COLSTRIP POWER PLANT

Prepared for:

TALEN MONTANA, LLC
303 N 28th St., Suite 400
Billings, Montana 59101

WRITTEN CLOSURE PLAN

Per Requirements of 40 CFR §257.102

J Cell
Colstrip Steam Electric Station
Colstrip, Montana

Prepared by:

Geosyntec consultants

10211 Wincopin Circle, 4th Floor
Columbia, Maryland 21044

Project Number ME1343

July 2016

CERTIFICATION STATEMENT

I, Carrie H. Pendleton, a registered Professional Engineer in the State of Montana (License No. 38837PE), certify that the *Written Closure Plan* and *Design of the Final Cover System* for the ***Colstrip Steam Electric Station's J Cell*** fulfills the minimum requirements of ***40 CFR 257.102(b) Written Closure Plan*** and ***40 CFR 257.102(d)(3) Final Cover System,*** respectively.

This certification is made in compliance with the specific requirements of §257.102(b)(4) and §257.102(d)(3)(iii).

This certification is based in part on review of reference documentation and data provided to Geosyntec Consultants (Geosyntec) by Talen Montana, LLC (Talen). These references, which are listed below, contain information regarding existing site infrastructure and past operations, which Geosyntec has relied upon (without independent verification of accuracy) for preparation of this certification.

- Bechtel (1982). "Effluent Holding Pond Design Report." Bechtel Power Corporation. October 1982.

- SCG (2014). "J Cell Phase 1 Earthworks Project, PPL-Montana – Colstrip Power Plant, Units 3 & 4 EHP Construction Drawings." Summit Consulting Group, March 2014.

- United States Environmental Protection Agency (USEPA) (2015). "Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule." Title 40 Code of Federal Regulations, Parts 257 and 261.

- United States Geological Survey (USGS) (2014). "Colstrip SE Quadrangle Montana-Rosebud Co. 7.5-Minute Series." Accessed 17 March 2016. http://store.usgs.gov/b2c_usgs/usgs/maplocator/(ctype=areadetails&xcm=r3standardpitrex_prd&carea=%24root&layout=6_1_61_48&uiarea=2)/.do

- Womack (2009). "C Cell-Old Clearwell (C/CW) Piezometers and Slope Stability." Womack & Associates, Inc. May 2009.

Geosyntec Consultants

C.H. Pendleton

Carrie H. Pendleton, P.E.
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MONTANA
CARRIE HALE PENDLETON
No. 38837PE
LICENSED
PROFESSIONAL ENGINEER

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1. INTRODUCTION

1.1 Organization and Terms of Reference

On 17 April 2015, the United States Environmental Protection Agency (USEPA) published the final rule for disposal of coal combustion residuals (CCR) from electric power utilities under Subtitle D of the Resource Conservation and Recovery Act (RCRA), contained in Part 257 of Title 40 of the Code of Federal Regulations (40 CFR 257 Subpart D), referred to herein as the CCR Rule. Geosyntec Consultants (Geosyntec) has prepared this Written Closure Plan (Plan) for Talen Montana, LLC (Talen) to demonstrate the manner in which J Cell, an existing CCR impoundment at the Colstrip Steam Electric Station (CSES), will be closed in compliance with the CCR Rule. Closure requirements for CCR units are specified under §257.102.

This Plan was prepared by Ms. Jennifer Padgett, P.E. and Mr. Mike Nolden, E.I.T., and reviewed in accordance with Geosyntec's internal review policy by Mr. David Espinoza, Ph.D., P.E., Mr. Jeremy Morris, Ph.D., P.E., and Ms. Carrie Pendleton, P.E., all of Geosyntec. Ms. Pendleton is a registered Professional Engineer in the State of Montana.

1.2 Site Location

J Cell is part of the Units 3 and 4 Effluent Holding Pond (EHP) area at the CSES, which is located in Colstrip, Rosebud County, Montana. The location of J Cell is shown on a United States Geological Survey (USGS) 7.5-minute topographic map for the Colstrip Southeast Quadrangle (Figure 1). J Cell is located southeast of the CSES generating facilities.

1.3 Site Description

J Cell is an active unlined CCR surface impoundment within the CSES EHP, which was constructed between 1983 and 1984 to accept CCR such as scrubber effluent and bottom ash from the CSES (Bechtel 1982). The EHP was constructed in the basin between Cow Creek and South Fork Cow Creek, the uppermost rim of which consists of baked and semi-baked shale underlain by sedimentary rock and coal beds (Bechtel 1982). A thin deposit of alluvium and colluvium covers most of the basin floor.

J Cell is bounded by the EHP Main Dam to the north, the EHP Saddle Dam to the northeast and east, and divider dikes to the south and west. The Main and Saddle Dams are zoned earth-fill dams with vertical cores extending to bedrock and sand and gravel drainage zones (Bechtel 1982). The divider dikes are constructed variously of baked shale fill, fly ash, and bottom ash (Womack 2009; SCG 2014).

Although J Cell historically impounded free liquids, it has been operated since 2009 only for the disposal of CCR solids and currently impounds CCR paste and solids without impounding free liquids (Geosyntec 2015). However, because the top surface of CCR paste and solids in J Cell is significantly below surrounding grades, during and following rain events stormwater runoff accumulates in J Cell.

2. CCR RULE REQUIREMENTS FOR WRITTEN CLOSURE PLAN

2.1 Written Closure Plan Requirements per §257.102(b)

As specified under §257.102(b), the Plan prepared for J Cell must describe the steps necessary to close the CCR unit at any point during the active life of the CCR unit consistent with recognized and generally accepted good engineering practices. The Plan must include, at a minimum:

(i) A narrative description of how the CCR unit will be closed in accordance with §257.102.
(ii) If closure of the CCR unit will be accomplished through removal of CCR, a description of the procedures to remove the CCR and decontaminate the CCR unit in accordance with paragraph §257.102(c).
(iii) If closure of the CCR unit will be accomplished by leaving CCR in place, a description of the final cover, designed in accordance with paragraph §257.102(d), and the methods and procedures to be used to install the final cover. The closure plan must also discuss how the final cover will achieve the performance standards specified in paragraph §257.102(d).
(iv) An estimate of the maximum inventory of CCR ever on-site over the active life of the CCR unit.
(v) An estimate of the largest area of the CCR unit ever requiring a final cover as required by paragraph §257.102(d) at any time during the CCR unit's active life.
(vi) A schedule for completing all activities necessary to satisfy the closure criteria, including an estimate of the year in which all closure activities will be completed as well as duration of such activities. The schedule should provide sufficient information to describe the sequential steps that will be taken to close the CCR unit, including identification of major milestones such as coordinating with and obtaining necessary approvals and permits from other agencies, construction of the final cover, and the estimated timeframes to complete each step or phase of CCR unit closure. If the owner or operator of a CCR unit estimates that the time required to complete closure will exceed the timeframes specified in paragraph §257.102(f)(1)(ii), that is within five years of commencement of closure activities, an extension may be available provided certain standards are met. The schedules should consider the requirements of §257.102(e) (Initiation of Closure Activities) and §257.102(f) (Completion of Closure Activities).

In addition, the owner or operator of the CCR unit must comply with the requirements of §257.102(g), (h), (i), and (j), which pertain to notification of intent to close, notification of closure, deed notations, and recordkeeping requirements, respectively.

2.2 Compliance with Closure Requirements

The table below summarizes where applicable CCR Rule requirements are addressed in this Plan.

RULE SECTION	RULE REQUIREMENT	LOCATION WHERE ADDRESSED IN DOCUMENT
§257.102(b)(1)(i)	Narrative description of how unit will be closed with CCR in place	Section 3.1
§257.102(b)(1)(ii)	Narrative of how unit will be closed by removal of CCR	Not applicable: J Cell will be closed by leaving CCR in place
§257.102(b)(1)(iii)	Description of final cover system design	Section 3.2.1
	Discussion of how final cover system will meet performance standard of §257.102(d)(1)	Sections 3.1, 3.2.2, and 3.2.4
	Discussion of drainage and stabilization requirements of §257.102(d)(2)	Section 3.2.3
	Description of methods and procedures used to install the final cover system	Section 3.2.4
§257.102(b)(1)(iv)	Estimate of the maximum on-site CCR inventory	Section 3.3
§257.102(b)(1)(v)	Estimate of the largest area of the CCR unit requiring closure	Section 3.4
§257.102(b)(1)(vi)	Closure schedule	Section 3.5
§257.102(g) and §257.102(h)	Closure notifications	CERTIFICATION STATEMENT and Section 3.6
§257.102(i)	Notification of deed notations	Section 3.6
§257.102(j)	Recordkeeping requirements	Section 3.6

3. CLOSURE PLAN

3.1 Description of Closure

Talen has elected to voluntarily close this CCR unit in 2016 under the applicable regulations. Per §257.102(b)(1)(i), this section provides a narrative description of CCR unit closure. J Cell will be closed by leaving CCR in place, constructing a final alternative cover system over the entire area of the unit, and complying with other applicable requirements of the CCR Rule.

The top surface of CCR paste and solids in J Cell is currently about 30-60 feet below surrounding grades, which results in stormwater runoff into the cell during and following rain events. To minimize infiltration through the J Cell cover system after closure and satisfy the performance standard specified in §257.102(d)(1)(i), therefore, a protective drainage layer and dewatering system is included in the design of the final cover system as discussed in Section 3.2. As further described in Section 3.2.2, the cover system for J Cell will be protected from erosion damage by the construction of a new CCR unit (J-1 Cell) over J Cell.

Constructing the final cover as described in the remainder of this Plan emphasizes passive management systems (e.g., gravity drainage of liquids in the dewatering system), which will serve to minimize the need for long-term maintenance of J Cell after closure and construction of J-1 Cell. The final cover design thus meets the requirement under §257.102(d)(1)(iv).

Existing conditions at J Cell are illustrated on Figure 2. Details of the J Cell closure design are presented in Figure 3.

3.2 Final Cover System Design

Section 257.102(b)(1)(iii) requires a description of the final cover system designed in accordance with §257.102(d)(3) and a demonstration of compliance with the performance standards specified in 257.102(d)(1).

3.2.1 Description of Final Cover System

The J Cell final cover will be an alternate cover system designed according to the requirements of §257.102(d)(3)(ii). The composite cover system design includes (from top to bottom):

- 18-inch bottom ash protective drainage layer;
- 8-oz non-woven geotextile cushion;
- 60-mil textured high density polyethylene (HDPE) geomembrane; and
- geosynthetic clay liner (GCL).

The GCL will be installed above a prepared subgrade of CCR paste and bottom ash.

As designed, the proposed final cover system includes a composite infiltration layer comprising an upper geomembrane component and lower GCL component overlain by a bottom ash protective drainage layer. The protective drainage layer provides lateral drainage, which will minimize the head on the geomembrane and limit infiltration through the final cover. The drainage layer will be graded at a 2% slope to drain to a dewatering system, which comprises perforated HDPE liquid collection pipes embedded in protective gravel mounds at 375 feet spacings on the final cover as well as in toe drains at the boundary between J Cell sideslopes and the final cover. Liquids collected in the pipes and toe drains will be conveyed to sumps fitted with riser pipes in which pumps will be operated to remove liquids.

3.2.2 Performance Standard

J Cell will be closed in a manner to minimize, to the extent feasible, post-closure infiltration of liquid into the waste per §257.102(d)(1)(i) by incorporating a low permeability final cover that meets the requirements of §257.102(d)(3)(ii)(A) through (C).

§257.102(d)(3)(ii)(A) – Reduction in Infiltration

The infiltration layer of the alternate final cover must achieve an equivalent reduction in infiltration as the infiltration layer specified in §257.102(d)(3)(i)(A), which requires that the permeability of the final cover system be less than or equal to the permeability of the bottom liner or natural subsoils present (or 1 x 10^{-5} cm/sec, whichever is less), and §257.102(d)(3)(i) (B), which requires the use of an infiltration layer that contains a minimum of 18 inches of earthen material.

As J Cell is unlined, the permeability of the final cover must be less than or equal to that of the natural subsoils or 1 x 10^{-5} cm/sec, whichever is less. However, the permeability of natural subsoils was not established as part of this design because the permeabilities of the geomembrane and GCL used in the final cover are 2 x 10^{-13} cm/sec and 1 x 10^{-8} cm/sec, respectively, far lower than the permeability of natural soils. The final cover design thus meets the performance standard under §257.102(d)(3)(i)(A).

The low permeability of the final cover is achieved through the use of a composite infiltration layer comprising an upper geomembrane component and a lower GCL component overlain by an 18-inch bottom ash protective drainage layer. The Final Cover Drainage Layer Analysis performed by Geosyntec (Appendix A.1) shows that the drainage layer is sufficient to limit the head on the geomembrane liner to the thickness of the drainage layer, which will allow any liquid to flow freely to the dewatering system collection pipes.

§257.102(d)(3)(ii)(B) – Erosion Protection

The design of the final cover system must include an erosion layer that provides equivalent protection from wind or water erosion as the erosion layer specified in §257.102(d)(3)(i)(C), that is an erosion layer that contains a minimum of six inches of earthen material that is capable of sustaining native plant growth. As designed, closure of J Cell will be followed by construction of J-1 Cell. The placement of J-1 Cell above the composite infiltration layer for J Cell will protect the J Cell cover system from erosion. As such, the J-1 Cell liner system serves the function of the erosion layer such that the final cover design for J Cell meets this erosion protection performance standard.

§257.102(d)(3)(ii)(C) – Integrity of the Final Cover

The final cover will be constructed of earthen and geosynthetic components that are sufficiently flexible to accommodate local differential settlements and subsidence expected at J Cell, as demonstrated by the settlement analysis by the Final Cover Settlement Analysis performed by Geosyntec (Appendix A.2). As previously demonstrated in Appendix A.1, the proposed grading of the final cover system and design of the lateral drainage layer and dewatering system are such that there will be no unwanted or uncontrolled impounding of water, sediment, or slurry above the final cover, as required by § 257.102(d)(1)(ii). The calculations in Appendix A.2 also demonstrate that the final cover system grades will not be reversed and the lateral drainage layer and dewatering system will continue to perform as designed even after settlement of the underlying waste under the maximum overburden loading from J-1 Cell has occurred. The final cover design thus meets the performance standard in §257.102(d)(3)(ii)(C).

At the time of final cover system construction, quality control and quality assurance measures will be implemented such that the final cover will be constructed as designed and the cover system will maintain major slope stability and integrity throughout the closure and post-closure periods, as required under §257.102(d)(1)(iii). The stability of the final cover system under design conditions is demonstrated by the Veneer Slope Stability Analysis performed by Geosyntec (Appendix A.3). The final cover design thus meets this performance standard.

3.2.3 Drainage and Stabilization of CCR Surface Impoundments

Requirements for draining and stabilizing waste in CCR surface impoundments prior to the construction of the final cover are specified in §257.102(d)(2).

As described in Section 1.2, J Cell was most recently used for CCR solid management and not process water and currently impounds CCR paste and solids without free water liquids. However, during and following rain events, stormwater runoff collects in J Cell. Prior to construction of the final cover, free liquids will be pumped from J Cell in accordance with §257.102(d)(2)(i). Following elimination of free liquids, the Global Slope Stability Analysis performed by Geosyntec (Appendix A.4) demonstrates that the remaining solid wastes will be sufficiently stable to support the final cover system, as required under §257.102(d)(2)(ii).

3.2.4 Methods and Procedures for Final Cover System Installation

Section 257.102(b)(1)(iii) requires this Plan to include a description of the methods and procedures to be used to install the final cover system.

During construction, construction quality assurance (CQA) will be performed to verify compliance with this Closure Plan and the CCR Rule. Construction oversight will include the following:

1. Observation of the subgrade surface following removal of vegetation and debris and completion of final grading to verify that surface debris is removed prior to subgrade preparation;

2. Observation of subgrade preparation, including removal of oversized rocks and rolling of the surface to provide a smooth surface for GCL installation;

3. Observation and documentation of geosynthetics installation including verification of material conformance with project requirements prior to installation, verification of proper installation techniques, and verification of geomembrane seam strength using non-destructive and destructive testing;

4. Observation and documentation of protective drainage layer placement including verification of material conformance with project requirements prior to and during installation, verification of proper installation techniques, and verification of proper layer thickness; and

5. Obtaining necessary documentation of construction, including material conformance information, field forms, laboratory testing of soils and geosynthetics, and as-built surveying.

The methods and materials of construction discussed above were specified such that the final cover meets the performance standard of §257.102(d)(1)(v). As such, the final cover design and proposed methods and procedures for installation of the final cover are intended to allow completion of closure construction in the shortest amount of time consistent with good engineering practices.

3.3 <u>Maximum Inventory of CCR</u>

The CCR Rule per §257.102(b)(1)(iv) requires that the written closure plan provides an estimate of the maximum inventory of CCR on site over the active life of the CCR unit. J Cell has been in operation since 1983 as an unlined impoundment.

J Cell has an area of 50.8 acres and an estimated maximum waste depth ranging between 30 and 80 feet. Based on this, the maximum inventory of CCR in the unit is estimated to be approximately 9.2 million cubic yards.

3.4 Maximum Area Requiring a Final Cover

The CCR Rule per §257.102(b)(1)(v) requires that the written closure plan provides an estimate of the largest area of the CCR unit requiring final cover at any one time in the CCR unit's active life.

The entirety of J Cell is to be closed by the installation of a single final cover constructed all at one time. The final cover will provide closure of approximately 57.1 acres.

3.5 Closure Schedule

The CCR Rule per §257.102(b)(1)(vi) requires the written closure plan to include a schedule for completing all activities necessary to satisfy the closure criteria, including an estimate of the year in which all closure activities will be completed as well as the duration of such activities.

J Cell closure is scheduled to begin in the summer of 2016. It is expected that the final receipt of CCR in the unit will be immediately prior to commencement of closure construction. Closure activities will commence within 30 days of the known final receipt of waste in accordance with §257.102(e)(1)(i). Closure activities are expected to be completed by the end of 2016, which is within the timeframe required by §257.102(f)(1)(ii).

The conceptual schedule below lists major milestones expected during closure activities. The estimated times to reach each milestone, starting from the commencement of closure activities, are included.

Milestone	Maximum Allowable Time for Completion
Final Closure System Design	Prior to Commencing Closure
Commencement of Closure System Construction Activities	Within 30 days of final receipt of CCR
Complete Construction of Closure System	Within 5 years of commencing closure

3.6 Notifications, Deed Notations, and Recordkeeping

The owner or operator of the CCR impoundment must comply with the requirements of §257.102(g) through (j), which pertain to notification of intent to close, notification of closure, deed notations, and recordkeeping requirements, respectively. Key dates and milestones that will be observed in order to comply with these requirements include the following

1. Notification of Intent to Close: This notification must be placed in the operating record no later than the date the owner or operator initiates closure of a CCR unit. The notification must include the certification required in §257.102(d)(3)(iii), which is provided at the front of this Plan.

2. Notification of Closure: The notification must be placed in the operating record within 30 days of completion of closure of the CCR unit. As required in §257.102 (f)(3), the notification must include certification from a qualified professional engineer verifying that closure has been completed in accordance with this Plan.

3. Deed Notation: No timing is specified for recording notations on the deed to the property (or similar instrument) following closure. Within 30 days of recording a notation on the deed to the property, however, the owner or operator must prepare a notification stating that the notation has been recorded. The owner or operator has completed the notification when it has been placed in the facility's operating record.

4. Closure Recordkeeping Requirements: The owner or operator of the CCR unit must comply with the closure recordkeeping requirements specified in §257.105(i), the closure notification requirements specified in §257.106(i), and the closure Internet requirements specified in §257.107(i). The timing for compliance with §257.105(i) is specified only in terms of placing required information in the facility's operating record (as required in §257.102). The timing for compliance with §257.106(i) and §257.107(i) is triggered by fulfilment of §257.105(i).

4. REFERENCES

Bechtel (1982). "Effluent Holding Pond Design Report." Bechtel Power Corporation. October 1982.

Geosyntec (2015). "Master Plan for Coal Combustion Residual Waste Management Systems, Colstrip Steam Electric Station." Geosyntec Consultants, Inc. 6 November 2015.

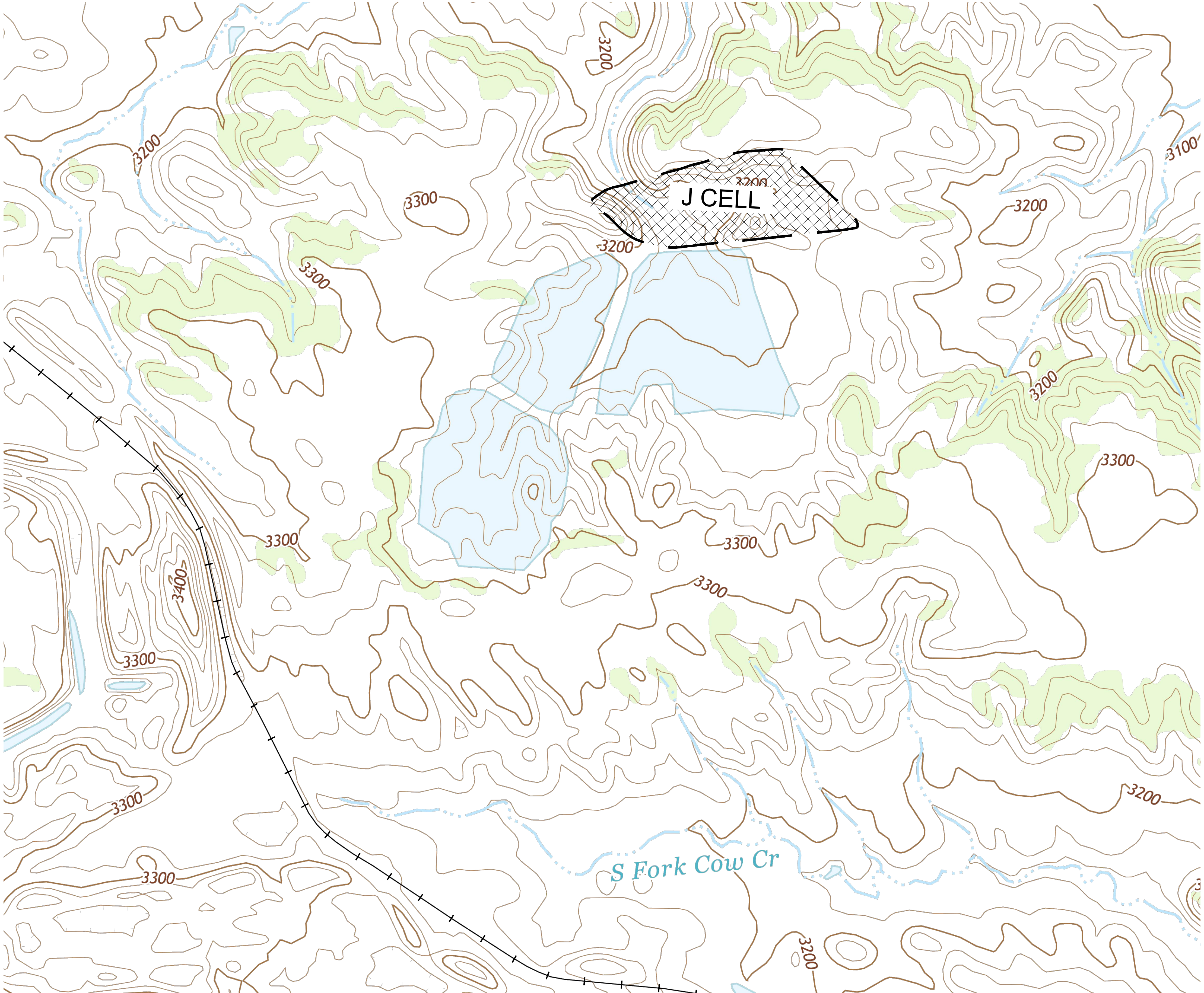
SCG (2014). "J Cell Phase 1 Earthworks Project, PPL-Montana – Colstrip Power Plant, Units 3 & 4 EHP Construction Drawings." Summit Consulting Group, March 2014.

United States Environmental Protection Agency (USEPA) (2015). "Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule." Title 40 Code of Federal Regulations, Parts 257 and 261.

United States Geological Survey (USGS) (2014). "Colstrip SE Quadrangle Montana-Rosebud Co. 7.5-Minute Series." Accessed 17 March 2016. http://store.usgs.gov/b2c_usgs/usgs/maplocator/(ctype=areadetails&xcm=r3standardpitrex_prd&carea=%24root&layout=6_1_61_48&uiarea=2)/.do

Womack (2009). "C Cell-Old Clearwell (C/CW) Piezometers and Slope Stability." Womack & Associates, Inc. May 2009.

FIGURES



N

LEGEND

- EXISTING GRADE CONTOUR (FEET-MSL)
- EXISTING RAILROAD TRACKS
- EXISTING WATERLINE
- SITE BOUNDARY

REFERENCE:
BACKGROUND IMAGE IS A USGS
7.5 MINUTE SERIES QUAD MAP FOR ROSEBUD, MONTANA

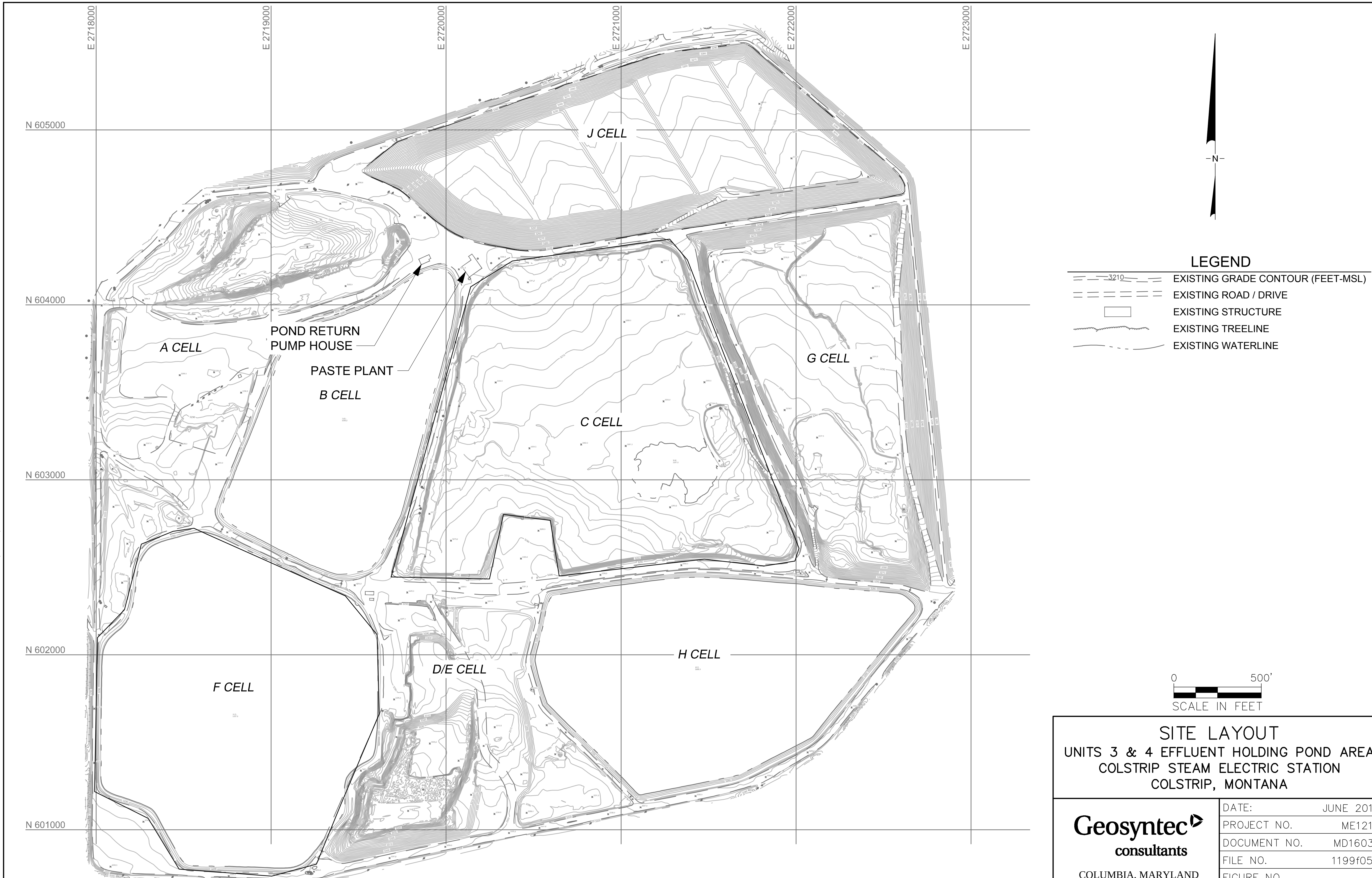
0 1,000'
SCALE IN FEET

J CELL LOCATION MAP

UNITS 3 & 4 EFFLUENT HOLDING POND AREA
COLSTRIP STEAM ELECTRIC STATION
COLSTRIP, MONTANA

Geosyntec consultants
COLUMBIA, MARYLAND

DATE:	JUNE 2016
PROJECT NO.	ME1210
DOCUMENT NO.	MD16039
FILE NO.	1199f054
FIGURE NO.	1

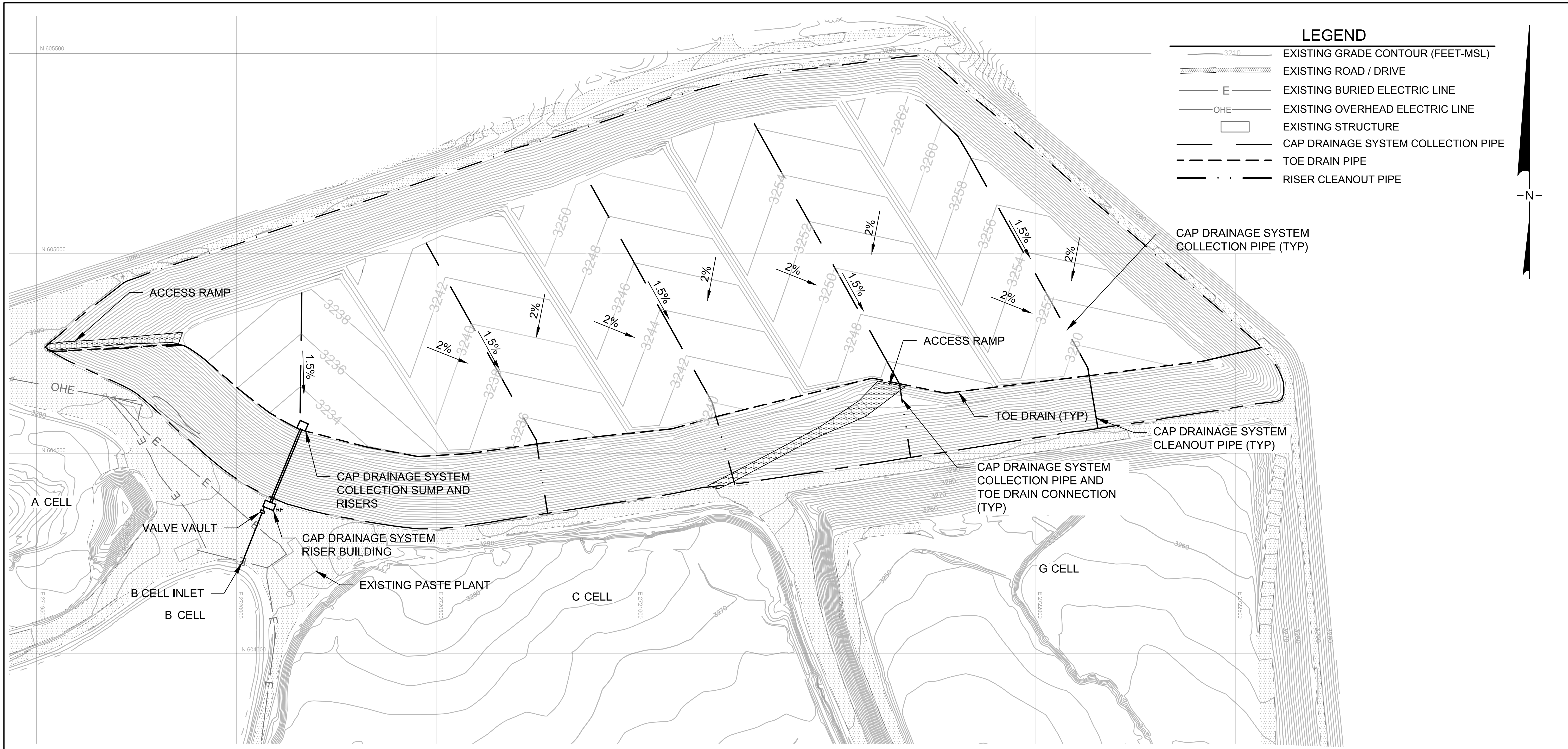


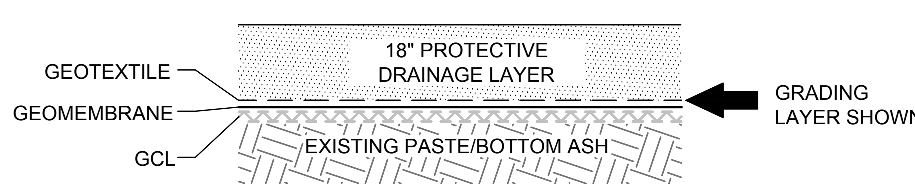
SITE LAYOUT

UNITS 3 & 4 EFFLUENT HOLDING POND AREA
COLSTRIP STEAM ELECTRIC STATION
COLSTRIP, MONTANA

Geosyntec consultants
COLUMBIA, MARYLAND

DATE:	JUNE 2016
PROJECT NO.	ME1210
DOCUMENT NO.	MD16039
FILE NO.	1199f053
FIGURE NO.	2





GRADING KEY

250 125 0 250 250
SCALE IN FEET

CONCEPTUAL CLOSURE DESIGN

Geosyntec consultants
COLUMBIA, MARYLAND

DATE:	JUNE 2016
PROJECT NO.	ME1343
DOCUMENT NO.	MD16039
FILE NO.	1210f213
FIGURE NO.	3

APPENDIX A

Engineering Calculations

APPENDIX A.1

Final Cover Drainage Layer Calculations

Geosyntec consultants

COMPUTATION COVER SHEET

Client: Talen Montana, LCC **Project:** EHP J Cell **Project #:** ME1343 **Task #:** 01

TITLE OF COMPUTATIONS GENERATION RATE OF IMPOUNDMENT WATER ABOVE COVER SYSTEM FOR J CELL (HELP MODEL)

COMPUTATIONS BY:
Signature [signature] 05/24/2016 DATE
Printed Name and Title: Zichang Li, Staff Engineer

ASSUMPTIONS AND PROCEDURES CHECKED BY: (Peer Reviewer)
Signature [signature] 05/25/2016 DATE
Printed Name and Title: Chunling Li, Project Engineer

COMPUTATIONS CHECKED BY:
Signature [signature] 05/31/2016 DATE
Printed Name and Title: Mohammad AI-Quraan, Staff Engineer

COMPUTATIONS BACKCHECKED BY: (Originator)
Signature [signature] 05/31/2016 DATE
Printed Name and Title: Zichang Li, Staff Engineer

APPROVED BY: (PM or Designate)
Signature [signature] 07/06/2016 DATE
Printed Name and Title: David Espinoza, Senior Principal

APPROVAL NOTES:

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

GENERATION RATE OF IMPOUNDMENT WATER ABOVE COVER SYSTEM FOR J CELL (HELP MODEL)

OBJECTIVE

The objective of this calculation package is to evaluate the generation rate of impoundment water and the potential water head above the cover system for J Cell, and the infiltration through the J Cell cover system at the Colstrip Steam Electric Station (CSES) in Colstrip, Rosebud County, Montana. The Hydrologic Evaluation of Landfill Performance (HELP) Version 3.07 [USEPA, 1994] computer program was used to aid the analysis.

ASSUMPTIONS AND METHOD

The top surface of CCR paste and solids in J Cell is currently about 30-60 feet below surrounding grades, which results in stormwater runoff into the cell during and following rain events. To minimize infiltration through the J Cell cover system after closure, a protective drainage layer and dewatering system is included in the design of the cover system for J Cell. Following completion of J Cell closure, Talen proposes to construct a new CCR Rule-compliant surface impoundment, designated as J-1 Cell, as a surface impoundment overfill directly above J Cell.

Analysis of potential infiltration through the J Cell Cover System is performed in this analysis. Figure 1 shows the grades of the cover system for J Cell (also being the base grades of the liner system for J-1 Cell). This calculation package evaluates the water head above the J Cell cap drainage system and the infiltration rate through the J Cell cap drainage system by considering the four operating conditions of overlying J-1 Cell, which include: open cell, daily fill, intermediate fill and final grade as shown in Figure 2. Prior to construction of the final cover for J-1 Cell, the water infiltration through the placed CCR waste will still occur in other sub-cells of J-1 Cell achieving the final grade condition. Therefore, the J-1 final grade condition is considered in this analysis. Figure 3 shows the final grades of J-1 Cell. In modeling these different conditions using the HELP program, the assumptions summarized in the following paragraph are made.

- The HELP model calculates a per acre rate of water collected from the cap drainage system. Because the amount of infiltration collected in the cap drainage system is directly proportional to the area, the per-acre value calculated by the HELP model is multiplied by the area to estimate water generation above the cap drainage system for the entire site.

INPUT DATA

The input data in the HELP model is classified into site/design specific data such as the layering configuration and material properties, and location specific data such as climatic data. For both types of input data properties, HELP offers the option of using default values or user defined values. Each set of input data is described in the following sections.

Weather Data

The HELP model requires the following weather-related input data: (i) evapotranspiration, (ii) precipitation, (iii) temperature, and (iv) solar radiation data. The HELP model provides default values and synthetically generated weather data for specific cities in the United States. The closest city to the site available in the HELP program, Billings, Montana, is selected for weather data input. Weather data is synthetically generated for a 30-year period.

The HELP default values for evaporation zone depths are used for defining Leaf Area Index (LAI). LAI is a dimensionless ratio of the leaf area that is actively transpiring vegetation to the nominal surface area of the land on which the vegetation is growing. For open cell, daily fill, and intermediate fill, no soil is used to cover the placed CCR waste at J-1 Cell, leading to a default value of 12 inches (in). Before constructing the final cover for J-1 Cell, the landfill at the final grade condition is conservatively assumed to support a poor stand of grass, leading to a default evaporation zone depth of 15 in. According to the HELP manual, the default LAI of 0.0 ("Bare" condition of vegetation) is used for the conditions of open cell, daily fill and intermediate fill. For final grade condition, the default LAI of 1.0 ("Poor Stand of Grass" condition of vegetation) is used for the project location.

Soil, Waste, and Geosynthetic Material Data

The cover system design for J Cell considered in the analysis is:

- 18 in bottom ash layer (protective cover) with hydraulic conductivity of 9.7×10^{-3} cm/s;
- Geotextile cushion;
- 60 mil high density polyethylene (HDPE) geomembrane;
- Geosynthetic Clay Liner (GCL);
- 70 ft compacted paste with hydraulic conductivity of 1.89×10^{-4} cm/s.

Waste

Soil texture number 30 (coal-burning electric plant fly ash) was chosen for the placed CCR waste. The default saturated hydraulic conductivity, 5×10^{-5} cm/s, is used to conservatively estimate the infiltration rate.

Daily and Intermediate Cover Soils

No cover soil is used when disposing of paste in the impoundment; therefore, no additional cover layer is included in the design.

Bottom Ash Protective/Drainage Layer

The 18 in bottom ash protective/drainage layer is designed to protect the liner and to convey liquids infiltrating through waste and collecting above the HDPE geomembrane. It is modeled as a drainage layer, using material texture number 31 (coal-burning electric plant bottom ash). The laboratory tests presented in Attachment 1 show that the saturated hydraulic conductivity of the bottom ash is 9.7×10^{-3} cm/s.

Geomembrane Liner

The geomembranes used for the base liner is 60-mil (0.06 in) HDPE geomembrane. The geosynthetic material number chosen for the HELP simulation is 35. The geomembrane liner is modeled conservatively as having a pinhole density of five pinholes per acre, and are conservatively assumed to have a poor placement quality.

Subbase (Ash Paste)

Based on the field geotechnical investigation performed by Geosyntec Consultants in June 2015, the ash paste at J Cell is estimated to be 50 ft thick. The laboratory tests presented in Attachment 2 show that the hydraulic conductivity of the compacted ash paste is 1.89×10^{-4} cm/s.

Surface Data

HELP models the surface runoff using the Soil Conservation Service (SCS) curve number method. HELP uses the surface slopes, lengths, soil type, and vegetative cover to determine a runoff curve number, which is used for runoff calculations. The surface characteristics vary depending upon the cell conditions. For open cell, daily fill and intermediate fill conditions, it is conservatively assumed that no runoff (0 %) is occurred. For final grade condition, 100 percent runoff is assumed as a positive drainage slope is achieved. The conditions used for this analysis are shown in Table 1.

Table 1. Surface Condition and Runoff Curve Numbers

Condition	Surface Slope (%)***	Surface Slope Length (ft)	Soil Texture	Vegetative Cover	Percent Possible Runoff	Runoff Curve Numbers
Open Cell	2	375	31	Bare Ground	0	96.8
	33	190			0	97.1
Daily Fill (10 ft paste daily fill)	0.6*	375	30	Bare Ground	0	96.7
Intermediate Fill (100 ft paste)	0.6*	375	30	Bare Ground	0	96.7
Final Grade	2.5**	150	30	Poor Strand of Grass	100	96.8

Note: * Minimum input accepted in HELP; ** Design drainage slope for final grade condition; *** Rounded inputs showed in the HELP outputs (Attachment 3), e.g. 0.6% being 1.% and 2.5% being 2.% in the result notes.

Drainage Distance and Slope

According to the base grading plan shown in Figure 1, the base grades will be constructed to have a drainage slope of 2 percent in the base of J-1 Cell. After the settlement of subsurface materials beneath the cap drainage system, the base of J-1 Cell was calculated to be 1.5 percent. Therefore, a drainage slope of 1.5 percent is used for the base of J-1 Cell for daily fill condition based on the subsurface settlement analysis. To be conservative, a drainage slope of 1.0 percent is assumed for intermediate fill condition and a drainage slope of 0.9 percent is assumed for final grade condition in the analysis. A drainage slope of 33 percent is used for the sideslopes. Inside of the cell, the maximum drainage distance is 375 ft in the base of the cell and 190 ft on the sideslopes. For daily fill and intermediate fill conditions, the surface slope of the placed CCR waste is conservatively assumed to be 0.6 percent, the minimum input value allowed in HELP. The drainage distance of the surface slope is also assumed to be 375 ft. As shown in Figure 3 the surface slope for final grade condition on the majority of the landfill is approximately 33 percent with a maximum drainage length of approximately 150 ft. The design slope at the top surface is 2.5 percent, which is the minimum slope required to achieve a satisfied positive drainage slope (not less than 2 percent) after the settlement of the placed CCR waste following the J-1 Cell closure. Given that the sideslopes are steeper than 2.5 percent, modeling the entire cover areas as having a slope of 2.5 percent in the water infiltration calculation yields a conservative design.

HELP MODEL RESULTS

Water Generation above Cap Drainage System

HELP simulation outputs for the four cell conditions are included as Attachment 3. The peak daily average water head above the cap drainage system for the four cell conditions are summarized in Table 2. As shown in Table 2, at all times the head above liner is less than 18 inches, the thickness of the bottom ash drainage layer. The maximum monthly water generation rate for the four cell conditions are summarized in Table 3.

Table 2. Water Head above the Cap Drainage System

Condition	Drainage Slope (%)	Drainage Distance (ft)	Water Head above the Cap Drainage System (in)
Open Cell	2	375	8.9
	33	190	7.0
Daily Fill (10 ft paste daily fill)	1.5*	375	2.8
Intermediate Fill (100 ft paste)	1.0*	375	1.1
Final Grade	0.9*	375	0.8

Note: * Drainage slope after settlement of subsurface materials.

Table 3. Maximum Monthly Water Volume above Cap Drainage System

Condition	Drainage Slope (%)	Drainage Distance (ft)	Paste of daily Fill (ft)	Maximum Monthly Water Volume (in.)
Open Cell	2	375	0	0.17
	33	190		0.55
Daily Fill	1.5	375	10	0.05
Intermediate Fill	1.0	375	100	0.03
Final Grade	0.9	375	210	0.02

HELP model outputs for water infiltration volume impingement are given in units of inches per acre per month. Calculation of the yearly infiltration water volume estimate begins with conversion of the HELP output into units of gallons per month per acre. The following equation is used for the unit conversion:

$$\frac{\text{acre–in. per acre}}{\text{month}} \times \frac{43{,}560\,\text{ft}^2}{\text{acre}} \times \frac{\text{ft}}{12\,\text{in.}} \times \frac{7.48\,\text{gal.}}{\text{ft}^3} = \frac{\text{gal.}}{\text{month}\,\text{acre}}$$

Considering the various combinations of the cell conditions for each landfill cell, the total infiltration water generation rates for J Cell are calculated and provided in Attachment 4. The maximum monthly and annual water generation volumes above the cap drainage system for the entire J Cell are summarized in Table 4.

Table 4. Infiltration Water above the Cover System for J Cell.

Water Generation above the Cover System for J Cell	Volumes
Maximum Monthly Generation (gal/mon)	310,827
Average Daily Generation in max. month (gal/day)	10,191
Maximum Annual Infiltration Water Generation (gal/year)	873,553
Average Daily Generation in max. year (gal/day)	2,393

Water Infiltration through Cap System for J Cell

Considering the various combinations of cell conditions for each landfill cell, the total water infiltration through the Cap System for J Cell for the four conditions are calculated and provided in Attachment 5. The maximum annual water infiltration through the Cap System for J Cell is expected to occur when J-1 Cell is open for placing CCR waste. The maximum annual infiltration water and average daily are summarized in Table 5.

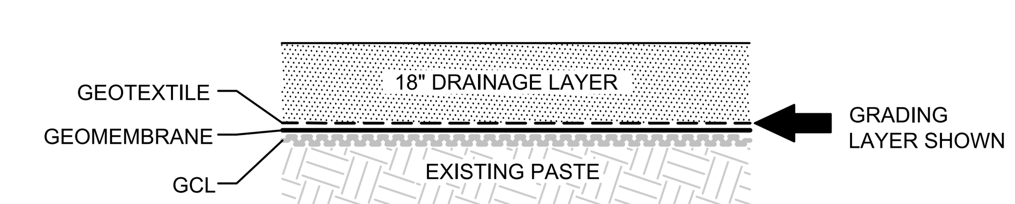
Table 5. Water Infiltration through the Cap System for J Cell.

Water through Cap System for J Cell	Volumes
Maximum Annual Infiltration Water Generation (gal/year)	465
Average Daily Generation in max. year (gal/day)	1.27

REFERENCES

Schroeder, P. Rs., Aziz, N. M., Lloyd, C. M. and Zappi, P. A. (1994). "The Hydrologic Evaluationa of Landfill Performance (HELP) Model: User's Guide for Version 3," EPA/600/R-94/168a, September 1994, U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

FIGURES

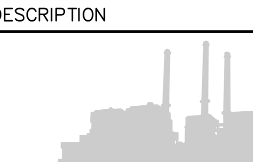


1 – DETAIL GRADING KEY

SCALE: NTS

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10220 OLD COLUMBIA ROAD, SUITE A
COLUMBIA, MARYLAND 21046 USA
PHONE: 410.381.4333



TALEN MONTANA, LLC
PO BOX 36
COLSTRIP, MONTANA 59323
406-748-5008

TITLE: SUBGRADE GRADING PLAN

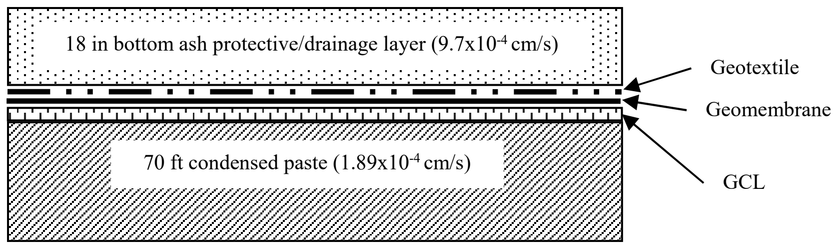
PROJECT: EHP J CELL CONSTRUCTION

SITE: COLSTRIP STEAM ELECTRIC STATION COLSTRIP, MONTANA

DESIGNED BY:	CHP	DATE:	NOVEMBER 2015
DRAWN BY:	TSJ	PROJECT NO.:	ME1210
CHECKED BY:	JMP	FILE:	1210-205
REVIEWED BY:	CHP	DRAWING NO.:	
APPROVED BY:	KEK		1 OF 3

SIGNATURE

(a) Open cell (base grade)



(b) Daily fill

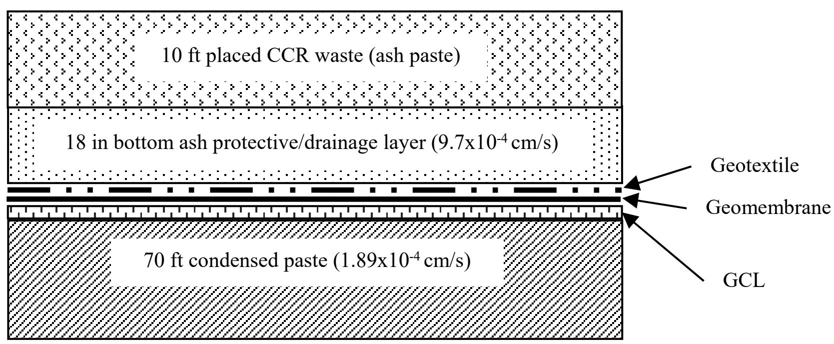
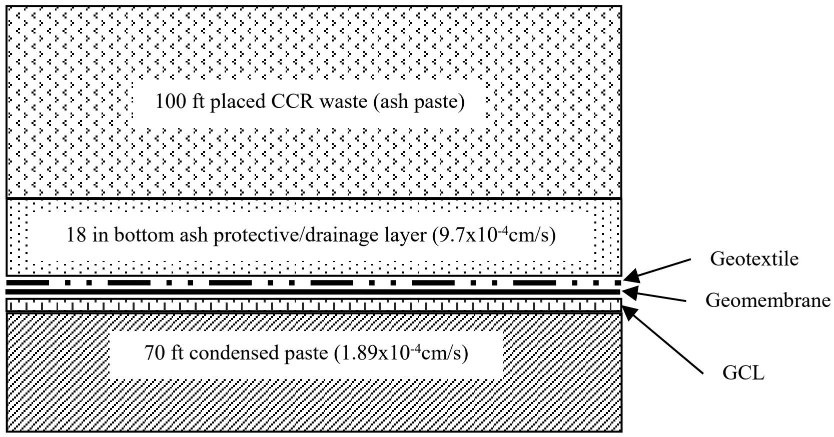


Figure 2. Operating Conditions Considered in the Analysis.

(c) Intermediate fill



(d) Final grade

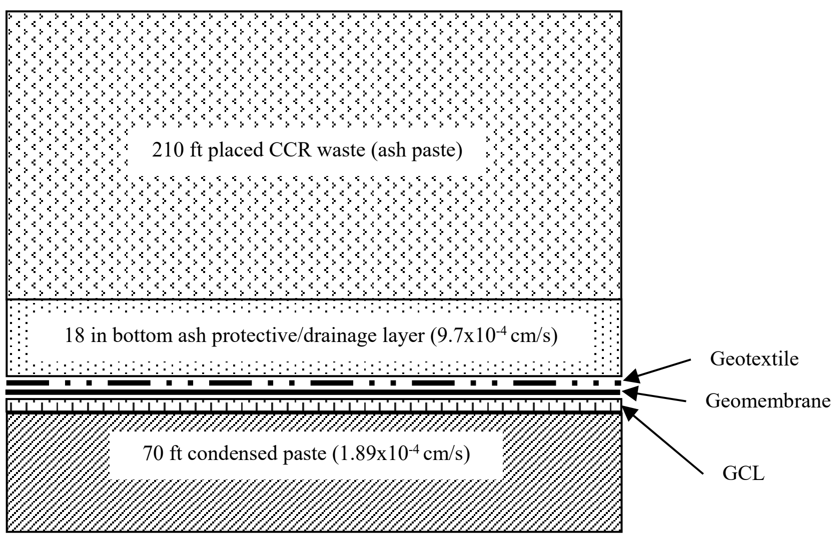


Figure 2 (continued). Operating Conditions Considered in the Analysis.

LEGEND

EXISTING GRADE CONTOUR (FEET-MSL)

3290 PROPOSED GRADE CONTOUR (FEET-MSL)

EXISTING ROAD / DRIVE

EXISTING STRUCTURE

EXISTING TREELINE

VOLUME SCHEDULE

CELL	VOLUME (C.Y.)
B	2,750,000
C	6,350,000
F	4,950,000
H	3,750,000
J	8,000,000
TOTAL	25,800,000

NOTES:

1. PROPOSED CAP GRADES ARE 3% FOR CELLS B, C, F, H AND 3H:1V FOR CELL J.

0 500'
SCALE IN FEET

CONCEPTUAL FINAL GRADING PLAN

COLSTRIP SITE 3 ASH PONDS
COLSTRIP LANDFILL
COLSTRIP, MONTANA

Geosyntec consultants
COLUMBIA, MARYLAND

DATE:	SEPTEMBER 2014
PROJECT NO.	ME1343
DOCUMENT NO.	
FILE NO.	1132f003
FIGURE NO.	3

P:\cadd\1132 colstrip\1132-000\1132f003.dwg, fg, 9/10/2014 2:18:52 PM, jconnor

ATTACHMENT 1

Laboratory Permeability Result of Bottom Ash

Rigid Wall Constant Head Permeability

Client: Geosyntec Consultants

Project: Colstrip Eletric Plant

Sample: Bottom Ash - Tamp in Place

TRI Log#: E2391-90-07

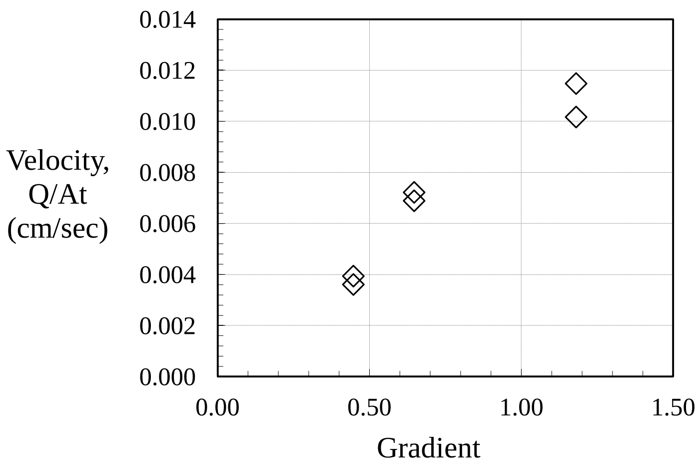
Test Method: ASTM D 2434

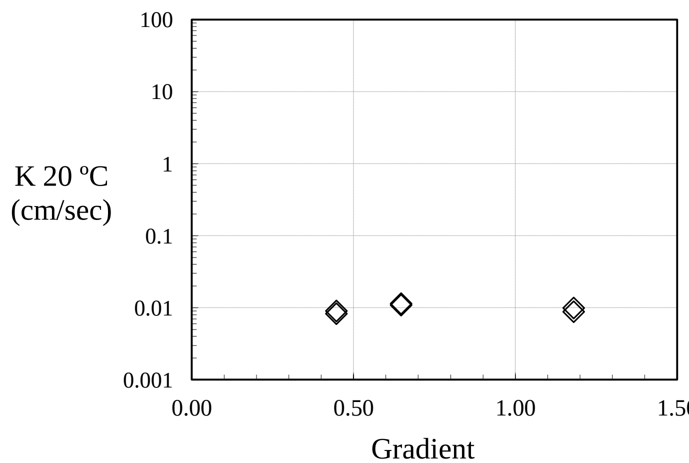
Test Date: 01/22/16

Manometer Reading (cm)		Gradient	Flow Volume, Q (ml)	Flow Time, t (s)	Temperature (°C)	Flow Rate (cm^3/s)	Velocity, Q/At (cm/s)	System Permeability (cm/s)	System Permeability @ 20 °C, $K_{20°C}$ (cm/s)	Average System Permeability @ 20 °C (cm/s)
1	2									
Gradient No. 1										
3.4	0	0.45	54	300	19.2	0.2	3.9E-03	8.8E-03	9.0E-03	**8.6E-03**
3.4	0	0.45	49	300	19.2	0.2	3.6E-03	8.1E-03	8.3E-03	
Gradient No. 2										
4.9	0	0.65	99	300	19.3	0.3	7.2E-03	1.1E-02	1.1E-02	**1.1E-02**
4.9	0	0.65	94	300	19.3	0.3	6.9E-03	1.1E-02	1.1E-02	
Gradient No. 3										
9.0	0	1.18	157	300	19.4	0.5	1.1E-02	9.7E-03	9.9E-03	**9.4E-03**
9.0	0	1.18	139	300	19.3	0.5	1.0E-02	8.6E-03	8.8E-03	

Specimen Cross-sectional Area, A (cm^2): 45.6

Final Avg. k at 20 deg C (cm/sec) : **9.7E-03**





Note: Soil specimen was tamped in place per test request.

Jeffrey A. Kuhn, Ph.D., P.E., 2/2/2016

Quality Review/Date

Tested by: KH

ATTACHMENT 2

Laboratory Permeability Result of Condensed Paste at J Cell

2511 Holman Avenue
P. O. Box 80190
Billings, Montana 59108-0190
p: 406.652.3930; f: 406.652.3944
www.skgeotechnical.com

Constant Head Hydraulic Conductivity

ASTM D 5084

Date: August 1, 2015

SK Project: **15-3361L Laboratory Testing**
Geosyntec Consultants, Inc. Proj#ME1210
Colstrip SES, J Cell, Colstrip, Montana

Client: Mr. Ranjiv Gupta, PhD, PE
Geosyntec Consultants, Inc.
8217 Shoal Creek Blvd, Suite 200
Austin, Texas 78757

Copies: Vinay Krishnan, EIT, Geosyntec, Inc.

Sample no.: GB-1 15-17.5'
Sampled by: client
Date sampled: 6/29-7/1/15

Received: 7/1/15
Tested by: DNF,JBD/SKG
Date tested: 7/20-7/31

Description: Silt Paste, fine to medium, grey, saturated, very dense

Sample Type: Undisturbed Shelby thinwall tube
Average Diameter: 2.871 "
Average Height: 4.003 "
Moisture: 44.3 %
Moist Unit Weight: 110.4 pcf

Run #	Pressure Head (h), psi	Flow Volume (Q), cc	Flow Time (t), sec	Hydraulic Conductivity (k), cm/s
1	5.0	1843.1	7200	1.77E-04
2	5.0	4058.6	14400	1.95E-04
3	5.0	7542.2	28800	1.82E-04
4	5.0	16518.5	57600	1.99E-04
5	5.0	24917.1	86400	2.00E-04

Average Hydraulic Conductivity (k): 1.91E-04

Remarks: Permeability and porosity in practice are sensitive to several other material properties, and conditions, in the field and lab. No individual lab property of a material can substitute for overall best practices in geotechnical design, construction, and field testing by qualified professionals.

Joe B. DeBar, PE
Materials Lab Manager

2511 Holman Avenue
P. O. Box 80190
Billings, Montana 59108-0190
p: 406.652.3930; f: 406.652.3944
www.skgeotechnical.com

Constant Head Hydraulic Conductivity

ASTM D 5084

Date: August 1, 2015

SK Project: **15-3361L Laboratory Testing**
Geosyntec Consultants, Inc. Proj#ME1210
Colstrip SES, J Cell, Colstrip, Montana

Client: Mr. Ranjiv Gupta, PhD, PE
Geosyntec Consultants, Inc.
8217 Shoal Creek Blvd, Suite 200
Austin, Texas 78757

Copies: Vinay Krishnan, EIT, Geosyntec, Inc.

Sample no.: GB-2 10-12'
Sampled by: client
Date sampled: 6/29-7/1/15

Received: 7/1/15
Tested by: DNF,JBD/SKG
Date tested: 7/20-7/31

Description: Silt Paste, fine to medium, grey, moist, very dense

Sample Type: Undisturbed Shelby thinwall tube
Average Diameter: 2.870 "
Average Height: 4.346 "
Moisture: 43.5 %
Moist Unit Weight: 112.2 pcf

Run #	Pressure Head (h), psi	Flow Volume (Q), cc	Flow Time (t), sec	Hydraulic Conductivity (k), cm/s
1	5.0	1661.5	7200	1.74E-04
2	5.0	3657.1	14400	1.91E-04
3	5.0	7394.1	28800	1.93E-04
4	5.0	14396.4	57600	1.88E-04
5	5.0	21394.1	86400	1.86E-04

Average Hydraulic Conductivity (k): 1.87E-04

Remarks: Permeability and porosity in practice are sensitive to several other material properties, and conditions, in the field and lab. No individual lab property of a material can substitute for overall best practices in geotechnical design, construction, and field testing by qualified professionals.

Joe B. DeBar, PE
Materials Lab Manager

ATTACHMENT 3

HELP Output

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                   **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                 USAE WATERWAYS EXPERIMENT STATION                        **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************
```

```
PRECIPITATION DATA FILE:    C:\HELP3\J\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\J\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\J\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\J\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\J\DA1JC020.D10
OUTPUT DATA FILE:           C:\HELP3\J\DA1JC020.OUT
```

TIME: 17:29   DATE: 5/31/2016

****

TITLE: Colstrip, Base Grading, 2.00% slope, 375'

****

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 2 - LATERAL DRAINAGE LAYER

MATERIAL TEXTURE NUMBER 31

```
THICKNESS                  =     18.00   INCHES
POROSITY                   =      0.5780 VOL/VOL
FIELD CAPACITY             =      0.0760 VOL/VOL
WILTING POINT              =      0.0250 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.1194 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.410000002000E-02 CM/SEC
SLOPE                      =      2.00   PERCENT
DRAINAGE LENGTH            =    375.0    FEET
```

LAYER 2

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 35

```
THICKNESS                  =      0.06   INCHES
POROSITY                   =      0.0000 VOL/VOL
FIELD CAPACITY             =      0.0000 VOL/VOL
WILTING POINT              =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =      5.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY      =  4 - POOR
```

LAYER 3

TYPE 3 - BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 17

```
THICKNESS                  =      0.24   INCHES
POROSITY                   =      0.7500 VOL/VOL
FIELD CAPACITY             =      0.7470 VOL/VOL
WILTING POINT              =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.300000003000E-08 CM/SEC
```

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	840.00 INCHES
POROSITY	=	0.5010 VOL/VOL
FIELD CAPACITY	=	0.2840 VOL/VOL
WILTING POINT	=	0.1350 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2840 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.188999998000E-03 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #31 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 375. FEET.

SCS RUNOFF CURVE NUMBER	=	96.80	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.122	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.936	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.300	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	240.886	INCHES
TOTAL INITIAL WATER	=	240.886	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM BILLINGS MONTANA

STATION LATITUDE	=	45.80 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	130
END OF GROWING SEASON (JULIAN DATE)	=	278
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES

AVERAGE ANNUAL WIND SPEED	=	11.30 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	59.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	54.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	47.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.97	0.71	1.05	1.93	2.39	2.07
0.85	1.05	1.26	1.16	0.85	0.80

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
20.90	28.40	33.80	44.60	54.90	64.00
72.30	70.30	59.40	49.30	35.00	27.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BILLINGS MONTANA AND STATION LATITUDE = 45.80 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

PRECIPITATION

TOTALS	0.96	0.78	0.95	1.77	2.26	2.05
	1.09	1.02	1.23	1.13	0.92	0.82
STD. DEVIATIONS	0.49	0.41	0.48	0.90	0.98	0.81
	0.59	0.66	0.86	0.69	0.59	0.43

RUNOFF

TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

EVAPOTRANSPIRATION

TOTALS	0.694	0.490	0.753	1.702	2.012	1.929
	1.220	0.925	1.078	0.946	0.861	0.610
STD. DEVIATIONS	0.242	0.273	0.390	0.703	0.702	0.658
	0.639	0.600	0.751	0.535	0.467	0.265

LATERAL DRAINAGE COLLECTED FROM LAYER 1

TOTALS	0.1212	0.1027	0.1073	0.1332	0.1718	0.1670
	0.1678	0.1586	0.1452	0.1443	0.1350	0.1345
STD. DEVIATIONS	0.0427	0.0364	0.0373	0.0406	0.0635	0.0639
	0.0657	0.0612	0.0547	0.0515	0.0458	0.0439

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.0002	0.0001	0.0001	0.0002	0.0003	0.0003
	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0001	0.0001	0.0002	0.0004	0.0001	0.0004
	0.0003	0.0004	0.0000	0.0002	0.0001	0.0001
STD. DEVIATIONS	0.0006	0.0006	0.0008	0.0011	0.0006	0.0011
	0.0010	0.0011	0.0000	0.0008	0.0006	0.0006

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	3.1559	2.9329	2.7925	3.5841	4.4726	4.4934
	4.3692	4.1292	3.9058	3.7563	3.6310	3.5020
STD. DEVIATIONS	1.1125	1.0338	0.9719	1.0918	1.6522	1.7186
	1.7091	1.5924	1.4716	1.3409	1.2308	1.1429

****

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.97 (2.581)	54346.0	100.00
RUNOFF	0.000 (0.0000)	0.00	0.000
EVAPOTRANSPIRATION	13.219 (1.9061)	47983.83	88.293
LATERAL DRAINAGE COLLECTED FROM LAYER 1	1.68876 (0.52345)	6130.211	11.27998
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.00256 (0.00105)	9.290	0.01709
AVERAGE HEAD ON TOP OF LAYER 2	3.727 (1.153)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00252 (0.00152)	9.138	0.01682
CHANGE IN WATER STORAGE	0.061 (1.0218)	222.77	0.410

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	1.75	6352.500
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 1	0.01100	39.92551
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.000023	0.08404
AVERAGE HEAD ON TOP OF LAYER 2	8.876	
MAXIMUM HEAD ON TOP OF LAYER 2	13.563	
LOCATION OF MAXIMUM HEAD IN LAYER 1 (DISTANCE FROM DRAIN)	88.4 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.003148	11.42720
SNOW WATER	1.43	5192.0435

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3595

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0250

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	3.7363	0.2076
2	0.0000	0.0000
3	0.1800	0.7500
4	238.5585	0.2840
SNOW WATER	0.252	

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**                                                                            **
**                                                                            **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                 **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                  **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                    USAE WATERWAYS EXPERIMENT STATION                       **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                **
**                                                                            **
**                                                                            **
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```
PRECIPITATION DATA FILE:    C:\HELP3\J\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\J\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\J\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\J\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\J\DA1JC330.D10
OUTPUT DATA FILE:           C:\HELP3\J\DA1JC330.OUT
```

TIME: 17:34   DATE: 5/31/2016

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********************************************************************************

     TITLE:  Colstrip, Base Grading, 33.0% slope, 190'

********************************************************************************
```

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 2 - LATERAL DRAINAGE LAYER


```
              MATERIAL TEXTURE NUMBER  31
THICKNESS                  =     18.00   INCHES
POROSITY                   =      0.5780 VOL/VOL
FIELD CAPACITY             =      0.0760 VOL/VOL
WILTING POINT              =      0.0250 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0877 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.410000002000E-02 CM/SEC
SLOPE                      =     33.00   PERCENT
DRAINAGE LENGTH            =    190.0    FEET
```

LAYER 2

```
            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                  =      0.06   INCHES
POROSITY                   =      0.0000 VOL/VOL
FIELD CAPACITY             =      0.0000 VOL/VOL
WILTING POINT              =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =      5.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY      =  4 - POOR
```

LAYER 3

```
              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  17
THICKNESS                  =      0.24   INCHES
POROSITY                   =      0.7500 VOL/VOL
FIELD CAPACITY             =      0.7470 VOL/VOL
WILTING POINT              =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.300000003000E-08 CM/SEC
```

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	840.00 INCHES
POROSITY	=	0.5010 VOL/VOL
FIELD CAPACITY	=	0.2840 VOL/VOL
WILTING POINT	=	0.1350 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2840 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.188999998000E-03 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #31 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 33.% AND A SLOPE LENGTH OF 190. FEET.

SCS RUNOFF CURVE NUMBER	=	97.10
FRACTION OF AREA ALLOWING RUNOFF	=	0.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000 ACRES
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.122 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.936 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.300 INCHES
INITIAL SNOW WATER	=	0.000 INCHES
INITIAL WATER IN LAYER MATERIALS	=	240.315 INCHES
TOTAL INITIAL WATER	=	240.315 INCHES
TOTAL SUBSURFACE INFLOW	=	0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM BILLINGS MONTANA

STATION LATITUDE	=	45.80 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	130
END OF GROWING SEASON (JULIAN DATE)	=	278
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES

AVERAGE ANNUAL WIND SPEED	=	11.30 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	59.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	54.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	47.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.97	0.71	1.05	1.93	2.39	2.07
0.85	1.05	1.26	1.16	0.85	0.80

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
20.90	28.40	33.80	44.60	54.90	64.00
72.30	70.30	59.40	49.30	35.00	27.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BILLINGS MONTANA AND STATION LATITUDE = 45.80 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

PRECIPITATION

TOTALS	0.96	0.78	0.95	1.77	2.26	2.05
	1.09	1.02	1.23	1.13	0.92	0.82
STD. DEVIATIONS	0.49	0.41	0.48	0.90	0.98	0.81
	0.59	0.66	0.86	0.69	0.59	0.43

RUNOFF

TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

EVAPOTRANSPIRATION

TOTALS	0.694	0.490	0.751	1.703	2.011	1.929
	1.216	0.926	1.077	0.950	0.865	0.611
STD. DEVIATIONS	0.242	0.273	0.387	0.704	0.700	0.659
	0.634	0.600	0.749	0.534	0.469	0.265

LATERAL DRAINAGE COLLECTED FROM LAYER 1

TOTALS	0.0121	0.0013	0.0500	0.5512	0.5042	0.1943
	0.1163	0.0555	0.0514	0.0673	0.0773	0.0648
STD. DEVIATIONS	0.0165	0.0017	0.1209	0.4783	0.4549	0.1741
	0.1254	0.0492	0.0356	0.0789	0.0815	0.0912

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.0108	0.0012	0.0443	0.5047	0.4467	0.1779
	0.1031	0.0492	0.0471	0.0597	0.0708	0.0574
STD. DEVIATIONS	0.0146	0.0016	0.1071	0.4380	0.4031	0.1594
	0.1112	0.0436	0.0326	0.0700	0.0746	0.0808

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	14.97	(2.581)	54346.0	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	13.221	(1.8932)	47992.88	88.310
LATERAL DRAINAGE COLLECTED FROM LAYER 1	1.74577	(0.99536)	6337.146	11.66075
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.00007	(0.00004)	0.246	0.00045
AVERAGE HEAD ON TOP OF LAYER 2	0.131	(0.075)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00000	(0.00000)	0.000	0.00000
CHANGE IN WATER STORAGE	0.004	(0.7652)	15.92	0.029

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	1.75	6352.500
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 1	0.13193	478.89526
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.000006	0.02322
AVERAGE HEAD ON TOP OF LAYER 2	3.624	
MAXIMUM HEAD ON TOP OF LAYER 2	6.996	
LOCATION OF MAXIMUM HEAD IN LAYER 1 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000000	0.00000
SNOW WATER	1.43	5192.0435

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3605

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0250

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	1.4562	0.0809
2	0.0000	0.0000
3	0.1800	0.7500
4	238.5589	0.2840
SNOW WATER	0.252	

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**                                                                         **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE              **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                  **
**                    USAE WATERWAYS EXPERIMENT STATION                    **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                         **
**                                                                         **
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PRECIPITATION DATA FILE:    C:\HELP3\J\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\J\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\J\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\J\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\J\DA2JC006.D10
OUTPUT DATA FILE:           C:\HELP3\J\DA2JC006.OUT


TIME:  17:40     DATE:   5/31/2016


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     TITLE:  Colstrip, DAILY, 0.6% slope, 375'

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
```



```
                        MATERIAL TEXTURE NUMBER  30
THICKNESS                   =   120.00   INCHES
POROSITY                    =     0.5410 VOL/VOL
FIELD CAPACITY              =     0.1870 VOL/VOL
WILTING POINT               =     0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.1863 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999987000E-04 CM/SEC


                                   LAYER  2
                                   --------

                      TYPE 2 - LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER  31
THICKNESS                   =    18.00   INCHES
POROSITY                    =     0.5780 VOL/VOL
FIELD CAPACITY              =     0.0760 VOL/VOL
WILTING POINT               =     0.0250 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0774 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.410000002000E-02 CM/SEC
SLOPE                       =     1.50   PERCENT
DRAINAGE LENGTH             =   375.0    FEET


                                   LAYER  3
                                   --------

                      TYPE 4 - FLEXIBLE MEMBRANE LINER
                        MATERIAL TEXTURE NUMBER  35
THICKNESS                   =     0.06   INCHES
POROSITY                    =     0.0000 VOL/VOL
FIELD CAPACITY              =     0.0000 VOL/VOL
WILTING POINT               =     0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =     5.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =     1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  4 - POOR


                                   LAYER  4
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TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.24 INCHES
POROSITY	=	0.7500 VOL/VOL
FIELD CAPACITY	=	0.7470 VOL/VOL
WILTING POINT	=	0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08 CM/SEC

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	840.00 INCHES
POROSITY	=	0.5010 VOL/VOL
FIELD CAPACITY	=	0.2840 VOL/VOL
WILTING POINT	=	0.1350 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2840 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.188999998000E-03 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #30 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 1.% AND A SLOPE LENGTH OF 375. FEET.

SCS RUNOFF CURVE NUMBER	=	96.70	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.917	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.492	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.564	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	262.483	INCHES
TOTAL INITIAL WATER	=	262.483	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM BILLINGS MONTANA

STATION LATITUDE	=	45.80 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	130
END OF GROWING SEASON (JULIAN DATE)	=	278
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	11.30 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	59.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	54.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	47.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.97	0.71	1.05	1.93	2.39	2.07
0.85	1.05	1.26	1.16	0.85	0.80

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
20.90	28.40	33.80	44.60	54.90	64.00
72.30	70.30	59.40	49.30	35.00	27.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING

COEFFICIENTS FOR BILLINGS MONTANA
AND STATION LATITUDE = 45.80 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.96	0.78	0.95	1.77	2.26	2.05
	1.09	1.02	1.23	1.13	0.92	0.82
STD. DEVIATIONS	0.49	0.41	0.48	0.90	0.98	0.81
	0.59	0.66	0.86	0.69	0.59	0.43
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.695	0.490	0.796	2.088	2.236	2.063
	1.320	0.918	1.121	1.039	0.907	0.643
STD. DEVIATIONS	0.241	0.273	0.450	0.895	0.805	0.854
	0.709	0.670	0.777	0.625	0.476	0.276
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0415	0.0376	0.0413	0.0406	0.0433	0.0434
	0.0457	0.0461	0.0444	0.0453	0.0431	0.0439
STD. DEVIATIONS	0.0211	0.0194	0.0212	0.0203	0.0207	0.0195
	0.0198	0.0196	0.0190	0.0196	0.0191	0.0199
PERCOLATION/LEAKAGE THROUGH LAYER 4						

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0000	0.0001	0.0000	0.0001	0.0001	0.0001
	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001
STD. DEVIATIONS	0.0000	0.0006	0.0000	0.0006	0.0006	0.0006
	0.0008	0.0000	0.0000	0.0000	0.0000	0.0006

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3						
AVERAGES	1.4391	1.4318	1.4346	1.4559	1.5036	1.5551
	1.5866	1.5990	1.5917	1.5717	1.5456	1.5221
STD. DEVIATIONS	0.7323	0.7367	0.7341	0.7275	0.7178	0.7001
	0.6856	0.6813	0.6809	0.6805	0.6845	0.6904

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	14.97	(2.581)	54346.0	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	14.316	(2.1801)	51968.68	95.626
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.51613	(0.23145)	1873.542	3.44744

PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00082 (0.00041)	2.973	0.00547
AVERAGE HEAD ON TOP OF LAYER 3	1.520 (0.682)		
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00073 (0.00135)	2.666	0.00491
CHANGE IN WATER STORAGE	0.138 (1.1460)	501.05	0.922

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	1.75	6352.500
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 2	0.00258	9.37662
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000005	0.01640
AVERAGE HEAD ON TOP OF LAYER 3	2.779	
MAXIMUM HEAD ON TOP OF LAYER 3	4.735	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	55.4 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.003148	11.42705
SNOW WATER	1.43	5192.0435

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4568

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0865

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	25.1715	0.2098
2	2.4610	0.1367
3	0.0000	0.0000
4	0.1800	0.7500
5	238.5594	0.2840
SNOW WATER	0.252	

****
****

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\J\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\J\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\J\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\J\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\J\DA3JC006.D10
OUTPUT DATA FILE:           C:\HELP3\J\DA3JC006.OUT


TIME:  17:46     DATE:   5/31/2016


******************************************************************************

     TITLE:  Colstrip, Intermediate, 0.60%, 375'

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
```



```
                           MATERIAL TEXTURE NUMBER  30
          THICKNESS                 =   1200.00   INCHES
          POROSITY                  =      0.5410 VOL/VOL
          FIELD CAPACITY            =      0.1870 VOL/VOL
          WILTING POINT             =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT  =      0.1869 VOL/VOL
          EFFECTIVE SAT. HYD. COND.   =  0.499999987000E-04 CM/SEC


                                   LAYER  2
                                   --------

                       TYPE 2 - LATERAL DRAINAGE LAYER
                           MATERIAL TEXTURE NUMBER   0
          THICKNESS                 =     18.00   INCHES
          POROSITY                  =      0.5780 VOL/VOL
          FIELD CAPACITY            =      0.0760 VOL/VOL
          WILTING POINT             =      0.0250 VOL/VOL
          INITIAL SOIL WATER CONTENT  =      0.0774 VOL/VOL
          EFFECTIVE SAT. HYD. COND.   =  0.970000029000E-02 CM/SEC
          SLOPE                     =      1.00   PERCENT
          DRAINAGE LENGTH           =    375.0    FEET


                                   LAYER  3
                                   --------

                       TYPE 4 - FLEXIBLE MEMBRANE LINER
                           MATERIAL TEXTURE NUMBER  35
          THICKNESS                 =      0.06   INCHES
          POROSITY                  =      0.0000 VOL/VOL
          FIELD CAPACITY            =      0.0000 VOL/VOL
          WILTING POINT             =      0.0000 VOL/VOL
          INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
          EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
          FML PINHOLE DENSITY       =      5.00   HOLES/ACRE
          FML INSTALLATION DEFECTS  =      1.00   HOLES/ACRE
          FML PLACEMENT QUALITY     =  4 - POOR


                                   LAYER  4
                                   --------
```

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

```
THICKNESS                  =      0.24   INCHES
POROSITY                   =      0.7500 VOL/VOL
FIELD CAPACITY             =      0.7470 VOL/VOL
WILTING POINT              =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.300000003000E-08 CM/SEC
```

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

```
THICKNESS                  =    840.00   INCHES
POROSITY                   =      0.5010 VOL/VOL
FIELD CAPACITY             =      0.2840 VOL/VOL
WILTING POINT              =      0.1350 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.2840 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.188999998000E-03 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #30 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 1.% AND A SLOPE LENGTH OF 375. FEET.

```
SCS RUNOFF CURVE NUMBER            =     96.70
FRACTION OF AREA ALLOWING RUNOFF   =      0.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
EVAPORATIVE ZONE DEPTH             =     12.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      1.917  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      6.492  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      0.564  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =    464.441  INCHES
TOTAL INITIAL WATER                =    464.441  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```


EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
BILLINGS MONTANA

```
STATION LATITUDE                        =  45.80 DEGREES
MAXIMUM LEAF AREA INDEX                 =   0.00
START OF GROWING SEASON (JULIAN DATE)   =    130
END OF GROWING SEASON (JULIAN DATE)     =    278
EVAPORATIVE ZONE DEPTH                  =  12.0  INCHES
AVERAGE ANNUAL WIND SPEED               =  11.30 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  59.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  54.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  47.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  58.00 %
```

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.97	0.71	1.05	1.93	2.39	2.07
0.85	1.05	1.26	1.16	0.85	0.80

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
20.90	28.40	33.80	44.60	54.90	64.00
72.30	70.30	59.40	49.30	35.00	27.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING

COEFFICIENTS FOR BILLINGS MONTANA
AND STATION LATITUDE = 45.80 DEGREES

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.96	0.78	0.95	1.77	2.26	2.05
	1.09	1.02	1.23	1.13	0.92	0.82
STD. DEVIATIONS	0.49	0.41	0.48	0.90	0.98	0.81
	0.59	0.66	0.86	0.69	0.59	0.43
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.695	0.490	0.796	2.088	2.236	2.063
	1.320	0.918	1.121	1.039	0.907	0.643
STD. DEVIATIONS	0.241	0.273	0.450	0.895	0.805	0.854
	0.709	0.670	0.777	0.625	0.476	0.276
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0271	0.0245	0.0267	0.0261	0.0283	0.0290
	0.0311	0.0314	0.0297	0.0298	0.0280	0.0284
STD. DEVIATIONS	0.0121	0.0113	0.0125	0.0122	0.0126	0.0119
	0.0119	0.0118	0.0112	0.0111	0.0106	0.0110
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000
	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3						
AVERAGES	0.5965	0.5911	0.5880	0.5943	0.6232	0.6603
	0.6842	0.6903	0.6763	0.6557	0.6366	0.6241
STD. DEVIATIONS	0.2669	0.2711	0.2743	0.2767	0.2774	0.2715
	0.2628	0.2596	0.2551	0.2453	0.2403	0.2419

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.97 (2.581)	54346.0	100.00
RUNOFF	0.000 (0.0000)	0.00	0.000
EVAPOTRANSPIRATION	14.316 (2.1801)	51968.68	95.626
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.34025 (0.13597)	1235.105	2.27267

PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00031 (0.00013)		1.110	0.00204
AVERAGE HEAD ON TOP OF LAYER 3	0.635 (0.254)			
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00021 (0.00080)		0.762	0.00140
CHANGE IN WATER STORAGE	0.314 (1.0706)		1141.39	2.100

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	1.75	6352.500
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 2	0.00163	5.92839
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000002	0.00550
AVERAGE HEAD ON TOP OF LAYER 3	1.114	
MAXIMUM HEAD ON TOP OF LAYER 3	1.985	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	40.8 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.003148	11.42626
SNOW WATER	1.43	5192.0435

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4568

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0865

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	233.1639	0.1943
2	1.7183	0.0955
3	0.0000	0.0000
4	0.1800	0.7500
5	238.5597	0.2840
SNOW WATER	0.252	

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**                                                                         **
**                                                                         **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE              **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                  **
**                    USAE WATERWAYS EXPERIMENT STATION                    **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                         **
**                                                                         **
*****************************************************************************
*****************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\J\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\J\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\J\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\J\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\J\DA4JC025.D10
OUTPUT DATA FILE:           C:\HELP3\J\DA4JC025.OUT


TIME:  18: 3     DATE:   5/31/2016


*****************************************************************************

     TITLE:  Colstrip, Final Grading, 2.5%, 150'

*****************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
```



```
                     MATERIAL TEXTURE NUMBER  30
   THICKNESS                  =   2520.00   INCHES
   POROSITY                   =     0.5410 VOL/VOL
   FIELD CAPACITY             =     0.1870 VOL/VOL
   WILTING POINT              =     0.0470 VOL/VOL
   INITIAL SOIL WATER CONTENT =     0.1865 VOL/VOL
   EFFECTIVE SAT. HYD. COND.  = 0.499999987000E-04 CM/SEC
 NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
          FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                           LAYER  2
                           --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                  =     18.00   INCHES
   POROSITY                   =     0.5780 VOL/VOL
   FIELD CAPACITY             =     0.0760 VOL/VOL
   WILTING POINT              =     0.0250 VOL/VOL
   INITIAL SOIL WATER CONTENT =     0.0798 VOL/VOL
   EFFECTIVE SAT. HYD. COND.  = 0.970000029000E-02 CM/SEC
   SLOPE                      =      0.90   PERCENT
   DRAINAGE LENGTH            =    375.0    FEET


                           LAYER  3
                           --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
   THICKNESS                  =      0.06   INCHES
   POROSITY                   =     0.0000 VOL/VOL
   FIELD CAPACITY             =     0.0000 VOL/VOL
   WILTING POINT              =     0.0000 VOL/VOL
   INITIAL SOIL WATER CONTENT =     0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.  = 0.199999996000E-12 CM/SEC
   FML PINHOLE DENSITY        =      5.00   HOLES/ACRE
   FML INSTALLATION DEFECTS   =      1.00   HOLES/ACRE
   FML PLACEMENT QUALITY      =  4 - POOR
```

LAYER 4

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.24 INCHES
POROSITY	=	0.7500 VOL/VOL
FIELD CAPACITY	=	0.7470 VOL/VOL
WILTING POINT	=	0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08 CM/SEC

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	840.00 INCHES
POROSITY	=	0.5010 VOL/VOL
FIELD CAPACITY	=	0.2840 VOL/VOL
WILTING POINT	=	0.1350 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2840 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.188999998000E-03 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #30 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 375. FEET.

SCS RUNOFF CURVE NUMBER	=	96.80
FRACTION OF AREA ALLOWING RUNOFF	=	100.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000 ACRES
EVAPORATIVE ZONE DEPTH	=	15.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.436 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	8.115 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.705 INCHES
INITIAL SNOW WATER	=	0.000 INCHES
INITIAL WATER IN LAYER MATERIALS	=	710.043 INCHES

TOTAL INITIAL WATER	=	710.043 INCHES
TOTAL SUBSURFACE INFLOW	=	0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
BILLINGS MONTANA

STATION LATITUDE	=	45.80 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	130
END OF GROWING SEASON (JULIAN DATE)	=	278
EVAPORATIVE ZONE DEPTH	=	15.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	11.30 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	59.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	54.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	47.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.97	0.71	1.05	1.93	2.39	2.07
0.85	1.05	1.26	1.16	0.85	0.80

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
20.90	28.40	33.80	44.60	54.90	64.00
72.30	70.30	59.40	49.30	35.00	27.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA
AND STATION LATITUDE = 45.80 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.96	0.78	0.95	1.77	2.26	2.05
	1.09	1.02	1.23	1.13	0.92	0.82
STD. DEVIATIONS	0.49	0.41	0.48	0.90	0.98	0.81
	0.59	0.66	0.86	0.69	0.59	0.43
RUNOFF						
TOTALS	0.045	0.126	0.187	0.456	0.487	0.337
	0.150	0.102	0.200	0.161	0.109	0.020
STD. DEVIATIONS	0.097	0.135	0.198	0.468	0.416	0.320
	0.151	0.144	0.268	0.160	0.175	0.054
EVAPOTRANSPIRATION						
TOTALS	0.692	0.510	0.679	1.615	2.015	1.713
	1.885	0.909	0.678	0.633	0.521	0.559
STD. DEVIATIONS	0.242	0.263	0.242	0.567	0.633	0.542
	0.516	0.520	0.426	0.367	0.209	0.245
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0151	0.0137	0.0149	0.0142	0.0147	0.0146
	0.0153	0.0152	0.0145	0.0149	0.0146	0.0153
STD. DEVIATIONS	0.0065	0.0060	0.0066	0.0062	0.0063	0.0063
	0.0070	0.0074	0.0072	0.0070	0.0064	0.0063

PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3						
AVERAGES	0.3701	0.3684	0.3646	0.3583	0.3601	0.3681
	0.3729	0.3706	0.3667	0.3646	0.3700	0.3733
STD. DEVIATIONS	0.1582	0.1608	0.1612	0.1560	0.1552	0.1599
	0.1708	0.1809	0.1814	0.1713	0.1606	0.1529

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.97 (2.581)	54346.0	100.00
RUNOFF	2.381 (0.9951)	8643.53	15.905
EVAPOTRANSPIRATION	12.409 (1.7480)	45045.17	82.886
LATERAL DRAINAGE COLLECTED	0.17704 (0.07502)	642.672	1.18256

FROM LAYER 2			
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00017 (0.00007)	0.632	0.00116
AVERAGE HEAD ON TOP OF LAYER 3	0.367 (0.156)		
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00010 (0.00057)	0.381	0.00070
CHANGE IN WATER STORAGE	0.004 (1.0596)	14.18	0.026

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	1.75	6352.500
RUNOFF	1.184	4297.3921
DRAINAGE COLLECTED FROM LAYER 2	0.00104	3.78746
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000001	0.00378
AVERAGE HEAD ON TOP OF LAYER 3	0.791	
MAXIMUM HEAD ON TOP OF LAYER 3	1.433	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	35.1 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.003139	11.39376
SNOW WATER	1.43	5192.0435

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.2831

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0470

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	469.6844	0.1864
2	1.4852	0.0825
3	0.0000	0.0000
4	0.1800	0.7500
5	238.5589	0.2840
SNOW WATER	0.252	

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****

ATTACHMENT 4

Analysis: Estimated Volume of Infiltration Water above the Cover System for J Cell

Analysis: Estimated Volume of Infiltration Water above the Cover System for J Cell.

J Cell, Colstrip Steam Electric Station, Colstrip, Montana

Cell	J-1(A)	J-1(B)	J-1(C)	J-1(D)	J-1(E)	Total
Area (acre)	10.5	8.4	10.1	10.8	11.1	50.9

Note: J-1(A) to J-1(E) Cells from West to East

Cell Condition	O	D	I	F
Max. Monthly Infiltration Water Vol.(in/month)	0.5512	0.0461	0.0314	0.0153
Max. Monthly Infiltration Water Vol.(gal/month/ac)	14966.4	1251.7	852.6	415.4
Average Yearly Infiltration Water Vol.(cf/yr/ac)	6337.2	1873.5	1235.1	642.7
Average Yearly Infiltration Water Vol.(gal/yr/ac)	47406	14015	9239	4808

Note: O = Open Cell, D = Daily Fill, I = Intermediate Fill, F = Final Grade.

Scenario	Cell Operating Condition					Area (acre)				Max. Monthly Water Gen. (gal/mon)	Average Yearly Water Gen. (gal/yr)
	J-1(A)	J-1(B)	J-1(C)	J-1(D)	J-1(E)	O	D	I	F		
1	O					10.5				157,147	497,758
2	D	O				8.4	10.5			138,861	545,362
3	I/F	D	O			10.1	8.4	5.3	5.3	168,332	670,265
4	I/F	I/F	D	O		10.8	10.1	9.5	9.5	186,262	786,270
5	I/F	I/F	I/F	D	O	11.1	10.8	14.5	14.5	198,032	881,238
6	I/F	I/F	I/F	I/F	O	11.1		19.9	19.9	191,361	805,731
7	F	F	F	F	F				50.9	21,145	244,702

Note: Water in the non-operating cells will be drained.

Maximum Monthly Generation (gal/mon)	198,032
Average Daily Generation in max. month (gal/day)	6,493
Maximum Annual Infiltration Water Generation (gal/year)	881,238
Average Daily Generation in max. year (gal/day)	2,414

ATTACHMENT 5

Analysis: Estimated Volume of Water Infiltration through the Cap System for J Cell

Analysis: Estimated Volume of Water Infiltration through the Cap System for J Cell.

J Cell, Colstrip Steam Electric Station, Colstrip, Montana

Cell	J-1(A)	J-1(B)	J-1(C)	J-1(D)	J-1(E)	Total
Area (acre)	10.5	8.4	10.1	10.8	11.1	50.9

Note: J-1(A) to J-1(E) Cells from West to East

Cell Condition	O	D	I	F
Leakage Rate (cu. ft./acre/year)	9.1380	2.6660	0.7620	0.3810

Note: O = Open Cell, D = Daily Fill, I = Intermediate Fill, F = Final Grade.

Scenario	Cell Operating Condition					Area (acre)				Total (gal/year)	Total (gal/day)
	J-1(A)	J-1(B)	J-1(C)	J-1(D)	J-1(E)	O	D	I	F		
1	O	O	O	O	O	50.9				465.1	1.27
2	D	O	O	O	O	40.4	10.5			397.2	1.09
3	I/F	D	O	O	O	32.0	8.4	5.3	5.3	320.8	0.88
4	I/F	I/F	D	O	O	21.9	10.1	9.5	9.5	237.9	0.65
5	I/F	I/F	I/F	D	O	11.1	10.8	14.5	14.5	146.8	0.40
6	I/F	I/F	I/F	I/F	O	11.1		19.9	19.9	124.2	0.34
7	F	F	F	F	F				50.9	19.4	0.05

Maximum Annual Infiltration Water Generation (gal/year)	465
Average Daily Generation in max. year (gal/day)	1.27

APPENDIX A.2

Final Cover Settlement Analysis

Geosyntec consultants

COMPUTATION COVER SHEET

Client: Talen Montana, LLC **Project:** EHP J Cell Liner System Design **Project No.:** ME1210 **Task No.:** 4

TITLE OF COMPUTATIONS EVALUATION OF SETTLEMENT BELOW LINER SYSTEM AT CELL J OF EHP

COMPUTATIONS BY: Signature [signature] 10/21/2015 DATE

Printed Name and Title: V. Krishnan, Staff Engineer

ASSUMPTIONS AND PROCEDURES CHECKED BY: (Peer Reviewer) Signature [signature] 11/05/2015 DATE

Printed Name and Title: C. Li, Project Engineer

COMPUTATIONS CHECKED BY: Signature [signature] 10/21/2015 DATE

Printed Name and Title: R. Gupta, Project Engineer

COMPUTATIONS BACKCHECKED BY: (Originator) Signature [signature] 12/07/2015 DATE

Printed Name and Title: V. Krishnan, Staff Engineer

APPROVED BY: (PM or Designate) Signature [signature] 11/19/2015 DATE

Printed Name and Title: D. Espinoza, Senior Principal

APPROVAL NOTES:

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

Written by: **V. Krishnan** Date: **10/21/2015** Reviewed by: **R. Gupta, C. Li** Date: **10/21/2015**

Client: **Talen Montana, LLC** Project: **EHP J Cell Liner System Design** Project No.: **ME1210** Phase No.: **04**

EVALUATION OF SETTLEMENT BELOW THE LINER SYSTEM AT CELL J OF EFFLUENT HOLDING POND

1 INTRODUCTION

1.1 Purpose

The purpose of this calculation package is to evaluate the one-dimensional compression of the foundation materials in order to estimate the settlement and strain in the liner system for Cell J of the Effluent Holding Pond (site) at Colstrip Steam Electric Station, Rosebud County, Montana. Specifically, the settlement of the most critical portion of the liner grades along the leachate collection system corridor (1.5% slope) of the subcells is evaluated. The leachate collection system corridor should maintain positive drainage towards the low point on the cell floor after foundation settlements have occurred. Also, calculated strains due to differential settlement should not exceed tolerable strains for the liner system.

Subsurface materials beneath the landfill liner are expected to compress as waste is placed in the landfill (i.e., as load is applied). The resulting foundation settlements may not be uniform across the site because: (i) the subsurface materials vary in thickness beneath the landfill; and (ii) the loading of the foundation by the landfill waste varies across the length of the cross section considered.

1.2 Method

The settlement analysis is performed using a combination of two theories based on the type of subsurface material: the theory of elasticity, which is applicable to subsurface materials that behave similar to sands or low plasticity silts; and one-dimensional consolidation theory, which is applicable to subsurface materials that behave similar to clays or elastic silts. According to the theory of elasticity, the subsurface material is expected to elastically compress immediately upon loading; whereas according to the one-dimensional consolidation theory, the subsurface material is expected to exhibit increased pore water pressure upon loading, and compress over an extended period of time while dissipating pore water pressure.

1.3 Overview of the Subsurface Strata

The subsurface strata beneath the proposed liner for Cell J can be divided into the following general layers, from top to bottom:

- Layer I consists of bottom ash, which is a Coal Combustion Residual (CCR) material disposed in J-Cell;
- Layer II consists of scrubber slurry paste, also referred to as paste, which is a CCR material disposed in J-Cell;
- Layer III consists of silt and silty clay that likely represent native ground soils; and

- Layer IV consists of interbedded shale and sandstone.

In addition, an additional deposit of baked shale and sandstone, red to orange, brittle and fractured was identified along portions of the north sideslope of J Cell during review of previous geological reports at the site (Bechtel Power Corporation, 1980). This material was not encountered during the site investigation.

The total settlement of the liner system due to placement of waste in the landfill is evaluated by estimating the settlement of all four layers, and adding the values obtained.

2 CRITICAL CROSS SECTIONS

In order to evaluate the settlement resulting from the load of the landfill, critical cross-sections are first selected. The cross sections considered include sections along the leachate collection corridor of the subcells. The purpose of evaluating settlement along the leachate collection corridors is to evaluate the post-settlement liner grades, and to determine if positive drainage to the low point of the sub-cell is likely to be maintained. In addition, the cross sections considered incorporate a broad variation of slope geometry, waste thickness, and representative foundation materials beneath the site; thus the resulting analysis may be considered to be a reasonable representation of the liner's performance across the site. The overall top of liner grading plan, overall top of final cover grading plan, and borehole logs are considered for the development of the critical cross sections. The top of liner grading plan and top of final cover grading plan with the location of the cross sections are shown on Figures 1 and 2 of this calculation package, respectively. A drawing from a previous geological report showing the extent of the baked shale and sandstone layer is shown in Figure 3. The resulting cross sections (sections A-A', B-B', C-C', D-D', and E-E') are shown in Figures 4 through 8 of this calculation package. A profile of the proposed liner system and cover system for Cell J is shown in Figure 9.

Several points along the liner system are selected for evaluation of settlement at each cross section; these points correspond to locations where slopes and thickness of the landfill waste or subsurface strata change. The elevations of the selected points along the cross section, in addition to the corresponding elevations of the overburden materials and subsurface layer boundaries, are used as input to the settlement analysis. The elevations of the leachate collection system corridor and final cover system are obtained from the top of liner and top of final cover grading plans. The elevations of the subsurface layer boundaries are determined from nearby boring logs included in Attachment A. Settlement is estimated based on the expected compressibility of subsurface materials from about 3290 feet above mean sea level (ft-MSL) down to about 3100 ft-MSL.

3 MATERIAL PROPERTIES

The material properties for this analysis are selected based on a geotechnical site investigation performed at the site in June 2015 by Geosyntec Consultants. Laboratory tests relevant to this analysis that were conducted as part of the investigation include: grain size analysis, percent passing No. 200 sieve, Atterberg limits, USCS soil classification, moisture content, dry unit weight, and one-dimensional consolidation tests. The results from relevant laboratory tests are used to develop the material properties used in this analysis.

3.1 Unit Weights

Foundation Materials
The average unit weight of Layers I, II, and IV is estimated from laboratory test results of dry unit weight and moisture content, as shown in Table 1. The unit weight for Layer III is estimated based on the soil type and consistency, as provided by Kulhawy and Mayne (1990). The soil type is assumed as well graded silty sand, and the consistency is estimated from the SPT blow count values as shown in Table 2 and Table 3.

Coal Combustion Residuals (CCR)
The primary type of coal combustion residual waste received at Cell J is paste, and this material is expected to be similar to Layer II. It is expected that the plant will utilize dry processing technology in future, and the unit weight of dry CCR disposed is expected to be less than the unit weight of moist CCR, i.e., Layer II. In this analysis, the unit weight of the CCR disposed in the landfill is conservatively assumed to be same as that of Layer II. A 1.5 foot thick layer of bottom ash will be placed immediately above the new liner system in the cell; the unit weight of this material is assumed to be same as the unit weight of Layer I.

Final Cover Soil
The unit weight of the final cover soil is assumed as 120 pcf.

3.2 Consolidation Properties of Bottom Ash, Paste, and Interbedded Shale

The preconsolidation pressure, primary compression index, recompression index, and initial void ratio of Layers I, II, and IV is determined based on results of consolidation tests performed on samples from these layers, as shown in Table 1.

The ratio of the secondary compression index to primary compression index is constant for several soils, independent of effective vertical stress and time elapsed after primary consolidation; for inorganic clays and silts, this ratio is 0.04±0.01, per Terzaghi et al. (1996). The secondary compression index is evaluated by multiplying the constant ratio with the primary virgin compression index in case of normally consolidated soils, and with the primary recompression index in case of over-consolidated soils. The bottom ash and paste layers are expected to behave similar to silts; therefore the secondary compression index of these materials is estimated using this procedure.

3.3 Elastic Properties of Layer III

Layer III is silt and silty clay and is assumed to behave elastically for this settlement analysis. The constrained elastic modulus, the thickness, and the net increase in effective stress are used to estimate the settlement due to placement of waste. The constrained elastic modulus is estimated using the following empirical correlation with effective vertical stress and porosity, per Kulhawy and Mayne (1990):

$$\frac{M_{ds}}{p_a} = m\left(\frac{\sigma'_v}{p_a}\right)^{0.5} \quad \text{(Eqn. 1)}$$

where:

M_{ds} = drained secant constrained elastic modulus;
σ'_v = effective vertical stress;
m = modulus number, correlated with porosity; and
p_a = atmospheric pressure.

Assuming the porosity of Layer III as 0.35, the modulus number is estimated as 150, as shown in Figure 10. The evaluation of the constrained modulus for Layer III is shown in Table 4, and is estimated as 445 ksf.

The geological description of the baked shale and sandstone deposit identified in J Cell indicates that it is likely to exhibit similar compressibility as Layer III. Therefore, the compression of this deposit is estimated based on the compressibility properties determined for Layer III.

3.4 Groundwater Table

Although groundwater was not encountered during the site investigation, for this analysis, the groundwater table is conservatively assumed at the bottom of the liner system. It is expected that Layer I, Layer II, and Layer IV will develop pore water pressures upon placement of waste in the cell, and the gradual dissipation of pore water pressure over time in these layers will result in settlement due to primary consolidation. Placement of fly ash in future is not expected to raise the groundwater table because the liner system would have been installed.

The geotechnical properties of the subsurface materials used for calculation of settlement are summarized in Table 5.

4 ANALYSIS PROCEDURE

4.1 Elastic Settlement

The elastic settlement of a granular subsurface material is estimated based on the constrained elastic modulus, the layer thickness, and the corresponding change in vertical effective stress due to loading, per the following equation by Qian et al. (2001):

$$S_E = \frac{\Delta\sigma_v \times H}{M_{ds}} \quad \text{(Eqn. 2)}$$

where: S_E = immediate settlement of subsurface layer;
$\Delta\sigma_v$ = increment of vertical stress due to applied load;
H = initial thickness of subsurface layer; and
M_{ds} = drained secant constrained elastic modulus of subsurface layer.

The constrained modulus is defined as the ratio of vertical stress to vertical strain under uniaxial strain conditions, i.e., strain in the horizontal direction is zero. The foundation materials are expected to exhibit one-dimensional compression due to placement of waste, and horizontal strain of the foundation materials is not anticipated.

The thickness of the layer and the increment of vertical stress due to the applied load are determined from the critical cross section and evaluated waste properties. The constrained elastic modulus of the layer is evaluated using the empirical correlation described in Section 3.3.

4.2 Settlement due to Primary Consolidation

The ultimate settlement of a fine grained, cohesive subsurface material due to primary consolidation is estimated based on the current stress in the layer, the expected load to be applied, and the compressibility of the subsurface material, according to the following set of equations described by Terzaghi et al. (1996):

$$S_P = \frac{C_c}{1+e_0} H \log\left(\frac{\sigma'_{v0}+\Delta\sigma_v}{\sigma'_{v0}}\right) \text{ for } \sigma'_{v0} > P_P \qquad \text{(Eqn. 3)}$$

$$S_P = \frac{C_c}{1+e_0} H \log\left(\frac{\sigma'_{v0}+\Delta\sigma_v}{P_P}\right) + \frac{C_r}{1+e_0} H \log\left(\frac{P_P}{\sigma'_{v0}}\right) \text{ for } \sigma'_{v0} < P_P \text{ and } \sigma'_{v0}+\Delta\sigma_v > P_P \qquad \text{(Eqn. 4)}$$

$$S_P = \frac{C_r}{1+e_0} H \log\left(\frac{\sigma'_{v0}+\Delta\sigma_v}{\sigma'_{v0}}\right) \text{ for } \sigma'_{v0}+\Delta\sigma_v < P_P \qquad \text{(Eqn. 5)}$$

where: S_p = ultimate settlement due to primary consolidation;
C_c = primary virgin compression index;
C_r = primary recompression index;
e_0 = initial void ratio;
H = initial thickness of compressible layer;
σ'_{v0} = initial vertical effective stress at mid-depth of compressible layer;
$\Delta\sigma_v$ = increment of vertical stress due to applied load; and
P_p = preconsolidation pressure.

4.3 Settlement due to Secondary Compression

The settlement of a fine grained, cohesive subsurface material due to secondary compression is estimated based on the thickness of the material, the secondary compression index, and the time elapsed after primary consolidation, according to the following equation described by Terzaghi et al. (1996):

$$S_S = \frac{\left(C_\alpha / C_c\right) \times C_c}{1 + e_0} H \log\left(\frac{t_2}{t_1}\right) \quad \text{(Eqn. 6)}$$

where:

S_s = settlement due to secondary compression;
C_α / C_c= ratio of secondary compression index to primary compression index;
C_c = primary compression index;
e_0 = initial void ratio;
H = initial thickness of compressible layer;
t_1 = time at which secondary compression begins, i.e., end of primary consolidation; and
t_2 = time at which secondary compression is calculated.

The secondary compression index is defined as the reduction in void ratio during one logarithmic cycle of the ratio t_2/t_1. The ratio of the secondary compression index to primary compression index is constant for a geotechnical material, independent of vertical effective stress and time elapsed after primary consolidation. For purposes of these calculations, the time at which primary consolidation ends and secondary compression begins is assumed to be 1 year while t_2 is assumed to be 60 years.

4.4 Total Settlement

The total settlement of the foundation materials in the long term is estimated as the sum of the immediate settlement, settlement due to primary consolidation, and settlement due to secondary compression.

$$S_T = S_E + S_P + S_S \quad \text{(Eqn. 7)}$$

where:

S_T = total settlement of foundation soils;
S_E = immediate (elastic) settlement of Layer III;
S_P = settlement due to primary consolidation of Layers I, II, and IV; and
S_S = settlement due to secondary compression of Layers I, II, and IV.

4.5 Differential Settlement and Strain in the Liner System

Differential settlement refers to the settlement of a point relative to the settlement of adjacent points, and is evaluated in order to determine the change in slope of the leachate collection corridor due to settlement.

The strain in the liner system refers to the change in length of segments of the liner system due to settlement, relative to the initial length of the segment considered.

5 RESULTS AND DISCUSSION

The results of the liner system settlement analysis are presented in Attachment B. The calculated total settlement ranges from 0.8 feet to 7.6 feet for Section A-A’, 0.5 feet to 7.0 feet for Section B-B’, 0.1 feet to 5.2 feet for Section C-C’, 0.3 feet to 7.3 feet for Section D-D’, and 0.3 feet to 7.3 feet for Section E-E’. The maximum strain calculated in the liner system is 0.98% for Section A-A’, 1.24% for Section B-B’, 0.62% for Section C-C’, 0.91% for Section D-D’, and 0.95% for Section E-E’. The minimum post-settlement liner grade calculated is 0.75% for Section A-A’, 0.75% for Section B-B’, 0.22% for Section C-C’, 0.68% for Section D-D’, and 0.25% for Section E-E’.

The CCR disposed in the cell is expected to be relatively incompressible due to being relatively inert and of low compressibility. In addition, the CCR will be placed in lifts and compacted. Settlement within the CCR due to self-weight and overburden is expected to occur as the filling progresses; therefore, most of the settlement is expected to have been completed before the final cover system is constructed. As a result, it is reasonable to conclude that the final cover system will experience negligible settlement due to settlement of underlying waste. The final cover system may experience some settlement due to compression of the underlying foundation strata, but it would only be expected to settle a small fraction of the total foundation settlement.

6 SUMMARY AND CONCLUSIONS

The critical cross sections are selected for analysis and settlements are estimated at various points along the section. Properties of subsurface materials and waste are assigned based on laboratory results, correlations from published literature, and Geosyntec’s previous experience.

Based on the analyses presented herein, the following conclusions are drawn:

- The calculated differential settlements and estimated strain in the liner system is well below the 3-4 percent yield strain for high density polyethylene (HDPE) geomembranes as reported by Berg and Bonaparte (1993). Therefore, the calculated settlements and strains are considered acceptable.
- The calculated magnitude of settlement, based on the conservative approach adopted throughout this evaluation, is not expected to result in any adverse effects on the liner system or the performance of Cell J in general.
- The calculated post-settlement slopes along the leachate collection corridors indicate that positive drainage to the leachate drain pipes is expected to be maintained. Further, the final cover system is expected to experience only a fraction of the settlement calculated for the liner system, so its functionality is not expected to be adversely affected.

Written by: **V. Krishnan** Date: **10/21/2015** Reviewed by: **R. Gupta, C. Li** Date: **10/21/2015**

Client: **Talen Montana, LLC** Project: **EHP J Cell Liner System Design** Project No.: **ME1210** Phase No.: **04**

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TABLES

TABLE 1. SUMMARY OF CONSOLIDATION PROPERTIES OF LAYERS I, II, AND IV

Layer	Boring Number	Sample Depth		Preconsolidation Pressure	Compression Index	Recompression Index	Moisture Content (%)	Dry Unit Weight	Bulk Unit Weight	Initial Void Ratio
		Start	End	σ'_p	C_c	C_r	w (%)	γ_d		e_0
		ft, BGS	ft, BGS	psf				pcf	pcf	
I	GB-4	35	37.5	5,028	0.12	0.02	19.7	106.9	128.0	0.547
II	GB-1	15	17.5	1,965	0.15	0.01	44.3	76.5	110.4	1.163
II	GB-2	10	12	1,401	0.14	0.01	43.5	78.2	112.2	1.117
IV	GB-1	100	101	14,103	0.11	0.04	15.1	116.9	134.6	0.415

NOTES

1.) The consolidation parameters for settlement calculation are obtained from the table above. In case of Layer II, the average consolidation parameters from the two tests is adopted for the analysis, except in cases of Sections AA' and CC', wherein the properties from the test at GB -1 and GB-2 are adopted, respectively.

TABLE 2. CONSISTENCY OF LAYER III BASED ON STANDARD PENETRATION TEST BLOW COUNTS

Borehole	Depth (ft)	Sample Elevation (ft, MSL)	Blow Counts (N, blows per ft)	N_{60} (Use C_{ER}=0.75)	Consistency
GB-1	80	3155	25	18.75	Medium Dense
GB-1	90	3145	Refusal	-	Very Dense
GB-2	45	3199	Refusal	-	Very Dense
GB-2	50	3194	Refusal	-	Very Dense
GB-2	60	3184	Refusal	-	Very Dense
GB-4	70	3181	Refusal	-	Very Dense
GB-4	75	3176	Refusal	-	Very Dense
GB-4	80	3171	Refusal	-	Very Dense
GB-4	85	3166	Refusal	-	Very Dense
GB-4	90	3161	Refusal	-	Very Dense
GB-4	95	3156	Refusal	-	Very Dense

NOTES

1.) N_{60} denotes the SPT N value corrected for the effects of hammer energy ratio (C_{ER}), borehole diameter (C_B), sampling method (C_S), and rod length (C_R).

2.) The correction factors for the SPT N value are assumed as C_{ER}=0.75, C_B=1.0, C_S=1.0, and C_R=1.0.

3.) Consistency of the SPT split spoon sample is determined based on N_{60} value, per Kulhawy and Mayne (1990), p. 2-19.

TABLE 3. ESTIMATION OF UNIT WEIGHT OF LAYER III (KULHAWY AND MAYNE, 1990)

Table 2-8

TYPICAL SOIL UNIT WEIGHTS

Soil Type	Approximate Particle Size (mm)			Uniformity Coefficient	Void Ratio		Normalized Unit Weight			
							Dry, γ_{dry}/γ_w		Saturated, γ_{sat}/γ_w	
	D_{max}	D_{min}	D_{10}	D_{60}/D_{10}	e_{max}	e_{min}	Min.	Max.	Min.	Max.
Uniform granular soil										
Equal spheres (theoretical)	-	-	-	1.0	0.92	0.35	-	-	-	-
Standard Ottawa sand	0.84	0.59	0.67	1.1	0.80	0.50	1.47	1.76	1.49	2.10
Clean, uniform sand	-	-	-	1.2 to 2.0	1.00	0.40	1.33	1.89	1.35	2.18
Uniform, inorganic silt	0.05	0.005	0.012	1.2 to 2.0	1.10	0.40	1.28	1.89	1.30	2.18
Well-graded granular soil										
Silty sand	2.0	0.005	0.02	5 to 10	0.90	0.30	1.39	2.04	1.41	2.28
Clean, fine to coarse sand	2.0	0.05	0.09	4 to 6	0.95	0.20	1.36	2.21	1.38	2.37
Micaceous sand	-	-	-	-	1.20	0.40	1.22	1.92	1.23	2.21
Silty sand and gravel	100	0.005	0.02	15 to 300	0.85	0.14	1.43	2.34	1.44	2.48
Silty or sandy clay	2.0	0.001	0.003	10 to 30	1.80	0.25	0.96	2.16	1.60	2.36
Gap-graded silty clay w. gravel or larger	250	0.001	-	-	1.00	0.20	1.35	2.24	1.84	2.42
Well-graded gravel, sand, silt, and clay	250	0.001	0.002	25 to 1000	0.70	0.13	1.60	2.37	2.00	2.50
Clay (30 to 50% < 2μ size)	0.05	0.5μ	0.001	-	2.40	0.50	0.80	1.79	1.51	2.13
Colloidal clay (over 50% < 2μ size)	0.01	10Å	-	-	12.00	0.60	0.21	1.70	1.14	2.05
Organic silt	-	-	-	-	3.00	0.55	0.64	1.76	1.39	2.10
Organic clay (30 to 50% < 2μ size)	-	-	-	-	4.40	0.70	0.48	1.60	1.30	2.00

Note: γ_w = 62.4 lb/ft^3 = 1 gm/cm^3 = 0.983 t/m^3 = 9.80 kN/m^3 (at STP conditions).

Source: Hough (26), pp. 34, 35.

2-18

NOTES

1.) Based on the material consistency reported in Table 2, the relative density of Layer III is assumed as 85% to 90%. Therefore, the bulk unit weight is estimated as: (1.41+0.875×(2.28-1.41))×62.4 pcf = 135 pcf.

TABLE 4. SUMMARY OF COMPRESSIBILITY PROPERTIES OF LAYER III

Borehole	Depth (ft)	Sample Elevation (ft, MSL)	Blow Counts (N, blows per ft)	Effective Vertical Stress (psf)	Constrained Modulus (ksf)
GB-1	80	3155	25	3968	430
GB-1	90	3145	Refusal	4694	470
GB-2	45	3199	Refusal	2232	330
GB-2	50	3194	Refusal	2595	350
GB-2	60	3184	Refusal	3321	400
GB-4	70	3181	Refusal	4112	440
GB-4	75	3176	Refusal	4475	460
GB-4	80	3171	Refusal	4838	480
GB-4	85	3166	Refusal	5201	500
GB-4	90	3161	Refusal	5564	510
GB-4	95	3156	Refusal	5927	530
		Average constrained elastic modulus for Layer III			445

NOTES

1.) Constrained modulus is determined based on effective vertical stress and porosity, per Kulhawy and Mayne (1990), p. 6-12.

TABLE 5. SUMMARY OF GEOTECHNICAL PROPERTIES OF SUBSURFACE MATERIALS

Layer	I	II	III	IV
Description	Bottom Ash	Paste	Silt and Silty Clay	Interbedded Shale/Sandstone
USCS Classification[1]	-	-	ML, CL-ML	-
Bulk Unit Weight (pcf)	128	112	135	135
Primary Compression Index[2]	0.12	0.15 at GB-1 (15') 0.14 at GB-2 (10')	-	0.11
Primary Recompression Index[2]	0.02	0.01 at GB-1 (15') and GB-2 (10')	-	0.04
Preconsolidation Pressure[2,3] (psf)	5,028	1,965 at GB-1 (15') 1,401 at GB-2 (10')	-	14,103
Initial Void Ratio[2]	0.547	1.163 at GB-1 (15') 1.117 at GB-2 (10')	-	0.415
Ratio of Secondary Compression Index to Primary Compression Index[4]	0.04±0.01	0.04±0.01	-	0.04±0.01
Constrained Modulus[5] (ksf)	-	-	445	-

NOTES

1.) The Unified Soil Classification System (USCS) is limited to naturally occurring soils, per ASTM 2487. Based on the particle size and plasticity characteristics, the coal combustion residual materials could be assigned the following USCS classifications as an aid to describe them: (i) bottom ash (Layer I) – non-plastic, 39% to 49% fines, "silty sand (SM)"; and (ii) paste (Layer II) – plasticity index zero to 15%, "elastic silt (MH)"."

2.) Consolidation tests performed on samples from Layers I, II, and IV are used to determine the compressibility properties of these layers. In case of Layer II, settlement is calculated using consolidation parameters obtained from the sample at GB-1 (15') for section A-A', the sample at GB-2 (10') for section C-C', and the average value of the parameters from the two tests for sections B-B', D-D', and E-E'.

3.) The preconsolidation pressure reported is applicable for samples that are over-consolidated, i.e., maximum past vertical effective stress is greater than the current effective vertical stress.

4.) The ratio of secondary compression index to primary compression index is determined based on the value applicable for inorganic clays and silts, per Terzaghi et al. (1996).

5.) The secant constrained elastic modulus under drained conditions for Layer III is evaluated based on an empirical correlation with effective vertical stress and porosity, per Kulhawy and Mayne (1990), p.6-12.

FIGURES

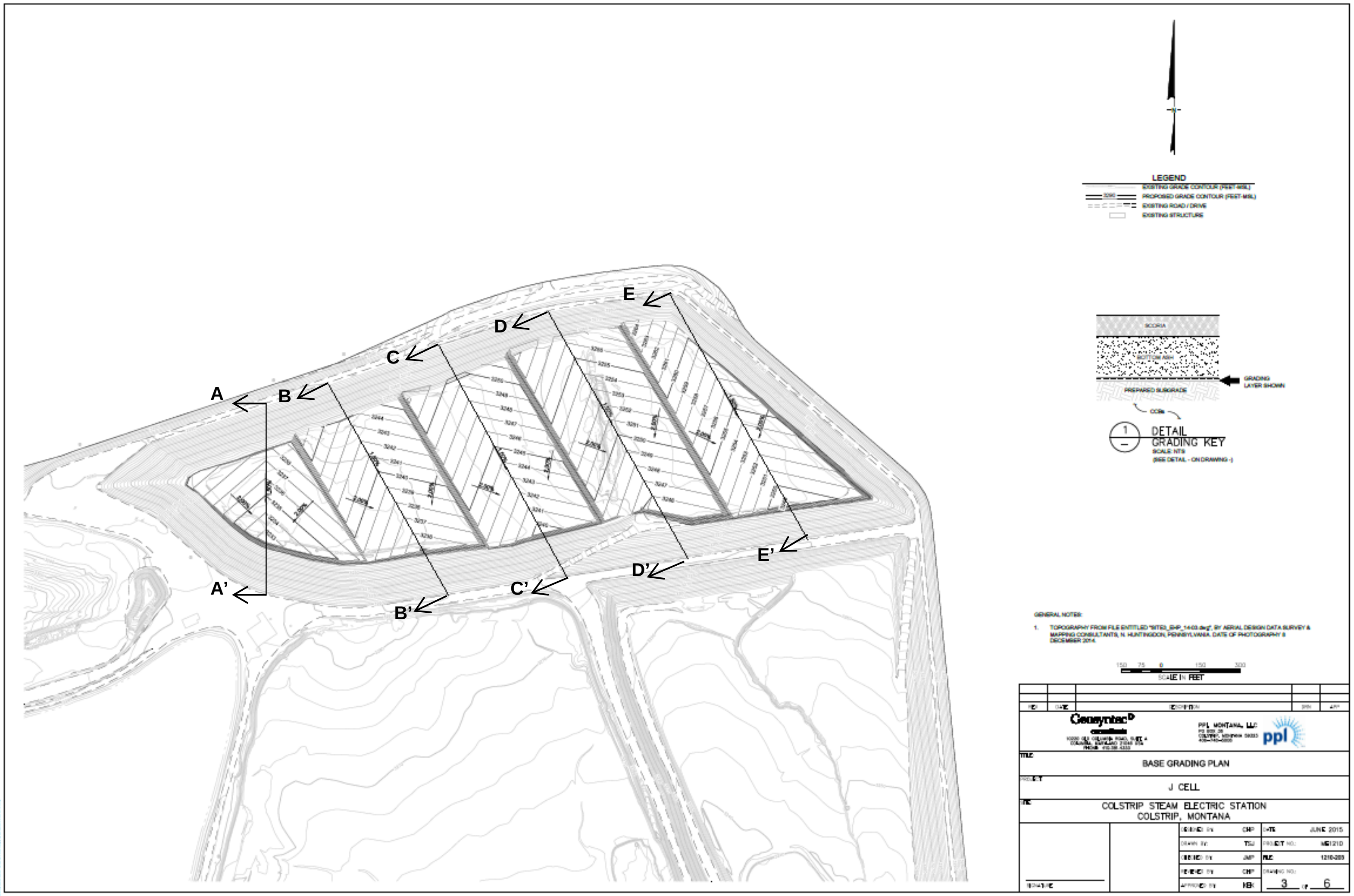

Figure 1. Location of Critical Cross Sections shown on the Top of Liner Grading Plan

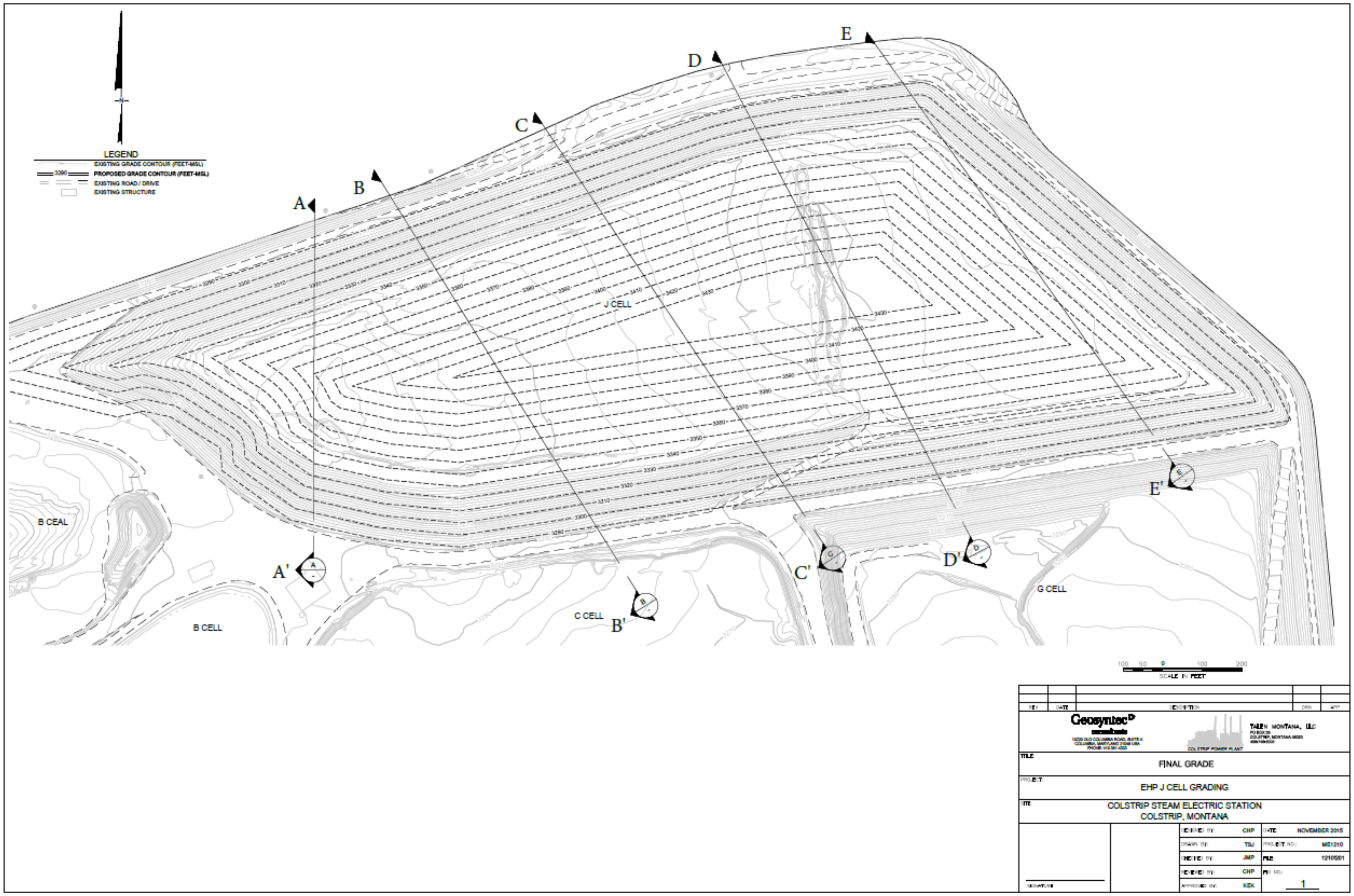

Figure 2. Location of Critical Cross Sections shown on Top of Final Cover Grading Plan

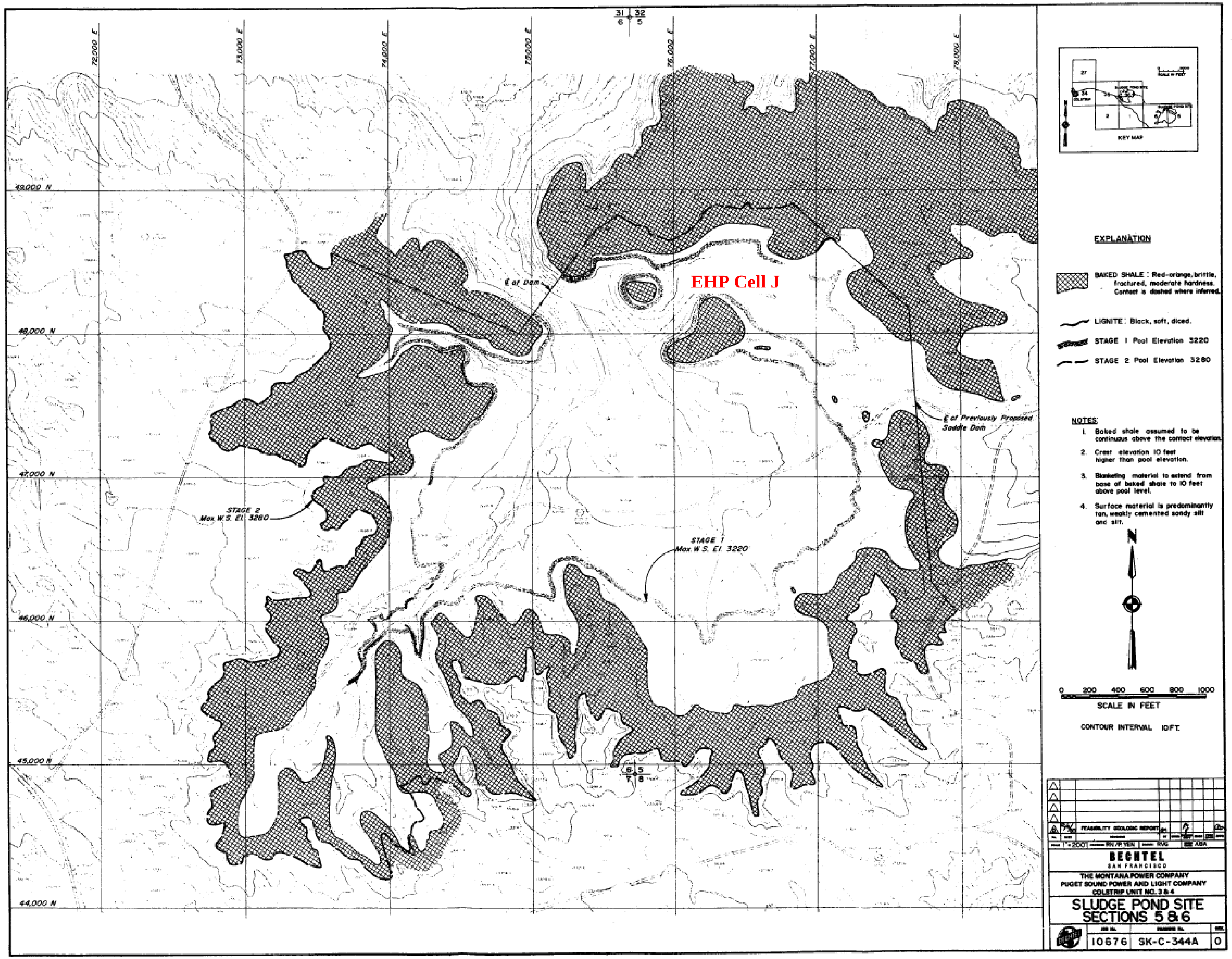

Figure 3. Drawing showing areal extent of baked shale layer (Bechtel Power Corporation, 1980)

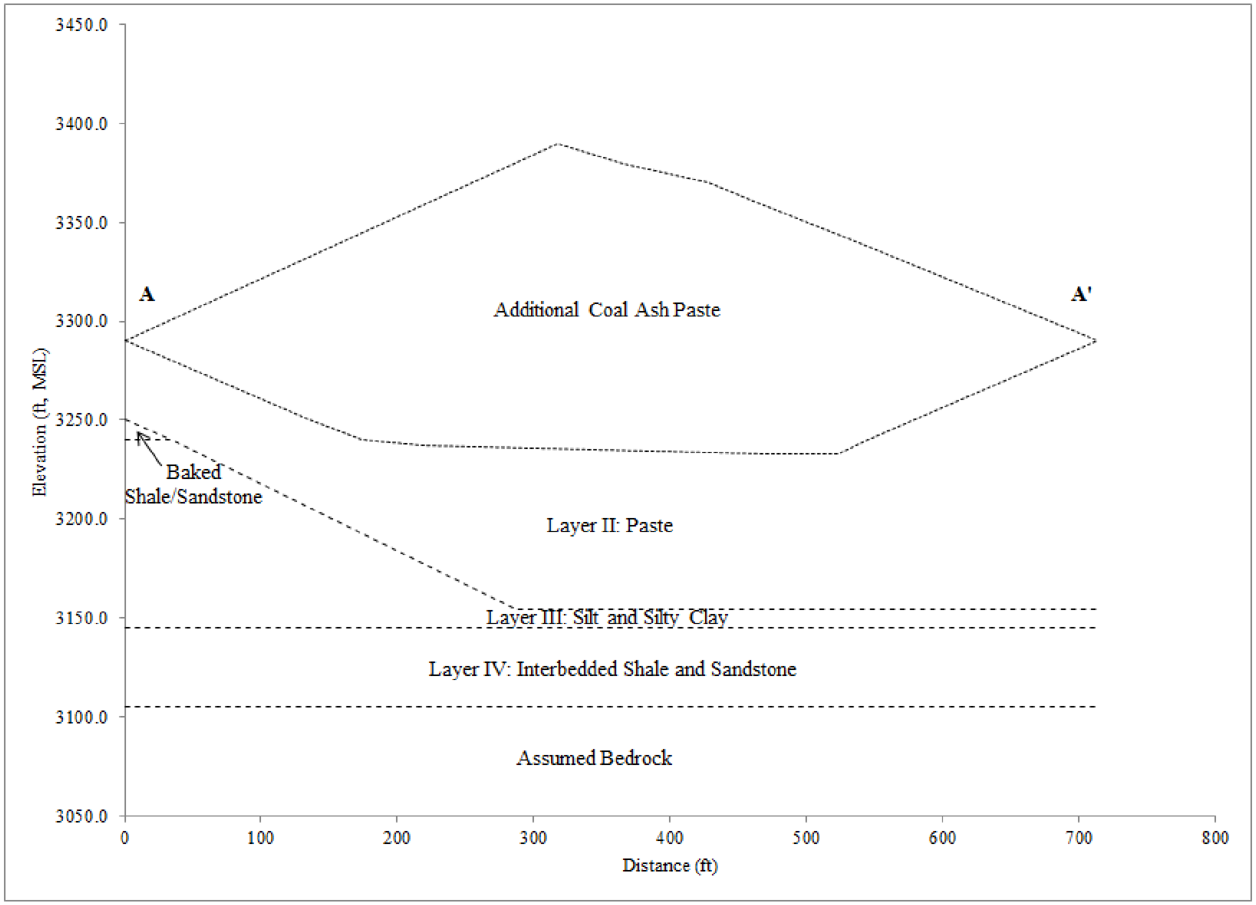

Figure 4. Cross Section AA' along Leachate Collection Corridor

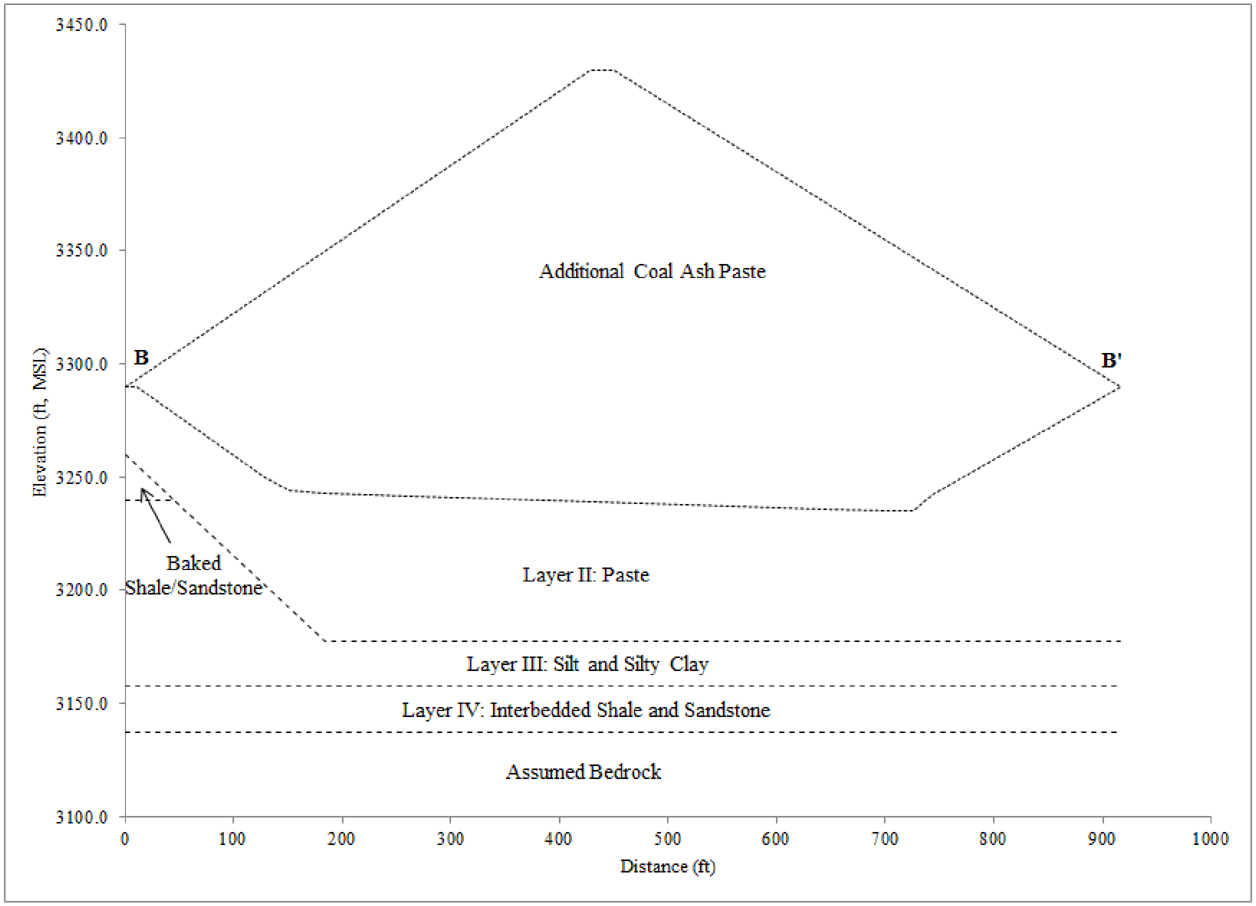

Figure 5. Cross Section BB' along Leachate Collection Corridor

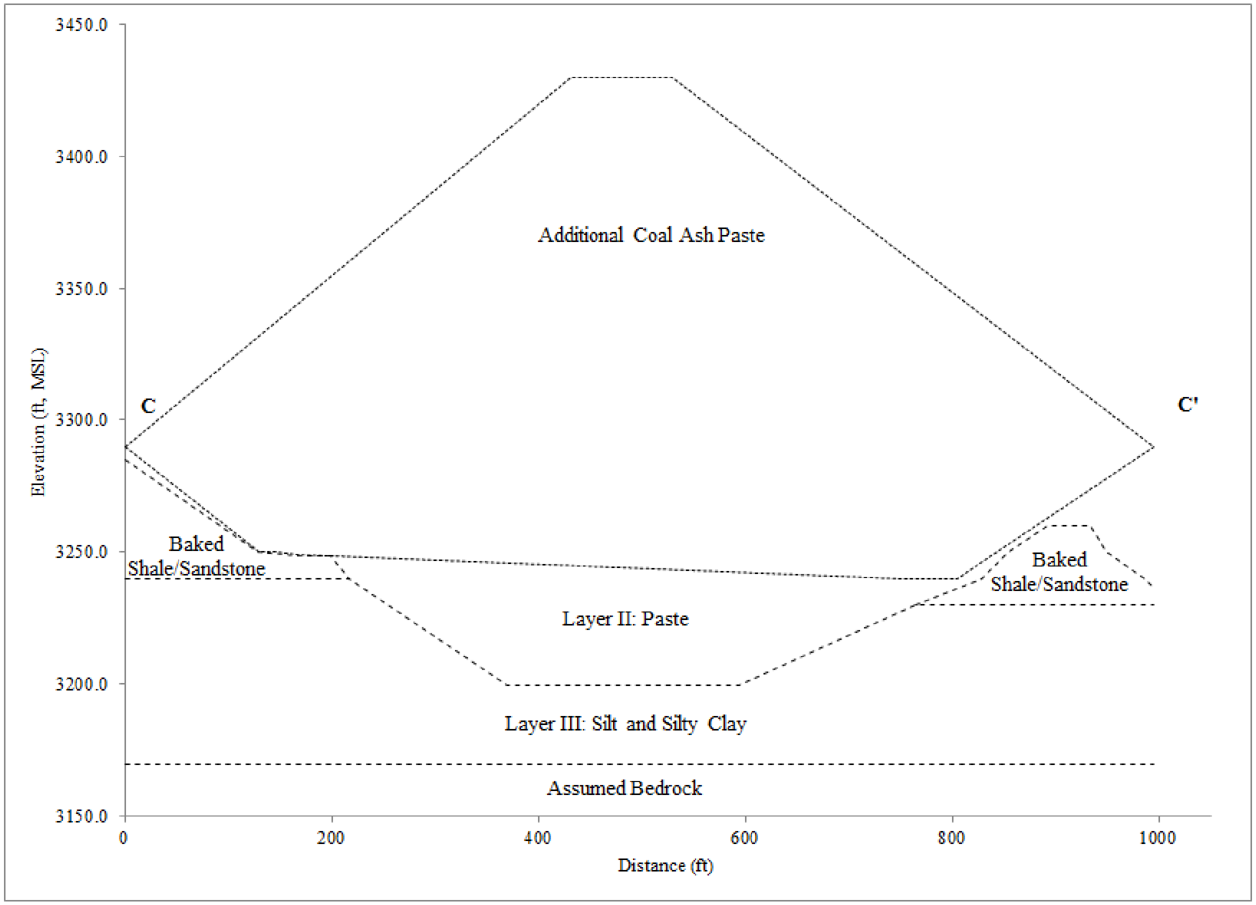

Figure 6. Cross Section CC’ along Leachate Collection Corridor

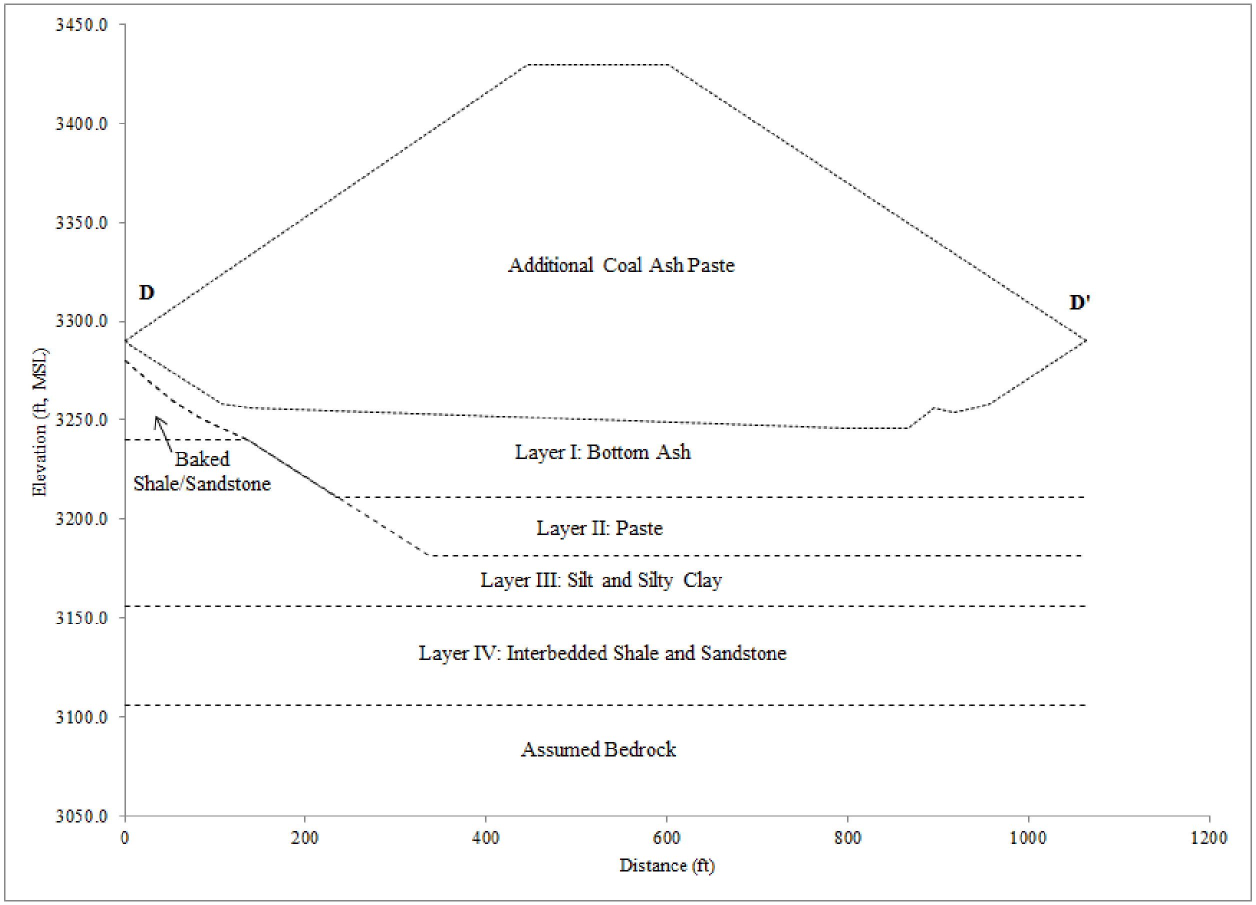

Figure 7. Cross Section DD' along Leachate Collection Corridor

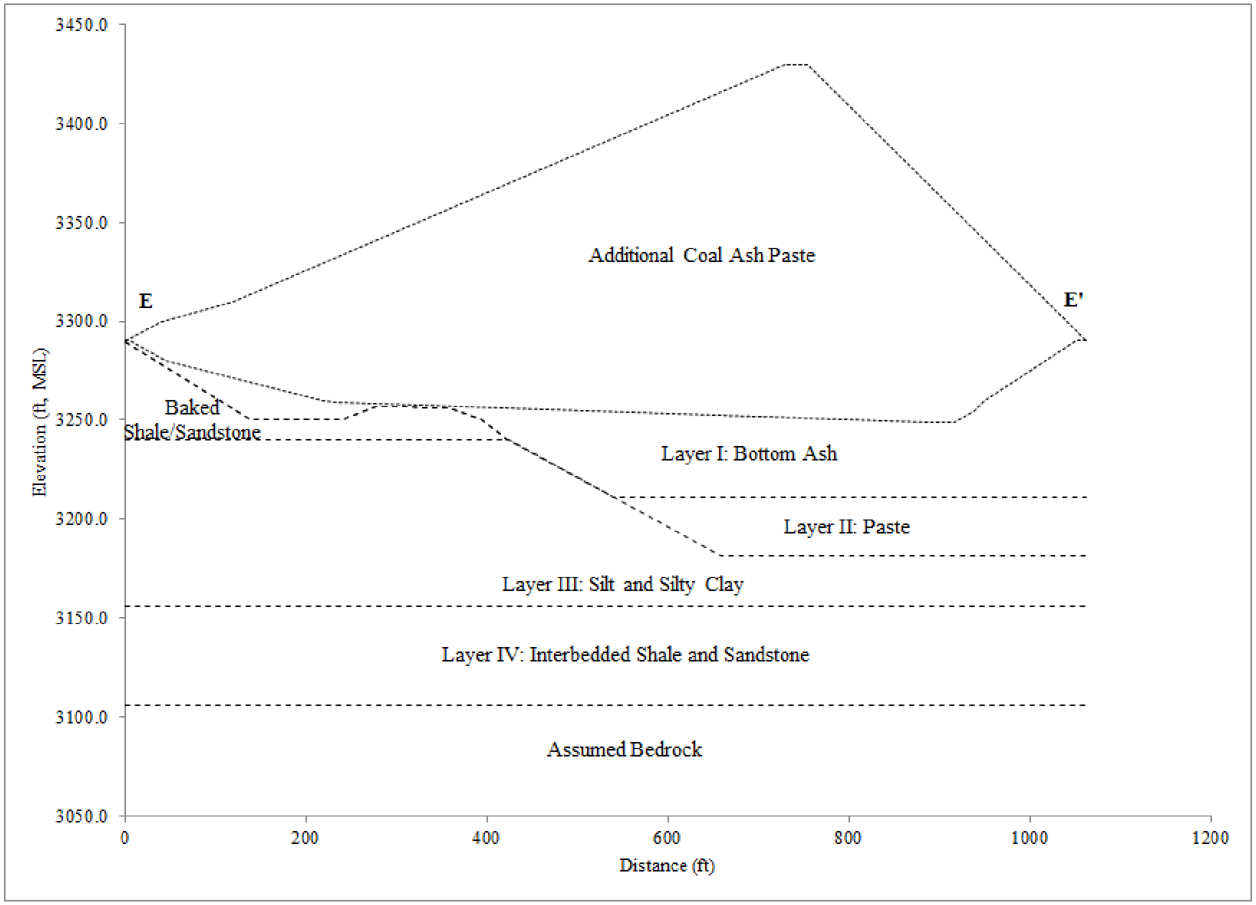

Figure 8. Cross Section EE' along Leachate Collection Corridor

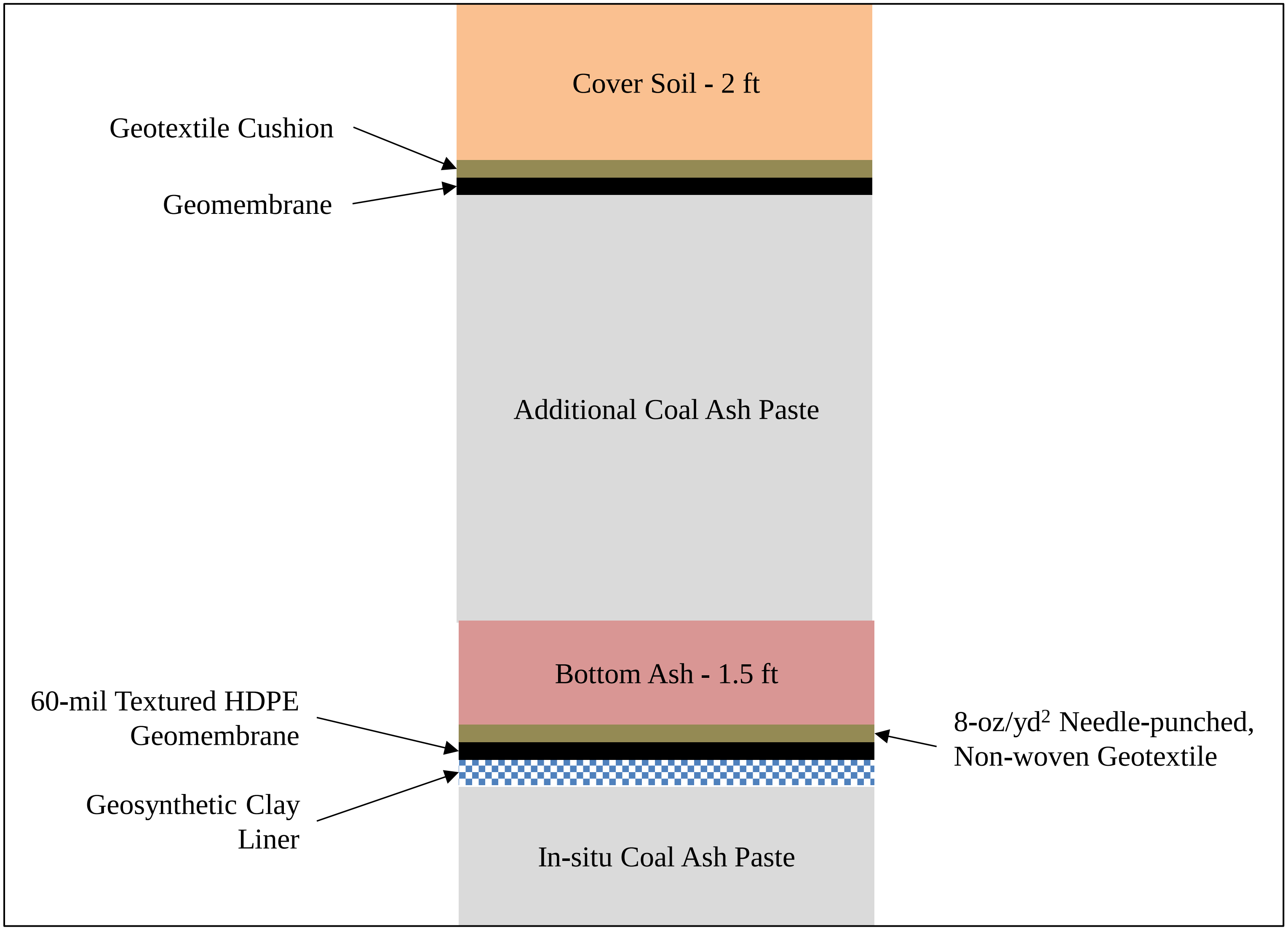

Figure 9. Proposed Liner and Cover System Profiles (Not to Scale)

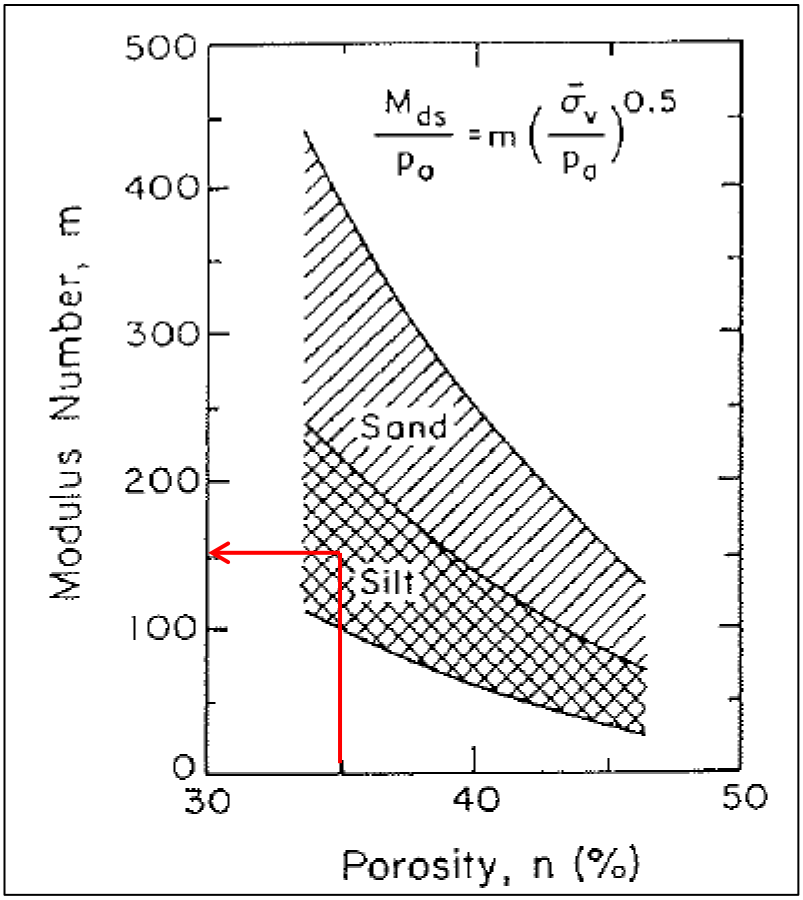

Figure 10. Estimation of Modulus Number for Layer III (Kulhawy and Mayne, 1990)

ATTACHMENT A

BOREHOLE LOGS

Project: **Colstrip SES** Project Location: **Colstrip, MT** Project Number: **ME1210**	Geosyntec consultants engineers | scientists | innovators	Log of Boring GB-1 **Sheet 1 of 3**

Date(s) Drilled **June 18-20, 2015**	Logged By **Vinay Krishnan**	Checked By **Ranjiv Gupta**
Drilling Method **Hollow Stem Auger**	Drill Bit Size/Type **4.25" ID, 7.625" OD**	Total Depth of Borehole **131.5 ft-bgs**
Drill Rig Type **CME 850**	Drilling Contractor **Yellow Jacket Drilling Services**	Approximate Surface Elevation **3234.8 ft, MSL**
Groundwater Level and Date Measured **Not Encountered**	Sampling Method(s) **Split Spoon and Shelby Tube**	Hammer Data **Automatic Trip Hammer**
Borehole Backfill **Bentonite chips and borehole cuttings**	Location **EHP Cell J**	

Depth (feet)	Elevation (feet, MSL)	Sample Number	Sample Type	Blows Per Foot (N)	Material Type	MATERIAL DESCRIPTION	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	% Passing No. 200 Sieve
0	3234.8	0-1.5		2	MH	Paste: Elastic SILT, light gray, very soft, wet	46.5			
		3-4.5		4	MH	Paste: Elastic SILT, light gray, soft, wet	46.8			
5	3229.8	5-6.5		20	MH	Paste: Elastic SILT, gray, wet, very stiff, 99.8% silty fines	56.2	68	15	99.8
		6.5-8		30	MH	Paste: Elastic SILT, gray, moist to wet, very stiff				
		8-9.5		27	MH	Paste: Elastic SILT, light gray, moist to wet, very stiff				
10	3224.8	9.5-11		33	MH	Paste: Elastic SILT, gray, wet, hard	52.4			
		11-12.5		49	MH	Paste: Elastic SILT, light gray, moist, hard				
15	3219.8	15-17			MH	Paste: Elastic SILT, light gray, dry				
20	3214.8	20-21.5		51	MH	Paste: Elastic SILT, light gray, wet, very hard	52.7			
25	3209.8	25-26.5		21	MH	Paste: Elastic SILT, gray, dry, very stiff				
30	3204.8	30-31.5		16	MH	Paste: Elastic SILT, gray, wet, very stiff	75.2			
35	3199.8	35-36.5		27	MH	Paste: Elastic SILT, light gray, wet, very stiff, non-plastic, 100% silty fines	52.4		NP	100
40	3194.8	40-41.5		38	MH	Paste: Elastic SILT, light gray, wet, hard	48.4			
45	3189.8	45-46.5		46	MH	Paste: Elastic SILT, dark gray, dry, hard, sulfur odor				
50	3184.8									

Project: **Colstrip SES**
Project Location: **Colstrip, MT**
Project Number: **ME1210**

Geosyntec consultants
engineers | scientists | innovators

Log of Boring GB-1

Depth (feet)	Elevation (feet, MSL)	Sample Number	Sample Type	Blows Per Foot (N)	Material Type	MATERIAL DESCRIPTION	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	% Passing No. 200 Sieve
50	3184.8	50-51			MH	Paste: Elastic SILT, dark gray, moist to wet	49.2			
55	3179.8	55-56.5		10	MH	Paste: Elastic SILT, dark gray, wet, stiff, 96.2% silty fines	96.6	67	11	96.2
60	3174.8	60-61.5		28	MH	Paste: Elastic SILT, dark gray, wet, very stiff, non-plastic, 87.7% silty fines	74.6		NP	87.7
65	3169.8									
70	3164.8	70-71.5		50 (4")	MH	Paste: Elastic SILT, dark gray, moist to wet, very hard	47.7			
75	3159.8									
80	3154.8	80-81.5		25	ML	SILT with sand, trace gravel, clinker, and gray coal ash paste, orange to brown, moist, very stiff, 75.4% silty fines	23.9	27	5	75.4
85	3149.8									
90	3144.8	90-91.5		50 (3")	CL	Lean CLAY, trace gravel, brown to gray, moist, very hard				
95	3139.8									
100	3134.8									

Project: **Colstrip SES**	Geosyntec consultants	Log of Boring GB-1
Project Location: **Colstrip, MT**	engineers | scientists | innovators	**Sheet 3 of 3**
Project Number: **ME1210**		

Depth (feet)	Elevation (feet, MSL)	Sample Number	Sample Type	Blows Per Foot (N)	Material Type	MATERIAL DESCRIPTION	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	% Passing No. 200 Sieve
100	3134.8	100-101.5			CL	Lean CLAY, gray, dry, very hard, strong cementation				
105	3129.8									
110	3124.8	110-111.5		50 (3")	CL	Lean CLAY, gray, dry, very hard, strong cementation, 98.6% clayey fines	16.0	39	18	98.6
115	3119.8									
120	3114.8	120-121.5		50 (2")	CL	Lean CLAY, gray, moist, very hard, strong cementation				
125	3109.8									
130	3104.8	130-131.5		50 (5")	CL	Lean CLAY, gray, dry, very hard, strong cementation, 99.4% clayey fines	16.6	39	17	99.4
						End of Boring at 131.5 ft-bgs				
135	3099.8									
140	3094.8									
145	3089.8									
150	3084.8									

Project: **Colstrip SES**	Geosyntec consultants (engineers | scientists | innovators)	Log of Boring GB-2
Project Location: **Colstrip, MT**		**Sheet 1 of 2**
Project Number: **ME1210**		

Date(s) Drilled **June 21 & 23, 2015**	Logged By **Vinay Krishnan**	Checked By **Ranjiv Gupta**
Drilling Method **Hollow Stem Auger**	Drill Bit Size/Type **4.25" ID, 7.625" OD**	Total Depth of Borehole **75 ft-bgs**
Drill Rig Type **CME 850**	Drilling Contractor **Yellow Jacket Drilling Services**	Approximate Surface Elevation **3244.3 ft, MSL**
Groundwater Level and Date Measured **Not Encountered**	Sampling Method(s) **Split Spoon and Shelby Tube**	Hammer Data **Automatic Trip Hammer**
Borehole Backfill **Bentonite chips and borehole cuttings**	Location **EHP Cell J - N 604,807.53; E 2,720,994.25**	

Depth (feet)	Elevation (feet, MSL)	Sample Number	Sample Type	Blows Per Foot (N)	Material Type	MATERIAL DESCRIPTION	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	% Passing No. 200 Sieve
0	3244.3	0-1.5		5	CL-ML	Paste: Silty CLAY, light gray, moist, firm, non-plastic, 98.9% fines	38.5		NP	98.9
		1.5-3		13	MH	Paste: Elastic SILT, light gray, moist, stiff				
		3-4.5		8	MH	Paste: Elastic SILT, light gray, wet, firm				
5	3239.3	4.5-6		4	MH	Paste: Elastic SILT, light gray, moist, soft	33.1			
10	3234.3	10-12			MH	Paste: Elastic SILT, light gray, moist				
15	3229.3	15-16.5		18	MH	Paste: Elastic SILT, light gray, moist, very stiff	40.4			
20	3224.3	20-21.5		8	MH	Paste: Elastic SILT, light gray to gray, wet, firm	52.6			
25	3219.3	25-26.5		33	MH	Paste: Elastic SILT, light gray, dry, hard				
30	3214.3	30-31.5		14	MH	Paste: Elastic SILT, light gray to gray, wet, stiff	63.5			
35	3209.3	35-36			MH	Paste: Elastic SILT, gray, dry to moist				
40	3204.3	40-41.5		21	CL-ML	Paste: Silty CLAY; trace sand, gravel; variable color including gray, orange brown, and black; dry, stiff				
45	3199.3	45-46.5		56	SP	Poorly-graded SAND, trace brown clay, light gray to brown, moist, very hard	26			
50	3194.3									

Project: **Colstrip SES**	Geosyntec consultants	Log of Boring GB-2
Project Location: **Colstrip, MT**	engineers | scientists | innovators	**Sheet 2 of 2**
Project Number: **ME1210**		

Depth (feet)	Elevation (feet, MSL)	Sample Number	Sample Type	Blows Per Foot (N)	Material Type	MATERIAL DESCRIPTION	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	% Passing No. 200 Sieve
50	3194.3	50-51.5		50 (5")	SP	Poorly-graded SAND, trace clay, light brown, moist, very hard				
55	3189.3	55-56			SP	Poorly-graded SAND, light brown, moist				
60	3184.3	60-61.5		50 (4")	SP	Poorly-graded SAND with clay, light brown, moist, very hard				
65	3179.3									
70	3174.3	70-71.5		50 (5")	SP	Poorly-graded SAND, trace clay, light brown, moist, very hard				
75	3169.3					End of Boring at 75 ft-bgs				
80	3164.3									
85	3159.3									
90	3154.3									
95	3149.3									
100	3144.3									

Project: **Colstrip SES** Project Location: **Colstrip, MT** Project Number: **ME1210**	Geosyntec consultants engineers | scientists | innovators	Log of Boring GB-4 **Sheet 1 of 3**

Date(s) Drilled **June 15-17, 2015**	Logged By **Vinay Krishnan**	Checked By **Ranjiv Gupta**
Drilling Method **Hollow Stem Auger**	Drill Bit Size/Type **4.25" ID, 7.625" OD**	Total Depth of Borehole **145 ft-bgs**
Drill Rig Type **CME 850**	Drilling Contractor **Yellow Jacket Drilling Services**	Approximate Surface Elevation **3251.0 ft, MSL**
Groundwater Level and Date Measured **Not Encountered**	Sampling Method(s) **Split Spoon and Shelby Tube**	Hammer Data **Automatic Trip Hammer**
Borehole Backfill **Bentonite chips and borehole cuttings**	Location **EHP Cell J - N 605,172.93; E 2,721,551.60**	

Depth (feet)	Elevation (feet, MSL)	Sample Number	Sample Type	Blows Per Foot (N)	Material Type	MATERIAL DESCRIPTION	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	% Passing No. 200 Sieve
0	3251									
5	3246									
10	3241	9-10.5		50 (4")	SM	Bottom ash: Silty SAND, gray, dry to moist, very hard	17.7			
15	3236	15-16.5		50 (10")	SM	Bottom ash: Silty SAND with clay, gray, dry to moist, very hard, non-plastic, some gravel	16.8		NP	49.4
20	3231	20-21.5		50 (3")	SM	Bottom ash: Silty SAND, gray, dry to moist, very hard	17			
25	3226	25-26.5		50 (3")	SM	Bottom ash: Silty SAND, gray, dry to moist, very hard	19.4			
30	3221	30-31.5		5	SM	Bottom ash: Silty SAND, gray, moist, firm, trace clinker and reddish clay, non-plastic	23.7		NP	39.2
35	3216	35-37			SC	Bottom ash: Clayey SAND, reddish brown, moist	22.0			
40	3211	40-41.5		50 (5")	MH	Paste: Elastic SILT, light gray, moist, very hard, trace bentonite	22.3			
45	3206	45-46.5		50 (4")	MH	Paste: Elastic SILT, gray, moist, very hard				
50	3201									

Project: **Colstrip SES**	Geosyntec consultants	Log of Boring GB-4
Project Location: **Colstrip, MT**	engineers | scientists | innovators	**Sheet 2 of 3**
Project Number: **ME1210**		

Depth (feet)	Elevation (feet, MSL)	Sample Number	Sample Type	Blows Per Foot (N)	Material Type	MATERIAL DESCRIPTION	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	% Passing No. 200 Sieve
50	3201	50-51.5		50 (2")	CL-ML	Paste: Silty CLAY, light gray to brown, wet, very hard				
55	3196	55-56.5		50 (3")	CL-ML	Paste: Silty CLAY, light gray, moist, very hard				
60	3191	60-61.5		50 (5")	MH	Paste: Elastic SILT, gray, moist, very hard				
65	3186	65-66.5		50 (4")	MH	Paste: Elastic SILT, light gray, dry to moist, very hard				
		66.5-67.5			MH	Paste: Elastic SILT, light gray, moist	23.5			
70	3181	70-71.5		50 (2")	CL-ML	Silty CLAY, light brown, moist to wet, very hard	28.4	24	7	84.7
75	3176	75-76.5		50 (2")	SM	Silty SAND, light gray, dry, very hard				
80	3171	80-81.5		50 (3")	SM	Silty SAND, gray to brown, dry, very hard	15.9			
85	3166	85-86.5		50 (5")	SC	Clayey SAND, trace shale, brown, wet, very hard				
90	3161	90-91.5		50 (3")	SC	Clayey SAND, light brown, moist, very hard	28.5			
95	3156	95-96.5		50 (2")	CL	Lean CLAY, trace clayey sand, brownish gray, moist, very hard	25.7			
100	3151									

Depth (feet)	Elevation (feet, MSL)	Sample Number	Sample Type	Blows Per Foot (N)	Material Type	MATERIAL DESCRIPTION	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	% Passing No. 200 Sieve
100	3151	100-101.5		50 (5")	CL	Lean CLAY, light gray, dry, very hard				
105	3146	105-106.5		50 (5")	CL	Lean CLAY, grayish brown, moist, very hard	24.6	28	11	96.0
110	3141									
115	3136	115-116.5		50 (5")	CL	Lean CLAY, light gray, moist, very hard, strong cementation	18.7			
120	3131									
125	3126	125-126.5		50 (3")	GP	Coal seam: Poorly-graded GRAVEL, black, moist, very hard	17.8			
130	3121									
135	3116	135-136.5		50 (5")	CL	Lean CLAY, light gray, dry, very hard	13.8			
140	3111									
145	3106				CL	Lean CLAY, light gray, dry	8.2			
						End of Boring at 145 ft-bgs				
150	3101									

ATTACHMENT B

SETTLEMENT CALCULATION FOR EHP CELL J

SETTLEMENT OF CLAY LINER DUE TO PLACEMENT OF WASTE - SECTION AA'

DISTANCE	Point #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Coordinate along critical section (ft)	0	34	135	174	219	287	318	367	428	464	478	512	523	539	546	714
UNIT WEIGHTS	Cover Soil (γ_{cover}, pcf)	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
	Sublayer 1: Bottom Ash (pcf)	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
	Sublayer 2: Coal Ash Paste (pcf)	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112
	Sublayer 3: Silt and Silty Clay (pcf)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	Sublayer 4: Stiff Paste (pcf)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	Groundwater (pcf)	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4
ELEVATIONS	Final Cover Elevation (ft, MSL)	3290.0	3300.6	3332.5	3344.8	3359.0	3380.2	3390.0	3380.0	3370.0	3360.0	3356.2	3347.2	3344.2	3340.0	3338.1	3290.0
	Base Grade Elevation (ft, MSL)	3290.0	3280.0	3250.0	3240.0	3237.0	3236.0	3235.5	3234.7	3233.8	3233.2	3233.0	3233.0	3233.0	3237.9	3240.0	3290.0
	Bottom Ash to Coal Ash Paste Interface (ft, MSL)	3290.0	3280.0	3250.0	3240.0	3237.0	3236.0	3235.5	3234.7	3233.8	3233.2	3233.0	3233.0	3233.0	3237.9	3240.0	3290.0
	Coal Ash Paste to Silt/Silty Clay Interface (ft, MSL)	3250.0	3240.0	3205.9	3192.7	3177.5	3154.8	3154.8	3154.8	3154.8	3154.8	3154.8	3154.8	3154.8	3154.8	3154.8	3154.8
	Silt/Silty Clay to Stiff Paste Interface (ft, MSL)	3144.8	3144.8	3144.8	3144.8	3144.8	3144.8	3144.8	3144.8	3144.8	3144.8	3144.8	3144.8	3144.8	3144.8	3144.8	3144.8
	Stiff Paste to "Bedrock" Interface (ft, MSL)	3104.8	3104.8	3104.8	3104.8	3104.8	3104.8	3104.8	3104.8	3104.8	3104.8	3104.8	3104.8	3104.8	3104.8	3104.8	3104.8
	Groundwater Table (ft, MSL)	3240.0	3240.0	3240.0	3240.0	3237.0	3236.0	3235.5	3234.7	3233.8	3233.2	3233.0	3233.0	3233.0	3233.0	3233.0	3233.0
LAYER THICKNESS	Thickness of Final Cover (ft)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Thickness of Additional Coal Ash Paste (ft)	0.0	17.1	79.0	101.3	118.5	140.8	151.0	141.8	132.7	123.3	119.7	110.7	107.7	98.6	94.6	0.0
	Thickness of Additional Bottom Ash (ft)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Sublayer 1: Bottom Ash	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sublayer 2: Coal Ash Paste	40.0	40.0	44.1	47.3	59.5	81.2	80.7	79.9	79.0	78.4	78.2	78.2	78.2	83.1	85.2	135.2
	Sublayer 3: Silt and Silty Clay	105.2	95.2	61.1	47.9	32.7	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
	Sublayer 4: Stiff Paste	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
SUBLAYER 1: BOTTOM ASH	Elevation of midpoint of sublayer (ft msl)	3290.0	3280.0	3250.0	3240.0	3237.0	3236.0	3235.5	3234.7	3233.8	3233.2	3233.0	3233.0	3233.0	3237.9	3240.0	3290.0
	Groundwater depth at midpoint of sublayer (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Initial effective stress (psf)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Final effective stress (psf)	432	2349	9275	11782	13702	16197	17347	16311	15298	14239	13835	12828	12493	11477	11023	432
	Preconsolidation pressure (if overconsolidated, psf)	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028
	Initial Void Ratio	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
	Compression Index	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
	Recompression Index	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Secondary Compression Index	0.0008	0.0008	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0008
	Ultimate settlement due to primary consolidation (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Secondary compression (ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Settlement of sublayer (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SUBLAYER 2: COAL ASH PASTE	Elevation of midpoint of sublayer (ft msl)	3270.0	3260.0	3228.0	3216.3	3207.3	3195.4	3195.1	3194.8	3194.3	3194.0	3193.9	3193.9	3193.9	3196.3	3197.4	3222.4
	Groundwater depth at midpoint of sublayer (ft)	0.0	0.0	12.0	23.7	29.7	40.6	40.3	40.0	39.5	39.2	39.1	39.1	39.1	36.7	35.6	10.6
	Initial effective stress (psf)	2240.0	2240.0	1717.2	1173.9	1475.1	2012.7	2000.7	1982.1	1958.4	1944.9	1939.4	1939.4	1939.4	2365.5	2549.8	6909.8
	Final effective stress (psf)	2672.0	4588.7	10991.9	12955.4	15177.5	18209.3	19347.5	18293.0	17256.4	16184.0	15774.5	14767.6	14432.0	13842.2	13573.1	7341.8
	Preconsolidation pressure (if overconsolidated, psf)	1965	1965	1965	1965	1965	1965	1965	1965	1965	1965	1965	1965	1965	1965	1965	1965
	Initial Void Ratio	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16
	Compression Index	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	Recompression Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Secondary Compression Index	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060
	Ultimate settlement due to primary consolidation (ft)	0.2	0.9	2.3	2.7	3.7	5.4	5.5	5.3	5.2	5.0	4.9	4.8	4.7	4.4	4.3	0.2
	Secondary compression (ft)	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.7
	Total Settlement of sublayer (ft)	0.4	1.1	2.5	3.0	4.0	5.8	5.9	5.7	5.6	5.4	5.3	5.1	5.1	4.8	4.7	0.9
SUBLAYER 3: SILT AND SILTY CLAY	Elevation of midpoint of sublayer (ft msl)	3197.4	3192.4	3175.4	3168.7	3161.2	3149.8	3149.8	3149.8	3149.8	3149.8	3149.8	3149.8	3149.8	3149.8	3149.8	3149.8
	Groundwater depth at midpoint of sublayer (ft)	42.6	47.6	64.6	71.3	75.8	86.2	85.7	84.9	84.0	83.4	83.2	83.2	83.2	83.2	83.2	83.2
	Initial effective stress (psf)	8,923	7,936	5,029	4,085	4,138	4,388	4,364	4,327	4,280	4,253	4,242	4,242	4,242	4,789	5,026	10,626
	Final effective stress (psf)	9,355	10,284	14,304	15,867	17,840	20,585	21,711	20,638	19,578	18,492	18,077	17,070	16,734	16,266	16,049	11,058
	Constrained modulus of layer (psf)	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000
	Estimated settlement by elastic method (ft)	0.1	0.5	1.3	1.3	1.0	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.0
SUBLAYER 4: STIFF COAL ASH PASTE	Elevation of midpoint of sublayer (ft msl)	3124.8	3124.8	3124.8	3124.8	3124.8	3124.8	3124.8	3124.8	3124.8	3124.8	3124.8	3124.8	3124.8	3124.8	3124.8	3124.8
	Groundwater depth at midpoint of sublayer (ft)	115.2	115.2	115.2	115.2	112.2	111.2	110.7	109.9	109.0	108.4	108.2	108.2	108.2	108.2	108.2	108.2
	Initial effective stress (psf)	14193.5	12843.5	8699.7	7274.9	6777.7	6203.4	6179.5	6142.2	6094.8	6067.7	6056.7	6056.7	6056.7	6604.1	6840.7	12440.7
	Final effective stress (psf)	14625.5	15192.2	17974.4	19056.4	20480.1	22400.0	23526.3	22453.1	21392.8	20306.9	19891.9	18885.0	18549.4	18080.7	17864.1	12872.7
	Preconsolidation pressure (if overconsolidated, psf)	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103
	Initial Void Ratio	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Compression Index	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Recompression Index	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	Secondary Compression Index	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0016
	Ultimate settlement due to primary consolidation (ft)	0.0	0.1	0.6	0.7	0.9	1.0	1.1	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.0
	Secondary compression (ft)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1
	Total Settlement of sublayer (ft)	0.3	0.4	0.8	1.0	1.1	1.2	1.3	1.3	1.2	1.1	1.1	1.0	1.0	0.9	0.9	0.1
TOTAL SETTLEMENT AND STRAINS	Total Settlement (ft)	0.8	1.9	4.6	5.2	6.1	7.4	7.6	7.4	7.1	6.8	6.7	6.5	6.4	6.0	5.9	1.0
	Base Grade Elevation (ft, MSL)	3289.2	3278.1	3245.4	3234.8	3230.9	3228.6	3227.9	3227.4	3226.7	3226.4	3226.3	3226.5	3226.6	3231.9	3234.1	3289.0
	Intial Liner Segment Length, L_o (ft)		35.200	105.601	40.625	45.100	67.508	31.129	48.589	61.841	35.338	14.377	33.750	11.250	16.451	7.113	176.002
	Post Settlement Liner Segment Length, L_f(ft)		35.547	106.382	40.781	45.168	67.541	31.133	48.586	61.837	35.334	14.375	33.751	11.250	16.559	7.163	177.435
	Post Settlement Liner Strain (- comp, + tension)		0.984%	0.740%	0.384%	0.151%	0.049%	0.014%	-0.007%	-0.006%	-0.009%	-0.009%	0.003%	0.003%	0.658%	0.708%	0.815%
	Differential Settlement (%)		3.29%	2.50%	1.52%	1.98%	1.95%	0.71%	-0.52%	-0.44%	-0.79%	-0.77%	-0.74%	-0.76%	-2.15%	-2.30%	-2.75%
LEACHATE COLLECTION PIPE GRADE	Initial Grade (%)	-	-	-	-	-	1.55%	1.55%	1.55%	1.55%	1.55%	1.55%	-	-	-	-	-
	Post Settlement Grade (%)	-	-	-	-	-	3.49%	2.26%	1.03%	1.11%	0.75%	0.77%	-	-	-	-	-
	Average Initial Grade (%)											1.55%					
	Average Post Settlement Grade (%)											1.18%					

SETTLEMENT OF CLAY LINER DUE TO PLACEMENT OF WASTE - SECTION BB'

DISTANCE	Point #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Coordinate along critical section (ft)	0	11	45	129	152	186	428	451	473	512	585	647	714	726	743	917
UNIT WEIGHTS	Cover Soil (γ_{cover}, pcf)	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
	Sublayer 1: Bottom Ash (pcf)	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
	Sublayer 2: Coal Ash Paste (pcf)	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112
	Sublayer 3: Silt and Silty Clay (pcf)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	Sublayer 4: Stiff Paste (pcf)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	Groundwater (pcf)	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4
ELEVATIONS	Final Cover Elevation (ft, MSL)	3290.0	3293.7	3304.7	3332.3	3339.6	3350.7	3430.0	3430.0	3423.4	3411.6	3389.6	3371.1	3350.8	3347.4	3342.3	3290.0
	Base Grade Elevation (ft, MSL)	3290.0	3290.0	3278.6	3250.0	3244.0	3243.0	3239.3	3239.0	3238.6	3238.0	3236.9	3236.0	3235.0	3235.0	3242.0	3290.0
	Bottom Ash to Coal Ash Paste Interface (ft, MSL)	3290.0	3290.0	3278.6	3250.0	3244.0	3243.0	3239.3	3239.0	3238.6	3238.0	3236.9	3236.0	3235.0	3235.0	3242.0	3290.0
	Coal Ash Paste to Silt/Silty Clay Interface (ft, MSL)	3260.0	3255.0	3240.0	3202.5	3192.5	3177.7	3177.7	3177.7	3177.7	3177.7	3177.7	3177.7	3177.7	3177.7	3177.7	3177.7
	Silt/Silty Clay to Stiff Paste Interface (ft, MSL)	3157.7	3157.7	3157.7	3157.7	3157.7	3157.7	3157.7	3157.7	3157.7	3157.7	3157.7	3157.7	3157.7	3157.7	3157.7	3157.7
	Stiff Paste to "Bedrock" Interface (ft, MSL)	3137.7	3137.7	3137.7	3137.7	3137.7	3137.7	3137.7	3137.7	3137.7	3137.7	3137.7	3137.7	3137.7	3137.7	3137.7	3137.7
	Groundwater Table (ft, MSL)	3244.0	3244.0	3244.0	3244.0	3244.0	3243.0	3239.3	3239.0	3238.6	3238.0	3236.9	3236.0	3235.0	3235.0	3235.0	3235.0
LAYER THICKNESS	Thickness of Final Cover (ft)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Thickness of Additional Coal Ash Paste (ft)	0.0	0.2	22.6	78.8	92.1	104.2	187.2	187.5	181.2	170.0	149.2	131.6	112.3	108.9	96.8	0.0
	Thickness of Additional Bottom Ash (ft)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Sublayer 1: Bottom Ash	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sublayer 2: Coal Ash Paste	30.0	35.0	38.6	47.5	51.5	65.3	61.6	61.3	60.9	60.3	59.2	58.3	57.3	57.3	64.3	112.3
	Sublayer 3: Silt and Silty Clay	102.3	97.3	82.3	44.8	34.8	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	Sublayer 4: Stiff Paste	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
SUBLAYER 1: BOTTOM ASH	Elevation of midpoint of sublayer (ft msl)	3290.0	3290.0	3278.6	3250.0	3244.0	3243.0	3239.3	3239.0	3238.6	3238.0	3236.9	3236.0	3235.0	3235.0	3242.0	3290.0
	Groundwater depth at midpoint of sublayer (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Initial effective stress (psf)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Final effective stress (psf)	432	452	2967	9255	10751	12098	21397	21434	20732	19475	17141	15166	13008	12630	11279	432
	Preconsolidation pressure (if overconsolidated, psf)	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028
	Initial Void Ratio	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
	Compression Index	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
	Recompression Index	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Secondary Compression Index	0.0008	0.0008	0.0008	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0008
	Ultimate settlement due to primary consolidation (ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Secondary compression (ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Settlement of sublayer (ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SUBLAYER 2: COAL ASH PASTE	Elevation of midpoint of sublayer (ft msl)	3275.0	3272.5	3259.3	3226.3	3218.3	3210.4	3208.5	3208.3	3208.2	3207.9	3207.3	3206.9	3206.4	3206.4	3209.9	3233.9
	Groundwater depth at midpoint of sublayer (ft)	0.0	0.0	0.0	17.8	25.8	32.7	30.8	30.6	30.5	30.2	29.6	29.2	28.7	28.7	25.2	1.2
	Initial effective stress (psf)	1680.0	1960.0	2160.0	1552.4	1277.2	1619.4	1528.1	1519.7	1511.5	1496.6	1469.1	1445.8	1421.0	1421.0	2031.4	6217.0
	Final effective stress (psf)	2112.0	2411.7	5127.0	10807.5	12027.8	13717.3	22924.7	22954.0	22243.4	20971.7	18609.9	16611.5	14429.3	14051.1	13310.1	6649.0
	Preconsolidation pressure (if overconsolidated, psf)	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683
	Initial Void Ratio	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
	Compression Index	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	Recompression Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Secondary Compression Index	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060
	Ultimate settlement due to primary consolidation (ft)	0.2	0.2	1.0	2.7	3.1	4.2	4.9	4.9	4.8	4.6	4.3	4.1	3.8	3.7	3.7	0.2
	Secondary compression (ft)	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.6
	Total Settlement of sublayer (ft)	0.4	0.4	1.2	2.9	3.4	4.5	5.2	5.2	5.1	4.9	4.6	4.4	4.1	4.0	4.0	0.8
SUBLAYER 3: SILT AND SILTY CLAY	Elevation of midpoint of sublayer (ft msl)	3208.9	3206.4	3198.9	3180.1	3175.1	3167.7	3167.7	3167.7	3167.7	3167.7	3167.7	3167.7	3167.7	3167.7	3167.7	3167.7
	Groundwater depth at midpoint of sublayer (ft)	35.2	37.7	45.2	63.9	68.9	75.3	71.6	71.3	70.9	70.3	69.2	68.3	67.3	67.3	67.3	67.3
	Initial effective stress (psf)	8,072	8,138	7,058	4,357	3,818	3,965	3,782	3,765	3,749	3,719	3,664	3,618	3,568	3,568	4,352	9,728
	Final effective stress (psf)	8,504	8,590	10,025	13,612	14,568	16,063	25,179	25,200	24,481	23,194	20,805	18,783	16,576	16,198	15,631	10,160
	Constrained modulus of layer (psf)	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000
	Estimated settlement by elastic method (ft)	0.1	0.1	0.5	0.9	0.8	0.5	1.0	1.0	0.9	0.9	0.8	0.7	0.6	0.6	0.5	0.0
SUBLAYER 4: STIFF COAL ASH PASTE	Elevation of midpoint of sublayer (ft msl)	3147.7	3147.7	3147.7	3147.7	3147.7	3147.7	3147.7	3147.7	3147.7	3147.7	3147.7	3147.7	3147.7	3147.7	3147.7	3147.7
	Groundwater depth at midpoint of sublayer (ft)	96.3	96.3	96.3	96.3	96.3	95.3	91.6	91.3	90.9	90.3	89.2	88.3	87.3	87.3	87.3	87.3
	Initial effective stress (psf)	12511.4	12396.4	10771.4	6708.9	5806.9	5416.9	5234.1	5217.5	5200.9	5171.3	5116.3	5069.7	5020.1	5020.1	5804.1	11180.1
	Final effective stress (psf)	12943.4	12848.1	13738.4	15964.0	16557.5	17514.7	26630.8	26651.7	25932.9	24646.3	22257.1	20235.4	18028.3	17650.1	17082.7	11612.1
	Preconsolidation pressure (if overconsolidated, psf)	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103
	Initial Void Ratio	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Compression Index	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Recompression Index	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	Secondary Compression Index	0.0016	0.0016	0.0016	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0016
	Ultimate settlement due to primary consolidation (ft)	0.0	0.0	0.1	0.3	0.3	0.4	0.7	0.7	0.7	0.6	0.6	0.5	0.4	0.4	0.3	0.0
	Secondary compression (ft)	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
	Total Settlement of sublayer (ft)	0.0	0.0	0.1	0.4	0.4	0.5	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.5	0.5	0.0
TOTAL SETTLEMENT AND STRAINS	Total Settlement (ft)	0.5	0.5	1.9	4.2	4.6	5.5	7.0	6.9	6.8	6.6	6.1	5.7	5.2	5.1	5.0	0.9
	Base Grade Elevation (ft, MSL)	3289.5	3289.5	3276.7	3245.8	3239.4	3237.5	3232.4	3232.0	3231.8	3231.5	3230.9	3230.3	3229.8	3229.9	3237.0	3289.1
	Intial Liner Segment Length, L_o (ft)		11.250	35.632	89.081	23.286	33.765	242.820	22.086	22.003	39.380	73.133	61.882	67.507	11.250	18.269	180.861
	Post Settlement Liner Segment Length, L_f(ft)		11.250	36.075	89.875	23.394	33.803	242.845	22.086	22.001	39.377	73.128	61.877	67.502	11.250	18.318	181.994
	Post Settlement Liner Strain (- comp, + tension)		0.001%	1.242%	0.891%	0.461%	0.113%	0.011%	-0.001%	-0.007%	-0.008%	-0.008%	-0.008%	-0.008%	0.002%	0.265%	0.626%
	Differential Settlement (%)		0.34%	3.68%	2.68%	1.74%	2.64%	0.59%	-0.10%	-0.61%	-0.63%	-0.65%	-0.69%	-0.73%	-0.69%	-0.69%	-2.27%
LEACHATE COLLECTION PIPE GRADE	Initial Grade (%)	-	-	-	-	-	2.96%	1.52%	1.52%	1.52%	1.52%	1.52%	1.52%	1.48%	-	-	-
	Post Settlement Grade (%)	-	-	-	-	-	5.60%	2.10%	1.42%	0.90%	0.89%	0.87%	0.83%	0.75%	-	-	-
	Average Initial Grade (%)													1.51%			
	Average Post Settlement Grade (%)													1.44%			

SETTLEMENT OF CLAY LINER DUE TO PLACEMENT OF WASTE - SECTION CC'

DISTANCE	Point #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Coordinate along critical section (ft)	0	129	146	169	199	218	370	431	530	594	759	765	804	827	855	893	934	949	986	996
UNIT WEIGHTS	Cover Soil (γ_{cover}, pcf)	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
	Sublayer 1: Bottom Ash (pcf)	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
	Sublayer 2: Coal Ash Paste (pcf)	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112
	Sublayer 3: Silt and Silty Clay (pcf)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	Sublayer 4: Stiff Paste (pcf)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	Groundwater (pcf)	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4
ELEVATIONS	Final Cover Elevation (ft, MSL)	3290.0	3332.1	3337.5	3344.9	3354.6	3360.7	3410.3	3430.0	3430.0	3410.8	3361.0	3359.3	3347.5	3340.7	3332.3	3321.0	3308.6	3304.1	3292.8	3290.0
	Base Grade Elevation (ft, MSL)	3290.0	3250.0	3250.0	3249.0	3248.5	3248.3	3245.9	3245.0	3243.5	3242.5	3240.0	3240.0	3240.0	3246.0	3253.3	3263.1	3273.9	3277.8	3287.6	3290.0
	Bottom Ash to Coal Ash Paste Interface (ft, MSL)	3290.0	3250.0	3250.0	3249.0	3248.5	3248.3	3245.9	3245.0	3243.5	3242.5	3240.0	3240.0	3240.0	3246.0	3253.3	3263.1	3273.9	3277.8	3287.6	3290.0
	Coal Ash Paste to Silt/Silty Clay Interface (ft, MSL)	3285.0	3250.0	3249.3	3248.5	3248.5	3240.0	3199.3	3199.3	3199.3	3199.3	3229.0	3230.0	3236.2	3239.7	3250.0	3260.0	3260.0	3250.0	3240.0	3236.6
	Silt/Silty Clay to Stiff Paste Interface (ft, MSL)	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3
	Stiff Paste to "Bedrock" Interface (ft, MSL)	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3
	Groundwater Table (ft, MSL)	3250.0	3250.0	3250.0	3249.0	3248.5	3248.3	3245.9	3245.0	3243.5	3242.5	3240.0	3240.0	3240.0	3240.0	3240.0	3240.0	3240.0	3240.0	3240.0	3240.0
LAYER THICKNESS	Thickness of Final Cover (ft)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Thickness of Additional Coal Ash Paste (ft)	0.0	78.6	84.0	92.4	102.6	109.0	160.9	181.5	183.0	164.7	117.5	115.8	104.0	91.2	75.4	54.4	31.2	22.8	1.8	0.0
	Thickness of Additional Bottom Ash (ft)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Sublayer 1: Bottom Ash	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sublayer 2: Coal Ash Paste	5.0	0.0	0.7	0.5	0.0	8.3	46.6	45.7	44.2	43.2	11.0	10.0	3.8	6.3	3.3	3.1	13.9	27.8	47.6	53.4
	Sublayer 3: Silt and Silty Clay	115.7	80.7	80.0	79.2	79.2	70.7	30.0	30.0	30.0	30.0	59.7	60.7	66.9	70.4	80.7	90.7	90.7	80.7	70.7	67.3
	Sublayer 4: Stiff Paste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBLAYER 1: BOTTOM ASH	Elevation of midpoint of sublayer (ft msl)	3290.0	3250.0	3250.0	3249.0	3248.5	3248.3	3245.9	3245.0	3243.5	3242.5	3240.0	3240.0	3240.0	3246.0	3253.3	3263.1	3273.9	3277.8	3287.6	3290.0
	Groundwater depth at midpoint of sublayer (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Initial effective stress (psf)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Final effective stress (psf)	432	9231	9845	10777	11920	12635	18448	20759	20929	18883	13596	13406	12080	10651	8882	6524	3931	2987	629	432
	Preconsolidation pressure (if overconsolidated, psf)	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028
	Initial Void Ratio	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
	Compression Index	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
	Recompression Index	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Secondary Compression Index	0.0008	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0008	0.0008	0.0008	0.0008
	Ultimate settlement due to primary consolidation (ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Secondary compression (ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Settlement of sublayer (ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SUBLAYER 2: COAL ASH PASTE	Elevation of midpoint of sublayer (ft msl)	3287.5	3250.0	3249.7	3248.8	3248.5	3244.1	3222.6	3222.2	3221.4	3220.9	3234.5	3235.0	3238.1	3242.9	3251.7	3261.6	3266.9	3263.9	3263.8	3263.3
	Groundwater depth at midpoint of sublayer (ft)	0.0	0.0	0.3	0.3	0.0	4.1	23.3	22.9	22.1	21.6	5.5	5.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Initial effective stress (psf)	280.0	0.4	16.1	12.4	1.1	204.8	1156.5	1133.6	1096.0	1071.9	273.0	248.0	94.8	352.5	186.7	174.2	776.5	1555.6	2663.1	2990.4
	Final effective stress (psf)	712.0	9231.2	9861.4	10789.0	11921.2	12839.6	19604.5	21892.5	22024.6	19954.4	13868.8	13654.3	12175.2	11003.2	9068.9	6698.5	4707.1	4543.0	3292.6	3422.4
	Preconsolidation pressure (if overconsolidated, psf)	1401	1401	1401	1401	1401	1401	1401	1401	1401	1401	1401	1401	1401	1401	1401	1401	1401	1401	1401	1401
	Initial Void Ratio	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
	Compression Index	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
	Recompression Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Secondary Compression Index	0.0004	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056
	Ultimate settlement due to primary consolidation (ft)	0.0	0.0	0.0	0.0	0.0	0.6	3.6	3.6	3.5	3.3	0.8	0.7	0.3	0.4	0.2	0.2	0.5	0.9	0.3	0.2
	Secondary compression (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3
	Total Settlement of sublayer (ft)	0.0	0.0	0.0	0.0	0.0	0.6	3.8	3.8	3.7	3.5	0.8	0.7	0.3	0.4	0.2	0.2	0.6	1.0	0.5	0.5
SUBLAYER 3: SILT AND SILTY CLAY	Elevation of midpoint of sublayer (ft msl)	3227.2	3209.6	3209.3	3208.9	3208.9	3204.7	3184.3	3184.3	3184.3	3184.3	3199.1	3199.7	3202.7	3204.5	3209.7	3214.7	3214.7	3209.7	3204.7	3203.0
	Groundwater depth at midpoint of sublayer (ft)	22.8	40.4	40.7	40.1	39.6	43.6	61.6	60.7	59.2	58.2	40.9	40.3	37.3	35.5	30.3	25.3	25.3	30.3	35.3	37.0
	Initial effective stress (psf)	6,944	2,930	2,938	2,900	2,877	2,976	3,402	3,356	3,281	3,233	2,713	2,699	2,617	3,242	3,927	4,889	6,093	6,665	7,893	8,212
	Final effective stress (psf)	7,376	12,160	12,783	13,676	14,797	15,611	21,850	24,115	24,210	22,115	16,309	16,106	14,698	13,893	12,809	11,413	10,024	9,652	8,522	8,644
	Constrained modulus of layer (psf)	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000
	Estimated settlement by elastic method (ft)	0.1	1.7	1.8	1.9	2.1	2.0	1.2	1.4	1.4	1.3	1.8	1.8	1.8	1.7	1.6	1.3	0.8	0.5	0.1	0.1
SUBLAYER 4: STIFF COAL ASH PASTE	Elevation of midpoint of sublayer (ft msl)	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3	3169.3
	Groundwater depth at midpoint of sublayer (ft)	80.7	80.7	80.7	79.7	79.2	79.0	76.6	75.7	74.2	73.2	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7
	Initial effective stress (psf)	11143.8	5858.5	5843.8	5774.7	5752.0	5542.4	4491.0	4445.2	4370.1	4321.7	4879.6	4902.8	5044.9	5798.1	6856.2	8181.3	9385.9	9593.9	10459.0	10654.6
	Final effective stress (psf)	11575.8	15089.3	15689.1	16551.3	17672.2	18177.2	22939.0	25204.1	25298.6	23204.3	18475.4	18309.2	17125.3	16448.7	15738.4	14705.6	13316.5	12581.3	11088.5	11086.6
	Preconsolidation pressure (if overconsolidated, psf)	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103
	Initial Void Ratio	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Compression Index	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Recompression Index	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	Secondary Compression Index	0.0016	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0016	0.0016	0.0016	0.0016
	Ultimate settlement due to primary consolidation (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Secondary compression (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total Settlement of sublayer (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL SETTLEMENT AND STRAINS	Total Settlement (ft)	0.1	1.7	1.8	2.0	2.1	2.6	5.0	5.2	5.1	4.8	2.6	2.6	2.1	2.1	1.8	1.5	1.4	1.5	0.6	0.5
	Base Grade Elevation (ft, MSL)	3289.9	3248.3	3248.2	3247.0	3246.4	3245.7	3240.9	3239.8	3238.4	3237.7	3237.4	3237.4	3237.9	3243.9	3251.5	3261.6	3272.5	3276.3	3286.9	3289.5
	Intial Liner Segment Length, L_o (ft)		135.417	16.875	22.522	30.003	18.752	152.518	60.632	99.387	64.007	165.394	5.625	39.375	23.286	29.065	38.754	42.629	15.502	38.754	9.688
	Post Settlement Liner Segment Length, L_f(ft)		135.884	16.876	22.529	30.007	18.766	152.573	60.636	99.385	64.003	165.375	5.625	39.378	23.283	29.139	38.836	42.663	15.462	38.994	9.712
	Post Settlement Liner Strain (- comp, + tension)		0.344%	0.004%	0.029%	0.010%	0.072%	0.037%	0.006%	-0.002%	-0.007%	-0.011%	0.008%	0.007%	-0.014%	0.253%	0.213%	0.078%	-0.258%	0.621%	0.239%
	Differential Settlement (%)		1.15%	0.84%	0.61%	0.57%	2.56%	1.58%	0.38%	-0.11%	-0.53%	-1.31%	-1.28%	-1.20%	0.06%	-0.98%	-0.83%	-0.31%	1.04%	-2.36%	-0.93%
LEACHATE COLLECTION PIPE GRADE	Initial Grade (%)	-	-			1.52%	1.52%	1.52%	1.52%	1.52%	1.52%	1.52%	-	-	-	-	-	-	-	-	-
	Post Settlement Grade (%)	-	-			2.09%	4.08%	3.10%	1.90%	1.42%	0.99%	0.22%	-	-	-	-	-	-	-	-	-
	Average Initial Grade (%)											1.52%									
	Average Post Settlement Grade (%)											1.62%									

SETTLEMENT OF CLAY LINER DUE TO PLACEMENT OF WASTE - SECTION DD'

	Point #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
DISTANCE	Coordinate along critical section (ft)	0	6	26	53	86	107	135	141	235	338	360	428	446	601	804	866	894	917	939	956	1063
UNIT WEIGHTS	Cover Soil (γ_{cover}, pcf)	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
	Sublayer 1: Bottom Ash (pcf)	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
	Sublayer 2: Coal Ash Paste (pcf)	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112
	Sublayer 3: Silt and Silty Clay (pcf)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	Sublayer 4: Stiff Paste (pcf)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	Groundwater (pcf)	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4
ELEVATIONS	Final Cover Elevation (ft, MSL)	3290.0	3291.8	3298.2	3306.5	3317.1	3323.5	3332.4	3334.1	3363.6	3395.9	3403.0	3424.2	3430.0	3430.0	3368.3	3349.6	3341.1	3334.3	3327.5	3322.4	3290.0
	Base Grade Elevation (ft, MSL)	3290.0	3288.0	3281.9	3274.1	3264.1	3258.0	3256.3	3256.0	3254.6	3253.0	3252.7	3251.7	3251.4	3249.1	3246.0	3246.0	3256.0	3254.0	3256.0	3258.0	3290.0
	Bottom Ash to Coal Ash Paste Interface (ft, MSL)	3280.0	3277.9	3270.0	3260.0	3250.0	3245.8	3240.0	3238.4	3211.0	3211.0	3211.0	3211.0	3211.0	3211.0	3211.0	3211.0	3211.0	3211.0	3211.0	3211.0	3211.0
	Coal Ash Paste to Silt/Silty Clay Interface (ft, MSL)	3280.0	3277.9	3270.0	3260.0	3250.0	3245.8	3240.0	3238.4	3211.0	3181.0	3181.0	3181.0	3181.0	3181.0	3181.0	3181.0	3181.0	3181.0	3181.0	3181.0	3181.0
	Silt/Silty Clay to Stiff Paste Interface (ft, MSL)	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0
	Stiff Paste to "Bedrock" Interface (ft, MSL)	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0
	Groundwater Table (ft, MSL)	3258.0	3258.0	3258.0	3258.0	3258.0	3258.0	3256.3	3256.0	3254.6	3253.0	3252.7	3251.7	3251.4	3249.1	3246.0	3246.0	3246.0	3246.0	3246.0	3246.0	3246.0
LAYER THICKNESS	Thickness of Final Cover (ft)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Thickness of Additional Coal Ash Paste (ft)	0.0	0.3	12.8	28.9	49.5	62.0	72.5	74.6	105.5	139.4	146.8	169.0	175.1	177.4	118.8	100.1	81.6	76.8	68.0	60.9	0.0
	Thickness of Additional Bottom Ash (ft)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Sublayer 1: Bottom Ash	10.0	10.1	11.9	14.1	14.1	12.2	16.3	17.6	43.6	42.0	41.7	40.7	40.4	38.1	35.0	35.0	45.0	43.0	45.0	47.0	79.0
	Sublayer 2: Coal Ash Paste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	Sublayer 3: Silt and Silty Clay	124.0	121.9	114.0	104.0	94.0	89.8	84.0	82.4	55.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Sublayer 4: Stiff Paste	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
SUBLAYER 1: BOTTOM ASH	Elevation of midpoint of sublayer (ft msl)	3285.0	3282.9	3275.9	3267.1	3257.1	3251.9	3248.2	3247.2	3232.8	3232.0	3231.8	3231.3	3231.2	3230.0	3228.5	3228.5	3233.5	3232.5	3233.5	3234.5	3250.5
	Groundwater depth at midpoint of sublayer (ft)	0.0	0.0	0.0	0.0	0.9	6.1	8.2	8.8	21.8	21.0	20.8	20.3	20.2	19.0	17.5	17.5	12.5	13.5	12.5	11.5	0.0
	Initial effective stress (psf)	640	649	761	903	844	401	536	579	1430	1379	1368	1334	1325	1249	1148	1148	2100	1910	2100	2290	5056
	Final effective stress (psf)	1072	1111	2632	4568	6815	7782	9092	9370	13679	17422	18240	20693	21368	21553	14889	12791	11670	10940	10144	9538	5488
	Preconsolidation pressure (if overconsolidated, psf)	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028
	Initial Void Ratio	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
	Compression Index	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
	Recompression Index	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Secondary Compression Index	0.0008	0.0008	0.0008	0.0008	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
	Ultimate settlement due to primary consolidation (ft)	0.0	0.0	0.1	0.1	0.3	0.4	0.5	0.6	1.8	2.1	2.1	2.2	2.3	2.2	1.6	1.4	1.5	1.4	1.3	1.2	0.2
	Secondary compression (ft)	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.4
	Total Settlement of sublayer (ft)	0.0	0.0	0.1	0.1	0.4	0.4	0.6	0.7	2.0	2.3	2.3	2.5	2.5	2.4	1.8	1.6	1.7	1.6	1.5	1.5	0.7

SUBLAYER 2: COAL ASH PASTE	Elevation of midpoint of sublayer (ft msl)	3280.0	3277.9	3270.0	3260.0	3250.0	3245.8	3240.0	3238.4	3211.0	3196.0	3196.0	3196.0	3196.0	3196.0	3196.0	3196.0	3196.0	3196.0	3196.0	3196.0	3196.0
	Groundwater depth at midpoint of sublayer (ft)	0.0	0.0	0.0	0.0	8.0	12.2	16.3	17.6	43.6	57.0	56.7	55.7	55.4	53.1	50.0	50.0	50.0	50.0	50.0	50.0	50.0
	Initial effective stress (psf)	1280.0	1298.3	1521.8	1806.2	1307.0	802.3	1071.5	1157.1	2859.0	3501.4	3479.2	3412.5	3394.1	3241.3	3040.0	3040.0	4320.0	4064.0	4320.0	4576.0	8672.0
	Final effective stress (psf)	1712.0	1760.0	3392.9	5471.2	7278.3	8183.0	9627.4	9948.2	15108.1	19544.9	20351.5	22771.3	23437.5	23545.6	16781.1	14683.2	13889.6	13094.7	12363.8	11823.7	9104.0
	Preconsolidation pressure (if overconsolidated, psf)	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683
	Initial Void Ratio	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
	Compression Index	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	Recompression Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Secondary Compression Index	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060
	Ultimate settlement due to primary consolidation (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.6	1.7	1.8	1.8	1.6	1.4	1.1	1.1	1.0	0.9	0.0
	Secondary compression (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Total Settlement of sublayer (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.8	1.9	1.9	2.0	1.7	1.6	1.2	1.2	1.1	1.0	0.2
SUBLAYER 3: SILT AND SILTY CLAY	Elevation of midpoint of sublayer (ft msl)	3218.0	3216.9	3213.0	3208.0	3203.0	3200.9	3198.0	3197.2	3183.5	3168.5	3168.5	3168.5	3168.5	3168.5	3168.5	3168.5	3168.5	3168.5	3168.5	3168.5	3168.5
	Groundwater depth at midpoint of sublayer (ft)	40.0	41.1	45.0	50.0	55.0	57.1	58.3	58.8	71.1	84.5	84.2	83.2	82.9	80.6	77.5	77.5	77.5	77.5	77.5	77.5	77.5
	Initial effective stress (psf)	7,154	6,961	6,409	5,706	4,719	4,061	4,121	4,147	4,856	5,153	5,131	5,064	5,046	4,893	4,692	4,692	5,972	5,716	5,972	6,228	10,324
	Final effective stress (psf)	7,586	7,423	8,280	9,371	10,690	11,442	12,677	12,938	17,105	21,196	22,003	24,423	25,089	25,197	18,433	16,335	15,541	14,746	14,015	13,475	10,756
	Constrained modulus of layer (psf)	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000
	Estimated settlement by elastic method (ft)	0.1	0.1	0.5	0.9	1.3	1.5	1.6	1.6	1.5	0.9	0.9	1.1	1.1	1.1	0.8	0.7	0.5	0.5	0.5	0.4	0.0
SUBLAYER 4: STIFF COAL ASH PASTE	Elevation of midpoint of sublayer (ft msl)	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0
	Groundwater depth at midpoint of sublayer (ft)	127.0	127.0	127.0	127.0	127.0	127.0	125.3	125.0	123.6	122.0	121.7	120.7	120.4	118.1	115.0	115.0	115.0	115.0	115.0	115.0	115.0
	Initial effective stress (psf)	13470.2	13199.2	12362.0	11296.4	9946.4	9134.6	8984.9	8951.5	8667.4	7875.4	7853.2	7786.5	7768.1	7615.3	7414.0	7414.0	8694.0	8438.0	8694.0	8950.0	13046.0
	Final effective stress (psf)	13902.2	13660.9	14233.1	14961.4	15917.7	16515.3	17540.8	17742.6	20916.6	23918.9	24725.5	27145.3	27811.5	27919.6	21155.1	19057.2	18263.6	17468.7	16737.8	16197.7	13478.0
	Preconsolidation pressure (if overconsolidated, psf)	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103
	Initial Void Ratio	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Compression Index	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Recompression Index	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	Secondary Compression Index	0.0016	0.0016	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0016
	Ultimate settlement due to primary consolidation (ft)	0.0	0.0	0.1	0.2	0.4	0.5	0.6	0.7	1.0	1.2	1.3	1.5	1.5	1.5	1.1	0.9	0.7	0.7	0.6	0.5	0.0
	Secondary compression (ft)	0.1	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.1
	Total Settlement of sublayer (ft)	0.1	0.1	0.4	0.5	0.7	0.8	0.9	0.9	1.2	1.5	1.6	1.7	1.8	1.8	1.4	1.2	1.0	1.0	0.9	0.8	0.1
TOTAL SETTLEMENT AND STRAINS	Total Settlement (ft)	0.3	0.3	0.9	1.5	2.3	2.7	3.2	3.3	4.8	6.4	6.6	7.2	7.3	7.3	5.6	5.0	4.5	4.3	4.0	3.7	1.0
	Base Grade Elevation (ft, MSL)	3289.7	3287.7	3280.9	3272.6	3261.8	3255.3	3253.2	3252.7	3249.8	3246.6	3246.1	3244.5	3244.1	3241.8	3240.4	3241.0	3251.5	3249.7	3252.0	3254.3	3289.0
	Intial Liner Segment Length, L_o (ft)		5.970	21.511	27.378	35.200	21.511	28.174	5.635	93.886	103.012	22.503	67.508	18.585	154.601	203.731	61.875	29.850	22.589	22.589	16.993	111.563
	Post Settlement Liner Segment Length, L_f(ft)		5.973	21.707	27.544	35.439	21.628	28.204	5.641	93.921	103.050	22.506	67.518	18.588	154.600	203.713	61.878	30.020	22.569	22.619	17.026	112.367
	Post Settlement Liner Strain (- comp, + tension)		0.054%	0.912%	0.605%	0.678%	0.543%	0.104%	0.112%	0.038%	0.038%	0.017%	0.015%	0.014%	0.000%	-0.009%	0.005%	0.570%	-0.086%	0.135%	0.194%	0.721%
	Differential Settlement (%)		0.16%	3.06%	2.06%	2.30%	1.86%	1.56%	1.66%	1.62%	1.62%	0.87%	0.81%	0.76%	-0.03%	-0.83%	-0.96%	-1.66%	-1.03%	-1.41%	-1.55%	-2.42%
LEACHATE COLLECTION PIPE GRADE	Initial Grade (%)	-	-	-	-	-	-	-	-	1.51%	1.51%	1.51%	1.51%	1.51%	1.51%	1.51%	-	-	-	-	-	-
	Post Settlement Grade (%)	-	-	-	-	-	-	-	-	3.13%	3.13%	2.37%	2.31%	2.26%	1.48%	0.68%	-	-	-	-	-	-
	Average Initial Grade (%)															1.51%						
	Average Post Settlement Grade (%)															1.86%						

SETTLEMENT OF CLAY LINER DUE TO PLACEMENT OF WASTE - SECTION EE'

DISTANCE	Point #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Coordinate along critical section (ft)	0	6	40	45	119	139	219	236	240	278	315	334	360	394	424	660	729	755	894	917	939	951	1052	1063
UNIT WEIGHTS	Cover Soil (γ_{cover}, pcf)	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
	Sublayer 1: Bottom Ash (pcf)	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
	Sublayer 2: Coal Ash Paste (pcf)	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112
	Sublayer 3: Silt and Silty Clay (pcf)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	Sublayer 4: Stiff Paste (pcf)	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
	Groundwater (pcf)	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4
ELEVATIONS	Final Cover Elevation (ft, MSL)	3290.0	3291.4	3300.0	3300.7	3310.0	3313.8	3329.7	3333.0	3333.8	3341.2	3348.5	3352.2	3357.4	3364.0	3370.0	3416.5	3430.0	3430.0	3366.7	3356.5	3346.3	3341.2	3295.1	3290.0
	Base Grade Elevation (ft, MSL)	3290.0	3290.0	3281.3	3280.0	3271.5	3269.2	3260.0	3259.0	3258.9	3258.4	3257.8	3257.5	3257.1	3256.6	3256.2	3252.6	3251.5	3251.1	3249.0	3249.0	3255.0	3260.0	3290.0	3290.0
	Bottom Ash to Coal Ash Paste Interface (ft, MSL)	3289.5	3287.9	3278.2	3276.7	3255.6	3250.0	3250.0	3250.0	3250.0	3257.0	3257.0	3256.0	3256.0	3250.0	3240.0	3211.0	3211.0	3211.0	3211.0	3211.0	3211.0	3211.0	3211.0	3211.0
	Coal Ash Paste to Silt/Silty Clay Interface (ft, MSL)	3289.5	3287.9	3278.2	3276.7	3255.6	3250.0	3250.0	3250.0	3250.0	3257.0	3257.0	3256.0	3256.0	3250.0	3240.0	3181.0	3181.0	3181.0	3181.0	3181.0	3181.0	3181.0	3181.0	3181.0
	Silt/Silty Clay to Stiff Paste Interface (ft, MSL)	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0	3156.0
	Stiff Paste to "Bedrock" Interface (ft, MSL)	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0	3106.0
	Groundwater Table (ft, MSL)	3260.0	3260.0	3260.0	3260.0	3260.0	3260.0	3260.0	3259.0	3258.9	3258.4	3257.8	3257.5	3257.1	3256.6	3256.2	3252.6	3251.5	3251.1	3249.0	3249.0	3249.0	3249.0	3249.0	3249.0
LAYER THICKNESS	Thickness of Final Cover (ft)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Thickness of Additional Coal Ash Paste (ft)	0.0	1.4	15.2	17.2	35.0	41.1	66.2	70.5	71.3	79.3	87.2	91.2	96.8	103.9	110.3	160.4	175.0	175.4	114.2	104.0	87.8	77.7	1.6	0.0
	Thickness of Additional Bottom Ash (ft)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Sublayer 1: Bottom Ash	0.5	2.1	3.1	3.3	15.9	19.2	10.0	9.0	8.9	1.4	0.8	1.5	1.1	6.6	16.2	41.6	40.5	40.1	38.0	38.0	44.0	49.0	79.0	79.0
	Sublayer 2: Coal Ash Paste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	Sublayer 3: Silt and Silty Clay	133.5	131.9	122.2	120.7	99.6	94.0	94.0	94.0	94.0	101.0	101.0	100.0	100.0	94.0	84.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Sublayer 4: Stiff Paste	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
SUBLAYER 1: BOTTOM ASH	Elevation of midpoint of sublayer (ft msl)	3289.8	3288.9	3279.8	3278.3	3263.5	3259.6	3255.0	3254.5	3254.5	3257.7	3257.4	3256.8	3256.6	3253.3	3248.1	3231.8	3231.3	3231.1	3230.0	3230.0	3233.0	3235.5	3250.5	3250.5
	Groundwater depth at midpoint of sublayer (ft)	0.0	0.0	0.0	0.0	0.0	0.4	5.0	4.5	4.5	0.7	0.4	0.8	0.6	3.3	8.1	20.8	20.3	20.1	19.0	19.0	16.0	13.5	0.0	0.0
	Initial effective stress (psf)	32	134	202	212	1020	1208	328	295	293	45	26	50	37	217	530	1363	1329	1316	1246	1246	1818	2294	5056	5056
	Final effective stress (psf)	464	725	2332	2566	5373	6243	8176	8627	8714	9357	10229	10698	11308	12290	13315	19760	21359	21391	14473	13327	12080	11423	5669	5488
	Preconsolidation pressure (if overconsolidated, psf)	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028	5028
	Initial Void Ratio	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
	Compression Index	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
	Recompression Index	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Secondary Compression Index	0.0008	0.0008	0.0008	0.0008	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
	Ultimate settlement due to primary consolidation (ft)	0.0	0.0	0.0	0.0	0.2	0.3	0.3	0.3	0.3	0.1	0.0	0.1	0.1	0.3	0.7	2.2	2.3	2.3	1.7	1.5	1.6	1.6	0.3	0.2
	Secondary compression (ft)	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.4	0.4
	Total Settlement of sublayer (ft)	0.0	0.0	0.0	0.0	0.3	0.4	0.4	0.4	0.4	0.1	0.0	0.1	0.1	0.4	0.8	2.5	2.5	2.5	1.9	1.8	1.8	1.8	0.7	0.7

SUBLAYER 2: COAL ASH PASTE	Elevation of midpoint of sublayer (ft msl)	3289.5	3287.9	3278.2	3276.7	3255.6	3250.0	3250.0	3250.0	3250.0	3257.0	3257.0	3256.0
	Groundwater depth at midpoint of sublayer (ft)	0.0	0.0	0.0	0.0	4.4	10.0	10.0	9.0	8.9	1.4	0.8	1.5
	Initial effective stress (psf)	64.0	269.0	403.1	423.8	1761.8	1839.7	656.0	590.4	586.7	90.1	52.7	99.6
	Final effective stress (psf)	496.0	859.5	2533.8	2777.7	6115.6	6873.9	8503.8	8922.4	9007.7	9401.8	10255.2	10747.5
	Preconsolidation pressure (if overconsolidated, psf)	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683
	Initial Void Ratio	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
	Compression Index	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	Recompression Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Secondary Compression Index	0.0004	0.0004	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060
	Ultimate settlement due to primary consolidation (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Secondary compression (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total Settlement of sublayer (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUBLAYER 3: SILT AND SILTY CLAY	Elevation of midpoint of sublayer (ft msl)	3222.8	3221.9	3217.1	3216.3	3205.8	3203.0	3203.0	3203.0	3203.0	3206.5	3206.5	3206.0
	Groundwater depth at midpoint of sublayer (ft)	37.3	38.1	42.9	43.7	54.2	57.0	57.0	56.0	55.9	51.9	51.3	51.5
	Initial effective stress (psf)	6,751	6,798	5,973	5,846	5,375	5,252	4,068	4,003	3,999	3,756	3,719	3,730
	Final effective stress (psf)	7,183	7,388	8,104	8,200	9,729	10,286	11,916	12,335	12,420	13,068	13,921	14,377
	Constrained modulus of layer (psf)	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000
	Estimated settlement by elastic method (ft)	0.1	0.2	0.6	0.6	1.0	1.1	1.7	1.8	1.8	2.1	2.3	2.4
SUBLAYER 4: STIFF COAL ASH PASTE	Elevation of midpoint of sublayer (ft msl)	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0
	Groundwater depth at midpoint of sublayer (ft)	129.0	129.0	129.0	129.0	129.0	129.0	129.0	128.0	127.9	127.4	126.8	126.5
	Initial effective stress (psf)	13411.9	13400.7	12223.4	12042.2	10804.2	10479.1	9295.4	9229.8	9226.1	9237.7	9200.3	9174.6
	Final effective stress (psf)	13843.9	13991.2	14354.0	14396.2	15158.0	15513.3	17143.2	17561.8	17647.1	18549.4	19402.8	19822.5
	Preconsolidation pressure (if overconsolidated, psf)	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103
	Initial Void Ratio	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Compression Index	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Recompression Index	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	Secondary Compression Index	0.0016	0.0016	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044
	Ultimate settlement due to primary consolidation (ft)	0.0	0.0	0.1	0.1	0.3	0.3	0.6	0.6	0.6	0.7	0.8	0.8
	Secondary compression (ft)	0.1	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Total Settlement of sublayer (ft)	0.1	0.1	0.4	0.4	0.6	0.6	0.9	0.9	0.9	1.0	1.1	1.1
TOTAL SETTLEMENT AND STRAINS	Total Settlement (ft)	0.3	0.3	1.0	1.1	1.8	2.1	2.9	3.0	3.1	3.2	3.4	3.6
	Base Grade Elevation (ft, MSL)	3289.7	3289.7	3280.3	3278.9	3269.7	3267.2	3257.1	3256.0	3255.9	3255.2	3254.4	3253.9
	Intial Liner Segment Length, L_0 (ft)		5.625	35.208	5.417	74.737	19.628	81.154	16.905	3.750	37.504	37.504	18.752
	Post Settlement Liner Segment Length, L_f(ft)		5.625	35.388	5.435	74.821	19.662	81.250	16.913	3.751	37.507	37.509	18.755
	Post Settlement Liner Strain (- comp, + tension)		0.007%	0.509%	0.329%	0.112%	0.174%	0.118%	0.049%	0.014%	0.006%	0.013%	0.016%
	Differential Settlement (%)		1.18%	1.99%	1.31%	0.94%	1.43%	1.00%	0.78%	0.76%	0.35%	0.68%	0.82%
LEACHATE COLLECTION PIPE GRADE	Initial Grade (%)	-	-	-	-	-	-	-	-	1.52%	1.52%	1.52%	1.52%
	Post Settlement Grade (%)	-	-	-	-	-	-	-	-	2.28%	1.87%	2.20%	2.34%
	Average Initial Grade (%)												
	Average Post Settlement Grade (%)												

SUBLAYER 2: COAL ASH PASTE	Elevation of midpoint of sublayer (ft msl)	3256.0	3250.0	3240.0	3196.0	3196.0	3196.0	3196.0	3196.0	3196.0	3196.0	3196.0	3196.0
	Groundwater depth at midpoint of sublayer (ft)	1.1	6.6	16.2	56.6	55.5	55.1	53.0	53.0	53.0	53.0	53.0	53.0
	Initial effective stress (psf)	73.4	433.4	1059.5	3470.4	3401.9	3375.5	3236.8	3236.8	4004.8	4644.8	8484.8	8484.8
	Final effective stress (psf)	11344.8	12506.4	13845.1	21867.6	23432.0	23450.7	16463.2	15317.3	14267.4	13774.4	9097.8	8916.8
	Preconsolidation pressure (if overconsolidated, psf)	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683	1683
	Initial Void Ratio	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
	Compression Index	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	Recompression Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Secondary Compression Index	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060
	Ultimate settlement due to primary consolidation (ft)	0.0	0.0	0.0	1.7	1.8	1.8	1.5	1.4	1.2	1.0	0.1	0.0
	Secondary compression (ft)	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Total Settlement of sublayer (ft)	0.0	0.0	0.0	1.8	1.9	1.9	1.6	1.6	1.3	1.1	0.2	0.2
SUBLAYER 3: SILT AND SILTY CLAY	Elevation of midpoint of sublayer (ft msl)	3206.0	3203.0	3198.0	3168.5	3168.5	3168.5	3168.5	3168.5	3168.5	3168.5	3168.5	3168.5
	Groundwater depth at midpoint of sublayer (ft)	51.1	53.6	58.2	84.1	83.0	82.6	80.5	80.5	80.5	80.5	80.5	80.5
	Initial effective stress (psf)	3,703	3,846	4,109	5,122	5,053	5,027	4,888	4,888	5,656	6,296	10,136	10,136
	Final effective stress (psf)	14,975	15,919	16,894	23,519	25,084	25,102	18,115	16,969	15,919	15,426	10,749	10,568
	Constrained modulus of layer (psf)	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000	445,000
	Estimated settlement by elastic method (ft)	2.5	2.6	2.4	1.0	1.1	1.1	0.7	0.7	0.6	0.5	0.0	0.0
SUBLAYER 4: STIFF COAL ASH PASTE	Elevation of midpoint of sublayer (ft msl)	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0	3131.0
	Groundwater depth at midpoint of sublayer (ft)	126.1	125.6	125.2	121.6	120.5	120.1	118.0	118.0	118.0	118.0	118.0	118.0
	Initial effective stress (psf)	9148.4	9072.8	8972.9	7844.4	7775.9	7749.5	7610.8	7610.8	8378.8	9018.8	12858.8	12858.8
	Final effective stress (psf)	20419.8	21145.8	21758.5	26241.6	27806.0	27824.7	20837.2	19691.3	18641.4	18148.4	13471.8	13290.8
	Preconsolidation pressure (if overconsolidated, psf)	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103	14103
	Initial Void Ratio	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Compression Index	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Recompression Index	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	Secondary Compression Index	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0016	0.0016
	Ultimate settlement due to primary consolidation (ft)	0.9	1.0	1.0	1.4	1.5	1.5	1.0	0.9	0.8	0.7	0.0	0.0
	Secondary compression (ft)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.1	0.1
	Total Settlement of sublayer (ft)	1.2	1.2	1.3	1.7	1.8	1.8	1.3	1.2	1.1	1.0	0.1	0.1
TOTAL SETTLEMENT AND STRAINS	Total Settlement (ft)	3.8	4.1	4.5	7.0	7.3	7.3	5.6	5.2	4.7	4.5	1.1	1.0
	Base Grade Elevation (ft, MSL)	3253.4	3252.5	3251.6	3245.6	3244.2	3243.8	3243.4	3243.8	3250.3	3255.5	3288.9	3289.0
	Intial Liner Segment Length, L_0 (ft)	26.253	33.754	30.003	236.277	68.758	26.503	139.141	22.500	23.286	12.311	105.601	11.250
	Post Settlement Liner Segment Length, L_f(ft)	26.256	33.761	30.012	236.328	68.764	26.503	139.125	22.502	23.413	12.425	106.603	11.251
	Post Settlement Liner Strain (- comp, + tension)	0.012%	0.022%	0.028%	0.021%	0.008%	0.000%	-0.011%	0.011%	0.544%	0.925%	0.949%	0.006%
	Differential Settlement (%)	0.66%	1.08%	1.30%	1.05%	0.47%	-0.03%	-1.27%	-1.47%	-2.04%	-2.23%	-3.18%	-1.09%
LEACHATE COLLECTION PIPE GRADE	Initial Grade (%)	1.52%	1.52%	1.52%	1.52%	1.52%	1.52%	1.52%	-	-	-	-	-
	Post Settlement Grade (%)	2.18%	2.60%	2.82%	2.57%	1.99%	1.49%	0.25%	-	-	-	-	-
	Average Initial Grade (%)							1.52%					
	Average Post Settlement Grade (%)							1.90%					

APPENDIX A.3

Veneer Slope Stability Analysis

Geosyntec consultants

COMPUTATION COVER SHEET

Client: Talen Montana, LLC **Project:** EHP J Cell **Project #:** ME1210 **Task #:** 4

TITLE OF COMPUTATIONS LINER VENEER STABILITY

COMPUTATIONS BY: Signature [signature] 07/06/2015 DATE

Printed Name and Title: Zichang Li, Staff Engineer

ASSUMPTIONS AND PROCEDURES CHECKED BY: (Peer Reviewer) Signature [signature] 07/08/2016 DATE

Printed Name and Title: Chunling Li, Project Engineer

COMPUTATIONS CHECKED BY: Signature [signature] 07/08/2016 DATE

Printed Name and Title: Chunling Li, Project Engineer

COMPUTATIONS BACKCHECKED BY: (Originator) Signature [signature] 07/08/2016 DATE

Printed Name and Title: Zichang Li, Staff Engineer

APPROVED BY: (PM or Designate) Signature [signature] 07/08/2016 DATE

Printed Name and Title: David Espinoza, Senior Principal

APPROVAL NOTES:

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

LINER VENEER STABILITY ON SIDESLOPES

PURPOSE

The purpose of this calculation package is to present the veneer slope stability analysis of the liner system for the proposed Colstrip Steam Electric Station, J Cell located in Colstrip, Montana. As shown in the base grading plan in Figure 1, liner system will be constructed on a 3 horizontal to 1 vertical (3H:1V) with maximum slope height of 60 ft.

According to a technical manual published by the USEPA entitled "Solid Waste Disposal Facility Criteria" [USEPA, 1993], when there is no imminent danger to human life or threat of major environmental impact, the minimum recommended slope stability factor of safety is 1.25. Because a veneer stability failure of the liner system does not pose a threat to human life or the environment and a failure could be easily repaired, the stability of the liner system will be considered acceptable if the factor of safety is greater than or equal to 1.25.

PROCEDURE

An analysis of veneer stability considers noncircular wedge-type potential slip surfaces that extend parallel to the liner system components. The selected method of analysis is based on limit equilibrium and takes into account soil buttressing effect, geosynthetic tensile forces, and seepage forces within drainage layers. The finite slope factor of safety equation, as formulated by Giroud et al. [1995], is:

$$FS = \lambda \frac{\tan\delta}{\tan\beta} + \frac{a/\sin\beta}{\gamma_t(t-t_w)+\gamma_{sat}t_w} + \frac{\gamma_t(t-t_w^*)+\gamma_b t_w^*}{\gamma_t(t-t_w)+\gamma_{sat}t_w}\frac{t}{h}\frac{\sin\phi}{\sin 2\beta\cos(\beta+\phi)} + \frac{ct/h}{\gamma_t(t-t_w)+\gamma_{sat}t_w}\frac{\cos\phi}{\sin\beta\cos(\beta+\phi)} + \frac{T/h}{\gamma_t(t-t_w)+\gamma_{sat}t_w} \quad (1)$$

$FS = FS1 + FS2 + FS3 + FS4 + FS5$

where:

$$\lambda = \begin{cases} \dfrac{\gamma_t(t-t_w)+\gamma_b t_w}{\gamma_t(t-t_w)+\gamma_{sat}t_w} & \text{for failure surface above the geomembrane (dimensionless)} \\ 1 & \text{for failure surface below the geomembrane (dimensionless)} \end{cases}$$

FS	=	Factor of Safety (dimensionless)
$FS1$	=	Infinite slope friction term
$FS2$	=	Infinite slope adhesion term
$FS3$	=	Buttress resistance friction term
$FS4$	=	Buttress resistance cohesion term
$FS5$	=	Geosynthetic tension term
γ_t	=	total unit weight of soil (pcf)
γ_{sat}	=	saturated unit weight of soil (pcf)
γ_b	=	buoyant unit weight of soil (pcf)
t	=	thickness of soil layer (ft)
t_w	=	thickness of water flow along slope (ft)
t^*_w	=	thickness of water flow in toe of slope (ft)
β	=	slope angle (degrees)
δ	=	interface friction angle along slip surface (degrees)
a	=	interface adhesion (psf)
ϕ	=	internal friction angle of soil above critical surface (degrees)
h	=	height of slope (ft)
T	=	tension in geosynthetics (lb/ft)
c	=	cohesion of soil above critical surface (psf)

SOIL AND GEOSYNTHETIC PROPERTIES

Along the sideslopes, the liner system consists of the following components, from top to bottom:

- 18-in bottom ash drainage layer;
- Geotextile protection layer;
- 60-mil high density polyethylene (HDPE) geomembrane;
- Geosynthetic clay liner (GCL); and
- CCR paste subgrade.

The interfaces in the liner system, from top to bottom, are:

- Interface #1: bottom ash / non-woven geotextile;
- Interface #2: non-woven geotextile / textured HDPE geomembrane;
- Interface #3: textured HDPE geomembrane / GCL;
- Interface #4: non-woven geotextile (GCL facing) / paste.

Peak interface friction shear strengths for the liner system interfaces are determined from the laboratory testing as presented in Attachment 1. The table below summarizes the shear strength properties considered for this analysis.

Material/ Interface	Total Unit Weight, γ_t (pcf)	Saturated Unit Weight, γ_s (pcf)	Friction Angle (deg)	Cohesion/ Adhesion (psf)	Source
Bottom ash	94	112	40.0	0(1)	Golder [2001]
Bottom ash / geotextile interface	-	-	38.3(2)	0	Laboratory results (Attachment 1)
Geotextile / textured HDPE geomembrane interface	-	-	0.0	128(3)	Laboratory results (Attachment 1)
Geomembrane / GCL interface	-	-	25.8(4)	0	Laboratory results (Attachment 1)
GCL/ paste interface	-	-	31.9(4)	0	Laboratory results (Attachment 1)
Aged fly ash paste	102	102	35.0	0	WAI [2011]

Notes: (1) Cohesion of bottom ash was concretively assumed to be 0 in this analysis.
(2) Friction angle was determined from secant friction angle under normal stress of 150 psf.
(3) Adhesion was determined from the lower value of shear strength at normal stress of 150 and 300 psf.
(4) Friction angle was determined from secant friction angle under normal stress of 300 psf.

WATER DEPTH ABOVE GEOMEMBRANE

An analysis was conducted to determine the water depth above the HDPE geomembrane using the HELP model [USEPA, 1993]. The results of this analysis are included as Attachment 1. The protective/drainage layer is assumed to have a texture number of 31 (coal-burning electric plant bottom ash). The geotextile protection layer was ignored for the purposes of this analysis. The geomembrane was assumed to have poor placement quality as well as one pinhole and one installation defect per acre. The calculated average water depth (peak daily value) above the geomembrane is 7.1 in, and the maximum water depth is 13.4 in, which occurs at the toe of the slope.

SUMMARY OF INPUT PARAMETERS

The input parameters for Equation 1 are provided below. For this analysis, the resisting force due to tension in geosynthetics (T) is neglected (i.e., the effect of the anchor trench is conservatively neglected and the protective layer is mainly supported by frictional forces). Failure is assumed to occur between the interfaces discussed above.

γ_t = 94 pcf
γ_{sat} = 112 pcf
t_w = 7.104 in
t^*_w = 13.408 in
t = 18.0 in
β = 18.4°
a = 0 psf (conservatively assumed)
ϕ = 40° (bottom ash drainage layer)
c = 0 psf (bottom ash drainage layer)
h = 60 ft
T = 0 lb/ft
λ = 0.756 (failure above the geomembrane)
λ = 1 (failure below the geomembrane)

RESULTS

The calculation was conducted using Excel Spreadsheet. The output for the calculated cases is shown in Tables 1 through 4. The calculation shows that the critical interface is between the HDPE geomembrane and the GCL; therefore, the factor of safety for veneer stability is 1.48, which is greater than the minimum recommended value (i.e., FS = 1.25). The results of calculation are summarized below:

Interface (Above or Below the geomembrane)	Calculated FS
Bottom ash / geotextile interface (Above)	1.82
Geotextile / textured HDPE geomembrane interface (Above)	2.70
Geomembrane / GCL interface (Below)	1.48
GCL/ paste interface (Below)	1.90

REFERENCES

Eid, H.T. and Stark, T.D. (1997). "Shear Behavior of an Unreinforced Geosynthetic Clay Liner," *Geosynthetics International*, Vol. 4, No. 6, pp. 645-659.

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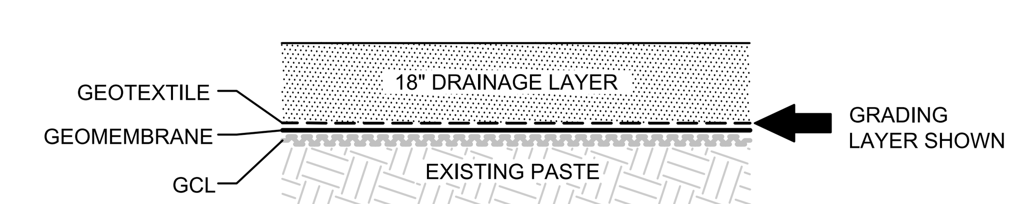
FIGURE

100 50 0 100 200

SCALE IN FEET



DETAIL 1/– GRADING KEY

SCALE: NTS

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10220 OLD COLUMBIA ROAD, SUITE A
COLUMBIA, MARYLAND 21046 USA
PHONE: 410.381.4333

COLSTRIP POWER PLANT

TALEN MONTANA, LLC
PO BOX 36
COLSTRIP, MONTANA 59323
406-748-5008

TITLE: SUBGRADE GRADING PLAN

PROJECT: EHP J CELL CONSTRUCTION

SITE: COLSTRIP STEAM ELECTRIC STATION
COLSTRIP, MONTANA

DESIGNED BY: CHP	DATE: NOVEMBER 2015	
DRAWN BY: TSJ	PROJECT NO.: ME1210	
CHECKED BY: JMP	FILE: 1210-205	
REVIEWED BY: CHP	DRAWING NO.:	
APPROVED BY: KEK	1 OF 1	SIGNATURE

TABLES

Table 1 - Veneer Failure Between the Bottom Ash and Geotextile
Colstrip Steam Electric Station, J Cell, Colstrip, Montana

Unit Weights (pcf)	
γ_w =	62.4
γ_t =	94.0
γ_s =	112.0
γ_b =	49.6

Cover Data		ft
t_w (in.) =	7.104	0.592
t_w* (in.) =	13.408	1.117333
t (in.) =	18.0	
t_w/t =	0.395	
t_w*/t =	0.745	
h (ft) =	60.0	
h (in.) =	720.0	
Lambda (c	0.756	

Slope and Strengths	
β (deg) =	18.4
β (rad) =	0.322
δ (deg) =	38.3
δ (rad) =	0.668
ϕ (deg) =	40.0
ϕ (rad) =	0.698
a (psf) =	0.0
c (psf) =	0.0

Factor of Safety	
FS1 =	1.79
FS2 =	0.00
FS3 =	0.03
FS4 =	0.00
FS5 =	0.00
FS =	1.82

Table 2 - Veneer Failure Between the Geotextile and Geomembrane
Colstrip Steam Electric Station, J Cell, Colstrip, Montana

Unit Weights (pcf)	
γ_w =	62.4
γ_t =	94.0
γ_s =	112.0
γ_b =	49.6

Cover Data		ft
t_w (in.) =	7.104	0.592
t_w* (in.) =	13.408	1.117333
t (in.) =	18.0	
t_w/t =	0.395	
t_w*/t =	0.745	
h (ft) =	60.0	
h (in.) =	720.0	
Lambda (c	0.756	

Slope and Strengths	
β (deg) =	18.4
β (rad) =	0.322
δ (deg) =	0.0
δ (rad) =	0.000
ϕ (deg) =	40.0
ϕ (rad) =	0.698
a (psf) =	128.0
c (psf) =	0.0

Factor of Safety	
FS1 =	0.00
FS2 =	2.67
FS3 =	0.03
FS4 =	0.00
FS5 =	0.00
FS =	2.70

Table 3 - Veneer Failure Between the Geomembrane and GCL
Colstrip Steam Electric Station, J Cell, Colstrip, Montana

Unit Weights (pcf)	
γ_w =	62.4
γ_t =	94.0
γ_s =	112.0
γ_b =	49.6

Cover Data		ft
t_w (in.) =	7.104	0.592
t_w* (in.) =	13.408	1.117333
t (in.) =	18.0	
t_w/t =	0.395	
t_w*/t =	0.745	
h (ft) =	60.0	
h (in.) =	720.0	

Slope and Strengths	
β (deg) =	18.4
β (rad) =	0.322
δ (deg) =	25.8
δ (rad) =	0.450
ϕ (deg) =	40.0
ϕ (rad) =	0.698
a (psf) =	0.0
c (psf) =	0.0

Factor of Safety	
FS1 =	1.45
FS2 =	0.00
FS3 =	0.03
FS4 =	0.00
FS5 =	0.00
FS =	1.48

Table 4 - Veneer Failure Between the Geomembrane and Paste
Colstrip Steam Electric Station, J Cell, Colstrip, Montana

Unit Weights (pcf)	
γ_w =	62.4
γ_t =	94.0
γ_s =	112.0
γ_b =	49.6

Cover Data		ft
t_w (in.) =	7.104	0.592
t_w* (in.) =	13.408	1.117333
t (in.) =	18.0	
t_w/t =	0.395	
t_w*/t =	0.745	
h (ft) =	60.0	
h (in.) =	720.0	

Slope and Strengths	
β (deg) =	18.4
β (rad) =	0.322
δ (deg) =	31.9
δ (rad) =	0.557
ϕ (deg) =	40.0
ϕ (rad) =	0.698
a (psf) =	0.0
c (psf) =	0.0

Factor of Safety	
FS1 =	1.87
FS2 =	0.00
FS3 =	0.03
FS4 =	0.00
FS5 =	0.00
FS =	1.90

ATTACHMENT 1

Laboratory Results of Interface Friction Tests

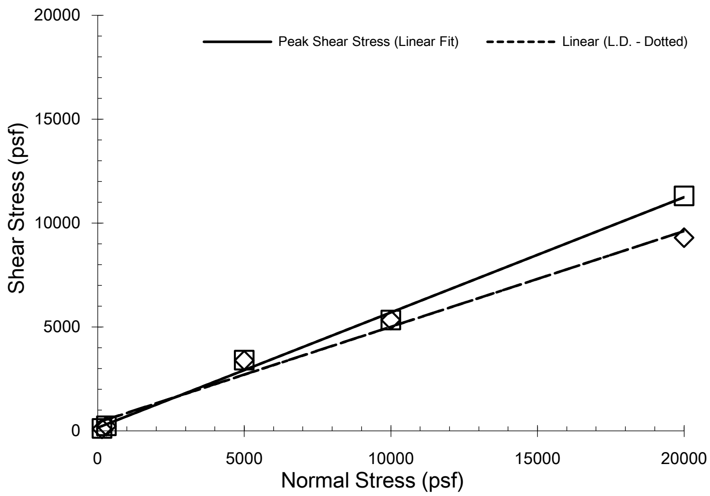
Interface Friction Test Report

Client: **Geosyntec Consultants**
Project: **Colstrip Steam Electric Station**
Date: 04-22-2016 to 04-22-2016

TRI Log#: 20132
Test Method: ASTM D5321

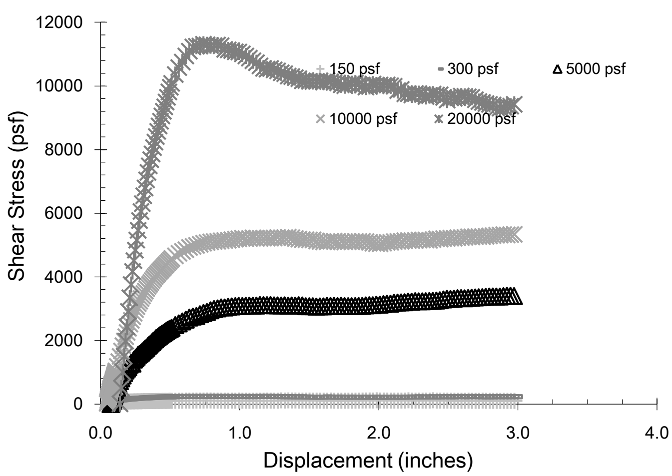
John M. Allen, P.E., 04/22/2016
Quality Review/Date

Tested Interface: Bottom Ash (A-Cell) vs. Skaps GE180 Non-woven Geotextile (42485.4)



Test Results		
	Peak	Large Displacement (@ 3.0 in.)
Friction Angle (degrees):	29.0	24.8
Y-intercept or Adhesion (psf):	148	403

Shearing occurred at the interface. The peak friction angle regression analysis was adjusted to fit a zero y-intercept.



Test Conditions	
Upper Box &	Bottom Ash remolded to 95% of the maximum dry density at the optimum moisture content +2% or 81.0 pcf at 29.2%
Lower Box	Skaps GE180 non-woven geotextile
Box Dimensions: 12"x12"x4"	
Interface Conditioning:	Interface soaked and loading applied for a minimum of 1 hour prior to shear.
Test Condition: Wet	
Shearing Rate: 0.04 inches/minute	

Test Data

Specimen No.	1	2	3	4	5
Bearing Slide Resistance (lbs)	9	11	56	103	198
Normal Stress (psf)	150	300	5000	10000	20000
Corrected Peak Shear Stress (psf)	118	245	3406	5337	11311
Corrected Large Displacement Shear Stress (psf)	100	230	3395	5337	9300
Peak Secant Angle (degrees)	38.3	39.2	34.3	28.1	29.5
Large Displacement Secant Angle (degrees)	33.6	37.4	34.2	28.1	24.9
Asperity (mils)	- -	- -	- -	- -	- -

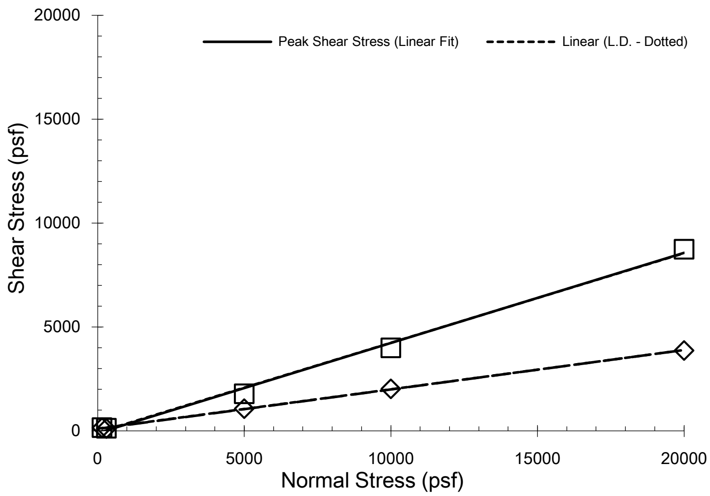
Interface Friction Test Report

Client: **Geosyntec Consultants**
Project: **Colstrip Steam Electric Station**
Date: 04-19-2016 to 04-19-2016

TRI Log#: 20132
Test Method: ASTM D5321

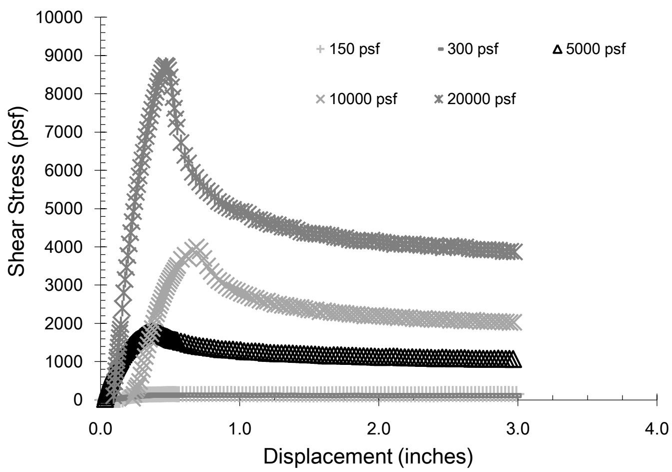
John M. Allen, P.E., 04/19/2016
Quality Review/Date

Tested Interface: Skaps GE180 Non-woven Geotextile (42485.4) vs. Solmax 60 mil HDPE Textured Geomembrane (5-21029)



Test Results		
	Peak	Large Displacement (@ 3.0 in.)
Friction Angle (degrees):	23.1	10.7
Y-intercept or Adhesion (psf):	0	104

Shearing occurred at the interface. The peak friction angle regression analysis was adjusted to fit a zero y-intercept.



Test Conditions	
Upper Box &	Skaps GE180 non-woven geotextile
Lower Box	Solmax 60 mil HDPE textured geomembrane (white side)
Box Dimensions: 12"x12"x4"	
Interface Conditioning:	Interface soaked and loading applied for a minimum of 1 hour prior to shear.
Test Condition: Wet	
Shearing Rate: 0.2 inches/minute	

Test Data

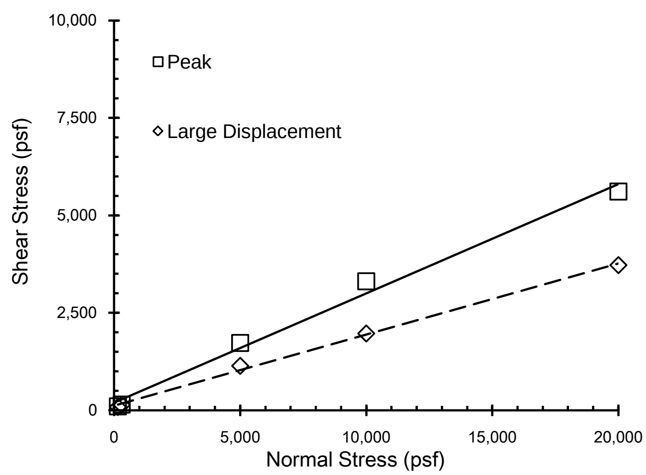
Specimen No.	1	2	3	4	5
Bearing Slide Resistance (lbs)	9	11	56	103	198
Normal Stress (psf)	150	300	5000	10000	20000
Corrected Peak Shear Stress (psf)	158	128	1786	3997	8743
Corrected Large Displacement Shear Stress (psf)	152	111	1069	2023	3869
Peak Secant Angle (degrees)	46.5	23.1	19.7	21.8	23.6
Large Displacement Secant Angle (degrees)	45.3	20.4	12.1	11.4	10.9
Asperity (mils)	14.0	13.4	15.2	12.6	13.2

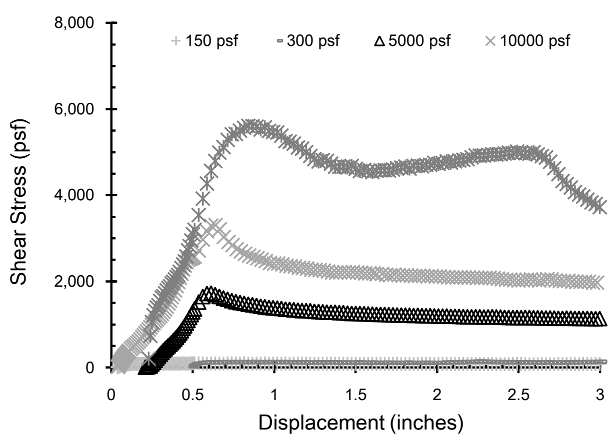
Interface Shear Strength of Geosynthetic Clay Liner by Direct Shear (ASTM D6243)

Client: Geosyntec Consultants
Project: Colstrip Steam Electric Station

TRI Log #: #REF!
Jeffrey A. Kuhn, Ph.D., P.E., 7/11/2016
Analysis & Quality Review/Date

Continuum DN GCL vs. Solmax 60 mil HDPE Textured Geomembrane





Test Results, Linear Regression			
Mohr-Coulomb Parameters		Peak	Large Displacement
Friction Angle	Degrees	15.7	10.3
Y-intercept or Adhesion	psf	190	117

*3.0 inches

Test Conditions		
Upper Box	Continuum DG GCL (black side) hydrated under 150 psf for a minimum 24 hours prior to mounting (15GCL002-13G)	
Lower Box	Solmax 60 mil HDPE textured geomemrbrane, black side (5-21029)	
Conditioning	Wet - Interface soaked and loaded at 1 psi/hr to the target stress which was maintained for a minimum of 16 hours prior to shear.	
Shearing Rate	inches/minute	0.04

Test Notes

Shearing occurred at the interface at all stresses.

Specimen No.		-	1	2	3	4	5
Normal Stress		psf	150	300	5,000	10,000	20,000
Box Edge Dimension		in	12	12	12	12	8
Bearing Slide Resistance		lbs	9	11	56	103	92
Peak	Normal Stress	psf	150	300	5,000	10,000	20,000
	Shear Stress	psf	99	145	1,726	3,309	5,611
	Secant Angle	deg.	33.5	25.8	19.0	18.3	15.7
Large Displacement	Normal Stress	psf	150	300	5,000	10,000	20,000
	Shear Stress	psf	83	136	1,138	1,969	3,723
	Secant Angle	deg.	28.8	24.3	12.8	11.1	10.5

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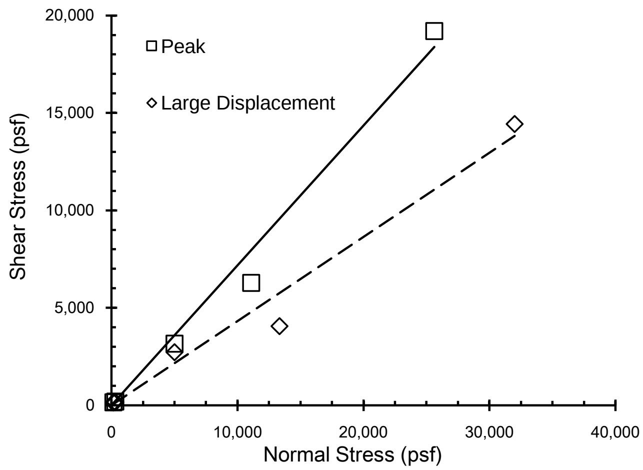
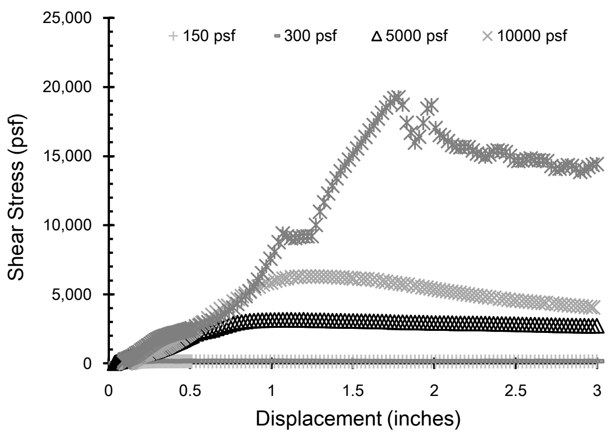
Interface Shear Strength of Geosynthetic Clay Liner by Direct Shear (ASTM D6243)

Client: Geosyntec Consultants
Project: Colstrip Steam Electric Station

TRI Log #: #REF!
Jeffrey A. Kuhn, Ph.D., P.E., 7/11/2016
Analysis & Quality Review/Date

Continuum DN GCL vs. Paste





Test Results, Linear Regression			
Mohr-Coulomb Parameters		Peak	Large Displacement
Friction Angle	Degrees	35.7	23.3
Y-intercept or Adhesion	psf	0	0

*3.0 inches

Test Conditions		
Upper Box	Continuum DG GCL (white side) hydrated under 150 psf for a minimum 24 hours prior to mounting.	
Lower Box	Paste remolded to 95% of the maximum dry density at the optimum moisture content +2% or 87.4 pcf at 26.8%	
Conditioning	Wet - Interface soaked and loaded at 1 psi/hr to the target stress which was maintained for a minimum of 16 hours prior to shear.	
Shearing Rate	inches/minute	0.04

Test Notes

Shearing occurred at the interface for specimens tested under stresses of 130, 300, and 5000 psf. The GCL sheared internally for specimens tested under normal stresses of 10,000 and 20,000 psf.

Specimen No.		-	1	2	3	4	5
Normal Stress		psf	150	300	5,000	10,000	20,000
Box Edge Dimension		in	12	12	12	12	8
Bearing Slide Resistance		lbs	9	11	56	103	92
Peak	Normal Stress	psf	150	300	5,000	11,085	25,620
	Shear Stress	psf	150	187	3,160	6,278	19,200
	Secant Angle	deg.	45.0	31.9	32.3	29.5	36.8
Large Displacement	Normal Stress	psf	150	300	5,000	13,333	32,000
	Shear Stress	psf	141	157	2,721	4,058	14,431
	Secant Angle	deg.	43.2	27.6	28.6	16.9	24.3

TRI ENVIRONMENTAL, INC.
9063 BEE CAVES RD. – AUSTIN, TX 78733 – USA | PH: 800.880.TEST OR 512.263.2101

ATTACHMENT 2

Calculation of Water Depth above Geomembrane

```
♀
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\c\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\c\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\c\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\c\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\c\DATA1833.D10
OUTPUT DATA FILE:           C:\HELP3\c\OPEN1833.OUT


TIME:  32:47     DATE:  12/10/2015


******************************************************************************

     TITLE:  Colstrip, Base Grading, 33.0% slope, 190'

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                        TYPE 2 - LATERAL DRAINAGE LAYER
```

```
                MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     18.00   INCHES
POROSITY                     =      0.5780 VOL/VOL
FIELD CAPACITY               =      0.0760 VOL/VOL
WILTING POINT                =      0.0250 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1476 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.207000005000E-03 CM/SEC
SLOPE                        =     33.00   PERCENT
DRAINAGE LENGTH              =    190.0    FEET


                        LAYER  2
                        --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      5.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  4 - POOR


                        LAYER  3
                        --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER  17
THICKNESS                    =      0.24   INCHES
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000003000E-08 CM/SEC


                        LAYER  4
                        --------
```

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	1200.00 INCHES
POROSITY	=	0.5010 VOL/VOL
FIELD CAPACITY	=	0.2840 VOL/VOL
WILTING POINT	=	0.1350 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2840 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999997000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #31 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 33.% AND A SLOPE LENGTH OF 190. FEET.

SCS RUNOFF CURVE NUMBER	=	97.10	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.652	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.936	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.300	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	343.637	INCHES
TOTAL INITIAL WATER	=	343.637	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
BILLINGS MONTANA

STATION LATITUDE	=	45.80	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	130	
END OF GROWING SEASON (JULIAN DATE)	=	278	
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES

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AVERAGE ANNUAL WIND SPEED = 11.30 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 59.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 54.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 47.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 58.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.97	0.71	1.05	1.93	2.39	2.07
0.85	1.05	1.26	1.16	0.85	0.80

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
20.90	28.40	33.80	44.60	54.90	64.00
72.30	70.30	59.40	49.30	35.00	27.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA
AND STATION LATITUDE = 45.80 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

PRECIPITATION

TOTALS	0.96	0.78	0.95	1.77	2.26	2.05
	1.09	1.02	1.23	1.13	0.92	0.82
STD. DEVIATIONS	0.49	0.41	0.48	0.90	0.98	0.81
	0.59	0.66	0.86	0.69	0.59	0.43

RUNOFF

TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

EVAPOTRANSPIRATION

TOTALS	0.694	0.490	0.753	1.687	2.045	1.973
	1.234	0.930	1.116	0.961	0.879	0.620
STD. DEVIATIONS	0.242	0.273	0.391	0.703	0.653	0.670
	0.633	0.617	0.793	0.549	0.471	0.259

LATERAL DRAINAGE COLLECTED FROM LAYER 1

TOTALS	0.1056	0.0863	0.0864	0.1070	0.1589	0.1614
	0.1634	0.1523	0.1351	0.1304	0.1209	0.1203
STD. DEVIATIONS	0.0503	0.0411	0.0411	0.0448	0.0797	0.0861
	0.0881	0.0831	0.0716	0.0678	0.0597	0.0558

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002
	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0001	0.0000	0.0000	0.0000	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002
	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0001	0.0000	0.0000	0.0000	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	1.8532	1.6627	1.5169	1.9413	2.7893	2.9267
	2.8673	2.6723	2.4509	2.2886	2.1928	2.1121
STD. DEVIATIONS	0.8824	0.7923	0.7216	0.8126	1.3993	1.5622
	1.5459	1.4589	1.2976	1.1901	1.0821	0.9801

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.97 (2.581)	54346.0	100.00
RUNOFF	0.000 (0.0000)	0.00	0.000
EVAPOTRANSPIRATION	13.381 (1.7992)	48573.55	89.378
LATERAL DRAINAGE COLLECTED FROM LAYER 1	1.52818 (0.65715)	5547.285	10.20736
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.00138 (0.00074)	5.012	0.00922
AVERAGE HEAD ON TOP OF LAYER 2	2.273 (0.975)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00138 (0.00074)	5.014	0.00923
CHANGE IN WATER STORAGE	0.061 (1.0067)	220.10	0.405

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	1.75	6352.500
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 1	0.01306	47.39835
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.000017	0.06008
AVERAGE HEAD ON TOP OF LAYER 2	7.104	
MAXIMUM HEAD ON TOP OF LAYER 2	13.408	
LOCATION OF MAXIMUM HEAD IN LAYER 1 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000033	0.11898
SNOW WATER	1.43	5192.0435
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4405	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0849	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	4.2241	0.2347
2	0.0000	0.0000
3	0.1800	0.7500
4	340.8000	0.2840
SNOW WATER	0.252	

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APPENDIX A.4

Global Slope Stability Analysis

Geosyntec consultants

COMPUTATION COVER SHEET

Client: Talen **Project:** Colstrip – EHP J Cell **Project #:** ME1210 **Task #:** 01

TITLE OF COMPUTATIONS SLOPE STABILITY EVALUATION

COMPUTATIONS BY:

Signature

Printed Name and Title: Chunling Li, Project Engineer

DATE: 12/17/2015

ASSUMPTIONS AND PROCEDURES CHECKED BY: (Peer Reviewer)

Signature

Printed Name and Title: R. David Espinoza, Senior Principal

DATE: 12/17/2015

COMPUTATIONS CHECKED BY:

Signature

Printed Name and Title: Zichang Li, Staff Engineer

DATE: 12/17/2015

COMPUTATIONS BACKCHECKED BY: (Originator)

Signature

Printed Name and Title: Chunling Li, Project Engineer

DATE: 12/17/2015

APPROVED BY: (PM or Designate)

Signature

Printed Name and Title: R. David Espinoza, Senior Principal

DATE: 12/17/2015

APPROVAL NOTES:

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

SLOPE STABILITY EVALUATION

PURPOSE

Cell J of the Effluent Hold Pond (EHP) at the Colstrip Power Plant is currently being redesigned with a new liner/capping system. The purpose of this calculation package is to evaluate the stability of Cell J under current and final condition.

BACKGROUND

A capping system is currently being designed to cap the existing coal combustion residuals (CCRs) waste at Cell J. This capping system will also serve as the liner system for placement of future CCR waste in Cell J. Figure 1 shows the liner system grading plan. According to the Draft Master Plan [Geosyntec, 2015], the future paste disposal will occur sequentially in Cell J, then Cell G and then Cell F. Eventually, these units will be used for dry CCR waste disposal when the plant finishes the conversion from wet disposal to dry disposal (estimated to start from Year 2028). The final grading plan for Cell J is included as Figure 2.

CROSS SECTIONS ANALYZED

Three cross sections, as shown in the plan view in Figure 1, were selected for analysis in this calculation package. The geometry and subsurface stratigraphy for these cross sections were determined from historical documents and the recent site investigation conducted by Geosyntec in 2015. The analyzed cross sections and sources of information are shown in Table 1.

Table 1. Analyzed Cross Sections and Source of Information

Cross Sections	Representative Area	References
A-A’	Main Dam	1. Main dam cross section is based on WAI Stage 2, typical section provided in the *Geotechnical Investigation Report for EHP Stage 2 Dam Raise* [Womack, 2011]. 2. Stratigraphy inside Cell J is based on Boring GB-1 conducted by Geosyntec in 2015.
B-B’	Saddle Dam	1. Saddle dam cross section is based on WAI Stage 2, typical sections provided in the Geotechnical investigation report for EHP Stage 2 Dam raise [Womack, 2011]. 2. Stratigraphy inside Cell J is based on Boring GB-4 conducted by Geosyntec in 2015.
C-C’	Cell G/J Dike	1. Stratigraphy inside Cell J is based on Boring GB-4 conducted by Geosyntec in 2015. 2. Stratigraphy inside Cell G is based on cross sections presented in *C-Cell Divider Dike Stability Assessment Report* by Womack [2014] 3. G/J dike configuration is based on *J Cell Phase I Earthworks Construction Drawings* by Summit [2014], and recent piezometer installation log for JC-15-07 SP.

LINER SYSTEM DESCRIPTION

The proposed liner system for Cell J is comprised of the following components, from top to bottom:

- 18-inch bottom ash drainage layer;
- Non-woven geotextile protective layer;
- 60-mil HDPE geomembrane;
- Geosynthetic clay liner (GCL);
- CCR paste subgrade.

METHOD

The stability of the pond cross section was evaluated based on limit equilibrium theory using the methods of slices. The computer program SLIDE [Rocscience, 2012] was used to perform the analyses. SLIDE is a 2D slope stability program for evaluating the factor of safety of circular and non-circular failure surfaces in soils. The procedure consists of analyzing numerous potential failure surfaces to find the critical failure surface that renders the minimum factor of safety (FS) for the slope. The Spencer method [Spencer, 1967] was used in this analysis. In the Spencer method both force and moment equilibrium are satisfied in each slice, the slope of the inter slice forces is assumed constant and parallel to each other.

Numerous potential failure surfaces were analyzed. Both circular and non-circular failure surface were considered for the analysis. During the analysis, the search boundaries were varied to ensure that the most critical surface was captured during the search. For the circular slip surface search, a search grid with 25 horizontal increments and 25 vertical increments was used. For non-circular block failure, the search for critical failure surface was conducted along a defined polyline along the liner system.

SLIDE provides both the minimum FS and a FS contour map for the computation. When the contour lines that contain the minimum FS were not fully closed, the search grid was expanded horizontally or vertically and the analysis performed again. This iterative process ensured that a global FS was calculated, not a local minimum factor of safety.

STABILITY CRITERION

In this analysis, the requirements of the new CCR Rule [Federal Register, 2015] for CCR impoundments are used to evaluate the slope stability. As shown below, the following minimum FSs for different loading conditions, obtained from the new CCR Rule, should be satisfied:

- Static factor of safety under the long-term, maximum storage pool loading condition > 1.5;
- Static factor of safety under the maximum surcharge pool loading condition > 1.4;
- Seismic factor of safety > 1.0;
- Static factor of safety under the end-of-construction loading condition > 1.3.

MATERIAL PROPERTIES

The selection of material properties for the analysis is described below.

G/J Dike

Based on *J Cell Phase I Earthworks Construction Drawings* by Summit [2014], the divider dike between Cells G and J is designed to have bottom ash in the upper 4 ft from dike crest and structural fill that is comprised of baked shale, fly ash, and/or bottom ash in the lower portion. Based on boring logs conducted for piezometer JC-15-07-SP by Geosyntec in 2015, the structural fill in the lower dike portion mainly classifies as silty clay. The appearance of this structural fill is similar to the dam shell according to the boring logs. Accordingly, the shear strength and unit weight for the G/J dike structural fill is assumed to be similar to dam shell.

Bedrock

Previous slope stability analyses indicate that the bedrock present at the site is consisted of sandstone, claystone, siltstone or baked shale [Bechtel, 1982; WAI, 2011]. Boring investigation conducted by Geosyntec in 2015 did not reveal bedrock at elevation 3,100 feet above mean sea level (ft-msl). For this analysis, the bedrock is conservatively assumed to have the lowest shear strength of all bedrock types from previous investigation.

Aged Fly Ash Paste

Based on the 2015 boring investigation by Geosyntec, the existing aged fly ash paste deposits at 10 ft below the current grades in Cell J has typically high standard penetration test blow counts (SPT-N, 30 to above 50 blows/ft) and show as cemented. The shear strength for the existing fly ash paste is selected based on laboratory test results conducted by WAI [2011].

Future Fly Ash Paste (Fly Ash Slurry)

Future fly ash paste placed in Cell J is expected to have less cementation. It is assumed to have the same material properties as used by Golder [2001] in the intermediate stage analysis. For final condition, it is assumed that sufficient time has allow the fly ash paste to develop cementation and the shear strength parameters for existing fly ash paste are used.

Liner Interface

The most critical interface for the liner system is expected to be that between the geomembrane and the GCL. Interface friction angle between textured HDPE geomembrane and GCL was reported to be between 18 and 37 degrees [Eid and Stark, 1997; and Stark et al. 1998]. From Geosyntec's past experience, interface friction angle may be as low as 13 degrees. Based on this, a thin layer of material is defined in the model to represent the most critical interface. The friction angle of this material is assumed 13 degrees, and the unit weight of this material is assumed based on the bottom ash drainage layer in the liner system.

WAI [2011] provided summary tables of material properties from their testing and from previous consultants. These tables are included as Appendix A to this calculation package. All other materials present in these cross sections are assumed based on information presented in Appendix A and are summarized in Table 2.

Table 2. Material Properties

Material	Effective Shear Strength		Total Shear Strength		Moist Unit Weight, lb/cu ft	Saturated Unit Weight, lb/cu ft	Source
	Cohesion, psf	Friction Angle, deg	Cohesion, psf	Friction Angle,			
G/J Dike Fill	0	33	750	22.5	125	130	Assumed similar to dam shell
Bottom Ash Fill	675	40	-	-	94	112	Golder [2001]
Dry Ash Fill	0	37.8	-	-	106	116	WAI [2011]
Liner Interface	0	13	-	-	94	112	Assumed from literature and experience
Dam Core	0	28.5	120	27	125	130	Bechtel [1982], WAI [2010]
Dam Shell	0	33	750	22.5	125	130	Bechtel [1982], WAI [2010]
Aged Fly Ash Paste	0	35	0.25*Eff. overburden stress	0	102	102	WAI [2011]
New Fly Ash Paste (fly ash slurry)	700	28	100 psf at top, increase by 9psf/ft with depth, 3000 psf max	-	103	103	Golder [2001]
Alluvium	0	28	0	21	124	124	Bechtel[1982]
Drain	0	35	-	-	130	135	Bechtel[1982]
Dam Fill	0	33	-	-	125	130	Bechtel[1982]
Bedrock	0	28	0	21	130	130	Bechtel[1982]

GROUNDWATER CONDITION

Because a liner system will be installed at Cell J, future fly ash placement is not expected to raise the phreatic surfaces within the dam/dike. For this analysis, it is assumed that the groundwater table in Cell J will be at the bottom of the liner system, and the phreatic surface within the dam/dike will remain at current level.

SEISMICITY

The EHP site is located at latitude 45 degrees, 52 minutes North and longitude 106 degrees 32 minutes West. The peak ground acceleration (PGA) in bedrock with 2% probability of exceedance in 50 years is 0.047g, according to the USGS National Seismic Hazard Maps [USGS, 2008] (see Figure 3). A seismic coefficient of 0.05 is assumed for the pseudo-static seismic slope stability analysis.

CASES ANALYZED

The following cases are analyzed for each of the cross sections in this analysis.

- *Case 1: Intermediate condition with static loading*. For this case, it is assumed that fly ash paste will be placed to elevation 3280 ft-msl. It is conservatively assumed that the fine-grained material will act as undrained.
- *Case 2: Final condition with static loading, short-term*. For this case, it is assumed that dry ash will be placed above elevation 3280 ft-msl, and fly ash paste deposits in lined Cell J has cemented. Fine-grained material is assumed to act undrained.
- *Case 3: Final condition with static loading, long-term*. For this case, it is assumed that all excess pore water pressure has fully dissipated, and drained shear strength applies. Other assumptions are the same as Case 2.
- *Case 4: Final condition with seismic loading*. For this case, a seismic coefficient of 0.05 is applied in the pseudo static analysis. Undrained shear strength is used to account for excess pore water pressure induced during earthquake. Other assumptions are the same as Case 2.

RESULTS OF ANALYSIS

The output of slope stability analyses is included in Appendix B. The calculated Factors of Safety for slope stability are summarized in Table 3. As shown in Table 3, all the FS calculated for the various loading condition exceeds the minimum requirement.

Table 3. Calculated Factor of Safety

Cross Sections	Cases	FS (Calculated) Circular / Non-Circular	FS (required)
A-A'	1	1.63/2.07	1.3
	2	1.48/1.72	1.3
	3	1.96/1.93	1.5
	4	1.25/1.43	1.0
B-B'	1	2.16/2.32	1.3
	2	1.68/1.66	1.3
	3	2.16/1.81	1.5
	4	1.43/1.40	1.0
C-C'	1	1.30/1.39	1.3
	2	1.30/1.62	1.3
	3	2.47/1.80	1.5
	4	1.06/1.38	1.0

REFERENCES

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FIGURES

N

LEGEND

EXISTING GRADE CONTOUR (FEET-MSL)
3290 PROPOSED GRADE CONTOUR (FEET-MSL)
EXISTING ROAD / DRIVE
EXISTING STRUCTURE
EXISTING TREELINE

NOTES:

1. BASE GRADES ARE: a) APPROXIMATED FOR CELLS B AND F FROM DESIGN PLANS (HYDROMETRICS, INC., DATE UNKNOWN FOR CELL B, AND 2005 FOR CELL F), b) NORMALIZED FOR CELL H FROM 2012 EXISTING GRADES (SEE NOTE 1 ON FIGURE 1), c) ESTIMATED FOR CELL D, AND d) PROPOSED FOR CELL J (GEOSYNTEC 2014).

0 500'
SCALE IN FEET

CONCEPTUAL BASE GRADING PLAN

COLSTRIP SITE 3 ASH PONDS
COLSTRIP LANDFILL
COLSTRIP, MONTANA

Geosyntec consultants
COLUMBIA, MARYLAND

DATE:	SEPTEMBER 2014
PROJECT NO.	ME1132
DOCUMENT NO.	
FILE NO.	1132f002
FIGURE NO.	2

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Figure 1

LEGEND

- EXISTING GRADE CONTOUR (FEET-MSL)
- 3290 PROPOSED GRADE CONTOUR (FEET-MSL)
- EXISTING ROAD / DRIVE
- EXISTING STRUCTURE
- EXISTING TREELINE

VOLUME SCHEDULE	
CELL	VOLUME (C.Y.)
B	2,750,000
C	6,350,000
F	4,950,000
H	3,750,000
J	8,000,000
TOTAL	25,800,000

NOTES:

1. PROPOSED CAP GRADES ARE 3% FOR CELLS B, C, F, H AND 3H:1V FOR CELL J.

0 500'
SCALE IN FEET

CONCEPTUAL FINAL GRADING PLAN

COLSTRIP SITE 3 ASH PONDS
COLSTRIP LANDFILL
COLSTRIP, MONTANA

Geosyntec consultants
COLUMBIA, MARYLAND

DATE:	SEPTEMBER 2014
PROJECT NO.	ME1132
DOCUMENT NO.	
FILE NO.	1132f003
FIGURE NO.	3

Figure 2

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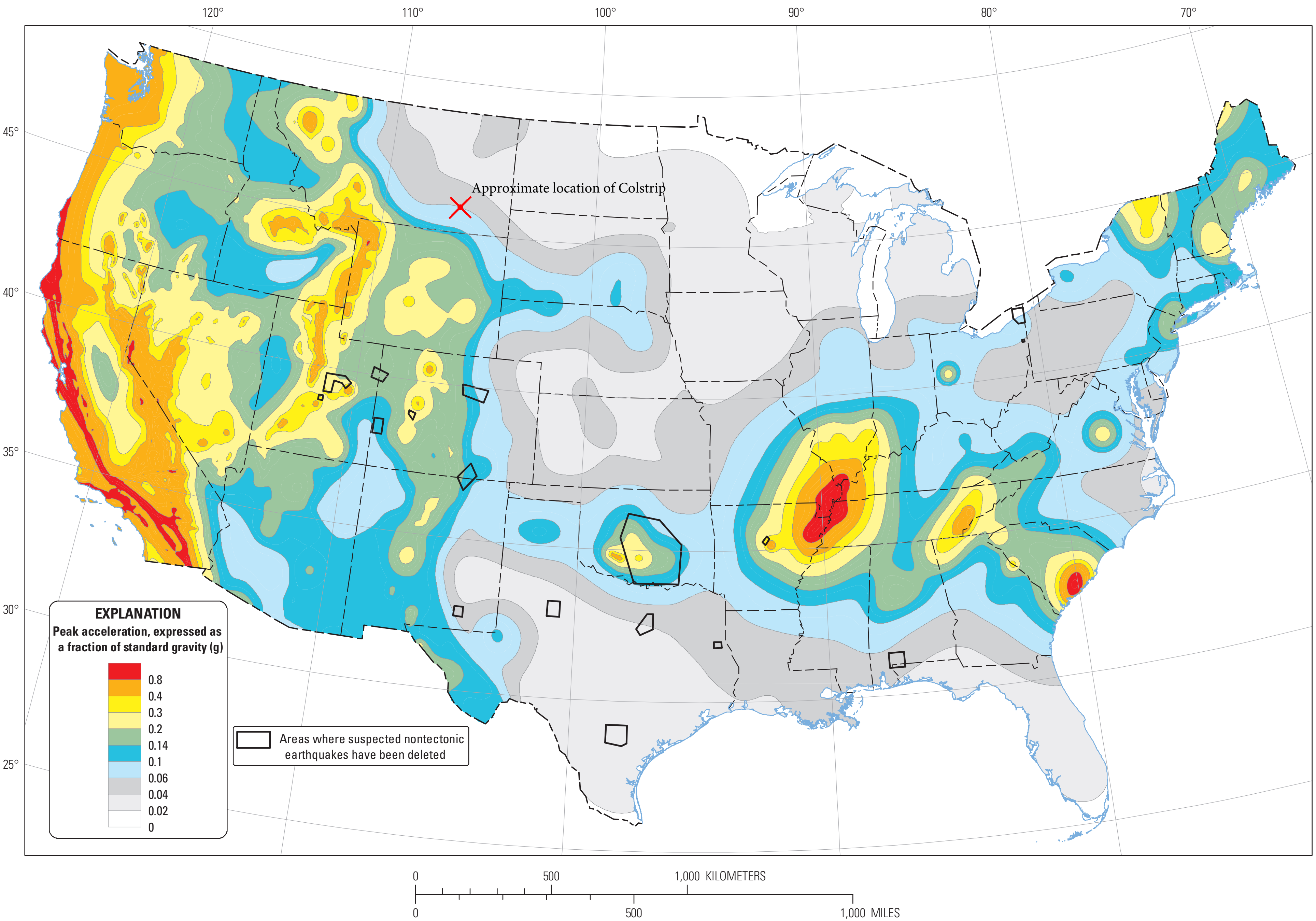


Two-percent probability of exceedance in 50 years map of peak ground acceleration

Figure 3

APPENDIX A

SUMMARY OF MATERIAL PROPERTIES
(Excerpt from WAI[2011])

Table 7.2-1 Laboratory Test Results

Soil Sample Origin				Physical Properties				Index Properties						CRS Consolidation & Permeability Test Results									Static DSS Test Results				Proctor				USCS
																		Coef of	Hydraulic	Preconsolidation	In-Situ		Effective	Effective	Normalized Strength	Undrained					
Soil	Borehole/Test Pit	Sample		Water	Total Unit	Dry Unit	Degree of	Liquid	Plasticity	Plasticity	Liquidity	% Passing	Initial Void	Compression	Recompression	Recompression	Compression	Consol	Conductivity	Stress	Stress	Overconsolidation	Strength	Cohesion	Ratio	Shear Strength	Standard		Modified		
Name	Source	No.	Depth	Content	Weight	Weight	Saturation	Limit	Index	Limit	Index	No. 200	Ratio	Index	Index	Ratio	Ratio	C_v	k	σ'_p	σ'_{vo}	Ratio	φ'	c'	C_u/σ'_{vo}	S_u	OMC	Max Dry	OMC	Max Dry	Classification
			(ft)	(%)	(pcf)	(pcf)	(%)	LL	PI	PL	LI		e_o	C_c	C_r	C'_r	C'_c	(ft^2/day)	(ft/day)	(psf)	(psf)	OCR	(degree)	(psf)	S	(psf)	(%)	Density(pcf)	(%)	Density(pcf)	
Clinker Ash	SD-10-P36	U1	10 - 13		114.5																										CL-ML
		U1a	11.35 - 11.55	23.3	120.1	97.4		25	6	19	0.72	50.4																			
		U1c	12.65 - 12.80	26.5	121.3	95.9																	26.6	950	0.25						
		U1b	12.80 - 13.00	24.4	121.9	96.1	96.4	25	7	18	1.26		0.751	0.301	0.009	0.005	0.172			15,000	800	18.8				2087					
		U1b (INC)	13	26.8	121.9	96.1		25	7	18	1.26		0.751																		
		U1d (INC)	10.96	24.4	124.1	99.8							0.686					1.12	1.71E-04												
Clinker Ash	SD-10-P38	U1	11.5 - 14.5		105.6																										CL
			11.78-11.98	23.5	126.1	102.1		29	10	19	0.45	52.4																			
Clinker Ash	SD-10-P38	U2	15 - 18		114.6																										CL
		U2a	16.18 - 16.36	26.0	125.9	100.0		29	10	19	0.70	55.2																			
		U2b	17.85 - 18.00	25.0	127.9	102.3	103.7	29	10	19	0.6		0.656							23,500	1,200	19.6				3241					
Clinker Ash Ave				**25.0**	**120.4**	**98.7**	**100.1**	**27.0**	**8.3**	**18.7**	**0.8**	**52.7**	**0.711**	**0.301**	**0.009**	**0.005**	**0.172**	**1.120**	**1.71E-04**	**19,250**	**1000.0**	**19.2**	**26.6**	**950**		**2664**					**CL**
Paste	MD-10-P7	U1	10.0 - 12.8		100.9																										ML
		U1a	10.50 - 10.66	45.2	109.5	75.4		43	8	35	1.28	95.4																			
		U1b	10.66 - 10.81	52.4	99.5	65.3	89.3	40	5	35	3.48		1.596	0.390	0.013	0.005	0.150			14,000	400	35.0			0.25	1719					
		U1c (INC)	10.81	47.2	90.3	61.3	73.1						1.744	0.335	0.091	0.0332	0.122	0.78	2.80E-05	16,000											
Paste	MD-10-P8	U1	5.0 - 8.0																												ML
		U1a	6.0-7.5	54.3	101.4	65.7	93.5	48	11	37	1.57		1.578	0.405	0.031	0.0121	0.157			28,000	300	93.3			0.25	2825					
Paste	MD-10-P9	U1	10.0 - 13.0		103.3																										ML
		U1a	11.65 - 11.90	43.9	109.1	75.8		42	6	36	1.32	95.9																			
		U1b	12.60 - 12.75	52.1	103.8	68.3	95.6	44	6	38	2.35		1.483	0.474	0.015	0.006	0.191			26,600	500	53.2				3004					
		U1c	12.75 - 12.90	50.8	102.9	68.2																	35	0	0.25						
Paste Ave				**49.4**	**102.3**	**68.6**	**87.9**	**43.4**	**7.2**	**36.2**	**2.0**	**95.7**	**1.600**	**0.401**	**0.038**	**0.014**	**0.155**	**0.780**	**2.80E-05**	**21,150**	**400.0**	**60.5**	**35**	**0**		**2664**					**ML**
Alluvium	SD-09-25P	U1/U2	28.5 - 31.0	15.4	128.5	111.3		27	12	15	0.03	76.8																			CL
Fly Ash Borrow	TP-10-4		3	49.7		74.2																							29.3	84.5	
	TP-10-4		8	43.6		78.0							1.243	1.974	0.063	0.028	0.88	23.6	1.31E+00	3800	840	4.5					36.6	79.4			
	TP-10-5		3.5	55.5		82.3							1.102	0.801	0.059	0.028	0.381	23.51	7.94E-02	3950	367.5	10.7	37.8	0							
	TP-10-5		7	44.8																							33.6	81.1			
Fly Ash Borrow Ave				**48.4**	**116.0**	**78.2**							**1.173**	**1.387**	**0.061**	**0.028**	**0.631**	**23.555**	**6.95E-01**	**3875.0**	**603.8**	**7.6**	**37.8**	**0**			**35.1**	**80.3**	**29.3**	**84.5**	

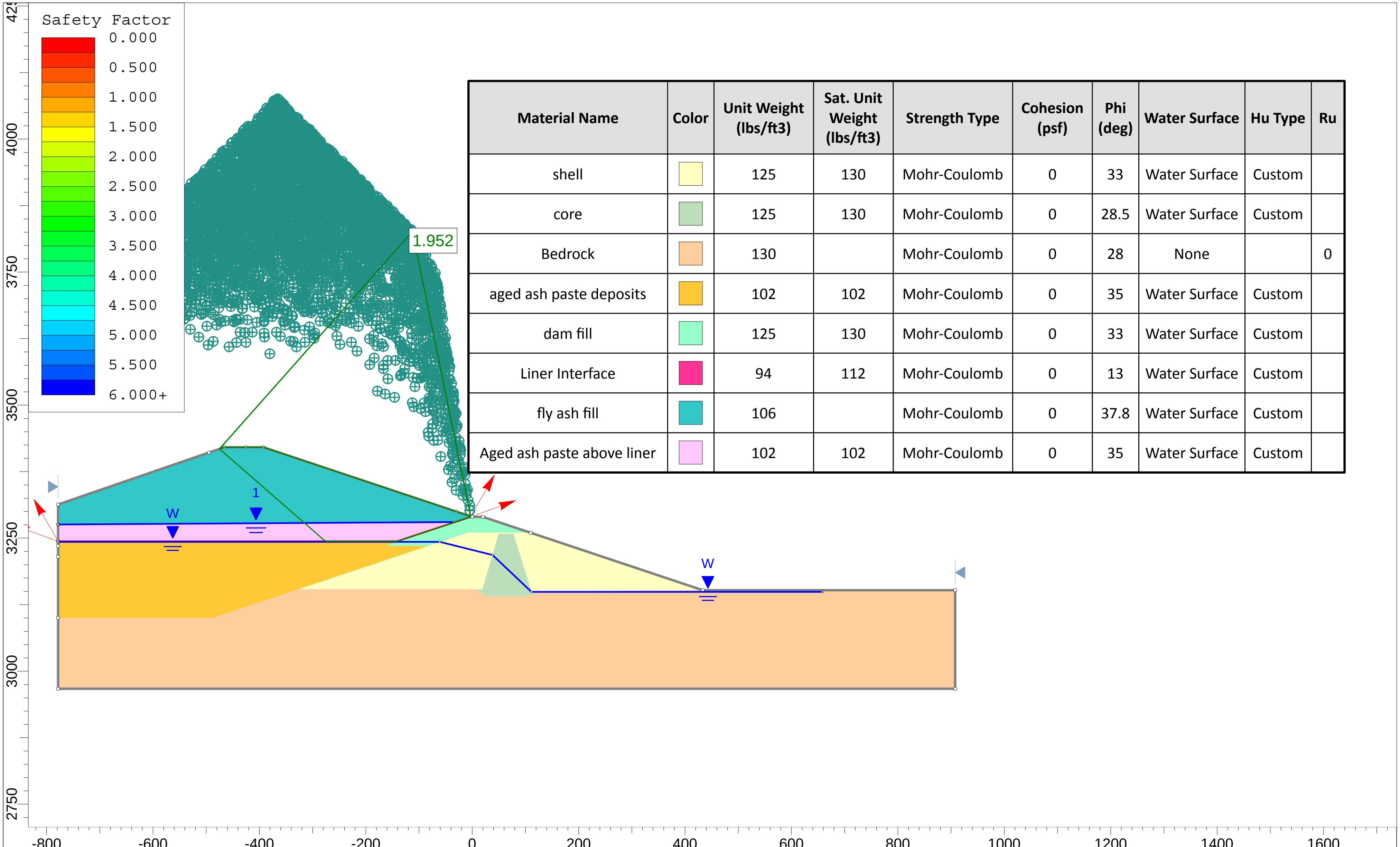
Table 8.2.3-1 Soil Design Parameters

Soil Sample Data		Physical Properties				Engineering Properties									Proctor			
Soil Name	Report / Test Source	Dry Unit Weight (pcf)	Moist Unit Weight (pcf)	Sat Unit Weight (pcf)	OMC (%)	Undrained Strength φ (degree)	Undrained Cohesion c (psf)	Effective Strength φ' (degree)	Effective Cohesion c' (psf)	Compression Index C_c	Recompression Index C_r	Recompression Ratio C'_r	Compression Ratio C'_c	Hydraulic Conductivity k (ft/s)	Standard OMC (%)	Standard Max Dry Density(pcf)	Modified OMC (%)	Modified Max Dry Density(pcf)
Core	Bechtel, 1982	113	125	130	15	27	120	28.5	0	0.1	0.01							
	WAI, 2010													1.50E-07				
Shell	Bechtel, 1982			130	15	22.5	750	33	0	0.1	0.01							
	WAI, 2010	107.5	123.6											2.00E-07				
Drain	Bechtel, 1982	105	130	135	15	35	0	35	0					0.0317				
Claystone/Siltstone	Bechtel, 1982		112	124		21	0	28	0					3.20E-08				
Clinker/Baked Shale	Bechtel, 1982		130	140	16	40	0	40	0					0.17				
Clinker Ash	This Report	99	120.4	125		0	2000	26.6	950	0.301	0.009	0.005	0.0172	1.98E-09				
Alluvium	Bechtel, 1982	97	112	124		21	0	28	0	0.1	0.01			4.80E-06				
Sandstone	WAI, 2010	99.8	121	124	22.2			40.1	0					2.40E-05				
Paste	This Report	68.6	102	112		0	1700	35	0	0.401	0.038	0.014	0.155	3.24E-10				
Fly Ash Slurry	WAI, C-CW, 09		100	103.4		*	*	28	700									
	Golder, 2001	74												3.28E-07				
Fly Ash Borrow	This Report	78.2	105.6	116	35.1			37.8	0	1.387	0.061	0.028	0.631	8.04E-06	35.1	80.3	29.3	84.5
	WAI, 2001					22	0											
Bottom Ash Fill	Golder, 2001	86	93.7	112.2	29.3	20.5	3295	40.3	675			0.04	0.23	5.00E-04	29.3	86		

* Undrained strength of fly ash slurry
C top layer = 100-psf
C rate of change = 9-psf/ft
C maximum = 3000-psf

APPENDIX B

SLOPE STABILITY ANALYSIS OUTPUT



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Ru
shell		125	130	Mohr-Coulomb	0	33	Water Surface	Custom	
core		125	130	Mohr-Coulomb	0	28.5	Water Surface	Custom	
Bedrock		130		Mohr-Coulomb	0	28	None		0
aged ash paste deposits		102	102	Mohr-Coulomb	0	35	Water Surface	Custom	
dam fill		125	130	Mohr-Coulomb	0	33	Water Surface	Custom	
Liner Interface		94	112	Mohr-Coulomb	0	13	Water Surface	Custom	
fly ash fill		106		Mohr-Coulomb	0	37.8	Water Surface	Custom	
Aged ash paste above liner		102	102	Mohr-Coulomb	0	35	Water Surface	Custom	

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Project

SLIDE - An Interactive Slope Stability Program

Analysis Description

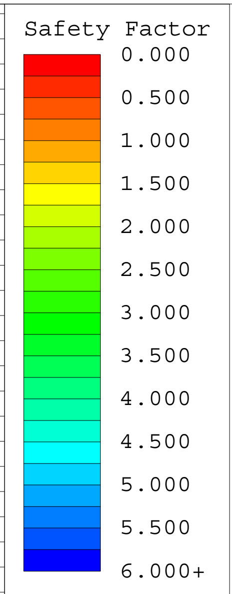
Drawn By

Scale 1:2994

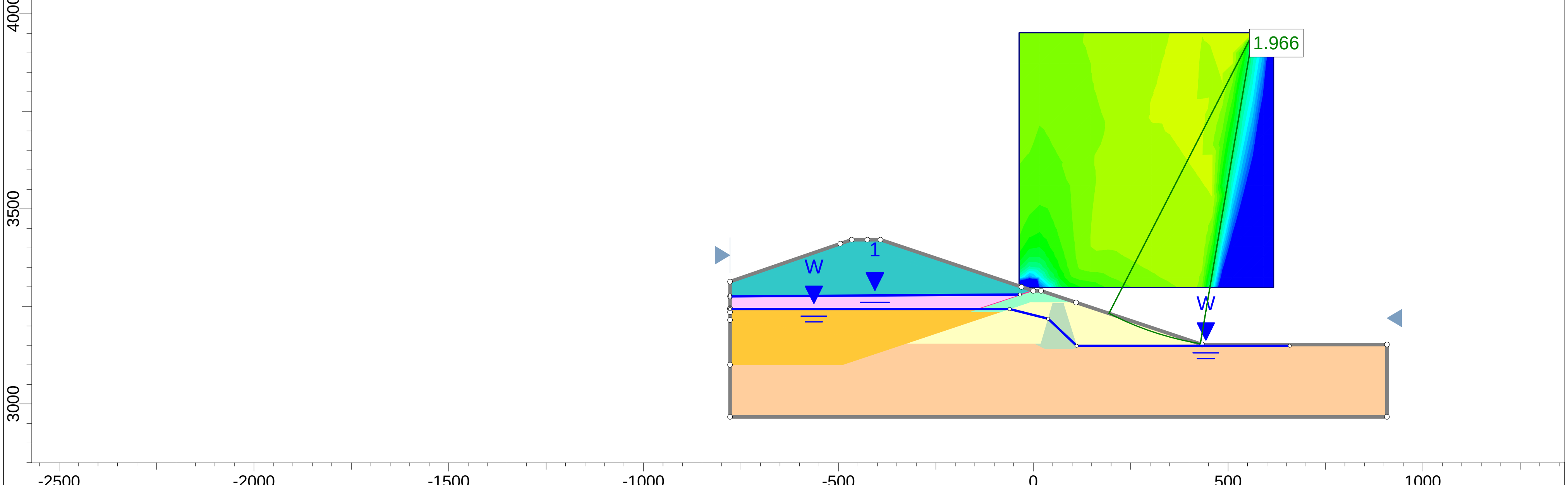
Company

Date 9/29/2015, 4:16:54 PM

File Name A-A'_final_ Long term_ non- circular.slim



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu	Ru
shell		125	130	Mohr-Coulomb	0	33	Water Surface	Custom	1	
core		125	130	Mohr-Coulomb	0	28.5	Water Surface	Custom	1	
Bedrock		130		Mohr-Coulomb	0	28	None			0
aged ash paste deposits		102	102	Mohr-Coulomb	0	35	Water Surface	Custom	1	
dam fill		125	130	Mohr-Coulomb	0	33	Water Surface	Custom	1	
Liner Interface		94	112	Mohr-Coulomb	0	13	Water Surface	Custom	1	
fly ash fill		106		Mohr-Coulomb	0	37.8	Water Surface	Custom	1	
Aged ash paste above liner		102	102	Mohr-Coulomb	0	35	Water Surface	Custom	1	



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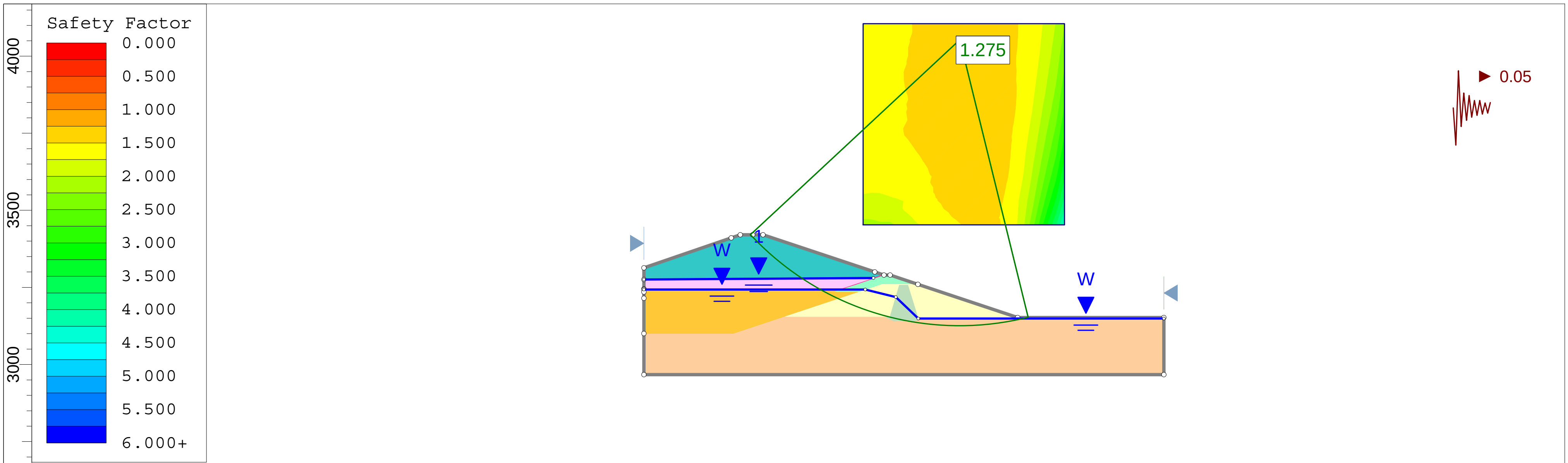

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
shell		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	1	
core		125	130	Mohr-Coulomb	120	27			Water Surface	Custom	1	
Bedrock		130		Mohr-Coulomb	0	21			None			0
aged ash paste deposits		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	1	
dam fill		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	1	
Liner Interface		94	112	Mohr-Coulomb	0	13			Water Surface	Custom	1	
fly ash fill		106		Mohr-Coulomb	0	37.8			Water Surface	Custom	1	
Aged ash paste above liner		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	1	

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Project	SLIDE - An Interactive Slope Stability Program
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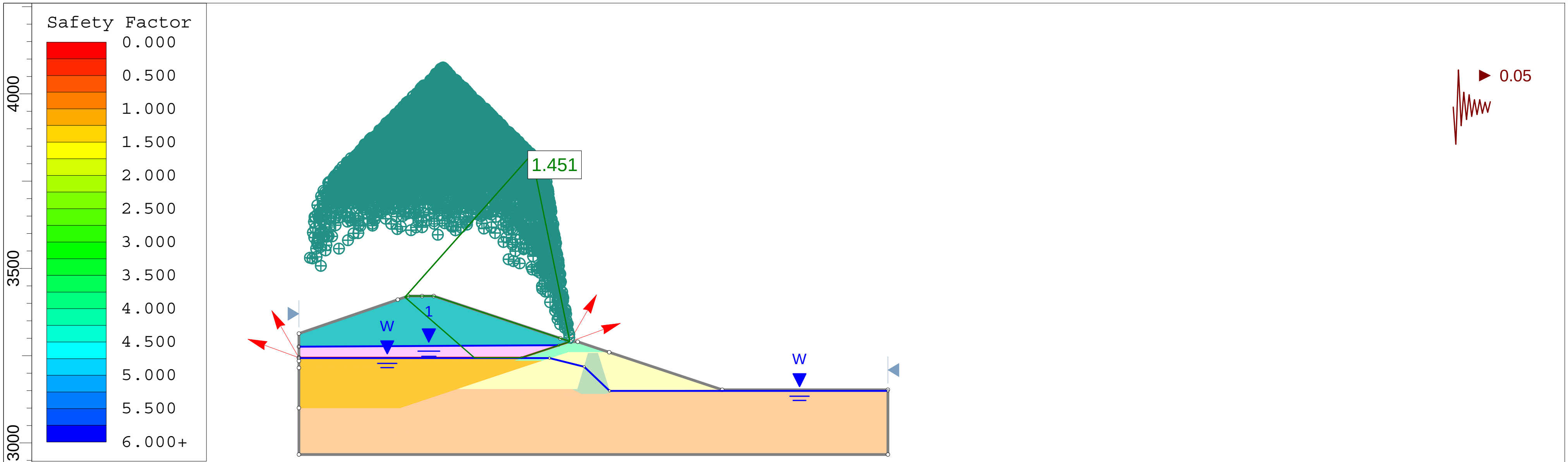

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Ru
shell		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	
core		125	130	Mohr-Coulomb	120	27			Water Surface	Custom	
Bedrock		130		Mohr-Coulomb	0	21			None		0
aged ash paste deposits		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	
dam fill		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	
Liner Interface		94	112	Mohr-Coulomb	0	13			Water Surface	Custom	
fly ash fill		106		Mohr-Coulomb	0	37.8			Water Surface	Custom	
Aged ash paste above liner		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	

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Project	SLIDE - An Interactive Slope Stability Program
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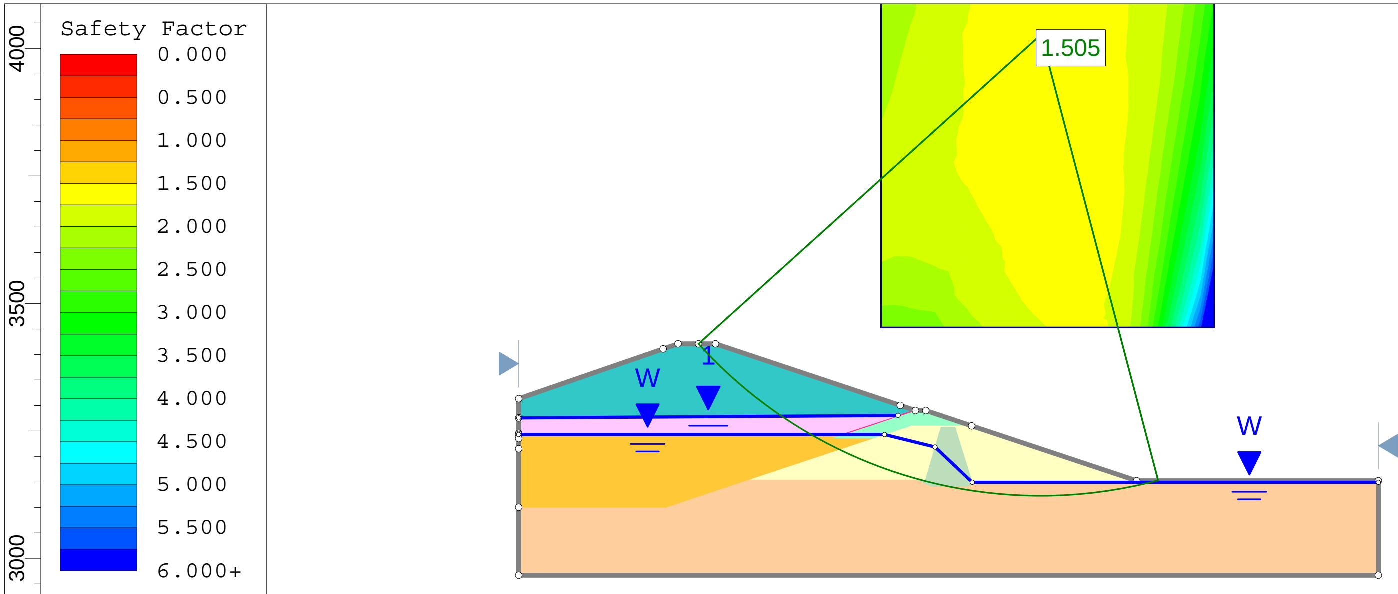

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Ru
shell		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	
core		125	130	Mohr-Coulomb	120	27			Water Surface	Custom	
Bedrock		130		Mohr-Coulomb	0	21			None		0
aged ash paste deposits		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	
dam fill		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	
Liner Interface		94	112	Mohr-Coulomb	0	13			Water Surface	Custom	
fly ash fill		106		Mohr-Coulomb	0	37.8			Water Surface	Custom	
Aged ash paste above liner		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	

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Analysis Description

Drawn By

Scale 1:4518

Company

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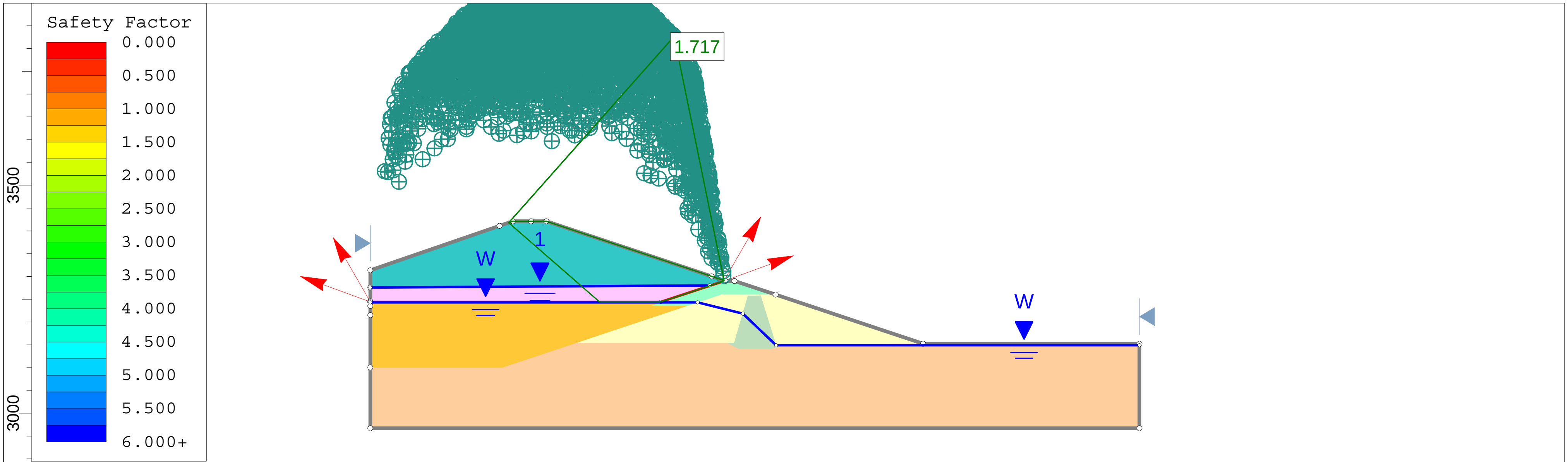

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Ru
shell		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	
core		125	130	Mohr-Coulomb	120	27			Water Surface	Custom	
Bedrock		130		Mohr-Coulomb	0	21			None		0
aged ash paste deposits		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	
dam fill		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	
Liner Interface		94	112	Mohr-Coulomb	0	13			Water Surface	Custom	
fly ash fill		106		Mohr-Coulomb	0	37.8			Water Surface	Custom	
Aged ash paste above liner		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	

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Project	SLIDE - An Interactive Slope Stability Program
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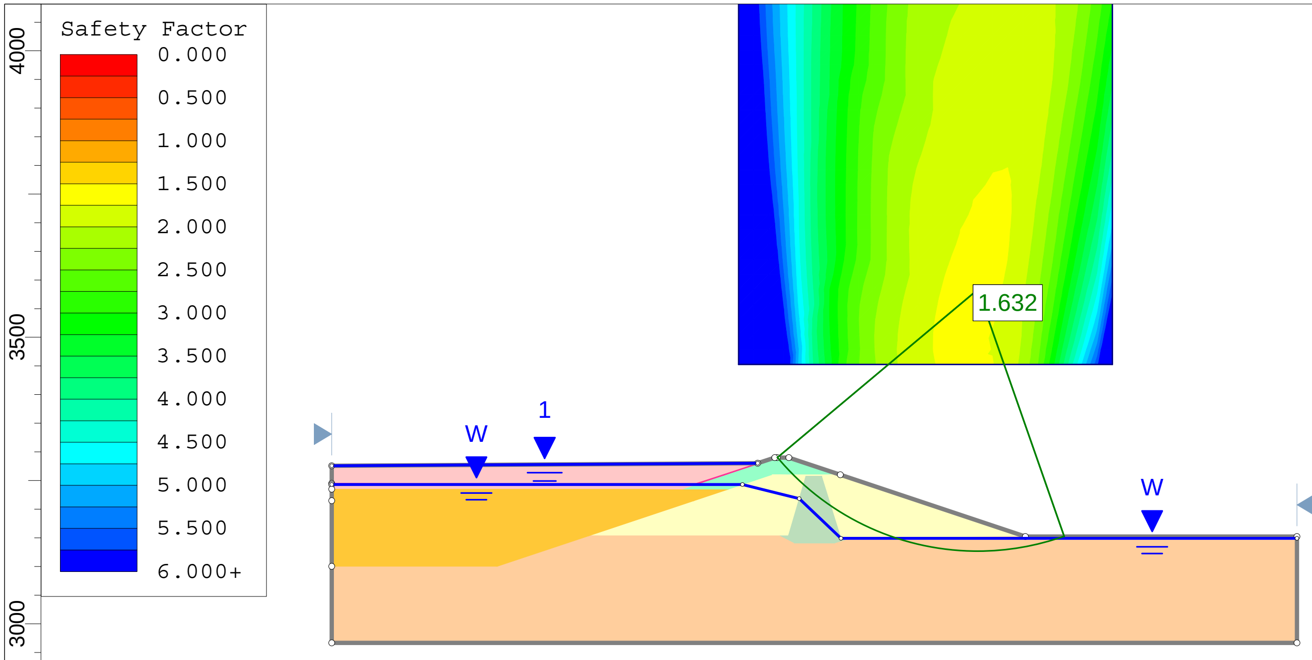

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type	Cohesion Change (psf/ft)	Cutoff (psf)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Ru
shell		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	
core		125	130	Mohr-Coulomb	120	27						Water Surface	Custom	
Bedrock		130		Mohr-Coulomb	0	21						None		0
aged ash paste deposits		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	
fly ash slurry		103	103	Undrained	100		FDepth	9	3000			None		0
dam fill		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	
Liner Interface		94	112	Mohr-Coulomb	0	13						Water Surface	Custom	

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Project	SLIDE - An Interactive Slope Stability Program
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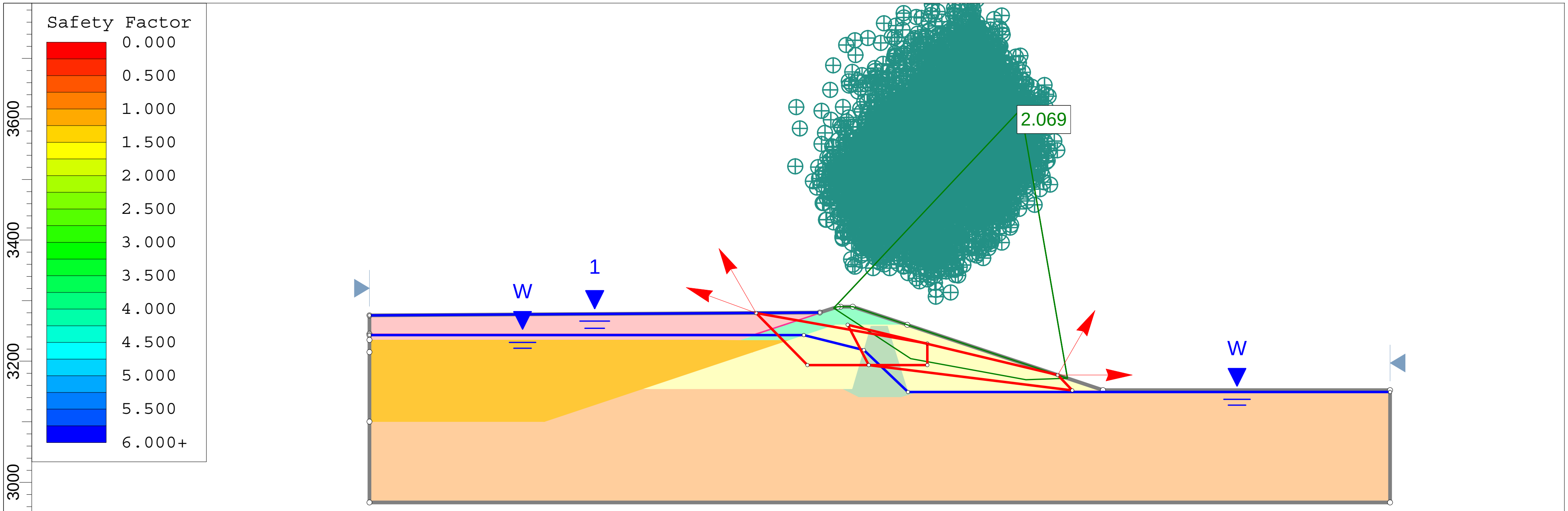

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type	Cohesion Change (psf/ft)	Cutoff (psf)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
shell		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	1	
core		125	130	Mohr-Coulomb	120	27						Water Surface	Custom	1	
Bedrock		130		Mohr-Coulomb	0	21						None			0
aged ash paste deposits		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	1	
fly ash slurry		103	103	Undrained	100		FDepth	9	3000			None			0
dam fill		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	1	
Liner Interface		94	112	Mohr-Coulomb	0	13						Water Surface	Custom	1	

2800 2600 2400

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Project SLIDE - An Interactive Slope Stability Program

Analysis Description

Drawn By

Scale 1:2947

Company

Date 9/29/2015, 4:16:54 PM

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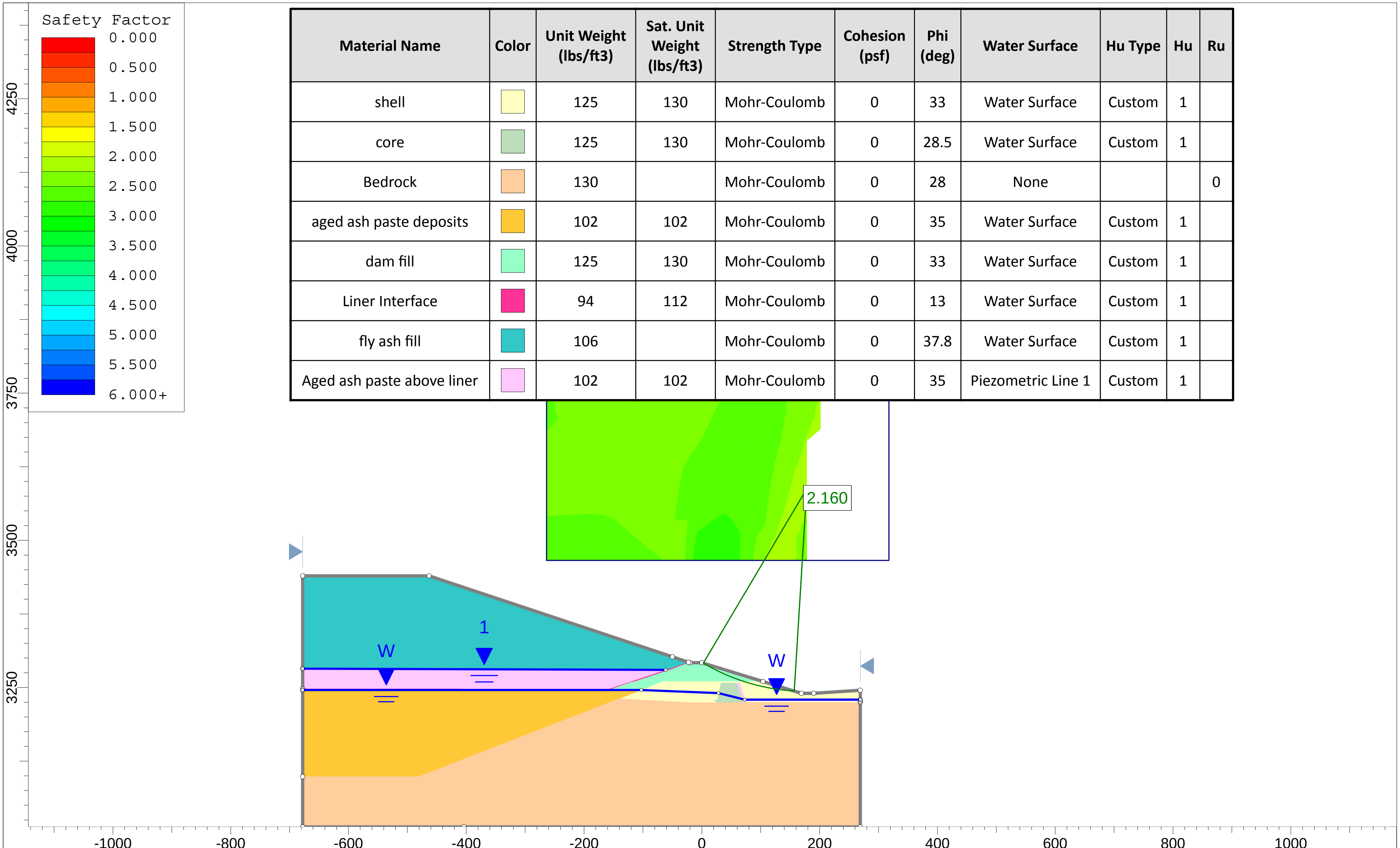

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu	Ru
shell		125	130	Mohr-Coulomb	0	33	Water Surface	Custom	1	
core		125	130	Mohr-Coulomb	0	28.5	Water Surface	Custom	1	
Bedrock		130		Mohr-Coulomb	0	28	None			0
aged ash paste deposits		102	102	Mohr-Coulomb	0	35	Water Surface	Custom	1	
dam fill		125	130	Mohr-Coulomb	0	33	Water Surface	Custom	1	
Liner Interface		94	112	Mohr-Coulomb	0	13	Water Surface	Custom	1	
fly ash fill		106		Mohr-Coulomb	0	37.8	Water Surface	Custom	1	
Aged ash paste above liner		102	102	Mohr-Coulomb	0	35	Piezometric Line 1	Custom	1	

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Project	SLIDE - An Interactive Slope Stability Program
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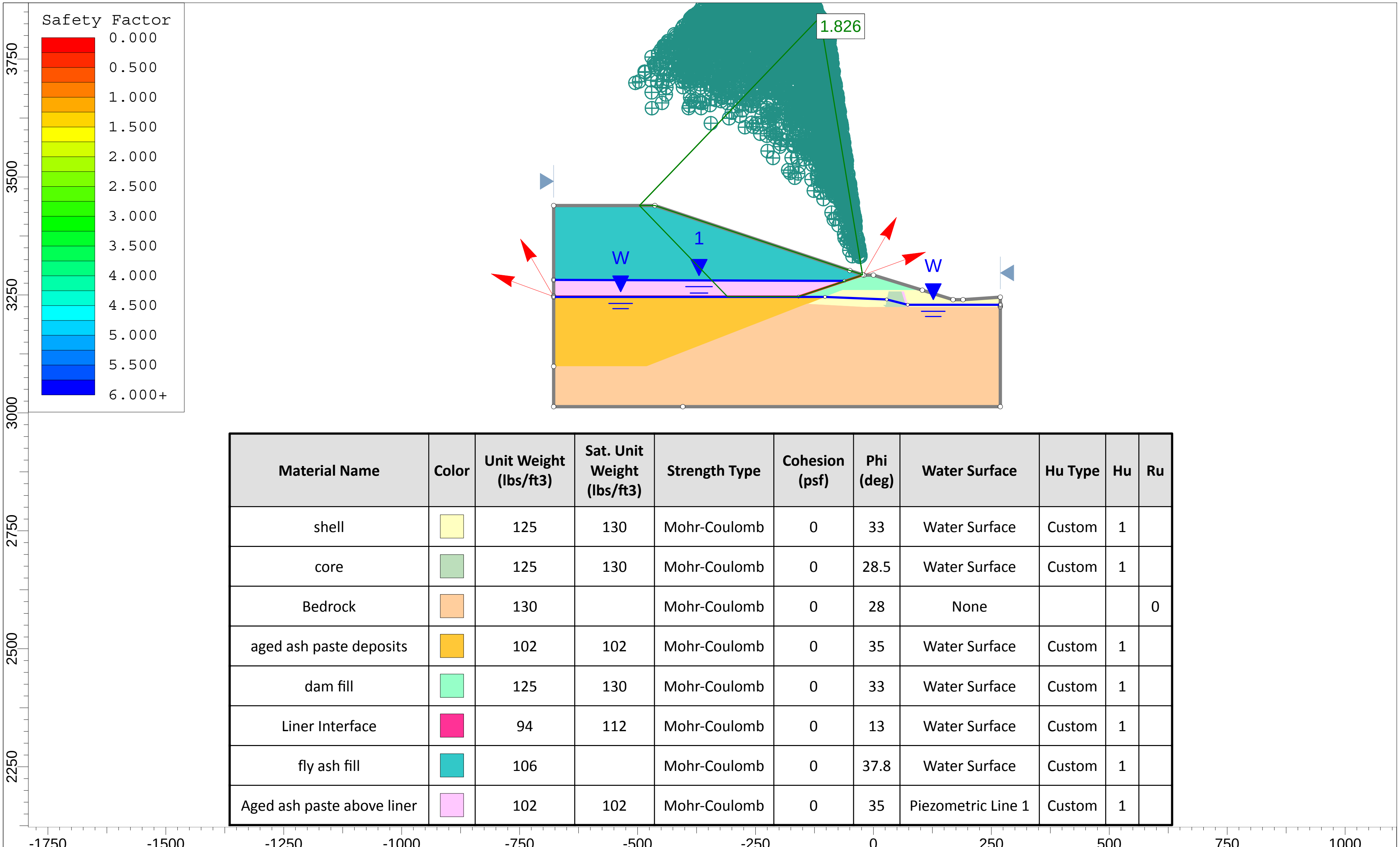

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu	Ru
shell		125	130	Mohr-Coulomb	0	33	Water Surface	Custom	1	
core		125	130	Mohr-Coulomb	0	28.5	Water Surface	Custom	1	
Bedrock		130		Mohr-Coulomb	0	28	None			0
aged ash paste deposits		102	102	Mohr-Coulomb	0	35	Water Surface	Custom	1	
dam fill		125	130	Mohr-Coulomb	0	33	Water Surface	Custom	1	
Liner Interface		94	112	Mohr-Coulomb	0	13	Water Surface	Custom	1	
fly ash fill		106		Mohr-Coulomb	0	37.8	Water Surface	Custom	1	
Aged ash paste above liner		102	102	Mohr-Coulomb	0	35	Piezometric Line 1	Custom	1	

rocscience	*Project* SLIDE - An Interactive Slope Stability Program	
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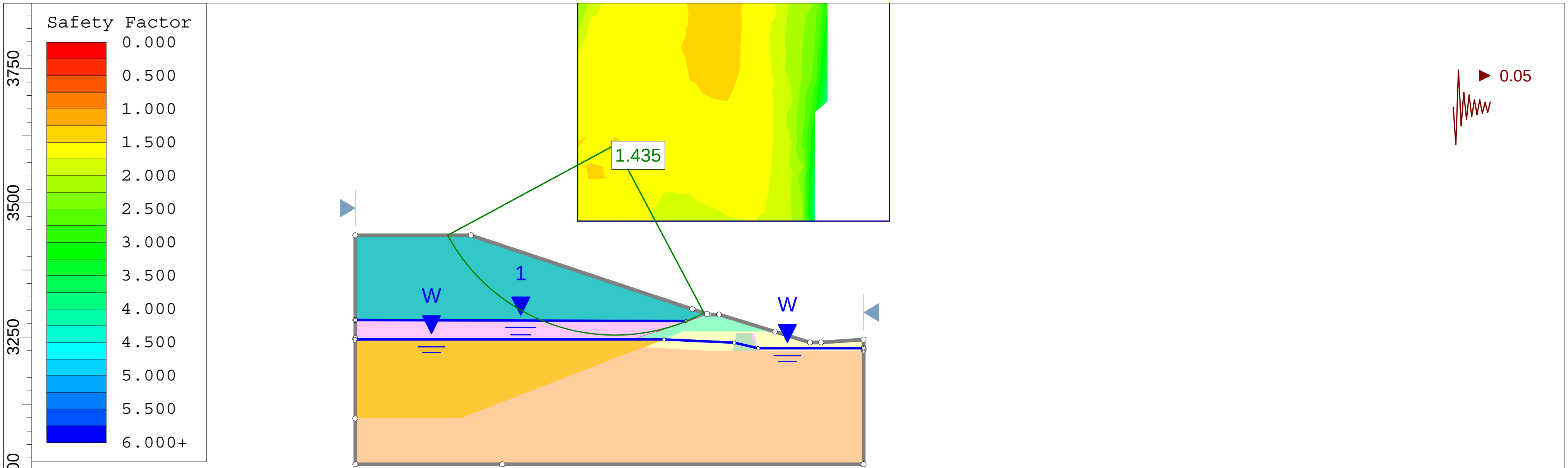
SLIDEINTERPRET 6.036	*Date* 9/25/2015, 12:20:39 PM	*File Name* B-B'_final_Long-term non_circular.slim



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
shell		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	1	
core		125	130	Mohr-Coulomb	120	27			Water Surface	Custom	1	
Bedrock		130		Mohr-Coulomb	0	21			None			0
aged ash paste deposits		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	1	
dam fill		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	1	
Liner Interface		94	112	Mohr-Coulomb	0	13			Water Surface	Custom	1	
fly ash fill		106		Mohr-Coulomb	0	37.8			Water Surface	Custom	1	
Aged ash paste above liner		102	102	Strength=F(overburden)			0.25	0	None			0

SLIDEINTERPRET 6.036

Project	SLIDE - An Interactive Slope Stability Program
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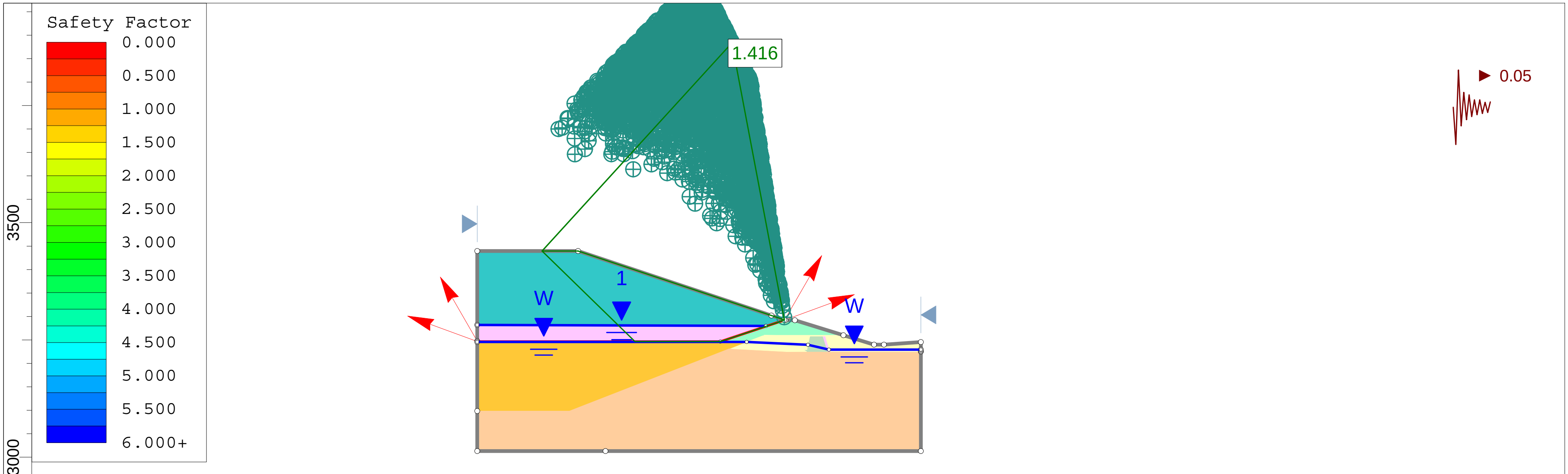

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
shell		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	1	
core		125	130	Mohr-Coulomb	120	27			Water Surface	Custom	1	
Bedrock		130		Mohr-Coulomb	0	21			None			0
aged ash paste deposits		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	1	
dam fill		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	1	
Liner Interface		94	112	Mohr-Coulomb	0	13			Water Surface	Custom	1	
fly ash fill		106		Mohr-Coulomb	0	37.8			Water Surface	Custom	1	
Aged ash paste above liner		102	102	Strength=F(overburden)			0.25	0	None			0

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2000

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SLIDEINTERPRET 6.036

Project
SLIDE - An Interactive Slope Stability Program

Analysis Description

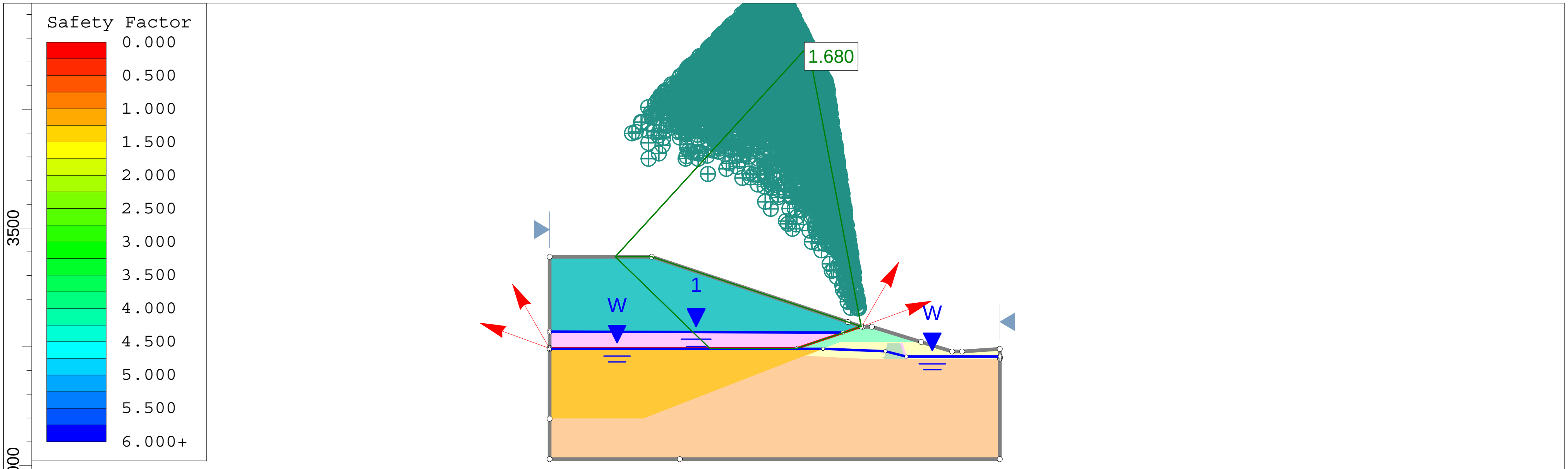
Drawn By

Scale 1:3808

Company

Date 9/25/2015, 12:20:39 PM

File Name B-B'_final_Seismic_ non_circular.slim



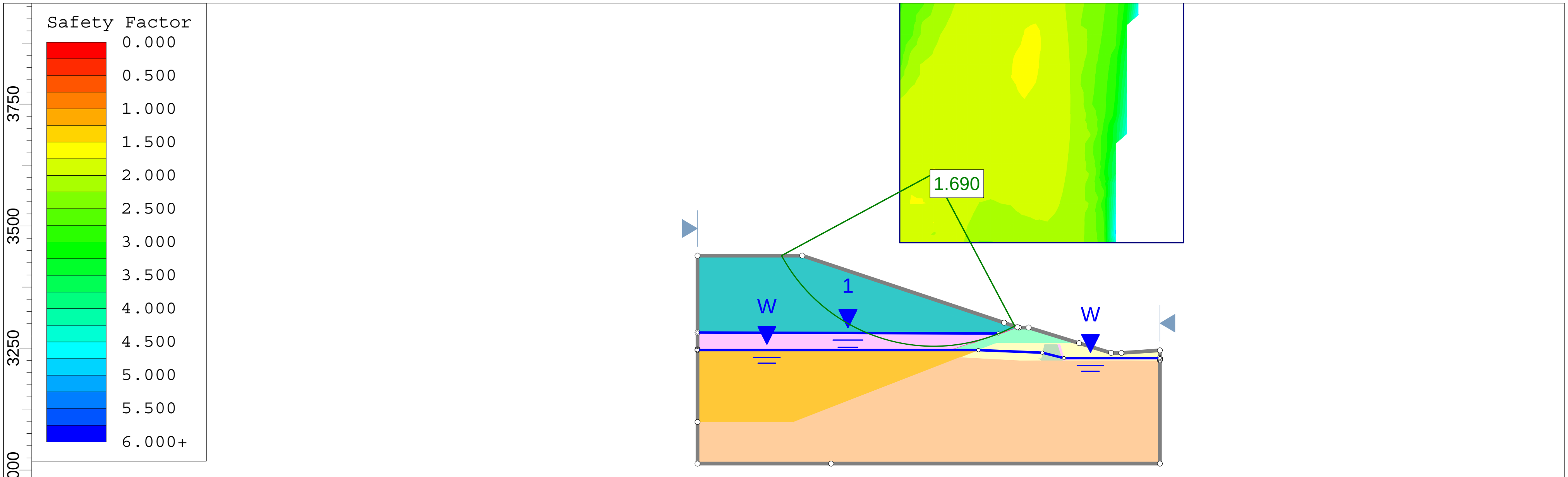
Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
shell		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	1	
core		125	130	Mohr-Coulomb	120	27			Water Surface	Custom	1	
Bedrock		130		Mohr-Coulomb	0	21			None			0
aged ash paste deposits		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	1	
dam fill		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	1	
Liner Interface		94	112	Mohr-Coulomb	0	13			Water Surface	Custom	1	
fly ash fill		106		Mohr-Coulomb	0	37.8			Water Surface	Custom	1	
Aged ash paste above liner		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	1	

2500

-1750 -1500 -1250 -1000 -750 -500 -250 0 250 500 750 1000 1250

SLIDEINTERPRET 6.036

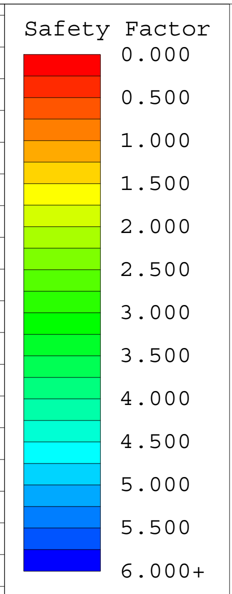
Project	SLIDE - An Interactive Slope Stability Program
Analysis Description	
Drawn By	
Scale	1:3752
Company	
Date	9/25/2015, 12:20:39 PM
File Name	B-B'_final_Short-term non_circular.slim

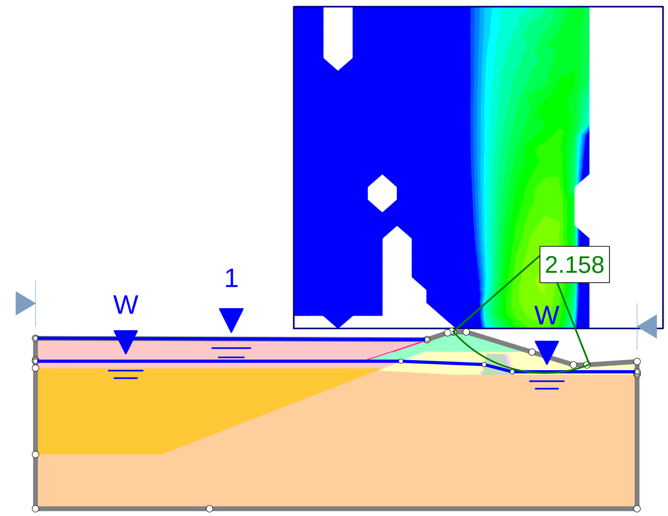


Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
shell		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	1	
core		125	130	Mohr-Coulomb	120	27			Water Surface	Custom	1	
Bedrock		130		Mohr-Coulomb	0	21			None			0
aged ash paste deposits		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	1	
dam fill		125	130	Mohr-Coulomb	750	22.5			Water Surface	Custom	1	
Liner Interface		94	112	Mohr-Coulomb	0	13			Water Surface	Custom	1	
fly ash fill		106		Mohr-Coulomb	0	37.8			Water Surface	Custom	1	
Aged ash paste above liner		102	102	Strength=F(overburden)			0.25	0	Water Surface	Custom	1	

Project	SLIDE - An Interactive Slope Stability Program
Analysis Description	
Drawn By	*Scale* 1:3653
Company	
Date 9/25/2015, 12:20:39 PM	*File Name* B-B'_final_Short-term_circular.slim

SLIDEINTERPRET 6.036

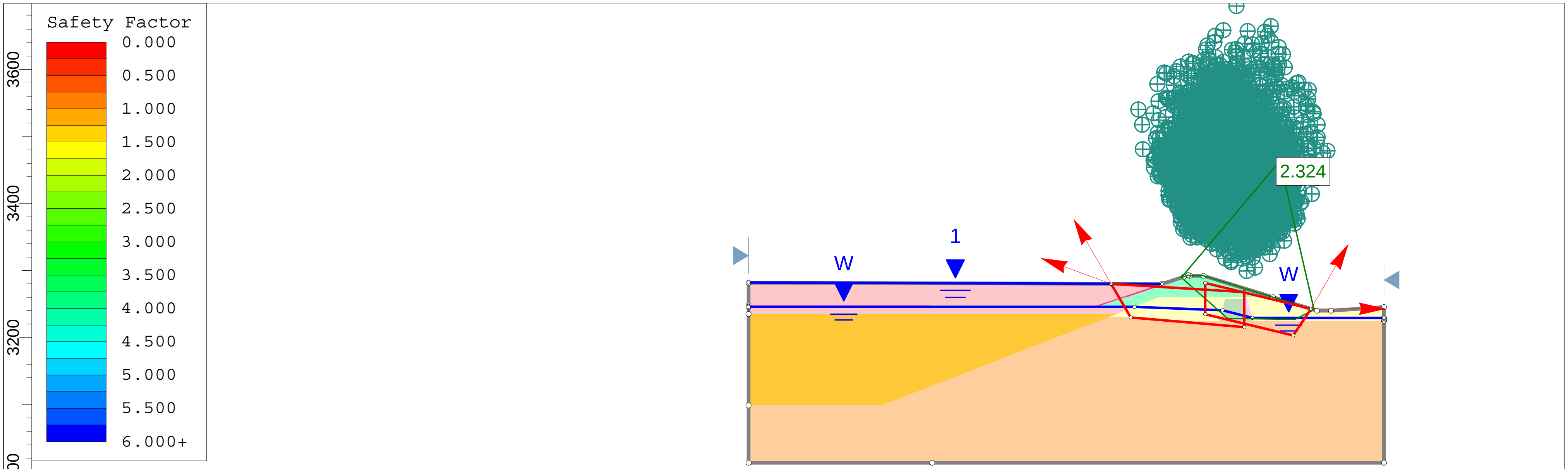




Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type	Cohesion Change (psf/ft)	Cutoff (psf)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
shell		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	1	
core		125	130	Mohr-Coulomb	120	27						Water Surface	Custom	1	
Bedrock		130		Mohr-Coulomb	0	21						None			0
aged ash paste deposits		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	1	
fly ash slurry		103	103	Undrained	100		FDepth	9	3000			None			0
dam fill		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	1	
Liner Interface		94	112	Mohr-Coulomb	0	13						Water Surface	Custom	1	
Aged ash paste above liner		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	1	

SLIDEINTERPRET 6.036

Project	SLIDE - An Interactive Slope Stability Program
Analysis Description	
Drawn By	
Scale	1:3629
Company	
Date	9/25/2015, 12:20:39 PM
File Name	B-B'_intermediate_Short-term circular.slim



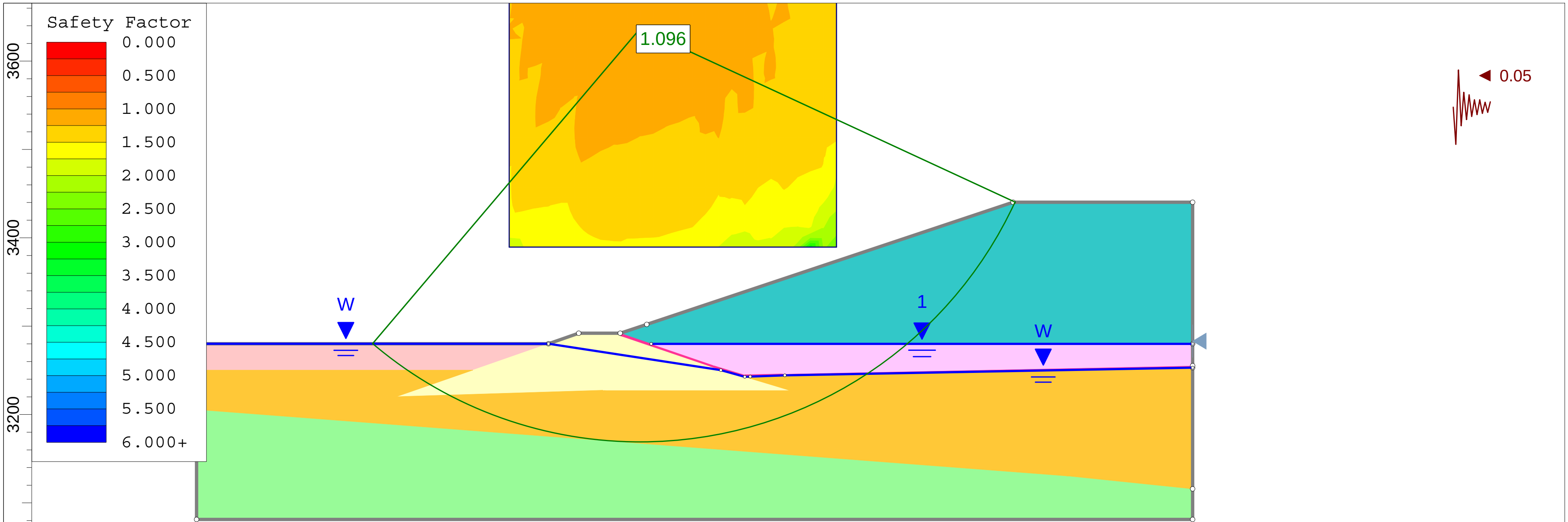
Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type	Cohesion Change (psf/ft)	Cutoff (psf)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
shell		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	1	
core		125	130	Mohr-Coulomb	120	27						Water Surface	Custom	1	
Bedrock		130		Mohr-Coulomb	0	21						None			0
aged ash paste deposits		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	1	
fly ash slurry		103	103	Undrained	100		FDepth	9	3000			None			0
dam fill		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	1	
Liner Interface		94	112	Mohr-Coulomb	0	13						Water Surface	Custom	1	
Aged ash paste above liner		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	1	

2800 2600 2400

-1600 -1400 -1200 -1000 -800 -600 -400 -200 0 200 400

SLIDEINTERPRET 6.036

Project	SLIDE - An Interactive Slope Stability Program
Analysis Description	
Drawn By	*Scale* 1:2658
Company	
Date 9/25/2015, 12:20:39 PM	*File Name* B-B'_intermediate_Short-term non_circular.slim



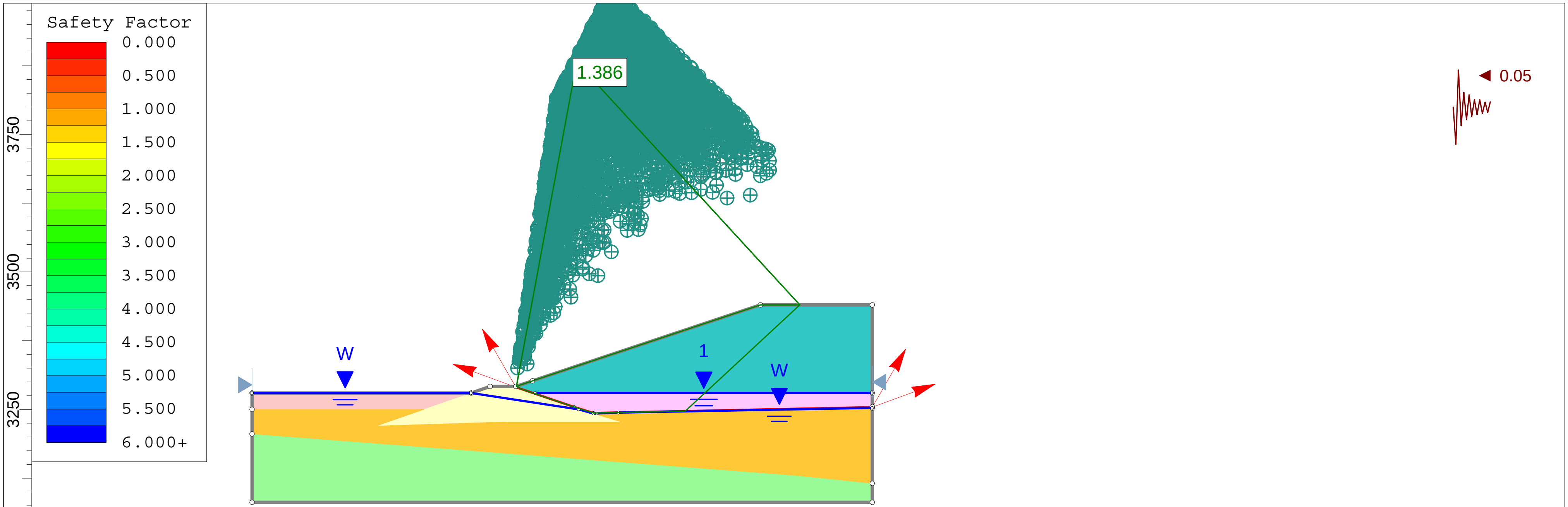
Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type	Cohesion Change (psf/ft)	Cutoff (psf)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Ru
dike fill		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	
aged ash paste deposits		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	
fly ash slurry		103	103	Undrained	100		FDepth	9	3000			None		0
Liner Interface		94	112	Mohr-Coulomb	0	13						Water Surface	Custom	
fly ash fill		106		Mohr-Coulomb	0	37.8						Water Surface	Custom	
Aged ash paste above liner		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	
alluvium		124	124	Mohr-Coulomb	0	21						Water Surface	Custom	

3000 2800

-400 -200 0 200 400 600 800 1000 1200

SLIDEINTERPRET 6.036

Project	SLIDE - An Interactive Slope Stability Program
Analysis Description	
Drawn By	*Scale* 1:2019
Company	
Date 9/25/2015, 12:07:38 PM	*File Name* C-C'_final seismic_circular.slim



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type	Cohesion Change (psf/ft)	Cutoff (psf)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
dike fill		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	1	
aged ash paste deposits		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	1	
fly ash slurry		103	103	Undrained	100		FDepth	9	3000			None			0
Liner Interface		94	112	Mohr-Coulomb	0	13						Water Surface	Custom	1	
fly ash fill		106		Mohr-Coulomb	0	37.8						Water Surface	Custom	1	
Aged ash paste above liner		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	1	
alluvium		124	124	Mohr-Coulomb	0	21						Water Surface	Custom	1	

3000 2750 2500

-500 -250 0 250 500 750 1000 1250 1500 1750 2000

SLIDEINTERPRET 6.036

Project SLIDE - An Interactive Slope Stability Program

Analysis Description

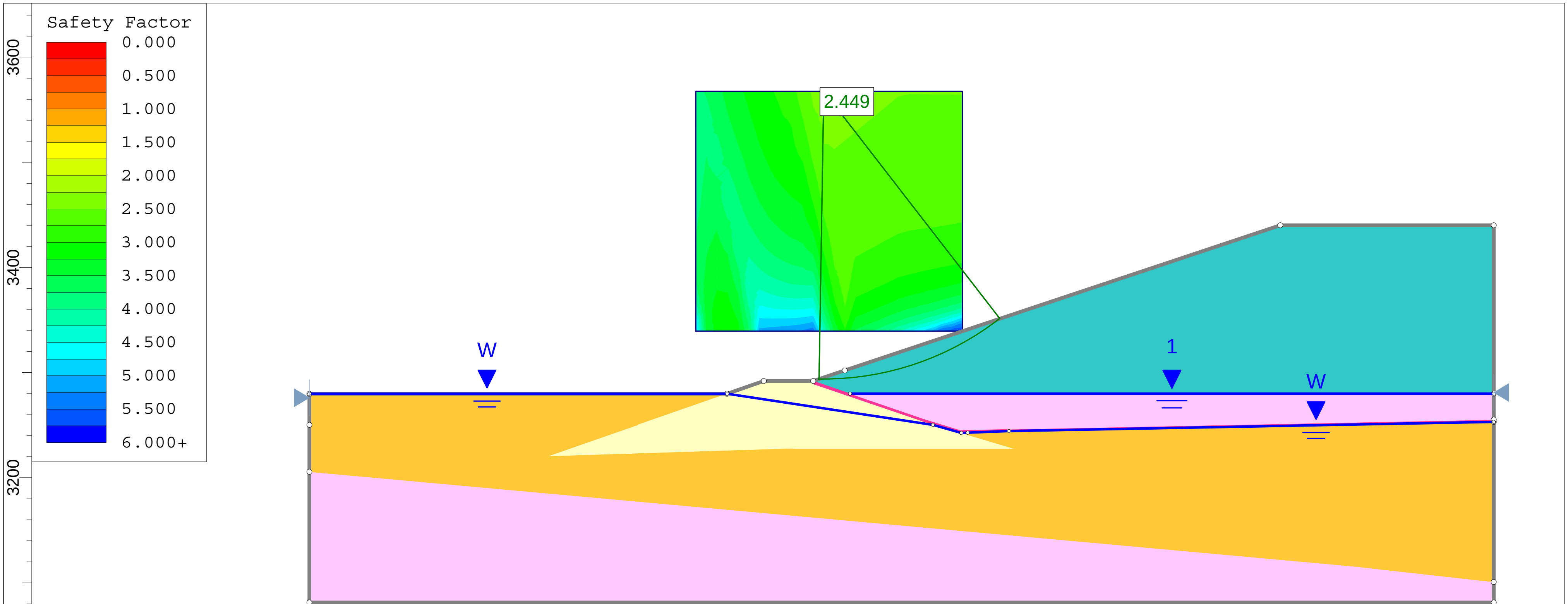
Drawn By

Scale 1:3244

Company

Date 9/25/2015, 12:07:38 PM

File Name C-C'_final seismic_non-circular.slim



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Dike Fill		125	130	Mohr-Coulomb	0	33	Water Surface	Custom	1
aged ash paste deposits		102	102	Mohr-Coulomb	0	35	Water Surface	Custom	1
Liner Interface		94	112	Mohr-Coulomb	0	13	Water Surface	Custom	1
fly ash fill		106		Mohr-Coulomb	0	37.8	Water Surface	Custom	1
Aged ash paste above liner		102	102	Mohr-Coulomb	0	35	Water Surface	Custom	1

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SLIDEINTERPRET 6.036

Project SLIDE - An Interactive Slope Stability Program

Analysis Description

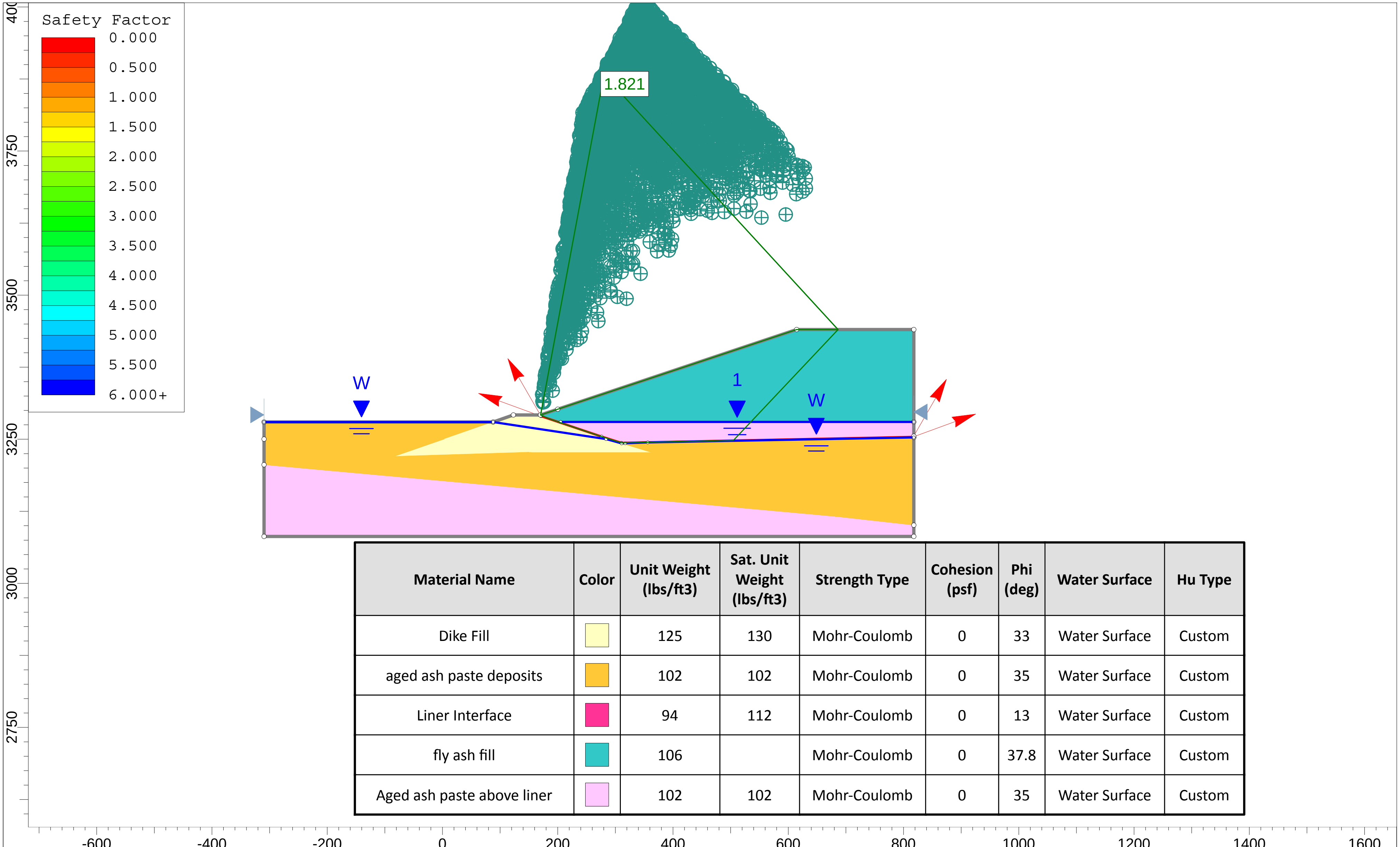
Drawn By

Scale 1:1698

Company

Date 9/25/2015, 12:07:38 PM

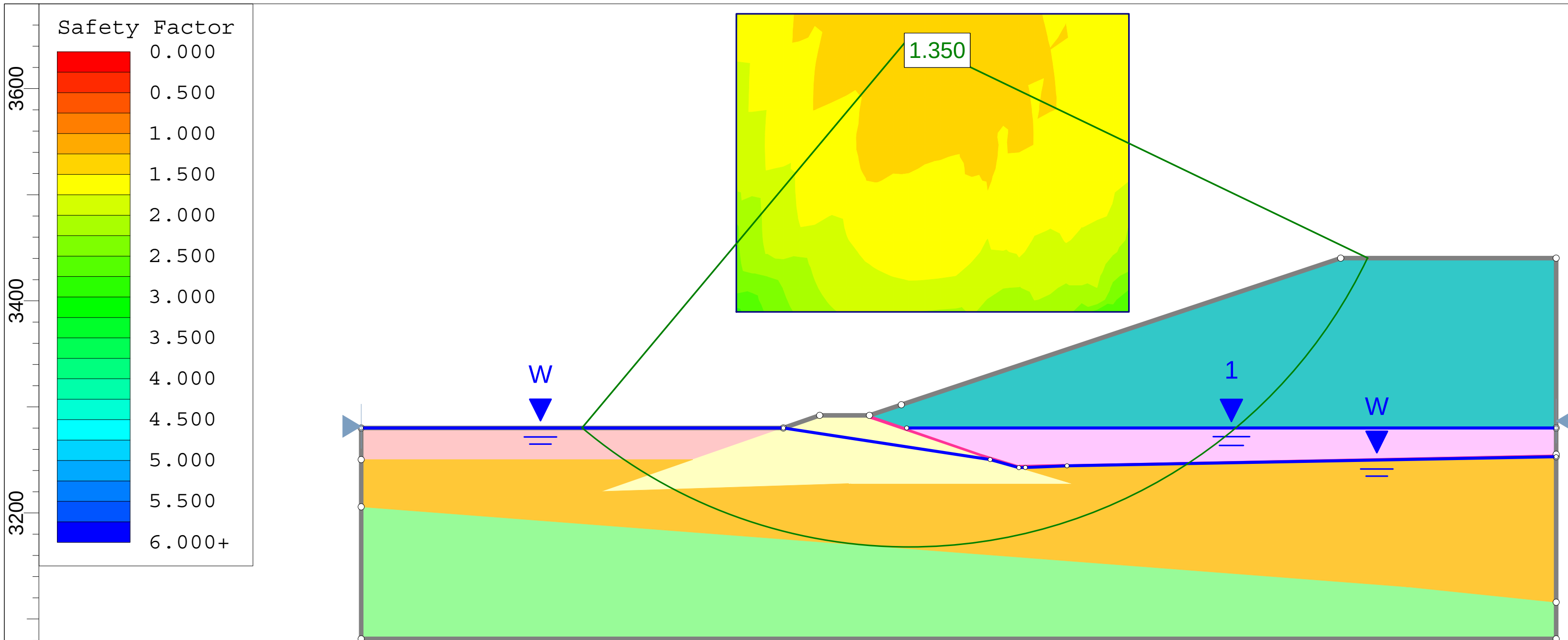
File Name C-C'_final_long term_circular.slim



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type
Dike Fill		125	130	Mohr-Coulomb	0	33	Water Surface	Custom
aged ash paste deposits		102	102	Mohr-Coulomb	0	35	Water Surface	Custom
Liner Interface		94	112	Mohr-Coulomb	0	13	Water Surface	Custom
fly ash fill		106		Mohr-Coulomb	0	37.8	Water Surface	Custom
Aged ash paste above liner		102	102	Mohr-Coulomb	0	35	Water Surface	Custom

Project	SLIDE - An Interactive Slope Stability Program		
Analysis Description			
Drawn By		*Scale* 1:2764	*Company*
Date 9/25/2015, 12:07:38 PM		*File Name* C-C'_final_long term_non-circular.slim	

SLIDEINTERPRET 6.036



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type	Cohesion Change (psf/ft)	Cutoff (psf)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
dike fill		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	1	
aged ash paste deposits		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	1	
fly ash slurry		103	103	Undrained	100		FDepth	9	3000			None			0
Liner Interface		94	112	Mohr-Coulomb	0	13						Water Surface	Custom	1	
fly ash fill		106		Mohr-Coulomb	0	37.8						Water Surface	Custom	1	
Aged ash paste above liner		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	1	
alluvium		124	124	Mohr-Coulomb	0	21						Water Surface	Custom	1	

-600 -400 -200 0 200 400 600 800 1000

Project

SLIDE - An Interactive Slope Stability Program

Analysis Description

Drawn By

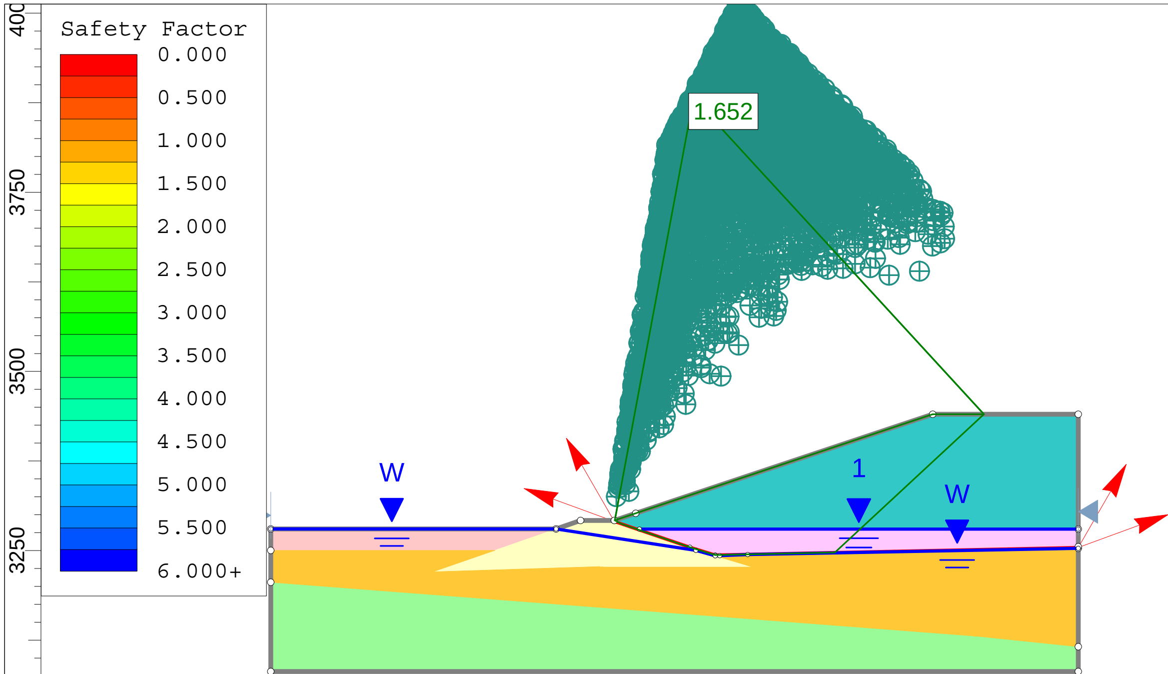
Scale 1:2062

Company

Date 9/25/2015, 12:07:38 PM

File Name C-C'_final_short term_circular.slim

SLIDEINTERPRET 6.036



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type	Cohesion Change (psf/ft)	Cutoff (psf)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
dike fill		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	1	
aged ash paste deposits		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	1	
fly ash slurry		103	103	Undrained	100		FDepth	9	3000			None			0
Liner Interface		94	112	Mohr-Coulomb	0	13						Water Surface	Custom	1	
fly ash fill		106		Mohr-Coulomb	0	37.8						Water Surface	Custom	1	
Aged ash paste above liner		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	1	
alluvium		124	124	Mohr-Coulomb	0	21						Water Surface	Custom	1	

-500 -250 0 250 500 750 1000 1250 1500 1750 2000

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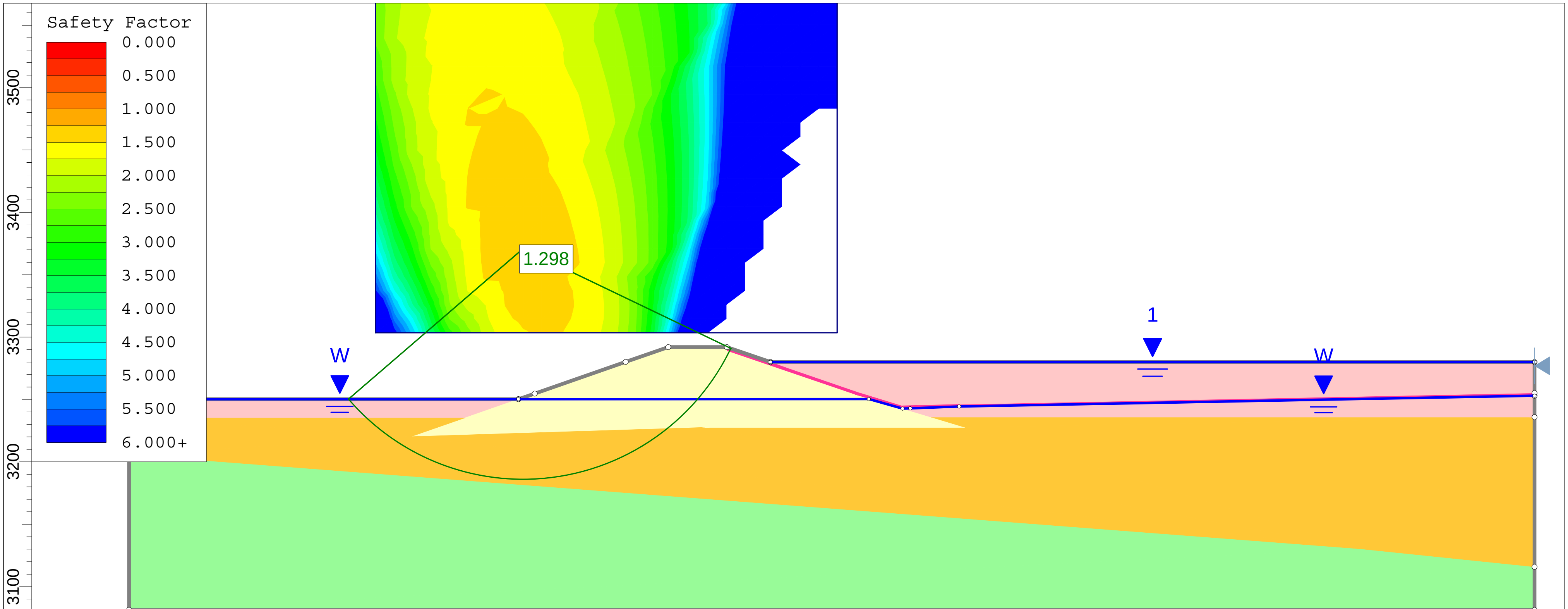
SLIDEINTERPRET 6.036

Project	SLIDE - An Interactive Slope Stability Program
Analysis Description	
Drawn By	*Scale* 1:3215
Company	
Date 9/25/2015, 12:07:38 PM	*File Name* C-C'_final_short term_non-circular.slim



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type	Cohesion Change (psf/ft)	Cutoff (psf)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
dike fill		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	1	
aged ash paste deposits		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	1	
fly ash slurry		103	103	Undrained	100		FDepth	9	3000			None			0
Liner Interface		94	112	Mohr-Coulomb	0	13						Water Surface	Custom	1	
alluvium		124	124	Mohr-Coulomb	0	21						Water Surface	Custom	1	

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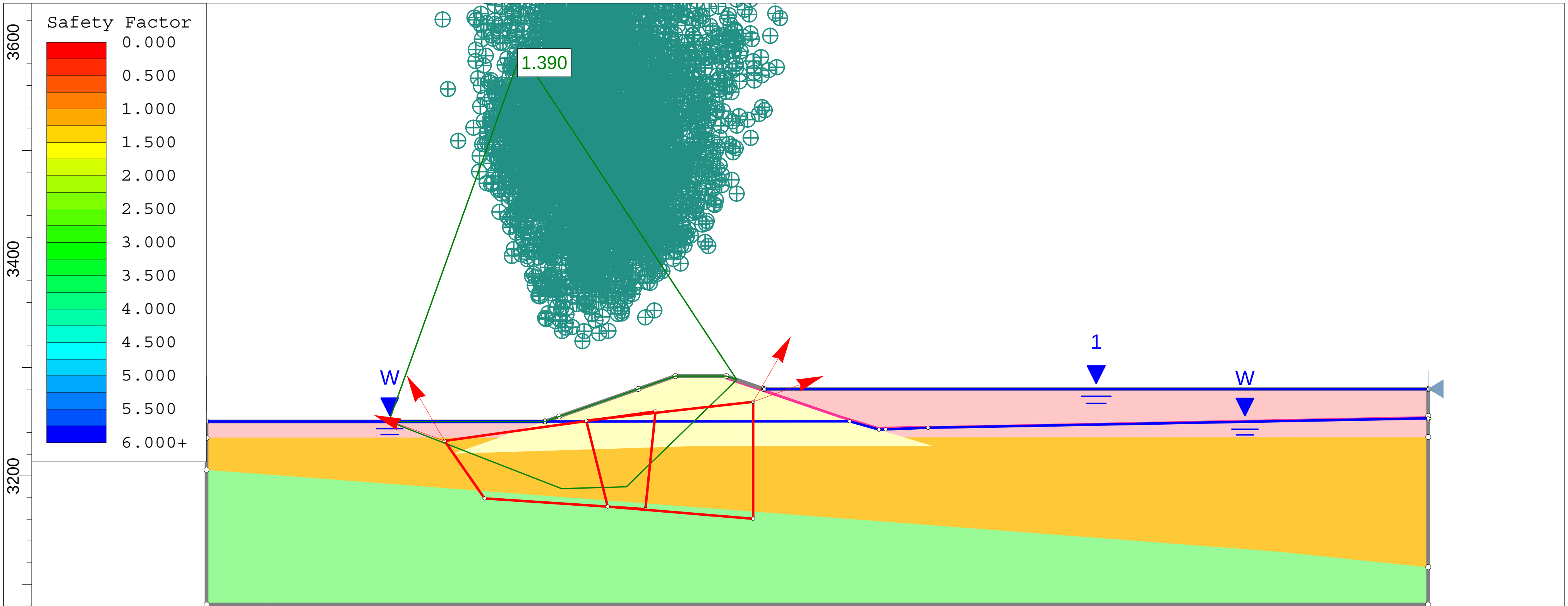
SLIDEINTERPRET 6.036

Project	SLIDE - An Interactive Slope Stability Program		
Analysis Description			
Drawn By		*Scale* 1:1431	*Company*
Date 9/25/2015, 12:07:38 PM		*File Name* C-C'_intermediate_short term_circular.slim	



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type	Cohesion Change (psf/ft)	Cutoff (psf)	Vertical Stress Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
dike fill		125	130	Mohr-Coulomb	750	22.5						Water Surface	Custom	1	
aged ash paste deposits		102	102	Strength=F(overburden)						0.25	0	Water Surface	Custom	1	
fly ash slurry		103	103	Undrained	100		FDepth	9	3000			None			0
Liner Interface		94	112	Mohr-Coulomb	0	13						Water Surface	Custom	1	
alluvium		124	124	Mohr-Coulomb	0	21						Water Surface	Custom	1	

3000 2800

-400 -200 0 200 400 600 800

Project

SLIDE - An Interactive Slope Stability Program

Analysis Description

Drawn By

Scale 1:1646

Company

Date 9/25/2015, 12:07:38 PM

File Name C-C'_intermediate_short term_non-circular.slim

SLIDEINTERPRET 6.036