MEMORANDUM

SUBJECT: EPA Comments on "Assessment of Dam Safety of Coal Combustion Surface Impoundments: GenOn Energy – Shawville Generating Station, Shawville, PA"

DATE: September 9, 2013

1. In Section 2 "Project /Facility Description," it would be advantageous to provide in summary the greatest dimensions, i.e., embankment height, volume, of the impoundment or independent Ash Ponds. It appears the most useful dimension for height would be from average low water mark in the Susquehanna River West Branch to max. crest height.
2. In Section 2.1.1 "Ash Ponds A and B," it would be advantageous to detail that there exists an interconnected system of decant devices, the basis for eventually rating the two Ash Ponds (correctly) as 1 impoundment. Additionally, although it may be evident to engineers, it may be advantageous to expressly state that there does not, and can not, exist a hydraulic differential between the two ponds.
3. In Section 2.2.1 "Ash Ponds A and B," it would be advantageous to explicitly state why it is the PA DEP, i.e., for which of there criteria previously listed, does not regulate the impoundments.
4. In Section 2.2.1 "Ash Ponds A and B," it would be advantageous to provide the reasoning as to why, exactly, the impact to the West Branch would be minimal in the event of a release. Although this may be accurate, the perception would be that given the proximity of the unit to the West Branch, i.e., the downstream slopes slope to the river, there would be significant damage to the environment given a breach or release of the unit.
5. In Section 2.3.1 "Embankment configuration," it may be advantageous to provide and approximate depth of the impoundment (Ash Pond A) and estimate of the accumulated height of material at the base of the impoundment. It is currently unclear from this section the depth of standing water from base of the "new" pond (Ash Ponds A + B) from the original base of Pond 1.
6. In Section 2.3.1 "Embankment configuration," it would be advantageous to explain if there exists any protective cover, e.g., rip-rap armor, on the outboard slope of the impoundments on the West Branch of the Susquehanna River. Typically, erosion is a concern in configurations such as this, i.e., slope that contact without buttress the surface of a water body, and is not addressed in the report.
7. On page 6, in Section 2.3.1, under Ash Pond B, last paragraph, first line, replace "Ash Pond A includes a synthetic liner" with "Ash Pond B includes a synthetic liner".
8. In Section 2.3.2 "Type of Materials Impounded," the presence or lack of FGD gypsum and boiler slag should explicitly be addressed in the report.
9. The report should address the original construction material of the embankments, if known. This should include the original embankment material from Pond 1 as well as the new material used for Ash Pond A and Ash Pond B. The divider dike is the only material that is stated in the report.
10. On page 8, in Table 3.1, was the document titled: "Response to EPA RFI" the RFI from the EPA's Office Of Water?
11. Throughout the report please replace "inspection" with "assessment" as it relates to O'Brien & Gere's activities (particularly in Section 4).

12. Incorporate as an appendix, the email from OB&G to Patrick Kelly concerning initial comments/inquiry on Draft Report.*

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*
From: Kelly, PatrickM
Sent: Wednesday, September 11, 2013 9:40 AM
To: 'Gary Emmanuel'
Cc: 'Robert Bowers'; Hoffman, Stephen
Subject: EPA CCR Dam Assessments - GenOn/NRG Shawville

Good morning Gary,

I just needed some clarification on an issue I have regarding the configuration of the impoundments at the GenOn/NRG Shawville Generating Station, specifically the northwest embankment of Ash Pond A and Ash Pond B. The issue relates to the need for performance of structural stability analyses on the unit and therefore has some bearing on the report.

In the report, it is apparent that the existing units, Ash Pond A and Ash Pond B, are built on top of the decommissioned Pond 2. The report goes on to state that the northwest embankment of the ponds is primarily composed of the natural slope of the river bank with an additional approx. 2' diked portion overlaying the natural slope to provide drive access on the crest. It does not appear from the report that the natural slope is armored in any way by rip-rap or other material protection.

Does the configuration of the embankment, specifically as seen in elevation views from Figure 3 in the attachements of the report, present a concern in a flood condition in the West Branch of the Susquehanna River, i.e., elevated phreatic surface and potential subsequent downstream rapid drawdown condition in the downstream(outboard) slope? Additionally, would it be overly-conservative to analyze the downstream embankment based on its configuration and subsequent lack of lateral soil pressure buffering the embankment?

Typically, with incised units, we have encountered some setback or buttressing from a river, stream, or lake, and more frequently units that are a negligible proximity to water body. Because the embankment of the unit is composed of the natural slope of the river which falls to the water itself, I wanted to ensure there wouldn't be any previously unforeseen consequences.

Thanks a bunch.

-PK

Patrick M. Kelly, P.E.

Environmental Engineer

U.S. Environmental Protection Agency

Office of Solid Waste and Emergency Response

Phone: (703)308-7271

Kelly.PatrickM@epa.gov

From: Gary Emmanuel [mailto:Gary.Emmanuel@obg.com]
Sent: Tuesday, September 17, 2013 5:24 PM
To: Kelly, PatrickM
Cc: Robert Bowers; Hoffman, Stephen; Englander, Jana; Stephen Szewczak; Dreher Whetstone
Subject: RE: EPA CCR Dam Assessments - GenOn/NRG Shawville

Patrick-

We have evaluated your questions regarding the lack of stability analysis of the northwestern slopes and offer the following clarifications/discussions:

Given the close proximity to the West Branch of the Susquehanna River and the lack of any setbacks, benches, etc. on the slope, a recommendation to perform geotechnical slope stability analyses of these slopes would not be perceived as overly conservative in our opinion; however, we considered the following during preparation of our report recommendations:

1. The current impoundments or prior impoundment have been in operation at this site for over 60 years with no history of slope distress, failure, or other related incident.

2. The groundwater level in the embankment between the impoundment and the embankment is basically at river level. The West Br. Susquehanna River is not likely to remain at flood stage long enough to saturate the embankment to the point of elevating the phreatic surface substantially, especially considering that the soils between the river and the impoundment are not currently saturated due to the geomembrane liner on the floor and slopes of the impoundment.

3. Even if the slope did become partially saturated during flood stage, it is unlikely that the river level would recede more quickly than the soils forming the slope could drain, which is the condition that would be necessary to create the rapid drawdown instability you mentioned.

4. If the slope was prone to instability due to post-flood river recession, it is our opinion that there would be some history of slope sloughing, or other outward signs of slope distress. No signs of such distress or of past repairs or stabilization efforts was observed in the site visit.

5. The impoundment is planned for closure in about 2 years .

If this impoundment were to remain in operation for an extended period of time, we would likely recommend a geotechnical study and slope stability evaluation. However, given it's long history with no incident and upcoming closure in the near future, we believe a regular visual monitoring plan looking for signs of slope distress is the most practical recommendation for Ponds A and B.

Please contact me with any more questions.

Regards,

Gary

O'BRIEN & GERE

Gary B. Emmanuel, P.E.

Sr. Managing Engineer

O'BRIEN & GERE

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Gary.Emmanuel@obg.com   www.obg.com

From: Kelly, PatrickM [mailto:Kelly.PatrickM@epa.gov]
Sent: Wednesday, September 18, 2013 9:17 AM
To: Gary Emmanuel
Cc: Robert Bowers; Hoffman, Stephen; Englander, Jana; Stephen Szewczak; Dreher Whetstone
Subject: RE: EPA CCR Dam Assessments - GenOn/NRG Shawville

Gary,

We concur with O'Brien and Gere's rationale for not requiring stability analysis of the embankments at the GenOn/NRG Shawille Plant based on the reasons enumerated in your email.

Please include these reasons in a signed memo on O'Brien and Gere letterhead as an attachment in the final draft of the Dam Assessment report, and include a reference in the body of the report to the attachment. Jana Englander will follow up with you regarding miscellaneous comments to the draft report to be incorporated in the final report in addition to the signed memo.

Again, thanks for your clarification on this issue.

Patrick M. Kelly, P.E.

Environmental Engineer

U.S. Environmental Protection Agency

Office of Solid Waste and Emergency Response

Phone: (703)308-7271

Kelly.PatrickM@epa.gov

From: Maines, Heath
To: Hoffman, Stephen; Englander, Jana
Subject: GenOn Shawville Power Plant Comments
Date: Tuesday, October 29, 2013 1:51:18 PM

All,

Pennsylvania DEP Dam Safety has reviewed the draft assessment report for GenOn's Shawville Power Plant. The Department concurs with the findings of the O'Brien & Gere report and offers the following additional comment:

Section 2.2.1 of the report states that "PADEP Division of Dam Safety currently does not regulate the impoundment containing Ash Ponds A and B." Upon review of the information presented in the report, the Department has determined that the dams are jurisdictional under 25 PA Code §105.3(a)(3) - *Dams used for the storage of fluids or semifluids other than water, the escape of which may result in air, water, or land pollution or in danger to persons or property.* The Department will regulate the ring dam that contains Ash Pond A and B and the appurtenant structures of the dam. The Department has preliminarily assigned the structure as class "C-4" dam based on the size and hazard potential and will regulate the dam until it is no longer used for ash disposal. The dam is now identified by the Department as D17-126 – Shawville Power Plant A and B. The dam will be periodically inspected by the Department and any deficiencies will be reported to the owner.

Thanks,

Heath

Heath A. Maines| Civil Engineer Hydraulic
Eastern Section
Division of Dam Safety
Department of Environmental Protection
Rachel Carson State Office Building
400 Market Street | Harrisburg, PA 17101
Phone: 717.772.5960 | Fax: 717.772.0409
www.depweb.state.pa.us

From:	Frank, Stephen
To:	Englander, Jana; Hoffman, Stephen
Subject:	Comment Request on Coal Ash Site Assessment Round 12 Draft Report - Shawville Generating Station
Date:	Wednesday, November 27, 2013 11:18:57 AM
Attachments:	07129_PartD_shawville_POND_1.pdf SH Pond A Overflow.pdf Final Shawville Evaluation 11.22.13.pdf SH Pond A Overflow Structure photos.pdf

Dear Mr. Hoffman and Ms. Englander,

As requested, NRG has reviewed and is providing the following comments on the Draft Report for Shawville Generating Station:

- The station owner and operator is NRG REMA LLC (NRG), a subsidiary of NRG Energy, Inc. and should replace "GenOn Energy" throughout the report.

- Based on the assessment conducted by Geosyntec (attached), the embankments for the Ash Filter Ponds are sufficiently stable, and it is appropriate for the EPA to report a condition of "Satisfactory," instead of "Fair," for continued safe and reliable operations of the impoundments at the Shawville Generating Station.

- Page 6, Section 2.3.2 – Types of materials impounded also includes clarifier sludge. A water balance for the ponds is attached.

- Page 9, last paragraph of Section 3.1, please replace the word "terminated" with the word "deactivated" with respect to the station's operating status.

- The conclusions for the Ash Filter Pond A did not reflect the presence of a gravity emergency overflow from Pond A to Pond B that would prevent overtopping of the embankments in Pond A. Additional information regarding this overflow is included in the Geosyntec report, which is attached to this e-mail. Photographs depicting the overflow structure are also attached.

- As recommended, NRG will increase maintenance activities to control heavy vegetation and to remove diseased and dead trees to facilitate visual inspections of the embankments for signs of erosion, movement, seepage or animal burrows.

Please do not hesitate to contact me with any questions or comments.

Thank you, Steve

Stephen M. Frank, PE

NRG Energy

Senior Environmental Specialist
NRG Energy Southpointe Operations Center
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P 724.597.8310
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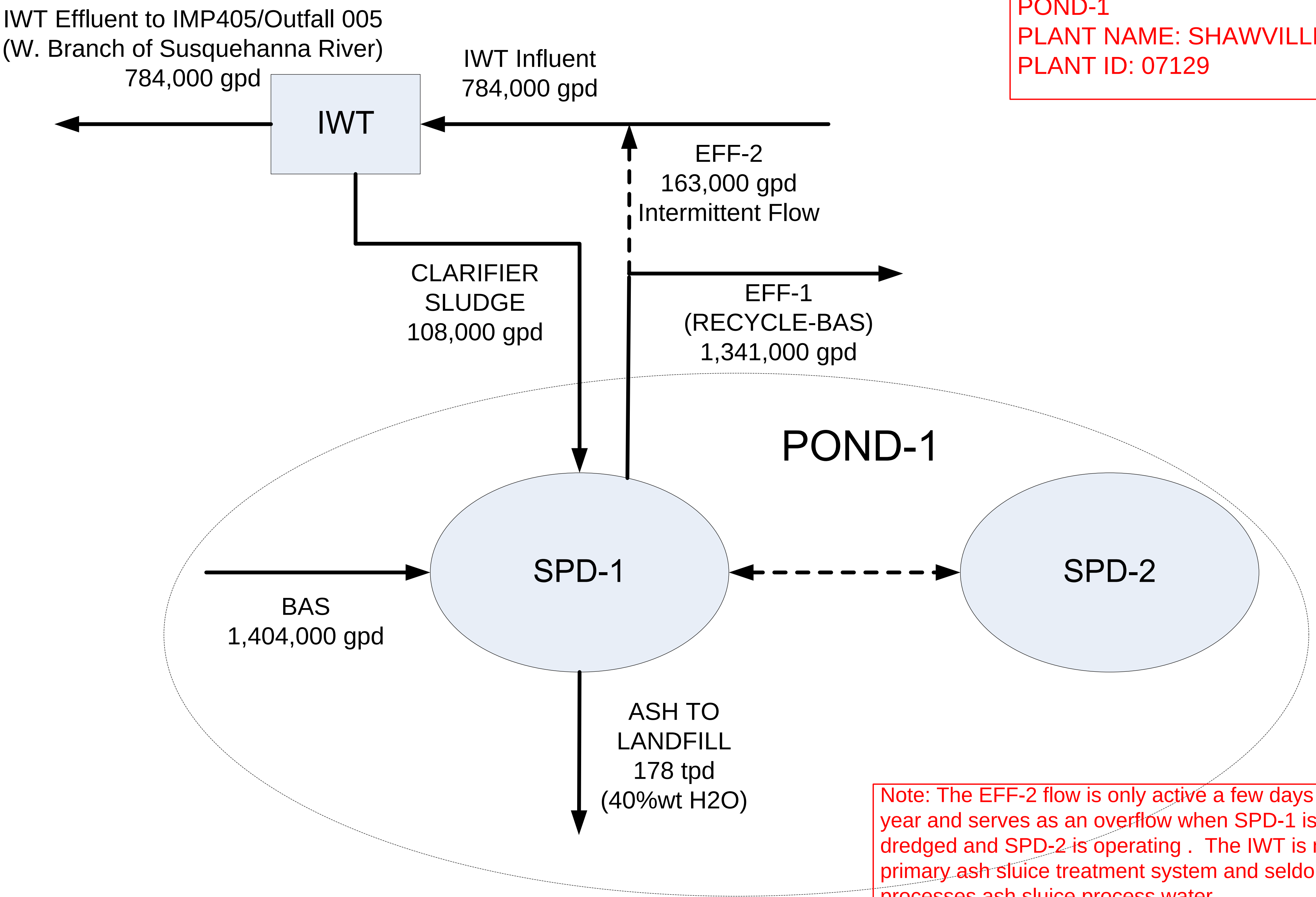
POND-1
PLANT NAME: SHAWVILLE
PLANT ID: 07129



Note: The EFF-2 flow is only active a few days of the year and serves as an overflow when SPD-1 is being dredged and SPD-2 is operating . The IWT is not a primary ash sluice treatment system and seldom processes ash sluice process water.

Geosyntec consultants

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22 November 2013

NRG Energy, Inc.
121 Champion Way
Suite 300
Canonsburg, PA 15317

Attention: Mr. Stephen Frank, P.E.
Senior Environmental Specialist

Subject: Bottom Ash Pond Assessment Report
Shawville Power Station
Shawville, Pennsylvania

Dear Mr. Frank:

Geosyntec is pleased to submit this letter report presenting the findings of an assessment of the bottom ash pond (BAP) embankments at the NRG REMA, LLC Shawville Power Station (site). The bottom ash water recycle system at the Shawville site consists of two ponds, denoted as Ponds A and B, which were recently evaluated by the United States Environmental Protection Agency (EPA) as part of its ongoing national effort to assess the management of coal combustion waste (CCW). The results of this evaluation by EPA are presented in the preliminary report (referred to as draft EPA report hereafter), prepared by O'Brien & Gere Engineers, Inc. and dated 17 December 2012.

This letter report was prepared by Geosyntec Consultants (Geosyntec) for NRG Energy, Inc. (NRG), in accordance with Geosyntec's proposal to GenOn dated 30 November 2012. After the approval of our proposal and prior to the conclusion of this report, NRG and GenOn combined and will retain the name NRG Energy, Inc. As a result of the merger and name change, GenOn REMA, LLC is now NRG REMA, LLC, a wholly owned subsidiary of NRG.

The main purpose of this report is to document the subsurface geotechnical condition and evaluate the embankment stability for both ponds. One of the review comments in EPA's draft report is the lack of stability analyses and as-built geotechnical information. Thus, the stability analysis and geotechnical information presented in this report supplement the EPA report. This report also provides additional information to address the comments and recommendations in EPA's draft report. This report complements Geosyntec's previous report dated 21 February 2013.

This report presents the results of the following activities: (i) field investigation of site conditions and soil properties; (ii) general assessment of the stability of the embankments; and (iii) hazard potential and condition assessment of the embankments. This letter report was prepared by Dr.

Chunling Li, P.E. and Dr. Lucas de Melo, P.E., and it was reviewed by Mr. Michael Houlihan, P.E., in accordance with Geosyntec's peer review policy.

BACKGROUND

The Shawville Power Station has two bottom ash ponds (BAPs) (i.e., Ash Pond A and Ash Pond B) that are part of the site's bottom ash water recycle system. Both ponds have an engineered liner system consisting of a PVC liner with geotextile cushion fabric. The ponds were constructed using a combination of diked and incised construction methods, with the embankments for the diked portion of the ponds running parallel to the west branch Susquehanna River (river). The current configuration of Ash Ponds A and B has been in service since 1989. The locations of the BAPs are shown in Figure 1, which also illustrates the orientation of the ponds in relation to the river. A typical cross section of the northwest embankment, depicting the spatial relationship of the pre-1989 embankment to the 1989 vertical expansion of the embankment, is provided in Figure 2.

EVALUATION BY EPA

EPA conducted inspections of the BAPs on 6 September 2012. The draft EPA report, prepared by O'Brien & Gere Engineers, Inc. on 17 December 2012, provided a Condition Assessment of "Fair" and a Hazard Assessment of "Low" to the BAPs. According to EPA's guidelines, the Condition Assessment result can be "Satisfactory", "Fair", "Poor", or "Unsatisfactory" based on potential management unit safety deficiencies, expected performance under applicable loading conditions (i.e., static, hydrologic, seismic), the need for remedial action, and the need for additional critical studies or investigations to identify any potential dam safety deficiencies. The Hazard Potential classification can be "less than low", "low", "significant", or "high" for an impoundment. Because the BAPs at the Shawville site have received a "low" hazardous rating in the draft EPA report, Geosyntec will not provide a hazard potential classification in this letter report.

EPA's draft report also provided recommendations on long-term improvement, maintenance and further study of both ponds. None of these recommended items are deemed as urgent by EPA. Therefore, NRG will continue to monitor and maintain the impoundments following industry standards and these long-term recommendations will be addressed at a later date. However, NRG would like to address in this present report a recommendation provided by EPA regarding the outlet of Pond A:

> "*consider installation of overflow section on the center dividing dike to control overtopping during large storm events.*"

Currently, the ash sluice discharge channel, which houses the ash discharging piping into Pond A and Pond B, also serves as an emergency discharge pathway. Pond A will drain into the Pond B through the ash sluice channel once the water level in Pond A reaches the level where the ash sluice discharging piping enter the pond at the southwest corner. This feature is shown on the Aerial Map (Figure 2) and Photo 15 of the draft EPA report. Therefore, it is our understanding that this recommendation is already implemented.

VISUAL INSPECTION

On 18 December 2012, Mr. Wade Tyner of Geosyntec performed a site walkthrough and visual assessment of the BAP embankments following the general guidance provided in the EPA's Coal Combustion Dam Inspection Checklist Form (checklist). Lawrence J. Rapski and Stephen Dixon, both from NRG, were present at the site during the walkthrough. Pictures taken during the visual inspection of the ponds' embankments are included in Appendix A. Geosyntec used EPA's checklist as a guide to field assessment in an attempt to focus field observations on areas and issues that might receive comments from EPA. A copy of this checklist form is included in Appendix B.

Mr. Tyner's observations and Geosyntec's comments regarding the overall performance of the ponds' embankments are presented in Table 1. The items in the table are correlated to the numbering presented in the EPA's checklist form.

GEOTECHNICAL FIELD INVESTIGATION

On 18 December 2012, Geosyntec conducted a geotechnical field investigation to collect data for assessing the stability of the BAP embankments. The geotechnical field investigation consisted of drilling four test borings, identified as HSA-1 through HSA-4, at the locations shown in Figure 1. Two borings were advanced along the inside crest of the northwest embankment for each BAP, which are the highest portions of the BAP embankments (i.e., approximately 24 feet high). Three borings were drilled to an approximate depth of 25 feet below the existing ground surface (ft-bgs); one boring (HSA-4) was drilled to a depth of approximately 30 ft-bgs.

A track-mounted drill rig with a hollow-stem auger was used to advance the test borings. The auger has an internal diameter of 3.25 inches and outside diameter of 6 inches. Soil samples were obtained using a split-spoon sampler in accordance with ASTM D 1586 [ASTM, 2009]. Sampling was conducted continuously (i.e. every 2 feet of depth) in three of the four borings; sampling in HSA-4 was conducted once for every five feet of depth. The soil penetration resistance was measured at all sample locations using the Standard Penetration Test (SPT) and recording blow counts (i.e., N-values). The N-value is the number of blows required for a 140-pound (lb) hammer dropping 30 inches (in.) to drive the sampler through a 12-in. interval. Boring logs and reports of laboratory test results are included in Appendix C of this report. Laboratory tests, including particle size analysis (ASTM D422, without hydrometer analysis) and Atterberg limits (ASTM D4318) were performed on select samples. The boreholes were backfilled to the ground surface using cuttings and coated bentonite pellets.

Based on Geosyntec's observations of the samples collected from the borings, the ponds' embankments were constructed using fine-grained soils with occasional layers of gravelly soils, which were visually classified under the Unified Soils Classification System as MH (high-plasticity silt), ML (sandy silt), SC (clayey sand), and GP (poorly graded gravel). SPT N-values varied between 6 and 36 blows/ft, with an average value of 16 blows/ft (excluding the soft layer between 20 to 26 ft-bgs in HSA-2, and gravel lenses where N-values were greater than 50). Sandstone bedrock was encountered at approximately 30 feet and 26 ft-bgs in the Pond B embankment, in HSA-3 and HSA-4, respectively. No rock coring was performed.

Due to the location of underground utilities, borings were progressed along the inside crest of the berms. In borings HSA-1 and HSA-2, which were drilled into the embankment of Ash Pond A, it is likely that the soil samples were collected from the portion of the embankment that was built over the pre-existing embankment (i.e. pre-1989 embankment) and from the native material that formed the bottom of the unlined ash pond that later became Ash Pond A. The cross section provided in Figure 2 depicts the approximate locations of borings HSA-1 and HSA-2 in relation to the pre-existing embankment. Because the pond was constructed using a combination of diked/incised construction methods, it is assumed that the pre-existing embankment was constructed using the material removed from the excavation of the pond. Based on the boring logs for HSA-1 and HSA-2, the native material is likely to be either a sandy clay (CL) or low-plasticity silt (ML). Therefore, it is assumed that the pre-existing berms are constructed from either CL or ML soil. Hence, two stability analyses were conducted: one assuming that the pre-existing berm was constructed using CL soils and another assuming that the pre-existing berm was constructed using ML soils. The shear strength parameters for these soils were conservatively selected based on the lower SPT N-values encountered for each material.

Shear-strength properties for the embankment, the pre-existing embankment, and the foundation soils were selected based on well-established correlations with soil type, N-value, and or plasticity of the soil (i.e. Atterberg Limits). References for these correlations and the selected shear-strength properties for each soil are presented in Appendix D (i.e., Stability Analysis).

Groundwater was encountered in the Pond A embankment at 25 feet and 22 ft-bgs in HSA-1 and HSA-2, respectively. In the Pond B embankment, groundwater was encountered at approximately 29 and 25 ft-bgs, in HSA-3 and HSA-4, respectively.

TABLE 1
VISUAL INSPECTION

BAP – Shawville Power Station
Shawville, Pennsylvania

EPA's Coal Combustion Dam Inspection Checklist Form		Comments
Item Number	**Item Description**	
1	Frequency of Company's Dam Inspections	Maintenance and inspection records were not available at the time of the walkthrough but, based on the conditions of the embankments' outer slopes at the time of the site walkthrough, it appears that vegetation is well established (see Photographs 5, 7, and 8 in Appendix A). No signs of significant erosion were observed (i.e., rills, gullies, or frost wedging). Design drawings that were prepared for the previous raising of the ash pond embankments were provided to Geosyntec for review by NRG for the purpose of estimating the steepness of the existing slope for use in the stability analysis. Neither as-built records for the ponds' embankments nor recent topographic surveys were available. Therefore, it was not possible to confirm that the design slopes accurately represent the dimensions of the existing embankments.

STABILITY EVALUATION

Geosyntec performed a stability analysis of the ponds' embankments. One representative cross section was selected for the analysis based on review of subsurface conditions, visual inspection, and pond geometry. The location of the selected cross section is the approximate center of the northwest embankment of Ash Pond A, as shown in Figure 1. This section was selected because of its proximity to HSA-2, where the weakest soil layer was encountered. In addition, Ash Pond A is the primary pond, meaning that water levels in Ash Pond A are typically higher than in Ash Pond B at any given time. Thus, the selected cross section at Ash Pond A represents the critical cross section and analysis results will likely represent the lowest expected factor of safety against failure of the BAPs' embankments.

The geometry of the embankment was obtained from the design plans prepared by Gilbert/Commonwealth, Inc., dated August 1987. Post-construction survey was not available to Geosyntec at the time of this evaluation. As a result, the actual steepness of the existing slopes could not be confirmed.

Stability was analyzed under static and seismic loading conditions. In the analysis, the pond was considered to be full because this is the critical failure scenario. No rapid drawdown analysis was found to be necessary because, under this loading condition, the inner slope of the empty pond would represent the critical failure condition, which would not cause ash release or result in a hazard of the type that is contemplated in the EPA assessment. The major static load applied to the foundation soils is the gravity load exerted by the weight of the berm. A surcharge load of 250 pounds per square foot (psf) was applied to the top of the embankment to model traffic loading on top of the embankment. This is a conservative assumption, because traffic loads are not permanent loads. Seismic loading was modeled considering the maximum horizontal acceleration in bedrock for the Shawville facility site of 0.146g (g is the gravitational acceleration) and seismic coefficient of 0.073. Details on the derivation of these parameters are included in Appendix D (i.e., Stability Analysis).

The groundwater table in the area is connected to the water level of the Susquehanna River located to the north of the ponds, which is estimated to be at elevation 1,044 ft-msl. In the analysis, a groundwater table at elevation 1044 ft-msl was assigned to the foundation soils.

A summary of stability analyses results are presented in Table 2. Complete analyses are included in Appendix D (i.e., Stability Analysis).

TABLE 2
RESULTING FACTOR OF SAFETY – SLOPE STABILITY ANALYSIS

BAP – Shawville Power Station
Shawville, Pennsylvania

Embankment Slopes	Loading Conditions	Failure Mode	Calculated F.S.	Target F.S
Case 1 (assume silt, i.e., ML, in pre-existing soil berm)	Static	Circular	1.51	1.5
		Block	1.59	1.5
	Seismic	Circular	1.27	1.2
		Block	1.33	1.2
Case 2 (assume clay, i.e. CL, in pre-existing soil berm)	Static	Circular	1.53	1.5
		Block	1.60	1.5
	Seismic	Circular	1.28	1.2
		Block	1.34	1.2

CONDITION ASSESSMENT

As presented in the Background section of this letter, the preliminary EPA report provided a Hazard Potential classification of "Low" to the BAPs. Thus, Geosyntec's evaluation focuses on the conditional assessment. A summary of EPA's definitions for each ratings is provided below, followed by a summary of Geosyntec's own data collection, visual inspection, and review of existing documents to support our opinion regarding the appropriate classification.

Condition Assessment definitions, as accepted by EPA, are as follows:

- *Satisfactory:* *No existing or potential management unit safety deficiencies are recognized. Acceptable performance is expected under all applicable loading conditions (static, hydrologic, seismic) in accordance with the applicable criteria. Minor maintenance items may be required.*

- *<u>Fair:</u> Acceptable performance is expected under all required loading conditions (static, hydrologic, seismic) in accordance with the applicable safety regulatory criteria. Minor deficiencies may exist that require remedial action and/or secondary studies or investigations.*

- *<u>Poor:</u> A management unit safety deficiency is recognized for a required loading condition (static, hydrologic, seismic) in accordance with the applicable dam safety regulatory criteria. Remedial action is necessary. "Poor" also applies when further critical studies or investigations are needed to identify any potential dam safety deficiencies.*

- *<u>Unsatisfactory:</u> Considered unsafe. A dam safety deficiency is recognized that requires immediate or emergency remedial action for problem resolution. Reservoir restrictions may be necessary."*

During the 18 December 2012 site visit, Geosyntec personnel met with the representatives of NRG to identify and review available BAP design data and historical geotechnical records. Monitoring well logs and design drawings for the BAPs were made available to Geosyntec for review, and this information was used in the preparation of this letter report.

The Condition Assessment results provided in the draft EPA report are "Fair" for both ponds. Based on Geosyntec's past experience, the "Fair" rating is generally due to the lack of stability analysis and documentation of geotechnical information. Now that such information has been provided in this report and the embankments of the ponds showed satisfactory factors of safety in the slope stability evaluation (see Table 2), it is our opinion that that the Condition Assessment result of the BAP ponds at Shawville can be improved from "Fair" to "Satisfactory" .

CONCLUSIONS

Based on the assessment described in this letter, Geosyntec recommends that the Condition Assessment result is "Satisfactory". Other than a ground-run survey to verify the dimensions (i.e., slope) of the embankments, no other action is recommended at this time.

We would be happy to discuss with you if EPA has additional comments or requires any immediate actions.

Geosyntec appreciates the opportunity to be of assistance to NRG on this project. Please call any of the undersigned if you have any questions.

Sincerely,

Chunling Li, Ph. D, P.E.
Project Professional

Lucas de Melo, Ph.D., P.E.
Senior Engineer

Attachments: Appendix A – Photographic Record
Appendix B – EPA'S Combustion Dam Inspection Checklist Form
Appendix C – Boring Logs and Laboratory Data
Appendix D – Stability Analysis

Copies to: Michael Houlihan, P.E. (Geosyntec)

FIGURES

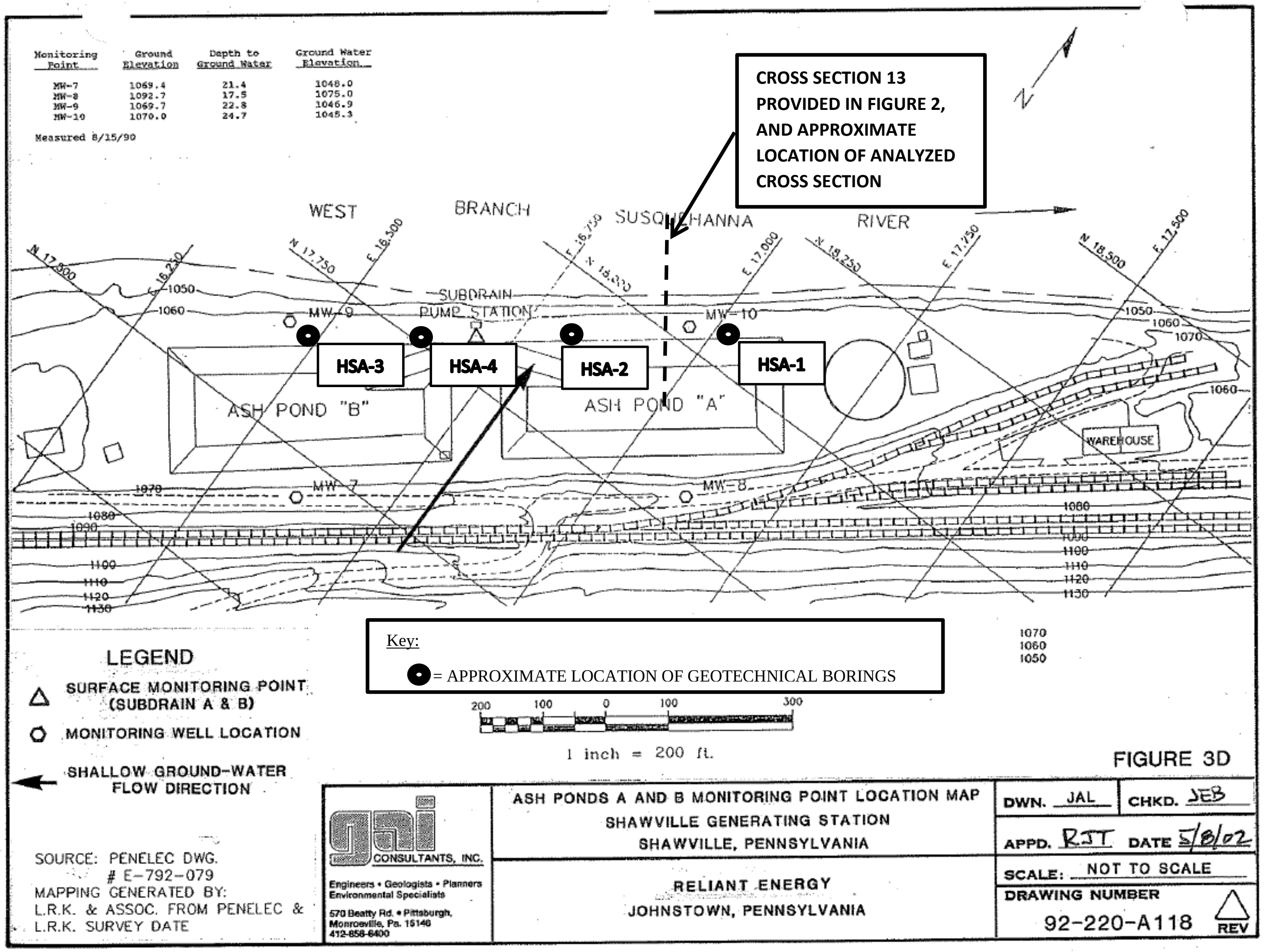

Figure 1 – Geotechnical Boring Locations

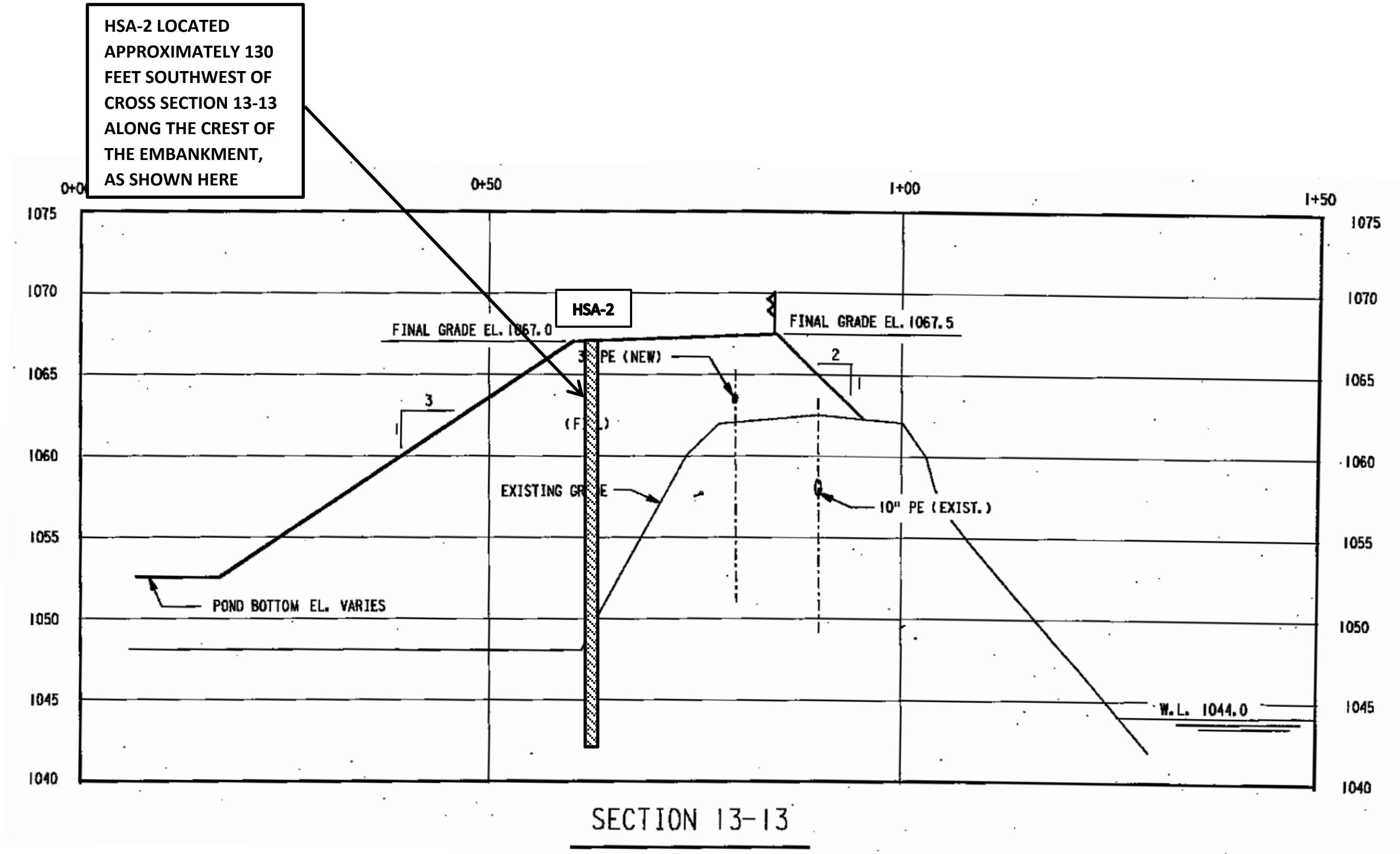

Figure 2 – Cross Section 13-13 of the Northwest Berm of Ash Pond A

APPENDIX A

PHOTOGRAPHIC RECORD

Geosyntec Consultants Photographic Record			
Client:	NRG, Inc.	Project Number:	ME0903
Site Name:	Shawville Power Station	Site Location:	Shawville, Pennsylvania

Photograph 1	
Date: 12/18/2012	
Location: Ash Pond A	
Ash Pond A as viewed from the north corner, looking south. The valve structure for the emergency overflow pipe is visible in the foreground.	

Photograph 2	
Date: 12/18/2012	
Location: Ash Pond A	
View of the northeast berm of Ash Pond A. Walkway on the right leads to the decant structure. The water treatment facility appears on the left side of the photo.	

GEOSYNTEC CONSULTANTS
Photographic Record

Client:	NRG, Inc.	Project Number:	ME0903
Site Name:	Shawville Power Station	Site Location:	Shawville, Pennsylvania

Photograph 3

Date: 12/18/2012

Location: Ash Pond A

Picture of the dividing berm between Ash Pond A and Ash Pond B. Picture is from the northwest berm of Ash Pond A, looking south.

Photograph 4

Date: 12/18/2012

Location: Ash Pond B

Picture of the dividing berm from the Ash Pond B side, looking southeast.

Client:	NRG, Inc.	Project Number:	ME0903
Site Name:	Shawville Power Station	Site Location:	Shawville, Pennsylvania

Photograph 5

Date: 12/18/2012

Location: River Bank

Outer slope (i.e. northwest slope) of Ash Pond A, looking southwest along the bank of the West Branch Susquehanna River. Large boulders, trees, and grass line the slopes.

Photograph 6

Date: 12/18/2012

Location: Ash Pond B

View of the southwest slope of Ash Pond B, looking southeast. Berm is relatively short (less than ten feet high, and a natural counterweight exists to the other side of the incised ditch shown here.

GEOSYNTEC CONSULTANTS Photographic Record			
Client: NRG, Inc.		Project Number:	ME0903
Site Name: Shawville Power Station		Site Location:	Shawville, Pennsylvania

Photograph 5

Date: 12/18/2012

Location: River Bank

Outer slope (i.e. northwest slope) of Ash Pond B, looking northeast along the bank of the West Branch Susquehanna River. Boulders, trees, and grass line the slopes.

Photograph 6

Date: 12/18/2012

Location: South Slope

Outer slope (i.e. northwest slope) of Ash Pond B, looking southwest along the bank of the West Branch Susquehanna River. Large boulders, trees, and grass line the slopes.

APPENDIX B

EPA'S COMBUSTION DAM INSPECTION CHECKLIST FORM

Coal Combustion Dam Inspection Checklist Form

US Environmental Protection Agency

Site Name:	Date:
Unit Name:	Operator's Name:
Unit I.D.:	Hazard Potential Classification: High Significant Low
Inspector's Name:	

Check the appropriate box below. Provide comments when appropriate. If not applicable or not available, record "N/A". Any unusual conditions or construction practices that should be noted in the comments section. For large diked embankments, separate checklists may be used for different embankment areas. If separate forms are used, identify approximate area that the form applies to in comments.

	Yes	No
1. Frequency of Company's Dam Inspections?		
2. Pool elevation (operator records)?		
3. Decant inlet elevation (operator records)?		
4. Open channel spillway elevation (operator records)?		
5. Lowest dam crest elevation (operator records)?		
6. If instrumentation is present, are readings recorded (operator records)?		
7. Is the embankment currently under construction?		
8. Foundation preparation (remove vegetation,stumps, topsoil in area where embankment fill will be placed)?		
9. Trees growing on embankment? (If so, indicate largest diameter below)		
10. Cracks or scarps on crest?		
11. Is there significant settlement along the crest?		
12. Are decant trashracks clear and in place?		
13. Depressions or sinkholes in tailings surface or whirlpool in the pool area?		
14. Clogged spillways, groin or diversion ditches?		
15. Are spillway or ditch linings deteriorated?		
16. Are outlets of decant or underdrains blocked?		
17. Cracks or scarps on slopes?		

	Yes	No
18. Sloughing or bulging on slopes?		
19. Major erosion or slope deterioration?		
20. Decant Pipes:		
Is water entering inlet, but not exiting outlet?		
Is water exiting outlet, but not entering inlet?		
Is water exiting outlet flowing clear?		
21. Seepage (specify location, if seepage carries fines, and approximate seepage rate below):		
From underdrain?		
At isolated points on embankment slopes?		
At natural hillside in the embankment area?		
Over widespread areas?		
From downstream foundation area?		
"Boils" beneath stream or ponded water?		
Around the outside of the decant pipe?		
22. Surface movements in valley bottom or on hillside?		
23. Water against downstream toe?		
24. Were Photos taken during the dam inspection?		

Major adverse changes in these items could cause instability and should be reported for further evaluation. Adverse conditions noted in these items should normally be described (extent, location, volume, etc.) in the space below and on the back of this sheet.

Inspection Issue #	Comments

APPENDIX C

BORING LOGS AND LABORATORY DATA

BORING LOG

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Boring ID	HSA-1		
Logged By	W. Tyner	Elevation	N/A
Date	12/18/2012	Northing	N/A
Project No.	ME0903	Easting	N/A
Project Name	GenOn Coal Ash Ponds		
		Drilling Method	HSA
Drilling Co.	Eichelbergers, Inc.	Bore Hole Diameter	6 INCHES
Driller(s)	Tom Growden / Mike Williams	Cave Depth	N/A
Rig Type	Track Mounted HSA	Depth to Water	25 feet BGS

Elevation	Depth (ft)	Blow Counts				N- Value	Material Description	USCS	Sample No.	Recovery
	0-2	-	-	-	-		Gravel road base with well graded sand	GW/SW	1	
	2-4	-	-	-	-					
	4-6	4	6	8	8	14	Yellowish orange fine silt (hit geotextile in anchor trench)	ML	2	50%
	6-8	4	8	20	20	28	Yellowish orange to greenish gray silt	ML	3	
	8-10	4	10	13	13	23	Yellowish orange to greenish gray silt with 5% gravel	ML	4	100%
	10-12	9	10	8	8	18	Light brown sandy silt with a ~2 inch thick layer of crushed limerock at about 11 feet BGS	ML	5	70%
	12-14	4	4	6	5	10	Transitioning to brown to light gray plastic silt with 25% gravel	MH/GP	6	75%
	14-16	7	5	4	4	9	Brown plastic silt with some caved in material in the top of the split-spoon (poor recovery)	ML/MH	7	30%
	16-18	4	3	4	4	7	Brown clayey sand with 5% gravel	SC	8	100%
	18-20	4	3	4	3	7	Crushed sandstone	Rock	9	10%
	20-22	4	6	6	5	12	Brown clayey sand with gravel (sandstone)	SC	10	60%
	22-24	5	5	4	2	9	Loamy soil with 15% gravel (moist - groundwater at approximately 25 feet BGS)	Loam	11	30%
	24-26	2	4	5	4	9	Silty fine sand - slightly plastic Boring terminated at 26 feet BGS. Backfilled with cuttings and three buckets of coated bentonite pellets.	SM/ML	12	100%

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BORING LOG

Boring ID	HSA-2		
Logged By	W. Tyner	Elevation	N/A
Date	12/18/2012	Northing	N/A
Project No.	ME0903	Easting	N/A
Project Name	GenOn Coal Ash Ponds		
		Drilling Method	HSA
Drilling Co.	Eichelbergers, Inc.	Bore Hole Diameter	6 INCHES
Driller(s)	Tom Growden / Mike Williams	Cave Depth	N/A
Rig Type	Track Mounted HSA	Depth to Water	22 feet BGS

Elevation	Depth (ft)	Blow Counts				N- Value	Material Description	USCS	Sample No.	Recovery
	0-2	-	-	-	-		Gravel road base and fine silt for first four feet of augering (as witnessed in cuttings - no samples collected)			
	2-4	-	-	-	-					
	4-6	4	6	10	10	16	Yellowish orange sandy silt and gravel	SM	1	50%
	6-8	14	18	18	18	36	silt with 35% gravel	GP-SM	2	100%
	8-10	12	11	11	14	22	Silty sand with 1/2" diameter gravel pieces (~50% gravel)	GP-SM	3	70%
	10-12	8	11	7	5	18	Silty sand with 1/2" diameter gravel pieces (~50% gravel)	GP-SM	4	50%
	12-14	3	3	3	2	6	Transitions to silty to clayer sand at 13 feet BGS	ML-SC	5	40%
	14-16	8	5	8	10	13	Silt transitioning to crushed sandstone at 15.5 feet BGS	ML-Rock	6	50%
	16-18	4	4	6	8	10	Clayey sand transitioning back to crushed sandstone	SC-Rock	7	60%
	18-20	8	8	5	3	13	Crushed sandstone transitions to loamy soil	Loam	8	50%
	20-22	6	3	2	4	5	Brown sandy clay	CL	9	50%
	22-24	2	1	1	2	2	Brown sandy clay below water table	CL	10	40%
	24-26	3	3	2	3	5	Sandy Clay Boring terminated at 26 feet BGS and backfilled with cuttings and three buckets of coated bentonite pellets.	CL	11	60%
							Lab Results for composite sample from 20' - 26' BGS: LL = 33; PL = 19; 61.7% Fines; 38.3% Sand			

BORING LOG

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Boring ID	HSA-3		
Logged By	W. Tyner	Elevation	N/A
Date	12/18/2012	Northing	N/A
Project No.	ME0903	Easting	N/A
Project Name	GenOn Coal Ash Ponds		
		Drilling Method	HSA
Drilling Co.	Eichelbergers, Inc.	Bore Hole Diameter	6 INCHES
Driller(s)	Tom Growden / Mike Williams	Cave Depth	N/A
Rig Type	Track Mounted HSA	Depth to Water	*Not encountered.*

Elevation	Depth (ft)	Blow Counts				N- Value	Material Description	USCS	Sample No.	Recovery
	0-2	-	-	-	-		Gravel road base and fine silt for first four feet of augering (as witnessed in cuttings - no samples collected)			
	2-4	-	-	-	-					
	4-6	8	9	16	5	25	Gravelly silt	GP	1	50%
	6-8	4	5	45	12	50	Gravelly silt, transitions to crushed sandstone at 7.5 ft BGS	GP-SM	2	40%
	8-10	15	12	15	7	27	Dry crushed sandstone with some silt	GP	3	50%
	10-12	6	5	4	6	9	Crushed sandstone transitions to sandy clay at 11 ft BGS	SC-CL	4	40%
	12-14	2	7	8	5	15	Clayey sand	SC-CL	5	80%
	14-16	4	2	6	6	8	Silty fine sand (brown)	SM	6	25%
	16-18	4	5	6	7	11	Silty fine sand	SM	7	75%
	18-20	6	>30	27	19	>57	Transition at 18.5 ft BGS to crushed sandstone with silt	GP	8	75%
	20-22	6	9	14	14	23	Brown silt	ML	9	50%
	22-24	10	13	16	20	29	Brown silt with 15% gravel	ML	10	60%
	24-26	9	10	13	13	23	Gray silt with 15% gravel	ML	11	80%
	26-28	10	12	14	12	26	Gray silty sand	SM	12	90%
	28-30	11	25	26	50	51	Sandstone at 29.5 feet BGS (no groundwater encountered) Boring terminated at 30 ft BGS. Backfilled with cutting and four buckets of coated bentonite pellets.			

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BORING LOG

Boring ID	HSA-4		
Logged By	W. Tyner	Elevation	N/A
Date	12/18/2012	Northing	N/A
Project No.	ME0903	Easting	N/A
Project Name	GenOn Coal Ash Ponds		
		Drilling Method	HSA
Drilling Co.	Eichelbergers, Inc.	Bore Hole Diameter	6 INCHES
Driller(s)	Tom Growden / Mike Williams	Cave Depth	N/A
Rig Type	Track Mounted HSA	Depth to Water	*25 feet (possibly perched)*

Elevation	Depth (ft)	Blow Counts				N- Value	Material Description	USCS	Sample No.	Recovery
	0-2 2-4	- -	- -	- -	- -		Gravel road base and fine silt for first four feet of augering (as witnessed in cuttings - no samples collected)			
	4-6	7	10	13	11	23	Yellowish orange silt with 15% gravel	SM	1	90%
	9-11	2	4	4	3	8	Mix of silt with 10% gravel, interspersed with gravel from shale and sandstone	ML	2	40%
	14-16	8	10	8	6	18	Brown silt with 10% gravel transitioning to sandstone at 15 feet BGS	ML	3	50%
	19-21	7	7	6	4	13	Limerock gravel	GP	4	10%
	24-26	1	4	9	9	13	Sandstone at 25.5 feet BGS with what appears to be perched water just above the stone. Below the sandstone (bottom of spoon), is a tight gray silt that appears to be dry.	ML/ Rock/ ML	5	
							Possible groundwater (maybe perched) at 25 feet BGS. Terminated boring at 26 feet BGS and backfilled with cuttings and four buckets of coated bentonite pellets.			

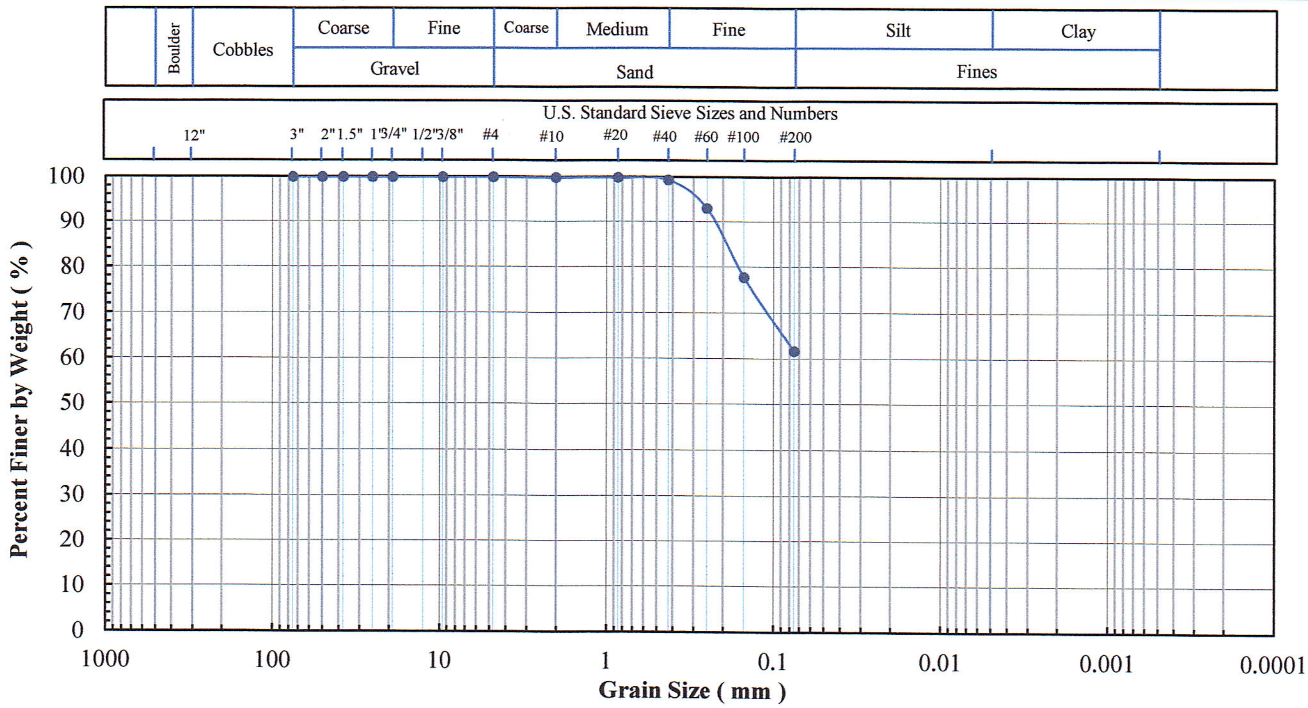
Excel Geotechnical Testing, Inc.
"Excellence in Testing"
953 Forrest Street, Roswell, Georgia 30075
Tel: (770) 910 7537 Fax: (770) 910 7538

Project Name:	Shawville Ash Ponds
Project No:	580
Client Sample ID:	HSA-2 (20-26')
Lab Sample No:	13A025

ASTM C 136, D 422, D 854, D 1140, D2216, D 2487, D4318

SOIL INDEX PROPERTIES

Grain Size, Spec. Gravity, Moist. Content, Eng. Classification, Atterberg Limits



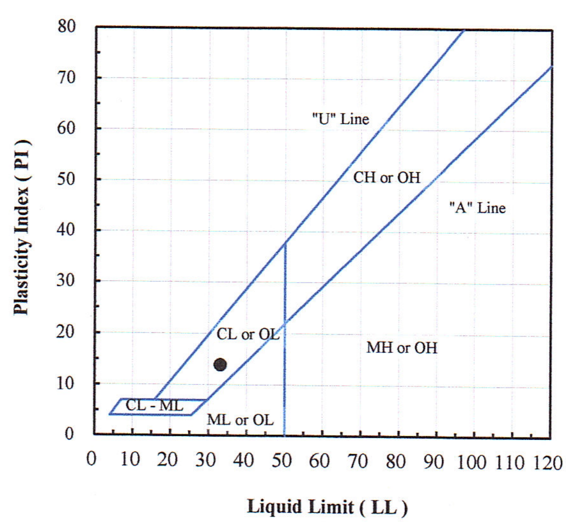
Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2.00	99.9
#20	0.850	99.9
#40	0.425	99.4
#60	0.250	93.0
#100	0.150	77.7
#200	0.075	61.7

Specific Gravity (-):	

Hydrometer Particle Diameter (mm)	% Finer

Gravel (%):	
Sand (%):	38.3
Fines (%):	61.7
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	
Coeff. Curv. (Cc):	



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (-)	PL (-)	PI (-)	Engineering Classification
HSA-2 (20-26')	13A025	24.9	61.7	33	19	14	CL - Sandy lean clay

Note(s):

1-14-13
NSR

APPENDIX D

STABILITY ANALYSIS

Geosyntec consultants

COMPUTATION COVER SHEET

Client: NRG **Project:** Shawville BAP Stability **Project/Proposal #:** ME0903 **Task #:** 02

TITLE OF COMPUTATIONS Stability Analysis for BAPs at Shawville Power Station

COMPUTATIONS BY:
Signature [signature] 2/21/2013 DATE
Printed Name and Title: Chunling Li, Engineer

ASSUMPTIONS AND PROCEDURES CHECKED BY: (Peer Reviewer)
Signature [signature] 2/21/2013 DATE
Printed Name and Title: Lucas de Melo, Senior Engineer

COMPUTATIONS CHECKED BY:
Signature [signature] 2/21/2013 DATE
Printed Name and Title: Lucas de Melo, Senior Engineer

COMPUTATIONS BACKCHECKED BY: (Originator)
Signature [signature] 2/21/2013 DATE
Printed Name and Title: Chunling Li, Engineer

APPROVED BY: (PM or Designate)
Signature [signature] 2/21/2013 DATE
Printed Name and Title: Michael Houlihan, Principal

APPROVAL NOTES:

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

STABILITY ANALYSIS FOR ASH POND AT SHAWVILLE POWER STATION

1. PURPOSE

As an ongoing national effort by the United States Environmental Protection Agency (USEPA) to assess the management of coal combustion waste (CCW), the stability of CCW ponds nationwide are target of a review. Geosyntec was engaged by NRG Energy, Inc. (NRG) to review the stability condition of two bottom ash ponds (BAPs) at the Shawville Power Station in Shawville, Pennsylvania. A slope stability analysis is conducted as a part of the review. The details of this analysis are presented in this calculation package.

2. BACKGROUND

Currently, there are two BAPs (denoted as Ash Pond A and Ash Pond B) at the Shawville facility. The embankments for Ash Pond A were constructed in prior to 1957, and later vertically raised to the current elevation in the late 1980's (placed into service in October 1989). The embankments for Ash Pond B were constructed concurrent with the vertical expansion of the Ash Pond A embankments. A liner system and decanting structures were also installed at the time of expansion. As a part of this pond stability assessment project, Geosyntec drilled four borings at the site, including two borings at each one of the ponds. The goal of this investigation was to collect samples and characterize the subsurface soils. Borings were advanced from the interior edge of the access road at the top of the pond embankments to a depth of approximately 26 to 30 feet at locations shown in Figure 1. The pond geometry was obtained from drawings by prepared Gilbert/Commonwealth, Inc. dated August 1987, and made available by NRG.

3. CROSS SECTIONS ANALYSED

One critical cross section was selected for the analysis based on review of subsurface condition and pond geometry. The location of the selected cross section is at the approximate mid-point of the northern embankment of Ash Pond A, as shown in Figure 1.

This section was selected because the embankment height at this location is the highest and has the weakest foundation soil layer based on standard penetration test blow counts (SPT-N) obtained during the field investigation (approximately 2 blows/ft.). Therefore, the selected analysis location at Ash Pond A likely represents the most critical condition.

4. STABILITY CRITERIA

According to the US Corps of Engineers [2003], the minimum recommended factor of safety (FS) against global slope stability failure for permanent conditions under static loading is 1.5 (EM 110-2-1902). For seismic condition, the minimum acceptable FS is selected to be 1.2, based on recommendation of presented by the Mine Safety and Health Administration document entitled Engineering and Design Manual: Coal Refuse Disposal Facilities [2009].

5. LOADING CONDITIONS

5.1 Static Loads

The major static load applied to the foundation soils is the gravity load exerted by the weight of the berm. A surcharge load of 250 pound per square feet (psf) is applied to the top of the embankment to represent traffic loading on top of the embankment.

5.2 Seismic Loads

The maximum horizontal acceleration in bedrock for the Shawville facility site is estimated to be 0.091g (g is the gravitational acceleration), based on a seismic hazard map with contours of peak acceleration with 2% probability of exceedance in 50 years as indicated in Figure 2 [USGS, 2008]. This represents the peak ground acceleration in bedrock.

The peak ground acceleration at a soil site should be adjusted to account for the stiffness of soil material overlying the bedrock, which is represented by a site classification in the International Building Code. Using the International Building Code (IBC) 2006 soil classification table, the Shawville lithology classifies as a site classification D (stiff soil profile). This classification is selected based on the average standard penetration resistance (N-value) within a upper 100 foot soil profile. An IBC 2006 site classification of D pertains to a soil profile with an average N-value between 15 and 50. This site classification table is attached as Figure 3. Using the site coefficient chart for site Class D the value of 1.6 is obtained as shown in Figure 4. Based on the site coefficient and the PGA in rock, the PGA in soil site is estimated to be 0.146g.

In slope stability analysis, the horizontal seismic loading is typically considered as the weight of the soil mass multiplied by seismic coefficient, *k*. Because the peak ground acceleration will only occur for a short duration, the seismic coefficient *k* used in the design analysis will be smaller than the PGA. A seismic design guidance provided by USEPA [Richardson et. al.,1995] recommends to use approximately half of PGA as seismic coefficient. For a design PGA of 0.146g, a seismic coefficient of 0.073 was used in this analysis.

6. STRATIGRAPHY AND MATERIAL PARAMETERS

The stratigraphy and material parameters used for the slope stability analysis are selected based on the results of boring investigation, which are described below:

Fill

The embankment is constructed by enlarging a pre-existing berm using fill material. Based on the boring logs, it appears that the fill materials in the upper and lower portion of the berm have different material properties.

The fill material in the upper 10 to 12 ft is generally granular and contains significant portion of gravel. This material generally classifies as poorly graded gravel (GP) or gravelly silty sand (SM-GP), according to the unified soil classification system (USCS). The SPT-N ranges from 16 to 50 blows/ft, with an average of 27 blows/ft. Using the empirical correlations between SPT-N and friction angle [Kulhawy and Mayne, 1990] (see Figure 5), the upper portion of the fill material is assumed to have a friction angle of 36 degrees and no cohesion.

The lower portion of the fill material generally contains some fines and is typically classified as silt (ML), clayey sand (SC) or silty sand (SM). The SPT-N values are typically within the range of 6 to 13 blows/ft. This material is assumed to have a friction angle of 32 degree, using the empirical correlation with SPT-N. The assumed friction angles are also comparable with the typical material properties of compacted soil provided by NAVFAC (see Figure 6).

Pre-Existing Embankment (prior to pond expansion)

Due to the alignment of the pre-existing embankment and the location of the utilities, it is unclear whether soil data from the pre-existing embankment in Ash Pond A was obtained. The cross section provided in Figure 2 depicts the typical location of the borings in relation to pre-existing embankment and the underground power lines that are located within the embankments. As shown in this cross section, the borings may have missed the inside toe of the pre-existing berm, but likely encountered the native material that formed the bottom of the unlined ash pond that later became Ash Pond A. Because the pond was constructed as a combination diked/incised pond, it is assumed that the pre-existing embankment was constructed using the material removed from the excavation of the pond. Based on the boring logs for HSA-1 and HSA-2, the native material is likely to be either a sandy clay (CL) or low-plasticity silt (ML). Hence, Geosyntec considered two different soil properties for the pre-existing soil berm in the analyses:

(i) the soil in the pre-existing berm is considered a low-plasticity silt (ML) based on the information collected from HSA-1. The SPT blow counts ranged from 7 to 28 (blow/ft), with an average of 15 blows/ft.

(ii) the soil in the pre-existing berm berm is conservatively assumed to consist of low-plasticity clay, with an SPT-N of 5 blows/ft (i.e., lower range of SPT-N found in the fill material).

The material properties for the silt (i.e., first scenario) are selected based on typical material properties for compacted soil provided by NAVFAC (See Figure 6). Additionally, the typical undrained shear strength provided is verified using the empirical correlations with SPT-N value [Kulhawy and Wayne, 1990]:

$$S_u/P_a = 0.06\ \mathrm{N}$$

Where: S_u = undrained shear strength;
P_a = atmospheric pressure (= 2,116 psf)
N = SPT-N value (blows/ft)

Using the average SPT-N value of 5 and 15 blows/ft, the undrained shear strength is estimated to be 600 and 1,900 psf, which are lower or comparable with the typical value provided by NAVFAC.

Foundation Soil

During the boring investigation, the soils underlying the pond embankment is consisted of clayey sand (SC), silt (ML) or sandy clay (CL). A composite soil sample composed of soils collected at HAS-2 boring between depths of 10 and 16 feet below ground surface (ft-bgs) was sent to the laboratory and classified according to the Unified Soil Classification system. Laboratory test results show that the material is a CL with a plasticity index (PI) of 14 (Attachment 1). The SPT-N of that material are generally between 2 and 9 blows/ft, and may be greater than 20 blows/ft at locations close to bedrock (HSA-3), where crushed sandstone was encountered. Using the lower bound of SPT-N, the foundation clay is assumed to have an undrained shear strength of 250 psf. Under drained condition, this clay is conservatively assumed to be normally-consolidated with a friction angle of 33.5, estimated using the empirical correlation between critical void ratio friction angle and plasticity index (see Figure 7). The cohesion of the foundation soil is conservatively neglected in this analysis.

Bedrock

The bedrock present at the site was estimated to be sandstone which typically has very high shear strength. However, the depth to the sound bedrock was not confirmed by the borings. However, the material at a depth greater than 30 ft consist of rock pieces and silt/clay, which is considered to derived from rock weathering process. For this analysis, the weathered bedrock was conservatively assumed to have a friction angle of 25 degree and a cohesion of 500 psf.

Table 1 summaries the material properties used in the slope stability analysis. The analyzed cross section is shown in Figure 8.

Table 1. Material Properties Used in Slope Stability Analyses

Material	Moist Unit Weight (lb/ft^3)	Saturated Unit Weight (lb/ft^3)	Drained Shear Strength		Undrained Shear Strength (psf)
			Cohesion (psf)	Friction Angle (deg)	
Fill (upper)	120	-	0	36	-
Fill (lower)	120	-	0	32	-
Pre-Existing Berm (silt)	125	-	190	32	600
Pre-Existing Berm (clay)	125	-	270	28	1,900
Foundation	125	130	0	33.5	250
Weathered rock	135	135	500	25	-

7. GROUNDWATER CONDITION

The groundwater table in the area is connected to the water level of the Susquehanna River located to the north of the ponds, which is estimated to be at elevation 1,044 ft-msl. In the analysis, a groundwater table at elevation 1044 ft-msl was assigned to the foundation soils.

For this analysis, the water level in the pond is assumed to be at elevation 1,064 ft-msl, which is the high water level as presented in the drawings by prepared Gilbert/Commonwealth, Inc . The water in the lined pond is modeled as material with no shear strength in the analysis.

8. METHOD OF SLOPE STABILITY ANALYSIS

The stability of the selected cross section was evaluated using the limit equilibrium method. The analyses were conducted using SLIDE [Rocscience, 2002], a two-dimensional (2D) slope stability computer program. The factors of safety for both circular and non-circular potential slip surface were evaluated. The Spencer's Method [Spencer, 1967], and the Janbu's Simplified Method [Janbu, 1954a, 1954b, 1973] were used in the analysis. The interslice force assumption made in the Spencer's Method satisfies force equilibrium in horizontal and vertical directions as well as moment equilibrium. Therefore, Spencer's method is considered as a rigorous methods, which generally provide more precise results for factor of safety than non-rigorous method. The factors of safety reported herein are from Spencer's method, and are verified using Janbu's simplified method.

Thousands of potential failure surfaces were analyzed to find the critical failure surface resulting in the minimum factor of safety for the slope. For the circular slip surface search, a search grid with 25 horizontal increments and 25 vertical increments was used. For the block failure analysis, two search windows were used for searching the most critical failure surface. SLIDE provides results graphically and as output text files. SLIDE graphical provides both the minimum factor of safety and contours of the calculated factors of safety. For each case analyzed, a figure and text are generated and presented in Attachment 2 of this calculation package.

9. RESULTS OF SLOPE STABILITY

The results of the SLIDE analyses using the material properties listed in Table 1 are summarized in Table 2.

Table 2. Summary of Slope Stability Results

Case of Analysis	Loading Conditions	Failure Mode	Calculated F.S.	Target F.S.
Case 1 (assume silt in pre-existing soil berm)	Static	Circular	1.51	1.5
		Block	1.59	1.5
	Seismic	Circular	1.27	1.2
		Block	1.33	1.2
Case 2 (assume clay in pre-existing soil berm)	Static	Circular	1.53	1.5
		Block	1.60	1.5
	Seismic	Circular	1.28	1.2
		Block	1.34	1.2

10. SUMMARY

The stability of the two BAPs at the Shawville facility was evaluated for several scenarios. Based on material properties derived from empirical correlations or typical material properties, the results of these analyses show factors of safety exceeding the minimum recommended factors of safety. Thus, the two BAPs at the Shawville facility are considered stable.

11. REFERENCES

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FIGURES

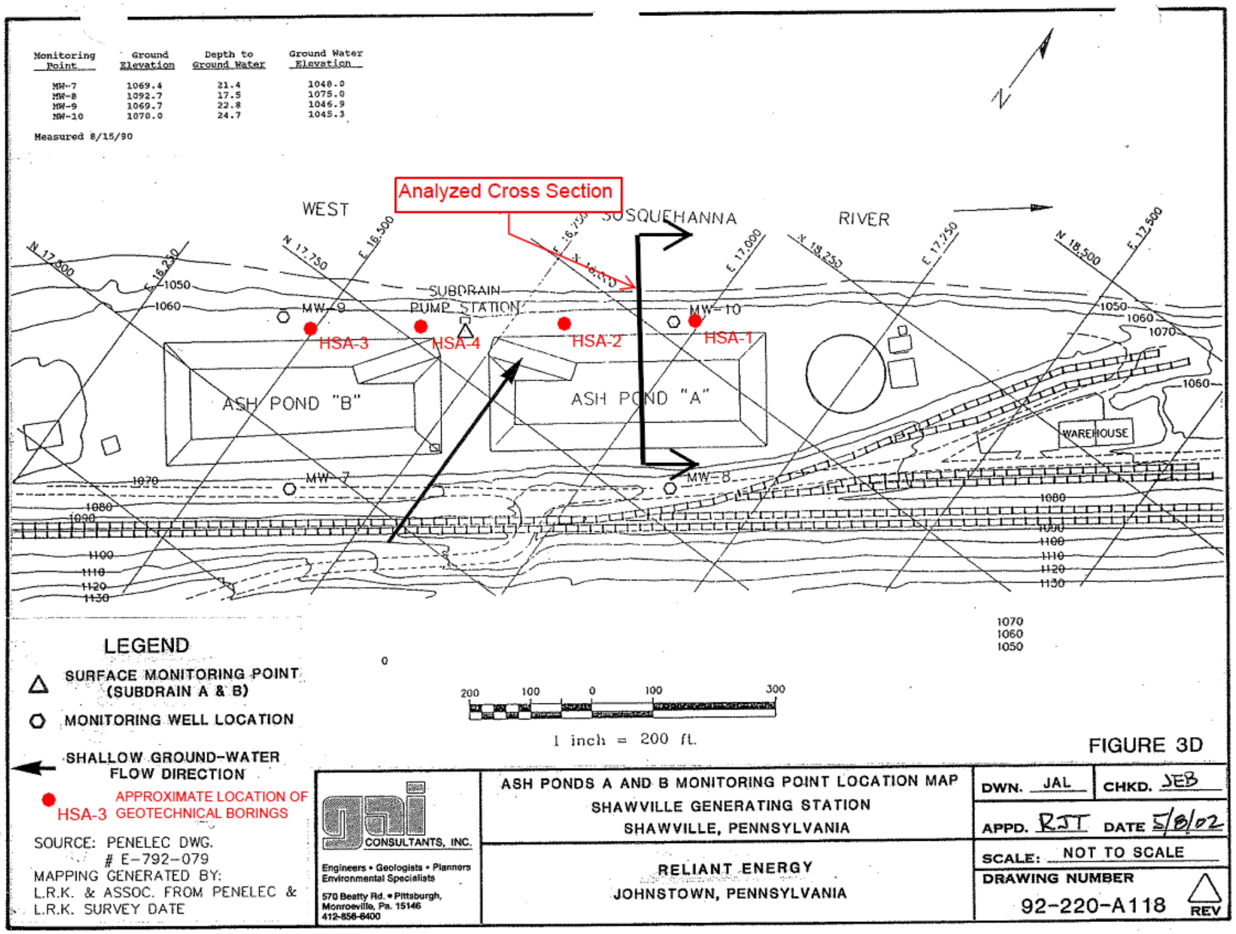
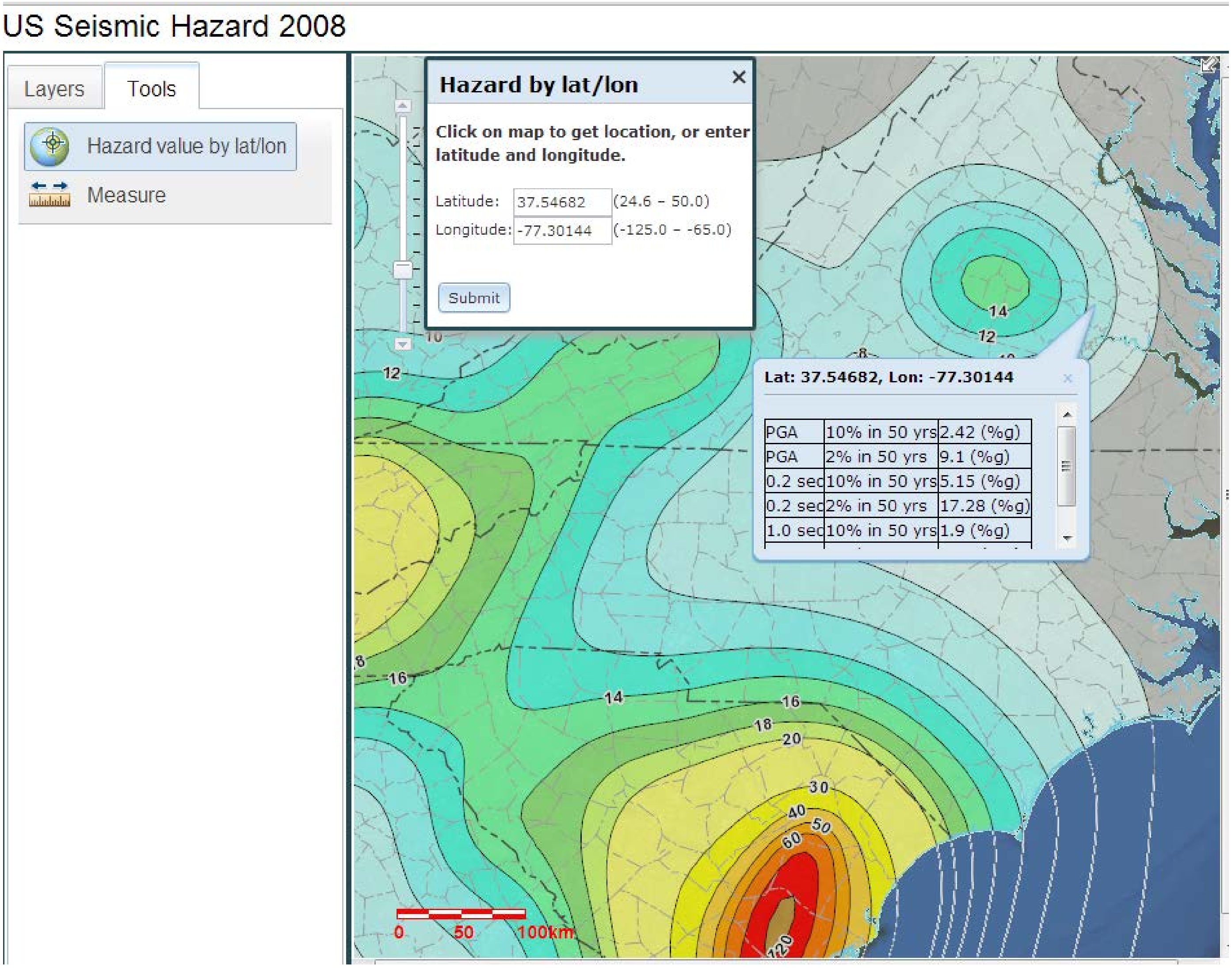


Figure 1. Location of Geotechnical Borings and Analyzed Cross Section



Source: USGS [2008]

Figure 2. USGS Seismic Hazard Map

TABLE 1613.5.2
SITE CLASS DEFINITIONS

SITE CLASS	SOIL PROFILE NAME	AVERAGE PROPERTIES IN TOP 100 feet, SEE SECTION 1613.5.5		
		Soil shear wave velocity, $\bar{v}_s$, (ft/s)	Standard penetration resistance, $\bar{N}$	Soil undrained shear strength, $\bar{s}_u$, (psf)
A	Hard rock	$\bar{v}_s > 5{,}000$	N/A	N/A
B	Rock	$2{,}500 < \bar{v}_s \leq 5{,}000$	N/A	N/A
C	Very dense soil and soft rock	$1{,}200 < \bar{v}_s \leq 2{,}500$	$\bar{N} > 50$	$\bar{s}_u \geq 2{,}000$
D	Stiff soil profile	$600 \leq \bar{v}_s \leq 1{,}200$	$15 \leq \bar{N} \leq 50$	$1{,}000 \leq \bar{s}_u \leq 2{,}000$
E	Soft soil profile	$\bar{v}_s < 600$	$\bar{N} < 15$	$\bar{s}_u < 1{,}000$
E	—	Any profile with more than 10 feet of soil having the following characteristics: 1. Plasticity index $PI > 20$, 2. Moisture content $w \geq 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H > 10$ feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H > 25$ feet with plasticity index $PI > 75$) 4. Very thick soft/medium stiff clays ($H > 120$ feet)		

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m², 1 pound per square foot = 0.0479 kPa. N/A = Not applicable

Source: International Building Code 2006

Figure 3. Site Classification

TABLE 1613.5.3(1)
VALUES OF SITE COEFFICIENT F_a [a]

SITE CLASS	MAPPED SPECTRAL RESPONSE ACCELERATION AT SHORT PERIOD				
	$S_S \leq 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	Note b	Note b	Note b	Note b	Note b

a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration at short period, S_s.
b. Values shall be determined in accordance with Section 11.4.7 of ASCE 7.

Source: International Building Code 2006

Figure 4. Site Coefficient

Table 4-3

N VERSUS $\bar{\phi}_{tc}$ RELATIONSHIPS

	N Value (blows/ft or 305 mm)	Relative Density	Approximate $\bar{\phi}_{tc}$ (degrees) (a)	Approximate $\bar{\phi}_{tc}$ (degrees) (b)
	0 to 4	very loose	< 28	< 30
Fill (lower)→	4 to 10	loose	28 to 30	30 to 35
Fill (upper)→	10 to 30	medium	30 to 36	35 to 40
	30 to 50	dense	36 to 41	40 to 45
	> 50	very dense	> 41	> 45

a - Source: Peck, Hanson, and Thornburn (12), p. 310.
b - Source: Meyerhof (13), p. 17.

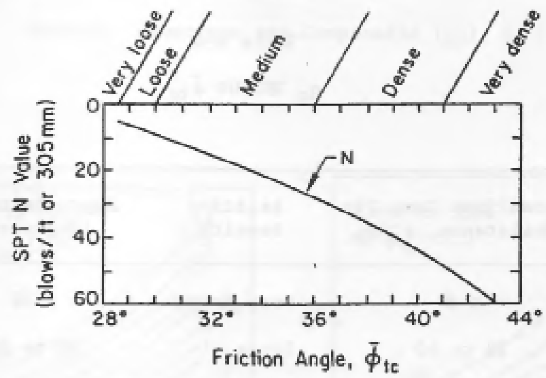


Figure 4-12. N versus $\bar{\phi}_{tc}$

Source: Peck, Hanson, and Thornburn (12), p. 310.

Reproduced from Kulhawy and Mayne [1990]

Figure 5 Empirical Correlation between SPT-N and Friction Angle

TYPICAL PROPERTIES OF COMPACTED SOILS (NAVFAC DM 7.2, Table 1, p7.2-39)

Group Symbol	Soil Type	Range of Maximum Dry Unit Weight, pcf	Range of Optimum Moisture, Percent	Typical Value of Compression		Typical Strength Characteristics				Typical Coefficient of Permeability ft/miin.	Range of CBR Values	Range of Subgrade Modulus k lbs/cu in
				At 1.4 tsf (20 psi)	At 3.6 tsf (50 psi)	Cohesion (as compacted) psf	Cohesion (saturated) psf	PHI (Effective Stress Friction Angle Degrees)	Tan PHI			
				Percent of Original Height								
GW	Well-graded clean gravels, gravel-sand mixture	125 - 135	11 - 8	0.3	0.6	0	0	>38	>0.79	5×10^{-2}	40 - 80	300 - 500
GP	Poorly graded clean gravels, gravel-sand mix	115 - 125	14 - 11	0.4	0.9	0	0	>37	>0.74	10^{-1}	30 - 60	250 - 400
GM	Silty gravels, poorly graded gravel-sand-silt	120 - 135	12 - 8	0.5	1.1	--	--	>34	>0.67	$>10^{-6}$	20 - 60	100 - 400
GC	Clayey gravels, poorly graded gravel-sand-clay	115 - 130	14 - 9	0.7	1.6	--	--	>31	>0.60	$>10^{-7}$	20 - 40	100 - 300
SW	Well graded clean sands, gravelly sands	110 - 130	16 - 9	0.6	1.2	0	0	38	0.79	$>10^{-3}$	20 - 40	200 - 300
SP	Poorly graded clean sands, sand-gravel mix	100 - 120	21 - 12	0.8	1.4	0	0	37	0.74	$>10^{-3}$	10 - 40	200 - 300
SM	Silty sands, poorly graded sand-silt mix	110 - 125	16 - 11	0.8	1.6	1050	420	34	0.67	5×10^{-5}	10 - 40	100 - 300
SM-SC	Sand-silt clay mix with slightly plastic fines.	110 - 130	15 - 11	0.8	1.4	1050	300	33	0.66	2×10^{-6}	5 - 30	100 - 300
SC	Clayey sands, poorly graded sand-clay-mix	105 - 125	19 - 11	1.1	2.2	1550	230	31	0.60	5×10^{-7}	5 - 20	100 - 300
ML	Inorganic silts and clayey silts	95 - 120	24 - 12	0.9	1.7	1400	190	32	0.62	$>10^{-5}$	15 or less	100 - 200
ML-CL	Mixture of inorganic silt and clay	100 - 120	22 - 12	1.0	2.2	1350	460	32	0.62	5×10^{-7}	--	--
CL	Inorganic clays of low to medium plasticity	95 - 120	24 - 12	1.3	2.5	1800	270	28	0.54	$>10^{-7}$	15 or less	50 - 200
OL	Organic silts and silt-clays, low plasticity	80 - 100	33 - 21	--	--	--	--	--	--	--	5 or less	50 - 100
MH	Inorganic clayey silts, plastic silts	70 - 95	40 - 24	2.0	3.8	1500	420	25	0.47	5×10^{-7}	10 or less	50 - 100
CH	Inorganic clays of high plasticity	75 - 105	36 - 19	2.6	3.9	2150	230	19	0.35	$>10^{-7}$	15 or less	50 - 150
OH	Organic clays and silty clays	65 - 100	45 - 21	--	--	--	--	--	--	--	5 or less	25 - 100

Notes: All properties are for Conditions of Standard Proctor maximum density, except values of k and CBR, which are for Modified Proctor maximum density. Typical strength values are effective strengths from USBR data. Compression values are for vertical loading with complete lateral confinement.

Figure 6. Typical Shear Strength of Compacted Soils

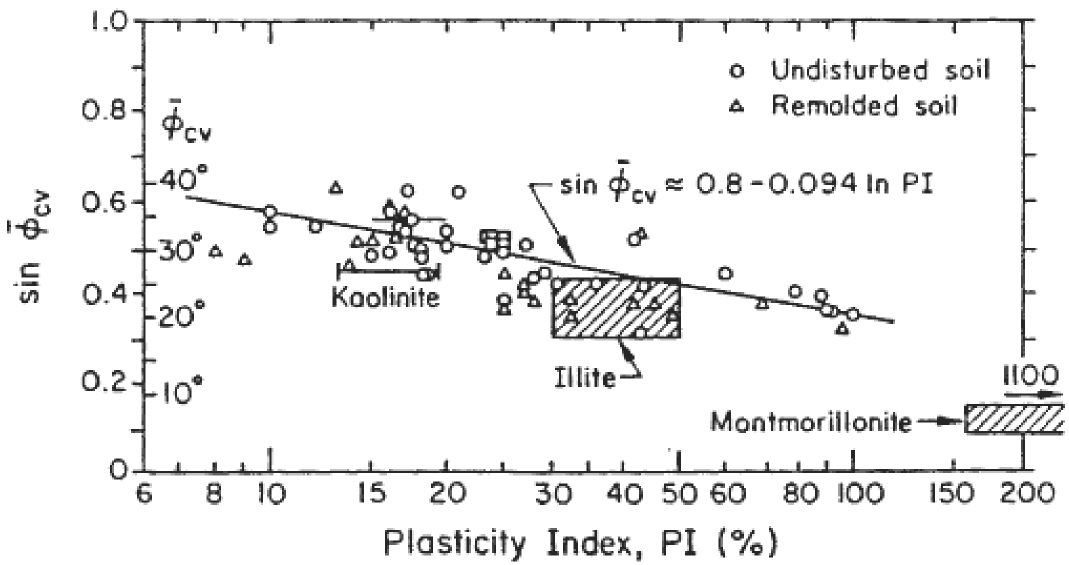


Figure 4-20. $\bar{\phi}_{cv}$ for NC Clays versus PI

Source: Mitchell (22), p. 284.

Reproduced from Kulhawy and Mayne [1990]

Figure 7. Empirical Correlations between Critical Void Ratio Friction Angle and Plasticity Index

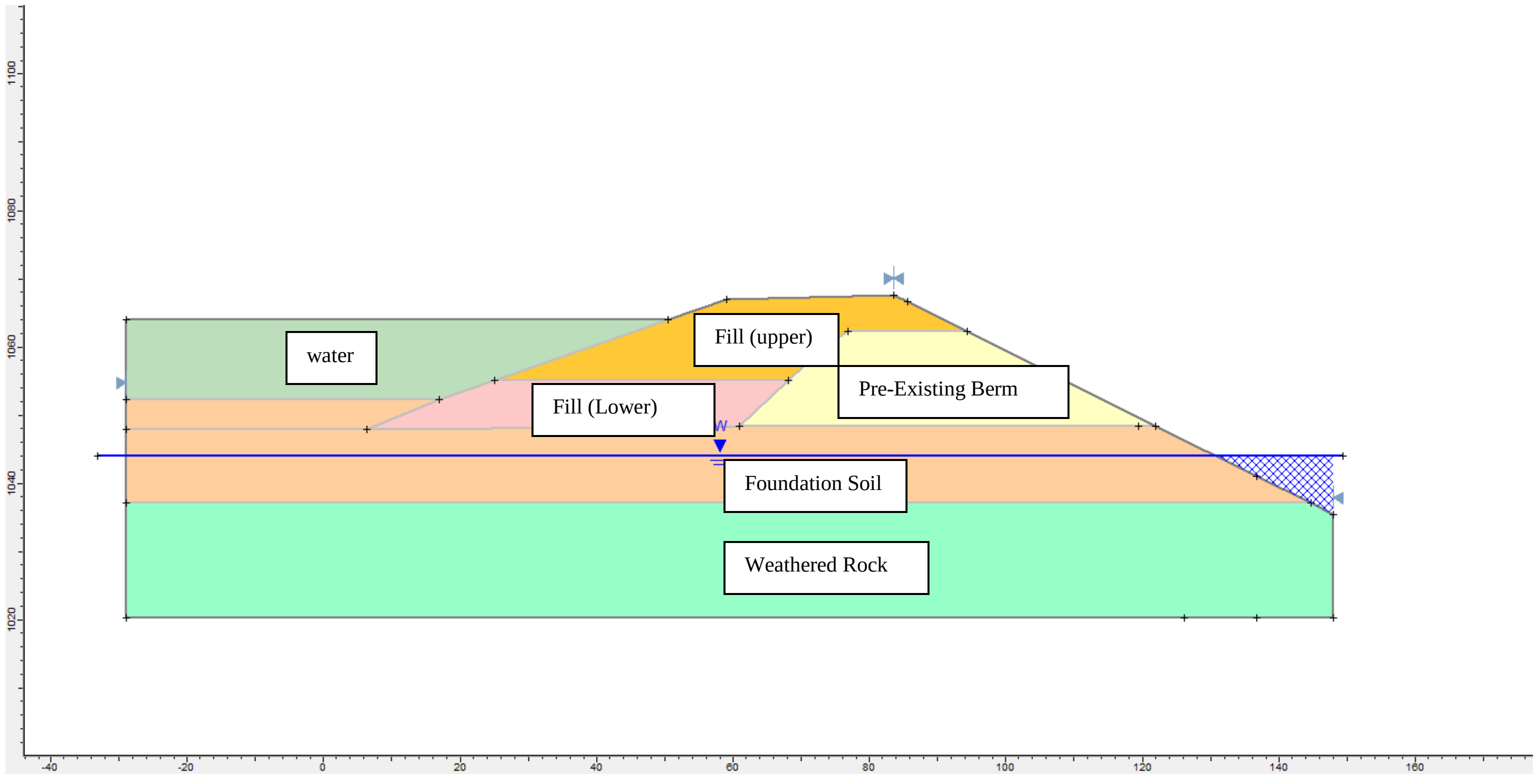


Figure 8. Analyzed Cross Section

Attachment 1

Laboratory Results

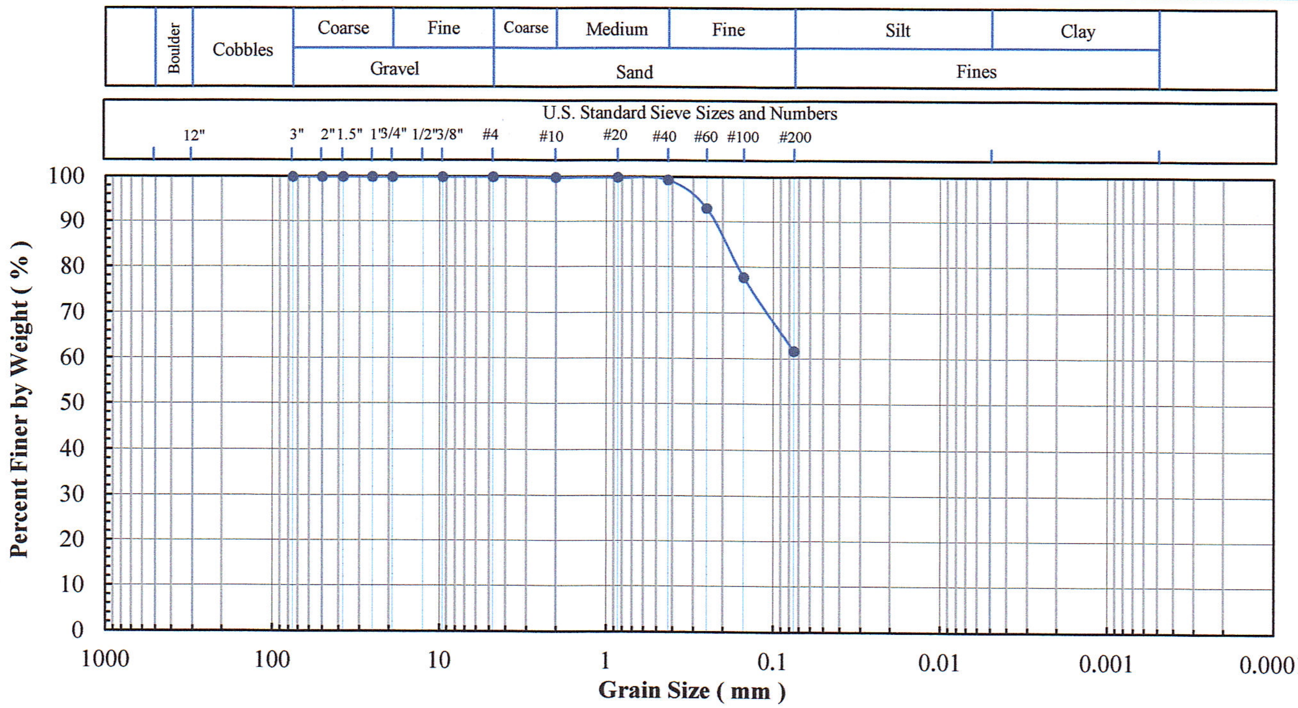
Excel Geotechnical Testing, Inc.
"Excellence in Testing"
953 Forrest Street, Roswell, Georgia 30075
Tel: (770) 910 7537 Fax: (770) 910 7538

Project Name:	Shawville Ash Ponds
Project No:	580
Client Sample ID:	HSA-2 (20-26')
Lab Sample No:	13A025

ASTM C 136, D 422, D 854, D 1140, D2216, D 2487, D4318

SOIL INDEX PROPERTIES

Grain Size, Spec. Gravity, Moist. Content, Eng. Classification, Atterberg Limits



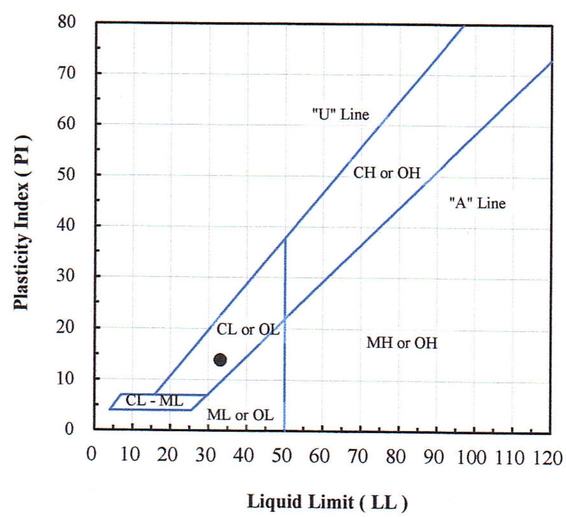
Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2.00	99.9
#20	0.850	99.9
#40	0.425	99.4
#60	0.250	93.0
#100	0.150	77.7
#200	0.075	61.7

Specific Gravity (-):	

Hydrometer Particle Diameter (mm)	% Finer

Gravel (%):	
Sand (%):	38.3
Fines (%):	61.7
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	
Coeff. Curv. (Cc):	



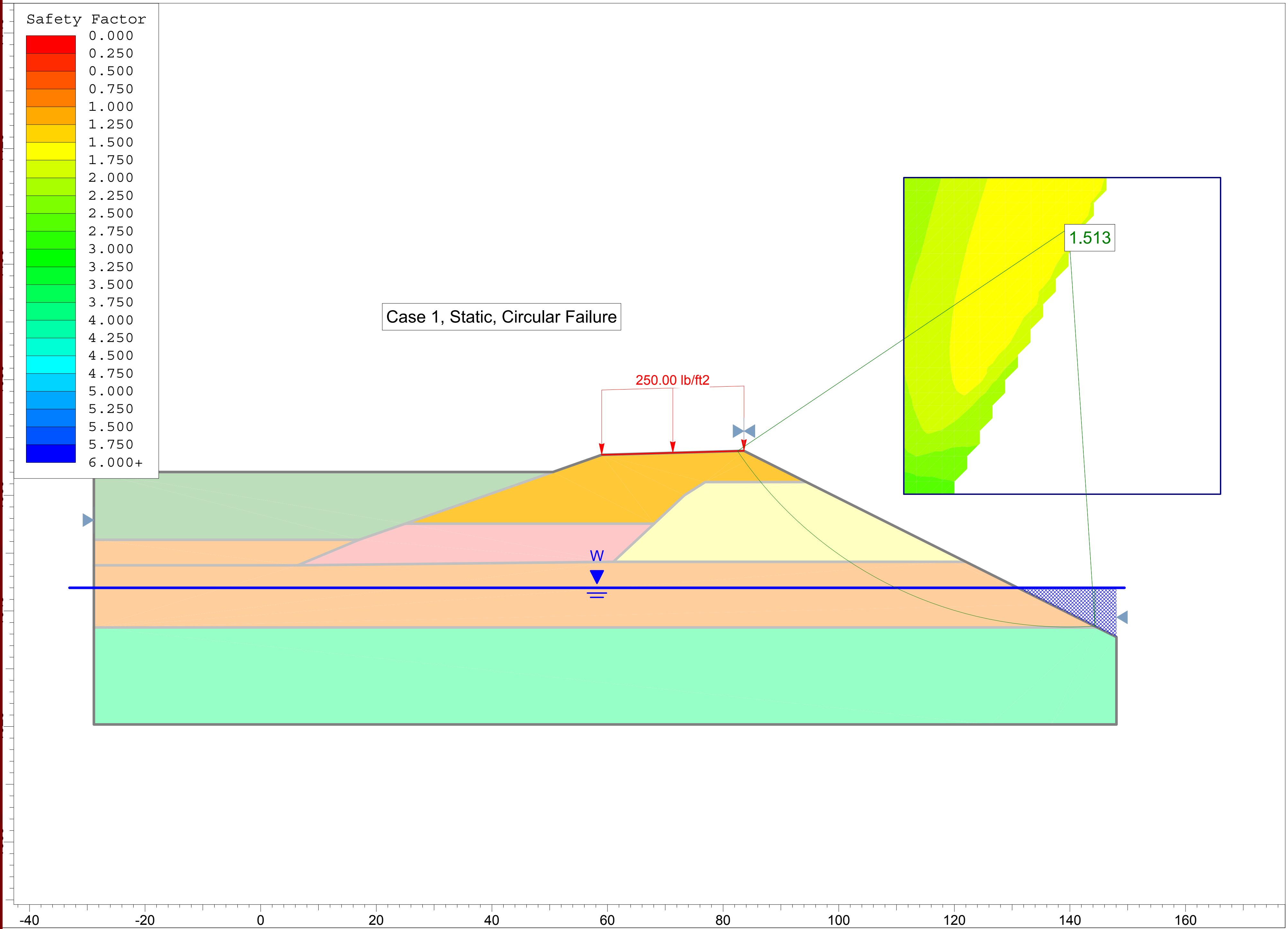
Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (-)	PL (-)	PI (-)	Engineering Classification
HSA-2 (20-26')	13A025	24.9	61.7	33	19	14	CL - Sandy lean clay

Note(s):

1-14-13
NSR

Attachment 2

SLIDE Output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0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
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3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
Case 1, Static, Circular Failure
250.00 lb/ft2
1.513
W
-40
-20
0
20
40
60
80
100
120
140
160

Slide Analysis Information

Document Name

File Name: shawville_circular.sli

Project Settings

Project Title:
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: On
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Bishop simplified
Janbu simplified
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: 1

Loading

1 Distributed Load present:
Distributed Load Constant Distribution, Orientation: Vertical, Magnitude: 250 lb/ft2

Material Properties

Material: Previous Berm
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 190 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: water
Strength Type: No strength
Unit Weight: 62.4 lb/ft3

Material: Foundation soil
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 125 lb/ft3
Saturated Unit Weight: 130 lb/ft3
Cohesion: 0 psf
Friction Angle: 33.5 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (upper)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 37 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (lower)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: whethered rock
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 135 lb/ft3
Saturated Unit Weight: 135 lb/ft3
Cohesion: 500 psf
Friction Angle: 25 degrees
Water Surface: Water Table
Custom Hu value: 1

Global Minimums

Method: bishop simplified
FS: 1.512190
Center: 141.946, 1112.800
Radius: 75.655
Left Slip Surface Endpoint: 81.253, 1067.633
Right Slip Surface Endpoint: 144.615, 1037.193
Left Slope Intercept: 81.253 1067.633
Right Slope Intercept: 144.615 1044.006
Resisting Moment=2.54185e+006 lb-ft
Driving Moment=1.68091e+006 lb-ft

Method: janbu simplified
FS: 1.433130
Center: 133.180, 1097.460

Radius: 60.192
Left Slip Surface Endpoint: 80.903, 1067.623
Right Slip Surface Endpoint: 142.889, 1038.056
Left Slope Intercept: 80.903 1067.623
Right Slope Intercept: 142.889 1044.006
Resisting Horizontal Force=33545.3 lb
Driving Horizontal Force=23407.1 lb

Method: spencer
FS: 1.512860
Center: 139.754, 1106.226
Radius: 69.040
Left Slip Surface Endpoint: 82.484, 1067.668
Right Slip Surface Endpoint: 144.325, 1037.337
Left Slope Intercept: 82.484 1067.668
Right Slope Intercept: 144.325 1044.006
Resisting Moment=2.27075e+006 lb-ft
Driving Moment=1.50096e+006 lb-ft
Resisting Horizontal Force=28420.8 lb
Driving Horizontal Force=18786.2 lb

Valid / Invalid Surfaces

Method: bishop simplified
Number of Valid Surfaces: 3097
Number of Invalid Surfaces: 4339
Error Codes:
Error Code -101 reported for 16 surfaces
Error Code -103 reported for 19 surfaces
Error Code -115 reported for 14 surfaces
Error Code -1000 reported for 4290 surfaces

Method: janbu simplified
Number of Valid Surfaces: 3097
Number of Invalid Surfaces: 4339
Error Codes:
Error Code -101 reported for 16 surfaces
Error Code -103 reported for 19 surfaces
Error Code -115 reported for 14 surfaces
Error Code -1000 reported for 4290 surfaces

Method: spencer
Number of Valid Surfaces: 3088
Number of Invalid Surfaces: 4348
Error Codes:
Error Code -101 reported for 16 surfaces
Error Code -103 reported for 19 surfaces
Error Code -111 reported for 9 surfaces
Error Code -115 reported for 14 surfaces
Error Code -1000 reported for 4290 surfaces

Error Codes

The following errors were encountered during the computation:

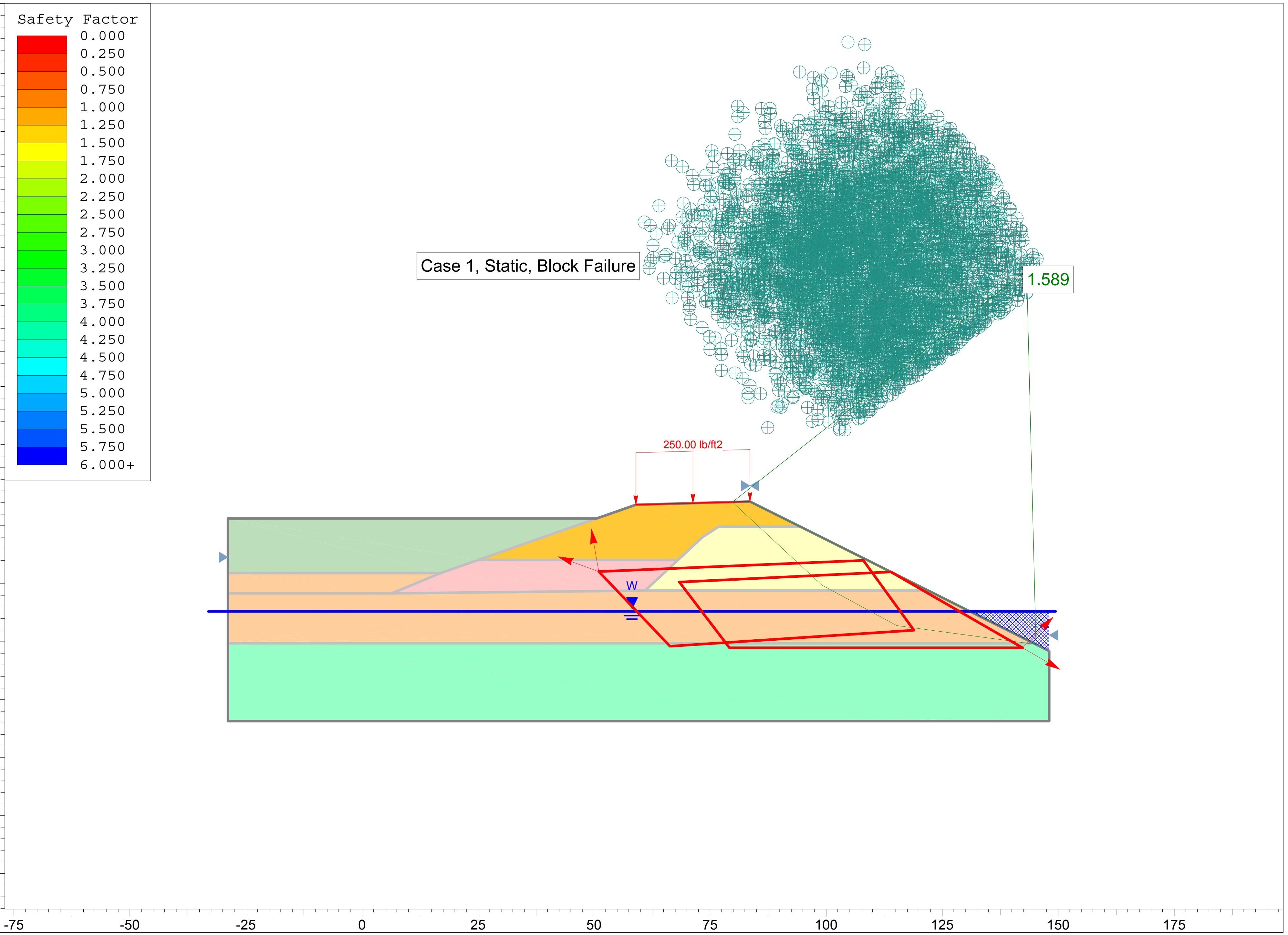
-101 = Only one (or zero)
surface / slope intersections.

-103 = Two surface / slope intersections,
but one or more surface / nonslope external polygon
intersections lie between them. This usually occurs
when the slip surface extends past the bottom of the
soil region, but may also occur on a benched
slope model with two sets of Slope Limits.

-111 = safety factor equation did not converge

-115 = Surface too shallow, below the minimum depth.

-1000 = No valid slip surfaces are generated
at a grid center. Unable to draw a surface.


Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
Case 1, Static, Block Failure
1.589
250.00 lb/ft2
W
-75
-50
-25
0
25
50
75
100
125
150
175

Slide Analysis Information

Document Name

File Name: shawville_block.sli

Project Settings

Project Title:
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: On
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Bishop simplified
Janbu simplified
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Non-Circular Block Search
Number of Surfaces: 5000
Pseudo-Random Surfaces: Enabled
Convex Surfaces Only: Disabled
Left Projection Angle (Start Angle): 100
Left Projection Angle (End Angle): 160
Right Projection Angle (Start Angle): -30
Right Projection Angle (End Angle): 45
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

1 Distributed Load present:
Distributed Load Constant Distribution, Orientation: Vertical, Magnitude: 250 lb/ft2

Material Properties

Material: Previous Berm
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 190 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: water
Strength Type: No strength
Unit Weight: 62.4 lb/ft3

Material: Foundation soil
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 125 lb/ft3
Saturated Unit Weight: 130 lb/ft3
Cohesion: 0 psf
Friction Angle: 33.5 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (upper)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 37 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (lower)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: whethered rock
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 135 lb/ft3
Saturated Unit Weight: 135 lb/ft3
Cohesion: 500 psf
Friction Angle: 25 degrees
Water Surface: Water Table
Custom Hu value: 1

Global Minimums

Method: bishop simplified
FS: 1.567390
Axis Location: 141.797, 1114.331
Left Slip Surface Endpoint: 81.441, 1067.639
Right Slip Surface Endpoint: 142.937, 1038.031
Left Slope Intercept: 81.441 1067.639
Right Slope Intercept: 142.937 1044.006
Resisting Moment=2.41367e+006 lb-ft
Driving Moment=1.53993e+006 lb-ft

Method: janbu simplified

FS: 1.512330
Axis Location: 141.797, 1114.331
Left Slip Surface Endpoint: 81.441, 1067.639
Right Slip Surface Endpoint: 142.937, 1038.031
Left Slope Intercept: 81.441 1067.639
Right Slope Intercept: 142.937 1044.006
Resisting Horizontal Force=27132.9 lb
Driving Horizontal Force=17941.1 lb

Method: spencer
FS: 1.589190
Axis Location: 143.208, 1117.648
Left Slip Surface Endpoint: 79.807, 1067.592
Right Slip Surface Endpoint: 145.212, 1036.894
Left Slope Intercept: 79.807 1067.592
Right Slope Intercept: 145.212 1044.006
Resisting Moment=2.83683e+006 lb-ft
Driving Moment=1.78508e+006 lb-ft
Resisting Horizontal Force=30703 lb
Driving Horizontal Force=19319.9 lb

Valid / Invalid Surfaces

Method: bishop simplified
Number of Valid Surfaces: 4595
Number of Invalid Surfaces: 405
Error Codes:
Error Code -107 reported for 35 surfaces
Error Code -108 reported for 201 surfaces
Error Code -111 reported for 82 surfaces
Error Code -112 reported for 87 surfaces

Method: janbu simplified
Number of Valid Surfaces: 4357
Number of Invalid Surfaces: 643
Error Codes:
Error Code -107 reported for 35 surfaces
Error Code -108 reported for 405 surfaces
Error Code -111 reported for 133 surfaces
Error Code -112 reported for 70 surfaces

Method: spencer
Number of Valid Surfaces: 3160
Number of Invalid Surfaces: 1840
Error Codes:
Error Code -107 reported for 35 surfaces
Error Code -108 reported for 1439 surfaces
Error Code -111 reported for 276 surfaces
Error Code -112 reported for 90 surfaces

Error Codes

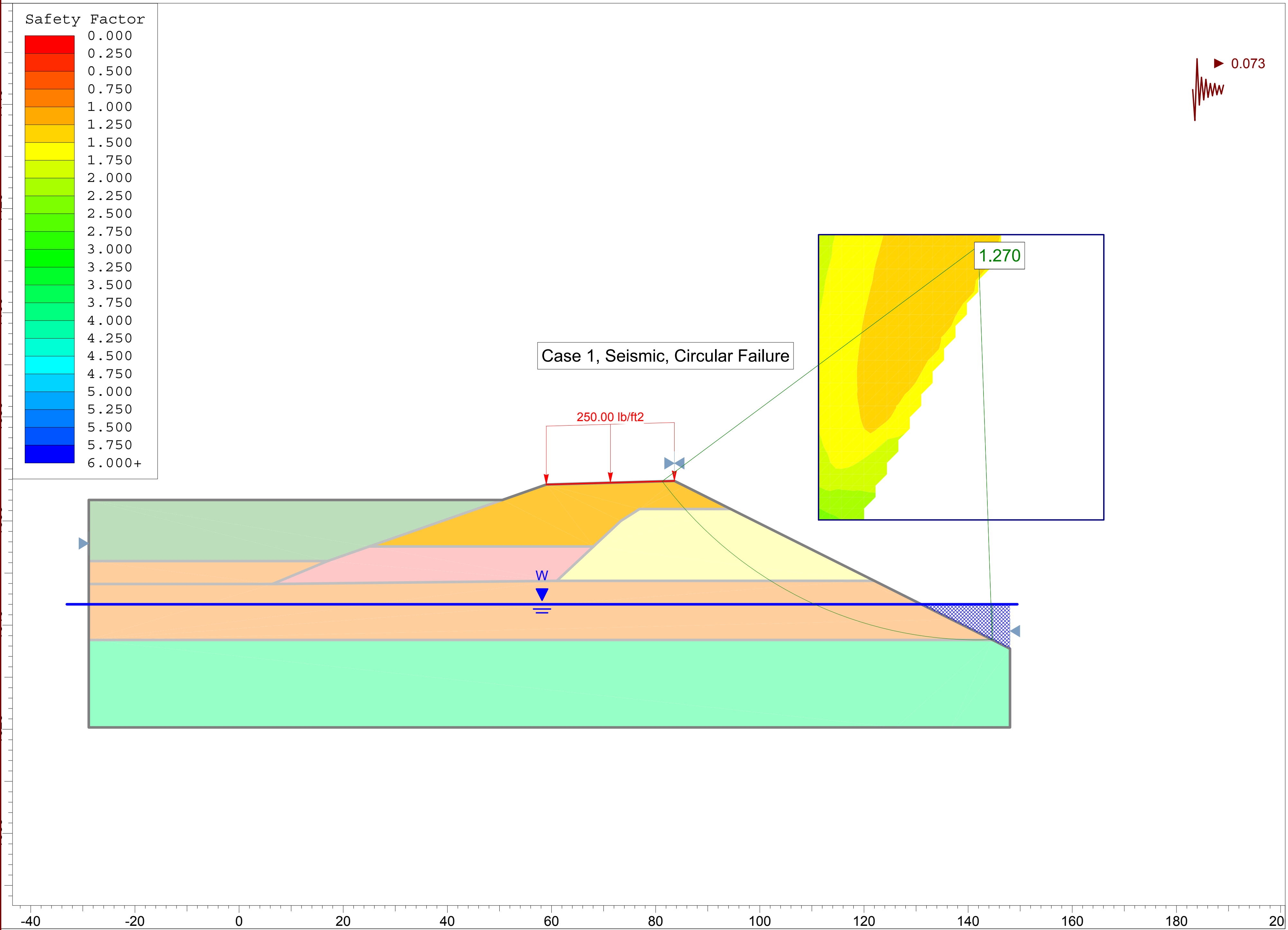
The following errors were encountered during the computation:

-107 = Total driving moment or total driving force is negative. This will occur if the wrong failure direction is specified, or if high external or anchor loads are applied against the failure direction.

-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).

-111 = safety factor equation did not converge

-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F) < 0.2 for the final iteration of the safety factor calculation. This screens out some slip surfaces which may not be valid in the context of the analysis, in particular, deep seated slip surfaces with many high negative base angle slices in the passive zone.



Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
0.073
1.270
Case 1, Seismic, Circular Failure
250.00 lb/ft2
W
-40
-20
0
20
40
60
80
100
120
140
160
180
20

Slide Analysis Information

Document Name

File Name: shawville_circular_seismic.sli

Project Settings

Project Title:
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: On
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Bishop simplified
Janbu simplified
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: 1

Loading

Seismic Load Coefficient (Horizontal): 0.073
1 Distributed Load present:
Distributed Load Constant Distribution, Orientation: Vertical, Magnitude: 250 lb/ft2

Material Properties

Material: Previous Berm
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 190 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: water
Strength Type: No strength
Unit Weight: 62.4 lb/ft3

Material: Foundation soil
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 125 lb/ft3
Saturated Unit Weight: 130 lb/ft3
Cohesion: 0 psf
Friction Angle: 33.5 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (upper)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 37 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (lower)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: whethered rock
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 135 lb/ft3
Saturated Unit Weight: 135 lb/ft3
Cohesion: 500 psf
Friction Angle: 25 degrees
Water Surface: Water Table
Custom Hu value: 1

Global Minimums

Method: bishop simplified
FS: 1.263250
Center: 141.946, 1112.800
Radius: 75.655
Left Slip Surface Endpoint: 81.253, 1067.633
Right Slip Surface Endpoint: 144.615, 1037.193
Left Slope Intercept: 81.253 1067.633
Right Slope Intercept: 144.615 1044.006
Resisting Moment=2.45094e+006 lb-ft
Driving Moment=1.94018e+006 lb-ft

Method: janbu simplified
FS: 1.195320

Center: 133.180, 1097.460
Radius: 60.192
Left Slip Surface Endpoint: 80.903, 1067.623
Right Slip Surface Endpoint: 142.889, 1038.056
Left Slope Intercept: 80.903 1067.623
Right Slope Intercept: 142.889 1044.006
Resisting Horizontal Force=32380 lb
Driving Horizontal Force=27088.9 lb

Method: spencer
FS: 1.270020
Center: 141.946, 1112.800
Radius: 75.655
Left Slip Surface Endpoint: 81.253, 1067.633
Right Slip Surface Endpoint: 144.615, 1037.193
Left Slope Intercept: 81.253 1067.633
Right Slope Intercept: 144.615 1044.006
Resisting Moment=2.46408e+006 lb-ft
Driving Moment=1.94018e+006 lb-ft
Resisting Horizontal Force=28232.2 lb
Driving Horizontal Force=22229.7 lb

Valid / Invalid Surfaces

Method: bishop simplified
Number of Valid Surfaces: 3097
Number of Invalid Surfaces: 4339
Error Codes:
Error Code -101 reported for 16 surfaces
Error Code -103 reported for 19 surfaces
Error Code -115 reported for 14 surfaces
Error Code -1000 reported for 4290 surfaces

Method: janbu simplified
Number of Valid Surfaces: 3097
Number of Invalid Surfaces: 4339
Error Codes:
Error Code -101 reported for 16 surfaces
Error Code -103 reported for 19 surfaces
Error Code -115 reported for 14 surfaces
Error Code -1000 reported for 4290 surfaces

Method: spencer
Number of Valid Surfaces: 3095
Number of Invalid Surfaces: 4341
Error Codes:
Error Code -101 reported for 16 surfaces
Error Code -103 reported for 19 surfaces
Error Code -111 reported for 2 surfaces
Error Code -115 reported for 14 surfaces
Error Code -1000 reported for 4290 surfaces

Error Codes

The following errors were encountered during the computation:

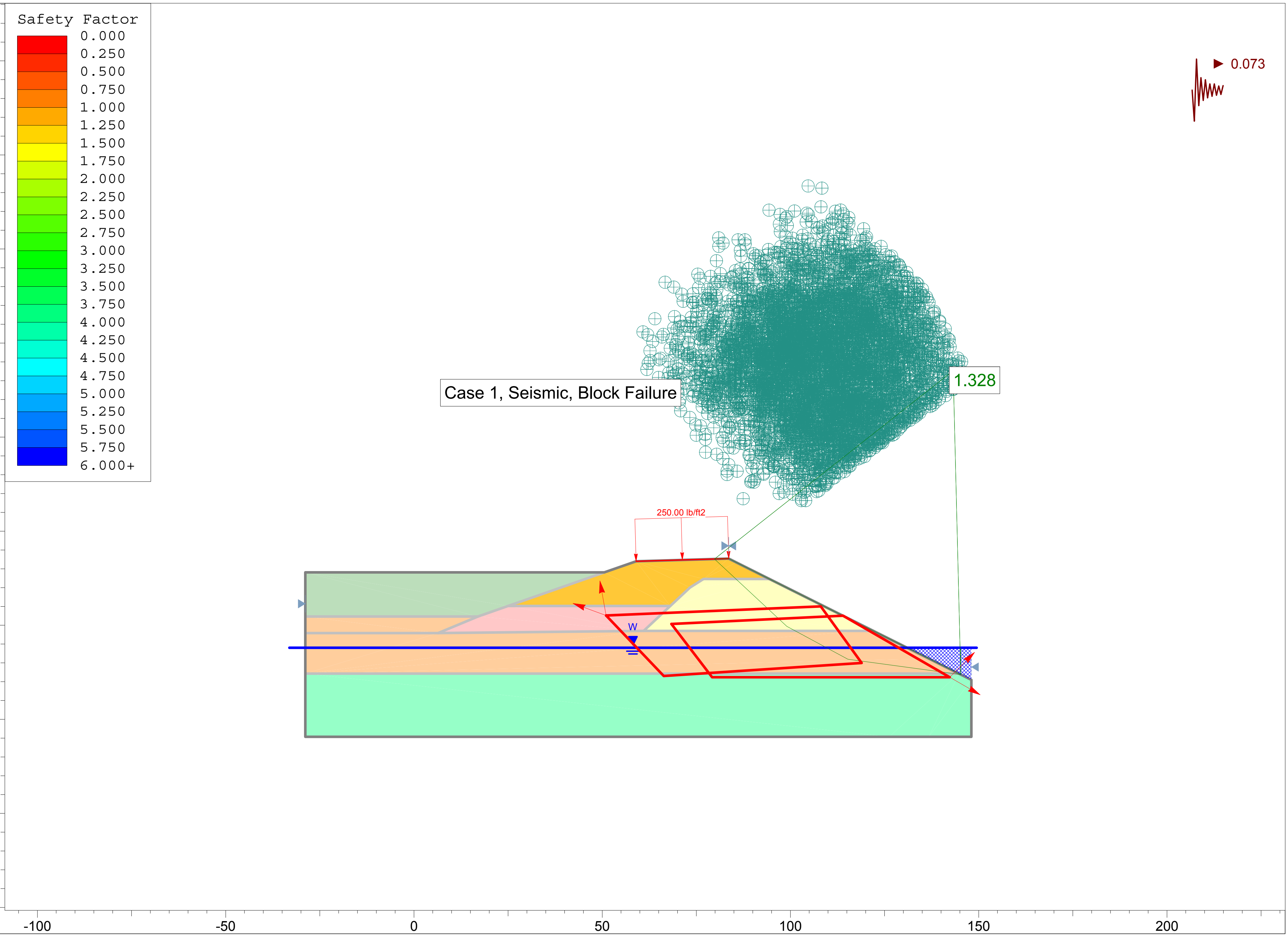
-101 = Only one (or zero)
surface / slope intersections.

-103 = Two surface / slope intersections,
but one or more surface / nonslope external polygon
intersections lie between them. This usually occurs
when the slip surface extends past the bottom of the
soil region, but may also occur on a benched
slope model with two sets of Slope Limits.

-111 = safety factor equation did not converge

-115 = Surface too shallow, below the minimum depth.

-1000 = No valid slip surfaces are generated
at a grid center. Unable to draw a surface.



Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
0.073
Case 1, Seismic, Block Failure
1.328
250.00 lb/ft2
W
-100
-50
0
50
100
150
200

Slide Analysis Information

Document Name

File Name: shawville_block_seismic.sli

Project Settings

Project Title:
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: On
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Bishop simplified
Janbu simplified
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Non-Circular Block Search
Number of Surfaces: 5000
Pseudo-Random Surfaces: Enabled
Convex Surfaces Only: Disabled
Left Projection Angle (Start Angle): 100
Left Projection Angle (End Angle): 160
Right Projection Angle (Start Angle): -30
Right Projection Angle (End Angle): 45
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

Seismic Load Coefficient (Horizontal): 0.073
1 Distributed Load present:
Distributed Load Constant Distribution, Orientation: Normal to boundary, Magnitude: 250 lb/ft2

Material Properties

Material: Previous Berm
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 190 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: water
Strength Type: No strength
Unit Weight: 62.4 lb/ft3

Material: Foundation soil
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 125 lb/ft3
Saturated Unit Weight: 130 lb/ft3
Cohesion: 0 psf
Friction Angle: 33.5 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (upper)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 37 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (lower)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: whethered rock
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 135 lb/ft3
Saturated Unit Weight: 135 lb/ft3
Cohesion: 500 psf
Friction Angle: 25 degrees
Water Surface: Water Table
Custom Hu value: 1

Global Minimums

Method: bishop simplified
FS: 1.312250
Axis Location: 141.797, 1114.331
Left Slip Surface Endpoint: 81.441, 1067.639
Right Slip Surface Endpoint: 142.937, 1038.031
Left Slope Intercept: 81.441 1067.639
Right Slope Intercept: 142.937 1044.006
Resisting Moment=2.33174e+006 lb-ft
Driving Moment=1.77691e+006 lb-ft

Method: janbu simplified
FS: 1.264180
Axis Location: 141.797, 1114.331
Left Slip Surface Endpoint: 81.441, 1067.639
Right Slip Surface Endpoint: 142.937, 1038.031
Left Slope Intercept: 81.441 1067.639
Right Slope Intercept: 142.937 1044.006
Resisting Horizontal Force=26232 lb
Driving Horizontal Force=20750.2 lb

Method: spencer
FS: 1.327950
Axis Location: 143.208, 1117.648
Left Slip Surface Endpoint: 79.807, 1067.592
Right Slip Surface Endpoint: 145.212, 1036.894
Left Slope Intercept: 79.807 1067.592
Right Slope Intercept: 145.212 1044.006
Resisting Moment=2.73671e+006 lb-ft
Driving Moment=2.06085e+006 lb-ft
Resisting Horizontal Force=29751.9 lb
Driving Horizontal Force=22404.4 lb

Valid / Invalid Surfaces

Method: bishop simplified
Number of Valid Surfaces: 4650
Number of Invalid Surfaces: 350
Error Codes:
Error Code -107 reported for 3 surfaces
Error Code -108 reported for 165 surfaces
Error Code -111 reported for 87 surfaces
Error Code -112 reported for 95 surfaces

Method: janbu simplified
Number of Valid Surfaces: 4444
Number of Invalid Surfaces: 556
Error Codes:
Error Code -107 reported for 3 surfaces
Error Code -108 reported for 346 surfaces
Error Code -111 reported for 120 surfaces
Error Code -112 reported for 87 surfaces

Method: spencer
Number of Valid Surfaces: 3116
Number of Invalid Surfaces: 1884
Error Codes:
Error Code -107 reported for 3 surfaces
Error Code -108 reported for 1298 surfaces
Error Code -111 reported for 488 surfaces
Error Code -112 reported for 95 surfaces

Error Codes

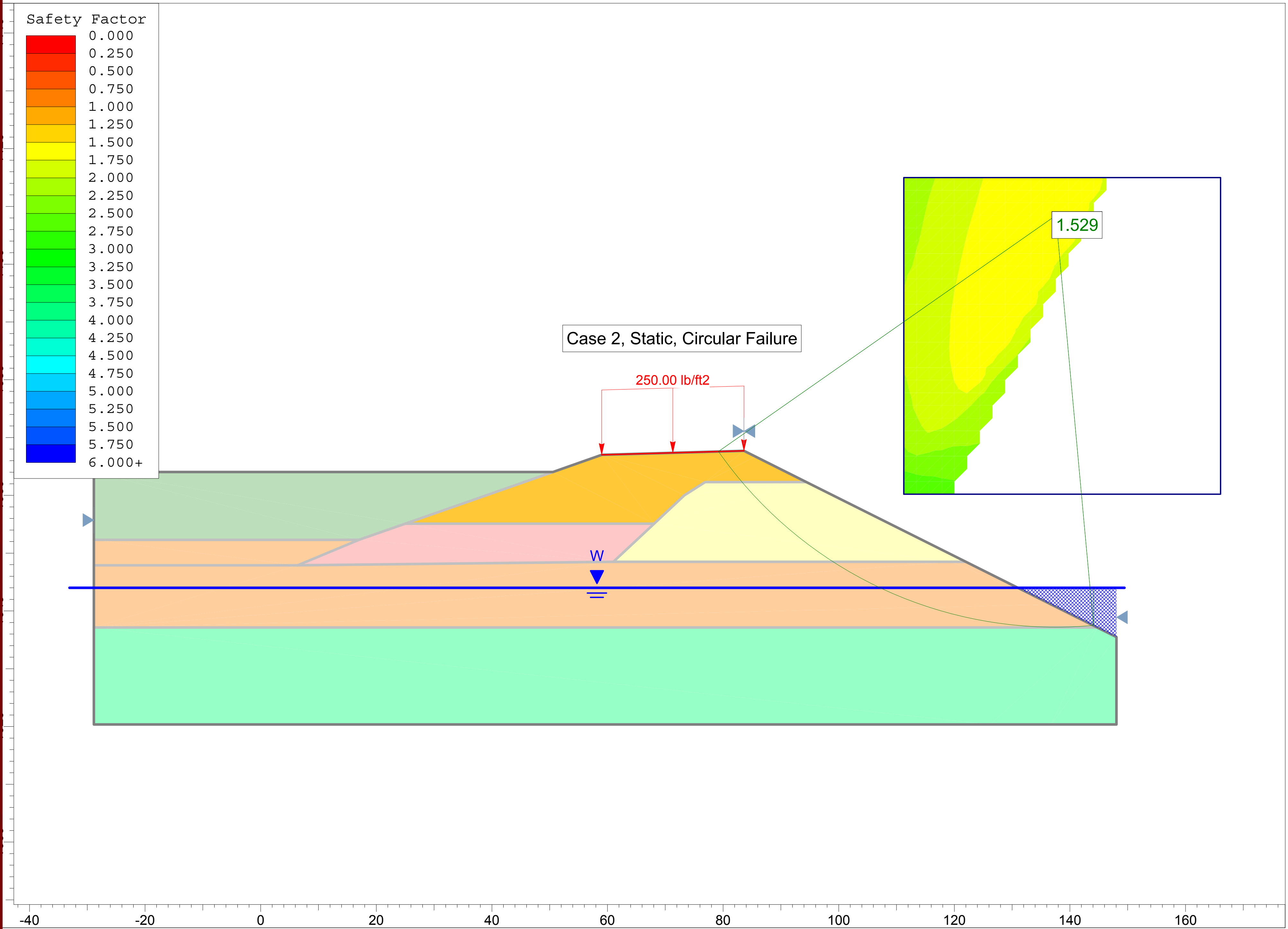
The following errors were encountered during the computation:

-107 = Total driving moment or total driving force is negative. This will occur if the wrong failure direction is specified, or if high external or anchor loads are applied against the failure direction.

-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).

-111 = safety factor equation did not converge

-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F) < 0.2 for the final iteration of the safety factor calculation. This screens out some slip surfaces which may not be valid in the context of the analysis, in particular, deep seated slip surfaces with many high negative base angle slices in the passive zone.



Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
Case 2, Static, Circular Failure
250.00 lb/ft2
1.529
W
-40
-20
0
20
40
60
80
100
120
140
160

Slide Analysis Information

Document Name

File Name: shawville_circular2.sli

Project Settings

Project Title:
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: On
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Bishop simplified
Janbu simplified
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: 1

Loading

1 Distributed Load present:
Distributed Load Constant Distribution, Orientation: Vertical, Magnitude: 250 lb/ft2

Material Properties

Material: Previous Berm
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 270 psf
Friction Angle: 28 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: water
Strength Type: No strength
Unit Weight: 62.4 lb/ft3

Material: Foundation soil
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 125 lb/ft3
Saturated Unit Weight: 130 lb/ft3
Cohesion: 0 psf
Friction Angle: 33.5 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (upper)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 37 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (lower)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: whethered rock
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 135 lb/ft3
Saturated Unit Weight: 135 lb/ft3
Cohesion: 500 psf
Friction Angle: 25 degrees
Water Surface: Water Table
Custom Hu value: 1

Global Minimums

Method: bishop simplified
FS: 1.522330
Center: 137.563, 1108.417
Radius: 71.255
Left Slip Surface Endpoint: 79.175, 1067.574
Right Slip Surface Endpoint: 144.079, 1037.461
Left Slope Intercept: 79.175 1067.574
Right Slope Intercept: 144.079 1044.006
Resisting Moment=2.85533e+006 lb-ft
Driving Moment=1.87563e+006 lb-ft

Method: janbu simplified
FS: 1.441410
Center: 133.180, 1099.651

Radius: 62.429
Left Slip Surface Endpoint: 79.614, 1067.587
Right Slip Surface Endpoint: 143.001, 1037.999
Left Slope Intercept: 79.614 1067.587
Right Slope Intercept: 143.001 1044.006
Resisting Horizontal Force=35603.6 lb
Driving Horizontal Force=24700.5 lb

Method: spencer
FS: 1.528830
Center: 137.563, 1108.417
Radius: 71.255
Left Slip Surface Endpoint: 79.175, 1067.574
Right Slip Surface Endpoint: 144.079, 1037.461
Left Slope Intercept: 79.175 1067.574
Right Slope Intercept: 144.079 1044.006
Resisting Moment=2.86753e+006 lb-ft
Driving Moment=1.87563e+006 lb-ft
Resisting Horizontal Force=34780.7 lb
Driving Horizontal Force=22749.8 lb

Valid / Invalid Surfaces

Method: bishop simplified
Number of Valid Surfaces: 3097
Number of Invalid Surfaces: 4339
Error Codes:
Error Code -101 reported for 16 surfaces
Error Code -103 reported for 19 surfaces
Error Code -115 reported for 14 surfaces
Error Code -1000 reported for 4290 surfaces

Method: janbu simplified
Number of Valid Surfaces: 3097
Number of Invalid Surfaces: 4339
Error Codes:
Error Code -101 reported for 16 surfaces
Error Code -103 reported for 19 surfaces
Error Code -115 reported for 14 surfaces
Error Code -1000 reported for 4290 surfaces

Method: spencer
Number of Valid Surfaces: 3092
Number of Invalid Surfaces: 4344
Error Codes:
Error Code -101 reported for 16 surfaces
Error Code -103 reported for 19 surfaces
Error Code -111 reported for 5 surfaces
Error Code -115 reported for 14 surfaces
Error Code -1000 reported for 4290 surfaces

Error Codes

The following errors were encountered during the computation:

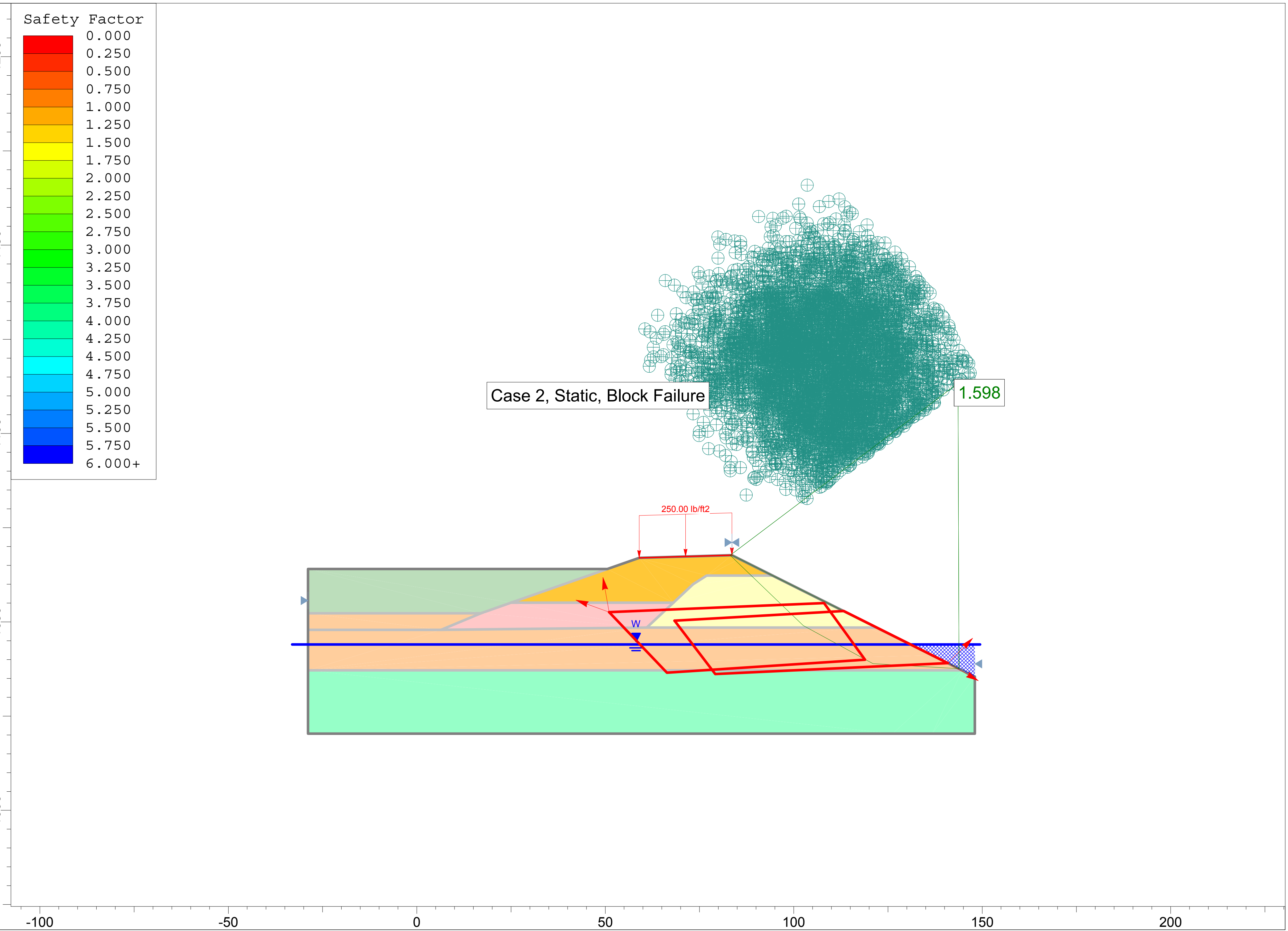
-101 = Only one (or zero) surface / slope intersections.

-103 = Two surface / slope intersections, but one or more surface / nonslope external polygon intersections lie between them. This usually occurs when the slip surface extends past the bottom of the soil region, but may also occur on a benched slope model with two sets of Slope Limits.

-111 = safety factor equation did not converge

-115 = Surface too shallow, below the minimum depth.

-1000 = No valid slip surfaces are generated at a grid center. Unable to draw a surface.



Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
Case 2, Static, Block Failure
1.598
250.00 lb/ft2
W
-100
-50
0
50
100
150
200

Slide Analysis Information

Document Name

File Name: shawville_block2.sli

Project Settings

Project Title:
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: On
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Bishop simplified
Janbu simplified
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Non-Circular Block Search
Number of Surfaces: 5000
Pseudo-Random Surfaces: Enabled
Convex Surfaces Only: Disabled
Left Projection Angle (Start Angle): 100
Left Projection Angle (End Angle): 160
Right Projection Angle (Start Angle): -30
Right Projection Angle (End Angle): 45
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

1 Distributed Load present:
Distributed Load Constant Distribution, Orientation: Vertical, Magnitude: 250 lb/ft2

Material Properties

Material: Previous Berm
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 270 psf
Friction Angle: 28 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: water
Strength Type: No strength
Unit Weight: 62.4 lb/ft3

Material: Foundation soil
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 125 lb/ft3
Saturated Unit Weight: 130 lb/ft3
Cohesion: 0 psf
Friction Angle: 33.5 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (upper)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 37 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (lower)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: whethered rock
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 135 lb/ft3
Saturated Unit Weight: 135 lb/ft3
Cohesion: 500 psf
Friction Angle: 25 degrees
Water Surface: Water Table
Custom Hu value: 1

Global Minimums

Method: bishop simplified
FS: 1.565900
Axis Location: 143.570, 1113.340
Left Slip Surface Endpoint: 83.121, 1067.686
Right Slip Surface Endpoint: 143.823, 1037.588
Left Slope Intercept: 83.121 1067.686
Right Slope Intercept: 143.823 1044.006
Resisting Moment=2.22067e+006 lb-ft
Driving Moment=1.41814e+006 lb-ft

Method: janbu simplified

FS: 1.522380
Axis Location: 143.570, 1113.340
Left Slip Surface Endpoint: 83.121, 1067.686
Right Slip Surface Endpoint: 143.823, 1037.588
Left Slope Intercept: 83.121 1067.686
Right Slope Intercept: 143.823 1044.006
Resisting Horizontal Force=24765 lb
Driving Horizontal Force=16267.3 lb

Method: spencer
FS: 1.597890
Axis Location: 143.570, 1113.340
Left Slip Surface Endpoint: 83.121, 1067.686
Right Slip Surface Endpoint: 143.823, 1037.588
Left Slope Intercept: 83.121 1067.686
Right Slope Intercept: 143.823 1044.006
Resisting Moment=2.23288e+006 lb-ft
Driving Moment=1.39739e+006 lb-ft
Resisting Horizontal Force=25187.4 lb
Driving Horizontal Force=15762.9 lb

Valid / Invalid Surfaces

Method: bishop simplified
Number of Valid Surfaces: 4598
Number of Invalid Surfaces: 402
Error Codes:
Error Code -107 reported for 36 surfaces
Error Code -108 reported for 197 surfaces
Error Code -111 reported for 87 surfaces
Error Code -112 reported for 82 surfaces

Method: janbu simplified
Number of Valid Surfaces: 4345
Number of Invalid Surfaces: 655
Error Codes:
Error Code -107 reported for 36 surfaces
Error Code -108 reported for 412 surfaces
Error Code -111 reported for 140 surfaces
Error Code -112 reported for 67 surfaces

Method: spencer
Number of Valid Surfaces: 3118
Number of Invalid Surfaces: 1882
Error Codes:
Error Code -107 reported for 36 surfaces
Error Code -108 reported for 1442 surfaces
Error Code -111 reported for 319 surfaces
Error Code -112 reported for 85 surfaces

Error Codes

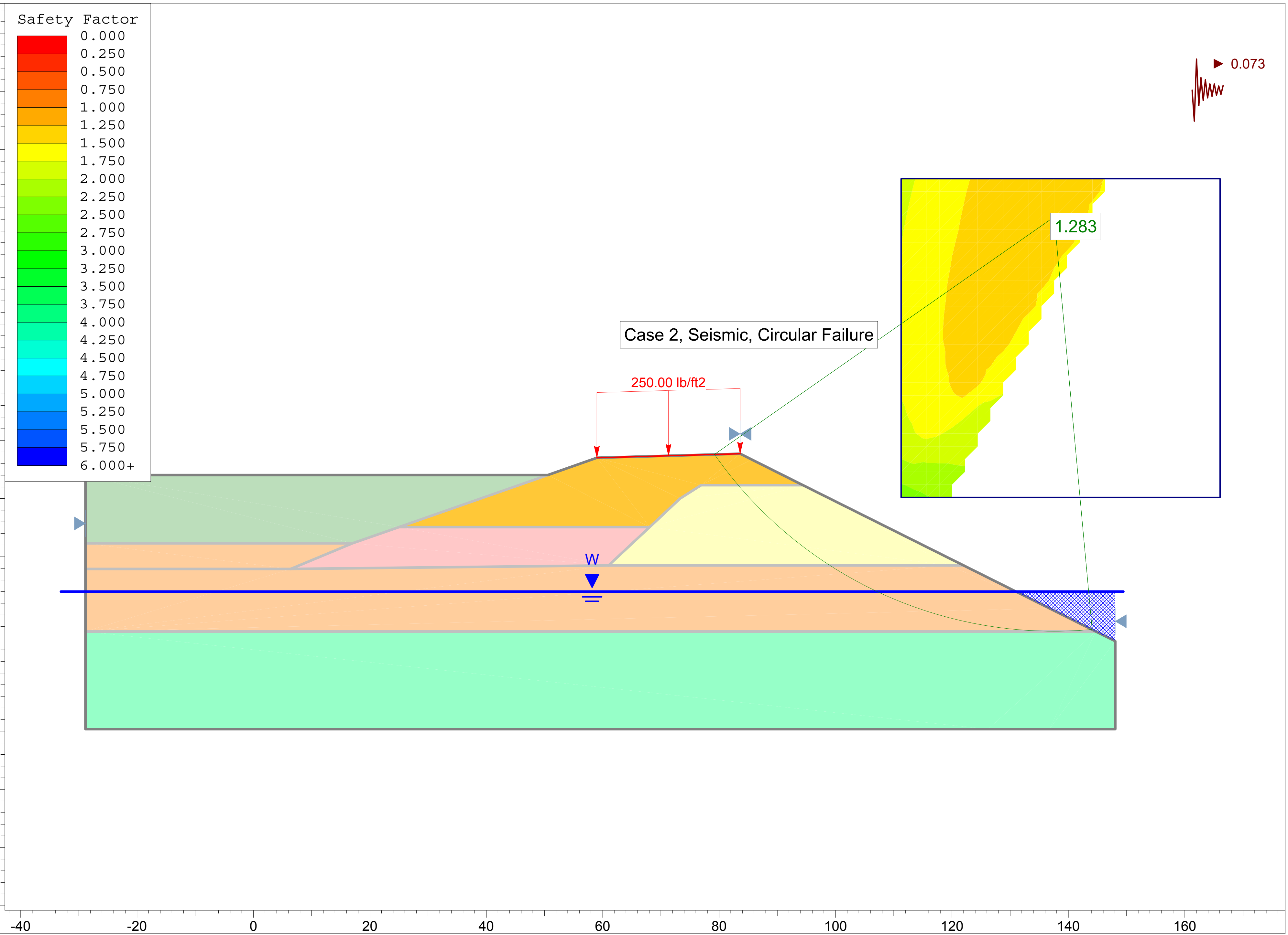
The following errors were encountered during the computation:

-107 = Total driving moment or
total driving force is negative. This will occur
if the wrong failure direction is specified,
or if high external or anchor loads are applied
against the failure direction.

-108 = Total driving moment
or total driving force < 0.1. This is to
limit the calculation of extremely high safety
factors if the driving force is very small
(0.1 is an arbitrary number).

-111 = safety factor equation did not converge

-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F)
< 0.2 for the final iteration of the safety factor calculation. This screens out
some slip surfaces which may not be valid in the context of the analysis, in
particular, deep seated slip surfaces with many high negative base angle
slices in the passive zone.



Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
0.073
1.283
Case 2, Seismic, Circular Failure
250.00 lb/ft2
W
-40
-20
0
20
40
60
80
100
120
140
160

Slide Analysis Information

Document Name

File Name: shawville_circular2_seismic.sli

Project Settings

Project Title:
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: On
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Bishop simplified
Janbu simplified
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: 1

Loading

Seismic Load Coefficient (Horizontal): 0.073
1 Distributed Load present:
Distributed Load Constant Distribution, Orientation: Vertical, Magnitude: 250 lb/ft2

Material Properties

Material: Previous Berm
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 270 psf
Friction Angle: 28 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: water
Strength Type: No strength
Unit Weight: 62.4 lb/ft3

Material: Foundation soil
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 125 lb/ft3
Saturated Unit Weight: 130 lb/ft3
Cohesion: 0 psf
Friction Angle: 33.5 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (upper)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 37 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (lower)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: whethered rock
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 135 lb/ft3
Saturated Unit Weight: 135 lb/ft3
Cohesion: 500 psf
Friction Angle: 25 degrees
Water Surface: Water Table
Custom Hu value: 1

Global Minimums

Method: bishop simplified
FS: 1.276730
Center: 137.563, 1108.417
Radius: 71.255
Left Slip Surface Endpoint: 79.175, 1067.574
Right Slip Surface Endpoint: 144.079, 1037.461
Left Slope Intercept: 79.175 1067.574
Right Slope Intercept: 144.079 1044.006
Resisting Moment=2.76215e+006 lb-ft
Driving Moment=2.16345e+006 lb-ft

Method: janbu simplified
FS: 1.206510

Center: 133.180, 1099.651
Radius: 62.429
Left Slip Surface Endpoint: 79.614, 1067.587
Right Slip Surface Endpoint: 143.001, 1037.999
Left Slope Intercept: 79.614 1067.587
Right Slope Intercept: 143.001 1044.006
Resisting Horizontal Force=34445.9 lb
Driving Horizontal Force=28550.2 lb

Method: spencer
FS: 1.283190
Center: 137.563, 1108.417
Radius: 71.255
Left Slip Surface Endpoint: 79.175, 1067.574
Right Slip Surface Endpoint: 144.079, 1037.461
Left Slope Intercept: 79.175 1067.574
Right Slope Intercept: 144.079 1044.006
Resisting Moment=2.77612e+006 lb-ft
Driving Moment=2.16345e+006 lb-ft
Resisting Horizontal Force=33822.3 lb
Driving Horizontal Force=26358 lb

Valid / Invalid Surfaces

Method: bishop simplified
Number of Valid Surfaces: 3097
Number of Invalid Surfaces: 4339
Error Codes:
Error Code -101 reported for 16 surfaces
Error Code -103 reported for 19 surfaces
Error Code -115 reported for 14 surfaces
Error Code -1000 reported for 4290 surfaces

Method: janbu simplified
Number of Valid Surfaces: 3097
Number of Invalid Surfaces: 4339
Error Codes:
Error Code -101 reported for 16 surfaces
Error Code -103 reported for 19 surfaces
Error Code -115 reported for 14 surfaces
Error Code -1000 reported for 4290 surfaces

Method: spencer
Number of Valid Surfaces: 3095
Number of Invalid Surfaces: 4341
Error Codes:
Error Code -101 reported for 16 surfaces
Error Code -103 reported for 19 surfaces
Error Code -111 reported for 2 surfaces
Error Code -115 reported for 14 surfaces
Error Code -1000 reported for 4290 surfaces

Error Codes

The following errors were encountered during the computation:

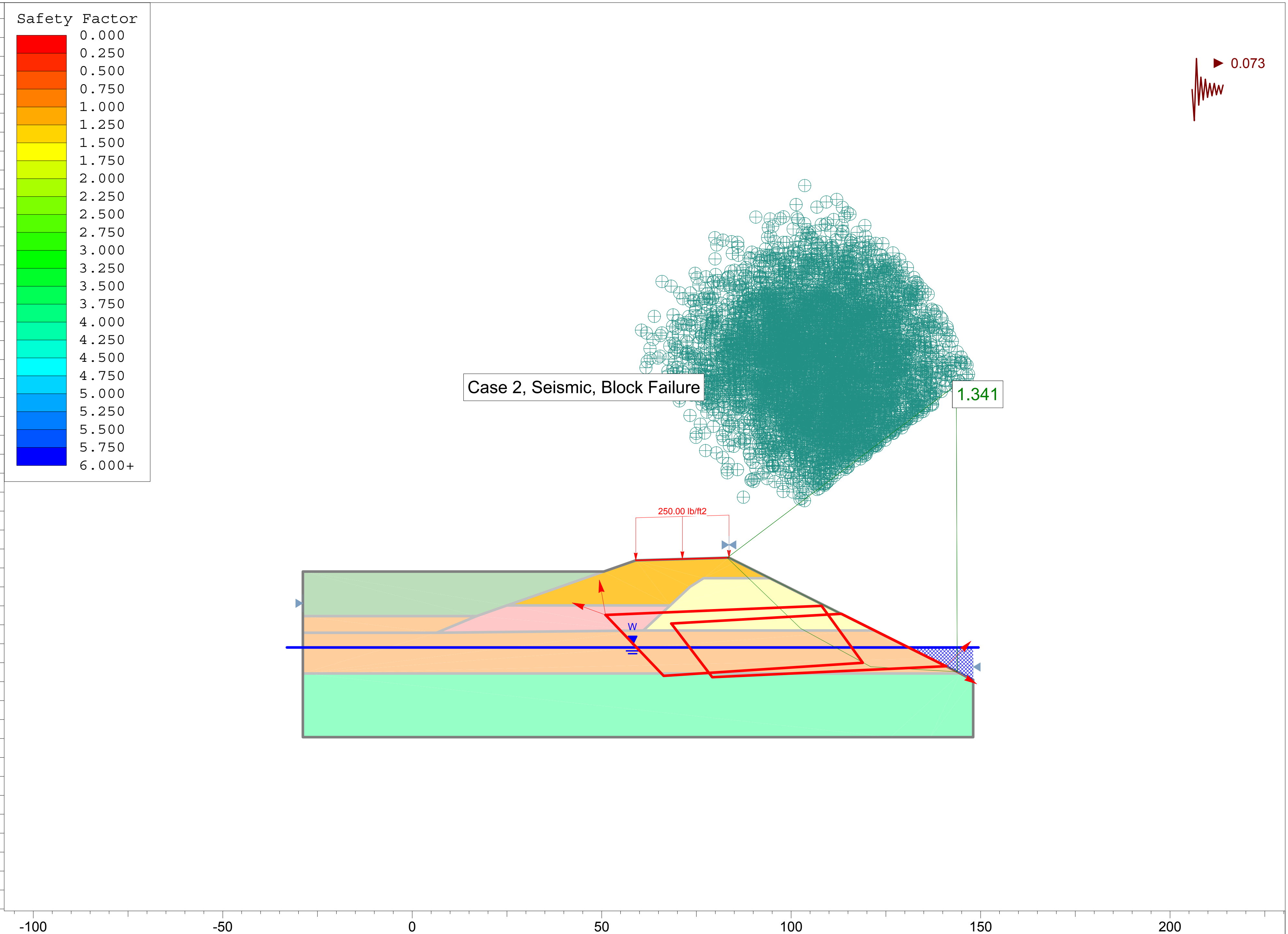
-101 = Only one (or zero)
surface / slope intersections.

-103 = Two surface / slope intersections,
but one or more surface / nonslope external polygon
intersections lie between them. This usually occurs
when the slip surface extends past the bottom of the
soil region, but may also occur on a benched
slope model with two sets of Slope Limits.

-111 = safety factor equation did not converge

-115 = Surface too shallow, below the minimum depth.

-1000 = No valid slip surfaces are generated
at a grid center. Unable to draw a surface.


Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
0.073
Case 2, Seismic, Block Failure
1.341
250.00 lb/ft2
W
-100
-50
0
50
100
150
200

Slide Analysis Information

Document Name

File Name: shawville_block2_seismic.sli

Project Settings

Project Title:
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: On
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Bishop simplified
Janbu simplified
Spencer

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Non-Circular Block Search
Number of Surfaces: 5000
Pseudo-Random Surfaces: Enabled
Convex Surfaces Only: Disabled
Left Projection Angle (Start Angle): 100
Left Projection Angle (End Angle): 160
Right Projection Angle (Start Angle): -30
Right Projection Angle (End Angle): 45
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

Seismic Load Coefficient (Horizontal): 0.073
1 Distributed Load present:
Distributed Load Constant Distribution, Orientation: Vertical, Magnitude: 250 lb/ft2

Material Properties

Material: Previous Berm
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 270 psf
Friction Angle: 28 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: water
Strength Type: No strength
Unit Weight: 62.4 lb/ft3

Material: Foundation soil
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 125 lb/ft3
Saturated Unit Weight: 130 lb/ft3
Cohesion: 0 psf
Friction Angle: 33.5 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (upper)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 37 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Fill (lower)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: whethered rock
Strength Type: Mohr-Coulomb
Unsaturated Unit Weight: 135 lb/ft3
Saturated Unit Weight: 135 lb/ft3
Cohesion: 500 psf
Friction Angle: 25 degrees
Water Surface: Water Table
Custom Hu value: 1

Global Minimums

Method: bishop simplified
FS: 1.310050
Axis Location: 143.570, 1113.340
Left Slip Surface Endpoint: 83.121, 1067.686
Right Slip Surface Endpoint: 143.823, 1037.588
Left Slope Intercept: 83.121 1067.686
Right Slope Intercept: 143.823 1044.006
Resisting Moment=2.14731e+006 lb-ft
Driving Moment=1.6391e+006 lb-ft

Method: janbu simplified
FS: 1.272900
Axis Location: 143.570, 1113.340
Left Slip Surface Endpoint: 83.121, 1067.686
Right Slip Surface Endpoint: 143.823, 1037.588
Left Slope Intercept: 83.121 1067.686
Right Slope Intercept: 143.823 1044.006
Resisting Horizontal Force=23946.3 lb
Driving Horizontal Force=18812.5 lb

Method: spencer
FS: 1.340820
Axis Location: 143.570, 1113.340
Left Slip Surface Endpoint: 83.121, 1067.686
Right Slip Surface Endpoint: 143.823, 1037.588
Left Slope Intercept: 83.121 1067.686
Right Slope Intercept: 143.823 1044.006
Resisting Moment=2.164e+006 lb-ft
Driving Moment=1.61393e+006 lb-ft
Resisting Horizontal Force=24490.6 lb
Driving Horizontal Force=18265.3 lb

Valid / Invalid Surfaces

Method: bishop simplified
Number of Valid Surfaces: 4656
Number of Invalid Surfaces: 344
Error Codes:
Error Code -107 reported for 3 surfaces
Error Code -108 reported for 171 surfaces
Error Code -111 reported for 82 surfaces
Error Code -112 reported for 88 surfaces

Method: janbu simplified
Number of Valid Surfaces: 4441
Number of Invalid Surfaces: 559
Error Codes:
Error Code -107 reported for 3 surfaces
Error Code -108 reported for 355 surfaces
Error Code -111 reported for 120 surfaces
Error Code -112 reported for 81 surfaces

Method: spencer
Number of Valid Surfaces: 3098
Number of Invalid Surfaces: 1902
Error Codes:
Error Code -107 reported for 3 surfaces
Error Code -108 reported for 1329 surfaces
Error Code -111 reported for 480 surfaces
Error Code -112 reported for 90 surfaces

Error Codes

The following errors were encountered during the computation:

-107 = Total driving moment or
total driving force is negative. This will occur
if the wrong failure direction is specified,
or if high external or anchor loads are applied
against the failure direction.

-108 = Total driving moment
or total driving force < 0.1. This is to
limit the calculation of extremely high safety
factors if the driving force is very small
(0.1 is an arbitrary number).

-111 = safety factor equation did not converge

-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F)
< 0.2 for the final iteration of the safety factor calculation. This screens out
some slip surfaces which may not be valid in the context of the analysis, in
particular, deep seated slip surfaces with many high negative base angle
slices in the passive zone.

Shawville Generating Station