337	0.1266	0.3695	1,341.3
	July	1.2713	0.9665	0.7433	0.5998	0.5001	0.4275	0.3722	0.3289	0.2939	0.2654	0.2416	0.2214	0.2042	0.1893	0.1763	0.1648	0.1546	0.1456	0.1375	0.1302	0.3767	1,367.5
	August	1.2464	0.9429	0.7287	0.5900	0.4931	0.4222	0.3681	0.3256	0.2913	0.2632	0.2397	0.2199	0.2028	0.1881	0.1752	0.1639	0.1538	0.1449	0.1369	0.1296	0.3713	1,347.9
	September	1.1804	0.8910	0.6918	0.5618	0.4706	0.4037	0.3524	0.3121	0.2794	0.2527	0.2303	0.2113	0.1950	0.1809	0.1686	0.1578	0.1481	0.1395	0.1318	0.1249	0.3542	1,285.8
	October	1.2019	0.8994	0.7015	0.5715	0.4797	0.4122	0.3603	0.3194	0.2862	0.2590	0.2362	0.2168	0.2002	0.1858	0.1732	0.1621	0.1523	0.1435	0.1356	0.1285	0.3613	1,311.4
	November	1.1575	0.8507	0.6664	0.5445	0.4581	0.3942	0.3450	0.3062	0.2746	0.2486	0.2269	0.2084	0.1925	0.1787	0.1667	0.1561	0.1466	0.1382	0.1306	0.1238	0.3457	1,254.9
	December	1.1626	0.8595	0.6761	0.5540	0.4671	0.4026	0.3528	0.3134	0.2813	0.2549	0.2327	0.2139	0.1977	0.1836	0.1713	0.1604	0.1507	0.1421	0.1343	0.1273	0.3519	1,277.5

		Year																				Monthly Average
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Precipitation (in)	January	4.78	3.56	2.65	4.30	3.61	6.04	5.40	2.95	7.88	4.18	3.73	2.37	2.95	2.19	1.77	3.65	3.07	3.02	1.15	2.52	3.59
	February	2.24	2.10	4.28	3.31	6.16	2.07	4.04	2.57	7.45	2.34	1.59	1.92	0.84	5.25	1.63	2.58	1.76	1.12	0.99	0.46	2.74
	March	4.70	4.29	4.23	5.49	9.48	3.59	3.78	4.54	5.36	3.16	2.19	5.43	3.75	5.68	2.25	4.27	0.34	4.34	2.07	3.47	4.12
	April	2.92	1.77	3.81	6.15	2.49	2.23	2.37	3.75	4.40	1.63	5.12	0.97	1.52	4.61	3.08	3.57	1.53	3.23	5.23	2.40	3.14
	May	7.35	3.11	6.77	4.25	2.63	6.27	4.77	1.10	4.20	4.51	5.94	3.96	3.80	10.11	5.50	3.99	3.28	3.24	3.58	7.59	4.80
	June	1.22	3.33	2.47	1.66	4.80	8.70	2.89	5.02	4.06	2.09	3.88	3.62	1.95	4.80	5.60	1.56	6.26	4.13	3.49	6.39	3.90
	July	3.40	10.01	2.88	6.64	7.04	6.17	6.34	6.31	1.95	3.40	2.01	4.23	2.86	4.78	9.43	6.51	2.07	3.26	3.13	2.68	4.76
	August	4.20	3.33	1.66	5.32	5.13	1.37	5.99	3.03	2.94	3.23	2.51	1.72	5.38	3.54	4.65	5.40	4.65	2.51	5.19	2.50	3.71
	September	1.00	2.38	4.00	2.12	4.82	3.36	9.79	3.91	1.30	10.76	4.58	2.00	2.49	9.58	4.84	0.38	7.55	0.39	6.07	2.72	4.20
	October	5.67	1.14	1.79	3.21	1.92	9.10	4.84	6.19	1.87	1.86	0.00	0.61	6.07	2.45	1.40	7.40	11.63	7.01	0.77	2.75	4.09
	November	1.90	1.45	9.11	8.24	1.72	4.75	2.69	4.42	1.37	2.77	1.52	0.66	5.16	3.23	5.79	3.25	5.63	0.67	2.45	8.17	3.75
	December	4.24	6.23	5.38	6.08	1.03	3.00	5.22	3.27	2.96	2.34	1.55	2.93	5.10	4.15	2.76	5.84	1.46	2.66	3.87	7.89	3.90
	Total	43.62	42.70	49.03	56.77	50.83	56.65	58.12	47.06	45.74	42.27	34.62	30.42	41.87	60.37	48.70	48.40	49.23	35.58	37.99	49.54	

HELP Model Analysis Attachment 2

Average Month and Year Leachate Flows

Attachment 2

		Condition	Average-Month Leachate Flow Per Acre												Average-Year Leachate Flow Per Acre
			January	February	March	April	May	June	July	August	September	October	November	December	
			gal	*gal*	*gal*	*gal*	*gal*	*gal*	*gal*	*gal*	*gal*	*gal*	*gal*	*gal*	*gal*
Bremo FFCP Facility	*1.00 ac*	10' CCR	45,689	45,987	52,627	50,467	48,149	39,208	34,073	31,902	30,855	33,806	38,511	44,362	495,635
		25' CCR	39,224	39,708	46,899	50,062	57,762	48,348	46,943	42,046	38,615	38,990	35,091	39,453	523,140
		40' CCR	27,086	21,862	29,456	35,232	42,597	39,324	40,598	36,303	33,046	32,908	27,724	29,290	395,426
		50' CCR	25,562	19,436	25,233	32,872	39,101	39,242	39,261	35,859	32,930	33,429	27,529	29,443	379,897
		70' CCR	23,917	16,899	18,856	25,128	31,771	36,164	35,663	34,119	30,907	32,361	25,947	27,693	339,426
		Closed	9,908	9,197	10,506	10,206	10,488	10,034	10,229	10,083	9,618	9,810	9,387	9,556	119,022

HELP Model Analysis Attachment 3

Annual Leachate Production Under Anticipated Operational Conditions

Attachment 3

Annual Leachate Production Under Anticipated Operational Conditions

Model Year	Annual Rainfall	HELP Model Leachate Production Volumes						Bremo FFCP Facility				
										Size:	46.5	*Acres*
		10' CCR	25' CCR	40' CCR	50' CCR	70' CCR	Closed	**Active Area**	**Closed**	**Condition**		**Annual Volume**
										Status	Year	
#	*in*	*CF/ac*	*CF/ac*	*CF/ac*	*CF/ac*	*CF/ac*	*CF/ac*	*ac*	*ac*		*#*	*gal*
1	43.62	64372.85	118271.80	78425.46	43466.34	51753.18	48225.72	28.00	0.00	10' CCR	1	13,877,789.06
2	42.70	59676.24	69170.79	60963.20	54474.12	34793.18	42066.45	28.00	0.00	25' CCR	1	14,647,932.17
3	49.03	61409.53	59278.72	43355.75	40987.35	38523.33	32196.29	46.50	0.00	40' CCR	1	18,387,297.06
4	56.77	98948.81	91880.52	62062.20	56686.40	43461.38	25906.96	46.50	0.00	50' CCR	1	17,665,220.17
5	50.83	122830.64	119878.83	79358.90	75435.45	57653.31	21560.80	46.50	0.00	70' CCR	1	15,783,298.63
6	56.65	67770.67	68653.51	59027.55	61252.61	55802.48	18404.68	0.00	46.50	Closed	1	16,775,034.46
7	58.12	94320.53	91075.55	63249.51	63121.02	54374.78	16009.87	0.00	46.50	Closed	2	14,632,568.81
8	47.06	71073.88	75095.42	59995.43	59975.66	52493.44	14134.85	0.00	46.50	Closed	3	11,199,290.54
9	45.74	93378.61	102711.89	81437.89	80865.90	70623.04	12626.08	0.00	46.50	Closed	4	9,011,584.50
10	42.27	40004.25	44473.38	43789.32	48003.03	49617.98	11393.87	0.00	46.50	Closed	5	7,499,798.65
11	34.62	41663.72	45990.00	40748.37	43478.50	44919.98	10367.34	0.00	46.50	Closed	6	6,401,961.02
12	30.42	30546.63	36013.64	33872.37	36857.91	39033.60	9499.91	0.00	46.50	Closed	7	5,568,937.64
13	41.87	30741.94	27334.05	26737.50	29140.12	32441.84	8756.09	0.00	46.50	Closed	8	4,916,726.17
14	60.37	107886.09	86292.78	42847.29	38615.38	30047.78	8115.03	0.00	46.50	Closed	9	4,391,909.48
15	48.70	56907.40	65797.72	49881.96	48559.25	41299.06	7555.79	0.00	46.50	Closed	10	3,963,292.35
16	48.40	71652.09	66634.76	46569.13	44851.06	35521.40	7063.98	0.00	46.50	Closed	11	3,606,217.10
17	49.23	83440.48	68368.54	50738.82	50074.65	44237.59	6627.22	0.00	46.50	Closed	12	3,304,487.59
18	35.58	55526.32	82221.62	64951.51	65099.90	55027.04	6238.97	0.00	46.50	Closed	13	3,045,753.06
19	37.99	33732.63	40072.44	37878.94	41583.00	42430.51	5890.85	0.00	46.50	Closed	14	2,822,764.02
20	49.54	39252.89	39458.21	31323.62	33169.83	33437.69	5577.07	0.00	46.50	Closed	15	2,628,237.94

HELP Model Analysis Attachment 4

Seven-Day Storage Volumes

Seven-Day Storage Volume							
Condition	Max Month Leachate Production	Max Month Leachate Production (ft^3/acre)	Average Daily (cf/day/acre)	7-Day Volume (cf/acre)	Active Area	7-Day Volume (ft^3)	7-Day Volume (gal)
10' CCR	**5.6237**	**20,413.91**	**658.51**	**4,609.59**	28.0	**129,068.61**	**965,500.35**
25' CCR	5.1266	18,609.55	620.32	4,342.23	28.0	121,582.38	909,499.39
40' CCR	3.1711	11,511.27	383.71	2,685.96	45.6	122,479.93	916,213.56
50' CCR	2.9135	10,576.14	352.54	2,467.77	45.6	112,530.12	841,783.84
70' CCR	2.1371	7,757.77	258.59	1,810.15	45.6	82,542.67	617,462.10
Closed	1.2903	4,683.68	156.12	1,092.86	45.6	49,834.41	372,787.27

HELP Model Analysis Attachment 5

HELP Model, 10-ft CCR

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Bremo FFCP Mgmt Facility **Simulated On:** 6/14/2023 10:52

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	120	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.3177	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
VDOT Stone
Material Texture Number 44

Thickness	=	18	inches
Porosity	=	0.39	vol/vol
Field Capacity	=	0.04	vol/vol
Wilting Point	=	0.013	vol/vol
Initial Soil Water Content	=	0.1468	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
250-mil Geocomposite
Material Texture Number 123

Thickness	=	0.25	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.1132	vol/vol
Effective Sat. Hyd. Conductivity	=	2.20E+00	cm/sec
Slope	=	5	%
Drainage Length	=	425	ft

Layer 4

Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 5

Type 3 - Barrier Soil Liner
Geosynthetic Clay Liner
Material Texture Number 43

Thickness	=	0.276	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.40E-09	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	91	
Fraction of Area Allowing Runoff	=	0	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	6	inches
Initial Water in Evaporative Zone	=	2.603	inches
Upper Limit of Evaporative Storage	=	3.246	inches
Lower Limit of Evaporative Storage	=	0.282	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	41.004	inches
Total Initial Water	=	41.004	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	37.71	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	90	days

End of Growing Season (Julian Date)	=	304	days
Average Wind Speed	=	5	mph
Average 1st Quarter Relative Humidity	=	58	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	77	%
Average 4th Quarter Relative Humidity	=	61	%

Note: Evapotranspiration data was obtained for Bremo Bluff, Virginia

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
3.365862	2.758621	3.928621	3.318276	4.841379	4.375517
4.655517	3.91	4.344828	3.914483	3.501724	3.806552

Note: Precipitation was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
36.4	38.7	46.2	56.3	64.7	73.3
77.5	76	69.3	58.1	47.8	40.4

Note: Temperature was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 37.71/-78.27

Average Annual Totals Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/14/2023 10:53

	Average Annual Totals for Years 1 - 20*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	46.48	[8.08]	168,706.1	100.00
Runoff	0.000	[0]	0.0000	0.00
Evapotranspiration	27.868	[3.098]	101,159.5	59.96
Subprofile1				
Lateral drainage collected from Layer 3	18.2643	[7.41]	66,299.5	39.30
Percolation/leakage through Layer 5	0.000003	[0]	0.0097	0.00
Average Head on Top of Layer 4	0.0352	[0.0156]	---	---
Water storage				
Change in water storage	0.3435	[4.9191]	1,247.1	0.74

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/14/2023 10:53

	Peak Values for Years 1 - 20*	
	(inches)	(cubic feet)
Precipitation	5.45	19,783.5
Runoff	0.000	0.0000
Subprofile1		
Drainage collected from Layer 3	0.3669	1,332.0
Percolation/leakage through Layer 5	0.000001	0.0024
Average head on Layer 4	5.9315	---
Maximum head on Layer 4	10.5336	---
Location of maximum head in Layer 3	43.33	(feet from drain)
Other Parameters		
Snow water	3.6144	13,120.2
Maximum vegetation soil water	0.5410	(vol/vol)
Minimum vegetation soil water	0.0470	(vol/vol)

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/14/2023 10:53
Simulation period: 20 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	44.7764	0.3731
2	2.8143	0.1563
3	0.0772	0.3088
4	0.0000	0.0000
5	0.2070	0.7500
Snow water	0.0000	---

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Bremo FFCP Mgmt Facility **Simulated On:** 5/13/2024 14:52

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	120	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.3177	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
VDOT Stone
Material Texture Number 44

Thickness	=	18	inches
Porosity	=	0.39	vol/vol
Field Capacity	=	0.04	vol/vol
Wilting Point	=	0.013	vol/vol
Initial Soil Water Content	=	0.1468	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
250-mil Geocomposite
Material Texture Number 123

Thickness	=	0.25	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.1186	vol/vol
Effective Sat. Hyd. Conductivity	=	2.20E+00	cm/sec
Slope	=	2.5	%
Drainage Length	=	225	ft

Layer 4

Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 5

Type 3 - Barrier Soil Liner
Geosynthetic Clay Liner
Material Texture Number 43

Thickness	=	0.276	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.40E-09	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	91	
Fraction of Area Allowing Runoff	=	0	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	6	inches
Initial Water in Evaporative Zone	=	2.603	inches
Upper Limit of Evaporative Storage	=	3.246	inches
Lower Limit of Evaporative Storage	=	0.282	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	41.005	inches
Total Initial Water	=	41.005	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	37.71	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	90	days

End of Growing Season (Julian Date)	=	304	days
Average Wind Speed	=	5	mph
Average 1st Quarter Relative Humidity	=	58	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	77	%
Average 4th Quarter Relative Humidity	=	61	%

Note: Evapotranspiration data was obtained for Bremo Bluff, Virginia

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
3.365862	2.758621	3.928621	3.318276	4.841379	4.375517
4.655517	3.91	4.344828	3.914483	3.501724	3.806552

Note: Precipitation was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
36.4	38.7	46.2	56.3	64.7	73.3
77.5	76	69.3	58.1	47.8	40.4

Note: Temperature was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 37.71/-78.27

Average Annual Totals Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/13/2024 14:53

	Average Annual Totals for Years 1 - 20*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	46.48	[8.08]	168,706.1	100.00
Runoff	0.000	[0]	0.0000	0.00
Evapotranspiration	27.868	[3.098]	101,159.5	59.96
Subprofile1				
Lateral drainage collected from Layer 3	18.2642	[7.4105]	66,299.1	39.30
Percolation/leakage through Layer 5	0.000003	[0]	0.0098	0.00
Average Head on Top of Layer 4	0.0374	[0.017]	---	---
Water storage				
Change in water storage	0.3437	[4.92]	1,247.5	0.74

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/13/2024 14:53

	Peak Values for Years 1 - 20*	
	(inches)	(cubic feet)
Precipitation	5.45	19,783.5
Runoff	0.000	0.0000
Subprofile1		
Drainage collected from Layer 3	0.3515	1,275.8
Percolation/leakage through Layer 5	0.000001	0.0032
Average head on Layer 4	7.8052	---
Maximum head on Layer 4	11.6341	---
Location of maximum head in Layer 3	57.21 (feet from drain)	
Other Parameters		
Snow water	3.6144	13,120.2
Maximum vegetation soil water	0.5410 (vol/vol)	
Minimum vegetation soil water	0.0470 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/13/2024 14:53
Simulation period: 20 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	44.7764	0.3731
2	2.8143	0.1563
3	0.0808	0.3234
4	0.0000	0.0000
5	0.2070	0.7500
Snow water	0.0000	---

HELP Model Analysis Attachment 6

HELP Model, 25-ft CCR

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Bremo FFCP Mgmt Facility **Simulated On:** 6/15/2023 10:57

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	300	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.3731	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
VDOT Stone
Material Texture Number 44

Thickness	=	18	inches
Porosity	=	0.39	vol/vol
Field Capacity	=	0.04	vol/vol
Wilting Point	=	0.013	vol/vol
Initial Soil Water Content	=	0.1563	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
250-mil Geocomposite
Material Texture Number 123

Thickness	=	0.25	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.3088	vol/vol
Effective Sat. Hyd. Conductivity	=	2.20E+00	cm/sec
Slope	=	5	%
Drainage Length	=	425	ft

Layer 4

Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 5
Type 3 - Barrier Soil Liner
Geosynthetic Clay Liner
Material Texture Number 43

Thickness	=	0.276	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.40E-09	cm/sec

Note: Initial moisture content of the layers and snow water were specified by the user.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	91	
Fraction of Area Allowing Runoff	=	0	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	6	inches
Initial Water in Evaporative Zone	=	2.239	inches
Upper Limit of Evaporative Storage	=	3.246	inches
Lower Limit of Evaporative Storage	=	0.282	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	115.028	inches
Total Initial Water	=	115.028	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	37.71	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	90	days

End of Growing Season (Julian Date)	=	304	days
Average Wind Speed	=	5	mph
Average 1st Quarter Relative Humidity	=	58	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	77	%
Average 4th Quarter Relative Humidity	=	61	%

Note: Evapotranspiration data was obtained for Bremo Bluff, Virginia

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
3.365862	2.758621	3.928621	3.318276	4.841379	4.375517
4.655517	3.91	4.344828	3.914483	3.501724	3.806552

Note: Precipitation was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
36.4	38.7	46.2	56.3	64.7	73.3
77.5	76	69.3	58.1	47.8	40.4

Note: Temperature was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 37.71/-78.27

Average Annual Totals Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/15/2023 10:58

	Average Annual Totals for Years 1 - 20*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	46.48	[8.08]	168,706.1	100.00
Runoff	0.000	[0]	0.0000	0.00
Evapotranspiration	27.860	[3.096]	101,130.7	59.94
Subprofile1				
Lateral drainage collected from Layer 3	19.2729	[7.3252]	69,960.6	41.47
Percolation/leakage through Layer 5	0.000003	[0]	0.0094	0.00
Average Head on Top of Layer 4	0.0360	[0.0137]	---	---
Water storage				
Change in water storage	-0.6571	[6.7855]	-2,385.2	-1.41

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/15/2023 10:58

	Peak Values for Years 1 - 20*	
	(inches)	(cubic feet)
Precipitation	5.45	19,783.5
Runoff	0.000	0.0000
Subprofile1		
Drainage collected from Layer 3	0.2457	892.0
Percolation/leakage through Layer 5	0.000000	0.0001
Average head on Layer 4	0.1677	---
Maximum head on Layer 4	0.3328	---
Location of maximum head in Layer 3	2.09	(feet from drain)
Other Parameters		
Snow water	3.6144	13,120.2
Maximum vegetation soil water	0.5410	(vol/vol)
Minimum vegetation soil water	0.0470	(vol/vol)

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/15/2023 10:58
Simulation period: 20 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	99.4441	0.3315
2	2.2268	0.1237
3	0.0078	0.0311
4	0.0000	0.0000
5	0.2070	0.7500
Snow water	0.0000	---

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Bremo FFCP Mgmt Facility **Simulated On:** 5/13/2024 15:02

Layer 1

Type 1 - Vertical Percolation Layer (Cover Soil)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	300	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.3177	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 2

Type 2 - Lateral Drainage Layer
VDOT Stone
Material Texture Number 44

Thickness	=	18	inches
Porosity	=	0.39	vol/vol
Field Capacity	=	0.04	vol/vol
Wilting Point	=	0.013	vol/vol
Initial Soil Water Content	=	0.1468	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec

Layer 3

Type 2 - Lateral Drainage Layer
250-mil Geocomposite
Material Texture Number 123

Thickness	=	0.25	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.1186	vol/vol
Effective Sat. Hyd. Conductivity	=	2.20E+00	cm/sec
Slope	=	2.5	%
Drainage Length	=	225	ft

Layer 4

Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 5

Type 3 - Barrier Soil Liner
Geosynthetic Clay Liner
Material Texture Number 43

Thickness	=	0.276	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.40E-09	cm/sec

Note: Initial moisture content of the layers and snow water were specified by the user.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	91	
Fraction of Area Allowing Runoff	=	0	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	6	inches
Initial Water in Evaporative Zone	=	1.906	inches
Upper Limit of Evaporative Storage	=	3.246	inches
Lower Limit of Evaporative Storage	=	0.282	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	98.189	inches
Total Initial Water	=	98.189	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	37.71	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	90	days

End of Growing Season (Julian Date)	=	304	days
Average Wind Speed	=	5	mph
Average 1st Quarter Relative Humidity	=	58	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	77	%
Average 4th Quarter Relative Humidity	=	61	%

Note: Evapotranspiration data was obtained for Bremo Bluff, Virginia

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
3.365862	2.758621	3.928621	3.318276	4.841379	4.375517
4.655517	3.91	4.344828	3.914483	3.501724	3.806552

Note: Precipitation was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
36.4	38.7	46.2	56.3	64.7	73.3
77.5	76	69.3	58.1	47.8	40.4

Note: Temperature was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 37.71/-78.27

Average Annual Totals Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/13/2024 15:03

	Average Annual Totals for Years 1 - 20*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	46.48	[8.08]	168,706.1	100.00
Runoff	0.000	[0]	0.0000	0.00
Evapotranspiration	27.854	[3.097]	101,109.6	59.93
Subprofile1				
Lateral drainage collected from Layer 3	18.4337	[6.6374]	66,914.5	39.66
Percolation/leakage through Layer 5	0.000003	[0]	0.0094	0.00
Average Head on Top of Layer 4	0.0364	[0.0131]	---	---
Water storage				
Change in water storage	0.1879	[5.9702]	682.0	0.40

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/13/2024 15:03

	Peak Values for Years 1 - 20*	
	(inches)	(cubic feet)
Precipitation	5.45	19,783.5
Runoff	0.000	0.0000
Subprofile1		
Drainage collected from Layer 3	0.2459	892.5
Percolation/leakage through Layer 5	0.000000	0.0001
Average head on Layer 4	0.1773	---
Maximum head on Layer 4	0.3466	---
Location of maximum head in Layer 3	4.90	(feet from drain)
Other Parameters		
Snow water	3.6144	13,120.2
Maximum vegetation soil water	0.5410	(vol/vol)
Minimum vegetation soil water	0.0470	(vol/vol)

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/13/2024 15:03
Simulation period: 20 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	99.5033	0.3317
2	2.2282	0.1238
3	0.0080	0.0320
4	0.0000	0.0000
5	0.2070	0.7500
Snow water	0.0000	---

HELP Model Analysis Attachment 7

HELP Model, 40-ft CCR

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Bremo FFCP Mgmt Facility **Simulated On:** 6/29/2023 9:47

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	480	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.3315	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
VDOT Stone
Material Texture Number 44

Thickness	=	18	inches
Porosity	=	0.39	vol/vol
Field Capacity	=	0.04	vol/vol
Wilting Point	=	0.013	vol/vol
Initial Soil Water Content	=	0.1237	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-01	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
250-mil Geocomposite
Material Texture Number 123

Thickness	=	0.25	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.0311	vol/vol
Effective Sat. Hyd. Conductivity	=	2.20E+00	cm/sec
Slope	=	5	%
Drainage Length	=	425	ft

Layer 4

Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 5

Type 3 - Barrier Soil Liner
Geosynthetic Clay Liner
Material Texture Number 43

Thickness	=	0.276	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.40E-09	cm/sec

Note: Initial moisture content of the layers and snow water were specified by the user.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	91	
Fraction of Area Allowing Runoff	=	39	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	6	inches
Initial Water in Evaporative Zone	=	1.989	inches
Upper Limit of Evaporative Storage	=	3.246	inches
Lower Limit of Evaporative Storage	=	0.282	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	161.561	inches
Total Initial Water	=	161.561	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	37.71	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	90	days

End of Growing Season (Julian Date)	=	304	days
Average Wind Speed	=	5	mph
Average 1st Quarter Relative Humidity	=	58	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	77	%
Average 4th Quarter Relative Humidity	=	61	%

Note: Evapotranspiration data was obtained for Bremo Bluff, Virginia

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
3.365862	2.758621	3.928621	3.318276	4.841379	4.375517
4.655517	3.91	4.344828	3.914483	3.501724	3.806552

Note: Precipitation was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
36.4	38.7	46.2	56.3	64.7	73.3
77.5	76	69.3	58.1	47.8	40.4

Note: Temperature was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 37.71/-78.27

Average Annual Totals Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/29/2023 9:48

	Average Annual Totals for Years 1 - 20*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	46.48	[8.08]	168,706.1	100.00
Runoff	5.009	[1.824]	18,181.0	10.78
Evapotranspiration	27.517	[3.096]	99,886.2	59.21
Subprofile1				
Lateral drainage collected from Layer 3	14.5688	[4.4107]	52,884.8	31.35
Percolation/leakage through Layer 5	0.000002	[0]	0.0091	0.00
Average Head on Top of Layer 4	0.0274	[0.0086]	---	---
Water storage				
Change in water storage	-0.6187	[5.4316]	-2,245.8	-1.33

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/29/2023 9:48

	Peak Values for Years 1 - 20*	
	(inches)	(cubic feet)
Precipitation	5.45	19,783.5
Runoff	2.246	8,152.1
Subprofile1		
Drainage collected from Layer 3	0.7970	2,893.0
Percolation/leakage through Layer 5	0.000000	0.0007
Average head on Layer 4	1.7731	---
Maximum head on Layer 4	3.0967	---
Location of maximum head in Layer 3	17.41 (feet from drain)	
Other Parameters		
Snow water	3.6144	13,120.2
Maximum vegetation soil water	0.5410 (vol/vol)	
Minimum vegetation soil water	0.0470 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/29/2023 9:48
Simulation period: 20 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	148.0471	0.3084
2	0.9258	0.0514
3	0.0077	0.0309
4	0.0000	0.0000
5	0.2070	0.7500
Snow water	0.0000	---

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Bremo FFCP Mgmt Facility **Simulated On:** 5/13/2024 15:17

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	480	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.3317	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
VDOT Stone
Material Texture Number 44

Thickness	=	18	inches
Porosity	=	0.39	vol/vol
Field Capacity	=	0.04	vol/vol
Wilting Point	=	0.013	vol/vol
Initial Soil Water Content	=	0.1238	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-01	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
250-mil Geocomposite
Material Texture Number 123

Thickness	=	0.25	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.032	vol/vol
Effective Sat. Hyd. Conductivity	=	2.20E+00	cm/sec
Slope	=	2.5	%
Drainage Length	=	225	ft

Layer 4

Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 5

Type 3 - Barrier Soil Liner
Geosynthetic Clay Liner
Material Texture Number 43

Thickness	=	0.276	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.40E-09	cm/sec

Note: Initial moisture content of the layers and snow water were specified by the user.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	91	
Fraction of Area Allowing Runoff	=	39	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	6	inches
Initial Water in Evaporative Zone	=	1.99	inches
Upper Limit of Evaporative Storage	=	3.246	inches
Lower Limit of Evaporative Storage	=	0.282	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	161.659	inches
Total Initial Water	=	161.659	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	37.71	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	90	days

End of Growing Season (Julian Date)	=	304	days
Average Wind Speed	=	5	mph
Average 1st Quarter Relative Humidity	=	58	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	77	%
Average 4th Quarter Relative Humidity	=	61	%

Note: Evapotranspiration data was obtained for Bremo Bluff, Virginia

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
3.365862	2.758621	3.928621	3.318276	4.841379	4.375517
4.655517	3.91	4.344828	3.914483	3.501724	3.806552

Note: Precipitation was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
36.4	38.7	46.2	56.3	64.7	73.3
77.5	76	69.3	58.1	47.8	40.4

Note: Temperature was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 37.71/-78.27

Average Annual Totals Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/13/2024 15:19

	Average Annual Totals for Years 1 - 20*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	46.48	[8.08]	168,706.1	100.00
Runoff	5.010	[1.825]	18,185.2	10.78
Evapotranspiration	27.523	[3.085]	99,907.0	59.22
Subprofile1				
Lateral drainage collected from Layer 3	14.5664	[4.4108]	52,876.0	31.34
Percolation/leakage through Layer 5	0.000003	[0]	0.0091	0.00
Average Head on Top of Layer 4	0.0290	[0.0091]	---	---
Water storage				
Change in water storage	-0.6232	[5.4204]	-2,262.1	-1.34

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/13/2024 15:19

	Peak Values for Years 1 - 20*	
	(inches)	(cubic feet)
Precipitation	5.45	19,783.5
Runoff	2.246	8,152.1
Subprofile1		
Drainage collected from Layer 3	0.9182	3,333.2
Percolation/leakage through Layer 5	0.000000	0.0009
Average head on Layer 4	2.2730	---
Maximum head on Layer 4	3.7088	---
Location of maximum head in Layer 3	28.27	(feet from drain)
Other Parameters		
Snow water	3.6144	13,120.2
Maximum vegetation soil water	0.5410	(vol/vol)
Minimum vegetation soil water	0.0470	(vol/vol)

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/13/2024 15:20
Simulation period: 20 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	148.0555	0.3084
2	0.9257	0.0514
3	0.0080	0.0319
4	0.0000	0.0000
5	0.2070	0.7500
Snow water	0.0000	---

HELP Model Analysis Attachment 8

HELP Model, 50-ft CCR

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Bremo FFCP Mgmt Facility **Simulated On:** 6/29/2023 9:53

Layer 1

Type 1 - Vertical Percolation Layer (Cover Soil)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	600	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.3084	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 2

Type 2 - Lateral Drainage Layer
VDOT Stone
Material Texture Number 44

Thickness	=	18	inches
Porosity	=	0.39	vol/vol
Field Capacity	=	0.04	vol/vol
Wilting Point	=	0.013	vol/vol
Initial Soil Water Content	=	0.0514	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-01	cm/sec

Layer 3

Type 2 - Lateral Drainage Layer
250-mil Geocomposite
Material Texture Number 123

Thickness	=	0.25	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.0309	vol/vol
Effective Sat. Hyd. Conductivity	=	4.04E-01	cm/sec
Slope	=	5	%
Drainage Length	=	425	ft

Layer 4

Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 5

Type 3 - Barrier Soil Liner
Geosynthetic Clay Liner
Material Texture Number 43

Thickness	=	0.276	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.40E-09	cm/sec

Note: Initial moisture content of the layers and snow water were specified by the user.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	91	
Fraction of Area Allowing Runoff	=	39	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	6	inches
Initial Water in Evaporative Zone	=	1.85	inches
Upper Limit of Evaporative Storage	=	3.246	inches
Lower Limit of Evaporative Storage	=	0.282	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	186.18	inches
Total Initial Water	=	186.18	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	37.71	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	90	days

End of Growing Season (Julian Date)	=	304	days
Average Wind Speed	=	5	mph
Average 1st Quarter Relative Humidity	=	58	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	77	%
Average 4th Quarter Relative Humidity	=	61	%

Note: Evapotranspiration data was obtained for Bremo Bluff, Virginia

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
3.365862	2.758621	3.928621	3.318276	4.841379	4.375517
4.655517	3.91	4.344828	3.914483	3.501724	3.806552

Note: Precipitation was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
36.4	38.7	46.2	56.3	64.7	73.3
77.5	76	69.3	58.1	47.8	40.4

Note: Temperature was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 37.71/-78.27

Average Annual Totals Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/29/2023 9:54

	Average Annual Totals for Years 1 - 20*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	46.48	[8.08]	168,706.1	100.00
Runoff	5.007	[1.825]	18,176.8	10.77
Evapotranspiration	27.523	[3.089]	99,908.8	59.22
Subprofile1				
Lateral drainage collected from Layer 3	13.9977	[3.7753]	50,811.6	30.12
Percolation/leakage through Layer 5	0.000006	[0.000001]	0.0218	0.00
Average Head on Top of Layer 4	0.1408	[0.0362]	---	---
Water storage				
Change in water storage	-0.0527	[5.3397]	-191.1	-0.11

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/29/2023 9:55

	Peak Values for Years 1 - 20*	
	(inches)	(cubic feet)
Precipitation	5.45	19,783.5
Runoff	2.246	8,152.1
Subprofile1		
Drainage collected from Layer 3	0.1863	676.1
Percolation/leakage through Layer 5	0.000000	0.0002
Average head on Layer 4	0.6065	---
Maximum head on Layer 4	1.1907	---
Location of maximum head in Layer 3	7.79 (feet from drain)	
Other Parameters		
Snow water	3.6144	13,120.2
Maximum vegetation soil water	0.5410 (vol/vol)	
Minimum vegetation soil water	0.0470 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/29/2023 9:55
Simulation period: 20 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	183.9612	0.3066
2	0.9262	0.0515
3	0.0323	0.1292
4	0.0000	0.0000
5	0.2070	0.7500
Snow water	0.0000	---

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Bremo FFCP Mgmt Facility **Simulated On:** 5/13/2024 16:11

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	600	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.3084	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
VDOT Stone
Material Texture Number 44

Thickness	=	18	inches
Porosity	=	0.39	vol/vol
Field Capacity	=	0.04	vol/vol
Wilting Point	=	0.013	vol/vol
Initial Soil Water Content	=	0.0514	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-01	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
250-mil Geocomposite
Material Texture Number 123

Thickness	=	0.25	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.0319	vol/vol
Effective Sat. Hyd. Conductivity	=	4.04E-01	cm/sec
Slope	=	2.5	%
Drainage Length	=	225	ft

Layer 4

Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 5

Type 3 - Barrier Soil Liner
Geosynthetic Clay Liner
Material Texture Number 43

Thickness	=	0.276	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.40E-09	cm/sec

Note: Initial moisture content of the layers and snow water were specified by the user.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	91	
Fraction of Area Allowing Runoff	=	39	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	6	inches
Initial Water in Evaporative Zone	=	1.85	inches
Upper Limit of Evaporative Storage	=	3.246	inches
Lower Limit of Evaporative Storage	=	0.282	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	186.18	inches
Total Initial Water	=	186.18	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	37.71	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	90	days

End of Growing Season (Julian Date)	=	304	days
Average Wind Speed	=	5	mph
Average 1st Quarter Relative Humidity	=	58	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	77	%
Average 4th Quarter Relative Humidity	=	61	%

Note: Evapotranspiration data was obtained for Bremo Bluff, Virginia

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
3.365862	2.758621	3.928621	3.318276	4.841379	4.375517
4.655517	3.91	4.344828	3.914483	3.501724	3.806552

Note: Precipitation was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
36.4	38.7	46.2	56.3	64.7	73.3
77.5	76	69.3	58.1	47.8	40.4

Note: Temperature was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 37.71/-78.27

Average Annual Totals Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/13/2024 16:12

	Average Annual Totals for Years 1 - 20*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	46.48	[8.08]	168,706.1	100.00
Runoff	5.007	[1.825]	18,176.8	10.77
Evapotranspiration	27.523	[3.089]	99,908.8	59.22
Subprofile1				
Lateral drainage collected from Layer 3	13.9976	[3.7727]	50,811.2	30.12
Percolation/leakage through Layer 5	0.000006	[0.000001]	0.0229	0.00
Average Head on Top of Layer 4	0.1484	[0.0377]	---	---
Water storage				
Change in water storage	-0.0526	[5.3373]	-190.8	-0.11

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/13/2024 16:12

	Peak Values for Years 1 - 20*	
	(inches)	(cubic feet)
Precipitation	5.45	19,783.5
Runoff	2.246	8,152.1
Subprofile1		
Drainage collected from Layer 3	0.1766	640.9
Percolation/leakage through Layer 5	0.000000	0.0002
Average head on Layer 4	0.6071	---
Maximum head on Layer 4	1.1502	---
Location of maximum head in Layer 3	12.41 (feet from drain)	
Other Parameters		
Snow water	3.6144	13,120.2
Maximum vegetation soil water	0.5410 (vol/vol)	
Minimum vegetation soil water	0.0470 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/13/2024 16:12
Simulation period: 20 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	183.9612	0.3066
2	0.9262	0.0515
3	0.0345	0.1380
4	0.0000	0.0000
5	0.2070	0.7500
Snow water	0.0000	---

HELP Model Analysis Attachment 9

HELP Model, 70-ft CCR

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Bremo FFCP Mgmt Facility **Simulated On:** 6/29/2023 10:06

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	840	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.3066	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
VDOT Stone
Material Texture Number 44

Thickness	=	18	inches
Porosity	=	0.39	vol/vol
Field Capacity	=	0.04	vol/vol
Wilting Point	=	0.013	vol/vol
Initial Soil Water Content	=	0.0515	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
250-mil Geocomposite
Material Texture Number 123

Thickness	=	0.25	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.1292	vol/vol
Effective Sat. Hyd. Conductivity	=	4.04E-01	cm/sec
Slope	=	5	%
Drainage Length	=	425	ft

Layer 4

Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 5

Type 3 - Barrier Soil Liner
Geosynthetic Clay Liner
Material Texture Number 43

Thickness	=	0.276	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.40E-09	cm/sec

Note: Initial moisture content of the layers and snow water were specified by the user.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	91	
Fraction of Area Allowing Runoff	=	56.5	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	6	inches
Initial Water in Evaporative Zone	=	1.84	inches
Upper Limit of Evaporative Storage	=	3.246	inches
Lower Limit of Evaporative Storage	=	0.282	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	258.71	inches
Total Initial Water	=	258.71	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	37.71	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	90	days

End of Growing Season (Julian Date)	=	304	days
Average Wind Speed	=	5	mph
Average 1st Quarter Relative Humidity	=	58	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	77	%
Average 4th Quarter Relative Humidity	=	61	%

Note: Evapotranspiration data was obtained for Bremo Bluff, Virginia

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
3.365862	2.758621	3.928621	3.318276	4.841379	4.375517
4.655517	3.91	4.344828	3.914483	3.501724	3.806552

Note: Precipitation was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
36.4	38.7	46.2	56.3	64.7	73.3
77.5	76	69.3	58.1	47.8	40.4

Note: Temperature was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 37.71/-78.27

Average Annual Totals Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/29/2023 10:09

	Average Annual Totals for Years 1 - 20*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	46.48	[8.08]	168,706.1	100.00
Runoff	6.732	[2.432]	24,438.7	14.49
Evapotranspiration	27.427	[3.089]	99,558.5	59.01
Subprofile1				
Lateral drainage collected from Layer 3	12.5064	[2.8594]	45,398.1	26.91
Percolation/leakage through Layer 5	0.000011	[0.000014]	0.0415	0.00
Average Head on Top of Layer 4	0.2707	[0.347]	---	---
Water storage				
Change in water storage	-0.1899	[5.067]	-689.2	-0.41

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/29/2023 10:09

	Peak Values for Years 1 - 20*	
	(inches)	(cubic feet)
Precipitation	5.45	19,783.5
Runoff	2.927	10,625.2
Subprofile1		
Drainage collected from Layer 3	0.0714	259.1
Percolation/leakage through Layer 5	0.000001	0.0027
Average head on Layer 4	6.5344	---
Maximum head on Layer 4	11.6142	---
Location of maximum head in Layer 3	46.36 (feet from drain)	
Other Parameters		
Snow water	3.6144	13,120.2
Maximum vegetation soil water	0.5410 (vol/vol)	
Minimum vegetation soil water	0.0470 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/29/2023 10:09
Simulation period: 20 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	252.5017	0.3006
2	2.1632	0.1202
3	0.0411	0.1642
4	0.0000	0.0000
5	0.2070	0.7500
Snow water	0.0000	---

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Bremo FFCP Mgmt Facility **Simulated On:** 5/14/2024 12:27

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	840	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.3066	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
VDOT Stone
Material Texture Number 44

Thickness	=	18	inches
Porosity	=	0.39	vol/vol
Field Capacity	=	0.04	vol/vol
Wilting Point	=	0.013	vol/vol
Initial Soil Water Content	=	0.0515	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
250-mil Geocomposite
Material Texture Number 123

Thickness	=	0.25	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.138	vol/vol
Effective Sat. Hyd. Conductivity	=	4.04E-01	cm/sec
Slope	=	2.5	%
Drainage Length	=	225	ft

Layer 4

Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 5

Type 3 - Barrier Soil Liner
Geosynthetic Clay Liner
Material Texture Number 43

Thickness	=	0.276	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.40E-09	cm/sec

Note: Initial moisture content of the layers and snow water were specified by the user.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	91	
Fraction of Area Allowing Runoff	=	56.5	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	6	inches
Initial Water in Evaporative Zone	=	1.84	inches
Upper Limit of Evaporative Storage	=	3.246	inches
Lower Limit of Evaporative Storage	=	0.282	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	258.712	inches
Total Initial Water	=	258.712	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	37.71	Degrees
Maximum Leaf Area Index	=	0	
Start of Growing Season (Julian Date)	=	90	days

End of Growing Season (Julian Date)	=	304	days
Average Wind Speed	=	5	mph
Average 1st Quarter Relative Humidity	=	58	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	77	%
Average 4th Quarter Relative Humidity	=	61	%

Note: Evapotranspiration data was obtained for Bremo Bluff, Virginia

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
3.365862	2.758621	3.928621	3.318276	4.841379	4.375517
4.655517	3.91	4.344828	3.914483	3.501724	3.806552

Note: Precipitation was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
36.4	38.7	46.2	56.3	64.7	73.3
77.5	76	69.3	58.1	47.8	40.4

Note: Temperature was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 37.71/-78.27

Average Annual Totals Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/14/2024 12:28

	Average Annual Totals for Years 1 - 20*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	46.48	[8.08]	168,706.1	100.00
Runoff	6.732	[2.432]	24,438.7	14.49
Evapotranspiration	27.427	[3.089]	99,558.5	59.01
Subprofile1				
Lateral drainage collected from Layer 3	12.5063	[2.8582]	45,397.9	26.91
Percolation/leakage through Layer 5	0.000020	[0.000034]	0.0723	0.00
Average Head on Top of Layer 4	0.4763	[0.8158]	---	---
Water storage				
Change in water storage	-0.1898	[5.0663]	-689.1	-0.41

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/14/2024 12:28

	Peak Values for Years 1 - 20*	
	(inches)	(cubic feet)
Precipitation	5.45	19,783.5
Runoff	2.927	10,625.2
Subprofile1		
Drainage collected from Layer 3	0.0678	246.1
Percolation/leakage through Layer 5	0.000001	0.0029
Average head on Layer 4	6.9467	---
Maximum head on Layer 4	10.5464	---
Location of maximum head in Layer 3	54.10	(feet from drain)
Other Parameters		
Snow water	3.6144	13,120.2
Maximum vegetation soil water	0.5410	(vol/vol)
Minimum vegetation soil water	0.0470	(vol/vol)

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/14/2024 12:28
Simulation period: 20 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	252.5017	0.3006
2	2.1632	0.1202
3	0.0438	0.1751
4	0.0000	0.0000
5	0.2070	0.7500
Snow water	0.0000	---

HELP Model Analysis Attachment 10

HELP Model, Closed

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Bremo FFCP Mgmt Facility **Simulated On:** 6/29/2023 10:15

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
SL - Sandy Loam
Material Texture Number 6

Thickness	=	6	inches
Porosity	=	0.453	vol/vol
Field Capacity	=	0.19	vol/vol
Wilting Point	=	0.085	vol/vol
Initial Soil Water Content	=	0.2249	vol/vol
Effective Sat. Hyd. Conductivity	=	7.20E-04	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer
SL - Sandy Loam
Material Texture Number 6

Thickness	=	18	inches
Porosity	=	0.453	vol/vol
Field Capacity	=	0.19	vol/vol
Wilting Point	=	0.085	vol/vol
Initial Soil Water Content	=	0.1036	vol/vol
Effective Sat. Hyd. Conductivity	=	7.20E-04	cm/sec

Layer 3
Type 2 - Lateral Drainage Layer
MicroDrain/Super Gripnet
Material Texture Number 124

Thickness	=	0.13	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.0166	vol/vol
Effective Sat. Hyd. Conductivity	=	1.09E+01	cm/sec
Slope	=	33.33	%
Drainage Length	=	105	ft

Layer 4

Type 4 - Flexible Membrane Liner
LDPE Membrane
Material Texture Number 36

Thickness	=	0.05	inches
Effective Sat. Hyd. Conductivity	=	4.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 5
Type 1 - Vertical Percolation Layer
SL - Sandy Loam
Material Texture Number 6

Thickness	=	12	inches
Porosity	=	0.453	vol/vol
Field Capacity	=	0.19	vol/vol
Wilting Point	=	0.085	vol/vol
Initial Soil Water Content	=	0.2239	vol/vol
Effective Sat. Hyd. Conductivity	=	7.20E-04	cm/sec

Layer 6
Type 1 - Vertical Percolation Layer (Waste)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	1020	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.3006	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 7
Type 2 - Lateral Drainage Layer
VDOT Stone
Material Texture Number 44

Thickness	=	18	inches
Porosity	=	0.39	vol/vol
Field Capacity	=	0.04	vol/vol
Wilting Point	=	0.013	vol/vol
Initial Soil Water Content	=	0.1202	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec

Layer 8
Type 2 - Lateral Drainage Layer

250-mil Geocomposite
Material Texture Number 123

Thickness	=	0.25	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.1642	vol/vol
Effective Sat. Hyd. Conductivity	=	4.04E-01	cm/sec
Slope	=	5	%
Drainage Length	=	425	ft

Layer 9
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 10
Type 3 - Barrier Soil Liner
Geosynthetic Clay Liner
Material Texture Number 43

Thickness	=	0.276	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.40E-09	cm/sec

Note: Initial moisture content of the layers and snow water were specified by the user.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	61	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	24	inches
Initial Water in Evaporative Zone	=	3.214	inches
Upper Limit of Evaporative Storage	=	10.872	inches
Lower Limit of Evaporative Storage	=	2.04	inches

Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	314.927	inches
Total Initial Water	=	314.927	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	37.71	Degrees
Maximum Leaf Area Index	=	4	
Start of Growing Season (Julian Date)	=	90	days
End of Growing Season (Julian Date)	=	304	days
Average Wind Speed	=	5	mph
Average 1st Quarter Relative Humidity	=	58	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	77	%
Average 4th Quarter Relative Humidity	=	61	%

Note: Evapotranspiration data was obtained for Bremo Bluff, Virginia

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
3.365862	2.758621	3.928621	3.318276	4.841379	4.375517
4.655517	3.91	4.344828	3.914483	3.501724	3.806552

Note: Precipitation was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
36.4	38.7	46.2	56.3	64.7	73.3
77.5	76	69.3	58.1	47.8	40.4

Note: Temperature was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 37.71/-78.27

Average Annual Totals Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/29/2023 10:20

	Average Annual Totals for Years 1 - 20*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	46.48	[8.08]	168,706.1	100.00
Runoff	0.426	[0.915]	1,545.4	0.92
Evapotranspiration	16.867	[3.916]	61,227.4	36.29
Subprofile1				
Lateral drainage collected from Layer 3	29.1956	[5.8402]	105,980.2	62.82
Percolation/leakage through Layer 4	0.000004	[0]	0.0129	0.00
Average Head on Top of Layer 4	0.0005	[0.0001]	---	---
Subprofile2				
Lateral drainage collected from Layer 8	4.3854	[3.3946]	15,918.9	9.44
Percolation/leakage through Layer 10	0.000003	[0.000001]	0.0104	0.00
Average Head on Top of Layer 9	0.0447	[0.0346]	---	---
Water storage				
Change in water storage	-4.3983	[3.4454]	-15,965.8	-9.46

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/29/2023 10:21

	Peak Values for Years 1 - 20*	
	(inches)	(cubic feet)
Precipitation	5.45	19,783.5
Runoff	0.913	3,314.5
Subprofile1		
Drainage collected from Layer 3	2.4190	8,780.9
Percolation/leakage through Layer 4	0.000000	0.0000
Average head on Layer 4	0.0137	---
Maximum head on Layer 4	0.0274	---
Location of maximum head in Layer 3	0.00 (feet from drain)	
Subprofile2		
Drainage collected from Layer 8	0.0417	151.5
Percolation/leakage through Layer 10	0.000000	0.0001
Average head on Layer 9	0.1553	---
Maximum head on Layer 9	0.3084	---
Location of maximum head in Layer 8	1.90 (feet from drain)	
Other Parameters		
Snow water	3.6144	13,120.2
Maximum vegetation soil water	0.3425 (vol/vol)	
Minimum vegetation soil water	0.0850 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Bremo FFCP Mgmt Facility
Simulated on: 6/29/2023 10:21
Simulation period: 20 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	1.1774	0.1962
2	1.7787	0.0988
3	0.0014	0.0111
4	0.0000	0.0000
5	2.2800	0.1900
6	219.6515	0.2153
7	1.8494	0.1027
8	0.0153	0.0612
9	0.0000	0.0000
10	0.2070	0.7500
Snow water	0.0000	---

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Bremo FFCP Mgmt Facility **Simulated On:** 5/14/2024 14:43

Layer 1

Type 1 - Vertical Percolation Layer (Cover Soil)
SL - Sandy Loam
Material Texture Number 6

Thickness	=	6	inches
Porosity	=	0.453	vol/vol
Field Capacity	=	0.19	vol/vol
Wilting Point	=	0.085	vol/vol
Initial Soil Water Content	=	0.2249	vol/vol
Effective Sat. Hyd. Conductivity	=	7.20E-04	cm/sec

Layer 2

Type 1 - Vertical Percolation Layer
SL - Sandy Loam
Material Texture Number 6

Thickness	=	18	inches
Porosity	=	0.453	vol/vol
Field Capacity	=	0.19	vol/vol
Wilting Point	=	0.085	vol/vol
Initial Soil Water Content	=	0.1036	vol/vol
Effective Sat. Hyd. Conductivity	=	7.20E-04	cm/sec

Layer 3

Type 2 - Lateral Drainage Layer
MicroDrain/Super Gripnet
Material Texture Number 124

Thickness	=	0.13	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.0166	vol/vol
Effective Sat. Hyd. Conductivity	=	1.09E+01	cm/sec
Slope	=	33.33	%
Drainage Length	=	105	ft

Layer 4

Type 4 - Flexible Membrane Liner
LDPE Membrane
Material Texture Number 36

Thickness	=	0.05	inches
Effective Sat. Hyd. Conductivity	=	4.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 5
Type 1 - Vertical Percolation Layer
SL - Sandy Loam
Material Texture Number 6

Thickness	=	12	inches
Porosity	=	0.453	vol/vol
Field Capacity	=	0.19	vol/vol
Wilting Point	=	0.085	vol/vol
Initial Soil Water Content	=	0.2239	vol/vol
Effective Sat. Hyd. Conductivity	=	7.20E-04	cm/sec

Layer 6
Type 1 - Vertical Percolation Layer (Waste)
High-Density Electric Plant Coal Fly Ash
Material Texture Number 30

Thickness	=	1020	inches
Porosity	=	0.541	vol/vol
Field Capacity	=	0.187	vol/vol
Wilting Point	=	0.047	vol/vol
Initial Soil Water Content	=	0.3006	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E-05	cm/sec

Layer 7
Type 2 - Lateral Drainage Layer
VDOT Stone
Material Texture Number 44

Thickness	=	18	inches
Porosity	=	0.39	vol/vol
Field Capacity	=	0.04	vol/vol
Wilting Point	=	0.013	vol/vol
Initial Soil Water Content	=	0.1202	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec

Layer 8
Type 2 - Lateral Drainage Layer

250-mil Geocomposite
Material Texture Number 123

Thickness	=	0.25	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.1751	vol/vol
Effective Sat. Hyd. Conductivity	=	4.04E-01	cm/sec
Slope	=	2.5	%
Drainage Length	=	225	ft

Layer 9
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	0	Holes/Acre
FML Installation Defects	=	0	Holes/Acre
FML Placement Quality	=	2	Excellent

Layer 10
Type 3 - Barrier Soil Liner
Geosynthetic Clay Liner
Material Texture Number 43

Thickness	=	0.276	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.40E-09	cm/sec

Note: Initial moisture content of the layers and snow water were specified by the user.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	61	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	24	inches
Initial Water in Evaporative Zone	=	3.214	inches
Upper Limit of Evaporative Storage	=	10.872	inches
Lower Limit of Evaporative Storage	=	2.04	inches

Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	314.93	inches
Total Initial Water	=	314.93	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	37.71	Degrees
Maximum Leaf Area Index	=	4	
Start of Growing Season (Julian Date)	=	90	days
End of Growing Season (Julian Date)	=	304	days
Average Wind Speed	=	5	mph
Average 1st Quarter Relative Humidity	=	58	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	77	%
Average 4th Quarter Relative Humidity	=	61	%

Note: Evapotranspiration data was obtained for Bremo Bluff, Virginia

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
3.365862	2.758621	3.928621	3.318276	4.841379	4.375517
4.655517	3.91	4.344828	3.914483	3.501724	3.806552

Note: Precipitation was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
36.4	38.7	46.2	56.3	64.7	73.3
77.5	76	69.3	58.1	47.8	40.4

Note: Temperature was simulated using NOAA data for the following weather station
BREMO BLUFF, VA US, SCOTTSVILLE 6 SE, VA US, SCOTTSVILLE 1.2 E, VA US
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 37.71/-78.27

Average Annual Totals Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/14/2024 14:45

	Average Annual Totals for Years 1 - 20*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	46.48	[8.08]	168,706.1	100.00
Runoff	0.426	[0.915]	1,545.4	0.92
Evapotranspiration	16.867	[3.916]	61,227.4	36.29
Subprofile1				
Lateral drainage collected from Layer 3	29.1956	[5.8402]	105,980.2	62.82
Percolation/leakage through Layer 4	0.000004	[0]	0.0129	0.00
Average Head on Top of Layer 4	0.0005	[0.0001]	---	---
Subprofile2				
Lateral drainage collected from Layer 8	4.3855	[3.3943]	15,919.2	9.44
Percolation/leakage through Layer 10	0.000003	[0.000001]	0.0106	0.00
Average Head on Top of Layer 9	0.0472	[0.0366]	---	---
Water storage				
Change in water storage	-4.3984	[3.4452]	-15,966.2	-9.46

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/14/2024 14:45

	Peak Values for Years 1 - 20*	
	(inches)	(cubic feet)
Precipitation	5.45	19,783.5
Runoff	0.913	3,314.5
Subprofile1		
Drainage collected from Layer 3	2.4190	8,780.9
Percolation/leakage through Layer 4	0.000000	0.0000
Average head on Layer 4	0.0137	---
Maximum head on Layer 4	0.0274	---
Location of maximum head in Layer 3	0.00 (feet from drain)	
Subprofile2		
Drainage collected from Layer 8	0.0417	151.5
Percolation/leakage through Layer 10	0.000000	0.0001
Average head on Layer 9	0.1641	---
Maximum head on Layer 9	0.3213	---
Location of maximum head in Layer 8	4.61 (feet from drain)	
Other Parameters		
Snow water	3.6144	13,120.2
Maximum vegetation soil water	0.3425 (vol/vol)	
Minimum vegetation soil water	0.0850 (vol/vol)	

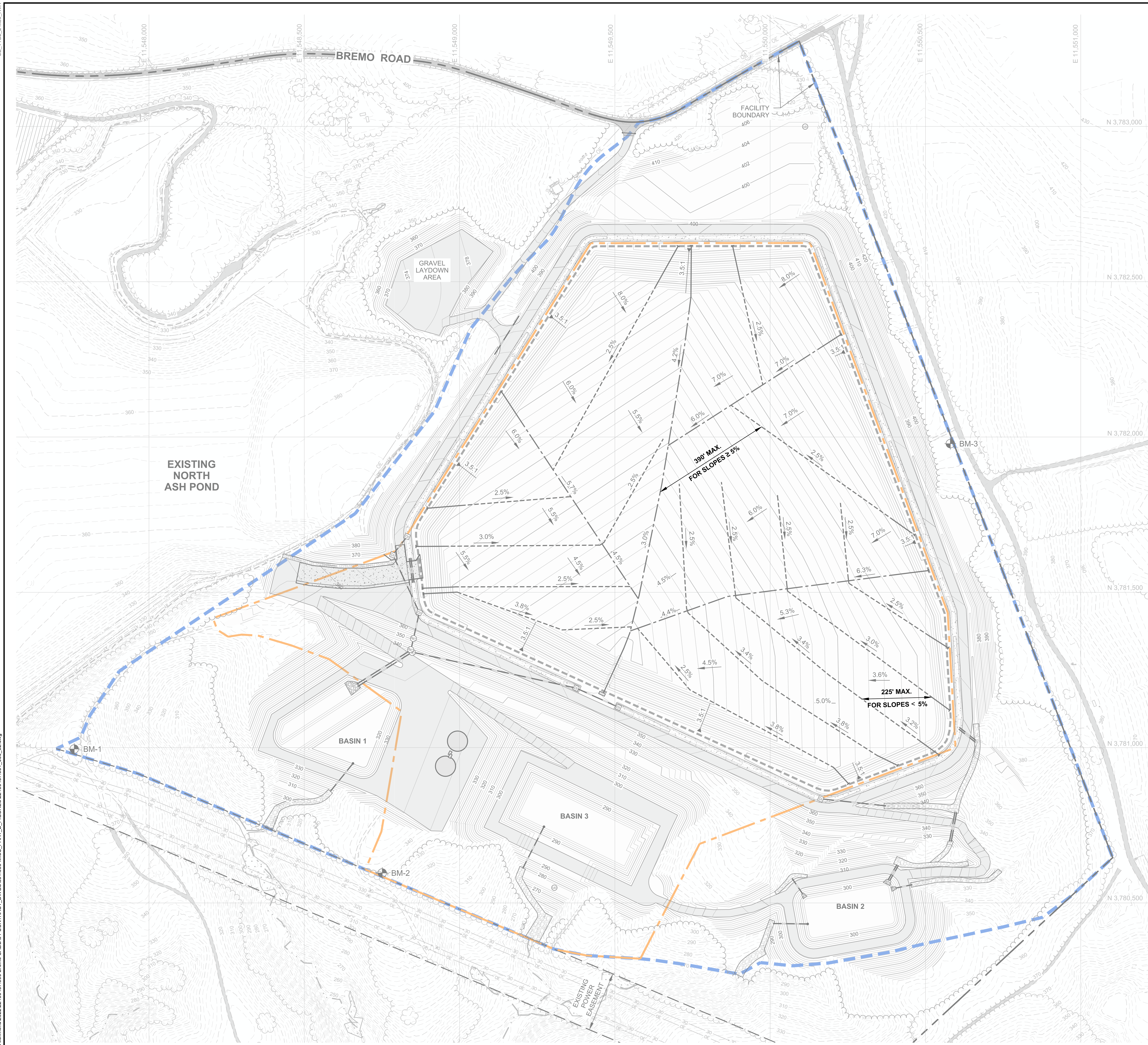
Final Water Storage in Landfill Profile at End of Simulation Period

Title: Bremo FFCP Mgmt Facility
Simulated on: 5/14/2024 14:45
Simulation period: 20 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	1.1774	0.1962
2	1.7787	0.0988
3	0.0014	0.0111
4	0.0000	0.0000
5	2.2800	0.1900
6	219.6515	0.2153
7	1.8494	0.1027
8	0.0160	0.0641
9	0.0000	0.0000
10	0.2070	0.7500
Snow water	0.0000	---

HELP Model Analysis Attachment 11

Maximum Drainage Length Figures



LEGEND

	PARCEL BOUNDARY
	EX. TOPOGRAPHIC CONTOURS (2' INTERVALS)
	PROP. TOPOGRAPHIC CONTOURS (2' INTERVALS)
	FACILITY BOUNDARY
	WASTE MANAGEMENT BOUNDARY
	DISPOSAL UNIT BOUNDARY / BOTTOM LINER ANCHOR TRENCH
	PROP. ROAD
	PROP. CONCRETE CHANNEL
	PROP. LEACHATE COLLECTION HEADER
	PROP. LEACHATE COLLECTION LATERAL
	PROP. NON-CONTACT STORMWATER PIPE / CULVERT
	PROP. RIP RAP CHANNEL ARMORING

REV.	DESCRIPTION	DES. BY	CAD BY	CHK. BY	DATE
0	ORIGINAL ISSUE	JRD	BPG	ATN	02/16/24

COMMONWEALTH OF VIRGINIA
JAMES R. DIFRANCESCO
Lic. No. 025260
02/16/2024
PROFESSIONAL ENGINEER

Schnabel ENGINEERING
9800 JEB Stuart Parkway, Suite 100
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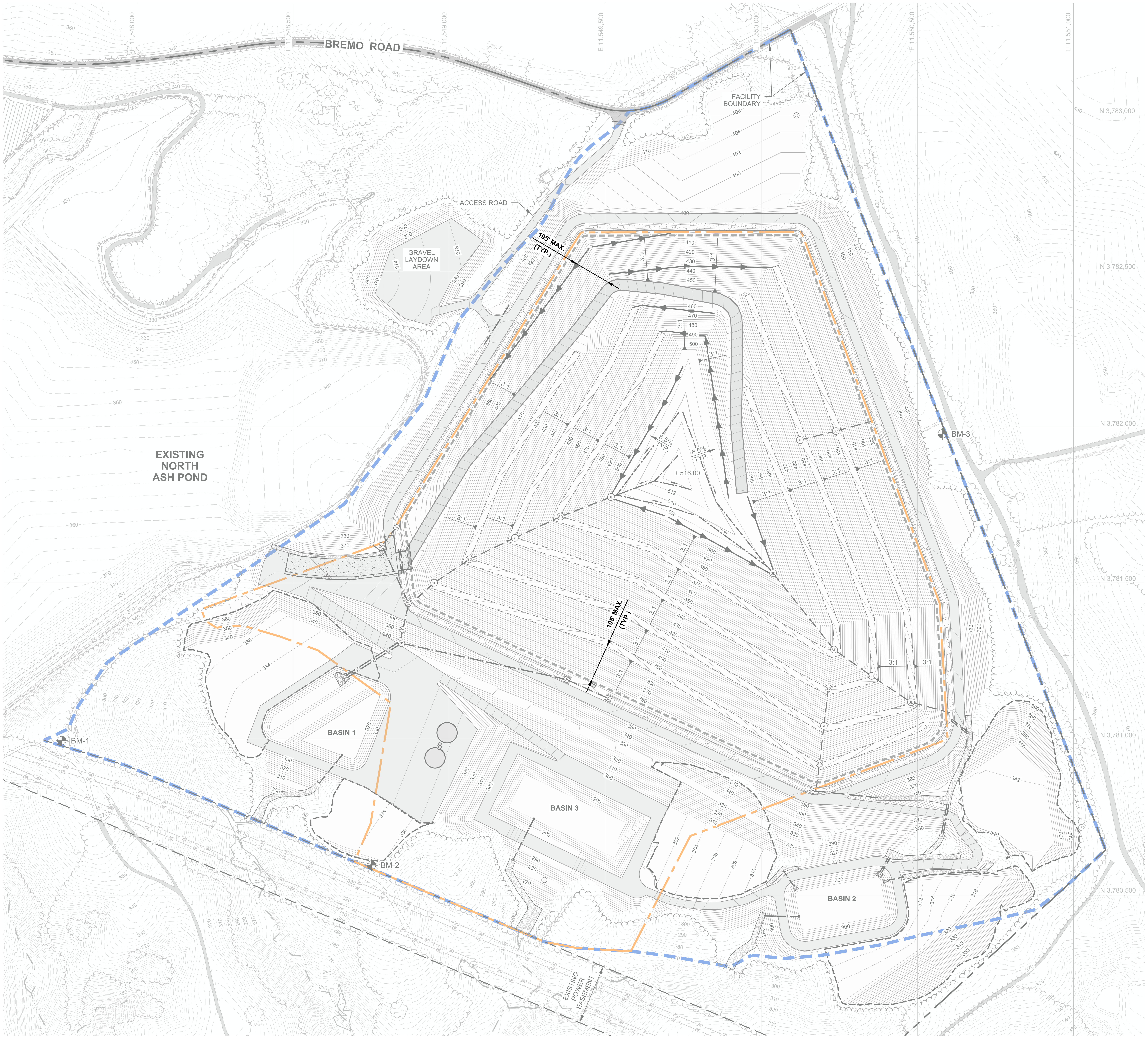
schnabel-eng.com

BREMO BLUFF FFCP MANAGEMENT FACILITY
SOLID WASTE PERMIT No. 627
FLUVANNA COUNTY, VIRGINIA

BOTTOM LINER SYSTEM DRAINAGE LENGTHS

PREPARED FOR:
Dominion Energy

PROJECT: 22130437.031
DATE: 02/16/24
FIGURE 1
SHEET - OF -



LEGEND

— — —	PARCEL BOUNDARY
- - 350 - -	EX. TOPOGRAPHIC CONTOURS (2' INTERVALS)
—— 350 ——	PROP. TOPOGRAPHIC CONTOURS (2' INTERVALS)
— — — (blue)	FACILITY BOUNDARY
— - — (orange)	WASTE MANAGEMENT BOUNDARY
- - - -	DISPOSAL UNIT BOUNDARY / BOTTOM LINER ANCHOR TRENCH
	PROP. ROAD
	PROP. CONCRETE CHANNEL
	PROP. DRAINAGE BENCH
	PROP. SLOPE DRAIN
	PROP. SLOPE DRAIN DROP INLET
	PROP. TOP DECK CAP DRAIN
	PROP. TACK-ON DIVERSION BERM
	PROP. NON-CONTACT STORMWATER PIPE / CULVERT
	PROP. RIP RAP CHANNEL ARMORING

N

SCALE: 1"=150'
0 150' 300'

REV.	DESCRIPTION	DES. BY	CAD BY	CHK. BY	DATE
0	ORIGINAL ISSUE	JRD	BPG	ATN	02/16/24

COMMONWEALTH OF VIRGINIA
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BREMO BLUFF FFCP MANAGEMENT FACILITY
SOLID WASTE PERMIT No. 627
FLUVANNA COUNTY, VIRGINIA

FINAL COVER SYSTEM DRAINAGE LENGTHS

PREPARED FOR:
Dominion Energy

PROJECT: 22130437.031
DATE: 02/16/24
FIGURE 2
SHEET - OF -

HELP Model Analysis Attachment 12

Bottom Liner System Geocomposite Hydraulic Conductivity

CALCULATIONS

Date: 5/09/2024
Project No.: 22130437.031
Subject: Bottom Liner System Geocomposite Hydraulic Conductivity
Project Title: Bremo Bluff FFCP Management Facility

Made by: J. Frantz
Checked by: S. McHenry
Reviewed by: R. DiFrancesco

1.0 Methodology: Based on methodology presented in Designing With Geosynthetics, Fifth Edition, Section 9.4 - Apply reduction factors to estimate transmissivity of landfill geosynthetic drainage systems.

Input	Values		Unit	Notes:
Performance Transmissivity	9.00E-04	2.20E-04	m^2/sec	Per GSE 100-HR Transmissivity Data and Proposed FFCP Facility Design
RFin	1.7	1.9		Intrusion (Range of Reduction: 1.5 -2.0)
RFcr	1.7	1.9		Creep (Range of Reduction: 1.4 - 2.0)
RFcc	1.5	1.5		Chemical Clogging (Range of Reduction: 1.5 - 2.0)
RFbc	1.5	1.5		Biological Clogging (Range of Reduction: 1.5 - 2.0)
Design Transmissivity	1.38E-04	2.71E-05	m^2/sec	$T_{design} = T_{manufactured} \left[\frac{1}{RF_{IN} \times RF_{CR} \times RF_{CC} \times RF_{BC}}\right]$

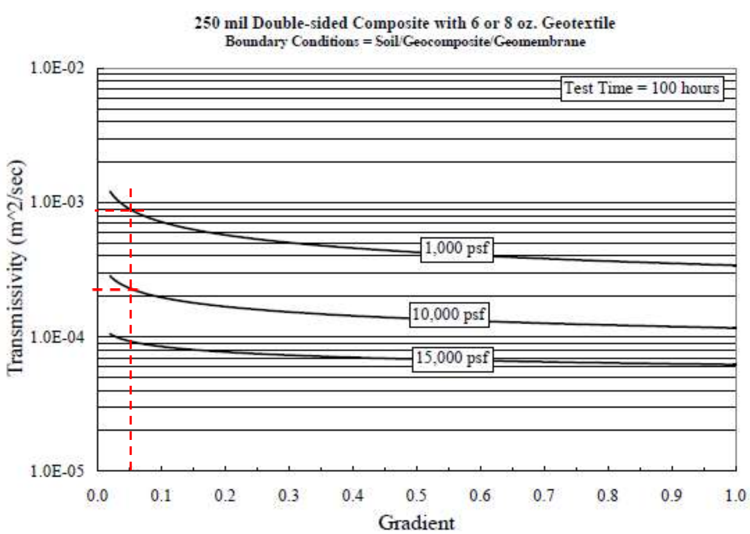


Figure A-6. Performance Transmissivity of a 250 mil GSE FabriNet HF geocomposite under Sand.

Design Values:		
GC Thickness (mils)	250	
Waste Density (lb/ft^3)	97	
Gradient (ft/ft)	0.05	0.05
Waste Height (Ft)	10	85
Load (lb/ft^2)	**970**	**8245**

*Use 1,000 & 10,000 PSF Lines

2.0 Methodology: Convert transmissivity to equivalent hydraulic conductivity considering geocomposite as unconfined aquifer.

Item	Values		Unit	Notes:
Design Transmissivity	1.38E-04	2.71E-05	m^2/sec	
Geonet Thickness	250	250	mils	
Equivalent Hydraulic Conductivity	**2.2**	**0.4**	**cm/sec**	$K_{design} = T_{design} \times Thickness$

ATTACHMENT 2

FINE AGGREGATE FILTER COMPATIBILITY CALCULATIONS

Project: Bremo Bluff FFCP Management Facility
Subject: Fine Aggregate Filter Compatibility
Reference No.: 22130437.031
Date: 02/01/2024

Made by: ERR
Checked by: SDRM
Reviewed by: JRD

Objective

Determine the filter compatibility of CCR and VDOT A, B, and No. 10 sands.

Method

Step 1: Plot the gradation curve (grain-size distribution) of the base soil material.

See attached graph.

Step 2: Proceed to step 4 if the base soil contains no gravel (material larger than No. 4 Sieve).

Base soil contains gravel (Y/N)? N

Step 3: Prepare adjusted gradation curves for base soils that have particles larger than the No. 4 Sieve.

Percent passing No. 4 Sieve (base material) = 100 %

Correction Factor = N/A

Sieve No.	Percent Passing	Correction Factor	Adjusted Value
4		N/A	N/A
8		N/A	N/A
16		N/A	N/A
30		N/A	N/A
50		N/A	N/A
100		N/A	N/A
200		N/A	N/A

Step 4: Place the base soil in a category determined by the percent passing the No. 200 sieve from the regradation curve data.

Base Soil Category	% finer than No. 200 sieve	Base soil description
1	>85	Fine silt and clays
2	40-85	Sands, silts, clays, and silty & clayey soils
3	15-39	Silty & clayey sands and gravel
4	<15	Sands and gravel

Base Soil Category = 2

Step 5: To satisfy filtration requirements, determine the maximum allowable D_{15} size for the filter.

d_{85}* = 0.135 Not Required
A = Not Required

* - For Category 4, d_{85} value is after regrading
A = % passing #200 Sieve after regrading

Maximum D_{15} = 0.70

Step 6: Determine the minimum allowable D_{15}.

d_{15}* = 0.0092

* - before regrading

Minimum D_{15} = 0.14

Step 7: Establish the minimum and maximum D_{60} sizes. The minimum D_{60} is equal to the maximum D_{15} size esablished in Step 6. The maximum D60 is five times the minimum D60.

Minimum D_{60} = 0.70
Maximum D_{60} = 3.50

Step 8: **Determine the minimum D_5 and the maximum D_{100} sizes of the filter.**

Base Soil Category	maximum D_{100}	minimum D_5
All	50	0.075

Step 9: **To minimize segregation during construction, the relationship between the maximum D_{90} and the minimum D_{10} of the filter is important.**

Minimum D_{10} = 0.12

Maximum D_{90} = 20

Soil D_{10} = 0.006

Step 10: **Connect Control points 4,2, and 5 to form a partial design for the fine side of the filter band. Connect Control points 6,7,3, and 1 to form a design for the coarse side of the filter band. Complete the design by extrapolating the coarse and fine curves to the 100 percent finer value.**

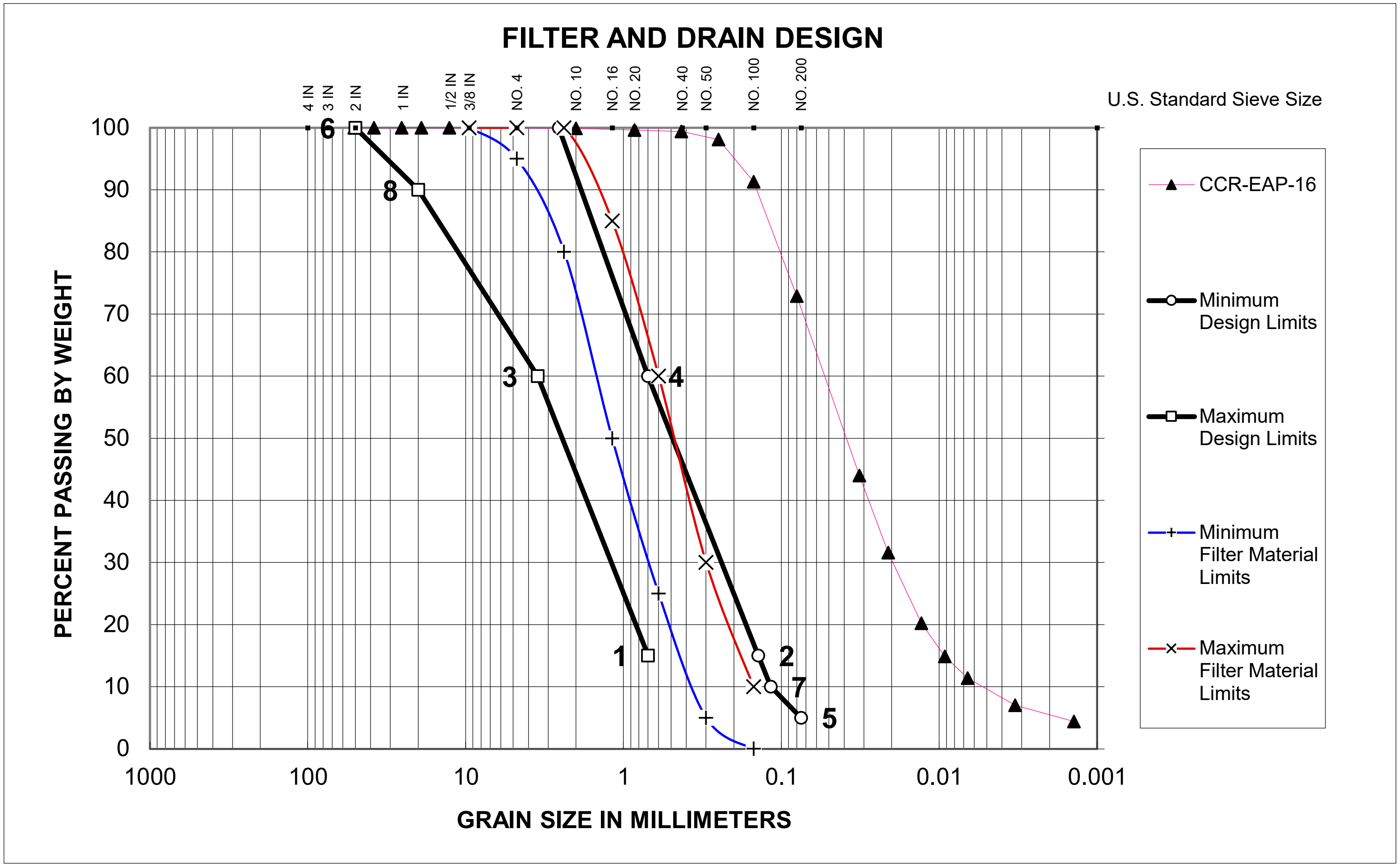
Extrapolation Estimate (Min D_{100}) = 2.58

Results

	Control Points	
Min D_5	5	**0.075**
Min D_{10}	7	**0.12**
Min D_{15}	2	**0.14**
Min D_{60}	4	**0.70**
Min D_{100}	Extrapolation Estimate	**2.58**
Max D_{15}	1	**0.70**
Max D_{60}	3	**3.50**
Max D_{90}	8	**20.00**
Max D_{100}	6	**50.00**

References

1. USDA-NRCS NEH 633, Chapter 26 Gradation Design of Sand and Gravel Filters.



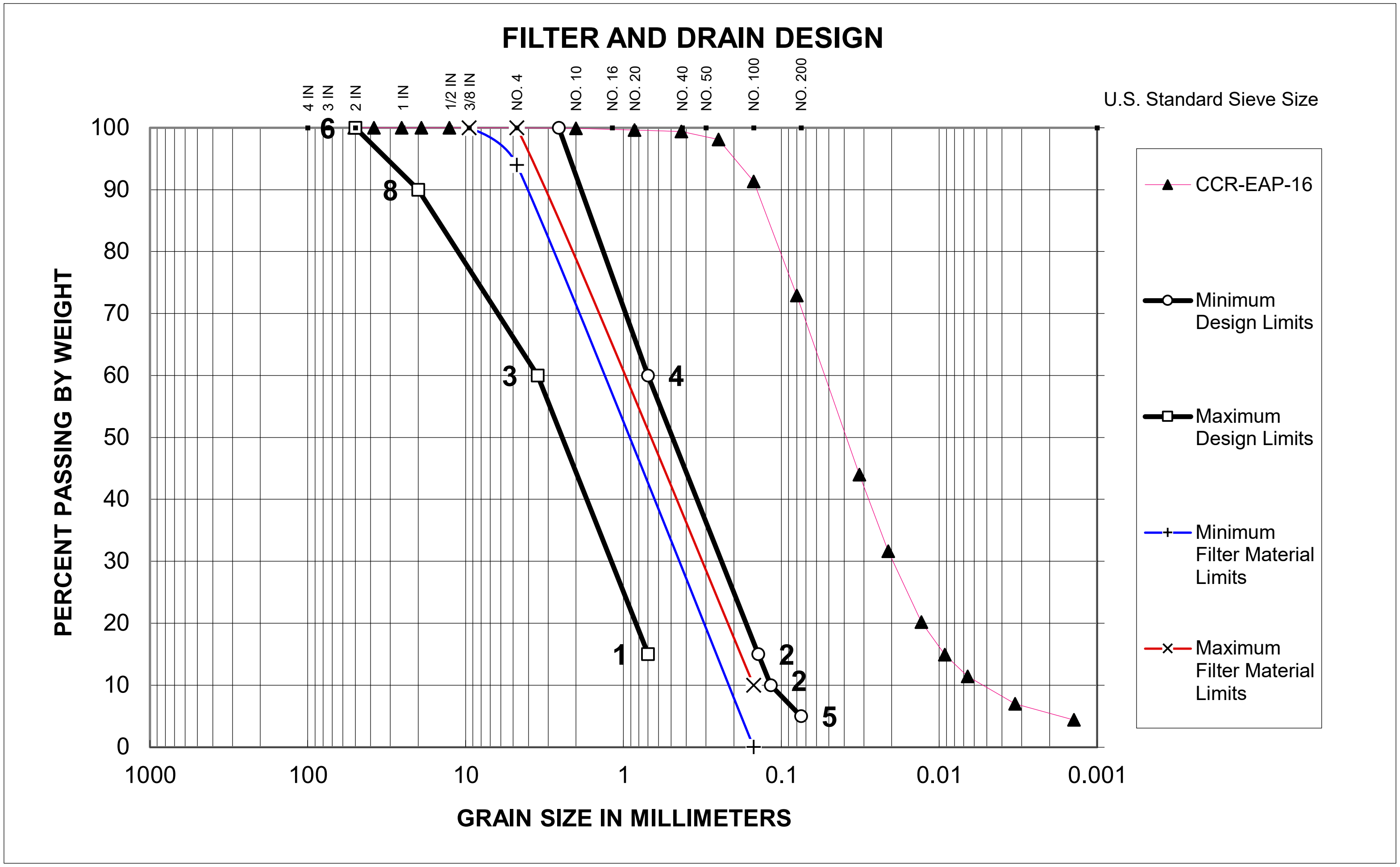
Remarks:

Control Points:

1 = 0.70
2 = 0.14
3 = 3.50
4 = 0.70
5 = 0.075
6 = 50
7 = 0.12
8 = 20

Filter Material:
VDOT A Sand

Base Material:
CCR-EAP-16



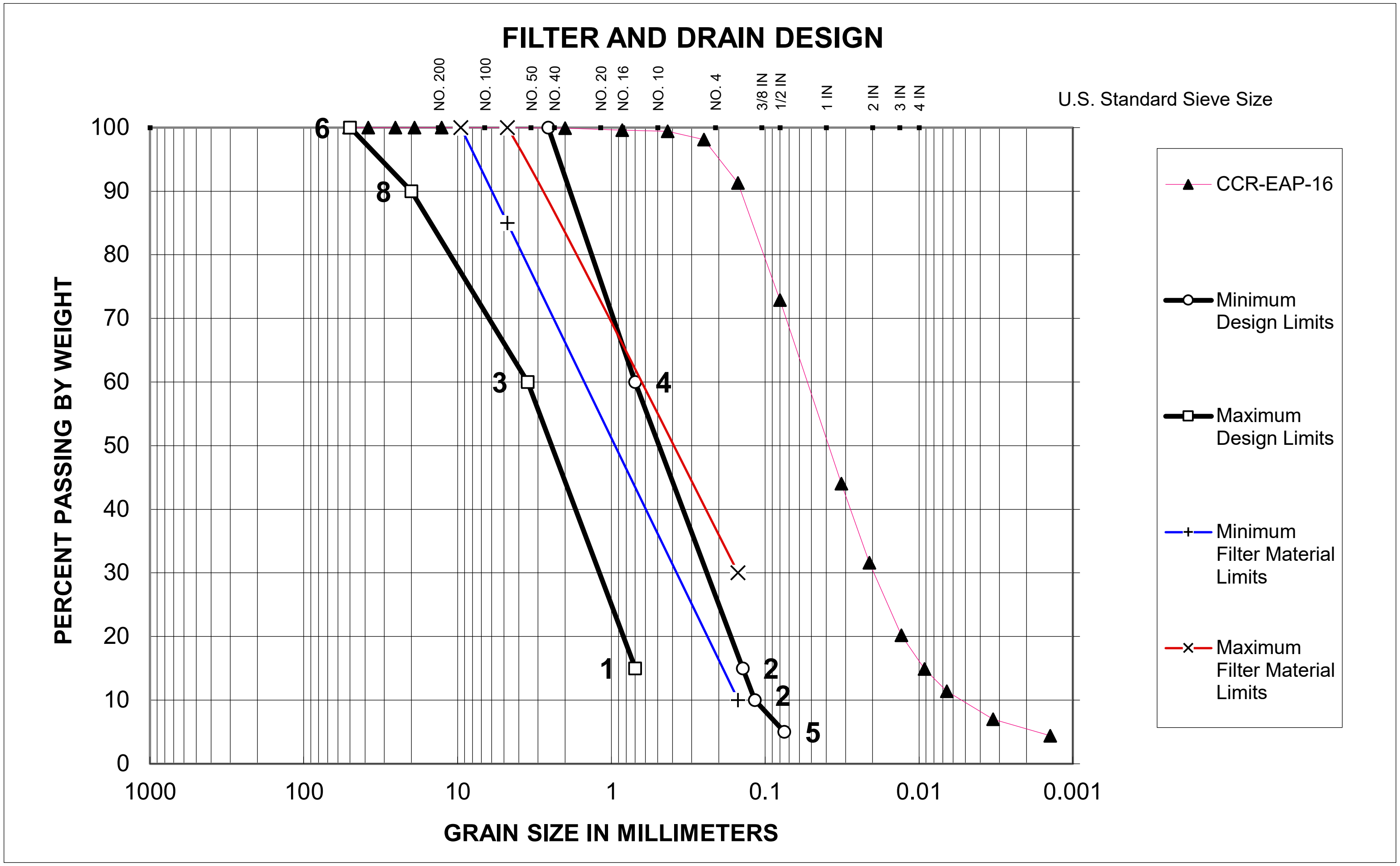
Remarks:

Control Points:

1 = 0.70	4 = 0.70	7 = 0.12
2 = 0.14	5 = 0.075	8 = 20
3 = 3.50	6 = 50	

Filter Material:
VDOT B Sand

Base Material:
CCR-EAP-16



Remarks:

Control Points:

1 = 0.70	4 = 0.70	7 = 0.12
2 = 0.14	5 = 0.075	8 = 20
3 = 3.50	6 = 50	

Filter Material:
VDOT NO. 10 Sand

Base Material:
CCR-EAP-16

ATTACHMENT 3

GEOTEXTILE AOS CALCULATIONS

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Glen Allen, VA 23059
T: 804-649-7035

Calculations

PROJECT: Bremo Bluff FFCP Management Facility	**REFERENCE NO:** 22130437.031
SUBJECT: Geotextile AOS Calculations	**DATE:** 02/01/2024

1.0 OBJECTIVE

The objective of this analysis is to determine the appropriate maximum apparent opening size (AOS) for the geotextile components of the bottom liner system, underdrain, and leachate collection system for the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility).

2.0 METHODOLOGY

The selection of the geotextile AOS was made based on the Task Force 25 and Giroud methods. These methods are based on a sieve analysis and were used to determine the minimum AOS to prevent materials intended to be retained by the geotextile from passing through the geotextile.

The following options are proposed for the 18-inch-thick aggregate layer in the bottom liner system:

- Option 1 consists of a 12-inch-thick coarse aggregate layer overlain by a 6-inch-thick fine aggregate layer.
- Option 2 consists of an 18-inch-thick layer of coarse aggregate (Option 2A) or fine aggregate (Option 2B).

Where fine aggregate (i.e. sand) or CCR is placed atop coarse aggregate (i.e stone), a 10-ounce per square yard (oz) geotextile is proposed for filtration/separation to prevent the finer material from migrating into the coarser material. In Option 1, a 10-oz non-woven geotextile is proposed between the 6-inch-thick fine aggregate and 12-inch-thick coarse aggregate to prevent the fine aggregate from migrating into the coarse aggregate. In Option 2, a 10-oz non-woven geotextile is proposed above the 18-inch-thick coarse aggregate layer to prevent placed CCR from being deposited into the coarse aggregate. In the case of an 18-inch-thick layer of fine aggregate, a 10-oz non-woven geotextile is not necessary because the sand acts as a natural filter for the placed CCR. The aggregate layer will be underlain by a 250-mil geocomposite, double-sided with an 8-oz non-woven geotextile.

Leachate collection piping will be enveloped in Virginia Department of Transportation (VDOT) No. 57 stone. In the event that fine aggregate is used (Option 2B), the VDOT No. 57 stone shall be wrapped with a 10-oz non-woven geotextile to prevent the fine aggregate from migrating into the stone and leachate collection piping.

The underdrain piping will also be enveloped in VDOT No. 57 stone. Prior to being covered with structural fill, the VDOT No. 57 stone will be wrapped with a 10-oz non-woven geotextile to prevent soil from migrating into the stone and underdrain piping.

3.0 ASSUMPTIONS

Geotextile AOS calculations were based on the following assumptions and input parameters:

- The fine aggregate in the bottom liner system was assumed to be VDOT A-Sand. Example material index properties are included as Attachment 1.
- A CCR sample gradation that is coarser than approximately 50% of the site-specific sample data was

used and is included in Attachment 1. The sample is finer than bottom ash, which is anticipated to be placed in the CCR Unit first.

- The underdrain structural fill soil was assumed to be the on-site silty sands or sand-silt mixtures (Unified Soil Classification System SM). Sample data from the on-site SM soil was used and is included in Attachment 1.

4.0 CALCULATIONS

4.1 Task Force 25 Method

The Task Force 25 method examines the percentage of material passing the No. 200 sieve and selects an AOS based on the following recommendations.

1. Particles < 50% passing the No. 200 sieve, then AOS ≥ No. 30 sieve
2. Particles > 50% passing the No. 200 sieve, then AOS ≥ No. 50 sieve

For the sand, less than 50% of the material passes the No. 200 sieve. For the CCR, more than 50% of the material passes the No. 200 sieve. Per the Task Force 25 Method, the recommended maximum AOS for the 10-oz filter/separation geotextile is the No. 50 sieve (0.297 mm).

For the both the sand and the SM soils that could be in contact with the 10-oz pipe wrap geotextiles and the 8-oz geocomposite geotextile, less than 50% of the material passes the No. 200 sieve. Per the Task Force 25 Method, the recommended maximum AOS for these geotextiles is the No. 30 sieve (0.595 mm).

4.1 Giroud Method

The Giroud method uses a flowchart to determine the AOS for the geotextile. The paths taken through the flowchart are highlighted in Attachment 2.

For the fine aggregate, the following steps were followed:

1. The proposed material has less than 10% silt and more than 10% sand.
2. The drainage system design favors retention of material to prevent clogging.
3. C_c was calculated, based on the equation on the flowchart, as 0.77.
4. The material is considered unstable because C_c is less than 1.
5. C'_u was calculated, based on the equation on the flowchart, as 7.64.
6. The material is considered widely graded because C'_u is greater than 3.
7. The sand was considered “loose” to be conservative.

For the CCR, the following steps were followed:

1. The CCR has more than 10% silt and less than 20% clay.
2. The CCR is non-plastic.
3. The drainage system design favors retention of material to prevent clogging.
4. C_c was calculated, based on the equation on the flowchart, as 1.6.
5. The material is considered stable because C_c is between 1 and 3.
6. C'_u was calculated, based on the equation on the flowchart, as 4.77.
7. The material is considered widely graded because C'_u is greater than 3.
8. The sand was considered “dense.”

For the SM soil, the following steps were followed:

1. The SM soil has more than 10% silt and less than 20% clay.
2. The SM soil is non-plastic.
3. The drainage system design favors retention of material to prevent clogging.
4. C_c was calculated, based on the equation on the flowchart, as 3.33.
5. The material is considered unstable because C_c is greater than 3.
6. C'_u was calculated, based on the equation on the flowchart, as 0.892.
7. The material is considered uniformly graded because C'_u is less than 3.
8. The soil was considered "medium."

Based on the flowchart, the geotextile AOS for sand should be less than 1.1 mm or 0.04 inches, the geotextile AOS for CCR should be less than 0.15 mm or 0.0058 inches, and the geotextile AOS for SM soil should be less than 0.21 mm or 0.0084 inches.

6.0 CONCLUSION

Based on these calculations, the Giroud Method for CCR provides the more restrictive criteria for the 10-oz geotextile; therefore, the Giroud Method CCR AOS was used and the 10-oz filter/separation geotextile maximum AOS is 0.15 mm. The Giroud Method also provides the more restrictive criteria for sand and SM soil; therefore, the maximum AOS for the 10-oz geotextile for use in the leachate collection and underdrain pipe wrapping and the 8-oz geotextile portion of the geocomposite is 0.21 mm.

Attachments:

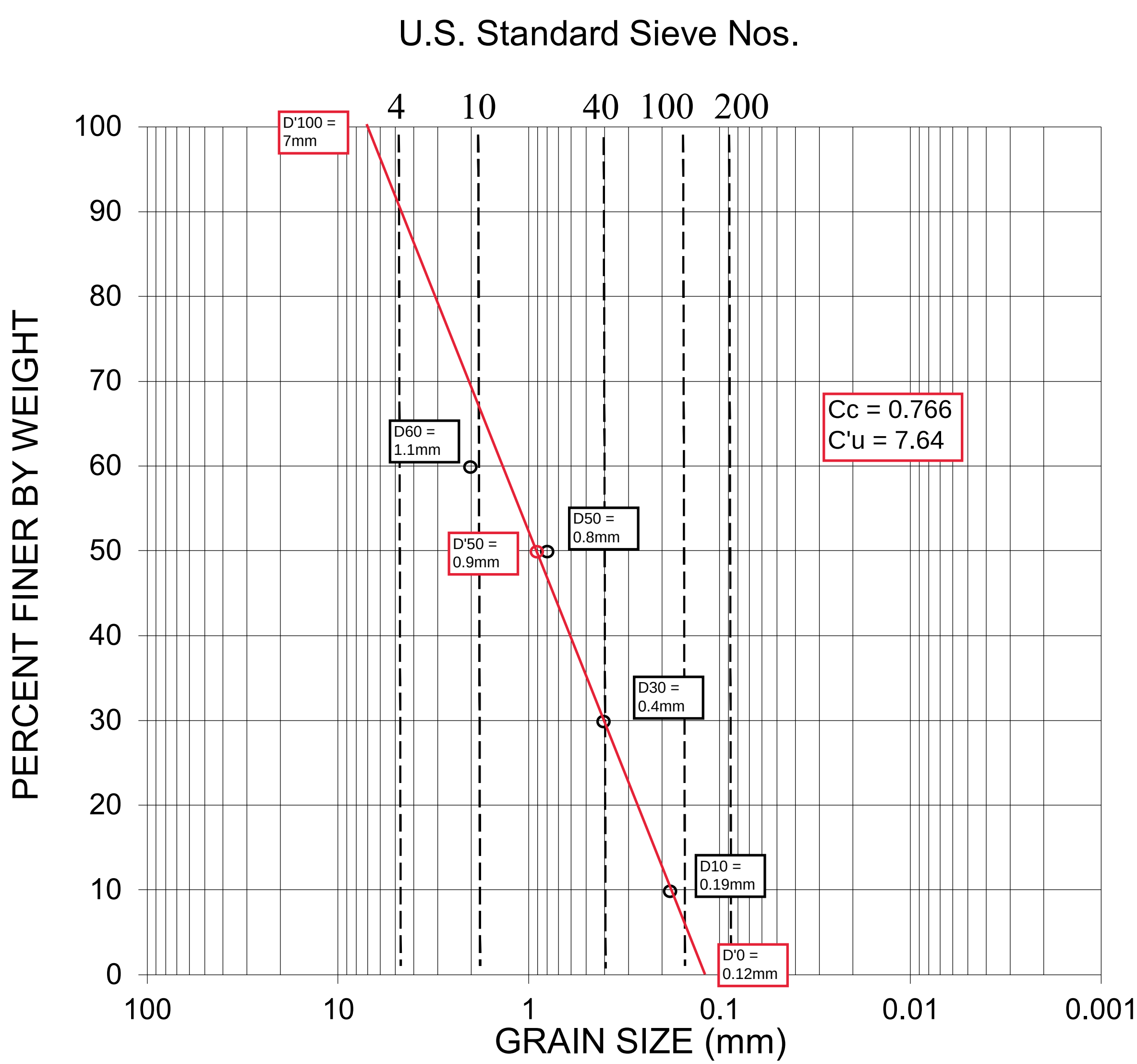
(1) Material Index Properties
(2) Giroud Method Flowchart

References:

(1) Qia, Xuede, Koerner, and Gray. Geotextile Filter Design, Application, and Product Specification Guide. 2002.
(2) Report on Task Force 25, Joint Committee Report of AASHTO-AGC-ARTBA, American Association of State Highway and Transportation Officials, Washington, DC, January, 1991.
(3) Ten Cate Nicolon Corporation. Geotextile Filter Design, Application, and Product Selection Guide. 2002.
(4) Virginia Department of Transportation. Road and Bridge Specifications. 2007.

Geotextile AOS Calculations Attachment 1

Material Index Properties



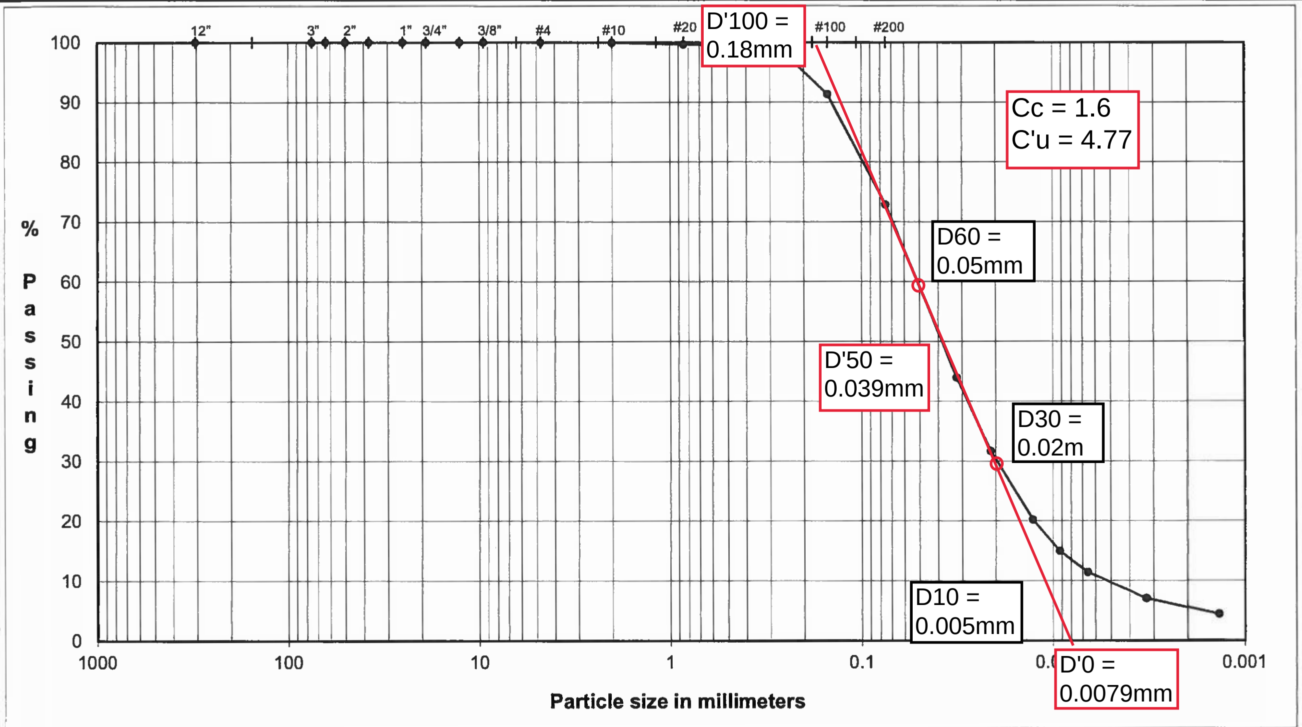
Index Properties of a VDOT A-Sand

Representative CCR Sample

AUGUST 2017 | 1520347-QA

PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS
ASTM D421, D422, D4318

PROJECT NAME: DOMINION/BREMO ASH POND CLOSURE CQA/VA
SAMPLE ID: CCR-EAP-16 Depth: -
TYPE: Bulk



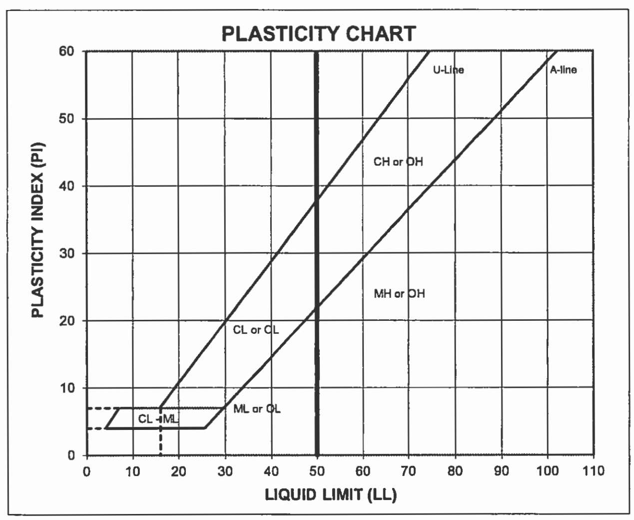
COBBLES	GRAVEL		SAND			FINES
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay

U.S. Standard Sieves Sizes and Numbers

	Particle Size (mm)	% Passing	Particle Size Classification	Percentage
12.0"	304.8	100.0		
3.0"	75.0	100.0	Cobbles	0.0
2.5"	63.5	100.0		
2.0"	50.0	100.0		
1.5"	37.5	100.0		
1.0"	25.0	100.0		
0.75"	19.0	100.0	Coarse Gravel	0.0
0.50"	12.7	100.0		
0.375"	9.5	100.0		
#4	4.8	100.0	Fine Gravel	0.0
#10	2.00	99.9	Coarse Sand	0.1
#20	0.85	99.6		
#40	0.43	99.4	Medium Sand	0.5
#60	0.25	98.1		
#100	0.15	91.3		
#200	0.075	72.9	Fine Sand	26.5

Hydrometer Analysis

(mm)	%Finer	Classification	Percentage
0.032	44.0		
0.021	31.6		
0.013	20.2	Fines	
0.0092	14.9	Silt or Clay	72.9
0.0066	11.4		
0.0033	7.0		
0.0014	4.4		



ATTERBERG LIMITS
Method -B (Dry preparation)

M_c	LL	PL	PI	LI
123.0				

LL (oven-dried)	
< 0.75 = ORGANIC (OL/OH)	

DESCRIPTION: sandy SILT, fine to coarse; dark gray.

USCS: (ML)

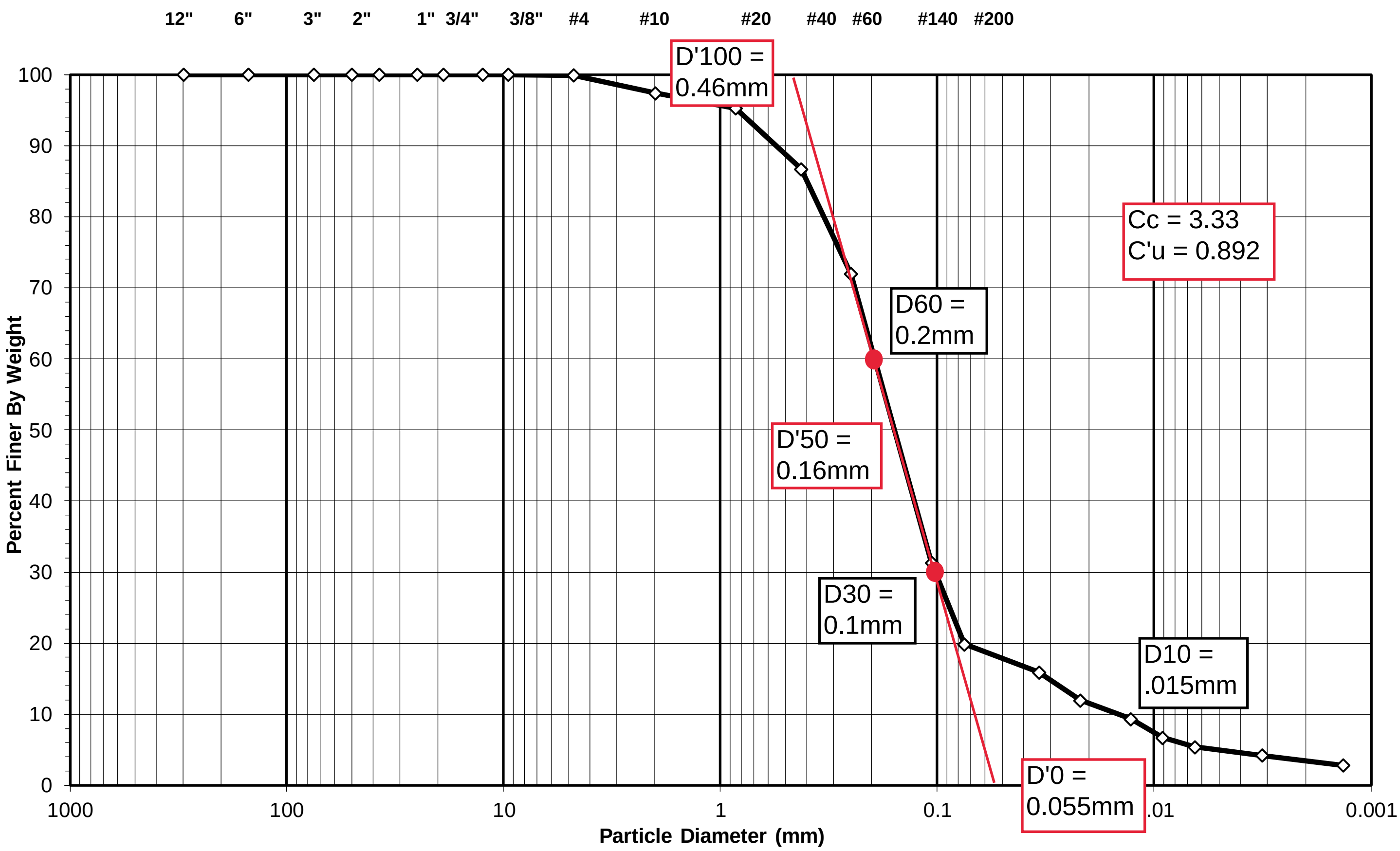
TECH	TB/FT
DATE	8/23/17
CHECK	[signature]
REVIEW	[signature]
APPROVE	

SIEVE AND HYDROMETER ANALYSIS

ASTM D 422-63 (2007)

Client	AECOM	Boring No.	PZ-20
Client Reference	Dominion - Bremo	Depth (ft)	28-30
Project No.	R-2020-043-001	Sample No.	SS-9
Lab ID	R-2020-043-001-006	Soil Color	Brown

	SIEVE ANALYSIS			HYDROMETER	
USCS	cobbles	gravel	sand	silt and clay fraction	
USDA	cobbles	gravel	sand	silt	clay



USCS Summary		
Sieve Sizes (mm)		**Percentage**
Greater Than #4	*Gravel*	0.10
#4 To #200	*Sand*	80.05
Finer Than #200	*Silt & Clay*	19.85
#200 To .005mm	*Silt*	14.98
Finer .005mm	Clay	4.87

USCS Symbol ***SM, TESTED***

(Non-Plastic Fines)

USCS Classification ***SILTY SAND***

DCN: CT-S3OR DATE: 7/26/2019 REVISION: 8 S\AECOM\2020-043 AECOM - Dominion - Bremo\2020-043-001\[2020-043-001-006 Grain Sieve Hyd10 SILT&CLAY.xls]Sheet1

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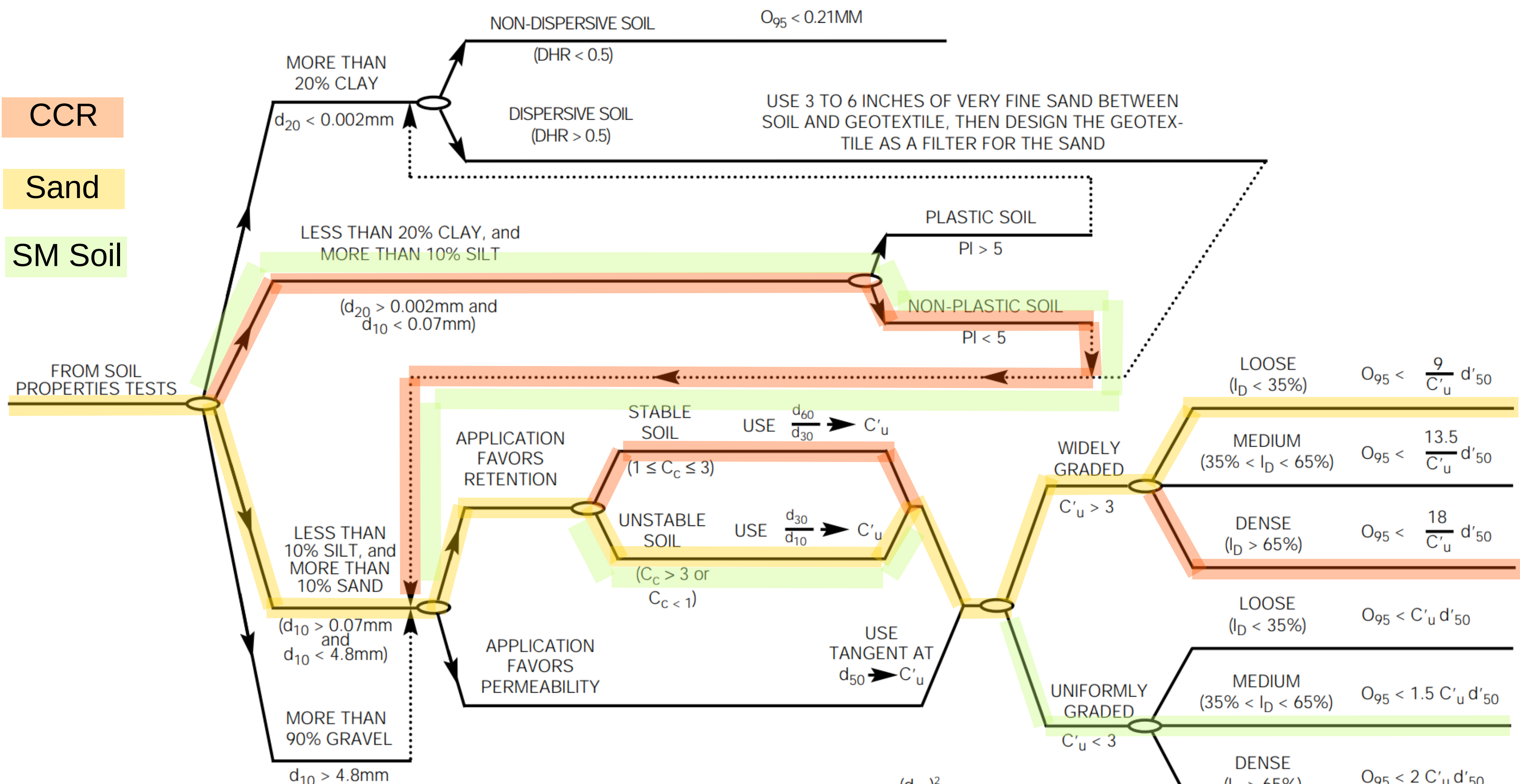
Geotextile AOS Calculations Attachment 2

Giroud Method Flowchart

Chart 1. Soil Retention Criteria of Steady-State Flow Conditions



NOTES:

d_x = particle diameter of which size *x* percent is smaller

$C'_u = \sqrt{\dfrac{d'_{100}}{d'_0}}$ where: d'_{100} and d'_0 are the extremeties of a straight line drawn through the particle-size distribution, as directed above and d'_{50} is the midpoint of this line

$C_c = \dfrac{(d_{30})^2}{d_{60} \times d_{10}}$

I_D = relative density of the soil
PI = plasticity index of the soil
DHR = double-hydrometer ratio of the soil
O_{95} = geotextile opening size

ATTACHMENT 4

PIPE CAPACITY CALCULATIONS

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Calculations

PROJECT: Bremo Bluff FFCP Management Facility	**REFERENCE NO:** 22130437.031
SUBJECT: Leachate Pipe Capacity	**DATE:** 06/01/2024

1.0 OBJECTIVE

The objective of this analysis is to confirm the proposed perforated leachate collection piping has the capacity to convey leachate flows after potential settlement of the foundation soil below the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility).

2.0 METHODOLOGY

In Attachment VI of the Part B Permit Application (Design Report), a foundation settlement calculation was completed to estimate total and differential settlements of the foundation soil below the proposed CCR Unit. Settlement at two points along each leachate collection header alignment was calculated and used to determine the resulting maximum change in slope. The changes to the leachate collection pipe slopes as a result of differential settlement did not result in any post-settlement slopes less than minimum design slopes; therefore, the leachate collection piping was evaluated at the minimum design slopes, i.e. 2.5% for leachate collection laterals and 3.0% for leachate collection headers.

Manning's equation was used to determine the capacity of the leachate collection headers and laterals. A Manning's coefficient of 0.011 was used.

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$$

Where:

Q = Flow Rate [cubic feet per second, (cfs)]
n = Manning's Roughness Coefficient
A = Cross-Sectional Flow Area [square feet (sf)]
R = Hydraulic Radius [feet (ft)]
S = Longitudinal Slope (ft/ft)

To ensure the leachate collection pipe perforation design allows for adequate inflow capacity for handling the peak flowrate, the perforations were analyzed using the orifice flow equation.

$$Q_o = C_d \times A \times \sqrt{2 \times g \times h}$$

Where:

Q_o = Orifice Inflow Rate per Linear Foot (cfs/ft)
C_d = Orifice Discharge Coefficient
A = Orifice Area per Linear Foot (sf/ft)
g = Gravitational Constant [feet per second squared (ft/s^2)]
h = Hydraulic head (ft)

3.0 ASSUMPTIONS

The anticipated flows to the leachate collection pipe headers and laterals were modeled via the Hydrologic

Evaluation of Landfill Performance (HELP) Model Program Version 4.0.1, as developed by the U.S. Army Engineering Waterways Experiment Station in Vicksburg, Mississippi for the U.S. Environmental Protection Agency (USEPA), to determine peak daily leachate generation rates. For this analysis, the results of the CCR Unit modeled with 40-ft of open CCR was used, as this condition produced the highest estimated peak daily leachate generation per acre, which was calculated to be 0.039 cfs.

Based on Attachment III of the Part B Permit Application (Design Plans), the CCR Unit limits of disposal is approximately 46 acres (ac). The design includes four leachate collection headers that convey flow from fifteen leachate collection laterals to the collection sump. The laterals are spaced at distances such that the maximum drainage length to a collection pipe is 225 ft where base grade slopes are less than 5% and 425 ft where base grade slopes are greater than 5%. The collection headers and laterals have nominal pipe sizes of 8-inch and 6-inch diameter, respectively. Per the JM Eagle high-density polyethylene (HDPE) pipe catalog (JM Eagle, 2018), standard dimension ratio (SDR) 11 pipe with these nominal sizes have inside diameters of 6.96 inches and 5.35 inches.

4.0 ANALYSIS

4.1 Pipe Capacity

The main collection header conveys leachate flow from the entire disposal area (45.6 ac); therefore, a peak flowrate of 1.76 cfs was used to verify capacity. The collection lateral with the largest contributing drainage area conveys flow from approximately 4.11 ac; therefore, a peak flowrate of 0.16 cfs was used. The maximum estimated flow depths during peak flows are 6.36 inches in the collection header and 1.87 inches in the collection lateral. The design parameters and results are summarized in the table below.

Table 1: Flowrate Summary

Leachate Collection Pipe	Slope (%)	Drainage Area (ac)	Pipe Capacity (cfs)	Peak Flowrate (cfs)	Peak Flow Depth (inch)
Header: 8-inch Perforated HDPE	3.00	45.6	1.80	1.76	6.36.58
Lateral: 6-inch Perforated HDPE	2.50	4.11	0.81	0.16	1.87

4.2 Perforation Capacity

The proposed perforation design consists of 4 rows of perforations around the circumference of the pipe, with 6-inch spacing between perforations in each row, and a 3-inch stagger between adjacent rows, resulting in 8 perforations per linear foot of pipe and a total open orifice area of 0.00614 sf/ft.

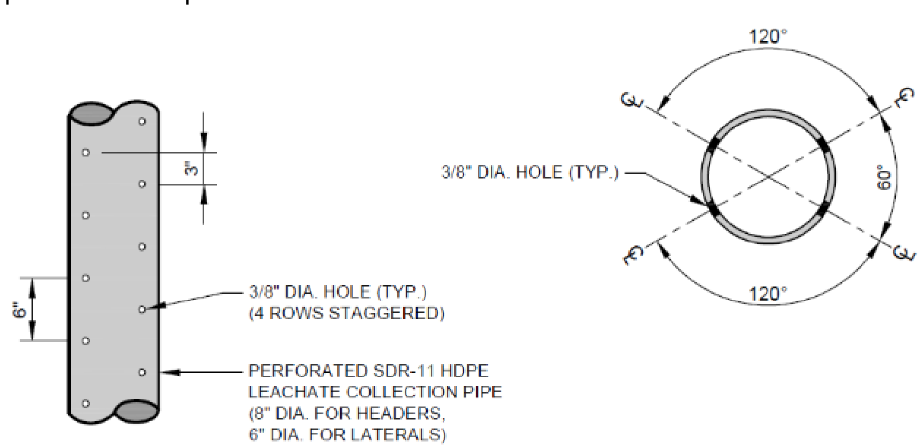

Figure 1: Leachate Collection Pipe Perforation Details

Distributing the peak flowrates equally along the length of the header and lateral (1.76 cfs over 1,155 ft and 0.16 cfs over 676 ft, respectively), yields an average flow distribution of 0.0015 cfs/ft and 0.00024 cfs/ft to be conveyed through the perforations of each respective pipe. An orifice discharge coefficient of 0.8 was chosen, as the pipe walls are equal to or thicker than the perforation diameter. The hydraulic head was assumed to be the maximum daily head on the liner, which was 3.709 inches for the 40-ft open CCR condition at 2.5% base grade slope.

Using these values, the pipes have an orifice inflow capacity of 0.022 cfs/ft. This capacity exceeds the peak flow rate distributions of 0.0015 cfs/ft and 0.00024 cfs/ft. The design parameters and results are summarized in the table below.

Table 2: Perforation Capacity

Leachate Collection Pipe	Peak Flowrate (cfs)	Pipe Length (ft)	Flow Distribution (cfs/ft)	Orifice Capacity (cfs/ft)
Header: 8-inch Perforated HDPE	1.76	1,155	0.0015	0.022
Lateral: 6-inch Perforated HDPE	0.16	676	0.00024	

5.0 CONCLUSION

Post-settlement, the proposed leachate collection headers and laterals have capacity to convey peak leachate flow rates. Additionally, the perforations are designed to adequately collect and convey leachate.

Attachments:

(1) Leachate Pipe Capacity Calculation Spreadsheet

References:

(1) JM Eagle (JM Eagle, 2018). HDPE Water/Sewer IPS. June 2018.

Leachate Pipe Capacity Attachment 1

Leachate Pipe Capacity Calculation Spreadsheet

Schnabel ENGINEERING

CALCULATIONS

Date: 5/14/2024
Project No.: 22130437.031
Subject: Leachate Header Pipe Capacity
Project Title: Bremo Bluff FFCP Management Facility

Made by: J. Frantz
Checked by: S. McHenry
Reviewed by: R. DiFrancesco

Methodology: Use Manning's Equation for uniform channel flow to determine pipe capacity.

Table 1: Pipe Dimensions			
Input	**Value**	**Unit**	**Notes:**
Inside Diameter, D	6.96	in	
	0.580	ft	
Radius, r	0.290	ft	$r = D/12$
Longitudinal Slope, S	0.0300	ft/ft	

Table 2: Flow Depth			
Input	**Value**	**Unit**	**Notes:**
Flow Depth, y	6.361	in	
	0.530	ft	
Θ:	1.193	rads	More than 1/2 full flow: $\theta = 2\arccos(\frac{r-(2r-y)}{r})$ Less than 1/2 full flow: $\theta = 2\arccos(\frac{r-y}{r})$

Table 3: Manning's Equation			
Input	**Value**	**Unit**	**Notes:**
Manning's Roughness Coefficient, n_{full}	0.011		
Cross Sectional Flow Area, A	0.253	sf	More than 1/2 full flow: $A = \pi r^2 - \frac{r^2(\theta - sin\theta)}{2}$ Less than 1/2 full flow: $A = \frac{r^2(\theta - sin\ )}{2}$
Wetted Perimeter, P	1.477	ft	More than 1/2 full flow: $A = 2\pi r - r\theta$ Less than 1/2 full flow: $A = r\theta$
Hydraulic Radius, R	0.172	ft	R = A/P
Variable Manning's Roughness Coefficient; n	0.011		Function of $\frac{y}{D}$

Table 4: Results			
Input	**Value**	**Unit**	**Notes:**
Flow Rate, Q	1.7591	CFS	$Q = \frac{1.49}{n} AR^{2/3} S^{1/2}$
Velocity, V	6.9437	ft/s	$V = Q/A$

Schnabel ENGINEERING

CALCULATIONS

Date: 5/14/2024
Project No.: 22130437.031
Subject: Leachate Lateral Pipe Capacity
Project Title: Bremo Bluff FFCP Management Facility

Made by: J. Frantz
Checked by: S. McHenry
Reviewed by: R. DiFrancesco

Methodology: Use Manning's Equation for uniform channel flow to determine pipe capacity.

Table 1: Pipe Dimensions

Input	Value	Unit	Notes:
Inside Diameter, D	5.35	in	
	0.446	ft	
Radius, r	0.223	ft	$r = D/12$
Longitudinal Slope, S	0.0250	ft/ft	

Table 2: Flow Depth

Input	Value	Unit	Notes:
Flow Depth, y	1.870	in	
	0.156	ft	
Θ:	2.531	rads	More than 1/2 full flow: $\theta = 2\arccos(\frac{r-(2r-y)}{r})$ Less than 1/2 full flow: $\theta = 2\arccos(\frac{r-y}{r})$

Table 3: Manning's Equation

Input	Value	Unit	Notes:
Manning's Roughness Coefficient, n_{full}	0.011		
Cross Sectional Flow Area, A	0.049	sf	More than 1/2 full flow: $A = \pi r^2 - \frac{r^2(\theta - sin\theta)}{2}$ Less than 1/2 full flow: $A = \frac{r^2(\theta - si\quad)}{2}$
Wetted Perimeter, P	0.564	ft	More than 1/2 full flow: $A = 2\pi r - r\theta$ Less than 1/2 full flow: $A = r\theta$
Hydraulic Radius, R	0.086	ft	R = A/P
Variable Manning's Roughness Coefficient; n	0.014		Function of $\frac{y}{D}$

Table 4: Results

Input	Value	Unit	Notes:
Flow Rate, Q	0.1587	CFS	$Q = \frac{1.49}{n} AR^{2/3} S^{1/2}$
Velocity, V	3.2644	ft/s	$V = Q/A$

ATTACHMENT 5

PIPE STRENGTH CALCULATIONS

Schnabel ENGINEERING

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Calculations

PROJECT: Bremo Bluff FFCP Management Facility	**REFERENCE NO:** 22130437.031
SUBJECT: Leachate Pipe Strength	**DATE:** 02/01/2024

1.0 OBJECTIVE

The objective of this analysis is to confirm the proposed leachate collection piping satisfies the design limits for compressive ring thrust, ring deflection, and wall buckling for the overburden pressure caused by the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility).

2.0 METHODOLOGY

The methodology presented in the Plastic Pipe Institute Handbook for Polyethylene Pipe (Plastic Pipe Institute, 2008) was used to calculate the compressive ring thrust, ring deflection, and wall buckling. Pipe strength is calculated with the maximum estimated CCR waste thickness, *i.e.,* maximum overburden pressure, for the leachate header pipes, lateral pipes, and sump collection pipes.

3.0 ASSUMPTIONS

Pipe strength calculations were based on the following assumptions and input parameters:

- Base grade and final grade elevations were based on the grading in Attachment III of the Part B Permit Application (Design Plans).
- The maximum CCR waste thickness above the leachate collection piping and the sump was estimated to be approximately 175 feet (ft) and 82 ft, respectively.
- CCR waste was assigned a unit weight of 110 pounds per cubic foot (pcf) based on results presented in the Bremo Power Station CCR Surface Impoundments, Impounding Structure Design Report, DCR Inventory #06520 (Golder, 2017).
- Two feet of final cover soil will be placed on top of the CCR. These soils were assigned a unit weight of 112 pcf based on the United States Department of Interior Bureau of Reclamation's Design of Small Dams Unified Soil Classification System (USBR, 1987) for the silty sand or sand-silt mixtures (SM) on-site.
- Aggregate in the bottom liner system was assigned a unit weight is 120 pcf.
- Confining soils are compacted to 95% of their standard proctor for leachate header, lateral, and sump area beddings.
- Leachate collection pipes are high-density polyethylene (HDPE) standard dimension ratio (SDR) 11 with a Standard Designation Code of PE4710.
- Leachate header and lateral collection pipes are nominal 8-inch (in) and 6-in perforated pipe with 3/8-in diameter holes spaced 6 in from center-to-center.
- Sump leachate collection pipes are nominal 24-in perforated pipe with 3/4-in diameter holes spaced 12 in from center-to-center.

4.0 ANALYSIS

Pipe design criteria was based on the methodology presented in the Plastic Pipe Institute Handbook for Polyethylene Pipe (Plastic Pipe Institute, 2008) for pipe burial greater than 50 ft. Compressive ring thrust strength, ring deflection, and wall buckling were calculated to determine the adequacy of the proposed leachate collection piping under the overburden stress of the proposed CCR Unit.

The Moore-Selig and modified Luscher methods were used to evaluate wall buckling. The Moore-Selig method is used to evaluate pipes in a dry condition, while the modified Luscher method is used for pipes buried beneath the groundwater table. Depending on CCR Unit conditions, leachate in the collection system could overtop the collection pipes, creating conditions corresponding to burial beneath the groundwater table.

The design overburden stress was determined at the location of the maximum CCR waste height above the leachate collection layer. The height of the soil, stone, and CCR waste was multiplied by the unit weight of each respective material. An overburden correction factor was applied to account for the leachate pipe perforations.

The following formulas were used to evaluate the proposed leachate collection pipes with the estimated overburden pressure.

4.1 Compressive Ring Thrust Strength

$$S = \frac{P_{RD} D_o}{288t}$$

Where:

- S = Pipe Wall Compressive Stress [pounds per square inch (psi)]
- P_{RD} = Radial Directed Earth Pressure (psi)
- D_o = Pipe Outside Diameter (in)
- t = Wall Thickness (in)

4.2 Ring Deflection (Watkins-Gaube)

$$\frac{\Delta X}{D_M}(100) = D_F \in_s$$

Where:

- D_M = Pipe Mean Diameter (in)
- ΔX = Change in Pipe Diameter (in)
- D_F = Deformation Factor
- E_s = Soil Strain (%)

4.3 Moore-Selig Constrained Pipe Wall Buckling:

$$P_{CR} = \frac{2.4\varphi R_H}{D_M}(EI)^{\frac{1}{3}}(E_S^*)^{\frac{2}{3}}$$

Where:

- P_{CR} = Critical constrained buckling pressure (psi)
- φ = Calibration Factor; 0.55 for granular soils
- R_H = Geometry Factor; 1.0 for deep burial in uniform soils
- E^*_S = Modified Secant Modulus of Soil (psi)
- E = Apparent Modulus of Elasticity of Pipe Material (psi)
- I = Pipe Wall Moment of Inertia [quartic inch per inch (in^4/in)]

4.4 Modified Luscher Constrained Pipe Wall Buckling:

$$P_{WC} = \frac{5.65}{N}\sqrt{RB'E'\frac{E}{12(DR-1)^3}}$$

Where:

- P_{WC} = Allowable Constrained Buckling Pressure (psi)
- N = Safety Factor; 2.0
- R = Buoyancy Reduction Factor
- B' = Soil Support Factor
- E' = Soil Reaction Modulus (psi)
- E = Apparent Modulus of Elasticity of Pipe Material (psi)
- DR = Pipe Dimension Ratio

5.0 RESULTS

The design overburden stress was calculated to be approximately 145.6 psi for the leachate headers and laterals and 71.6 psi for the sump piping. Compressive ring strength, ring deflection, and wall buckling for the leachate collection piping was calculated and compared to allowable design limits. The maximum compressive ring thrust was calculated to be approximately 621 psi for the headers and laterals and 320 psi for the sump, which are well below the 1,150 psi allowable compressive stress for a PE pipe with a PE4710 Standard Designation Code. The maximum ring deflection of the SDR-11 piping is 3.5 percent for the headers and laterals and 2.0 percent for the sump, which are within the safe deflection limits for the pipe. The Moore-Selig and Luscher wall buckling critical pressures were higher than the design overburden pressure for the pipe and represent acceptable factors of safety. The following table summarizes the calculated results and critical design values.

Table 1: Pipe Strength Summary Table

Leachate Collection Pipe	Compressive Ring Thrust Strength (psi)		Ring Deflection (%)		Wall Buckling Stress (psi)			
					Moore-Selig		Modified Luscher	
	Calculated	Critical	Calculated	Critical	Calculated	Critical	Calculated	Critical
Headers/ Laterals	621	1,150	3.5	5.0	145.6	663.1	145.6	240.3
Sump	320	1,150	2.0	5.0	71.6	596.8	71.6	238.5

7.0 CONCLUSION

The leachate headers pipes, lateral pipes, and sump pipes satisfy the acceptable limits and factors of safety with the overburden stress from the proposed CCR Unit.

Attachments:

(1) Leachate Pipe Strength Calculation Spreadsheet

References:

(1) Golder Associates (Golder, 2017). Bremo Power Station CCR Surface Impoundments, Impounding Structure Design Report, DCR Inventory #06520. March 2015, Revised March 2017.

(2) ISCO (2018). Product Catalogue, EPC Edition. Q3 2018.

(3) Plastic Pipe Institute (Plastic Pipe Institute, 2008). Handbook of Polyethylene Pipe, Second Edition. 2008.

(4) United States Department of Interiors Bureau of Reclamation (USBR, 1987). Design of Small Dams, Third Edition, 1987.

Leachate Pipe Strength Attachment 1

Leachate Pipe Strength Calculation Spreadsheet

Schnabel ENGINEERING

Calculations

Project:	Bremo Bluff FFCP Management Facility	**Made by:**	ERR
Subject:	Pipe Strength Calculations - Leachate Header	**Checked by:**	JAF
Reference No.:	22130437.031	**Reviewed by:**	JRD
Date:	2/01/2024		

Based on methodology presented in the Plastic Pipe Institute Handbook for Polyethylene Pipe, 2nd Edition, Section 3 - Deep Pipe Burial > 50 feet.

Table 1: Compressive Ring Thrust Strength

Input	Unit	8-in DR11	Notes:
Protective Cover Unit Weight, γ_{pc}	pcf	112	
Protective Cover Height, h_{pc}	ft	2.0	
Waste Unit Weight, γ_w	pcf	110	
Waste Height, h_w	ft	175.0	
Drainage Stone Unit Weight, γ_{ds}	pcf	120	
Drainage Stone Height, h_{ds}	ft	1.5	
Overburden Stress, δ_v	psf	19,654	$\sigma_v = (\gamma_{pc} * h_{pc})+(\gamma_w * h_w) + (\gamma_{ds} * h_{ds})$
Overburden Stress, δ_v	psi	136.5	
Pipe Outer Diameter, D_o	in	8.625	
Mean Diameter, D_m	in	7.841	$D_M = D_o - t$
Dimension Ratio, DR		11	Per Part B Design Plans
Wall Thickness, t	in	0.784	$t = \frac{D_o}{DR *}$
Radius to centroid, r_{CENT}	in	3.92	$r_{CENT} = \frac{D_o - t}{2}$
Hole Diameter	in	0.38	Per Part B Design Plans
Hole Spacing	in	6	Per Part B Design Plans
Number of holes around perimeter		4	Per Part B Design Plans
Reduced pipe length to account for perforations, L_p		0.75	
Length based overburden correction, L_{cp}		1.07	$L_{cp} = \frac{12}{12 - L_p}$
L_a		0.88	Length correction greater than area correction
Area based overburden correction, L_{ca}		1.02	$L_{ca} = \frac{D_o x12}{(D_o x12) - 2 * D_o}$
Design Overburden Stress, δ_d	psf	20,964	$\sigma_d = L_{cp} * \sigma_v$
Design Overburden Stress, δ_d	psi	145.6	
Constrained Modulus of Soil, M_s	psi	6,500	From Table 3-12, assumes 95% compaction
Assumed Pipe Temperature	°F	73	
Assumed Load Duration	years	50	
Apparent Modulus of Elasticity, E	psi	29,000	From Table B.1.1, assumes PE4XXX
Temperature Multiplier		1.00	From Table B.1.2
Hoop Thrust Stiffness Ratio, S_A		1.60	$S_A = \frac{1.43 M_S r_{CENT}}{Et}$
Vertical Arching Factor, VAF		0.78	$VAF = 0.88 - 0.71\frac{S_A - 1}{S_A + 2.5}$
Radial Directed Earth Pressure, P_{RD}	psf	16,262	$P_{RD} = (VAF) * \sigma_d$
Pipe Wall Compressive Stress, S	psi	621.1	$S = \frac{P_{RD} * (Do)}{288t}$
Allowable Compressive Strength	psi	1,150	From Table C.1
COMPRESSIVE STRESS CHECK		**PASS**	

Project:	Bremo Bluff FFCP Management Facility	**Made by:**	ERR
Subject:	Pipe Strength Calculations - Leachate Header	**Checked by:**	JAF
Reference No.:	22130437.031	**Reviewed by:**	JRD
Date:	2/01/2024		

Table 2: Ring Deflection (Watkins-Gaube)

Input	Unit	8-in DR11	Notes:
Poisson's ratio of backfill, μ		0.15	From Table 3-13 for coarse sand (Void Ratio 0.4-0.7)
Secant modulus of soil, E_S	psi	6,156	$E_S = M_s * \frac{(1+\mu)*(1-2\mu)}{(1-\mu)}$
Rigidity factor, R_F		2,547	$R_F = \frac{12 * E_s * (DR-1)^3}{E}$
Deformation Factor D_F		1.50	From R_F and Figure 3-6
Soil strain, ε_S	%	2.365	$\epsilon_s = \frac{\sigma_d}{144 * E_s} * 100$
Deflection, D	%	3.5	$D(\%) = D_F * \epsilon_S$
Acceptable deflection limit	%	5.00	From Table 3-11 for DR-11
DEFLECTION CHECK		**PASS**	

Table 3: Moore- Selig Constrained Pipe Wall Buckling

Input	Unit	8-in DR11	Notes:
Calibration factor, ϕ		0.55	0.55 for granular soils
Geometry factor, R_H		1.0	1.0 for deep burial in uniform soils
Pipe wall Moment of Inertial, I	in^3	0.040	$I = \frac{t^3}{12}$
Modified Secant Modulus of soil, E_s^*	psi	7,242	$E_S^* = \frac{E_S}{(1-\mu)}$
Critical constrained buckling pressure, P_{CR}	psi	663.1	$P_{CR} = \frac{2.4\varphi R_H}{D_M}(EI)^{1/3}(E_S^*)^{2/3}$
Factor of safety against buckling		4.6	$FS = \frac{P_{CR}}{\sigma_d}$
Acceptable factor of safety against buckling		2.0	
BUCKLING CHECK		**PASS**	

Table 4: Modified Luscher Constrained Pipe Wall Buckling

Input	Unit	8-in DR11	Notes:
Height of groundwater, H_{GW}	ft	1.00	Maximum allowable leachate head
Elastic support coefficient, B'		1.0	$B' = \frac{1}{1+4e^{-(0.065)(h)}}$
Soil Reaction Modulus, E'	psi	3,000	From table 3-7 for crushed rock
Bouyancy reduction factor, R		0.998	$R = 1 - 0.33\frac{H_{GW}}{h}$
Allowable constrained buckling pressure, P_{WC}	psi	240.3	$P_{WC} = \frac{5.65}{N}\sqrt{RB'E'\frac{E}{12(DR-1)^3}}$ N = 2 for Thermoplastic Pipe
BUCKLING CHECK		**PASS**	

Calculations

Project:	Bremo Bluff FFCP Management Facility	**Made by:**	ERR
Subject:	Pipe Strength Calculations - Leachate Lateral	**Checked by:**	JAF
Reference No.:	22130437.031	**Reviewed by:**	JRD
Date:	2/01/2024		

Based on methodology presented in the Plastic Pipe Institute Handbook for Polyethylene Pipe, 2nd Edition, Section 3 - Deep Pipe Burial > 50 feet.

Table 1 : Compressive Ring Thrust Strength

Input	Unit	6-in DR11	Notes:
Protective Cover Unit Weight, γ_{pc}	pcf	112	
Protective Cover Height, h_{pc}	ft	2	
Waste Unit Weight, γ_w	pcf	110	
Waste Height, h_w	ft	175	
Drainage Stone Unit Weight, γ_{ds}	pcf	120	
Drainage Stone Height, h_{ds}	ft	2	
Overburden Stress, δ_v	psf	19,654	$\sigma_v = (\gamma_{pc} * h_{pc}) + (\gamma_w * h_w) + (\gamma_{ds} * h_{ds})$
Overburden Stress, δ_v	psi	136.5	
Pipe Outer Diameter, D_o	in	6.625	
Mean Diameter, D_m	in	6.023	$D_M = D_o - t$
Dimension Ratio, DR		11	Per Part B Design Plans
Wall Thickness, t	in	0.602	$t = \frac{D_o}{DR *}$
Radius to centroid, r_{CENT}	in	3.01	$r_{CENT} = \frac{D_o - t}{2}$
Hole Diameter	in	0.38	Per Part B Design Plans
Hole Spacing	in	6	Per Part B Design Plans
Number of holes around perimeter		4	Per Part B Design Plans
Reduced pipe length to account for perforations, L_p		0.75	
Length based overburden correction, L_{cp}		1.07	$L_{cp} = \frac{12}{12 - L_p}$
L_a		0.88	Length correction greater than area correction
Area based overburden correction, L_{ca}		1.02	$L_{ca} = \frac{D_o x12}{(D_o x12) - 2 * D_o}$
Design Overburden Stress, δ_d	psf	20,964	$\sigma_d = L_{cp} * \sigma_v$
Design Overburden Stress, δ_d	psi	145.6	
Constrained Modulus of Soil, M_s	psi	6,500	From Table 3-12, assumes 95% compaction
Assumed Pipe Temperature	°F	73	
Assumed Load Duration	years	50	
Apparent Modulus of Elasticity, E	psi	29,000	From Table B.1.1, assumes PE4XXX
Temperature Multiplier		1.00	From Table B.1.2
Hoop Thrust Stiffness Ratio, S_A		1.60	$S_A = \frac{1.43 M_S r_{CENT}}{Et}$
Vertical Arching Factor, VAF		0.78	$VAF = 0.88 - 0.71 \frac{S_A - 1}{S_A + 2.5}$
Radial Directed Earth Pressure, P_{RD}	psf	16,262	$P_{RD} = (VAF) * \sigma_d$
Pipe Wall Compressive Stress, S	psi	621.1	$S = \frac{P_{RD} * (Do)}{288t}$
Allowable Compressive Strength	psi	1,150	From Table C.1
COMPRESSIVE STRESS CHECK		**PASS**	

Schnabel ENGINEERING

Calculations

Project:	Bremo Bluff FFCP Management Facility	**Made by:**	ERR
Subject:	Pipe Strength Calculations - Leachate Lateral	**Checked by:**	JAF
Reference No.:	22130437.031	**Reviewed by:**	JRD
Date:	2/01/2024		

Table 2 : Ring Deflection (Watkins-Gaube)

Input	Unit	6-in DR11	Notes:
Poisson's ratio of backfill, μ		0.15	From Table 3-13 for coarse sand (Void Ratio 0.4-0.7)
Secant modulus of soil, E_S	psi	6,156	$E_S = M_s * \frac{(1+\mu)*(1-2\mu)}{(1-\mu)}$
Rigidity factor, R_F		2,547	$R_F = \frac{12 * E_s * (DR-1)^3}{E}$
Deformation Factor D_F		1.50	From R_F and Figure 3-6
Soil strain, ε_S	%	2.365	$\epsilon_s = \frac{\sigma_d}{144 * E_s} * 100$
Deflection, D	%	3.5	$D(\%) = D_F * \epsilon_S$
Acceptable deflection limit	%	5.00	From Table 3-11 for DR-11
DEFLECTION CHECK		**PASS**	

Table 3: Moore- Selig Constrained Pipe Wall Buckling

Input	Unit	6-in DR11	Notes:
Calibration factor, ϕ		0.55	0.55 for granular soils
Geometry factor, R_H		1.0	1.0 for deep burial in uniform soils
Pipe wall Moment of Inertial, I	in^3	0.018	$I = \frac{t^3}{12}$
Modified Secant Modulus of soil, E_s*	psi	7,242	$E_S^* = \frac{E_S}{(1-\mu)}$
Critical constrained buckling pressure, P_{CR}	psi	663.1	$P_{CR} = \frac{2.4\varphi R_H}{D_M}(EI)^{1/3}(E_S^*)^{2/3}$
Factor of safety against buckling		4.6	$FS = \frac{P_{CR}}{\sigma_d}$
Acceptable factor of safety against buckling		2.0	
BUCKLING CHECK		**PASS**	

Table 4: Modified Luscher Constrained Pipe Wall Buckling

Input	Unit	6-in DR11	Notes:
Height of groundwater, H_{GW}	ft	1.00	Maximum allowable leachate head
Elastic support coefficient, B'		1.0	$B' = \frac{1}{1 + 4e^{-(0.065)(h)}}$
Soil Reaction Modulus, E'	psi	3,000	From table 3-7 for crushed rock
Bouyancy reduction factor, R		0.998	$R = 1 - 0.33\frac{H_{GW}}{h}$
Allowable constrained buckling pressure, P_{WC}	psi	240.3	$P_{WC} = \frac{5.65}{N}\sqrt{RB'E'\frac{E}{12(DR-1)^3}}$ N = 2 for Thermoplastic Pipe
BUCKLING CHECK		**PASS**	

Project: Bremo Bluff FFCP Management Facility
Subject: Pipe Strength Calculations - Sump
Reference No.: 22130437.031
Date: 2/01/2024

Made by: ERR
Checked by: JAF
Reviewed by: JRD

Based on methodology presented in the Plastic Pipe Institute Handbook for Polyethylene Pipe, 2nd Edition, Section 3 - Deep Pipe Burial > 50 feet.

Table 1 : Compressive Ring Thrust Strength

Input	Unit	24-in DR11	Notes:
Protective Cover Unit Weight, γ_{pc}	pcf	112	
Protective Cover Height, h_{pc}	ft	2	
Waste Unit Weight, γ_w	pcf	110	
Waste Height, h_w	ft	82	
Drainage Stone Unit Weight, γ_{ds}	pcf	120	
Drainage Stone Height, h_{ds}	ft	3.5	
Overburden Stress, δ_v	psf	9,664	$\sigma_v = (\gamma_{pc} * h_{pc})+(\gamma_w * h_w) + (\gamma_{ds} * h_{ds})$
Overburden Stress, δ_v	psi	67.1	
Pipe Outer Diameter, D_o	in	24.000	
Mean Diameter, D_m	in	21.818	$D_M = D_o - t$
Dimension Ratio, DR		11	Per Part B Design Plans
Wall Thickness, t	in	2.182	$t = \frac{D_o}{DR *}$
Radius to centroid, r_{CENT}	in	10.91	$r_{CENT} = \frac{D_o - t}{2}$
Hole Diameter	in	0.75	Per Part B Design Plans
Hole Spacing	in	12	Per Part B Design Plans
Number of holes around perimeter		8	Per Part B Design Plans
Reduced pipe length to account for perforations, L_p		0.75	
Length based overburden correction, L_{cp}		1.07	$L_{cp} = \frac{12}{12 - L_p}$
L_a		3.53	Length correction greater than area correction
Area based overburden correction, L_{ca}		1.03	$L_{ca} = \frac{D_o x12}{(D_o x12) - 2 * D_o}$
Design Overburden Stress, δ_d	psf	10,308	$\sigma_d = L_{cp} * \sigma_v$
Design Overburden Stress, δ_d	psi	71.6	
Constrained Modulus of Soil, M_s	psi	5,550	From Table 3-12, assumes 95% compaction
Assumed Pipe Temperature	°F	73	
Assumed Load Duration	years	50	
Apparent Modulus of Elasticity, E	psi	29,000	From Table B.1.1, assumes PE4XXX
Temperature Multiplier		1.00	From Table B.1.2
Hoop Thrust Stiffness Ratio, S_A		1.37	$S_A = \frac{1.43 M_S r_{CENT}}{Et}$
Vertical Arching Factor, VAF		0.81	$VAF = 0.88 - 0.71 \frac{S_A - 1}{S_A + 2.5}$
Radial Directed Earth Pressure, P_{RD}	psf	8,374	$P_{RD} = (VAF) * \sigma_d$
Pipe Wall Compressive Stress, S	psi	319.9	$S = \frac{P_{RD} * (Do)}{288t}$
Allowable Compressive Strength	psi	1,150	From Table C.1
COMPRESSIVE STRESS CHECK		**PASS**	

Project: Bremo Bluff FFCP Management Facility
Subject: Pipe Strength Calculations - Sump
Reference No.: 22130437.031
Date: 2/01/2024
Made by: ERR
Checked by: JAF
Reviewed by: JRD

Table 2 : Ring Deflection (Watkins-Gaube)

Input	Unit	24-in DR11	Notes:
Poisson's ratio of backfill, μ		0.15	From Table 3-13 for coarse sand (Void Ratio 0.4-0.7)
Secant modulus of soil, E_S	psi	5,256	$E_S = M_s * \frac{(1+\mu)*(1-2\mu)}{(1-\mu)}$
Rigidity factor, R_F		2,175	$R_F = \frac{12 * E_s * (DR-1)^3}{E}$
Deformation Factor D_F		1.50	From R_F and Figure 3-6
Soil strain, ε_S	%	1.362	$\epsilon_s = \frac{\sigma_d}{144 * E_s} * 100$
Deflection, D	%	2.0	$D(\%) = D_F * \epsilon_S$
Acceptable deflection limit	%	5.00	From Table 3-11 for DR-11
DEFLECTION CHECK		**PASS**	

Table 3: Moore- Selig Constrained Pipe Wall Buckling

Input	Unit	24-in DR11	Notes:
Calibration factor, ϕ		0.55	0.55 for granular soils
Geometry factor, R_H		1.0	1.0 for deep burial in uniform soils
Pipe wall Moment of Inertial, I	in^3	0.866	$I = \frac{t^3}{12}$
Modified Secant Modulus of soil, E_s*	psi	6,184	$E_S^* = \frac{E_S}{(1-\mu)}$
Critical constrained buckling pressure, P_{CR}	psi	596.8	$P_{CR} = \frac{2.4\varphi R_H}{D_M}(EI)^{1/3}(E_S^*)^{2/3}$
Factor of safety against buckling		8.3	$FS = \frac{P_{CR}}{\sigma_d}$
Acceptable factor of safety against buckling		2.0	
BUCKLING CHECK		**PASS**	

Table 4: Modified Luscher Constrained Pipe Wall Buckling

Input	Unit	24-in DR11	Notes:
Height of groundwater, H_{GW}	ft	1.00	Maximum allowable leachate head
Elastic support coefficient, B'		1.0	$B' = \frac{1}{1+4e^{-(0.065)(h)}}$
Soil Reaction Modulus, E'	psi	3,000	From table 3-7 for crushed rock
Bouyancy reduction factor, R		0.996	$R = 1 - 0.33\frac{H_{GW}}{h}$
Allowable constrained buckling pressure, P_{WC}	psi	238.5	$P_{WC} = \frac{5.65}{N}\sqrt{RB'E'\frac{E}{12(DR-1)^3}}$ N = 2 for Thermoplastic Pipe
BUCKLING CHECK		**PASS**	

TABLE 3-12
Typical Values of M_S, One-Dimensional Modulus of Soil

Vertical Soil Stress† (psi)	Gravelly Sand/Gravels 95% Std. Proctor (psi)	Gravelly Sand/Gravels 90% Std. Proctor (psi)	Gravelly Sand/Gravels 85% Std. Proctor (psi)
10	3000	1600	550
20	3500	1800	650
40	4200	2100	800
60	5000	2500	1000
80	6000	2900	1300
100	6500	3200	1450

* Adapted and extended from values given by McGrath[20]. For depths not shown in McGrath[20], the MS values were approximated using the hyperbolic soil model with appropriate values for K and n where n=0.4 and K=200, K=100, and K=45 for 95% Proctor, 90% Proctor, and 85% Proctor, respectively.

† Vertical Soil Stress (psi) = [soil depth (ft) x soil density (pcf)]/144

TABLE B.1.1
Apparent Elastic Modulus for 73°F (23°C)

Duration of Sustained Loading	Design Values For 73°F (23°C) (1,2,3)					
	PE 2XXX		PE3XXX		PE4XXX	
	psi	MPa	psi	MPa	psi	MPa
0.5hr	62,000	428	78,000	538	82,000	565
1hr	59,000	407	74,000	510	78,000	538
2hr	57,000	393	71,000	490	74,000	510
10hr	50,000	345	62,000	428	65,000	448
12hr	48,000	331	60,000	414	63,000	434
24hr	46,000	317	57,000	393	60,000	414
100hr	42,000	290	52,000	359	55,000	379
1,000hr	35,000	241	44,000	303	46,000	317
1 year	30,000	207	38,000	262	40,000	276
10 years	26,000	179	32,000	221	34,000	234
50 years	22,000	152	28,000	193	29,000	200
100 years	21,000	145	27,000	186	28,000	193

(1) Although there are various factors that determine the exact apparent modulus response of a PE, a major factor is its ratio of crystalline to amorphous content – a parameter that is reflected by a PE's density. Hence, the major headings PE2XXX, PE3XXX and, PE4XXX, which are based on PE's Standard Designation Code. The first numeral of this code denotes the PE's density category in accordance with ASTM D3350 (An explanation of this code is presented in Chapter 5).

(2) The values in this table are applicable to both the condition of sustained and constant loading (under which the resultant strain increases with increased duration of loading) and that of constant strain (under which an initially generated stress gradually relaxes with increased time).

(3) The design values in this table are based on results obtained under uni-axial loading, such as occurs in a test bar that is being subjected to a pulling load. When a PE is subjected to multi-axial stressing its strain response is inhibited, which results in a somewhat higher apparent modulus. For example, the apparent modulus of a PE pipe that is subjected to internal hydrostatic pressure – a condition that induces bi-axial stressing – is about 25% greater than that reported by this table. Thus, the Uni-axial condition represents a conservative estimate of the value that is achieved in most applications.

It should also be kept in mind that these values are for the condition of continually sustained loading. If there is an interruption or a decrease in the loading this, effectively, results in a somewhat larger modulus.

In addition, the values in this table apply to a stress intensity ranging up to about 400psi, a value that is seldom exceeded under normal service conditions.

TABLE B.1.2
Temperature Compensating Multipliers for Determination of the Apparent Modulus of Elasticity at Temperatures Other than at 73°F (23°C)

Equally Applicable to All Stress-Rated PE's (e.g., All PE2xxx's, All PE3xxx's and All PE4xxx's)

Maximum Sustained Temperature of the Pipe °F (°C)	Compensating Multiplier
-20 (-29)	2.54
-10 (-23)	2.36
0 (-18)	2.18
10 (-12)	2.00
20 (-7)	1.81
30 (-1)	1.65
40 (4)	1.49
50 (10)	1.32
60 (16)	1.18
73.4 (23)	1.00
80 (27)	0.93
90 (32)	0.82
100 (38)	0.73
110 (43)	0.64
120 (49)	0.58
130 (54)	0.50
140 (60)	0.43

TABLE C.1
Allowable Compressive Stress for 73°F (23°C)

	Pe Pipe Material Designation Code (1)					
	PE 2406		PE3408		PE 4710	
	PE 2708		PE 3608 PE 3708 PE 3710 PE 4708			
	psi	MPa	psi	MPa	psi	MPa
Allowable Compressive Stress	800	5.52	1000	6.90	1150	7.93

(1) See Chapter 5 for an explanation of the PE Pipe Material Designation Code.

TABLE 3-13
Typical range of Poisson's Ratio for Soil (Bowles [21])

Soil Type	Poisson's Ratio, μ
Saturated Clay	0.4-0.5
Unsaturated Clay	0.1-0.3
Sandy Clay	0.2-0.3
Silt	0.3-0.35
Sand (Dense)	0.2-0.4
Coarse Sand (Void Ratio 0.4-0.7)	0.15
Fine-grained Sand (Void Ratio 0.4-0.7)	0.25

TABLE 3-7
Values of E' for Pipe Embedment (See Howard [8])

Soil Type-pipe Embedment Material (Unified Classification System)[1]	E' for Degree of Embedment Compaction, lb/in²			
	Dumped	Slight, <85% Proctor, <40% Relative Density	Moderate, 85%-95% Proctor, 40%-70% Relative Density	High, >95% Proctor, >70% Relative Density
Fine-grained Soils (LL > 50)[2] Soils with medium to high plasticity; CH, MH, CH-MH	No data available: consult a competent soils engineer, otherwise, use E' = 0.			
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with less than 25% coarse grained particles.	50	200	400	1000
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with more than 25% coarse grained particles; Coarse-grained Soils with Fines, GM, GC, SM, SC[3] containing more than 12% fines.	100	400	1000	2000
Coarse-grained soils with Little or No Fines GW, GP, SW, SP[3] containing less than 12% fines	200	1000	2000	3000
Crushed Rock	1000	3000	3000	3000
Accuracy in Terms of Percentage Deflection[4]	±2%	±2%	±1%	±0.5%

[1] ASTM D-2487, USBR Designation E-3
[2] LL = Liquid Limit
[3] Or any borderline soil beginning with one of these symbols (i.e., GM-GC, GC-SC).
[4] For ±1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

Note: Values applicable only for fills less than 50 ft (15 m). Table does not include any safety factor. For use in predicting initial deflections only; appropriate Deflection Lag Factor must be applied for long-term deflections. If embedment falls on the borderline between two compaction categories, select lower E' value, or average the two values. Percentage Proctor based on laboratory maximum dry density from test standards using 12,500 ft-lb/cu ft (598,000 J/m²) (ASTM D-698, AASHTO T-99, USBR Designation E-11). 1 psi = 6.9 KPa.

TABLE 3-11
Safe Deflection Limits for Pressurized Pipe

DR or SDR	Safe Deflection as % of Diameter
32.5	7.5
26	7.5
21	7.5
17	6.0
13.5	6.0
11	5.0
9	4.0
7.3	3.0

* Based on Long-Term Design Deflection of Buried Pressurized Pipe given in ASTM F1962.

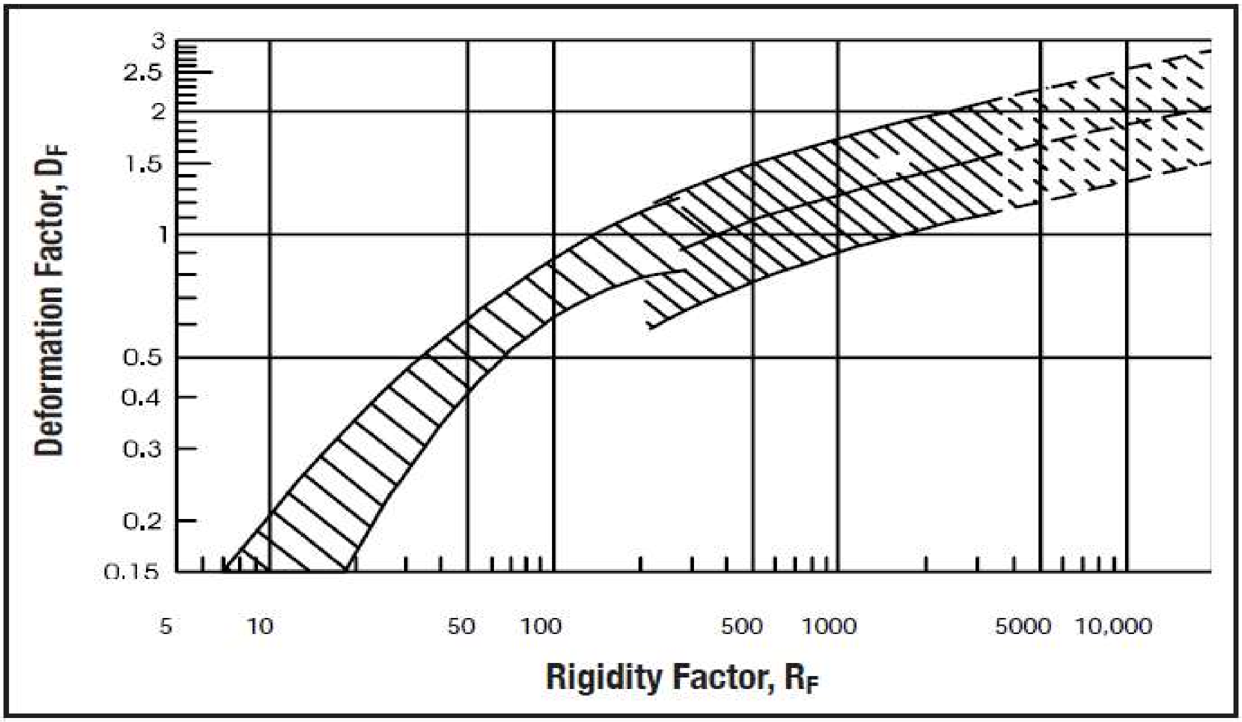

Figure 3-6 Watkins-Gaube Graph