SUBSURFACE EXPLORATION
AND
EMBANKMENT STABILITY ANALYSES
ACTIVE ASH BASIN DAM
(STATE ID NO. STOKE-116)
DUKE ENERGY BELEWS CREEK STEAM STATION
BELEWS CREEK, NORTH CAROLINA

S&ME Project No. 1356-09-029

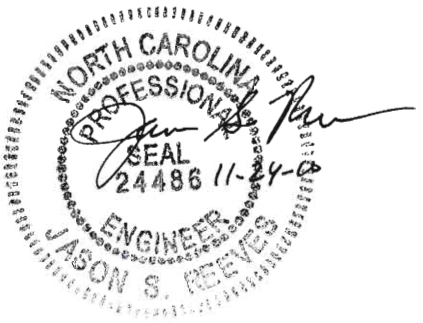
Prepared For:

Duke Energy®

3195 Pine Hall Road
Belews Creek, North Carolina 27009

Prepared by:

S&ME



9751 Southern Pine Boulevard
Charlotte, North Carolina 28273
NC PE Firm License No. F-0176

September 23, 2010

S&ME

September 23, 2010

Duke Energy
Belews Creek Steam Station
3195 Pine Hall Road
Belews Creek, North Carolina 27009

Attention: **Mr. Mike Cook, Senior Engineer**

Reference: **Geotechnical Investigation and Embankment Stability Analyses**
Ash Basin Dike
Active Ash Basin Dam (State ID No. Stoke-116)
Belews Creek Steam Station, Belews Creek, North Carolina
S&ME Project No. 1356-09-029, Task 3

Dear Mr. Cook:

S&ME, Inc. has completed our geotechnical investigation and embankment stability analyses for Ash Basin Dike at the Duke Energy (Duke) Belews Creek Steam Station. Our work was performed in accordance with S&ME Proposal No. 1356-22375-09 dated February 5, 2010 and under the terms and conditions of the Professional Services Agreement 0233032.04 MI 1342 002 COP01.1136 (PSA) with Duke. Authorization to proceed with this study was provided by issuance of Duke P.O. BC01.0000031575 dated February 12, 2010.

As part of our work we reviewed available historical documentation provided to us by Duke. A subsurface exploration program was planned and executed to support updated slope stability analyses for the Ash Dike. This report describes and presents findings of our subsurface exploration and our embankment slope stability analyses, and provides our geotechnical conclusions regarding the slope stability of the dam. S&ME is currently preparing a hydrologic and hydraulic review for the dam that will be issued under separate cover.

S&ME, INC. / 9751 Southern Pine Boulevard / Charlotte, NC 28273-5560 / *p* 704.523.4726 *f* 704.525.3953 / www.smeinc.com

We appreciate the opportunity to provide these services to Duke on this project. If you have any questions regarding the information in this report or we may be of further service, please contact us.

Sincerely,

S&ME, Inc.

Cedric Ruhl, P.E.
Project Engineer

Jason S. Reeves, P.E.
Senior Project Engineer
N.C. Registration No. 24486

NORTH CAROLINA PROFESSIONAL SEAL 24486 11-24-10 ENGINEER JASON S. REEVES

John C. Lessley, P.E.
Vice President, Technical Principal

CR/JSR/JCL/cps

S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Report\Ash Dike\AshDam.doc

TABLE OF CONTENTS

1. PROJECT INFORMATION 1
1.1 Background Information 1
1.2 Description of Ash Dike 1
1.3 Regulatory Jurisdiction 2
1.4 Recent Studies 2
2. ASH BASIN HISTORY 3
2.1 Historical Documentation Provided 3
2.2 Summary of Ash Dike Design, Construction, and Maintenance 3
2.2.1 1969 Subsurface Exploration by Law Engineering Testing Company 3
2.2.2 1971 Stability Analysis and Design by Duke Power Company 3
2.2.3 "Report of Safety Inspection" dated January 11, 1979 by Law Engineering Testing Company 4
2.2.4 Additional Evaluations by Duke Power Company – 1982-83 4
2.2.5 Installation of Horizontal Drains – 1984 to 1986 5
2.2.6 Reanalysis of Downstream Stability Duke Energy - 1988 5
2.2.7 3rd Independent Consultant Inspection, Law Engineering - 1988 6
2.2.8 5th Inspection by Law Engineering - 1999 6
2.2.9 6th Inspection by Law Engineering (Mactec) - 2004 6
2.2.10 Memorandum – Duke Engineering & Services -2004 7
2.2.11 7th Independent Consultant Report by S&ME – 2009 7
2.2.12 Assessment of Dam Safety by Clough, Harbour and Associates (CHA) – 2009 7
2.3 Historic Slope Stability Analyses 8
3. SUBSURFACE EXPLORATION PROGRAM 10
3.1 Soil Test Borings 10
3.2 Hand Auger Borings 12
3.3 CPT Soundings 12
3.4 Laboratory Testing 12
4. SUBSURFACE EXPLORATION FINDINGS 14
4.1 Subsurface Conditions 14
4.1.1 Embankment Fill 15
4.1.2 Drainage Blanket Fill 17
4.1.3 Residuum 18
4.1.4 Partially Weathered Rock 18
4.1.5 Refusal 19
4.1.6 Water Level Measurements 19
4.2 Laboratory Test Results 22
4.2.1 CU Triaxial Shear Strength Tests 22
4.2.2 Flexible Wall Permeability Tests 25
5. SEISMIC DEMAND 26
5.1 Seismic Coefficient for Pseudo-static Analysis 26
5.2 Liquefaction Triggering 26
6. SEEPAGE AND SLOPE STABILITY ANALYSES 27

TABLE OF CONTENTS (CONTINUED)

6.1 Cross-Sections for Stability Analyses 27
6.2 Interpreted Piezometric Head in Stability Analyses 27
6.3 Embankment Seepage Conditions 28
6.4 Embankment Seepage Modeling 29
6.5 Soil Properties in Stability Analyses 30
6.6 Minimum Safety Factor Standards 32
6.7 Slope Stability Analysis Method 32
6.8 Slope Stability Analyses Results 32
7. CONCLUSIONS 36
8. RECOMMENDATIONS 38
9. LIMITATIONS OF REPORT 41
10. REFERENCES 42
10.1 List of Report References 42
10.2 Five-Year Independent Consultant Reports 43
10.3 List of Historical Documentation from Duke Energy Archives 43
10.4 List of Drawings from Duke Energy Archives 44
10.5 List of Monitoring Information from Duke Energy 46

LIST OF FIGURES

Figure 1 – Site Vicinity Map
Figure 2 – Previous Subsurface Explorations
Figure 3 – Horizontal Drains
Figure 4 – Existing Wells
Figure 5 – 2010 Duke Energy Survey
Figure 6 – Field Test Location Plan
Figure 7 – Ash Dike Section Sta. 7+25
Figure 8 – Ash Dike Section Sta. 10+00
Figure 9 – Ash Dike Section Sta. 12+00

LIST OF APPENDICES

Appendix I – Field Exploration Data
Legend to Soil Classification and Symbols
Boring Logs
Hand Auger Boring Logs
CPT Soundings
Pore Pressure Dissipation Tests
Shear Wave Velocity Measurements
Table F-1 Permeability Calculated from Grain Size

TABLE OF CONTENTS (CONTINUED)

Appendix II – Laboratory Test Data
Table L1 – Laboratory Test Summary
Table L1a – Triaxial Testing Summary
Table L2 – Summary of Existing Duke Lab Data (1982 and 1983 borings)
Laboratory Test Data Sheets
Appendix III – Historic Water Level Information
Table WL-1 – Water Levels and Existing Instrumentation Station 7+25
Table WL-2 – Water Levels and Existing Instrumentation Station 10+00
Table WL-3 – Water Levels and Existing Instrumentation Station 12+00
Piezometer Water Level Plots (P-34, P-39, P-59, and P-61)
Appendix IV – Calculations
Seismic Coefficient
Liquefaction Potential Analyses
Seepage and Slope Stability Analyses

Photos

1. PROJECT INFORMATION

1.1 Background Information

Belews Creek Steam Station property is located approximately 18 miles north of Winston-Salem, North Carolina. The plant is a two-unit coal fired generating facility. The facility includes several dam embankments including the "Ash Dike" that impounds the active ash impoundment, the "Main Dam" and Saddle Dikes 1 through 4 that impound Belews Lake, the facility cooling pond, and the Chemical Washdown Pond Dam.

Evaluation of the Main Dam and Ash Dike embankments at the Belews Creek Steam Station facility were addressed in S&ME's February 5, 2010 proposal. The proposal addressed slope stability analyses for the Main Dam and Ash Dike embankments, as well as spillway capacity analyses for the Main Dam. Both hydrologic and hydraulic (H&H) and geotechnical analyses described in the February 5 proposal were recommended by S&ME in the seventh "Five-Year Independent Consultant Inspection Report", dated February 2009.

This report addresses stability analyses for the Ash Dike embankment only. The Ash Dike is located on Middleton Loop Road near Walnut Cove in Stokes County, North Carolina as shown on the attached Figure 1, Site Vicinity Map.

1.2 Description of Ash Dike

The Ash Dike is located on Little Belews Creek, a tributary of the Dan River. The dam impounds an approximate 350-acre lake used to impound coal combustion wastes. Coal combustion waste from the plant operations is discharged at the southern end of the active ash basin lake. Periodic ash removal by dredging is performed within the ash basin. Water is discharged from the ash basin through a tower located on the west side of the embankment. The ash basin area at full pond is 350 acres (0.55 sq mi) with a drainage area of approximately 711 acres.

The Ash Dike consists of an approximately 1,900 feet long earthen dam with a maximum crest height of approximately 130 feet and a crest width of 20 feet. The dam crest is near elevation 770 feet with a lowest downstream toe elevation of about elevation 640 feet near Station 10+60. Two benches or "berms" are located along the downstream slope of the dam embankment at approximate elevations 720 feet and 670 feet. These are referred to as the 720 Berm and 670 Berm, respectively. The 720 Berm is approximately 15 feet wide and the 670 Berm is approximately 25 feet wide.

The 720 and 670 Berms divide the downstream face into three segments. The original Duke Energy (Duke) Drawings BC 1037-1 and BC 1037-4 indicate the downstream slope to be constructed at 2.5 horizontal to 1 vertical (H:V) above the 670 Berm with the toe section below the 670 Berm constructed at 2.7H:1V. The upstream slope is constructed at 2H:1V. The ground surface of each berm slopes slightly upstream to concrete drainage ditches. These paved ditches drain to riprap lined drainage ditches that are located along

the left and right dam groin areas. Construction of the dam was completed in a single stage without use of ash material in construction of the embankment.

Underseepage and through-seepage is monitored by measuring the total flow at a common Parshall flume located below the left abutment (looking downstream) at approximately Station 12+00. There are no separate means to differentiate between flows from the individual drainage ditches or from underseepage at the toe. Quantity of flow from relief wells and from horizontal drainage pipes is monitored at individual discharge points.

The normal pool of the ash basin is reported to be maintained at a current operating level of about 752 feet. Previous operating levels of the ash basin are reported as high as 755.75 feet based on review of Duke monitoring data since 1985. The original design elevation of the reservoir is elevation 760 feet.

1.3 Regulatory Jurisdiction

The Ash Dike has historically been regulated by the North Carolina Utilities Commission (NCUC). Since January of 2010, the Ash Dike has been regulated by the North Carolina Department of Environment and Natural Resources (NCDENR) Dam Safety Division. The Ash Dike is referred to as Belews Creek Active Ash Basin Dam (STOKE-116) and is currently classified by the NCDENR Dam Safety Division as a Class C, Large, High Hazard Dam.

1.4 Recent Studies

S&ME prepared a "Five-Year Independent Consultant Inspection Report" (S&ME project No. 1411-08-126) dated February, 19, 2009. Detailed information regarding historic conditions of the dam is included in the five-year inspection reports that have been performed for the Ash Dike to satisfy NCUC requirements.

Subsequent to issuing the 2009 five-year report, an "Assessment of Dam Safety Coal Combustion Surface Impoundments (Task 3) Final Report" dated December 8, 2009 was issued by Clough, Harbour and Associates (CHA) for the Belews Creek Ash Dike. The report was issued to Lockheed Martin as a subcontractor to the United States Environmental Protection Agency (EPA). Several recommendations were provided regarding the Ash Dike for future action that included a stability analyses be performed for the embankment based on :1) the actual phreatic surface in the embankment; 2) the current operating conditions, 3) a rapid drawdown scenario; and 4) seismic conditions. Monitoring of all existing wells was recommended. The Ash Dike was given an overall rating of "Fair" by CHA.

In June of 2009, the EPA issued a "Fact Sheet" (EPA530-F-09-006) in which the ash basin dike at Belews Creek Steam Station was identified as a High Hazard structure according to criteria developed by the National Dam Safety Program for the National Inventory of Dams.

S&ME was requested to perform analyses consistent with those indicated in the 2009 CHA report. A summary of the historic documents and pertinent information provided to S&ME, recently performed subsurface exploration activities, site observations, and analyses related to the Ash Dike stability are summarized in the following sections of this report.

2. ASH BASIN HISTORY

2.1 Historical Documentation Provided

Beginning in December 2009, S&ME was provided with various historic Duke documents related to the original Ash Dike design, construction, analysis, maintenance, and monitoring of the Ash Dike. Various other documents were subsequently provided to S&ME as they have become available. These documents generally include the original geotechnical exploration data; design and construction information; original construction drawings and revised drawings reflecting maintenance items; internal Duke memoranda; five-year inspection reports; historic slope stability analyses; subsequent subsurface exploration and testing data; and instrumentation monitoring data.

2.2 Summary of Ash Dike Design, Construction, and Maintenance

A brief summary of some of the information provided to S&ME that is relevant to the analysis of the stability of the Ash Dike is provided in the subsequent paragraphs. The information is generally outlined in chronological order.

2.2.1 1969 Subsurface Exploration by Law Engineering Testing Company

A subsurface exploration was performed by Law Engineering Testing Company ("Law") in 1969 for the Ash Dike that included four soil test borings conducted along the crest centerline of the dam. Borings extended through the surface soils into the underlying rock.

The Ash Dike was founded on residual soils and partially weathered rock. Duke Drawing BC 1040-1 indicates that the embankment design included a 2-foot thick drainage blanket consisting of fine aggregate (Dan River sand) with a longitudinal filter drain incorporating a 1-foot thick gravel layer and transverse filter drains perpendicular to the longitudinal drain placed at 50-ft center-to-center spacings from approximate Station 11+25 to Station 15+97. The longitudinal drain was shown to extend below the right dam abutment (looking downstream).

2.2.2 1971 Stability Analysis and Design by Duke Power Company

Duke personnel performed seepage and slope stability analyses for the Ash Dike as part of the overall embankment design. The Law "Report of Safety Inspection" dated January 11, 1979 indicates that construction of the Ash Dike began in 1971 and was completed in October 1972.

Duke Drawing BC-1037-1 provides a summary of material parameters used for the slope stability analysis and applicable safety factors obtained at that time. Review of the Duke "Ash Dam – Stability Analysis" Volume 1 of 3, Calculation 49 dated May 1971 provides

slightly different design material parameters than shown on Drawing BC-1037-1. Results of the slope stability analyses are included in the calculations and indicate a downstream steady seepage safety factor of 1.5.

2.2.3 "Report of Safety Inspection" dated January 11, 1979 by Law Engineering Testing Company

General physical and hydrological characteristics of the Main Dam and Ash Basin Dike are presented in the first five-year independent consultant inspection report, "Report of Safety Inspection Belews Creek Dam and Ash Dike", by Law, dated January 11, 1979.

Law describes several adverse conditions observed during or shortly after construction of the Ash Dike. Some of these included observed seepage from the foundation soils in the toe area; seepage at the eastern (right) abutment; overtopping of the temporary cofferdams during construction; and potential clogging ("choking off") of the drainage blanket ("filter drain") by eroded soils. A portion of the drainage blanket near the toe was excavated before construction was completed and a rock toe drain was constructed at the end of the blanket drain. Shortly after completion of the dam in 1972, seepage was observed exiting the dam toe area above the blanket drain. A series of horizontal drains were installed in the rock toe drain and one at the left abutment in 1973.

The 1979 five-year report indicates that ground water elevations were observed in piezometers installed at representative locations on the downstream face to be higher than the original water levels assumed during design of the embankment. It was stated that this condition may have been be due to an anisotropic condition brought about by compaction of the embankment fill with horizontal permeability being somewhat greater than the vertical permeability. Another possible reason for the high phreatic lines suggested was that the internal drainage blanket may be of inadequate capacity. Referenced stability analyses by Duke for the Ash Dike indicated minimum safety factors of 1.34 and 1.31 for reservoir pools of elevation 745 feet and 760 feet (full pond), respectively, referenced from the Duke "Memo to File" dated December 13, 1978 (File BC-1419.00).

Also of note in the 1979 five-year report was that clear seepage was observed from the rock toe drain. Drainage from a swampy area at the right (looking downstream) abutment was observed to contribute to the seepage in the stream below the dam. The seepage from the right abutment and right abutment toe drain were observed to enter a culvert located below the embankment toe.

2.2.4 Additional Evaluations by Duke Power Company – 1982-83

Between 1982 and 1983, Duke had several additional soil test borings performed within the Ash Dike embankment and also performed laboratory testing on soil samples obtained in the borings. Borings were performed chiefly on the right abutment of the dike on the 720 Berm. The purpose of this additional work was to evaluate stability of the embankment under the higher than anticipated phreatic surface within the downstream face. The approximate boring locations performed by Duke are shown on Figure 2, Previous Subsurface Exploration.

Law issued a report titled "Belews Creek 1-2 Horizontal Drains for Ash Storage Basin Dam" on October 31, 1983 which proposes installation of PVC horizontal drains to relieve pore water pressures in the lower one-half of the downstream face. It was stated that Duke had investigated the high phreatic line condition with piezometers and found that the whole dam was affected. Law further stated that Duke had performed analyses assuming various levels of anisotropy of the embankment soils and determined that inadequate flow capacity of the internal blanket drain was the main cause of the higher phreatic levels. No separate report published by Duke Power Company to this effect has been found.

In their report, Law states that the blanket drain consisted of 2 feet of micaceous silty sands having 10 to 20 percent fines. The report stated that about 4 transverse drains comprised of coarse materials were present within the blanket drain along with two similar longitudinal drains. As of the date of the report, Piezometers P-30, P-35, P-40, P-42, and P-45 indicated water levels within about 3 feet of the ground surface, or 20 to 35 feet above the water surface assumed in design. Law concluded that the blanket drain material had a maximum permeability of about 4 to 5 x 10^{-3} cm/sec and further concluded that the blanket drain had a capacity of only 20 to 40 percent of the calculated seepage rate. Law proposed installing horizontal drains to lower the phreatic levels within the embankment on approximate 20-foot horizontal spacings.

2.2.5 Installation of Horizontal Drains – 1984 to 1986

Around 1984 and 1986, horizontal drains were installed in the Ash Dike near the toe, the 720 Berm and the 670 Berm levels. Based on Duke Drawing BC-1037-03, a total of approximately 27 horizontal drains were originally proposed.

Horizontal drains were drilled at upward inclinations of 0 to 7 degrees from the horizontal and to a penetration of up to 150 feet and drain by gravity into concrete flumes on the 670 Berm and 720 Berm and onto the ground surface where drilled below the 670 Berm. All of the drains were 2-inch PVC per Duke Drawing BC-1037-03. Volume of flow from each horizontal drain has been measured by Duke generally on a monthly basis. Attached Figure 3 shows the approximate horizontal drain locations based on the original Duke drawing. Approximate locations of the horizontal drains are shown on Figure 3, Horizontal Drains.

2.2.6 Reanalysis of Downstream Stability Duke Energy - 1988

Duke Energy provided additional stability analyses as report in "Belews Creek Steam Station Ash Dike Stability" under letter dated June 17, 1988 (Duke FSMR BC-172, File Nos. BC-1422.00, BC-1421.00, and BC 1434.00). This letter states that well testing had been completed on several wells from May to June 1988. In particular P-35, P-36, P-37, P-40, P-41, P-42, OW-47, OW-50, OW-56, OW-62, OW-66, OW-67, OW-68, OW-69, OW-80, OW-81, OW-84, OW-85, OW-86, and OW-87 were tested. Subsequent to this study, several piezometers were taken out of service; however, detailed information regarding this action has not been provided to S&ME.

Review of the Duke Ash Dam –Stability Analysis Volume 3 of 3 (Duke File BCC-0049) dated July 28, 1988 indicates that stability analyses were performed for the downstream slope for Stations 7+25 and 10+00 indicating safety factors of 1.36 and 1.55. It was concluded that the horizontal drains had been effective in improving the stability of the dam.

2.2.7 3rd Independent Consultant Inspection, Law Engineering - 1988

The 1988 Law "Third Independent Consultant Inspection" describes a reanalysis of the downstream slope of the Ash Dike in 1986 by Duke Power and Law. Sections were analyzed for Station 7+25 and 10+00 indicating safety factors of 1.35 at Station 7+25 and 1.42 for Station 10+00, respectively, for a pool elevation of 755 feet. Conditions modeled were prior to horizontal drain completion. It was stated that additional drains had been added since that analyses.

The 1988 Law report also states that the horizontal drains had been effective in lowering the phreatic surface in the Ash Dike. Observation Wells OW-53 and Piezometer P-60 indicated elevated levels. It was concluded that a reduction of uplift with depth was present below the phreatic surface, indicating horizontal as well as vertical water movement. It was recommended that the horizontal drains be cleaned with water jets due to slight increases in water levels measured with time in several of the piezometers.

2.2.8 5th Inspection by Law Engineering - 1999

The Law 1999 "Fifth Independent Consultant Inspection" report dated February 1999 states that water levels in Piezometers P-34, P-39, P-59, and P-61 to be gradually increasing over time. Increasing flow rates were also observed in Horizontal Drains HD4, HD5, HD20, HD21, HD23, HD24, HD18, and HD11A. Riprap had been placed in a wet area above the 670 Berm in 1998 at approximately Station 8+00. An area below the lower berm at about Station 11+50 was wet at about elevation 660 feet and had undergone recent subsidence. It was noted that a potentially rising phreatic surface was present between Stations 10+00 and 13+00. Clear seepage was observed flowing from the rock toe drain near the left and right abutment contacts. It was recommended that the horizontal drains be cleaned.

2.2.9 6th Inspection by Law Engineering (Mactec) - 2004

The 2004 Mactec "Sixth Independent Consultant Inspection" report dated January 13, 2004 indicated that Piezometers P-34, P-39, P-59, O-61, and P-54 had increasing water levels. It was noted that the flow from Horizontal Drains HD4, HD5, HD7B, HD20, HD21, HD18, and HD11A had increased with time. The report indicates that some horizontal drains were not shown on Drawing BC-1037-3.

Seepage was observed from the slope above the 670 Berm between Stations 13+00 and 13+25. A new wet condition was observed on the slope below the 670 Berm near Piezometer P-39. The report mentions 1988 Duke slope stability analyses that indicated a minimum safety factor of 1.6. It was recommended that the phreatic surface in the 1988 slope stability analyses be compared to the current phreatic surface. It was concluded that the horizontal drains generally appeared effective.

2.2.10 Memorandum – Duke Engineering & Services -2004

In 2004, Duke Engineering & Services issued a memorandum titled "Belews Creek Steam Station Ash Basin Dike and Main Dam Stability Evaluation" dated July 28, 2004. It was concluded that the phreatic levels within the embankment were similar to those used in the 1988 analyses and no additional stability analyses were required at that time.

Duke performed a partial survey of the dam embankment in July 2010. The survey information includes elevation and coordinate information along several cross-sections, along the ditch areas of the dam, riprap areas, and the top of casing and ground surface at the majority of the monitoring wells on the Ash Dike. An electronic copy of the survey was provided to S&ME. A copy of the figure is included as attached Figure 5.

2.2.11 7th Independent Consultant Report by S&ME – 2009

S&ME issued a "5-Year Independent Inspection Report" dated February 9, 2009. It was recommended that an evaluation of the hazard classification of the Ash Dike be performed. It was recommended that a seismic study of the dam be considered. It was further recommended that the piezometer and monitoring well data be reviewed to evaluate if the current water levels were within the original design assumptions. It was also recommended that the watershed characterization for the original design be updated to account for anticipated development levels around the reservoir to verify the spillway capacity. We found that water flow from the Parshall flume was impaired by the build up of sediment and recommended that the flume be cleaned out. Rising trends in the water surface readings were noted in Piezometers P-59, P-61, and P-64. Increasing flow rate were noted based on Duke monitoring data from HD1, HD2, HD3, HD4, and HD5 from the toe area, HD19, HD26, HD27 near the right abutment, and HD10 and HD11 between Stations 9+50 to 10+50.

2.2.12 Assessment of Dam Safety by Clough, Harbour and Associates (CHA) – 2009

CHA issued an "Assessment of Dam Safety Coal Combustion Surface Impoundments (Task 3) Final Report" dated December 8, 2009. Several areas were noted on the downstream face where riprap had been placed in seepage areas. An area of seepage was noted below a slope repair below the lowest bench. A damp area was noted at the toe of the slope in the vicinity of Station 10+00 that had soft soil and rutting from recent mowing activities that appeared related to a horizontal drain. The precipitation of iron oxide from the horizontal drains was noted in several areas including HD18 through HD22 and at the seepage monitoring point. It was noted that Piezometers P-61 and P-59 located on the downstream toe just above the 670 Berm at Station 10+07 appeared to be rising.

Several of the piezometers between the 670 Berm and 720 Berm were not being monitored and it was recommended that all of the piezometers be included in the next monitoring round. It was recommended that an updated stability analysis be performed including the actual phreatic surface in the embankment, current operating conditions, a rapid drawdown scenario, and seismic conditions. It was recommended that Duke develop a better methodology to quantify the seepage from the stone and embankment

materials. It was recommended that the hydrologic and hydraulic analysis for the Ash Dike be updated. A breach analysis was recommended. It was recommended that soil properties including shear strengths under the current conditions be reviewed.

2.3 Historic Slope Stability Analyses

S&ME has reviewed existing information provided by Duke related to slope stability analyses performed by Duke for the existing Ash Dike including the original design slope stability analysis information, 1984, and 1988 analyses. Based on review of the slope stability analyses provided to S&ME and Duke Drawing BC-1037-1, we understand that the following strength parameters were used in the Duke slope stability analyses as summarized in Table 1, for compacted fill used to construct the embankment.

Table 1 – Strength Parameters Used in Original Ash Dike Stability Analyses (Ref. Duke Drawing BC-1037-1)

Analysis Condition	Moist			Saturated			Minimum Calculated Safety Factor
	Unit Weight (pcf)	ϕ (deg)	C (psf)	Unit Weight (pcf)	ϕ (deg)	C (psf)	
BC-1037-1 Downstream							
-End of Const.	117	16	750				1.44
-Steady Seepage	117	27	400	120	27	400	1.50
BC-1037-1 Upstream							
-End of Const.	117	16	750				1.15
-Steady Seepage	117	27	400	120	27	400	1.68

Revised slope stability analyses were performed by Duke in 1978, 1984, and 1988 after installation of horizontal drains. The 1984 analyses and 1988 analyses are based on revised strength parameters estimated for the embankment materials based on the results of the subsurface explorations performed by Duke between 1982 and 1983. The material parameters used in these analyses are summarized in Table 2.

Table 2 - Historic Strength Parameters Used in Duke Slope Stability for Downstream Slope Stability Analyses

Material	Unit Weight (pcf)	Cohesion	Friction Angle (ϕ)	Description
Embankment Fill				
- 1978 Analysis	120	400	27	Saturated Conditions
- 1984 Analysis	120	0	34	
- 1988 Analysis	120	0	34	

Table 2 - Historic Strength Parameters Used in Duke Slope Stability for Downstream Slope Stability Analyses				
Material	**Unit Weight (pcf)**	**Cohesion**	**Friction Angle (ϕ)**	**Description**
Residual Soils				
-1978 Analysis	120	250	30	Saturated Conditions
-1984 Analysis	120	250	30	σ_v less than 2 ksf
-1988 Analysis	120	250	30	
Residual Soils				
-1978 Analysis	120	400	27	Saturated Conditions
-1984 Analysis	120	400	25	σ_v greater than 2 ksf
-1988 Analysis	120	400	25	
Weathered Rock				
-1978 Analysis	135	750	30	
-1984 Analysis	135	750	25	
-1988 Analysis	135	750	25	
Filter Material				
- 1984 Analysis	120	0	32	
- 1988 Analysis	120	0	32	

The results of the slope stability analyses performed by Duke in 1978, 1984, and 1988 based on review of the Duke files are summarized in Table 3. The stability analyses were performed for the steady seepage condition for the downstream slope with the material parameters from Table 2. Various cross-sections and water pond levels were analyzed. For the 1984 analyses, pool elevations of 745.6 feet and 760 feet were analyzed for Station 10+00. For the 1988 analyses, cross-sections at Stations 7+25 and 10+00 were analyzed with pond elevations of 752, 755, and 760 feet. The results of the slope stability analyses with corresponding pool elevations are included in Table 3.

Table 3 - Summary of Historic Duke Slope Stability Analyses						
Analysis Condition	**Required Safety Factor**	**Minimum Calculated Safety Factor**				
Steady Seepage Downstream Slope		**Pool Elevation (ft)**				
		745	**745.6**	**752**	**755**	**760**
- 1971 Analysis	1.5					1.50
- 1978 Analysis (1)	1.5	1.34				1.31
- 1984 Analysis (2)	1.5		1.45			1.37
- 1988 Analysis Sta. 7+25 (3)	1.5			1.57	1.57	1.55
- 1988 Analysis Sta. 10+00	1.5			1.38	1.37	1.36

(1) Ref. Duke Memo to File dated December 13, 1978 File BC-1419.00
(2) Ref. Duke Ash Dam Stability Analysis Calc. File No. 49 Vol. 2 of 3
(3) Ref. Duke Ash Dam Stability Analysis Calc. File BC-0049 Vol. 3 of 3

In order to comply with recommendations in the 2009 CHA report, Duke requested that S&ME perform a revised stability analyses for the Ash Dike embankment. As part of this study, additional subsurface exploration, laboratory testing, and engineering analyses related to the stability of the dam were performed. These tasks are summarized in the following sections of this report.

3. SUBSURFACE EXPLORATION PROGRAM

The 2009 CHA "Assessment" report recommended that the design shear strength parameters be further evaluated and a revised stability analyses be performed. S&ME performed additional subsurface exploration with undisturbed soil sampling and additional laboratory testing in conjunction with a review of existing shear strength data to verify and/or refine the shear strength parameters for updated slope stability analyses.

A subsurface exploration program was planned and executed to obtain subsurface data to support an updated slope stability analyses. The exploration included eight (8) soil test borings, four (4) hand auger borings, and three (3) Cone Penetration Test (CPT) soundings. Pore water dissipation and shear wave velocity testing were also performed in conjunction with the CPT soundings.

Selected soil samples obtained by thin-walled tube sampling or split-spoon sampling were subjected to laboratory testing. Water level measurements were also attempted in the borings, hand auger borings, and CPT soundings. The boring logs, hand auger logs, and cone penetration test records are included in Appendix I – Field Exploration Data.

In general, soil test borings, cone penetration or dilatometer soundings, or other sampling methods were advanced at the marked locations by methods as described more fully below.

3.1 Soil Test Borings

A Field Test Location Plan, Figure 6 is attached that shows the locations of recent soil test borings performed by S&ME in 2010. Borings AD-1, AD-3, and AD-12 were drilled along the crest of the dam; borings AD-4 and AD-6 were performed along the 720 Berm; and borings AD-7, AD-9, and AD-10 were performed along the 670 Berm.

The soil test borings were performed by an S&ME drill crew using a CME-750 drill rig mounted on an all terrain vehicle (ATV) carrier. The soil test borings were extended to depths ranging between 19.4 and 103.7 feet below the existing ground surface. Hollow-stem, continuous flight augers were used to advance the borings into the ground.

Split-spoon samples and Standard Penetration Resistances (N-values) were obtained at selected intervals in general accordance with method ASTM D-1586, "*Standard Test*

Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils." An "autohammer" was used for the SPT in the borings. The autohammer typically has a higher efficiency than a traditional "safety" hammer, and this was compensated for in our analysis. Uncorrected N_{FIELD}-values as recorded in the field are shown on the boring logs in Appendix I.

In addition to the split-spoon samples, twenty-four (24) relatively undisturbed thin-walled tube samples were obtained with a Shelby tube or fixed piston sampler. Undisturbed samples were obtained either in conjunction with conventional split spoon sampling and penetration tests, or in separate parallel borings advanced specifically for the purpose of obtaining samples in targeted horizons or seams.

Undisturbed samples were obtained by pushing sections of three-inch outside diameter, 16 gauge, steel tubing (Shelby tube) into the soil at the desired sampling intervals. The procedures used generally follow those described in ASTM D 1587, "*Standard Practice for Thin-Walled Tube Geotechnical Sampling of Soils*." Tube lengths are standard 30-inches unless otherwise indicated. After advancing the tube, a short set period was allowed for pore pressure dissipation, then the tube was slowly spun in place to shear and break off the end of the sample. The Shelby tube, together with the encased soil, was then carefully removed from the ground.

After withdrawal, the length of the recovered soil was measured and the sample preserved in accordance with the sampling plan. Recovered Shelby tube samples were typically treated as either Group B or Group C samples as defined by ASTM D 4220, "*Standard Practices for Preserving and Transporting Soil Samples*," Section 4, depending on the level of care to be exercised during transport. Locations and depths of undisturbed samples were recorded on each field test boring record.

The soil samples obtained from the split-spoon and undisturbed sampling were examined in the field and laboratory by S&ME geotechnical professionals, and visual and manual classifications were estimated, using the general procedures of the Unified Soil Classification System (USCS).

The boring locations were established in the field by our personnel by using a hand held global positioning system device with a horizontal accuracy of approximately 10 feet. The boring locations were chosen to supplement existing historic data and to develop representative cross-sections for the slope stability analyses.

Boring logs presenting the subsurface information obtained are included in Appendix I The ground surface elevations shown on the boring logs are based on interpolating elevations from available North Carolina Department of Transportation (NCDOT) digital 2-foot topographic contour information available for the site.

The boreholes were abandoned by grouting them in place with neat bentonite cement grout.

3.2 Hand Auger Borings

Hand auger borings AD-HA-7, AD-HA-7A, AD-HA-10 were performed along the 670 Berm and AD-HA-11 was performed along the downstream toe area as shown on Figure 6, Field Test Location Plan. The hand auger borings were advanced to depths of 4.5 to 5.3 feet below the existing ground surface by manually twisting a hand auger into the ground. Water level measurements were attempted in the hand auger boreholes. The hand auger borings were abandoned by backfilling the hand auger boreholes with bentonite. The hand auger boring logs are included in Appendix I.

3.3 CPT Soundings

CPT soundings AD-2, AD-5, and AD-8 were performed within the existing dam footprint and were extended to depths ranging from 34.6 to 49.7 feet below the existing ground surface. CPT sounding AD-2 was performed along the crest of the dam; sounding AD-5 was performed along the 720 Berm; and sounding AD-8 was performed along the 670 Berm as shown on Figure 6, Field Test Location Plan.

The CPT soundings were performed using an ATV mounted vehicle to hydraulically advance the electronically instrumented cone penetrometer. During penetration, the tip resistance, pore water pressure and sleeve friction were measured and recorded during penetration, in general accordance with ASTM D-5778, "*Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils*." The testing also utilized a seismic piezocone. Using theoretical and empirical correlations, the CPT data was used to evaluate soil stratigraphy and to estimate soil strength parameters. The method produces a nearly continuous record of soil data.

Pore pressure dissipation testing was performed at selected depths in CPT soundings AD-2 and AD-5. The pore pressure dissipation testing consisted of recording the pore pressure induced during advance of the CPT cone using an electronic pore pressure meter mounted in the CPT tip section and allowing the pore pressure to decay to a minimum of 50 percent dissipation of the initial excess pore pressure. The time at 50 percent excess pore pressure dissipation, t_{50} was estimated. The horizontal hydraulic conductivity, k, was estimated by using the relationship by Leroueil and Jamiolowski (1991). The results of the pore pressure dissipation testing are included of the pore pressure dissipation records included in Appendix I.

Shear wave velocities within the CPT sounding were estimated by using an instrumented hammer to impart an impact force at a known location on the ground surface. The time for surface waves to travel from the ground surface to the seismic sensor was estimated by an electronic trigger mounted on the hammer. The depth of the seismic sensor was estimated based on the CPT probe depth. The shear wave velocity is estimated directly from the time interval and distances measured during the testing. The shear wave velocity test results are included in Appendix I.

3.4 Laboratory Testing

The chief driller prepared field test boring records or sounding records recording subsurface conditions encountered during field work. Field records contain information

about the drilling or push method, samples attempted and sample recovery, presence of coarse gravel, cobbles, etc, and indications of materials encountered between sample intervals. Field records are retained at our office.

Handling of recovered samples was in general accordance with one or more of the procedures described by ASTM D 4220, section 4, or ASTM D 5079 "*Standard Practices for Preserving and Transporting Rock Core Samples*," section 7.5.1, as described below. Carbon copies of field boring records accompanied the samples. Recovered samples not expended in laboratory tests are commonly retained in our laboratory for 60 days following completion of drilling.

Soil Samples were handled as either ASTM Group B or Group C samples as defined by ASTM D4220. Group B samples are those samples not suspected of being contaminated and for which only water content and classification, or profile logging will be performed. Group B samples also include portions of bulk samples intended to be remolded in the laboratory for compaction, swell pressure, percent swell, consolidation, permeability, CBR, or shear testing, which are segregated from the sample to preserve natural water content. Selected undisturbed samples intended for use in physical testing for shear strength parameters were handled as Group C samples. Thin-walled tube samples were sealed at the ends with paraffin and capped with plastic end caps. Samples were transported in the upright position in containers providing complete encasement in cushioning or insulation for individual samples.

Representative samples of the cuttings or split spoon samples, or representative bulk samples, were placed in suitably identified, sealed glass jars or plastic containers and transported to the laboratory. Sample identification numbers on the containers corresponded to sample numbers recorded on field boring records or test pit records.

Soils were classified in the laboratory by the geotechnical engineer in general accordance with ASTM D 2488, "*Standard Practice for Description and Identification of Soils (Visual-Manual Method)"*. Classification is based on visual-manual manipulation of samples with only limited reliance on laboratory classification tests. The system provides 67 soil classifications for sands, gravels, silts, clays and organic soils.

Undisturbed samples were stored in the vertical position in the laboratory. Samples were extruded from the thin-walled sampler, using a specially constructed extruder, in the same direction of travel as the sample entered the tube during sampling. In certain cases it was found necessary to cut the tube into short sections to facilitate removal of the soil without compressing or disturbing the sample.

Specimens were trimmed using a wire saw or steel straightedge. Where removal of pebbles or crumbling resulting from trimming caused voids on the surface of the specimens selected for quantitative laboratory testing, they were filled with remolded soil obtained from the trimmed portion of the sample.

Selected tube samples and split-spoon samples were subjected to the following laboratory tests:

- Natural Moisture Content
- Particle-Size Distribution
- Atterberg Limits
- Flexible Wall Permeability
- Insitu Unit Weight
- Specific Gravity of Solids
- Consolidated Undrained (CU) Triaxial Shear with Pore Pressure Measurements

The laboratory test results are discussed in terms of the described properties of individual soil zones later in this report. A summary of the laboratory tests is included in Table L1 in Appendix II of this report. Detailed results and information for the individual tests are also included on data sheets included in Appendix II. The testing was performed in general accordance with applicable ASTM testing standards.

4. SUBSURFACE EXPLORATION FINDINGS

Recovered field samples and field boring records were reviewed in the laboratory by the geotechnical engineer. Finished soil test boring records, electronic cone penetrometer test records and other field data are assembled in Appendix I.

S&ME's interpreted subsurface stratification is indicated in the subsurface profiles included in Figures 7 through 9. In figures 7 through 9 the interpreted profile is shown at right angles to the crest of the embankment at approximately stations 7+25, 10+00 and 12+00. Profiles include S&ME boring data as well as Law or Duke boring or piezometer data to the extent that such data could be found in previous records or reports.

The depth and thickness of the subsurface strata indicated on the profiles and the soil test boring records and on other field records were generalized from and interpolated between test locations. The transition between materials will be more or less gradual than indicated and may be abrupt. Information on actual subsurface conditions exists only at the specific boring locations and is relevant to the time the exploration was performed. The stratification lines were used for our analytical purposes and, unless specifically stated otherwise, should not be used as the basis for design or construction cost estimates.

4.1 Subsurface Conditions

The following brief generalized description of subsurface conditions encountered in the Ash Dike embankment is provided. For purposes of discussion, soils were subdivided generally according to the original Duke design drawings and historic slope stability analyses.

Three cross-sections that were developed based on the previous and recent subsurface data obtained in the embankment area are presented in Figures 7 through 9. The soil layer boundaries shown in these cross-sections are interpretive, and should be considered approximate. The cross-sections were developed based on the survey data, Duke Drawings BC-1037-1 through BC-1037-4, the 1969 Law report, 1982 and 1983 Duke

borings, recent soil test borings performed by S&ME, and other information from historical documentation, and interpolation between data collected in our exploration.

Subsurface conditions encountered within the Ash Dike embankment generally consist of a thin layer of rootmat material underlain by embankment fill, drainage blanket fill, residual soils, partially weathered rock, and auger refusal material. The residual soils have formed from the in-place weathering of the underlying parent bedrock. The residual soils generally transition with depth into partially weathered rock. Borings performed during dam design in 1969 penetrated substantial thicknesses of alluvial soils which were not encountered in S&ME 2010 borings. Previous reports have suggested that alluvial soils and lower consistency residual soils present in this area were undercut and replaced during preparation of the foundation under the observation of Duke.

The generalized subsurface conditions at the site are described in the following sections. For more detailed information, please refer to the individual boring logs, hand auger boring logs, and cone penetration test records included in Appendix I. The ground surface elevations indicated on the boring logs, hand auger boring logs, and cone penetration test records were interpolated from available NCDOT 2-foot topographic information available for the site and the original design drawings and should be considered approximate.

4.1.1 Embankment Fill

Existing embankment fill soils that are part of the original dam construction were encountered to various depths in the borings performed on the face of the dam. Using as built plans by Duke from the original construction, profiles 7 through 9 each include an approximate contact line between the embankment fill and the underlying drainage blanket or residual soils which more or less conforms to the undercut line presented on the drawings to the extent that this line was corroborated by the boring data.

Borings AD-1, AD-3, and AD-12 performed along the dam crest encountered embankment fill to depths of about 74, 44.5, and 99 feet, respectively. Fill depths encountered in borings AD-4 and AD-6 performed along the 720 Berm were approximately 44.5 and 44.1 feet, respectively. Topographic data suggests that fill depths diminish substantially on the 720 Berm as it approaches the groin.

Only the profile cross section drawn at station 10+00 indicates a classic dam profile, with the base of the dam more or less level and the fill thickness become consistently greater proceeding upslope from the downstream toe. Topographic drawings suggest that the face of the dam oriented on a 2.5H:1V inclination follows the original grade downhill for a substantial distance downstream of the 720 Berm and beyond approximately station 11+00, with a fill thickness of only about 10 to 15 feet over a wide section of the downstream face. This is particularly apparent on the section shown along Station 12+00 and to a lesser extent on the section 7+25.

The embankment fill in borings AD-7, AD-9, and AD-10 performed along the 670 Berm ranged in depths from approximately 13.5, 18, and 24.8 feet below the existing ground surface. As with the 720 Berm, fill depths along the 670 Berm near the toe of the dam

become very thin as the fill feathers out approaching the groin areas. Hand auger borings AD-HA-7, AD-HA-7A, and AD-HA-10 encountered fill to the termination depths ranging from 4.5 to 5.3 feet below the existing ground surface. The lowest bench is only a few feet thick over much of its length.

The embankment fill soils generally consisted of firm to hard sandy silt (ML), silty clay (CL), and clayey silt (MH) and very loose to dense silty sand (SM and SP) as determined by visual-manual examination of the recovered samples. We observed no samples that contained fibrous organic material or exhibited an organic odor. N_{Field}-values obtained with the autohammer typically ranged from 11 to 15 blows per foot (bpf) in the lower portion of the downstream slope and from 20 to 25 blows per foot in more deeply buried portions of the slope on the 720 Berm to the crest. There was only one N_{Field}-value of about 8 bpf near the surface that implied loose conditions.

Soil specimens washed over a No. 200 sieve indicated 44 to 65 percent clay or silt by weight (material passing a No. 200 sieve). The CPT soil index parameter Ic suggests a fines content of 25 to over 50 percent using the relationship by Robertson and Fear (1998). The minus No. 40 sieve portion of the tested soils indicated a liquid limit (LL) ranging from 36 to 57 percent with Plastic Limit (PL) values of 26 to 32 percent. Plasticity Index values thus obtained range from 10 to 15 percent, with one or two outlying values of 25 to 35 percent among the older data. Moisture contents ranged from about 15 to 22 percent oven-dried, substantially below the plastic limit.

CPT penetration data imply a variable, stratified deposit consisting of moderately thick (6 inch to 12 inch) layers of alternating sands and clays or silts. CPT tip stresses obtained ranged from 40 to 50 tons per square foot (tsf) but all three soundings exhibit numerous spikes in the penetration data to about 150 tsf over intervals of one to two feet. Variations in the penetration properties and pore pressure values in the CPT records indicate some variation in physical composition of the fill when placed in individual lifts as well as variations in the density achieved during compaction.

CPT penetration data indicate soil consistencies approximately the same as implied by the standard penetration data. Relative density of the sandier lenses or seams estimated using the relationship by Kulhawy and Mayne (1990) range from medium dense to dense. Cone penetrometer tip resistances in layers indicating more cohesive soils ranged from 40 to 50 tsf. The relationship by Robertson & Campanella (1988) gives values of undrained shear strength ranging from 2.5 to 3 tsf, using a cone factor N_{kt} of 15. This is consistent with very stiff cohesive soils.

Shear-wave velocity measurements were made using a seismic cone penetrometer instrumented with geophones at sounding locations AD-2 and AD-5 performed at the approximate locations shown on the attached “Test Location Plan”. The shear wave velocity profile depicted for the sounding resolves into vertical intervals of roughly 3 feet within this zone. Shear wave velocity tests extended to termination of the soundings at depths of 43 to 49 feet below the crest of the dam.

Shear wave velocities measured in CPT Soundings AD-2 and AD-5 ranged from 523 to 1836 feet per second (fps) with average shear wave velocities of 931 and 840 fps, respectively. There is substantial contrast between interpreted velocities in adjacent vertical intervals. A best-fit profile evaluated from the scatter of the data may be expressed as a shear wave velocity ranging from about 600 fps near the top of this layer, increasing linearly with depth of a maximum value of 1000 to 1500 fps at the termination of the soundings. The linear trend of increase with depth is typical of most saturated cohesive deposits, including fills that are not heavily overconsolidated. Please refer to the Shear Wave Velocity Calculations and Shear Wave Velocity Profiles included in Appendix I for more detailed information.

4.1.2 Drainage Blanket Fill

Duke Drawing BC 1040-1 indicates that the embankment design included a 2-foot thick drainage blanket consisting of fine aggregate (Dan River sand). The drawing calls out a requirement for a maximum grain size of ½ inch; 85-100 percent passing the No. 4 sieve; 70-95 percent passing the No. 8 sieve; 50-85 percent passing the No. 16 sieve; 25-70 percent passing the No. 30 sieve; 5-25 percent passing the No. 50 sieve; 0-8 percent passing the No. 100 sieve; and zero passing the No. 200 sieve.

Silty sands (SP and SM) were encountered in borings AD-7, AD-9, and AD-10 performed along the 670 Berm at depths consistent with the drainage blanket fill material shown on the design drawings. The drainage blanket was encountered at depths of approximately 12.5 feet to 15.5 feet, 24 feet to 25 feet, and 23.8 feet to 24.8 feet, respectively, in the three borings. Owing to differences in the elevation of the undercut line during construction of the dam, the drainage blanket differs substantially in elevation in different locations in the lower downstream face. The drainage blanket slopes downward towards the toe at roughly the same slope as the downstream face of the dam on cross sections close to the abutments, and in addition slopes towards the centerline of the dam. In addition, the lateral extent of the drainage blanket differs by station.

Penetrated thicknesses of drainage material were 3 feet, 1 foot, and 1 foot at each location. Boring AD-4 on the 720 Berm encountered drainage blanket fill material consisting of silty sand (SM) from approximately 16.3 feet to 17.2 feet, less than one foot thick.

N_{Field}-values obtained in the drainage blanket fill material in AD-4, AD-7, and AD-9 ranged from 10 to 20 bpf, indicating loose to medium dense relative densities. Based on the N_{Field}-values it appears that the drainage blanket fill material was moderately to well compacted.

Recovered samples indicate an SM classification based on gradation and distribution of particle sizes does not appear to conform to the requirements for “fine aggregate filter” indicated on the Duke drawings for the main dam. The drainage blanket material had fines contents ranging from 13 to 28 percent among several tests conducted by washing the #200 material through a sieve. The sand sized portion of the material appears to be

gap graded in the medium sand range and does not conform to requirements of the drawing in the fine sand and fines ranges.

Gradation	Percent Passing				Remarks
Drawing BC 1040-1		AD-4 15-16.5 ft	AD-7 13-14.5	AD-9 23-25 ft	
½ inch	100	100	100	100	
#4	85-100	96	95	96	
#8	70-95	91	90	92	
#16	50-85	83	82	81	
#50	5-25	50	36	47	Out of Spec
#100	0-8	38	22	32	Out of Spec
#200	0	28	13	22	Out of Spec

4.1.3 Residuum

Piedmont residual soils were encountered below the embankment fill or drainage blanket and extend to the underlying partially weathered rock or to refusal to the borings. These soils represent the remnant of the original soil profile after preparation of the foundation of the dam, and softer residuum would have likely been removed as part of this work. Residual soils below the 670 Berm will provide the chief resistance to any sliding envelope passing below the toe of the dam through the lower portion of the downstream face.

Average thickness of the residual soil layer ranges from 5 to 10 feet at the downstream toe and 10 to 20 feet further upstream along the centerline of the embankment as indicated on the subsurface profile at Station 10+00. Earlier boring data suggest substantially greater thicknesses of residuum on the left abutment. Thicknesses of up to 40 feet are shown along Station 12+00.

These soils are completely decomposed from weathered rock and retain most of the parent rock bedding and foliation. Where sampled, the residuum typically consists of medium dense to dense silty sand (SM) and stiff to very hard sandy silt (ML). USCS classifications of ML and SM were established by visual-manual procedure. These soils had between 11 and 62 percent soil fines. Liquid Limit of the residuum ranged from non-plastic to 46 with PI values ranging from non-plastic to 15.

A layer of loose silty sand was encountered in boring AD-9 from 35 to 36.5 feet (N_{Field}-value of 4 bpf). N_{Field}-values obtained in the residuum ranged from 8 to 10 bpf below the 670 Berm.

4.1.4 Partially Weathered Rock

Partially weathered rock (PWR) was encountered underlying embankment fill, drainage blanket fill, or residual soils in borings AD-1, AD-4, AD-6, AD-7, AD-9, AD-10, and AD-12 at depths of approximately 17 to 99 feet below the existing ground surface.

Partially weathered rock is defined in this study as residual soils exhibiting N_{Field}-values in excess of 50 blows per 6 inches (50/6"). When sampled, the PWR generally breaks down into sandy silts and silty sands with rock fragments.

Borings AD-1, AD-3, AD-4, AD-7, AD-9, and AD-12 were terminated in the PWR at depths ranging between 19.4 and 103.7 feet below the existing ground surface.

4.1.5 Refusal

Borings AD-6 and AD-10 were terminated upon encountering auger refusal at depths of 78.5 and 26 feet below the existing ground surface, respectively. Auger refusal is defined as material that could not be penetrated with the drilling equipment used on the project. Auger refusal material may consist of large boulders, rock ledges, lenses, seams or the top of parent bedrock. Core drilling techniques would be required to evaluate the character and continuity of the refusal material. However, rock coring was beyond the scope of this study.

Original borings A-1 through A-4 performed by Law in 1969 indicate bedrock consisting of muscovite garnet schist is present beneath the PWR.

4.1.6 Water Level Measurements

Water level readings were made in the open boreholes immediately after completing drilling and withdrawal of the tools. All 2010 borings by S&ME were performed as open wells. Temporary observation wells were constructed in the open boreholes by inserting PVC casing to the termination depth. In these cases no slotted sections were used to isolated specific intervals of interest. Where feasible, measurements were repeated after an elapsed period of at least 24 hours to gauge the stabilized water level.

Water levels were measured in the open boreholes and in temporary standpipes installed in the boreholes at intervals of 1 to 8 days after termination of drilling. Water levels noted during drilling or in open boreholes after drilling are noted on the logs where these were collected. Procedures for measurement of liquid levels in open boreholes are described in ASTM D 4750, "*Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well).*"

CPT penetration pore pressures include the in-situ equilibrium pore pressure, controlled by the local ground water regime, and the excess pore pressure, generated by insertion of the probe. In clays and silts, penetration is essentially undrained and recorded pore pressures significantly exceed in-situ equilibrium pore pressures. In sands and gravels, penetration is essentially drained and recorded pore pressures are essentially equal to the in-situ equilibrium pore pressure. The piezometric surface, defined as the point of zero equilibrium pore pressure, was obtained by plotting in-situ equilibrium pore pressure vs. depth using only pore pressure data from sand or gravel soils. Where possible, derived piezometric surface was verified by tape measurement through the sounding opening after removal of the CPT rod and before collapse of the soils.

Water was measured in borings AD-1, AD-3, and AD-12 performed on the dam crest at depths of at 39.1, 38.9, and 44.6 feet, respectively. Cone penetration test AD-2 indicated a ground water surface at about 21 feet depth based on an interpreted hydrostatic pore pressure line in the sandy soils underlying that depth. Crest elevation of the dam is 770 feet and current pool is 752 feet, 18 feet below the crest. Water elevations recorded in the borings along the crest lie substantially below current pool, but the piezometer elevation suggested by pore pressure readings in sounding AD-2 appear to agree well with the current pool elevation and with observation wells installed by Duke along the crest.

Water was measured in borings AD-4 and AD-6 on the 720 Berm at depths of 25.9 and 39.0 feet, respectively. In boring AD-4 fill extended to a depth of only 16 feet, ground water at this location was measured below the underlying drainage blanket and within the residuum. Piezometer elevation suggested by pore pressure readings in sounding AD-5 at 25 feet agree well with ground water measured in AD-4. In boring AD-6 the ground water depth of 39 feet lies a few feet above the base of the fill but substantially below the elevations suggested by boring AD-4 or CPT sounding AD-5. However, ground water measured in boring AD-6 appears to agree with Duke Piezometer P-83, which extends to similar depth a short distance away.

SUMMARY OF GROUNDWATER MEASUREMENTS

Boring Number	Ground Water Depth (ft)	Time of Measurement	Elevation (ft)	Remarks
AD-1	74 39.1	TOB. 24 hour	696 730.9	At crest - elevation 770 feet. Depth 103 ft TOB reading at base of fill.
AD-2	21	CPT reading	749	At crest - CPT sounding, water level interpolated from pore water pressure trend
AD-3	35 38.9	6 days 8 days	735 731.1	At crest - elevation 770 feet. Depth 54 ft Readings near base of fill. No Blanket here.
AD-4	33 25.9	TOB. 24 hour	687	720 Berm - Sand Blanket Encountered From 16.3 to 17.2 ft – Water level below blanket. Boring depth 49 feet.
AD-5	25	CPT reading	695	720 Berm - CPT sounding, water level interpolated from pore water pressure trend
AD-6	39	24 hour	681	720 Berm – No sand blanket encountered. Measured water 6 feet above base of fill.
AD-7	Dry 2.3	TOB 24 hour	-- 667.7	670 Berm – Sand Blanket encountered From 12.5 to 15.5 ft. Boring depth 19 feet.
AD-8	7	CPT reading	663	670 Berm - CPT sounding, water level interpolated from pore water pressure trend Drainage blanket estimated 18 feet based on Qc readings.

SUMMARY OF GROUNDWATER MEASUREMENTS

Boring Number	Ground Water Depth (ft)	Time of Measurement	Elevation (ft)	Remarks
AD-9	21 11.5 6.9	TOB 1 hour 8 days	649 658.5 663.1	670 Berm – boring 38 feet to termination in rock. Possible drainage blanket at depth 25-29 ft.
AD-10	4 2	TOB 8 days	666 668	670 Berm – Sand Blanket Encountered From 23.8 to 24.8 ft. Boring 26 ft deep.
AD-12	69 44.6	TOB 24 hour	701 725.4	At crest – elevation 770 feet. Boring extends through 99 feet of fill and terminates at 104 ft.
AD-HA-7	3.2	4 days	666.8	670 Berm – Refused at 5 feet
AD-HA-7A	4.1	24 hour.	665.9	670 Berm – Refused at 4.5 feet
AD-HA-10	2.3	24 hour	667.7	670 Berm
AD-HA-11	dry	24 hour	--	On slope below 670 Berm elevation 651 ft.
B-794	21	T.O.B.	20.6	Water Surface Elevation

T.O.B = Time of Boring 24-hr. = Reading made 24-hours after completing boring

Water levels monitored in borings performed along the 670 Berm were fairly consistent. But in several borings, notably borings AD-7 and AD-9, water was either not initially encountered or was encountered close to the projected elevation of the drainage blanket. Observed water levels in the borings appeared to require a period of several hours to a full day to rise to levels that corresponded to nearby Duke observation wells.

Duke observation well readings with time are included with seepage and slope stability analyses in Appendix IV and selected readings are shown on cross sections shown at Stations 7+25, 10+00 and 12+00 for illustrative purposes. It is evident on the sections that there are substantial differences in observations of water in different types of borings. Shallow observation wells typically record water within a few feet of the surface whether performed on the 670 or 720 berms. Borings or wells on the 720 Berm which extend to sufficient depth to penetrate the fill, or the drainage blanket where present, indicate water levels substantially lower than the shallow wells. This would suggest that the drainage blanket is to some degree relieving pore pressures within at least some distance in the surrounding soils. This condition may also be due to layering effects within the embankment fill. Since the 670 Berm is relatively low this trend could not be observed there.

In most cases open standpipe readings are only considered valid for very shallow wells or borings. Ground water in low permeability soils may require many hours to seep into the open borings. Open standpipes or open borings also have a disadvantage that differing layer of soils may be under different hydrostatic pressures. The measured free water level in the boring could lead to a false assumption that the ground-water level recorded

in the boring indicates a hydrostatic pressure regime for the full depth of the boring below that depth.

The ground-water characteristics of a layered soil profile consisting of alternating beds of pervious and somewhat less pervious soils, or in soils lying close to a drainage blanket, is difficult to define by a single set of borings or wells. Borings or wells extending through relatively impervious soils into an aquifer may indicate a piezometric surface which can exist well above the top of the saturated, fully confined aquifer. Where well screening and bentonite or cement plugs are used to isolate specific vertical intervals the measured water level in the borings or well indicates the piezometric surface – an imaginary surface that everywhere coincides with the static water level in an aquifer – within that interval. The measured water level in the standpipe is not necessarily the free water surface in the surrounding soils.

4.2 Laboratory Test Results

Select samples of soils obtained from the drilling program were subjected to laboratory tests for general classification and for shear strength parameters. The laboratory test results are summarized in Table L1 - Laboratory Test Data Summary and Table L1a – Triaxial Testing Summary included in Appendix II.

4.2.1 CU Triaxial Shear Strength Tests

Shear strength parameters used in previous analyses of slope stability are summarized in Table 2 in section 2.3. These parameters were used initially to develop some conceptual failure envelopes through the embankment to permit an estimate of the range of confining stresses that would apply along potential failure surfaces. Using this information, S&ME evaluated shear strength parameters of relatively undisturbed soil samples obtained at representative locations in the downstream face, performing a total of 5 Consolidated Undrained (CU) triaxial shear tests with pore pressure measurements at various confining stresses for a total of 13 individual soil specimens. The triaxial tests were performed on samples of both the embankment fill and the residual foundation soils.

Confining stresses for individual tests were assigned based on consideration of the typical stress range for the anticipated failure surfaces, approximately 2,000 psf to 3,000 psf, and also considered in situ stresses of the samples. Curvilinear relationships for the effective shear strength, τ, for the embankment fill (Figure 10) and residuum (Figure 11) shown below were estimated were interpreted from the CU triaxial tests based on a failure criteria defined by the maximum principal stress ratio. Linear relationships were estimated for total stress shear strengths for the embankment fill (Figure 12) and residuum (Figure 13). The total stress strength parameters, C_R and ϕ_R were defined based on total stress strengths interpreted at maximum deviator stress, generally at 15 percent vertical strain.

A summary of the laboratory test results is included in Table L1 and Table L1a and individual triaxial test graphic and tabular results are included in Appendix II. Also included in Table L2 are historical triaxial test data presented in previous reports.

Figure 10 - Derived Effective Strength Envelope for Ash Dike Embankment Fill

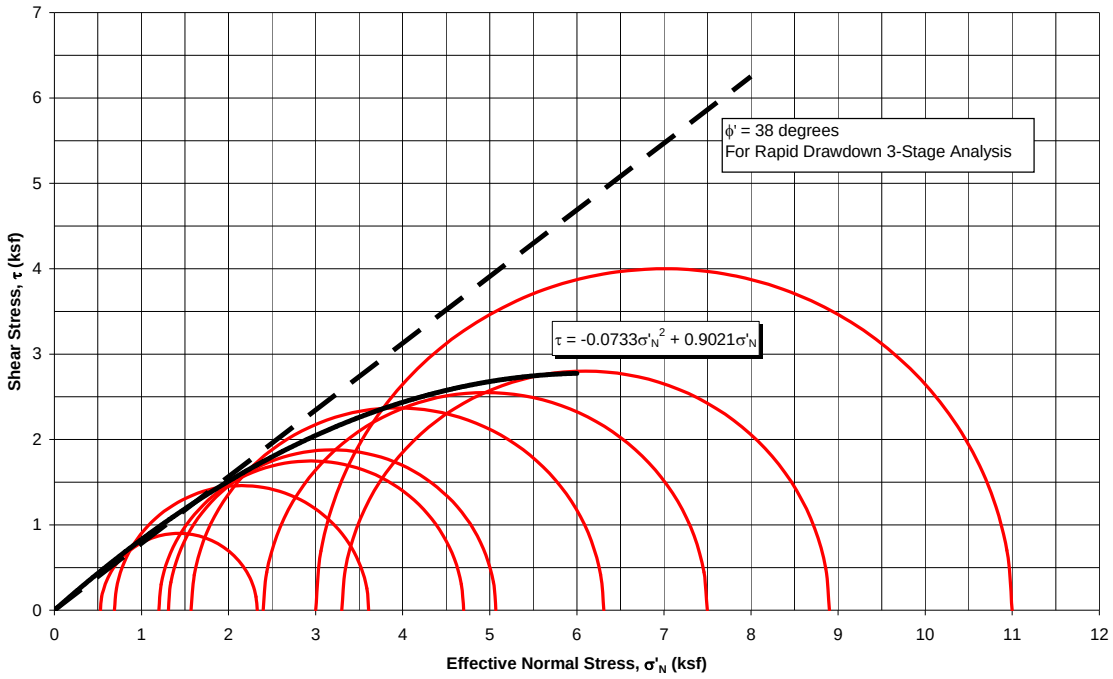


Figure 11 - Derived Effective Strength Envelope for Ash Dike Residuum

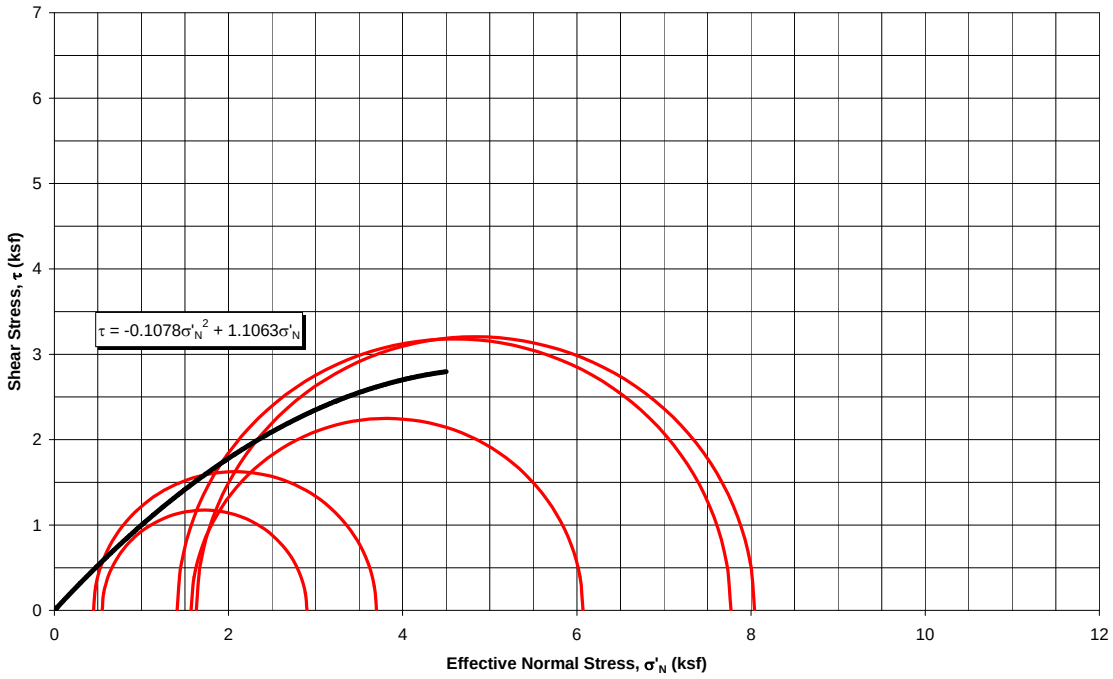


Figure 12 - Derived Total Strength Envelope for Ash Dike Embankment Fill

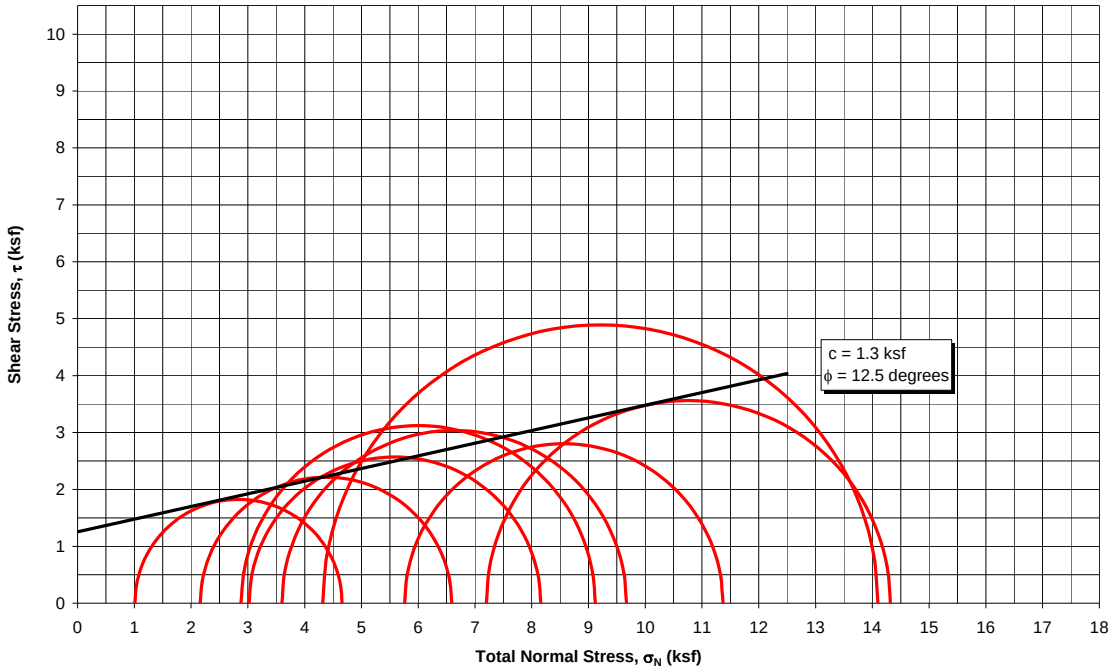
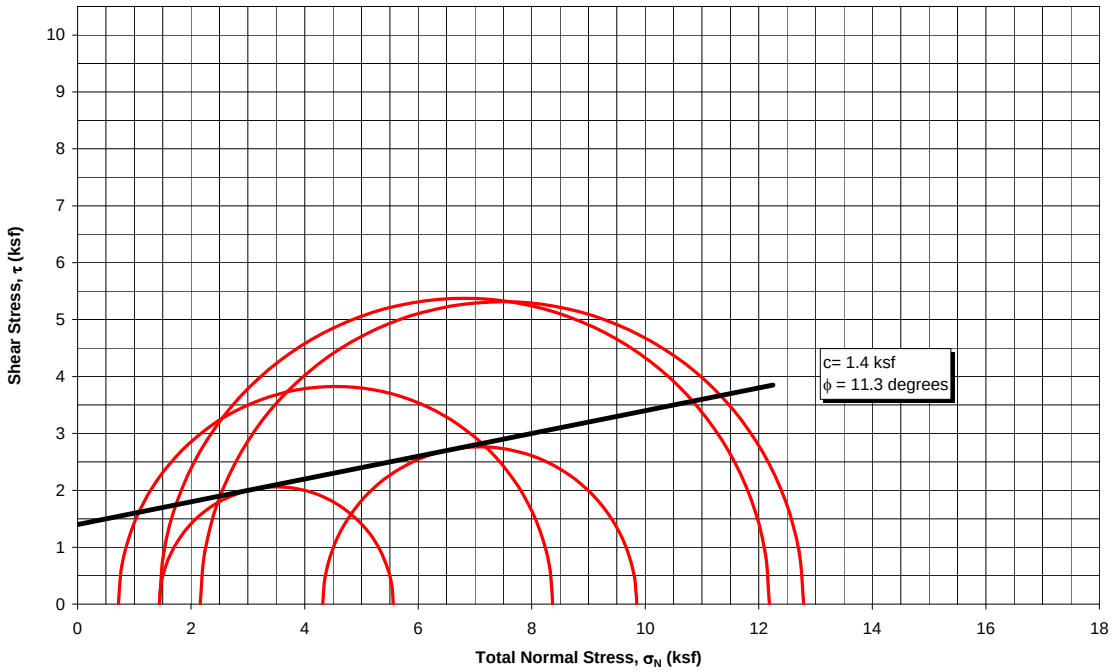


Figure 13 - Derived Total Shear Strength Envelope for Ash Dike Residuum



The derived effective stress relationships values for the embankment fill material and residual soils for effective confining pressures less than about 4,000 psf were modeled using equation 1 and equation 2 as follows:

$\tau = -0.0733\sigma'_N{}^2 + 0.9021\sigma'_N$ (Embankment Fill – Equation 1)

$\tau = -0.1078\sigma'_N{}^2 + 1.1063\sigma'_N$ (Residuum – Equation 2)

where:

τ = effective shear strength (ksf)
σ'_N = effective normal stress (ksf)

For analysis purposes, the effective shear strengths projected beyond the test range were assumed to gradually increase to maximum effective shear strength values, τ of 2.8 ksf and for the embankment fill and 3.5 ksf, respectively at upper bound effective normal stresses of 20 ksf.

The effective strength envelope of rapid drawdown analyses was based an effective cohesion, c' of 0 ksf and an effective friction angle of 38 degrees. These values were used along with the estimated total stress shear strengths in Corps of Engineers 3-stage rapid drawdown analyses.

The total stress cohesion, C_R and friction angle, ϕ_R values for the embankment fill were estimated to be 1.3 ksf at 12.5 degrees as shown on Figure 12. The estimated C_R and ϕ_R values for the residuum were estimated to be 1.4 ksf at 11.3 degrees as shown on Figure 13.

4.2.2 Flexible Wall Permeability Tests

Flexible wall permeability tests were performed on selected samples of the embankment fill soils prior to triaxial testing. The flexible wall permeability test results indicate vertical hydraulic conductivity values for the embankment fill ranging from 3.4×10^{-5} to 5.4×10^{-7} cm/sec. Pore pressure dissipation testing was performed in CPT soundings AD-2 and AD-5 to provide an indication of in-place horizontal permeability. Time to 50 percent dissipation (t_{50}) values ranged from approximately 60 to 600 seconds. Estimated horizontal hydraulic conductivity values in the embankment fill based on the t_{50} values ranged from 6×10^{-6} to 3×10^{-7} cm/sec.

Estimated hydraulic conductivity values for the drainage blanket were based on the grain-size analysis data using the Hazen formula. Estimated values are included in Table F1 – Permeability Calculated from Grain Size sheets included in Appendix I.

Permeability test results for the residual soils indicated a vertical hydraulic conductivity of 5.1×10^{-7} cm/sec.

5. SEISMIC DEMAND

Seismicity of the site is relatively low. For purpose of deriving computational values for input into pseudo-static analyses of dam stability under earthquake conditions and to determine whether liquefaction hazards exist, U.S. Geological Survey (USGS) probabilistic site hazard data was used to estimate an approximate horizontal acceleration within a potential failure mass.

5.1 Seismic Coefficient for Pseudo-static Analysis

Computation of seismic accelerations is included in Appendix IV. A maximum ground surface acceleration of 0.1g was estimated for the site using USGS probabilistic site hazard data for the 2 percent probability in 50 year event. A maximum dam crest horizontal acceleration of 0.36g was estimated based on procedures outlined by Harder (1991) and FHWA (1997). Horizontal earthquake induced accelerations were estimated with depth within the embankment were based on procedures by Makdisi and Seed (1977). This approach results in an average horizontal acceleration of 0.06g acting on a potential failure mass.

5.2 Liquefaction Triggering

A moment magnitude of 7.3 was utilized for the liquefaction analyses based on USGS earthquake deaggregation data for the site.

In order to evaluate the liquefaction potential of the dam embankment and foundation soils, the cyclic stress ratio induced by a seismic event (CSR_{EQ}) was compared to the cyclic resistance ratio (CRR) of the soils developed from SPT data. The method used to evaluate liquefaction potential is in general accordance with that proposed by Youd et al. (2001) and is generally referred to as the "Simplified Method". A safety factor of 1.2 was assumed to be acceptable safety factor against liquefaction.

Representative borings AD-4, AD-9, and AD-12 located along the 670 Berm, 720 Berm, and Ash Dike crest, respectively, were analyzed for liquefaction potential. The procedures outlined within the above documents were coded into a spreadsheet and evaluated based on data from those specific boring locations. Detailed analysis procedures are outlined in the Liquefaction Analyses calculation package included in Appendix IV.

Two isolated zones with safety factors of less than 1.2 were encountered in borings AD-4 (670 Berm) and AD-12 (crest). Based on review of conditions at these two locations, we conclude that the zone in boring AD-4 at 33.5 to 35 feet consists of Piedmont residual soils which would not generally be considered to be liquefiable due to their age and due to built-in relict bonding. The zone in boring AD-12 from 1 to 2.5 feet is above the water table and is therefore not considered to be liquefiable.

Please refer to the attached Liquefaction Potential Analysis calculation package included in Appendix IV for more detailed information.

6. SEEPAGE AND SLOPE STABILITY ANALYSES

As summarized in Section 2.0, Ash Basin History, the Ash Dike has had a history of seepage and stability related issues since its original construction. Historic slope stability analyses have been performed for the embankment with the last analyses performed around 1988 after installation of the horizontal drains was completed. Various slope stability analyses indicated factors of safety less than the minimum NCDENR safety factor for normal conditions of 1.5.

6.1 Cross-Sections for Stability Analyses

Three cross-sections were developed based on the subsurface data, historical documents, water level measurements, and 2010 Duke survey data. These cross-sections include the following Ash Dike locations:

1) Ash Dike Section Station 7+25;
2) Ash Dike Section Station 10+00; and
3) Ash Dike Section Station 12+00.

These cross-sections at these approximate Stations 7+25, 10+00, and 12+00 are included as attached Figures 7 through 9. The locations of these cross-sections are shown in plan view on Figure 6, Field Test Location Plan.

The existing ground surface was based on the 2010 Duke survey data provided to us (attached Figure 5), NCDOT GIS 2-foot topographic data, and historic Duke Drawings BC 1037-1 and BC 1037-4. The original prepared ground line was based on the Duke design drawings, the recent soil test borings by S&ME, and Duke 1982 and 1983 boring data provided to us.

The section at Station 7+25 (Figure 7) used in our stability analysis is intended to represent the right abutment area (referenced looking downstream). At this section the dike crest is approximately elevation 770 feet and the toe of the downstream slope intersects the original ground surface near a drainage ditch at approximately elevation 660 feet.

The cross section at Station 10+00 (Figure 8) is intended to represent the central, tallest portion of the embankment. The crest elevation is at about 770 feet and the toe of the downstream slope intersects the ground surface at about 640 feet at the drainage ditch.

The cross section at Station 12+00 (Figure 9) is intended to represent the left abutment area. The crest elevation is at about 770 feet and the toe of the downstream slope intersects the original ground surface at about 650 feet.

6.2 Interpreted Piezometric Head in Stability Analyses

Head pressures within the embankment have a considerable influence on stability since the presence of high pore pressures along a potential failure surface reduces effective confinement of the soils and reduces shear strength. As summarized in Section 2.0, Ash

Basin History, the Ash Dike has had a history of seepage and stability related issues since its original construction. Historic slope stability analyses have been performed for the embankment with the last analyses performed around 1988 after installation of the horizontal drains was completed. Various slope stability analyses indicated factors of safety less than the minimum NCDENR safety factor for normal conditions of 1.5.

The influence on pore water pressures on stability have been recognized in previous work. A Memorandum by Duke Engineering and Services dated July 28, 2004 concluded that additional slope stability analyses were not required at that time since similar water levels were obtained in the monitoring wells as previously used in the analyses.

In February 25, 2010, Duke personnel attempted water level measurements at all of the existing monitoring well and piezometer locations at the Ash Dike and performed a general observed conditions survey for the wells. Several of these wells and piezometers had not been monitored for several years. At the time of those monitoring readings, the ash basin water elevation was 750.95 feet.

The February, 2010 water level readings were utilized for the current slope stability analyses. In July 2010, Duke performed a partial survey of the Ash Dike embankment. The majority of the existing monitoring instruments were surveyed at the top of casing and ground surface. The recent Duke survey data for the instruments was reflected in the computed water elevations for each well. The water levels used for the slope stability analyses at each section are shown on Figures 7 through 9 and are summarized in Tables WL-1, WL-2, and WL-3 included in Appendix III.

6.3 Embankment Seepage Conditions

The current Ash Dike flow regime is affected by several factors based on historic analyses, monitoring well data, and recent subsurface exploration and laboratory testing data. These factors include: 1) a partially effective drainage blanket that has been found to contain excessive soil fines; 2) sections of drainage blanket that are located at relatively shallow depths along the abutment areas; 3) existing relief wells located along the 670 Berm toe; 4) embankment soils that have been estimated to have anisotropic permeability conditions; and 5) and existing horizontal wells that were previously installed to help lower the phreatic levels within the Ash Dike.

Several of the instruments within the Ash Dike consist of nested piezometers with various sealed screened intervals within the original foundation soils and at various levels within the embankment. Historically, lower water levels have been observed in piezometers extending into the foundation soils with water levels generally increasing with the height of the screened intervals. This was described by others as a “reverse uplift condition” resulting in pore water pressures less than hydrostatic conditions. For example, February 2010 water levels in Observation Well OW-78 and Piezometer P-79 (Figure 7 – Section 7+25) indicated water elevations of 750.78 feet and 721.26 feet or a vertical difference of about 29.5 feet. As previously mentioned, this phenomenon has

been attributed to anisotropic flow conditions, the location of the drainage blanket, and the horizontal wells.

Horizontal hydraulic conductivity values estimated from pore pressure dissipation testing performed in CPT soundings AD-2 and AD-5 indicated horizontal hydraulic conductivity, k_h values on the order of 2 x 10^{-6} to 6 x10^{-6} cm/sec while vertical flexible wall permeability testing on an undisturbed fill soil sample from boring AD-3 indicate a vertical hydraulic conductivity value as low as 5 x 10^{-7} cm/sec. Based on the results of the permeability testing, the ratio of horizontal to vertical permeability may be on the order of 10 in some sections of the dam embankment based on these hydraulic conductivity estimates.

Review of water level records for Piezometers P-34, P-39, P-59, and P-61 from 1985 through 2010 have shown steady increases in water levels of approximately 5.8, 3.9, 3.8, and 3.9 feet, respectively. Based on Duke Drawing BC 1037-4, these piezometers are located between approximate Station 10+07 and 11+70 slightly above and below the 670 Berm area. Based on these water levels, a change within the embankment pore pressures within this area has been occurring. Plots of water level data for each of the above piezometers along with their associated 12-month moving average through December 2009 are included in Appendix III.

Flows from the majority of the horizontal drains located above and below the 670 Berm have shown an upward trend between 2001 and 2010. Plots of horizontal drain flow data through December 2009 are included in Appendix III.

Wet spots and unstable areas have progressively been reported over time along the left abutment, above the 670 Berm ditch area, and below the 670 Berm in the vicinity of Piezometer P-39. Based on our observations between March and May 2010, little to no flow was observed from the toe drain area immediately below the central downstream toe area. Observation of the design transverse drain location was not visible. Significant amounts of seepage were observed along the left and right abutment contacts. Riprap has been placed along the majority of the slope above the ditch section along the 670 Berm for slope stabilization.

The previously swampy area was observed below the 670 Berm and right abutment intersection. A significant amount of seepage appears to be concentrated in this area. Based on review of Duke Drawing BC 1037-1, this is in the general area of a design drainage blanket transverse drain outlet that may be partially covered and could be decreasing flows from the blanket drain.

6.4 Embankment Seepage Modeling

S&ME utilized the Geostudios SeepW Version 7.17 two-dimensional finite element seepage program to model the existing seepage conditions within the dam embankment. Existing monitoring well and piezometer data presented on Figures 7 through 9 were incorporated into the seepage models. Near surface water levels were generally modeled as zero pressure boundary condition. Vertical and horizontal permeabilities for the

embankment fill, drainage blanket, residual soils, partially weathered rock, and underlying rock were estimated based on the field and laboratory test results and our experience.

The seepage models were calibrated by 1) estimating model seepage flows generally near the observed seepage rate from the Parshall flume below the dam and 2) comparing the total head values with the total head contours generated by the model. The material hydraulic conductivity values and anisotropy ratios, k_v / k_h were varied until reasonable agreement was achieved between the modeled and estimated flow rate and modeled and estimated total heads at the piezometer screen interval depths and observation well locations. The phreatic surface modeled includes existing monitoring well data from the February 2010 monitoring event with a water surface elevation of 750.95 feet.

Once the models were calibrated, a final seepage analyses was performed to create a pore pressure or total head model through the potential failure surfaces within the downstream face for import into the stability model. The parameters used for each cross-section are summarized in the Table 4.

A Seepage and Slope Stability calculation package is included in Appendix IV. The results of the seepage analyses including model input and output information are included in Appendix IV. Graphical figures showing the SeepW program output with total head contours and phreatic levels for Section Station 7+25, Section Station 10+00, and Section Station 12+00 are also included in Appendix IV.

Table 4 - Hydraulic Conductivities in Seepage Analyses

Material	Station 7+25		Station 10+00		Station 12+00	
	k_h (cm/sec)	k_v/k_h ratio	k_h (cm/sec)	k_v/k_h ratio	k_h (cm/sec)	k_v/k_h ratio
Embankment Fill	1.0 E-06	0.08	1.0 E-06	0.1	3.0 E-06	0.1
Blanket Drain	1.0 E-04	1	1.0 E-04	1	1.0 E-04	1
Residuum	1.0 E-04	0.1	1.0 E-04	1	1.0 E-05	1
PWR	1.0 E-05	0.1	1.0 E-05	1	1.0 E-05	1
Rock	1.0 E-07	0.1	1.0 E-05	1	-	-

6.5 Soil Properties in Stability Analyses

Based on laboratory testing and our experience, the moist unit weights shown in Table 5 were selected for use in the stability analyses. The parent rock material was assumed to be impenetrable in the model.

Table 5 - Material Unit Weights			
Material	**γ_{sat} (pcf)**	**γ_{moist} (pcf)**	**Comments**
Embankment Fill	123	121	
Blanket Drain	120	120	
Residuum	124	-	
PWR	140	-	
Rock	-	-	Impenetrable
Water	62.4	-	

CU triaxial testing was performed on relatively undisturbed Shelby tube samples collected from the Ash Dike during the 2010 geotechnical exploration as summarized in Table L1 in Appendix II. In addition the results of previous CU triaxial tests performed by Duke in 1982 and 1983 were reviewed and are summarized in Table L2 in Appendix II. Rapid drawdown conditions were assumed to affect only the embankment fill, and thus total stress shear strength parameters were not developed for the other soil types.

The following shear stress parameters were estimated for the existing embankment fill material based on the laboratory testing. Based on the testing, soil correlations, and our experience, the shear stress parameters shown in Table 6 were selected for use in the stability analyses.

Table 6 - Estimated Material Shear Strengths									
Material	Steady-State and Surcharge Pool			Pseudo-Static		Rapid Drawdown			
	Effective Stress			Total Stress		Effective Stress		Total Stress	
	c' (ksf)	ϕ' (degrees)	τ * (ksf)	c_R (ksf)	ϕ_R (degrees)	c' (ksf)	ϕ' (degrees)	c_R (ksf)	ϕ_R (degrees)
Embankment Fill	-	-	Figure 10	1.3	12.5	0	38	1.3	12.5
Blanket Drain	0	36	-	0	36	0	36	-	-
Residuum	-	-	Figure 11	1.4	11.3	0	36	1.4	11.3
PWR	1.0	38	-	1.0	38	1.0	38	-	-
Rock	-	-	-	-	-	-	-	-	-

*For the steady-state and surcharge pool conditions, the effective shear strength for the embankment fill and residuum were estimated using Equation 1 and Equation 2, respectively.

6.6 Minimum Safety Factor Standards

State and federal regulations were consulted to select minimum design safety factors for the slope stability analyses. The representative minimum safety factors are summarized below in Table 7.

Table 7 - Minimum Design Slope Stability Safety Factors

Condition	Minimum Safety Factor			Selected Safety Factor
	NCDENR	USACE	USCS	
Steady-State Seepage	1.5	1.5	1.5	**1.5**
Surcharge Pool		1.4		**1.4**
Pseudo-Static with Steady-State Seepage	-	1.0	1.1	**1.0***
Rapid Drawdown	1.25	1.1	1.2	**1.25**

* A minimum factor of safety of 1.0 was selected based on Corps of Engineers guidelines.

6.7 Slope Stability Analysis Method

The stability analyses for the Ash Dike was performed using the phreatic surface and pore pressure output from the Geostudios SeepW program and directly importing the seepage data into the SlopeW version 7.17 program. The stability analyses were performed using Spencer's method of slices with a non-circular optimization feature. The critical potential failure surface used in the slope stability analysis may be comprised of circles, planes, or other shapes considered to yield the minimum factor of safety against sliding and in the judgment of the geotechnical engineer appropriate to the soil and geologic site conditions. Slopes often appear to fail on circular slip surfaces and in this particular instance we considered it reasonable to analyze slope stability using randomly generated circular slip surfaces using a search algorithm contained as a subroutine within the program.

The stability analyses performed includes the steady-state seepage (elevation 750.95 feet) steady-state 100-yr pool elevation (751.4 feet), steady-state surcharge pool (elev. 760 feet), lowered steady-state pool (elevation 745.63 feet), pseudo-static with steady-state seepage, and rapid draw down conditions. Detailed information regarding the stability analyses are summarized in the Seepage and Slope Stability Calculations package included in Appendix IV.

6.8 Slope Stability Analyses Results

The results of the downstream slope steady-state seepage ("normal") conditions (Table 8a), steady-state 100-year pool elevation of 751.4 feet (Table 8b), historic maximum surcharge pool analysis elevation 760 feet (Table 8c), lowered steady-state pool elevation of 745.63 feet (Table 8d), and pseudo-static slope stability analyses (Table 8e) for

Sections Station 7+25, Section Station 10+00, and Section Station 12+00 for the downstream slope are included below. Each section was evaluated for overall global stability, local stability between the crest and 720 Berm ("upper"), and local stability between the 720 Berm and 670 Berm ("lower").

The 760 surcharge elevation analyses were performed to evaluate the effects of a higher normal pool surface on the embankment stability; however, recorded monthly lake water level data indicates that the water level has been maintained between elevations 747.5 and 755.75 feet since October 1985; therefore, this does not represent actual operating conditions.

A horizontal acceleration of 0.06g was assumed for the pseudo-static analyses. The program input and output information and graphical analysis figures are included in the Seepage and Slope Stability calculation package in Appendix IV.

The calculated slope stability safety factors for the downstream steady-state condition were modeled with a pool elevation of 750.95 feet based on the February 2010 monitoring event. The analysis sections indicated safety factors of 1.5 or greater with the exception of the Station 12+00 lower embankment area that had a calculated safety factor of 1.37. The steady-state seepage analyses results are summarized in Table 8a.

Table 8a – Steady-State Slope Stability Analyses Results

Cross-section	Condition Analyzed	Calculated Safety Factor	Minimum Safety Factor	SF Criteria Met
Station 7+25	Steady-State - Global	1.58	1.5	Yes
Station 7+25	Steady-State - Upper	1.96	1.5	Yes
Station 7+25	Steady-State - Lower	1.55	1.5	Yes
Station 10+00	Steady-State - Global	1.46	1.5	Yes
Station 10+00	Steady-State - Upper	2.08	1.5	Yes
Station 10+00	Steady-State - Lower	1.79	1.5	Yes
Station 12+00	Steady-State - Global	1.51	1.5	Yes
Station 12+00	Steady-State - Upper	2.06	1.5	Yes
Station 12+00	Steady-State - Lower	**1.37**	1.5	**No**

Note: "Upper" refers to potential slip surfaces between the crest and the 720 Berm. "Lower" refers to potential slip surfaces between the 720 Berm and the embankment toe.
Steady-state seepage analyses summarized in Table 8b for the 100-year pool elevation of 751.4 feet indicated calculated safety factors of 1.4 or greater.

Table 8b – Steady-State 100-yr Surcharge Pool Elevation 751.4 Feet Slope Stability Analyses Results				
Cross-section	**Condition Analyzed**	**Calculated Safety Factor**	**Minimum Safety Factor**	**SF Criteria Met**
Station 7+25	100-Year Storm Pool - Global	1.58	1.4	Yes
Station 7+25	100-Year Storm Pool - Upper	1.97	1.4	Yes
Station 7+25	100-Year Storm Pool - Lower	1.55	1.4	Yes
Station 10+00	100-Year Storm Pool - Global	1.46	1.4	Yes
Station 10+00	100-Year Storm Pool - Upper	2.08	1.4	Yes
Station 10+00	100-Year Storm Pool - Lower	1.79	1.4	Yes
Station 12+00	100-Year Storm Pool - Global	1.52	1.4	Yes
Station 12+00	100-Year Storm Pool - Upper	2.09	1.4	Yes
Station 12+00	100-Year Storm Pool - Lower	1.37	1.4	Yes *

* Calculated safety factor meets required value based on rounding.

The 760 pool analyses for the downstream slope are summarized in Table 8c indicate calculated safety factors less than 1.4 for the Station 12+00 global and lower local stability conditions. As previously mentioned, historic water level readings since 1985 indicate that the maximum pool elevation has been 755.75. This water level is higher than recent operating conditions.

Table 8c – Surcharge Pool Elevation 760 Feet Slope Stability Analyses Results				
Cross-section	**Condition Analyzed**	**Calculated Safety Factor**	**Minimum Safety Factor**	**SF Criteria Met**
Station 7+25	760 feet Pool - Global	1.51	1.4	Yes
Station 7+25	760 feet Pool - Upper	1.57	1.4	Yes
Station 7+25	760 feet Pool - Lower	1.36	1.4	Yes*
Station 10+00	760 feet Pool - Global	1.42	1.4	Yes
Station 10+00	760 feet Pool - Upper	1.72	1.4	Yes
Station 10+00	760 feet Pool -Lower	1.46	1.4	Yes
Station 12+00	760 feet Pool -Global	**1.33**	1.4	**No**
Station 12+00	760 feet Pool -Upper	1.92	1.4	Yes
Station 12+00	760 feet Pool -Lower	**1.05**	1.4	**No**

* Calculated safety factor meets required value based on rounding.

The effects of a lowering the Ash Basin water level to the elevation of the lowest outlet elevation on the outlet tower of 745.63 feet was evaluated for steady-state conditions for the downstream slope. The calculated slope stability safety factors were 1.5 or greater. The calculated slope stability safety factor of 1.37 for Station 12+00 current conditions was shown to increase to a calculated safety factor of 1.47 for the lowered pool level.

Table 8d – Lowered Pool Elevation 745.63 Feet Steady-State				
Cross-section	**Condition Analyzed**	**Calculated Safety Factor**	**Minimum Safety Factor**	**SF Criteria Met**
Station 7+25	745.63 Pool – Global	1.63	1.5	Yes
Station 10+00	745.63 Pool - Upper	1.83	1.5	Yes
Station 12+00	745.63 Pool - Lower	1.47	1.5	Yes*

* Calculated safety factor meets required value based on rounding.

Pseudo-static analyses for the downstream slopes indicated calculated safety factors greater than 1.0 for Stations 7+50, 10+00, and 12+00.

Table 8e – Pseudo-Static Slope Stability Analyses Results				
Cross-section	**Condition Analyzed**	**Calculated Safety Factor**	**Minimum Safety Factor**	**SF Criteria Met**
Station 7+25	Pseudo-Static - Global	1.25	1.0	Yes
Station 7+25	Pseudo-Static -Upper Berm	1.63	1.0	Yes
Station 7+25	Pseudo-Static - Lower Berm	1.99	1.0	Yes
Station 10+00	Pseudo-Static - Global	1.13	1.0	Yes
Station 10+00	Pseudo-Static - Upper Berm	1.94	1.0	Yes
Station 10+00	Pseudo-Static - Lower Berm	1.49	1.0	Yes
Station 12+00	Pseudo-Static -Global	1.17	1.0	Yes
Station 12+00	Pseudo-Static - Upper Berm	1.75	1.0	Yes
Station 12+00	Pseudo-Static - Lower Berm	1.69	1.0	Yes

The rapid drawdown condition was modeled by SLOPE/W assuming the lake water surface dropped from the normal pool elevation of 750.95 feet during the February 2010 monitoring event to an elevation of 745.63 feet which represents the lowest outlet level. The upstream rapid drawdown condition was analyzed using the general methodology of the US Army Corps of Engineers (3-Stage Method) using the SLOPE/W program. Please

refer to the Seepage and Slope Stability calculation package in Appendix IV for more detailed information. The results of the rapid drawdown analysis are summarized in Table 9.

Table 9 – Upstream Rapid Drawdown Slope Stability Results

Cross-section	Condition	Calculated Safety Factor	Minimum Safety Factor	SF Criteria Met
Station 7+25	Rapid Drawdown (3-Stage Method)	1.47	1.25	Yes
Station 10+00	Rapid Drawdown (3-Stage Method)	1.34	1.25	Yes
Station 12+00	Rapid Drawdown (3-Stage Method)	1.45	1.25	Yes

An understanding of the role of the factor of safety is important in design of slopes. One well-recognized role of the factor of safety is to account for uncertainties and act as a factor of ignorance with regard to the reliability of the forces that enter into the analysis. These include strength parameters, pore pressure distribution, and stratigraphic variations. In certain cases a higher factor of safety than usual may be required after the geotechnical engineer reviews the soil data. This particularly happens where limitations to the reliability of the soil data increase the risk of unsatisfactory performance of the slope. In general, the lower the quality of the site investigation, the higher the factor of safety should be.

Based on sensitivity analyses of the model parameters, slight differences in the friction angle or shear strength of the soils do not appear to have a significant effect on safety factor. However, differences in the water table appear to have more significant effects on the calculated safety factors. For example, the Station 12+00 section was analyzed for steady-state seepage conditions with water levels of 750.95 feet (February 2010 level) and the historic surcharge pool elevation of 760 feet. The calculated factors of safety were 1.37 and 1.05 for the lower slope stability. Therefore, the water elevations within the Ash Basin have a significant effect on the stability of the slopes. This also reinforces the importance of long-term monitoring of the embankment piezometric levels.

7. CONCLUSIONS

Our analysis indicates that stability of the slope is governed chiefly by the phreatic water levels within the embankment. Changes in the shear strength or friction angle of the fill soils and the underlying residuum have a relatively small influence on factors of safety calculated.

Others have stated that the blanket drain material has been shown to have an excessive amount of soil fines. Grain-size analyses performed by S&ME on soil samples taken from the blanket drain area indicated similar findings. Therefore, it appears that the blanket drain was either constructed of poorer quality material or migration of fines has

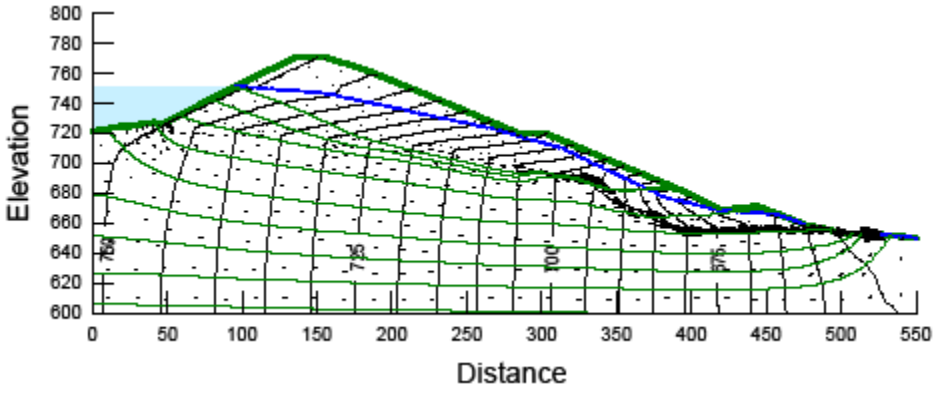
occurred into the drain that has reduced the blanket drain flow capacity. It is also possible that the original design was inadequate to handle the actual seepage flows.

Based on the combination of observed water level increases, increased flows from the horizontal drains, and progressive near surface instability observed near the 670 Berm and toe area, it appears that the flow through the blanket drain may be continuing to decrease and stability of the embankment, particularly in along the left abutment area appears to have decreased with the corresponding increases in water levels.

The calculated factors of safety, particularly along the abutment areas are sensitive to increases in water levels. Therefore, these historically increasing water levels between approximate Ash Dike Station 10+00 to the left abutment are a concern.

An interpreted seepage flownet generated with the SeepW 2-dimensional seepage program for Station 12+00 near the left abutment for a pool elevation of 750.95 feet is shown on Figure 14. Based on the seepage analysis and flow net, it appears that the geometry of the abutment and drain is having a negative effect on the flow conditions and stability in the left abutment area near Station 12+00. The blanket drain has a relatively steep inclination in this area based on the original prepared ground contours on Duke Drawing BC 1037-4. Relatively shallow fill depths over the drain are also present in some areas, particularly near the 720 Berm. The drainage blanket actually appears to be inclined in a 3-dimensional manner with the blanket drain generally following the original abutment contact contours.

Figure 14 – Seepage Flow Net for Station 12+00



Based on the seepage modeling and indicated flow vectors shown on Figure 14, which illustrate the relative seepage velocities, it appears that the rear of the drainage blanket is being charged by seepage flows from the embankment fill and residuum. This is consistent with the higher flows historically observed in horizontal drains HD5, HD6, HD7, HD7A, HD 7B, and HD 11A that appear to penetrate the blanket drain generally between Stations 11+00 to 12+50.

The resulting seepage to the blanket drain indicates a slight uplift condition below the 670 Berm, and the model shows that seepage daylights on the downstream slope between

the 670 Berm and the toe. This condition appears to have been physically manifested in the field as the wet areas above the 670 Berm (Photo 1) and the seepage area that was previously stabilized with riprap near piezometer P-39 as shown on Photo 2 (see Detail B on Duke Drawing BC-1025.01.01). In addition, this may partially explain the rises in the piezometric levels that have been observed in piezometers P-34, P-39, P-59, and P-61 discussed in Section 6.3.

As a result of the seepage conditions being experienced near Station 12+00 for the current steady-state seepage conditions, relatively shallow water levels, and relatively steeply inclined blanket drain, a lower factor of safety of 1.37 was calculated for the steady-state seepage condition modeled for a pool elevation of 750.95 feet, which is less than the NCDENR safety factor of 1.5 for steady-state conditions.

Based on modeling the surcharge pool elevation of 760 feet, a safety factor of 1.05 was calculated for that condition. This illustrates that a dramatic reduction in safety factor can occur with raising the pool elevation by 9 feet; illustrates the sensitivity of the calculated safety factor with changes in water levels; and also reinforces the importance of water level monitoring within the embankment.

8. RECOMMENDATIONS

Results of slope stability analyses for the embankment indicate acceptable minimum global stability safety factors for the conditions analyzed. Steady-state seepage conditions near the left abutment indicate a minimum localized safety factor for sloughing type failure between the 720 Berm and 670 Berm of approximately 1.4 for a pool elevation of 751 feet. This indicates that the embankment is stable, but the minimum safety factor for sloughing failure below the intermediate bench is slightly less than NCDENR requirements.

Based on the results of seepage and stability analyses, we have developed the following recommendations related to the continued Ash Basin operations and stability of the Ash Dike. Various factors such as NCDENR regulatory requirements, on-going plant operations requirements, Ash Basin design life, planned future Ash Basin modifications, reliability of proposed improvement methods, design and modification costs, and schedule must also be weighed when considering these options. These options are presented a follows:

1) Maintain current operating pool level with no additional embankment improvements – Since the embankment appears stable under the current operations conditions, maintaining the current pool elevation with no embankment improvements can be considered. If the current operating conditions are continued, we recommend that monitoring of the embankment instruments, as well as periodic embankment observations be continued. We recommended that in conjunction with the monitoring program that the phreatic levels within the embankment be reviewed on an annual basis to determine if additional revised stability analyses are necessary, as outlined in the “Monitoring Data

Summary and Recommendations" report dated September 17, 2010 (S&ME Project No. 1356-09-029).

2) Lower the operating pool level –
Based on Duke Drawing BC 1375-05, it appears that the lowest outlet elevation for the pond is at the concrete outlet riser 21-inch outlet pipe that is shown with an invert elevation of approximately 745.63 feet. Slope stability analyses for this lowered pool level indicates a minimum calculated steady-state safety factor of approximately 1.5 near the left abutment area. Therefore, analysis results indicate that modifying the current operations level to elevation 745.63 feet will increase the local downstream stability for stead-state seepage to within NCDENR standards.

If this option is implemented, we recommend that the embankment instruments be monitored to evaluate the effects of lowering the operating pool level, since these conclusions are based on an estimated phreatic surface within the embankment based on seepage modeling and not on actual water level measurements for the elevation 745.6 feet pool operating condition.

Depending on the actual water levels after lowering the pool elevation, revised slope stability analyses may be required. Monitoring of the embankment instruments, as well as periodic embankment observations should be continued. We recommend that in conjunction with the monitoring program that the phreatic levels within the embankment be reviewed on an annual basis to determine if additional revised stability analyses are necessary, as outlined in the "Monitoring Data Summary and Recommendations" report dated September 17, 2010 (S&ME Project No. 1356-09-029).

There is the possibility that lowering of the operating pool may not result in the desired lowering of the phreatic surface due to unknown factors affecting the embankment flow regime. Therefore, additional embankment improvements may be required if embankment stability improvements are necessary.

3) Installation of Additional Horizontal Drains –
As outlined in Recommendation 1 above, we recommend that the operating pool level be maintained at or below elevation 751 feet. Based on the past performance of the embankment after installation of horizontal drains, it is our opinion that installation of additional horizontal drains near the left abutment along the 670 Berm may provide some lowering of the phreatic surface within the embankment and increase the downstream embankment safety factors. It is generally anticipated that the drains would be installed between Stations 10+00 and 13+00, the area of increasing phreatic levels. The horizontal drains likely have a limited area of influence where they are embedded entirely in fill. Therefore, the horizontal drains should be installed in locations, elevations, and inclinations to allow the horizontal drains to penetrate through the blanket drain and into the underling residual soils.

The number of horizontal drains required will be dependent on the effectiveness of the drains in lowering the phreatic surface. The drains could be installed in phases,

depending on the effectiveness of the initial drain installations in lowering the phreatic surface. Depending on the actual water levels after installation of the horizontal drains, revised slope stability analyses may be required.

Monitoring of the embankment instruments, as well as periodic embankment observations should be continued. We recommend that in conjunction with the monitoring program that the phreatic levels within the embankment be reviewed on an annual basis to determine if additional revised stability analyses are necessary, as outlined in the "Monitoring Data Summary and Recommendations" report dated September 17, 2010 (S&ME Project No. 1356-09-029).

If installation of additional horizontal drains is considered, these repairs to the existing embankment would require additional engineering analyses and design, as well as preparation of a Dam Modification Permit Application to NCDENR. These would include a design report, project drawings, and specifications necessary to construct the improvements. We anticipate that once design plans are completed, up to 6 months may be required to achieve Dam Safety approval. Once approved, the work will be required to be certified by the design Engineer of Record based on construction monitoring.

It is possible that installation of additional horizontal drains may not provide the desired lowering of the phreatic surface due to unknown factors affecting the embankment flow regime. If additional lowering of embankment phreatic levels is required based on analysis of phreatic levels, modifications to the operating pool or embankment modifications such as construction of a stability berm may be required.

4) Construction of a stability berm along the 670 Berm -
As previously outlined in Recommendation 1 above, we recommend that the operating pool elevation by maintained at or below elevation 751 feet. The calculated embankment safety factors are sensitive to changes in water levels, particularly along the abutment areas. If the current operating level cannot be lowered or if continued monitoring indicates that the phreatic levels continue to increase within the embankment, structural improvements to the Ash Dike along the left abutment area could be considered to improve the long-term stability of the dam and bring the dam into compliance with current slope stability NCDENR standards.

In our opinion, construction of a stability berm near the left abutment generally between Station 10+00 and 13+00 and along the 670 Berm would be a practical solution to improve the downstream Ash Dike slope stability. The actual horizontal extents and geometry of the berm would required additional engineering analyses. A properly filtered slope drain and toe drain system would be required below the stability berm to convey water seepage water from the slope and beneath the berm to a drainage ditch at the embankment toe.

Graded rock fill material similar in gradation to riprap Class B or Class I could be considered. Earthfill could also be considered; however, the earthfill geometry would be need to be relatively flatter compared to a rockfill berm that we anticipate could be constructed at up to 1.5H:1V based on recent similar experience.

If a stabilization berm is constructed along the 670 Berm, we anticipate that many of the existing horizontal drains and instruments within the affected area will need to be abandoned. Additional seepage and slope stability analyses should be performed to evaluate the embankment stability with the loss of the horizontal drain function and diminishing blanket drain flows. The berm, toe drain, and slope drain system geometry may vary depending on the location along the dam and the estimated raised phreatic level within the dam.

As described above, repairs to the existing embankment would require additional engineering analyses anddesign, as well as preparation of a Dam Modification Permit Application to NCDENR. These would include a design report, project drawings, and specifications necessary to construct the improvements. We anticipate that once design plans are completed, up to 6 months may be required to achieve Dam Safety approval. Once approved, the work will be required to be certified by the design Engineer of Record based on construction monitoring.

5) Additional Alternatives -
Other alternatives for improving the Ash Dike embankment stability could also be considered. S&ME looks forward to continued discussions with Duke regarding the Ash Dike and assisting Duke with design related issues to help improve the stability of the Ash Dike.

9. LIMITATIONS OF REPORT

This report has been prepared in accordance with generally accepted engineering practice in this local area at this time. The conclusions and recommendations contained herein are based on the applicable standards of the profession at the time this report was prepared. No other warranty, express or implied, is made. The evaluations and recommendations submitted in this report are based, in part, upon the data obtained from the subsurface exploration. The subsurface conditions included are based on the information obtained from widely spaced borings. Variations in the subsurface conditions will occur between the boring locations. Water levels may fluctuate due to weather, climate, construction, plant operations, and other factors.

This stability analysis report is not intended as a comprehensive inspection report or assessment of the dike’s safety other than for the conditions outlined in this report.

10. REFERENCES

10.1 List of Report References

ASTM D 1587, "Standard Practice for Thin-Walled Tube Geotechnical Sampling of Soils".

ASTM D 2488, "Standard Practice for Description and Identification of Soils (Visual-Manual Method)".

ASTM D 4220, "Standard Practices for Preserving and Transporting Soil Samples".

ASTM D 4750, "Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)".

ASTM D 5778, "Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils".

Clough, Harbour and Associates (2009), "Assessment of Dam Safety Coal Combustion Surface Impoundments (Task 3) Final Report", December 8, 2009.

Environmental Protection Agency (2009), "Fact Sheet" (EPA530-F-09-006), June, 2009.

Federal Highway Administration (1997). "Geotechnical Engineering Circular No. 3: Design Guidance: Geotechnical Earthquake Engineering for Highways: Volume 1 – Design Principles," May, 1997.

Harder (1991), "Performance of Earth Dams During the Loma Prieta Earthquake", 1991.

Kulhawy and Mayne (1990), "Manual on Estimating Soil Properties for Foundation Design", 1990.

Leroueil, S. and M. Jamiolowski (1991), "Exploration of Soft Soil and Determination of Design Parameters", *Proceedings, GeoCoast'91*, 1991.

Makdisi, F. and H. Bolton Seed (1977). "A Simplified Procedure for Estimating Earthquake-Induced Deformations in Dams and Embankments," August 1977.

National Cooperative Highway Research Program (2007), "NCHRP Synthesis 368 Cone Penetration Testing", 2007.

North Carolina Department of Environment and Natural Resources (1980), "North Carolina Administrative Code - Title 15A Department of Environment and Natural Resources of Subchapter 2K - Dam Safety", June 15, 1980.

Robertson, Campanella, et. al. (1988), "Axial Capacity of Driven Piles in Deltaic Soils Using CPT", 1988.

Robertson and Wride (1998), "Evaluating Cyclic Liquefaction Potential Using the Cone Penetration Test", 1998.

US Army Corps of Engineers (2003), "Engineering and Design – Slope Stability, EM 1110-2-1902", October 31, 2003.

United States Geological Survey (2008), "PSH Deaggregation on NEHRP BC Rock".

Youd et al, (2001), "Liquefaction Resistance of Soils: Summary Report from the 1996NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils". ASCE Journal of Geotechnical and Geoenvironmental Engineering.

U.S. Department of Agriculture Soil Conservation Service Engineering Division (1985), "Earth Dams and Reservoirs", Technical Release No. 60, October 1985.

10.2 Five-Year Independent Consultant Reports

Law Engineering Testing Company (1979). "Report of Safety Inspection – Belews Creek Dam and Ash Dike". January 11, 1979.

Law Engineering Inc. (1988). "Belews Creek Steam Station: Dam and Ash Basin Dike – Third Independent Consultant Inspection". June 13, 1988.

Law Engineering and Environmental Services Inc. (1999). "Belews Creek Steam Station: Dam and Ash Basin Dike – Fifth Independent Consultant Inspection". February 25, 1999.

Mactec Engineering and Consulting Inc. (2004). "Belews Creek Steam Station: Dam and Ash Basin Dike – Sixth Independent Consultant Inspection". January 13, 2004.

S&ME, Inc. (2009). "Five-Year Independent Consultant Inspection Report". February, 2009.

10.3 List of Historical Documentation from Duke Energy Archives

Law Engineering Testing Company (1969). "Belews Creek Steam Station – Main Dam and Spillway – Preliminary Engineering Report". July 14, 1969.

Duke Energy (1969). "Stability Analysis". September 8, 1969.

Duke Energy (1969). Boring Logs for D-19 through D-30.

Duke Energy (1969). Boring Logs and Laboratory Testing for M-1 through M-3.

Duke Energy (1971). Belews Creek – Soil Testing. July 21, 1971.

Duke Energy (1973). Slope Stability Analyses. March, 1973.

Duke Energy (1982 / 1983). Belews Creek Steam Station – Ash Storage Basin – Drilling on the Ash Dike.

Law Engineering Testing Company (1983). "Belews Creek 1-2 Horizontal Drains for Ash Storage Basin Dam". October 31, 1983.

Duke Energy (1984). "Ash Dike Horizontal Drains". April 4, 1984.

Duke Energy (1986). "Belews Creek Steam Station – Ash Dike Stability". June 24, 1986.

Duke Energy (1988). "Belews Creek Steam Station – Ash Dike Stability". June 17, 1988.

Duke Energy (2004). "Belews Creek Steam Station – Ash Basin Dike and Main Dam Slope Stability Evaluation". July 28, 2004.

Duke Energy (2010). "Inventory of Monitoring Wells and Piezometers", February 25, 2010.

Unknown. "Belews Creek Steam Station – Main Dam – Supplement to Chapter 4".

Unknown. "Belews Creek Steam Station – Ash Dike – Chapter 7".

Duke Energy (varies). "Belews Creek Volume I Boring Logs Index".

Duke Energy (varies). "Belews Creek Volume II Boring Logs (file copy)".

Duke Energy (varies). "Ash Dam Stability Analysis Volume 1 of 3".

Duke Energy (varies). "Ash Dam Stability Analysis Volume 2 of 3".

Duke Energy (varies). "Ash Dam Stability Analysis Volume 3 of 3".

Duke Energy (varies). "Belews Creek Main Dam Stability".

10.4 List of Drawings from Duke Energy Archives

BC-1374-05, "Additional Ash Drainage Tower Concrete and Reinforcing Plans, Sections, and Details", July 10, 1987.

BC 1374-07, "Add. Ash Drainage Tower Discharge System Earthwork Plan, Sections, and Details", July 10, 1987.

BC-1374-1, “Ash Drainage Tower Concrete and Misc. Steel Plans, Sections, and Details”, Revision 5, April 22, 1994.

BC-1374-08, “Additional Ash Drainage Tower Discharge System Pipe Layout and Details”, July 10, 1987.

BC-1045-2, “Spillway Pier Concrete Plan Elevation and Sections”, Revision 4, June 26, 1973.

BC 1045-4, “Spillway Abutment Concrete Outline Plan Elevations and Sections”, Revision 5, June 26, 1973.

BC-1045-3, “Spillway Pier and Low Level Intake Concrete and Reinforcing Elev, Sections, and Details”, Revision 4, June 5, 1973.

BC 1049-2, “Spillway Taintor Gates, Gate Guides Structural Steel Sections and Details”, Revision 4, July 30, 1971.

BC 1045-1, “Spillway and Outlet Works General Plan Concrete Outline”, Revision 7, June 26, 1973.

BC-1025-1, “Borrow Areas & Boring Locations for Dam and Saddle Dike”, Revision 3, May 27, 2010.

BC-1004-1, “Dam, Dikes, and Spillway Typical Details”, Revision 3, June 1, 1970.

BC-1024-1, “Boring Plan Dam Spillway”, Revision 5, June 1, 1970.

BC-1028-4, “Ash Basin Holding Pond Outlet Works Access Pier Sections and Details”, October 19, 1972.

BC-1019-1, “Belews Creek Dam Slope Stability Analysis Summary”, March 1, 1973.

BC-1037-2, “Ash Dike Piezometer Installation Relief Wells and Trench Drains”, August 15, 1979.

BC-1025-01.01, “Main Dam, Ash Dike and Saddle Dike Repair Work Sections and Details”, Revision 1, October 27, 1979.

BC-1037-3, “Ash Dike Horizontal Drain Placement”, Revision B, October 10, 1986.

BC-1037-1, “Ash Dike Plan, Profile, and Sections”, Revision 10, January 21, 1999.

BC-1040-1, “Dam Plan, Profile, Sections, and Details”, Revision 14, October 15, 1999.

BC-1037-4, “Ash Dike Plan”, Revision 4, October 21, 1999.

Duke Energy, “Belews Creek Main Dam”, Survey Information, June 9, 2010.

Duke Energy, “Belews Creek Ash Dike”, Survey Information, June 9, 2010.

10.5 List of Monitoring Information from Duke Energy

Main Dam, Ash Dike, and Saddle Dike piezometer and observation well locations, Instrument Locations.xls.

Main Dam and Ash Dike observation well and piezometer monitoring information, July 1972 through August 2004, BLCPIEZO 10-16-03 (WMM).XLS.

Main Dam observation well and piezometer monitoring information, January 2005 through December 2009, Main Dam.xls.

Settlement monument monitoring information, June 1972 through September 1997, BLCSETTL.XLS.

Settlement monument monitoring information, November 2000 through October 2004, BLCSETTL 10-5-04 (DMP).XLS.

Settlement monument monitoring information, 2005, Belews Creek Dam Readings 2005.xls.

Settlement monument monitoring information, 2006, BELEWS CREEK DAM READINGS 2006.xls.

Settlement monument monitoring information, 2007, BELEWS CREEK SETTLEMENT READINGS 2007.xls.

Settlement monument monitoring information, 2008, Settlement Monuments2008.xls.

Settlement monument monitoring information, 2009, BELEWS CREEK SURFACE MON READINGS 2009.xlsx.

Ash Dike observation well and piezometer monitoring information, January 2005 through December 2009, Ash Dam.xls.

Horizontal drain monitoring information, February 1991 through November 2004, BLCHZDRAIN 10-16-03 (DMP).XLS.

Horizontal drain monitoring information, January 2005 through December 2009, Horizontal Drains.xls.

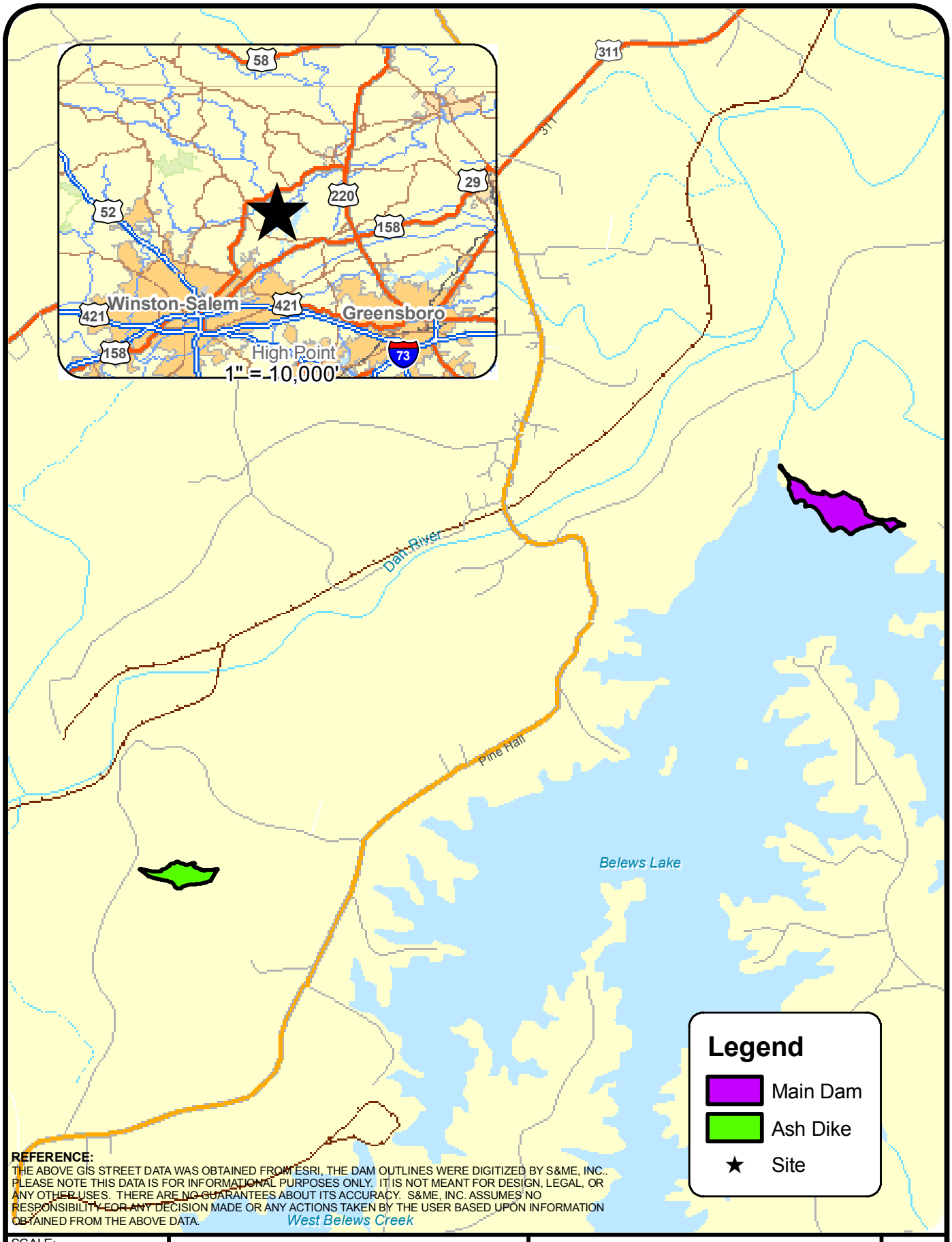
Monitoring Data and Notes, February 2010, pdf file of handwritten information

Photo 1 – View of Ash Dike looking west. Existing riprap stabilized areas can be seen above and below the lower 670 Berm to the upper right in the photo.

Photo 2 – View of stabilized slope area below Ash Dike 670 Berm and horizontal drain outlets for HD5, HD6, HD7, HD7A, and HD7B, looking southwest.

FIGURES

Figure 1 – Site Vicinity Map
Figure 2 – Previous Subsurface Exploration
Figure 3 – Horizontal Drains
Figure 4 – Existing Wells
Figure 5 – 2010 Duke Energy Survey
Figure 6 – Field Test Location Plan
Figure 7 – Ash Dike Section Sta. 7+25
Figure 8 – Ash Dike Section Sta. 10+00
Figure 9 – Ash Dike Section Sta. 12+00



REFERENCE:
THE ABOVE GIS STREET DATA WAS OBTAINED FROM ESRI, THE DAM OUTLINES WERE DIGITIZED BY S&ME, INC.. PLEASE NOTE THIS DATA IS FOR INFORMATIONAL PURPOSES ONLY. IT IS NOT MEANT FOR DESIGN, LEGAL, OR ANY OTHER USES. THERE ARE NO GUARANTEES ABOUT ITS ACCURACY. S&ME, INC. ASSUMES NO RESPONSIBILITY FOR ANY DECISION MADE OR ANY ACTIONS TAKEN BY THE USER BASED UPON INFORMATION OBTAINED FROM THE ABOVE DATA.

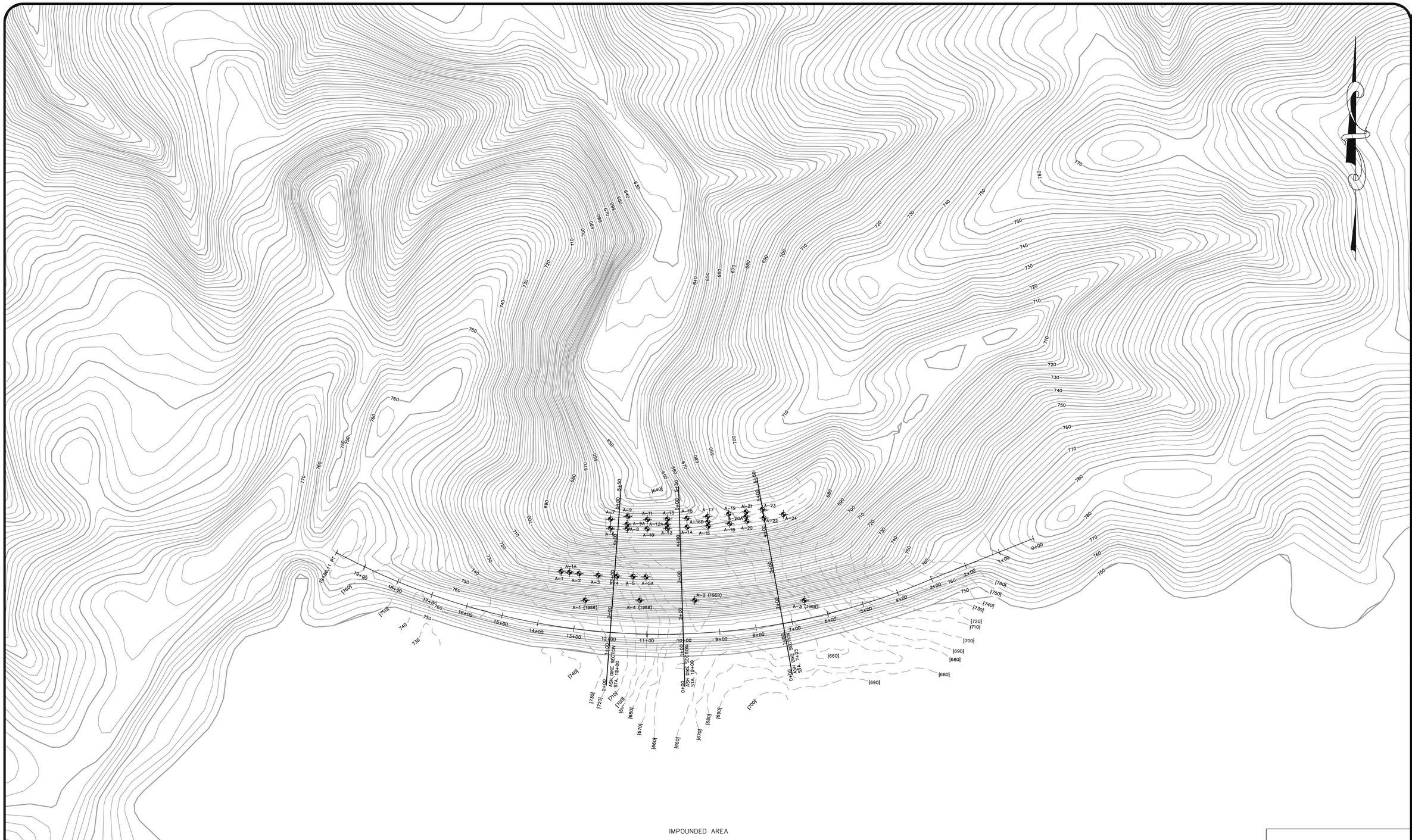
SCALE:	1" = 3,000'
DATE:	03-23-10
DRAWN BY:	CHR
PROJECT NO:	1356-09-029

S&ME
WWW.SMEINC.COM

SITE VICINITY MAP

DUKE ENERGY
BELEWS CREEK, NORTH CAROLINA

FIGURE NO.
1



IMPOUNDED AREA

LEGEND

- APPROXIMATE PRE-CONSTRUCTION CONTOUR (REFERENCE 1)
- EXISTING CONTOUR (REFERENCE 2)
- SLOPE STABILITY SECTION (REFERENCE 3)
- DAM BASELINE (REFERENCE 3)
- A- (1969) PRECONSTRUCTION BORING
- A- POSTCONSTRUCTION BORING (REFERENCE 4)

GRAPHIC SCALE

100 0 50 100 200

(IN FEET)

REFERENCES
1. PRE-CONSTRUCTION CONTOUR INFORMATION DIGITIZED FROM DUKE ENERGY DRAWING BC-1037-4 REVISION 4.
2. EXISTING CONTOUR INFORMATION FROM NCDOT LIDAR GIS DATA.
3. SLOPE STABILITY SECTIONS AND DAM BASELINE FROM BELEWS CREEK ASH DIKE, DUKE ENERGY SURVEY, JUNE 9, 2010
4. POSTCONSTRUCTION BORINGS PERFORMED BY DUKE ENERGY. BORING LOCATIONS WERE DIGITIZED FROM DUKE ENERGY CORRESPONDENCE FILES.

S&ME
WWW.SMEINC.COM
9751 SOUTHERN PINE BLVD.
CHARLOTTE N.C. 28273
(704) 523-4726

NO.	DATE	DESCRIPTION	BY

PREVIOUS SUBSURFACE EXPLORATION
ASH DIKE

EMBANKMENT ANALYSIS
BELEWS CREEK, NORTH CAROLINA

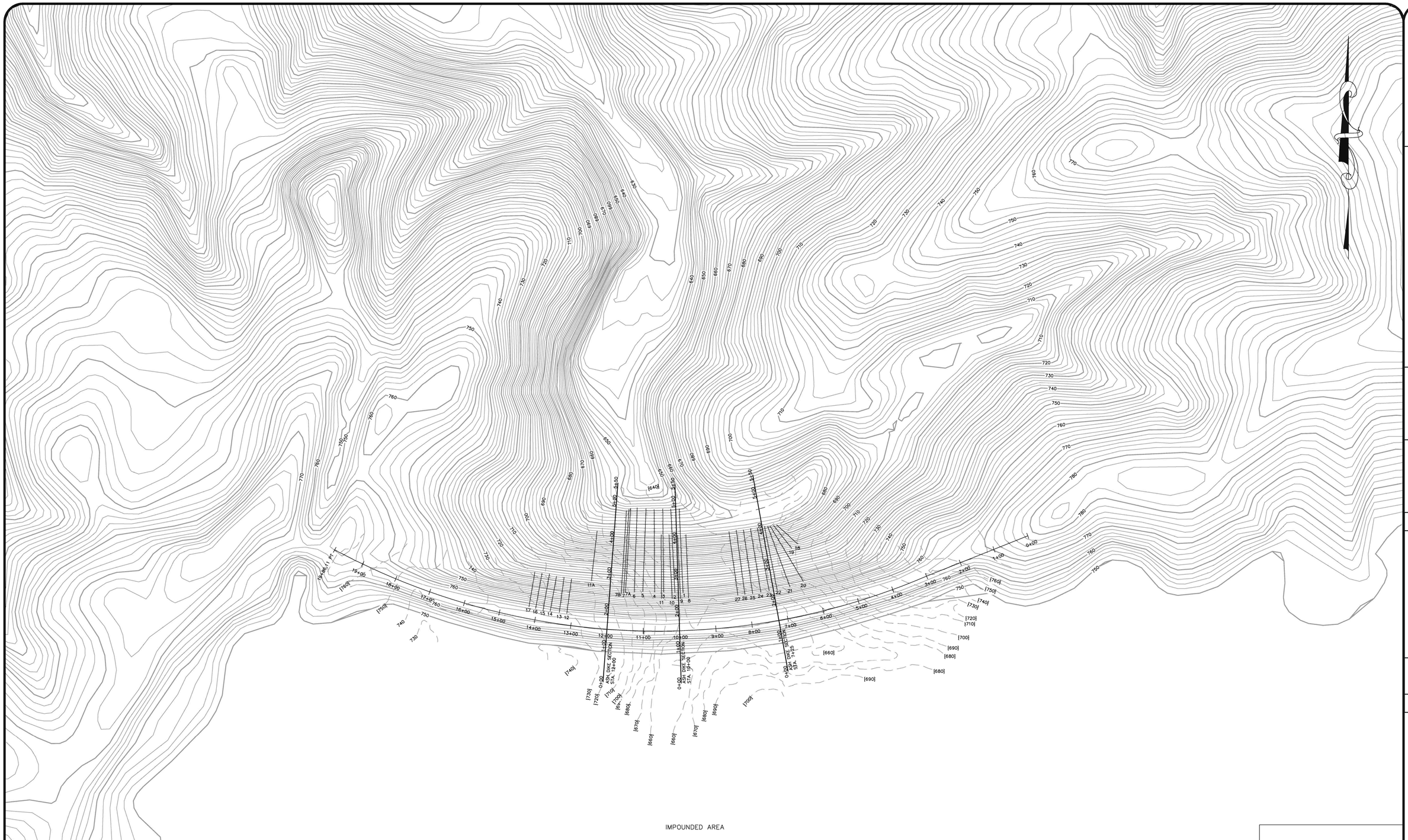
S&ME ENGINEERING LICENSE NO. **F-0176**

DRAWN BY: CHR	CHECKED BY:
DESIGNED BY:	APPROVED BY:

PROJECT NUMBER: 1356-09-029

SCALE: 1" = 100'	DATE: 09/07/10
FIGURE: 2	OF: 9

DRAWING PATH:



LEGEND

- APPROXIMATE PRE-CONSTRUCTION CONTOUR (REFERENCE 1)
- EXISTING CONTOUR (REFERENCE 2)
- SLOPE STABILITY SECTION (REFERENCE 3)
- DAM BASELINE (REFERENCE 3)
- 12 EXISTING HORIZONTAL DRAIN (REFERENCE 4)

REFERENCES
1. PRE-CONSTRUCTION CONTOUR INFORMATION DIGITIZED FROM DUKE ENERGY DRAWING BC-1037-4 REVISION 4.
2. EXISTING CONTOUR INFORMATION FROM NCDOT LIDAR GIS DATA.
3. SLOPE STABILITY SECTIONS AND DAM BASELINE FROM BELEWS CREEK ASH DIKE, DUKE ENERGY SURVEY, JUNE 9, 2010
4. HORIZONTAL DRAIN INFORMATION DIGITIZED FROM DUKE ENERGY DRAWING BC-1037-3 REVISION B.

GRAPHIC SCALE

100 0 50 100 200

(IN FEET)

S&ME
WWW.SMEINC.COM
9751 SOUTHERN PINE BLVD.
CHARLOTTE N.C. 28273
(704) 523-4726

NO.	DATE	DESCRIPTION	BY

HORIZONTAL DRAINS
ASH DIKE

EMBANKMENT ANALYSIS
BELEWS CREEK, NORTH CAROLINA

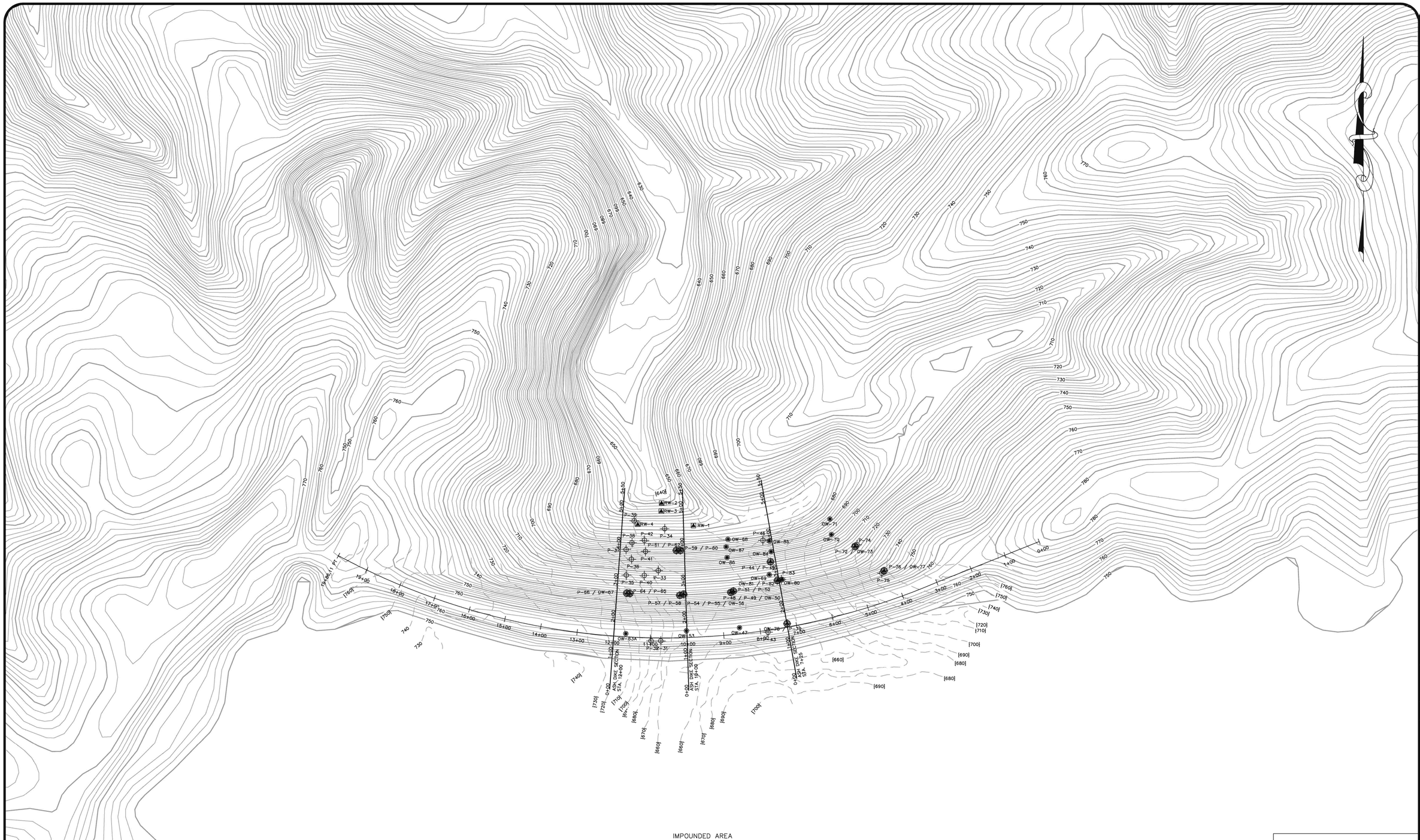
S&ME ENGINEERING LICENSE NO.
F-0176

DRAWN BY: CHR	CHECKED BY:
DESIGNED BY:	APPROVED BY:

PROJECT NUMBER
1356-09-029

SCALE: 1" = 100'	DATE: 09/07/10
FIGURE: 3	OF: 9

DRAWING PATH:



REFERENCES
1. PRE-CONSTRUCTION CONTOUR INFORMATION DIGITIZED FROM DUKE ENERGY DRAWING BC-1037-4 REVISION 4.
2. EXISTING CONTOUR INFORMATION FROM NCDOT LIDAR GIS DATA.
3. SLOPE STABILITY SECTIONS AND DAM BASELINE FROM BELEWS CREEK ASH DIKE, DUKE ENERGY SURVEY, JUNE 9, 2010
4. EXISTING PIEZOMETER, OBSERVATION WELL, NESTED WELL, AND RELIEF WELL LOCATIONS WERE OBTAINED FROM EITHER THE 2010 DUKE ENERGY SURVEY OR DIGITIZED FROM DUKE ENERGY DRAWING BC-1037-4 REV. 4.

LEGEND

- APPROXIMATE PRE-CONSTRUCTION CONTOUR (REFERENCE 1)
- EXISTING CONTOUR (REFERENCE 2)
- SLOPE STABILITY SECTION (REFERENCE 3)
- DAM BASELINE (REFERENCE 3)
- P– EXISTING PIEZOMETER (REFERENCE 4)
- OW– EXISTING OBSERVATION WELL (REFERENCE 4)
- P– / OW– EXISTING NESTED WELLS (REFERENCE 4)
- RW– EXISTING RELIEF WELL (REFERENCE 4)

GRAPHIC SCALE
100 0 50 100 200
(IN FEET)

S&ME
WWW.SMEINC.COM
9751 SOUTHERN PINE BLVD.
CHARLOTTE N.C. 28273
(704) 523-4726

NO.	DATE	DESCRIPTION	BY

EXISTING WELLS
ASH DIKE

EMBANKMENT ANALYSIS
BELEWS CREEK, NORTH CAROLINA

S&ME ENGINEERING LICENSE NO. **F-0176**

DRAWN BY: CHR	CHECKED BY:
DESIGNED BY:	APPROVED BY:

PROJECT NUMBER 1356-09-029

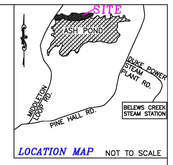
SCALE: 1" = 100'	DATE: 09/07/10
FIGURE: 4	OF: 9

DRAWING PATH:

NOTES:

- SURVEYED & MAPPED BY: DUKE ENERGY CAROLINAS, LLC
- SUBJECT PROPERTY IS NOT WITHIN 2000 FEET OF A GEODETIC SURVEY MONUMENT.
- ALL DISTANCES ARE HORIZONTAL GROUND DISTANCES UNLESS OTHERWISE NOTED.
- PROPERTY SUBJECT TO ANY VALID & ENFORCEABLE EASEMENTS, RESTRICTIONS & RIGHTS OF WAY OF RECORD.
- SURVEY IS BASED ON PHYSICAL EVIDENCE AND EXISTING MONUMENTATION FOUND DURING THE SURVEY.
- N.C. STATE PLANE GRID COORDINATES SHOWN ARE BASED ON NAD 83(2007) HORIZONTAL DATUM. ELEVATIONS SHOWN ARE BASED ON NAVD 88 VERTICAL DATUM. COORDINATES ARE IN U.S. SURVEY FEET.
- GRID COORDINATES ESTABLISHED FROM THE NC VRS NETWORK UTILIZING A TOPCON GR-3 RECEIVER WITH A HORIZONTAL POSITIONAL ACCURACY OF 0.10'±, AND VERTICAL POSITIONAL ACCURACY OF 0.20'±, USING NCGS RIVERCO FOR FIXED CONTROL USE. COORDINATES BASED ON NAD83(2007) HORIZONTAL AND NAVD 88 VERTICAL DATUMS.

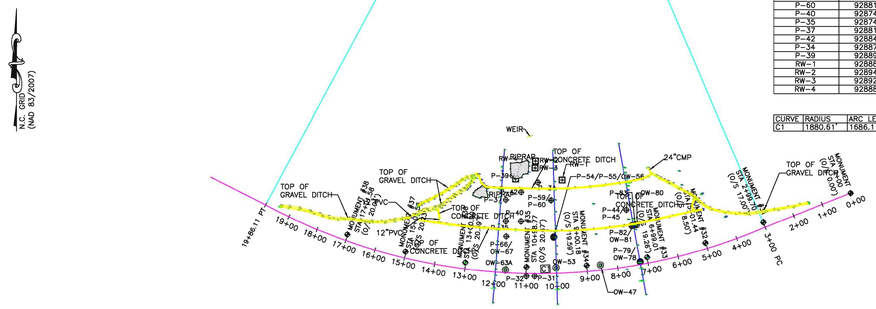
DESCRIPTION	NORTHING	EASTING	ELEVATION
MONUMENT #32	928676.94	1683603.66	767.37
MONUMENT #33	928630.42	1683413.77	767.59
MONUMENT #34	928603.35	1683218.63	767.65
MONUMENT #35	928598.18	1683020.32	767.46
MONUMENT #36	928612.82	1682821.02	767.80
MONUMENT #37	928648.53	1682625.87	767.12
MONUMENT #38	928704.59	1682436.19	765.55
MONUMENT #31	928744.40	1683792.65	766.59
STA 0+00 DISK IN CONCRETE	928839.32	1684076.89	779.71



LOCATION MAP NOT TO SCALE

DESCRIPTION	NORTHING	EASTING	TOP OF PVC ELEVATION	STATION	OFFSET	GROUND SHOT DESCRIPTION	GROUND SHOT ELEVATION
OW-47	928604.78	1683261.35	771.75	8+55.09	16.70	GS ⊕ OW-47	768.59
P-79	928615.93	1683390.86	773.36	7+24.38	9.23	GS ⊕ P-79 & OW-78	770.97
OW-78	928615.96	1683390.90	773.40	7+24.34	9.25	GS ⊕ P-79 & OW-78	770.97
OW-53	928596.37	1683116.78	771.35	10+01.30	18.38	GS ⊕ OW-53	768.22
P-31	928568.83	1683047.01	773.67	10+71.59	-8.31	GS ⊕ P-31	770.35
P-32	928568.83	1683020.43	773.37	10+98.05	-8.67	GS ⊕ P-32	769.98
OW-63A	928588.54	1682951.90	773.29	11+67.29	8.36	GS ⊕ OW-63A	770.78
OW-67	928698.69	1682954.36	730.24	11+71.41	118.46	GS ⊕ P-66 & OW-67	727.64
P-66	928698.71	1682954.45	730.26	11+71.32	118.49	GS ⊕ P-66 & OW-67	727.64
P-54	928695.73	1683109.18	729.48	10+06.13	117.93	GS ⊕ P-54 & P-55 & OW-56	726.84
P-55	928695.74	1683109.08	729.50	10+06.24	117.94	GS ⊕ P-54 & P-55 & OW-56	726.84
OW-56	928695.84	1683109.11	729.46	10+06.21	118.03	GS ⊕ P-54 & P-55 & OW-56	726.84
OW-81	928733.68	1683364.77	723.31	7+29.57	129.73	GS ⊕ P-82 & OW-81	720.99
P-82	928733.53	1683364.82	723.34	7+29.54	129.57	GS ⊕ P-82 & OW-81	720.99
OW-80	928736.58	1683377.95	723.24	7+15.07	130.23	GS ⊕ OW-80	720.69
P-83	928736.11	1683375.23	723.06	7+18.04	130.27	GS ⊕ P-83	720.64
P-44	928784.57	1683345.86	710.18	7+40.35	183.11	GS ⊕ P-44 & P-45	707.93
P-45	928784.54	1683345.78	710.20	7+40.47	183.10	GS ⊕ P-44 & P-45	707.93
P-59	928815.46	1683100.50	688.43	10+12.19	237.84	GS ⊕ P-59 & P-60	685.67
P-60	928815.33	1683100.44	688.51	10+12.26	237.72	GS ⊕ P-59 & P-60	685.67
P-40	928747.57	1683002.35	716.15	11+21.95	169.52	GS ⊕ P-40	713.73
P-35	928748.07	1682953.07	717.18	11+76.05	167.68	GS ⊕ P-35	714.55
P-37	928817.64	1682952.80	688.21	11+81.30	237.09	GS ⊕ P-37	685.54
P-42	928842.66	1683002.54	676.35	11+25.42	264.56	GS ⊕ P-42	673.66
P-34	928874.35	1683057.69	673.97	10+61.27	297.25	GS ⊕ P-34	670.96
P-39	928895.92	1682974.61	667.19	11+61.23	316.52	GS ⊕ P-39	664.64
RW-1	928882.18	1683136.17	669.41	9+67.88	303.21		
RW-2	928944.16	1683049.46	648.38	10+71.59	367.03		
RW-3	928921.64	1683048.21	653.02	10+72.94	344.50		
RW-4	928885.60	1682984.65	667.99	11+48.59	306.73		

CURVE	RADIUS	ARC LENGTH	CHORD LENGTH	CHORD BEARING	DELTA ANGLE	DEGREE OF CURVE
C1	1880.61'	1686.11'	1630.20'	S 87°26'57" E	51°22'12"	3°02'48"



"PRELIMINARY PLAT"
(NOT FOR RECORDATION, CONVEYANCES, OR SALES)

SITE: 007310

DUKE ENERGY CAROLINAS, LLC
BELEWS CREEK STEAM STATION

LOCATION OF DITCHES AT
BELEWS CREEK ASH DIKE
SAURATOWN TOWNSHIP
STOKES COUNTY, N.C.

BOOK:
DATE: 6/09/2010
SCALE: 1"=200'
100' 0 100' 200' 300'
SCALE IN FEET
CREW: KMM/JFM
DRAWN BY: KMM
R.O.P.= 1':10,000'+

LAND UNIT: 0045832/0045999
MAP: 007310-377804AD

Duke Energy®

400 S. TRYON STREET
PO BOX 1007
CHARLOTTE, N.C. 28201-1007
TELEPHONE NO. (704)382-6658
N.C. FIRM LICENSE #F-0566

LEGEND

- DAM CREST CENTERLINE
- ⊕ MONUMENT FOUND (1" REBAR IN CONCRETE)
- ⊕ PIEZOMETER LOCATION (P)
- ◎ OBSERVATION WELL LOCATION (OW)
- ⊡ RELIEF WELL LOCATION (RW)
- O/S = OFFSET (-=UPSTREAM OF C/L, +=DOWNSTREAM OF C/L)

I HEREBY CERTIFY THAT THIS MAP WAS PREPARED UNDER MY DIRECT SUPERVISION FOR THE PURPOSE OF ELEVATION DETERMINATION AND COORDINATE DETERMINATION ALONG BELEWS CREEK ASH DIKE AND OTHER ENGINEERING FEATURES ASSOCIATED WITH BELEWS CREEK ASH DIKE, AND IS NOT INTENDED TO BE A BOUNDARY SURVEY OF THE PROPERTY SHOWN. THIS SURVEY IS OF AN EXISTING PARCEL OR PARCELS OF LAND AND DOES NOT CREATE A NEW STREET OR CHANGE AN EXISTING STREET. THIS MAP IS EXEMPT FROM REVIEW BY A REVIEW OFFICER.

PROFESSIONAL LAND SURVEYOR
L-3914

S&ME
9751 SOUTHERN PINE BLVD.
CHARLOTTE, N.C. 28273
(704) 522-7426
WWW.SMEINC.COM

NO.	DATE	DESCRIPTION	BY

2010 DUKE ENERGY SURVEY
ASH DIKE

EMBANKMENT ANALYSIS
BELEWS CREEK, NORTH CAROLINA

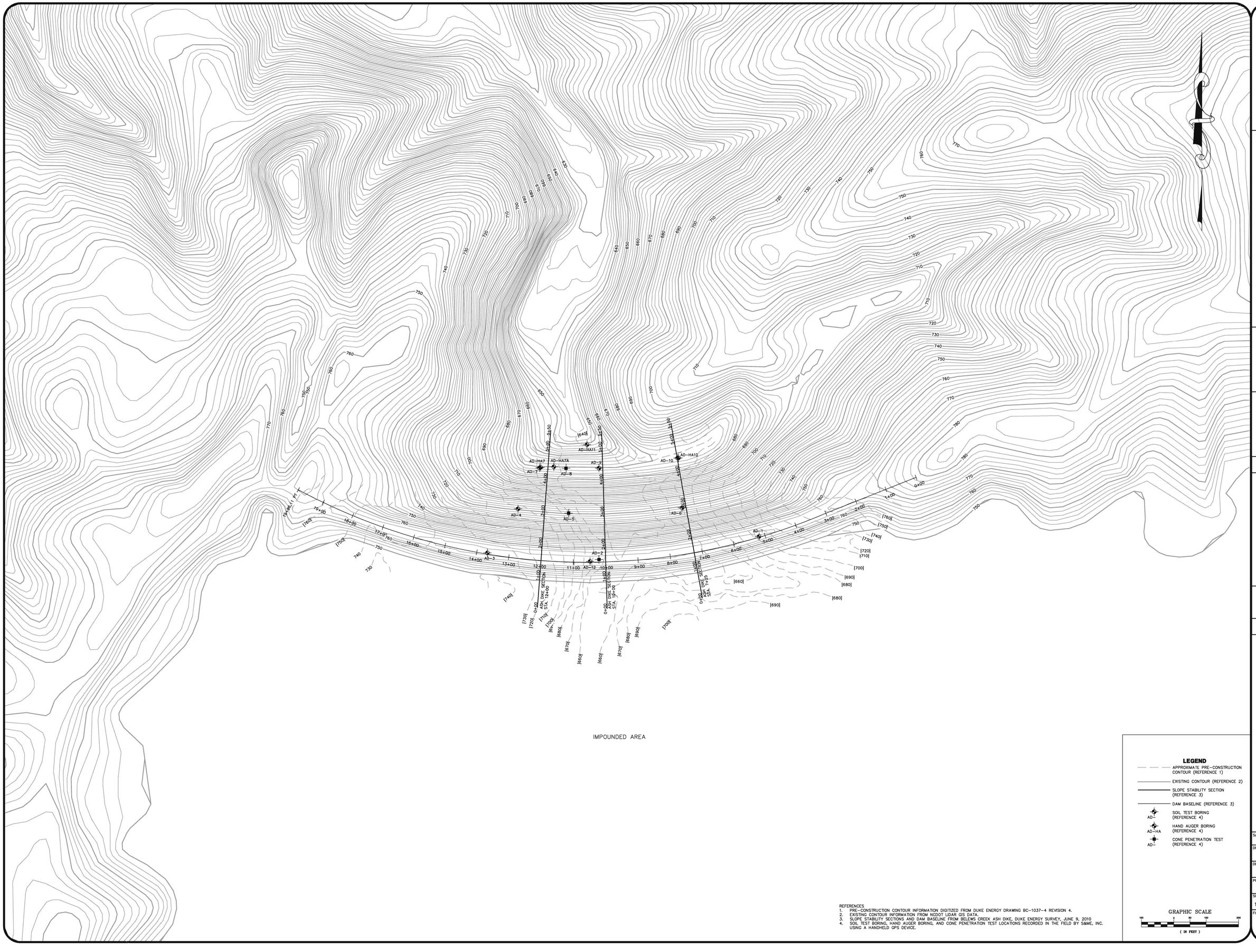
S&ME ENGINEERING LICENSE NO.
F-0176

DRAWN BY:	CHECKED BY:
CHR	
DESIGNED BY:	APPROVED BY:

PROJECT NUMBER
1356-09-029

SCALE:	DATE:
AS SHOWN	09/07/10
FIGURE:	OF:
5	9

DRAWING PATH:



LEGEND

- APPROXIMATE PRE-CONSTRUCTION CONTOUR (REFERENCE 1)
- EXISTING CONTOUR (REFERENCE 2)
- SLOPE STABILITY SECTION (REFERENCE 3)
- DAM BASELINE (REFERENCE 3)
- AD- SOIL TEST BORING (REFERENCE 4)
- AD-HA HAND AUGER BORING (REFERENCE 4)
- AD- CONE PENETRATION TEST (REFERENCE 4)

GRAPHIC SCALE

100 0 50 100 200

(IN FEET)

REFERENCES
1. PRE-CONSTRUCTION CONTOUR INFORMATION DIGITIZED FROM DUKE ENERGY DRAWING BC-1037-4 REVISION 4.
2. EXISTING CONTOUR INFORMATION FROM NCDOT LIDAR GIS DATA.
3. SLOPE STABILITY SECTIONS AND DAM BASELINE FROM BELEWS CREEK ASH DIKE, DUKE ENERGY SURVEY, JUNE 9, 2010
4. SOIL TEST BORING, HAND AUGER BORING, AND CONE PENETRATION TEST LOCATIONS RECORDED IN THE FIELD BY S&ME, INC. USING A HANDHELD GPS DEVICE.

S&ME
WWW.SMEINC.COM
9751 SOUTHERN PINE BLVD.
CHARLOTTE N.C. 28273
(704) 523-4726

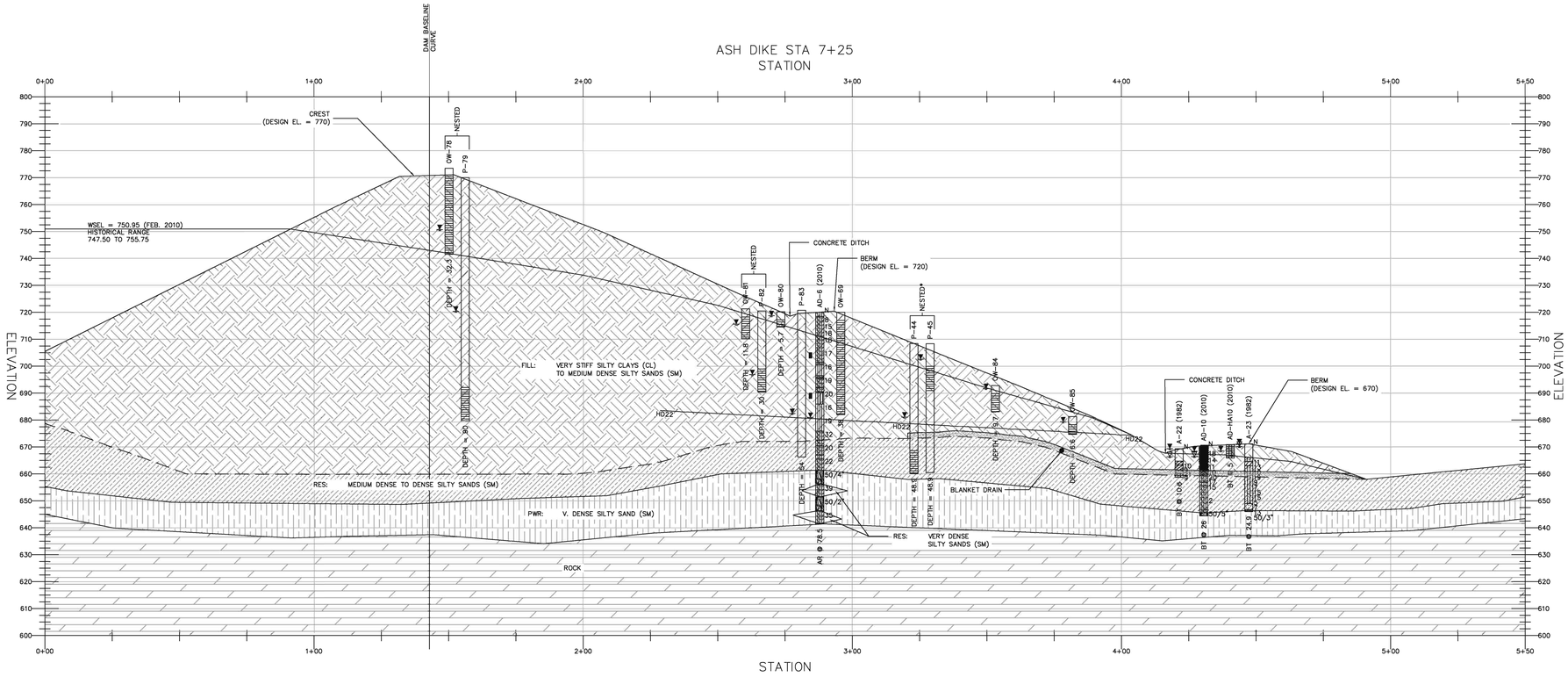
NO.	DATE	DESCRIPTION	BY

FIELD TEST LOCATION PLAN
ASH DIKE

EMBANKMENT ANALYSIS
BELEWS CREEK, NORTH CAROLINA

S&ME ENGINEERING LICENSE NO. F-0176	
DRAWN BY: CHR	CHECKED BY:
DESIGNED BY:	APPROVED BY:
PROJECT NUMBER 1356-09-029	
SCALE: 1" = 100'	DATE: 09/07/10
FIGURE: 6	OF: 9

DRAWING PATH:



*WATER LEVEL MEASUREMENTS FOR P-44 AND P-45 APPEAR TO HAVE BEEN TRANSPOSED. S&ME HAS CORRECTED THE WATER LEVEL MEASUREMENTS FOR THE PURPOSES OF THIS FIGURE.

Table WL1 - Water Levels in Existing Instrumentation - Ash Dike Station 7+25
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Description	Top of Casing Elevation (feet)	Source	Water Depth (feet)	Source	Water Elevation (feet)	Top of Screen Elevation (feet)	Bottom of Screen Elevation (feet)	Source
OW-78	773.4	2010 Duke Energy survey	22.62	February 2010 monitoring event	750.78	767.4	739.3	Note 2
P-79	773.36	2010 Duke Energy survey	52.10	February 2010 monitoring event	721.26	691.8	686.8	Note 1
OW-81	723.31	2010 Duke Energy survey	7.72	February 2010 monitoring event	715.59	717.3	710.0	Note 2
P-82	723.34	2010 Duke Energy survey	26.46	February 2010 monitoring event	696.88	697.5	692.5	Note 1
OW-80	723.24	2010 Duke Energy survey	4.52	February 2010 monitoring event	718.72	717.2	715.0	Note 2
P-83	723.06	2010 Duke Energy survey	40.62	February 2010 monitoring event	682.44	674.2	669.2	Note 1
OW-69	723.14	2010 Duke Energy survey	38 AND DRY	February 2010 monitoring event	DRY	717.1	685.1	Note 2
P-44	710.18	2010 Duke Energy survey	7.55	February 2010 monitoring event	702.63	666.5	661.5	Note 1
P-45	710.2	2010 Duke Energy survey	29.10	February 2010 monitoring event	681.10	697.5	692.5	Note 1
OW-84	695.29	2010 Duke Energy survey	3.61	February 2010 monitoring event	691.68	689.3	684.0	Note 2
OW-85	683.27	2010 Duke Energy survey	3.96	February 2010 monitoring event	679.31	677.3	675.1	Note 2

Note 1: Screen interval calculated by assuming a five foot screen length (typical piezometer detail on Duke Energy Drawing No. BC-1037-2) centered around the centerline of porous tube (elevation shown on Duke Energy Drawing No. BC-1037-4 Rev 4)

Note 2: Screen interval calculated by assuming top of screen is 6 feet below ground surface and the bottom of screen is at the elevation of the lowest point of drill holes (elevation shown on Duke Energy Drawing No. BC-1037-4 Rev 4)

Table WL1.1 - Data Locations - Ash Dike Station 7+25
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Description	Station (feet)	Notes
OW-78 / P-79	153	located by 2010 Duke Energy Survey
OW-81 / P-82	272	located by 2010 Duke Energy Survey
OW-80	273	located by 2010 Duke Energy Survey
P-83	273	located by 2010 Duke Energy Survey
AD-6	286	located by S&ME using handheld GPS unit
OW-69	292	digitized from Duke Energy drawing BC-1037-4 Rev. 4
P-44 / P-45	326	located by 2010 Duke Energy Survey
OW-84	353	digitized from Duke Energy drawing BC-1037-4 Rev. 4
OW-85	382	digitized from Duke Energy drawing BC-1037-4 Rev. 4
P-46	387	missing (February 2010), digitized from Duke Energy drawing BC-1037-4 Rev. 4
A-22	436	digitized from Duke Energy 1982 Boring Location Plan
AD-HA10	439	located by S&ME using handheld GPS unit
AD-10	440	located by S&ME using handheld GPS unit
A-23	460	digitized from Duke Energy 1982 Boring Location Plan
HD22	n/a	digitized from Duke Energy drawing BC-1037-3 Rev. B

Table WL1.2 - Material Properties - Ash Dike Station 7+25
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Material	γ_{sat} (pcf)	Steady State Effective Stress c' (psf)	Steady State Effective Stress ϕ' (degrees)	Pseudo-Static Total Stress c_R (psf)	Pseudo-Static Total Stress ϕ_R (degrees)	Rapid Drawdown Effective Stress c' (psf)	Rapid Drawdown Effective Stress ϕ' (degrees)	Rapid Drawdown Total Stress c_R (psf)	Rapid Drawdown Total Stress ϕ_R (degrees)	Hydraulic Conductivity k_h (cm/sec)	Hydraulic Conductivity k_v/k_h (ratio)
Embankment Fill	123*	$\tau = -0.0733\sigma'^2_N + 0.9021\sigma'_N$		1300	12.5	0	38	1300	13	1.0 E-06	0.08
Blanket Drain	120	0	36	0	36	0	36	-	-	1.0 E-04	1
Residuum	124	$\tau = -0.1.78\sigma'^2_N + 1.1063\sigma'_N$		1400	11.3	0	36	-	-	1.0 E-04	0.1
PWR	140	1000	38	1000	38	1000	38	-	-	1.0 E-05	0.1
Rock**	-	-	-	-	-	-	-	-	-	1.0 E-07	0.1

*A unit weight of 121 was assumed for the embankment fill above the water table
**Rock was modeled as an impenetrable surface

LEGEND

- APPROXIMATE PRE-CONSTRUCTION CONTOUR (REFERENCE 1)
- AS-BUILT CONTOUR (REFERENCE 2)
- HORIZONTAL DRAIN (REFERENCE 3)
- APPROXIMATE PHREATIC SURFACE
- UNDISTURBED SHELBY TUBE SAMPLE LOCATION
- WATER LEVEL, TOB
- WATER LEVEL, 24-HOUR
- TOPSOIL
- PIEZOMETER / WELL SCREEN
- ML, LOW PLASTICITY SILT
- MH, HIGH PLASTICITY SILT
- SM, SILTY SAND
- CL, LOW PLASTICITY CLAY
- SP/SM, POORLY GRADED SAND WITH SILT
- PARTIALLY WEATHERED ROCK
- SANDY SILT
- SANDY CLAY
- CLAYEY SILT
- SC, CLAYEY SAND
- SILTY SAND
- BEDROCK

REFERENCES
1. PRE-CONSTRUCTION CONTOUR INFORMATION DIGITIZED FROM DUKE ENERGY DRAWING BC-1037-4 REVISION 4.
2. AS-BUILT CONTOUR INFORMATION FROM "BELEWS CREEK ASH DIKE" SURVEY CONDUCTED BY DUKE ENERGY DATED JUNE 9, 2010.
3. HORIZONTAL DRAIN INFORMATION DIGITIZED FROM DUKE ENERGY DRAWING BC-1037-3 REVISION B.

9751 SOUTHERN PINE BLVD.
CHARLOTTE, N.C. 28273
(704) 522-7766
S&ME
WWW.SMEINC.COM

NO.	DATE	DESCRIPTION	BY

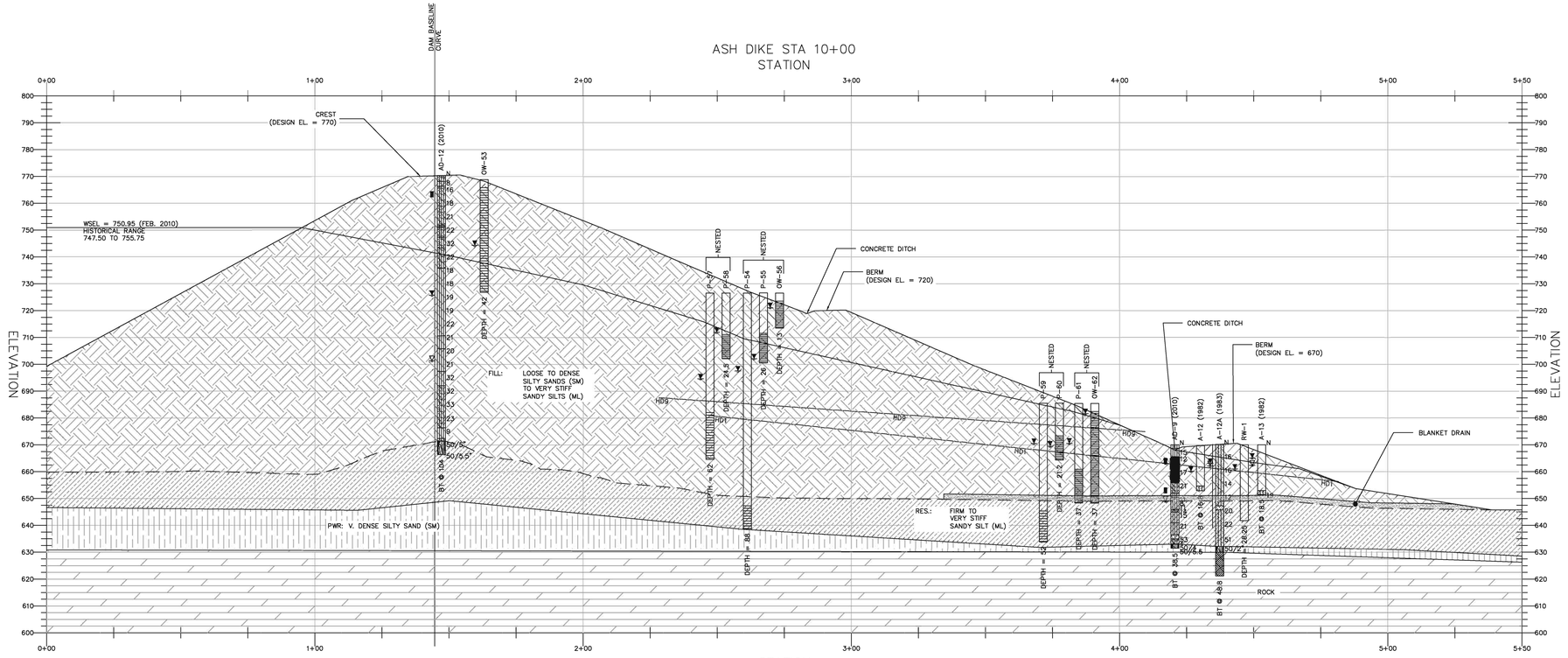
ASH DIKE SECTION
STA. 7+25

EMBANKMENT ANALYSIS
BELEWS CREEK, NORTH CAROLINA

S&ME ENGINEERING LICENSE NO.
F-0176

DRAWN BY:	CHECKED BY:
CHR	
DESIGNED BY:	APPROVED BY:
PROJECT NUMBER	
1356-09-029	
SCALE: AS SHOWN	DATE: 09/07/10
FIGURE: 7	OF: 9

DRAWING PATH:



GRAPHIC SCALE
(IN FEET)

GRAPHIC SCALE
(IN FEET)

Table WL2 - Water Levels in Existing Instrumentation - Ash Dike Station 10+00
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Description	Top of Casing Elevation (feet)	Source	Water Depth (feet)	Source	Water Elevation (feet)	Top of Screen Elevation (feet)	Bottom of Screen Elevation (feet)	Source
OW-53	771.35	2010 Duke Energy survey	27.02	February 2010 monitoring event	744.33	765.4	722.0	Note 2
P-57	729.64	2010 Duke Energy survey	35	February 2010 monitoring event	694.64	680.5	675.5	Note 1
P-58	729.65	2010 Duke Energy survey	17.7	February 2010 monitoring event	711.95	709.5	704.5	Note 1
P-54	729.5	assumed	31.96	February 2010 monitoring event	697.54	645.5	640.5	Note 1
P-55	729.5	2010 Duke Energy survey	27.42	February 2010 monitoring event	702.08	709.5	704.5	Note 1
OW-56	729.46	2010 Duke Energy survey	8.34	February 2010 monitoring event	721.12	723.5	639.0	Note 2
P-59	688.43	2010 Duke Energy survey	17.9	February 2010 monitoring event	670.53	643.5	638.5	Note 1
P-60	688.51	2010 Duke Energy survey	18.94	February 2010 monitoring event	669.57	671.5	666.5	Note 1
P-61	688.41	2010 Duke Energy survey	17.77	February 2010 monitoring event	670.64	659.5	654.5	Note 1
OW-62	688.42	2010 Duke Energy survey	6.77	February 2010 monitoring event	681.65	682.4	649.0	Note 2

Note 1: Screen interval calculated by assuming a five foot screen length (typical piezometer detail on Duke Energy Drawing No. BC-1037-2) centered around the centerline of porous tube (elevation shown on Duke Energy Drawing No. BC-1037-4 Rev 4)

Note 2: Screen interval calculated by assuming top of screen is 6 feet below ground surface and the bottom of screen is at the elevation of the lowest point of drill holes (elevation shown on Duke Energy Drawing No. BC-1037-4 Rev 4)

Table WL2.1 - Data Locations - Ash Dike Station 10+00
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Description	Station (feet)	Notes
AD-12	147	located by S&ME using handheld GPS unit
OW-53	163	located by 2010 Duke Energy Survey
P-57 / P-58	260	digitized from Duke Energy drawing BC-1037-4 Rev. 4
P-54 / P-55 / OW-56	263	located by 2010 Duke Energy Survey
P-59 / P-60	382	located by 2010 Duke Energy Survey
P-61 / OW-62	383	digitized from Duke Energy drawing BC-1037-4 Rev. 4
AD-9	435	located by S&ME using handheld GPS unit
A-12	436	digitized from Duke Energy 1982 Boring Location Plan
A-12A	445	additional sample and lab request
RW-1	448	located by 2010 Duke Energy Survey
A-13	461	digitized from Duke Energy 1982 Boring Location Plan
HD1	n/a	digitized from Duke Energy drawing BC-1037-3 Rev. B
HD9	n/a	digitized from Duke Energy drawing BC-1037-3 Rev. B

Table WL2.2 - Material Properties - Ash Dike Station 10+00
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Material	γ_{tot} (pcf)	Steady State Effective Stress c' (psf)	Steady State Effective Stress φ' (degrees)	Pseudo-Static Total Stress c_R (psf)	Pseudo-Static Total Stress ϕ_R (degrees)	Rapid Drawdown Effective Stress c' (psf)	Rapid Drawdown Effective Stress φ' (degrees)	Rapid Drawdown Total Stress c_R (psf)	Rapid Drawdown Total Stress ϕ_R (degrees)	Hydraulic Conductivity k_h (cm/sec)	Hydraulic Conductivity k_v/k_h (ratio)
Embankment Fill	123*	$\tau = -0.0733\sigma'^2_{3f} + 0.9021\sigma'_{3f}$		1300	12.5	0	38	1300	13	1.0 E-06	0.1
Blanket Drain	120	0	36	0	36	0	36	-	-	1.0 E-04	1
Residuum	124	$\tau = -0.178\sigma'^2_{3f} + 1.1063\sigma'_{3f}$		1400	11.3	0	36	-	-	1.0 E-04	1
PWR	140	1000	38	1000	38	1000	38	-	-	1.0 E-05	1
Rock**	-	-	-	-	-	-	-	-	-	1.0 E-05	1

*A unit weight of 121 was assumed for the embankment fill above the water table
**Rock was modeled as an impenetrable surface

LEGEND

- APPROXIMATE PRE-CONSTRUCTION CONTOUR (REFERENCE 1)
- AS-BUILT CONTOUR (REFERENCE 2)
- HORIZONTAL DRAIN (REFERENCE 3)
- APPROXIMATE PHREATIC SURFACE
- UNDISTURBED SHELBY TUBE SAMPLE LOCATION
- WATER LEVEL, TOB
- WATER LEVEL, 24-HOUR
- TOPSOIL
- PIEZOMETER / WELL SCREEN
- ML, LOW PLASTICITY SILT
- MH, HIGH PLASTICITY SILT
- SM, SILTY SAND
- CL, LOW PLASTICITY CLAY
- SP/SM, POORLY GRADED SAND WITH SILT
- PARTIALLY WEATHERED ROCK
- SANDY SILT
- SANDY CLAY
- CLAYEY SILT
- SC, CLAYEY SAND
- SILTY SAND
- BEDROCK

REFERENCES
1. PRE-CONSTRUCTION CONTOUR INFORMATION DIGITIZED FROM DUKE ENERGY DRAWING BC-1037-4 REVISION 4.
2. AS-BUILT CONTOUR INFORMATION FROM "BELEWS CREEK ASH DIKE" SURVEY CONDUCTED BY DUKE ENERGY DATED JUNE 9, 2010.
3. HORIZONTAL DRAIN INFORMATION DIGITIZED FROM DUKE ENERGY DRAWING BC-1037-3 REVISION B.

9751 SOUTHERN PINE BLVD.
CHARLOTTE, N.C. 28273
(704) 522-7726
S&ME
WWW.SMEINC.COM

NO. | DATE | DESCRIPTION | BY

ASH DIKE SECTION
STA. 10+00

EMBANKMENT ANALYSIS
BELEWS CREEK, NORTH CAROLINA

S&ME ENGINEERING LICENSE NO.
F-0176

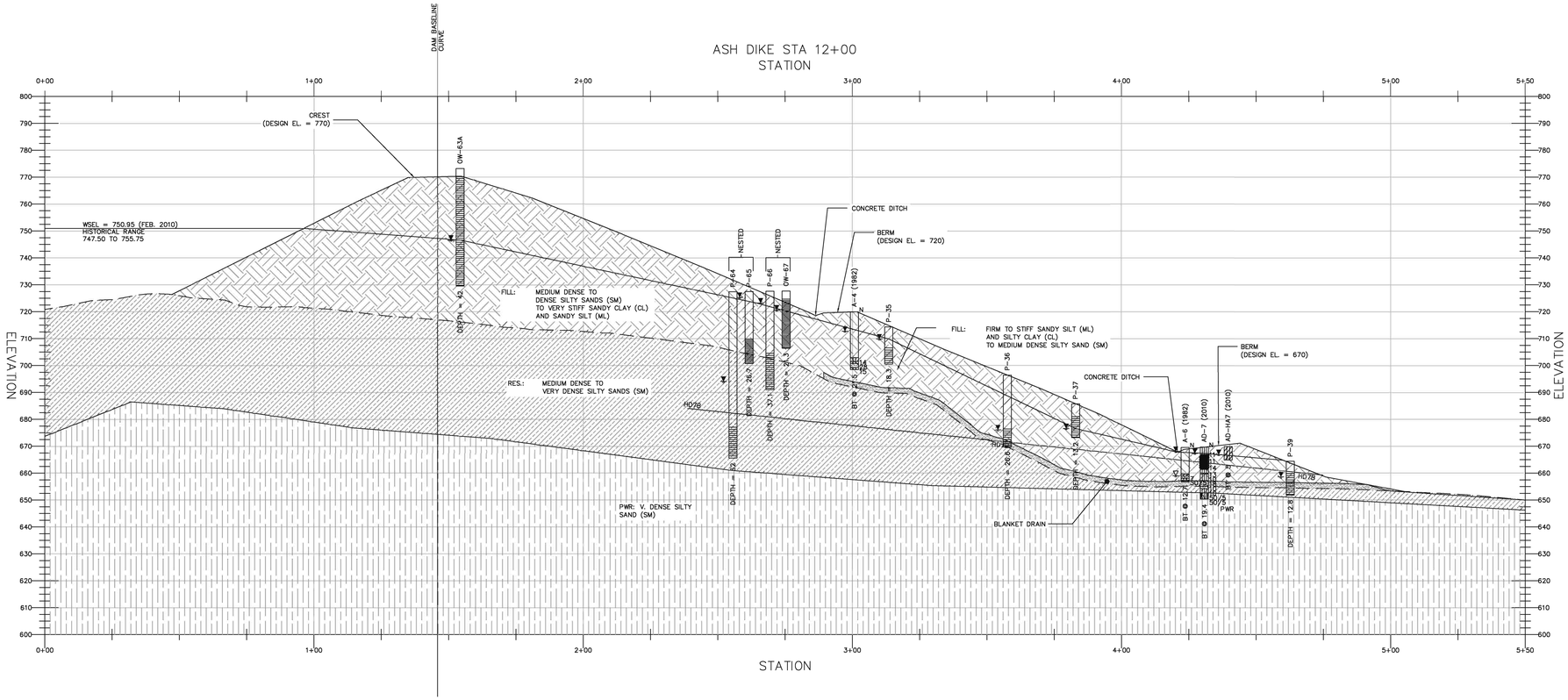
DRAWN BY:	CHECKED BY:
CHR	
DESIGNED BY:	APPROVED BY:

PROJECT NUMBER
1356-09-029

SCALE:	DATE:
AS SHOWN	09/07/10

FIGURE:	OF:
8	9

DRAWING PLOTS



GRAPHIC SCALE
(IN FEET)

GRAPHIC SCALE
(IN FEET)

Table WL3 - Water Levels in Existing Instrumentation - Ash Dike Station 12+00
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Description	Top of Casing Elevation (feet)	Source	Water Depth (feet)	Source	Water Elevation (feet)	Top of Screen Elevation (feet)	Bottom of Screen Elevation (feet)	Source
OW-63A	773.29	2010 Duke Energy survey	26.67	February 2010 monitoring event	746.62	767.3	727.0	Note 2
P-64	730.01	2010 Duke Energy survey	35.92	February 2010 monitoring event	694.09	675.5	670.5	Note 1
P-65	730.01	2010 Duke Energy survey	4.73	February 2010 monitoring event	725.28	708.5	703.5	Note 1
P-66	730.26	2010 Duke Energy survey	7.03	February 2010 monitoring event	723.23	702.5	697.5	Note 1
OW-67	730.24	2010 Duke Energy survey	9.62	February 2010 monitoring event	720.62	724.2	691.0	Note 2
P-35	717.18	2010 Duke Energy survey	7.32	February 2010 monitoring event	709.86	709.6	704.6	Note 1
P-36	696.43	interpolated from 2010 Duke Energy survey (may be broken)	20.37	February 2010 monitoring event	676.06	674.1	669.1	Note 1
P-37	688.21	2010 Duke Energy survey	11.64	February 2010 monitoring event	676.57	680.3	675.3	Note 1
P-39	667.19	2010 Duke Energy survey	8.61	February 2010 monitoring event	658.58	658.4	653.4	Note 1

Note 1: Screen interval calculated by assuming a five foot screen length (typical piezometer detail on Duke Energy Drawing No. BC-1037-2) centered around the centerline of porous tube (elevation shown on Duke Energy Drawing No. BC-1037-4 Rev 4)

Note 2: Screen interval calculated by assuming top of screen is 6 feet below ground surface and the bottom of screen is at the elevation of the lowest point of drill holes (elevation shown on Duke Energy Drawing No. BC-1037-4 Rev 4)

Table WL3.1 - Data Locations - Ash Dike Station 12+00
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Description	Station (feet)	Notes
OW-63A	154	located by 2010 Duke Energy Survey
P-64 / P-65	264	digitized from Duke Energy drawing BC-1037-4 Rev. 4
P-66 / OW-67	264	located by 2010 Duke Energy Survey
A-4	301	digitized from Duke Energy 1982 Boring Location Plan
P-35	314	located by 2010 Duke Energy Survey
P-36	358	digitized from Duke Energy 1982 Boring Location Plan
P-37	383	located by 2010 Duke Energy Survey
A-6	430	digitized from Duke Energy 1982 Boring Location Plan
AD-7	431	located by S&ME using handheld GPS unit
AD-HA7	433	located by S&ME using handheld GPS unit
HD7B	n/a	digitized from Duke Energy drawing BC-1037-3 Rev. B

Table WL3.2 - Material Properties - Ash Dike Station 12+00
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Material	γ_{tot} (pcf)	Steady State Effective Stress c' (psf)	Steady State Effective Stress φ' (degrees)	Pseudo-Static Total Stress c_R (psf)	Pseudo-Static Total Stress ϕ_R (degrees)	Rapid Drawdown Effective Stress c' (psf)	Rapid Drawdown Effective Stress φ' (degrees)	Rapid Drawdown Total Stress c_R (psf)	Rapid Drawdown Total Stress ϕ_R (degrees)	Hydraulic Conductivity k_h (cm/sec)	Hydraulic Conductivity k_v/k_h (ratio)
Embankment Fill	123*	$\tau = -0.0733\sigma'^2_N + 0.9021\sigma'_N$		1300	12.5	0	38	1300	13	3.0 E-06	0.1
Blanket Drain	120	0	36	0	36	0	36	-	-	1.0 E-04	1
Residuum	124	$\tau = -0.178\sigma'^2_N + 1.1063\sigma'_N$		1400	11.3	0	36	-	-	1.0 E-05	1
PWR	140	1000	38	1000	38	1000	38	-	-	1.0 E-05	1
Rock**	-	-	-	-	-	-	-	-	-	-	-

*A unit weight of 121 was assumed for the embankment fill above the water table
**Rock was modeled as an impenetrable surface

LEGEND

- APPROXIMATE PRE-CONSTRUCTION CONTOUR (REFERENCE 1)
- AS-BUILT CONTOUR (REFERENCE 2)
- HORIZONTAL DRAIN (REFERENCE 3)
- APPROXIMATE PHREATIC SURFACE
- UNDISTURBED SHELBY TUBE SAMPLE LOCATION
- WATER LEVEL, TOB
- WATER LEVEL, 24-HOUR
- TOPSOIL
- PIEZOMETER / WELL SCREEN
- ML, LOW PLASTICITY SILT
- MH, HIGH PLASTICITY SILT
- SM, SILTY SAND
- CL, LOW PLASTICITY CLAY
- SP/SM, POORLY GRADED SAND WITH SILT
- PARTIALLY WEATHERED ROCK
- SANDY SILT
- SANDY CLAY
- CLAYEY SILT
- SC, CLAYEY SAND
- SILTY SAND
- BEDROCK

REFERENCES
1. PRE-CONSTRUCTION CONTOUR INFORMATION DIGITIZED FROM DUKE ENERGY DRAWING BC-1037-4 REVISION 4.
2. AS-BUILT CONTOUR INFORMATION FROM "BELEWS CREEK ASH DIKE" SURVEY CONDUCTED BY DUKE ENERGY DATED JUNE 9, 2010.
3. HORIZONTAL DRAIN INFORMATION DIGITIZED FROM DUKE ENERGY DRAWING BC-1037-3 REVISION B.

9751 SOUTHERN PINE BLVD.
CHARLOTTE, N.C. 28273
(704) 522-7426
S&ME
WWW.SMEINC.COM

NO.	DATE	DESCRIPTION	BY

ASH DIKE SECTION
STA. 12+00

EMBANKMENT ANALYSIS
BELEWS CREEK, NORTH CAROLINA

S&ME ENGINEERING LICENSE NO. F-0176

DRAWN BY:	CHECKED BY:
CHR	
DESIGNED BY:	APPROVED BY:

PROJECT NUMBER 1356-09-029

SCALE:	DATE:
AS SHOWN	09/07/10

FIGURE:	OF:
9	9

DRAWING PLOTS

APPENDIX I

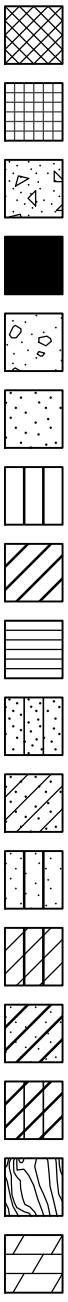
FIELD EXPLORATION DATA

Legend to Soil Classification and Symbols
Hand Auger Boring Logs
Soil Test Boring Logs
CPT Soundings
Pore Pressure Dissipation Tests
Shear Wave Velocity Measurements
Table F1 – Permeability Calculated from Grain Size

LEGEND TO SOIL CLASSIFICATION AND SYMBOLS

SOIL TYPES

(Shown in Graphic Log)



Fill
Asphalt
Concrete
Topsoil
Gravel
Sand
Silt
Clay
Organic
Silty Sand
Clayey Sand
Sandy Silt
Clayey Silt
Sandy Clay
Silty Clay
Partially Weathered Rock
Cored Rock

WATER LEVELS

(Shown in Water Level Column)

▽ = Water Level At Termination of Boring
▼ = Water Level Taken After 24 Hours
◄ = Loss of Drilling Water
HC = Hole Cave

CONSISTENCY OF COHESIVE SOILS

CONSISTENCY	STD. PENETRATION RESISTANCE BLOWS/FOOT
Very Soft	0 to 2
Soft	3 to 4
Firm	5 to 8
Stiff	9 to 15
Very Stiff	16 to 30
Hard	31 to 50
Very Hard	Over 50

RELATIVE DENSITY OF COHESIONLESS SOILS

RELATIVE DENSITY	STD. PENETRATION RESISTANCE BLOWS/FOOT
Very Loose	0 to 4
Loose	5 to 10
Medium Dense	11 to 30
Dense	31 to 50
Very Dense	Over 50

SAMPLER TYPES

(Shown in Samples Column)

■ Shelby Tube
⊠ Split Spoon
I Rock Core
□ No Recovery

TERMS

Standard Penetration Resistance - The Number of Blows of 140 lb. Hammer Falling 30 in. Required to Drive 1.4 in. I.D. Split Spoon Sampler 1 Foot. As Specified in ASTM D-1586.

REC - Total Length of Rock Recovered in the Core Barrel Divided by the Total Length of the Core Run Times 100%.

RQD - Total Length of Sound Rock Segments Recovered that are Longer Than or Equal to 4" (mechanical breaks excluded) Divided by the Total Length of the Core Run Times 100%.

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

LOG OF BORING NO. AD-HA7

PROJECT: **Belews Creek Ash Dike Investigation**
PROJECT NO: **1356-09-029**
PROJECT LOCATION: **Belews Creek, North Carolina**

WATER LEVEL:

DATE DRILLED: **4/8/10**
DRILLING CONTRACTOR: **S&ME**
DRILLING METHOD: **Hand Auger**

GROUND SURFACE ELEVATION: **670.00**
LOGGED BY:

This log is part of the report prepared for the named project and should be read together with that report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.

SAMPLE NUMBER	SAMPLE ADVANCE (ft.)	OVA (ppm)	ELEVATION (ft.)	DEPTH (ft.)	USCS	GRAPHIC SYMBOL	DESCRIPTION	REMARKS
			670.00	0			FILL: Red, Micaceous, Clayey **SILT** (moist)	▼
			665.00	5			Boring terminated upon hand auger refusal at 5 feet below land surface	

NOTES: **Water at 3.2 feet bls on 4/12/10**

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

LOG OF BORING AD-HA7

HAND AUGER LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/8/10

LOG OF BORING NO. AD-HA7A

PROJECT: **Belews Creek Ash Dike Investigation**
PROJECT NO: **1356-09-029**
PROJECT LOCATION: **Belews Creek, North Carolina**

WATER LEVEL:

DATE DRILLED: **4/12/10**
DRILLING CONTRACTOR: **S&ME**
DRILLING METHOD: **Hand Auger**

GROUND SURFACE ELEVATION: **670.00**
LOGGED BY:

SAMPLE NUMBER	SAMPLE ADVANCE (ft.)	OVA (ppm)	ELEVATION (ft.)	DEPTH (ft.)	USCS	GRAPHIC SYMBOL	DESCRIPTION	REMARKS
			670.00	0			FILL: Red-Brown, Micaceous, Silty Fine **SAND** with Light Gray and Tan, Silty Clay Lense at 1 foot	
							FILL: Red, Fine Sandy **CLAY**	
							FILL: Purple-Red, Micaceous, Silty Fine **SAND**	▼
							Boring terminated upon hand auger refusal at 4.5 feet below land surface	

This log is part of the report prepared for the named project and should be read together with that report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.

NOTES: **Water at 4.1 feet bls on 04-13-10**

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

LOG OF BORING AD-HA7A

HAND AUGER LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/8/10

LOG OF BORING NO. AD-HA10

PROJECT: **Belews Creek Ash Dike Investigation**
PROJECT NO: **1356-09-029**
PROJECT LOCATION: **Belews Creek, North Carolina**

WATER LEVEL:

DATE DRILLED: **4/8/10**
DRILLING CONTRACTOR: **S&ME**
DRILLING METHOD: **Hand Auger**

GROUND SURFACE ELEVATION: **670.00**
LOGGED BY:

SAMPLE NUMBER	SAMPLE ADVANCE (ft.)	OVA (ppm)	ELEVATION (ft.)	DEPTH (ft.)	USCS	GRAPHIC SYMBOL	DESCRIPTION	REMARKS
			670.00	0			FILL: Red, Micaceous, Clayey **SILT** (moist)	▼
			665.00	5			Boring terminated upon hand auger refusal at 5 feet below land surface	

This log is part of the report prepared for the named project and should be read together with that report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.

NOTES: **Water at 2.3 feet bls on 04-13-10**

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

LOG OF BORING AD-HA10

HAND AUGER LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/8/10

LOG OF BORING NO. AD-HA11

PROJECT: **Belews Creek Ash Dike Investigation**
PROJECT NO: **1356-09-029**
PROJECT LOCATION: **Belews Creek, North Carolina**

WATER LEVEL:

DATE DRILLED: **4/12/10**
DRILLING CONTRACTOR: **S&ME**
DRILLING METHOD: **Hand Auger**

GROUND SURFACE ELEVATION: **651.00**
LOGGED BY:

SAMPLE NUMBER	SAMPLE ADVANCE (ft.)	OVA (ppm)	ELEVATION (ft.)	DEPTH (ft.)	USCS	GRAPHIC SYMBOL	DESCRIPTION	REMARKS
			651.00	0			FILL: Red-Brown, Micaceous, Silty Fine **SAND** with Gravel (slightly moist)	
			646.00	5			Boring terminated upon hand auger refusal at 5.3 feet below land surface	

This log is part of the report prepared for the named project and should be read together with that report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.

NOTES: **Boring dry on 04-13-10**

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

LOG OF BORING AD-HA11

HAND AUGER LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/8/10

PROJECT:	**Belews Creek Ash Dike Investigation** **Belews Creek, North Carolina** **S&ME Project No. 1356-09-029**	**BORING LOG AD-1**
DATE DRILLED: **3/31/10**	ELEVATION: **770.0**	NOTES: **Water at 74 feet bls at termination. No Sand Blanket Encountered**
DRILLING METHOD: **3¼" H.S.A.**	BORING DEPTH: **103.7**	
LOGGED BY: **Courtney Withers**	WATER LEVEL: **Water at 39.1 ft bls on 04-01-10**	
DRILLER: **Don White**	DRILL RIG: **CME-750**	

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO.	N VALUE
5	FILL: Reddish Brown, Micaceous, Medium Dense to Dense, Slightly Clayey Silty Fine **SAND** (SM)	765.0	1 2	10 13
10	FILL: Reddish Brown and Tan, Micaceous, Medium Dense, Silty Fine **SAND** (SM) with Yellowish Red Clayey **SILT** (ML) Lenses at 9.3 ft and 14.5 ft	760.0	3 4	24 29
15	FILL: Brown Orange Tan, Very Stiff Fine to Coarse Sandy **SILT** (Shelby Tube Sample from 16 to 18 feet)	755.0	5	18
20	FILL: Yellowish Tan, Micaceous, Hard, Fine Sandy **SILT** (ML) FILL: Red and Tan, Hard, Silty **CLAY** (CL)	750.0	6	31
	FILL: Reddish Brown and Brown, Micaceous, Dense to Medium Dense, Silty Fine **SAND** (SM) with Manganese (Shelby Tube Sample Taken from 21 to 23 feet)		7	26

STANDARD PENETRATION TEST DATA (blows/ft)

10 20 30 60 80

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT: **Belews Creek Ash Dike Investigation**
Belews Creek, North Carolina
S&ME Project No. 1356-09-029

BORING LOG AD-1

DATE DRILLED: **3/31/10**
ELEVATION: **770.0**
NOTES: **Water at 74 feet bls at termination. No Sand Blanket Encountered**

DRILLING METHOD: **3¼" H.S.A.**
BORING DEPTH: **103.7**

LOGGED BY: **Courtney Withers**
WATER LEVEL: **Water at 39.1 ft bls on 04-01-10**

DRILLER: **Don White**
DRILL RIG: **CME-750**

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO. / SAMPLE TYPE	STANDARD PENETRATION TEST DATA (blows/ft)	N VALUE
	FILL: Reddish Brown and Brown, Micaceous, Dense to Medium Dense, Silty Fine **SAND** (SM) with Manganese (Shelby Tube Sample Taken from 21 to 23 feet) *(continued)*				
	FILL: Yellowish Red and Tan, MIcaceous, Very Stiff, Fine Sandy **SILT** (ML)				
30	FILL: Tan, Micaceous, Medium Dense, Silty Fine **SAND** (SM)	740.0	8		18
	FILL: Reddish Brown, Very Stiff, Clayey **SILT** (ML) (Shelby Tube Sample Taken from 31 to 33 feet)				
35	FILL: Yellowish Red and Reddish Brown, Micaceous, Very Stiff, Fine Sandy **SILT** (ML) with Red Clayey **SILT** (ML) Lense at 39 ft	735.0	9		17
40	FILL: Yellowish Red, Micaceous, Medium Dense, Silty Fine **SAND** (SM) with Manganese	730.0	10		22
45	FILL: Orange and Tan, Micaceous, Medium Dense, Silty Fine **SAND** (SM)	725.0	11		19
			12		23

STANDARD PENETRATION TEST DATA (blows/ft): 10 20 30 60 80

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT: **Belews Creek Ash Dike Investigation**
Belews Creek, North Carolina
S&ME Project No. 1356-09-029

BORING LOG AD-1

DATE DRILLED: **3/31/10**
ELEVATION: **770.0**
NOTES: **Water at 74 feet bls at termination. No Sand Blanket Encountered**

DRILLING METHOD: **3¼" H.S.A.**
BORING DEPTH: **103.7**

LOGGED BY: **Courtney Withers**
WATER LEVEL: **Water at 39.1 ft bls on 04-01-10**

DRILLER: **Don White**
DRILL RIG: **CME-750**

DEPTH (feet)	GRAPHIC LOG	MATERIAL DESCRIPTION	WATER LEVEL	ELEVATION (feet)	SAMPLE NO. SAMPLE TYPE	STANDARD PENETRATION TEST DATA (blows/ft) 10 20 30 60 80	N VALUE
		FILL: Reddish Brown and Tan, Micaceous, Very Stiff, Silty Fine **SAND** (SM) with Reddish Brown Clayey **SILT** (ML) Lense at 48.8 ft *(continued)*					
55		FILL: Yellowish Red, Very Stiff, Clayey **SILT** (ML)		715.0	13		20
60		FILL: Yellowish Red, Micaceous, Medium Dense, Silty Fine **SAND** (SM) with Tan Micaceous Fine Sandy **SILT** (ML) Lense at 64.7 ft		710.0	14		24
65				705.0	15		25
70		FILL: Reddish Brown and Brown, Micaceous, Dense, Silty Fine **SAND** (SM)		700.0	16		34
		FILL: Reddish Brown, Micaceous, Very Stiff, Silty **CLAY** (CL)	▽		17		19

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT: **Belews Creek Ash Dike Investigation**
Belews Creek, North Carolina
S&ME Project No. 1356-09-029

BORING LOG AD-1

DATE DRILLED: **3/31/10**
ELEVATION: **770.0**
NOTES: **Water at 74 feet bls at termination. No Sand Blanket Encountered**

DRILLING METHOD: **3¼" H.S.A.**
BORING DEPTH: **103.7**

LOGGED BY: **Courtney Withers**
WATER LEVEL: **Water at 39.1 ft bls on 04-01-10**

DRILLER: **Don White**
DRILL RIG: **CME-750**

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO.	N VALUE
80	RESIDUUM: Reddish Brown, Micaceous, Medium Dense, Silty Fine **SAND** (SM) *(continued)*	690.0	18	30
85	Gray Tan and White, Medium Dense, Fine **SAND** (SP)	685.0	19	30
	Tan and White, Micaceous, Medium Dense, Silty Fine **SAND** (SM)			
	White and Tan, Dense to Medium Dense, Fine **SAND** (SP)			
90	White and Tan, Hard, Fine Sandy **SILT** (ML)	680.0	20	47
	Tan White and Gray, Micaceous, Dense, Silty Fine **SAND** (SM)			
	Yellowish Brown and Tan, Micaceous, Very Stiff, Fine Sandy **SILT** (ML)			
95	White Gray and Tan, Micaceous, Medium Dense, Silty Fine **SAND** (SM)	675.0	21	30
			22	50/3"

STANDARD PENETRATION TEST DATA (blows/ft)
10 20 30 60 80

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT:	**Belews Creek Ash Dike Investigation** **Belews Creek, North Carolina** **S&ME Project No. 1356-09-029**	**BORING LOG AD-1**
DATE DRILLED: **3/31/10**	ELEVATION: **770.0**	NOTES: **Water at 74 feet bls at termination. No Sand Blanket Encountered**
DRILLING METHOD: **3¼" H.S.A.**	BORING DEPTH: **103.7**	
LOGGED BY: **Courtney Withers**	WATER LEVEL: **Water at 39.1 ft bls on 04-01-10**	
DRILLER: **Don White**	DRILL RIG: **CME-750**	

DEPTH (feet)	GRAPHIC LOG	MATERIAL DESCRIPTION	WATER LEVEL	ELEVATION (feet)	SAMPLE NO. SAMPLE TYPE	STANDARD PENETRATION TEST DATA (blows/ft) 10 20 30 60 80	N VALUE
		PARTIALLY WEATHERED ROCK: When Sampled Becomes Reddish Brown and Tan, Micaceous, Very Dense, Silty Fine **SAND** (SM) *(continued)*					
					23		50/ 3"
		Boring terminated at 103.7 feet below land surface Depth measurements are shown to illustrate the general arrangements of soil types encountered at the boring location. Do not use depth measurements for determination of distances or quantities.					

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT:	**Belews Creek Ash Dike Investigation** **Belews Creek, North Carolina** **S&ME Project No. 1356-09-029**	**BORING LOG AD-3**
DATE DRILLED: **4/1/10**	ELEVATION: **770.0**	NOTES: **Water at 35 ft bls on 4-7-10.** **No Sand Blanket Encountered**
DRILLING METHOD: **3¼" H.S.A.**	BORING DEPTH: **54.4**	
LOGGED BY: **Courtney Withers**	WATER LEVEL: **Water at 38.9 feet on 4-9-10**	
DRILLER: **Don White**	DRILL RIG: **CME-750**	

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO. / SAMPLE TYPE	N VALUE
	FILL: Brown and Gray, Micaceous, Medium Dense, Silty Fine **SAND (SM)** with Rock Fragments (Mica Schist)		1	15
5		765.0	2	16
	FILL: Red-Brown and Tan, Micaceous, Medium Dense, Slightly Clayey Silty Fine **SAND (SM)** (Shelby Tube Sample Taken from 10 to 12 feet)		3	17
10		760.0	4	22
15	**FILL:** Red-Brown and Yellow-Tan, Micaceous, Medium Dense, Silty Fine **SAND (SM)**	755.0	5	13
	FILL: Yellow-Red and Tan, Micaceous, Very Stiff, Silty **CLAY (CL)**		6	24
20	**FILL:** Red-Brown, Micaceous, Dense to Medium Dense, Silty Fine **SAND (SM)** with yellow, white, medium to fine **SAND (SP)** lense at 19 feet and yellow-red, micaceous clayey **SILT (ML)** lense at 24.4 feet (Shelby Tube Sample Taken from 25 to 27 feet)	750.0	7	32

STANDARD PENETRATION TEST DATA (blows/ft): 10 20 30 60 80

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT:	**Belews Creek Ash Dike Investigation** **Belews Creek, North Carolina** **S&ME Project No. 1356-09-029**	**BORING LOG AD-3**
DATE DRILLED: **4/1/10**	ELEVATION: **770.0**	NOTES: **Water at 35 ft bls on 4-7-10.** **No Sand Blanket Encountered**
DRILLING METHOD: **3¼" H.S.A.**	BORING DEPTH: **54.4**	
LOGGED BY: **Courtney Withers**	WATER LEVEL: **Water at 38.9 feet on 4-9-10**	
DRILLER: **Don White**	DRILL RIG: **CME-750**	

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO. / SAMPLE TYPE	STANDARD PENETRATION TEST DATA (blows/ft) 10 20 30 60 80	N VALUE
30	**FILL:** Red-Brown, Micaceous, Dense to Medium Dense, Silty Fine **SAND (SM)** with yellow, white, medium to fine **SAND (SP)** lense at 19 feet and yellow-red, micaceous clayey **SILT (ML)** lense at 24.4 feet (Shelby Tube Sample Taken from 25 to 27 feet) *(continued)*	740.0	8		24
35	**FILL:** Tan Orange Brown, Very Stiff, Fine to Coarse Sandy **SILT (ML)** with Mica (Shelby Tube Sample Taken from 36 to 38 feet)	735.0	9		18
40	**FILL:** Red-Brown, Micaceous, Very Stiff, Silty **CLAY (CL)**	730.0	10		20
45	**PARTIALLY WEATHERED ROCK:** When Sampled Becomes Tan and Gray, Micaceous, Very Dense, Silty Fine **SAND (SM)** with Rock Fragments and Manganese Staining (Mica Schist)	725.0	11	>>	50/ 5"
			12	>>	50/ 3"

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT:	**Belews Creek Ash Dike Investigation** **Belews Creek, North Carolina** **S&ME Project No. 1356-09-029**	**BORING LOG AD-3**
DATE DRILLED: **4/1/10**	ELEVATION: **770.0**	NOTES: **Water at 35 ft bls on 4-7-10.** **No Sand Blanket Encountered**
DRILLING METHOD: **3¼" H.S.A.**	BORING DEPTH: **54.4**	
LOGGED BY: **Courtney Withers**	WATER LEVEL: **Water at 38.9 feet on 4-9-10**	
DRILLER: **Don White**	DRILL RIG: **CME-750**	

DEPTH (feet)	GRAPHIC LOG	MATERIAL DESCRIPTION	WATER LEVEL	ELEVATION (feet)	SAMPLE NO. SAMPLE TYPE	STANDARD PENETRATION TEST DATA (blows/ft) 10 20 30 60 80	N VALUE
		PARTIALLY WEATHERED ROCK: When Sampled Becomes Tan and Gray, Micaceous, Very Dense, Silty Fine **SAND (SM)** with Rock Fragments and Manganese Staining (Mica Schist) *(continued)*			13	>>	50/ 5"
		Boring terminated at 54.4 feet below land surface Depth measurements are shown to illustrate the general arrangements of soil types encountered at the boring location. Do not use depth measurements for determination of distances or quantities.					

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT:	**Belews Creek Ash Dike Investigation** **Belews Creek, North Carolina** **S&ME Project No. 1356-09-029**	**BORING LOG AD-4**
DATE DRILLED: **3/31/10**	ELEVATION: **720.0**	NOTES: **Water at 33 ft bls at termination. Sand Blanket Encountered From 16.3 to 17.2 ft bls**
DRILLING METHOD: **3¼" H.S.A.**	BORING DEPTH: **49.2**	
LOGGED BY: **Courtney Withers**	WATER LEVEL: **Water at 25.9 feet on 4-01-10**	
DRILLER: **Don White**	DRILL RIG: **CME-750**	

DEPTH (feet)	GRAPHIC LOG	MATERIAL DESCRIPTION	WATER LEVEL	ELEVATION (feet)	SAMPLE NO. SAMPLE TYPE	STANDARD PENETRATION TEST DATA (blows/ft) 10 20 30 60 80	N VALUE
5		FILL: Tan and Reddish Brown, Micaceous, Stiff to Firm, Slightly Clayey Fine Sandy **SILT** (ML) with Manganese Staining		715.0	1	11	11
					2	8	8
		FILL: Yellowish Tan, Micaceous, Loose, Silty Fine **SAND** (SM)			3	12	12
10		FILL: Yellowish Red, Micaceous, Stiff, Silty **CLAY** (CL)		710.0	4	8	8
		FILL: Yellowish Red, Micaceous, Stiff, Slightly Clayey Fine Sandy **SILT** (ML)			5	11	11
		FILL: Yellowish Red, Micaceous, Stiff, Clayey **SILT** (ML)			6	13	13
15		FILL: Brown, Micaceous, Medium Dense, Silty Fine to Coarse **SAND** (SM)		705.0	7	10	10
		FILL: Brown, Micaceous, Medium Dense, Silty Fine to Coarse **SAND** (SM) **"DRAINAGE BLANKET"**			8	13	13
		FILL: Brown, Micaceous, Very Stiff, Clayey **SILT** (ML) with Rock Fragments			9	20	20
20		FILL: Red and Reddish Brown, Micaceous, Medium Dense, Silty Fine **SAND** (SM)		700.0	10	17	17
		RESIDUUM: Brown, Micaceous, Medium Dense, Silty Fine **SAND** (SM) with Rock Fragments (Mica Schist) (Shelby Tube Sample Taken from 18.5 to 20.5 feet)			11	31	31

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT: **Belews Creek Ash Dike Investigation**
Belews Creek, North Carolina
S&ME Project No. 1356-09-029

BORING LOG AD-4

DATE DRILLED: **3/31/10**
ELEVATION: **720.0**
DRILLING METHOD: **3¼" H.S.A.**
BORING DEPTH: **49.2**
LOGGED BY: **Courtney Withers**
WATER LEVEL: **Water at 25.9 feet on 4-01-10**
DRILLER: **Don White**
DRILL RIG: **CME-750**

NOTES: **Water at 33 ft bls at termination. Sand Blanket Encountered From 16.3 to 17.2 ft bls**

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO.	N VALUE
	Brownish Gray, Micaceous, Dense, Silty Fine **SAND** (SM) with Rock Fragments (Amphibolite) *(continued)*			
30		690.0	12	20
	Brown Tan, Very Dense to Medium Dense, Silty Fine to Coarse **SAND** (SM) with Mica (Shelby Tube Sample Taken from 30 to 32 feet)		13	51
35		685.0		
	Brown, Micaceous, Very Hard, Fine Sandy **SILT** (ML)		14	51
40	Reddish Brown, Micaceous, Very Dense, Silty Fine **SAND** (SM)	680.0		
			15	50/3
45	PARTIALLY WEATHERED ROCK: When Sampled Becomes Brown and Gray, Very Dense, Silty Fine **SAND** (SM) with Rock Fragments (Mica Schist)	675.0		
			16	50/3

STANDARD PENETRATION TEST DATA (blows/ft)
10 20 30 60 80

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT:	**Belews Creek Ash Dike Investigation** **Belews Creek, North Carolina** **S&ME Project No. 1356-09-029**	**BORING LOG AD-4**
DATE DRILLED: **3/31/10**	ELEVATION: **720.0**	NOTES: **Water at 33 ft bls at termination. Sand Blanket Encountered From 16.3 to 17.2 ft bls**
DRILLING METHOD: **3¼" H.S.A.**	BORING DEPTH: **49.2**	
LOGGED BY: **Courtney Withers**	WATER LEVEL: **Water at 25.9 feet on 4-01-10**	
DRILLER: **Don White**	DRILL RIG: **CME-750**	

DEPTH (feet)	GRAPHIC LOG	MATERIAL DESCRIPTION	WATER LEVEL	ELEVATION (feet)	SAMPLE NO. SAMPLE TYPE	STANDARD PENETRATION TEST DATA (blows/ft) 10 20 30 60 80	N VALUE
		Boring terminated at 49.2 feet below land surface Depth measurements are shown to illustrate the general arrangements of soil types encountered at the boring location. Do not use depth measurements for determination of distances or quantities.					

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT: **Belews Creek Ash Dike Investigation**
Belews Creek, North Carolina
S&ME Project No. 1356-09-029

BORING LOG AD-6

DATE DRILLED: **3/30/10**
ELEVATION: **720.0**
NOTES: **No Sand Blanket Encountered**

DRILLING METHOD: **3¼" H.S.A.**
BORING DEPTH: **78.5**

LOGGED BY: **Courtney Withers**
WATER LEVEL: **Water at 39.05 feet on 3-31-10**

DRILLER: **Don White**
DRILL RIG: **CME-750**

DEPTH (feet)	GRAPHIC LOG	MATERIAL DESCRIPTION	WATER LEVEL	ELEVATION (feet)	SAMPLE NO. SAMPLE TYPE	STANDARD PENETRATION TEST DATA (blows/ft) 10 20 30 60 80	N VALUE
		FILL: Yellowish Red, Micaceous, Firm, Clayey **SILT** (ML)			1		8
5				715.0	2		15
					3		18
		FILL: Reddish Brown and Tan, Micaceous, Medium Dense to Loose, Silty Fine **SAND** (SM) with Rock Fragments (Shelby Tube Sample Taken from 15 to 17 feet)			4		18
10				710.0			
					5		17
15				705.0			
					6		16
20		FILL: Reddish Brown, Tan, Yellowish Tan, and White, Micaceous, Medium Dense, Silty Fine **SAND** (SM)		700.0			
		FILL: Yellowish Red. Micaceous, Very Stiff, Clayey **SILT** (ML)			7		19

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT: **Belews Creek Ash Dike Investigation**
Belews Creek, North Carolina
S&ME Project No. 1356-09-029

BORING LOG AD-6

DATE DRILLED: **3/30/10**
ELEVATION: **720.0**
NOTES: **No Sand Blanket Encountered**

DRILLING METHOD: **3¼" H.S.A.**
BORING DEPTH: **78.5**

LOGGED BY: **Courtney Withers**
WATER LEVEL: **Water at 39.05 feet on 3-31-10**

DRILLER: **Don White**
DRILL RIG: **CME-750**

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO. / SAMPLE TYPE	N VALUE
	FILL: Tan, Micaceous, Medium Dense, Silty Fine **SAND** (SM) with Tan Micaceous Silty Clay Lense at 24 ft bls.			
	FILL: Tan and White, Micaceous, Medium Dense, Fine **SAND** (SP)			
30	FILL: Yellowish Tan, Micaceous, Medium Dense, Slightly Clayey Silty Fine **SAND** (SM) *(continued)*	690.0	8	20
	FILL: Reddish Brown and Tan, Micaceous, Medium Dense, Slightly Clayey Silty Fine **SAND** (SM)			
	FILL: Tan and Gray, Micaceous, Medium Dense, Slightly Clayey Silty Fine **SAND** (SM) with Rock Fragments			
35	FILL: Orange Tan Brown, Fine to Coarse Sandy Clayey **SILT** (MH) with Mica (Shelby Tube Sample Taken from 30 to 32 feet)	685.0	9	16
	FILL: Yellowish Red, Micaceous, Very Stiff, Clayey **SILT** (ML) ▼		10	19
40		680.0		
45	RESIDUUM: Brown-Red and Tan, Micaceous, Dense to Medium Dense, Silty Fine **SAND** (SM)	675.0	11	32
			12	20

STANDARD PENETRATION TEST DATA (blows/ft)
10 20 30 60 80

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT: **Belews Creek Ash Dike Investigation**
Belews Creek, North Carolina
S&ME Project No. 1356-09-029

BORING LOG AD-6

DATE DRILLED: **3/30/10**
ELEVATION: **720.0**
NOTES: **No Sand Blanket Encountered**

DRILLING METHOD: **3¼" H.S.A.**
BORING DEPTH: **78.5**

LOGGED BY: **Courtney Withers**
WATER LEVEL: **Water at 39.05 feet on 3-31-10**

DRILLER: **Don White**
DRILL RIG: **CME-750**

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO. SAMPLE TYPE	N VALUE
	Red and Tan, Micaceous, Medium Dense, Slightly Clayey Silty Fine **SAND** (SM) *(continued)*			
	Red and Tan, Micaceous, Very Stiff, Fine Sandy Clayey **SILT** (ML)			
55	Reddish Brown, Micaceous, Medium Dense, Slightly Clayey Silty Fine **SAND** (SM)	665.0	13	22
60	PARTIALLY WEATHERED ROCK: When Sampled Becomes Brown, Micaceous, Very Dense, Silty Fine **SAND** with Rock Fragments	660.0	14	50/4"
	RESIDUUM: Brown, Micaceous, Dense, Silty Fine **SAND** (SM) with Rock Fragments			
65	RESIDUUM: Gray and Tan, Dense, Silty Fine **SAND** (SM)	655.0	15	39
70	PARTIALLY WEATHERED ROCK: When Sampled Becomes Tan, Micaceous, Very Dense, Silty Fine **SAND** (SM)	650.0	16	50/2"
			17	35

STANDARD PENETRATION TEST DATA (blows/ft)
10 20 30 60 80

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT:	**Belews Creek Ash Dike Investigation** **Belews Creek, North Carolina** **S&ME Project No. 1356-09-029**	**BORING LOG AD-6**
DATE DRILLED: **3/30/10**	ELEVATION: **720.0**	NOTES: **No Sand Blanket Encountered**
DRILLING METHOD: **3¼" H.S.A.**	BORING DEPTH: **78.5**	
LOGGED BY: **Courtney Withers**	WATER LEVEL: **Water at 39.05 feet on 3-31-10**	
DRILLER: **Don White**	DRILL RIG: **CME-750**	

DEPTH (feet)	GRAPHIC LOG	MATERIAL DESCRIPTION	WATER LEVEL	ELEVATION (feet)	SAMPLE NO. SAMPLE TYPE	STANDARD PENETRATION TEST DATA (blows/ft) 10 20 30 60 80	N VALUE
		RESIDUUM: Tan, Micaceous, Dense, Silty Fine **SAND** (SM) *(continued)*					
		*Boring terminated upon **Auger Refusal** at 78.5 feet below land surface* Depth measurements are shown to illustrate the general arrangements of soil types encountered at the boring location. Do not use depth measurements for determination of distances or quantities.					

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT: **Belews Creek Ash Dike Investigation**
Belews Creek, North Carolina
S&ME Project No. 1356-09-029

BORING LOG AD-7

DATE DRILLED: **3/29/10**
ELEVATION: **670.0**
DRILLING METHOD: **3¼" H.S.A.**
BORING DEPTH: **19.4**
LOGGED BY: **Courtney Withers**
WATER LEVEL: **Water at 2.3 feet on 3-30-10**
DRILLER: **Don White**
DRILL RIG: **CME-750**

NOTES: **Dry at terminaton.**
Sand Blanket Encountered From 12.5 to 15.5 ft bls

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO.	N VALUE
	FILL: Red and Tan, Micaceous, Stiff, Fine Sandy **SILT** (ML)		1	11
			2	11
5	FILL: Red, Micaceous, Stiff, Silty **CLAY** (CL)	665.0	3	14
	FILL: Reddish Brown, Micaceous, Stiff, Fine Sandy Clayey **SILT** (ML)		4	13
10	FILL: Brown and Gray, Medium Dense, Fine **SAND** (SP)	660.0	5	10
	FILL: Brown, Micaceous, Very Stiff to Stiff, Fine Sandy **SILT** with Gravel (ML)		6	18
	FILL: Tan, Medium Dense, Fine to Coarse **SAND** (SP) **"DRAINAGE BLANKET"**		7	10
15		655.0	8	10
	RESIDUUM: Red and Yellow, Stiff, Fine Sandy **SILT** with Gray Clay Lense (ML)		9	50/5
	PARTIALLY WEATHERED ROCK: When Sampled Becomes Tan and Red, Micaceous, Very Hard, Fine Sandy **SILT** (ML)		10	50/5

STANDARD PENETRATION TEST DATA (blows/ft)
10 20 30 60 80

Boring terminated at 19.4 feet below land surface.

Depth measurements are shown to illustrate the general arrangements of soil types encountered at the boring location. Do not use depth measurements for determination of distances or quantities.

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT: **Belews Creek Ash Dike Investigation**
Belews Creek, North Carolina
S&ME Project No. 1356-09-029

BORING LOG AD-9

DATE DRILLED: **3/30/10**
ELEVATION: **670.0**
DRILLING METHOD: **3¼" H.S.A.**
BORING DEPTH: **38.5**
LOGGED BY: **Courtney Withers**
WATER LEVEL: **Water at 6.9 feet on 4-8-10**
DRILLER: **Don White**
DRILL RIG: **CME-750**

NOTES: **Water at 21 feet bls at termination.**
Water at 11.5 feet at 1 hour.

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO.	SAMPLE TYPE	N VALUE
	FILL: Reddish Yellow, Micaceous, Stiff, Slightly Clayey **SILT** (ML)				
	FILL: Tan and Red, Micaceous, Stiff, Fine Sandy **SILT** (ML)		1		15
5	FILL: Red, Micaceous, Stiff, Silty **CLAY** (CL) (Shelby Tube Sample Taken from 5 to 7 feet)	665.0	2		12
	FILL: Reddish Brown and Gray, Micaceous, Stiff, Silty **CLAY** (CL)				
10	FILL: Red and Yellowish Red, Micaceous, Medium Dense, Silty Fine **SAND** (SM)	660.0	3		17
	FILL: Reddish Brown and Gray, Micaceous, Very Stiff, Silty **CLAY** (CL)				
	FILL: Yellowish Red, Micaceous, Very Stiff, Slightly Clayey Fine Sandy **SILT** (ML)		4		21
15	FILL: Reddish Brown and Gray, Micaceous, Very Stiff, Silty **CLAY** (CL) with Gravel	655.0			
	FILL: Orange Brown, Micaceous, Medium Dense, Silty Fine to Coarse **SAND** (SM) (Shelby Tube Sample Taken from 16 to 18 feet)				
	FILL: Brown, Micaceous, Stiff, Slightly Clayey Fine Sandy **SILT** (ML)		5		11
20	FILL: Brown, Micaceous, Stiff to Firm, Fine Sandy **SILT** (ML) with Manganese	650.0	6		8
			7		11
			8		14

STANDARD PENETRATION TEST DATA (blows/ft)
10 20 30 60 80

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT: **Belews Creek Ash Dike Investigation**
Belews Creek, North Carolina
S&ME Project No. 1356-09-029

BORING LOG AD-9

DATE DRILLED: **3/30/10**
ELEVATION: **670.0**
NOTES: **Water at 21 feet bls at termination. Water at 11.5 feet at 1 hour.**

DRILLING METHOD: **3¼" H.S.A.**
BORING DEPTH: **38.5**

LOGGED BY: **Courtney Withers**
WATER LEVEL: **Water at 6.9 feet on 4-8-10**

DRILLER: **Don White**
DRILL RIG: **CME-750**

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO.	SAMPLE TYPE	N VALUE
	FILL: Reddish Brown, Micaceous, Medium Dense, Silty Fine **SAND** (SM) Possible **"Drainage Blanket"**		9		15
	RESIDUUM: Reddish Brown, Micaceous, Stiff, Fine Sandy **SILT** (ML)				
30		640.0	10		21
	Brown, Micaceous, Very Stiff, Fine Sandy **SILT** (ML)				
	Tan, Very Dense, Micaceous, Silty Fine to Coarse **SAND** (SP)		11		53
35		635.0			
	Tan, Micaceous, Very Loose, Silty Silty Fine to Coarse **SAND** (SM)		12		4
	PARTIALLY WEATHERED ROCK: When Sampled Becomes Orange Tan, Micaceous, Very Dense, Silty Fine to Coarse **SAND** (SM) (Parent Rock Mica Schist)		13		>> 50/4
	Boring terminated at 38.5 feet below land surface.		14		>> 50/5.5

STANDARD PENETRATION TEST DATA (blows/ft)
10 20 30 60 80

Depth measurements are shown to illustrate the general arrangements of soil types encountered at the boring location. Do not use depth measurements for determination of distances or quantities

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT: **Belews Creek Ash Dike Investigation**
Belews Creek, North Carolina
S&ME Project No. 1356-09-029

BORING LOG AD-10

DATE DRILLED: **3/30/10**
ELEVATION: **670.0**
DRILLING METHOD: **3¼" H.S.A.**
BORING DEPTH: **26.0**
LOGGED BY: **Courtney Withers**
WATER LEVEL: **Water at 2.0 feet on 4-8-10.**
DRILLER: **Don White**
DRILL RIG: **CME-750**

NOTES: **Water at 4.0 feet bls at termination. Sand Blanket Encountered From 23.8 to 24.8 ft bls**

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO.	N VALUE
5	FILL: Yellowish Red, Micaceous, Very Stiff to Stiff, Silty **CLAY** (CL) with Manganese and Rock Fragments	665.0	1	18
			2	14
	FILL: Yellowish Red, Micaceous, Stiff, Fine Sandy **SILT** (ML) with a Rock Lense at 6.5 ft bls		3	11
	FILL: Yellowish Red, Micaceous, Stiff, Silty **CLAY** (CL)		4	10
10	FILL: Red and Tan, Micaceous, Stiff, Fine Sandy **SILT** (ML) (Sample was Soft and Wet)	660.0	5	20
	FILL: Brown and Gray, Stiff, Silty **CLAY** (CL)		6	17
	FILL: Red, Micaceous, Very Stiff, Silty **CLAY** (CL)			
	FILL: Brown and Yellowish Tan, Micaceous, Medium Dense, Silty Fine **SAND** (SM) with Rock Fragments		7	15
15	FILL: Yellowish Tan and White, Micaceous, Stiff, Fine Sandy **SILT** (ML)	655.0		
	FILL: Yellowish Tan and White, Micaceous, Very Loose, Silty Fine **SAND** (SM)		8	2
20		650.0		
			9	50/5"

STANDARD PENETRATION TEST DATA (blows/ft)
10 20 30 60 80

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT:	**Belews Creek Ash Dike Investigation** **Belews Creek, North Carolina** **S&ME Project No. 1356-09-029**	**BORING LOG AD-10**
DATE DRILLED: **3/30/10**	ELEVATION: **670.0**	NOTES: **Water at 4.0 feet bls at termination. Sand Blanket Encountered From 23.8 to 24.8 ft bls**
DRILLING METHOD: **3¼" H.S.A.**	BORING DEPTH: **26.0**	
LOGGED BY: **Courtney Withers**	WATER LEVEL: **Water at 2.0 feet on 4-8-10.**	
DRILLER: **Don White**	DRILL RIG: **CME-750**	

DEPTH (feet)	GRAPHIC LOG	MATERIAL DESCRIPTION	WATER LEVEL	ELEVATION (feet)	SAMPLE NO. SAMPLE TYPE	STANDARD PENETRATION TEST DATA (blows/ft) 10 20 30 60 80	N VALUE
		FILL: Tan and Gray, Medium Dense, Fine to Coarse **SAND** (SM) **"DRAINAGE BLANKET"**					
		PARTIALLY WEATHERED ROCK: When Sampled Becomes Silver, Micaceous, Very Dense, Silty Fine **SAND** (SM) (Parent Rock Mica Schist) *(continued)*					
		*Boring terminated upon **Auger Refusal** at 26 feet below land surface.*					
		Depth measurements are shown to illustrate the general arrangements of soil types encountered at the boring location. Do not use depth measurements for determination of distances or quantities.					

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT:	**Belews Creek Ash Dike Investigation** **Belews Creek, North Carolina** **S&ME Project No. 1356-09-029**	**BORING LOG AD-12**
DATE DRILLED: **4/8/10**	ELEVATION: **770.0**	NOTES: **Water at 69 feet bls at termination. No Sand Blanket Encountered.**
DRILLING METHOD: **3¼" H.S.A.**	BORING DEPTH: **104.0**	
LOGGED BY: **Courtney Withers**	WATER LEVEL: **Water at 44.6 feet on 4-9-10**	
DRILLER: **Don White**	DRILL RIG: **CME-750**	

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO. / SAMPLE TYPE	N VALUE
	FILL: Red-Brown, Micaceous, Loose, Slightly Clayey Silty Fine **SAND (SM)**		1	8
	FILL: Yellow-Red, Micaceous, Very Stiff, Clayey **SILT (ML)**		2	16
5		765.0		
10	**FILL:** Red-Brown, Tan, Micaceous, Medium Dense, Silty Fine **SAND (SM)** with Red Silty **CLAY (CL)** lenses at 9.6 feet and 9.8 feet and quartz gravel at 14.6 feet and 15 feet (Shelby Tube Sample Taken from 6 to 8 feet)	760.0	3	18
15		755.0	4	21
20	**FILL:** Yellow-Red, Medium Dense, Silty Fine **SAND (SM)** with White, Fine **SAND (SP)** lenses at 18.9 feet	750.0	5	22
	FILL: Red, Very Stiff, Clayey **SILT (ML)**			
	FILL: Yellow-Red, Medium Dense, Silty Fine **SAND (SM)** with Manganese Staining		6	32

STANDARD PENETRATION TEST DATA (blows/ft): 10, 20, 30, 60, 80

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT: **Belews Creek Ash Dike Investigation**
Belews Creek, North Carolina
S&ME Project No. 1356-09-029

BORING LOG AD-12

DATE DRILLED: **4/8/10**
ELEVATION: **770.0**
NOTES: **Water at 69 feet bls at termination. No Sand Blanket Encountered.**

DRILLING METHOD: **3¼" H.S.A.**
BORING DEPTH: **104.0**

LOGGED BY: **Courtney Withers**
WATER LEVEL: **Water at 44.6 feet on 4-9-10**

DRILLER: **Don White**
DRILL RIG: **CME-750**

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO. / SAMPLE TYPE	STANDARD PENETRATION TEST DATA (blows/ft) 10 20 30 60 80	N VALUE
	FILL: Red-Brown, Micaceous, Dense, Silty Fine **SAND (SM)**				
	FILL: Red-Brown, Micaceous, Dense, Silty Fine **SAND (SM)** *(continued)*				
30	**FILL:** Yellow-Red, Micaceous, Medium Dense, Silty Fine **SAND (SM)** with Manganese Staining	740.0	7		22
35		735.0	8		18
40	**FILL:** Yellow-Red and Yellow-Tan, Very Stiff, Slightly Clayey Fine Sandy **SILT (ML)** with Trace Mica and Manganese Staining	730.0	9		18
45		725.0	10		19
			11		19

▼ Water Level

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT:	**Belews Creek Ash Dike Investigation** **Belews Creek, North Carolina** **S&ME Project No. 1356-09-029**	**BORING LOG AD-12**
DATE DRILLED: **4/8/10**	ELEVATION: **770.0**	NOTES: **Water at 69 feet bls at termination. No Sand Blanket Encountered.**
DRILLING METHOD: **3¼" H.S.A.**	BORING DEPTH: **104.0**	
LOGGED BY: **Courtney Withers**	WATER LEVEL: **Water at 44.6 feet on 4-9-10**	
DRILLER: **Don White**	DRILL RIG: **CME-750**	

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO. / SAMPLE TYPE	STANDARD PENETRATION TEST DATA (blows/ft) 10 20 30 60 80	N VALUE
55	**FILL:** Yellow-Red and Yellow-Tan, Very Stiff, Slightly Clayey Fine Sandy **SILT (ML)** with Trace Mica and Manganese Staining *(continued)*	715.0	12		22
60	**FILL:** Red, Very Stiff, Clayey **SILT (ML)**	710.0	13		21
65		705.0	14		20
70	**FILL:** Yellow-Red and Yellow-Tan, Micaceous, Very Stiff, Slighty Clayey Fine Sandy **SILT (ML)** with Manganese Staining ▽	700.0	15		21
			16		32

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT: **Belews Creek Ash Dike Investigation**
Belews Creek, North Carolina
S&ME Project No. 1356-09-029

BORING LOG AD-12

DATE DRILLED: **4/8/10**
ELEVATION: **770.0**
DRILLING METHOD: **3¼" H.S.A.**
BORING DEPTH: **104.0**
LOGGED BY: **Courtney Withers**
WATER LEVEL: **Water at 44.6 feet on 4-9-10**
DRILLER: **Don White**
DRILL RIG: **CME-750**

NOTES: **Water at 69 feet bls at termination.**
No Sand Blanket Encountered.

DEPTH (feet)	MATERIAL DESCRIPTION	ELEVATION (feet)	SAMPLE NO. / SAMPLE TYPE	N VALUE
	FILL: Yellow-Red and Yellow-Tan, Hard, Clayey **SILT (ML)** with Yellow-Tan, Silty Fine Sand Lense at 78.2 feet *(continued)*			
80		690.0	17	32
85	**FILL:** Red-Brown and Tan, Micaceous, Dense to Medium Dense, Silty Fine **SAND (SM)** with Rock Fragments (Mica Schist)	685.0	18	33
90		680.0	19	23
			20	9
95	**FILL:** Red-Brown, Stiff, Clayey **SILT (ML)** with Rock Fragments (Mica Schist)	675.0		
			21	50/5"

STANDARD PENETRATION TEST DATA (blows/ft)
10 20 30 60 80

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

PROJECT:	**Belews Creek Ash Dike Investigation** **Belews Creek, North Carolina** **S&ME Project No. 1356-09-029**	**BORING LOG AD-12**
DATE DRILLED: **4/8/10**	ELEVATION: **770.0**	NOTES: **Water at 69 feet bls at termination. No Sand Blanket Encountered.**
DRILLING METHOD: **3¼" H.S.A.**	BORING DEPTH: **104.0**	
LOGGED BY: **Courtney Withers**	WATER LEVEL: **Water at 44.6 feet on 4-9-10**	
DRILLER: **Don White**	DRILL RIG: **CME-750**	

DEPTH (feet)	GRAPHIC LOG	MATERIAL DESCRIPTION	WATER LEVEL	ELEVATION (feet)	SAMPLE NO. SAMPLE TYPE	STANDARD PENETRATION TEST DATA (blows/ft) 10 20 30 60 80	N VALUE
		FILL: Red-Brown, Micaceous, Very Hard, Silty Fine **SAND (SM)** with Rock Fragments (Mica Schist) and Red Silty **CLAY (CL)** lense at 98.9 feet					
		PARTIALLY WEATHERED ROCK: When Sampled becomes Red-Brown and Tan, Micaceous, Very Dense, Silty Fine **SAND (SM)** with Rock Fragments (Mica Schist) *(continued)*			22 ☒	>>	50/ 5.5"
		Boring terminated at 104 feet. Water at 69 feet at termination and 44.6 feet on 4/9/10. Wet Spoon from 68.5 to 70 feet.					
		Depth measurements are shown to illustrate the general arrangements of soil types encountered at the boring location. Do not use depth measurements for determination of distances or quantities.					

BORING LOG COPY OF BELEWS CREEK ASH DIKE WITHOUT FILL.GPJ S&ME.GDT 9/14/10

NOTES:

1. ***THIS LOG IS ONLY A PORTION OF A REPORT PREPARED FOR THE NAMED PROJECT AND MUST ONLY BE USED TOGETHER WITH THAT REPORT.***
2. ***BORING, SAMPLING AND PENETRATION TEST DATA IN GENERAL ACCORDANCE WITH ASTM D-1586.***
3. ***STRATIFICATION AND GROUNDWATER DEPTHS ARE NOT EXACT.***
4. ***WATER LEVEL IS AT TIME OF EXPLORATION AND WILL VARY.***

S&ME
ENGINEERING • TESTING
ENVIRONMENTAL SERVICES

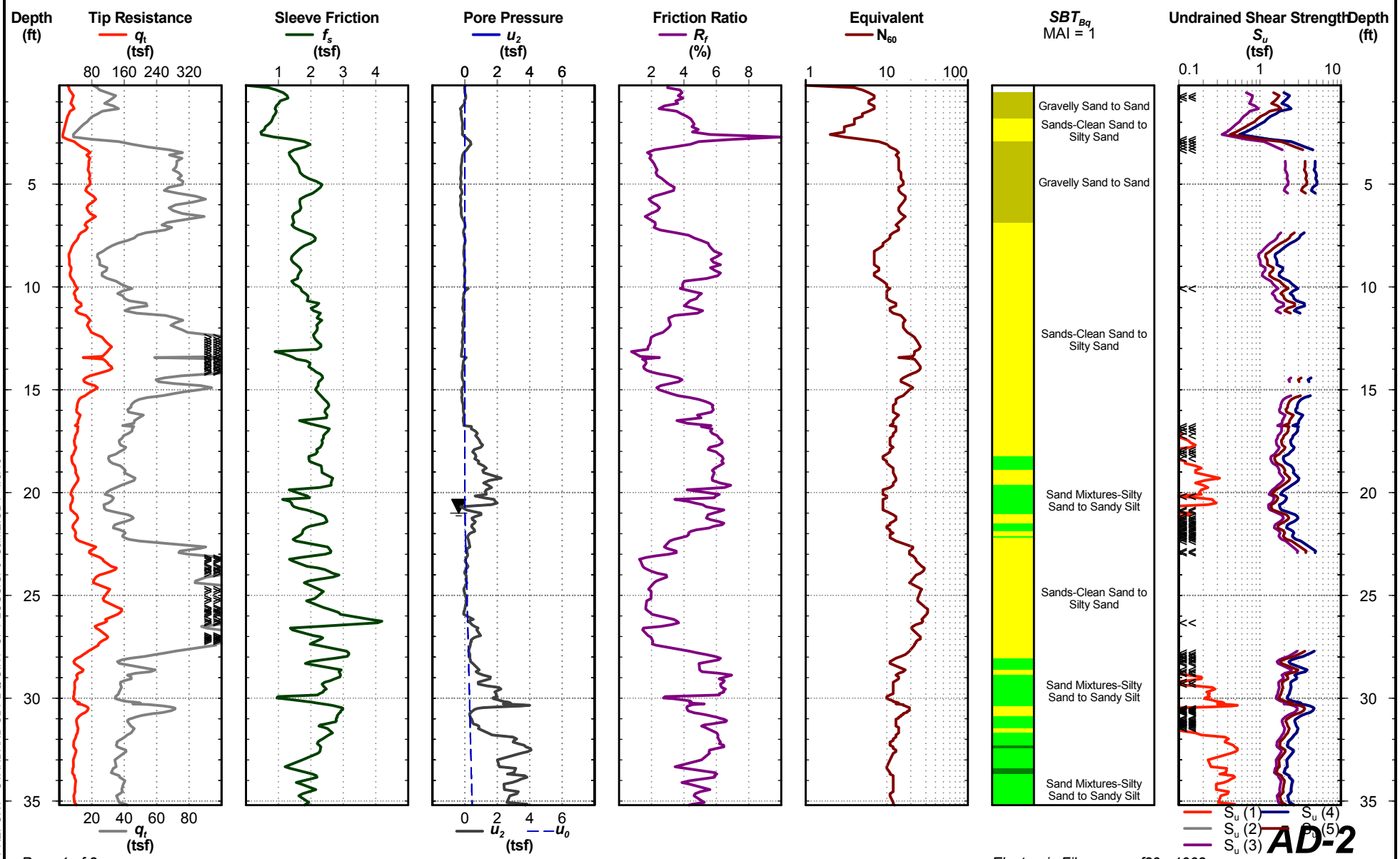
S&ME

Belews Creek Steam Station
Belews Creek, NC
S&ME Project No: 1356-09-029-4

Cone Penetration Test AD-2

Date: Mar. 29, 2010
Estimated Water Depth: 21 ft
Rig/Operator:

Total Depth: 49.7 ft
Termination Criteria:
Cone Size: 1.75



CPT REPORT - STANDARD SBT BQ GINT CPT LOGS.GPJ S&ME.GDT 4/8/10

Electronic Filename: f29m1002c.ecp

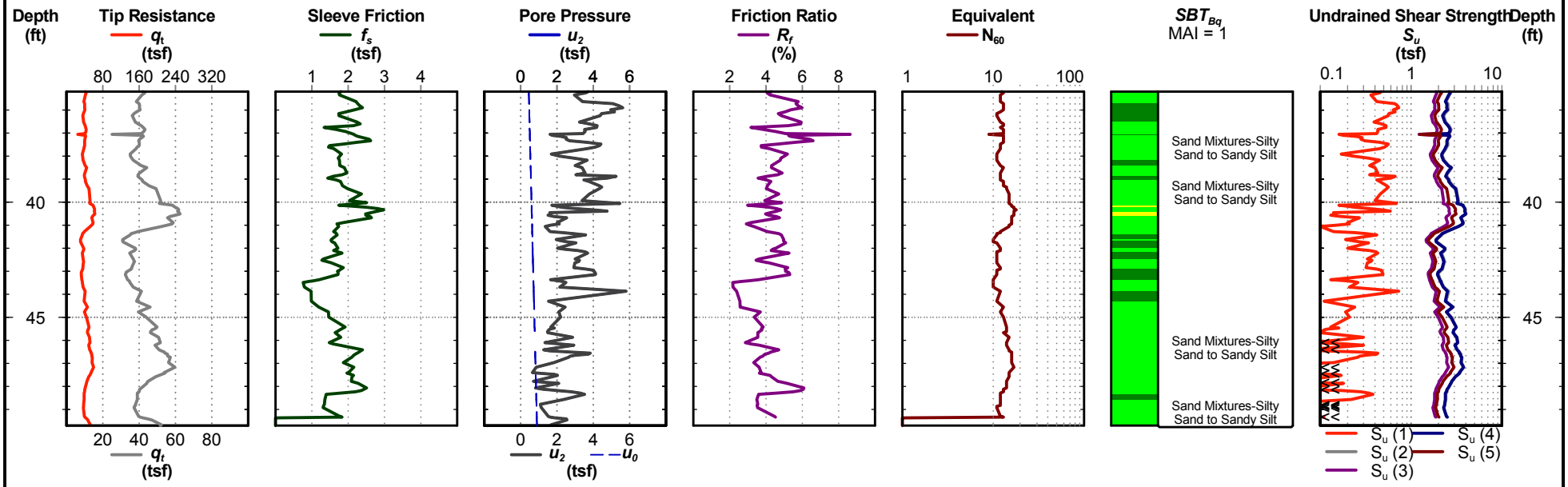
S&ME

Belews Creek Steam Station
Belews Creek, NC
S&ME Project No: 1356-09-029-4

Cone Penetration Test AD-2

Date: Mar. 29, 2010
Estimated Water Depth: 21 ft
Rig/Operator:

Total Depth: 49.7 ft
Termination Criteria:
Cone Size: 1.75



CPT REPORT - STANDARD SBT BQ GINT CPT LOGS.GPJ S&ME.GDT 4/8/10

Electronic Filename: f29m1002c.ecp

AD-2

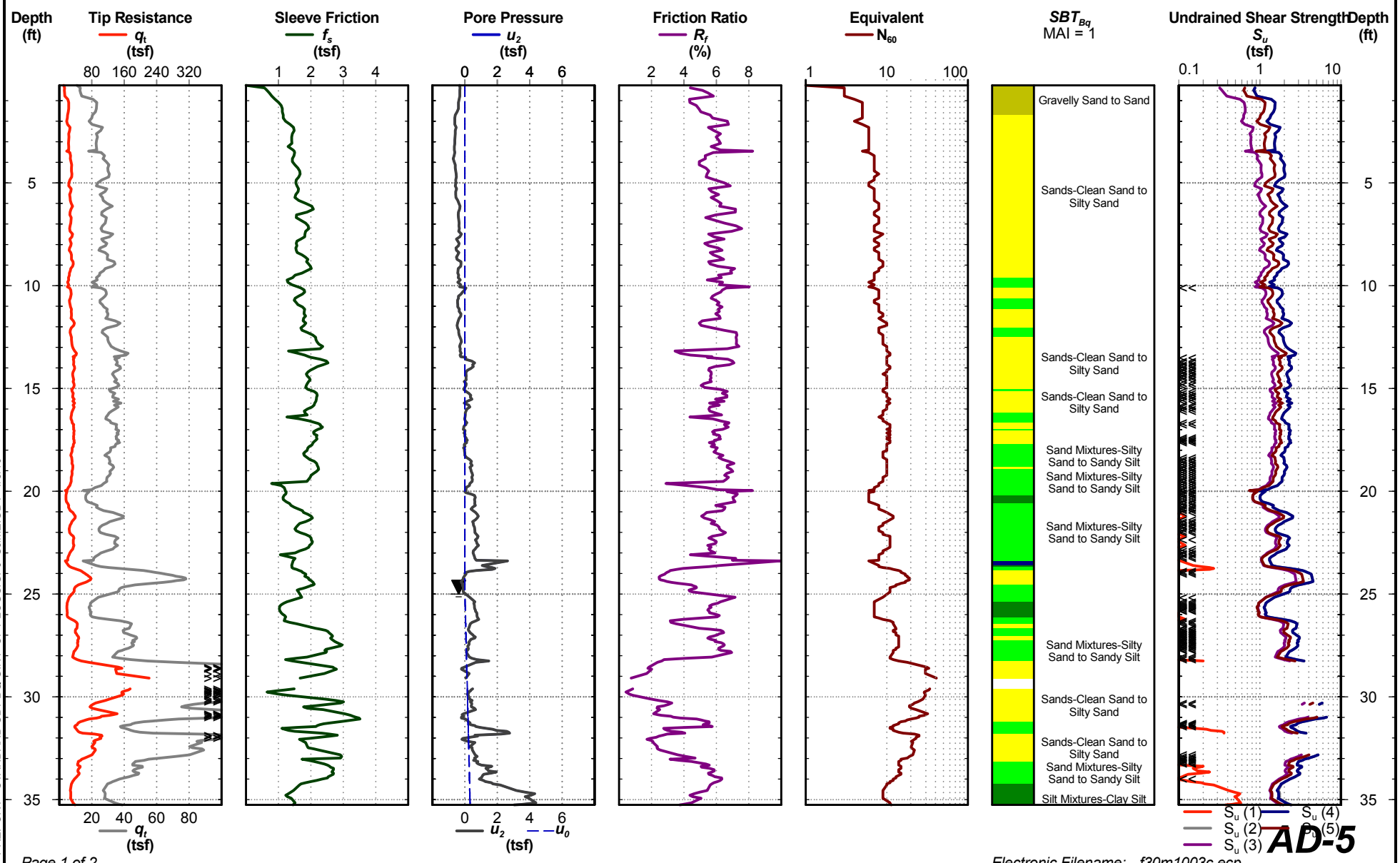
S&ME

Belews Creek Steam Station
Belews Creek, NC
S&ME Project No: 1356-09-029-4

Cone Penetration Test AD-5

Date: Mar. 30, 2010
Estimated Water Depth: 25 ft
Rig/Operator:

Total Depth: 43.3 ft
Termination Criteria:
Cone Size: 1.75



CPT REPORT - STANDARD SBT BQ GINT CPT LOGS.GPJ S&ME.GDT 4/8/10

Electronic Filename: f30m1003c.ecp

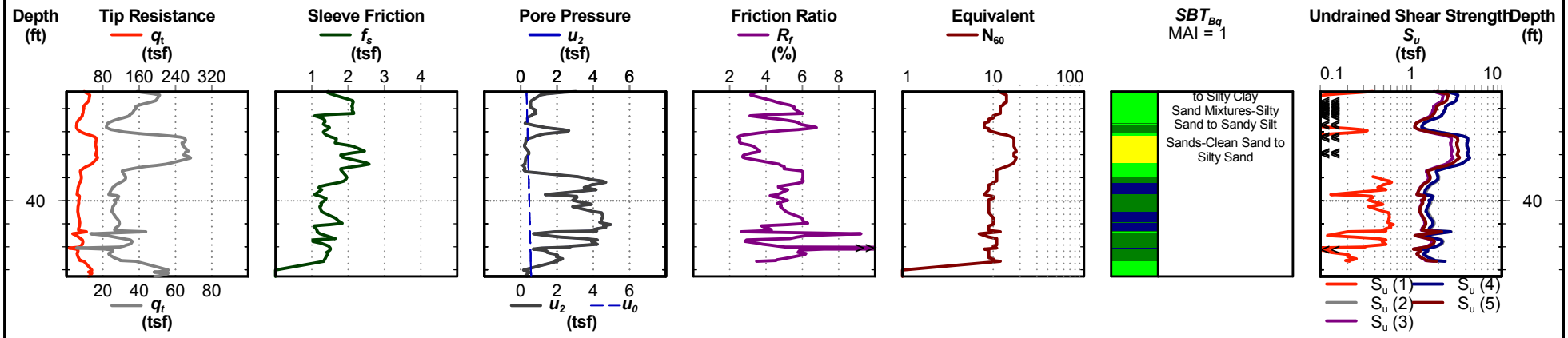
S&ME

Belews Creek Steam Station
Belews Creek, NC
S&ME Project No: 1356-09-029-4

Cone Penetration Test *AD-5*

Date: Mar. 30, 2010
Estimated Water Depth: 25 ft
Rig/Operator:

Total Depth: 43.3 ft
Termination Criteria:
Cone Size: 1.75



CPT REPORT - STANDARD SBT BQ GINT CPT LOGS.GPJ S&ME.GDT 4/8/10

Electronic Filename: f30m1003c.ecp

AD-5

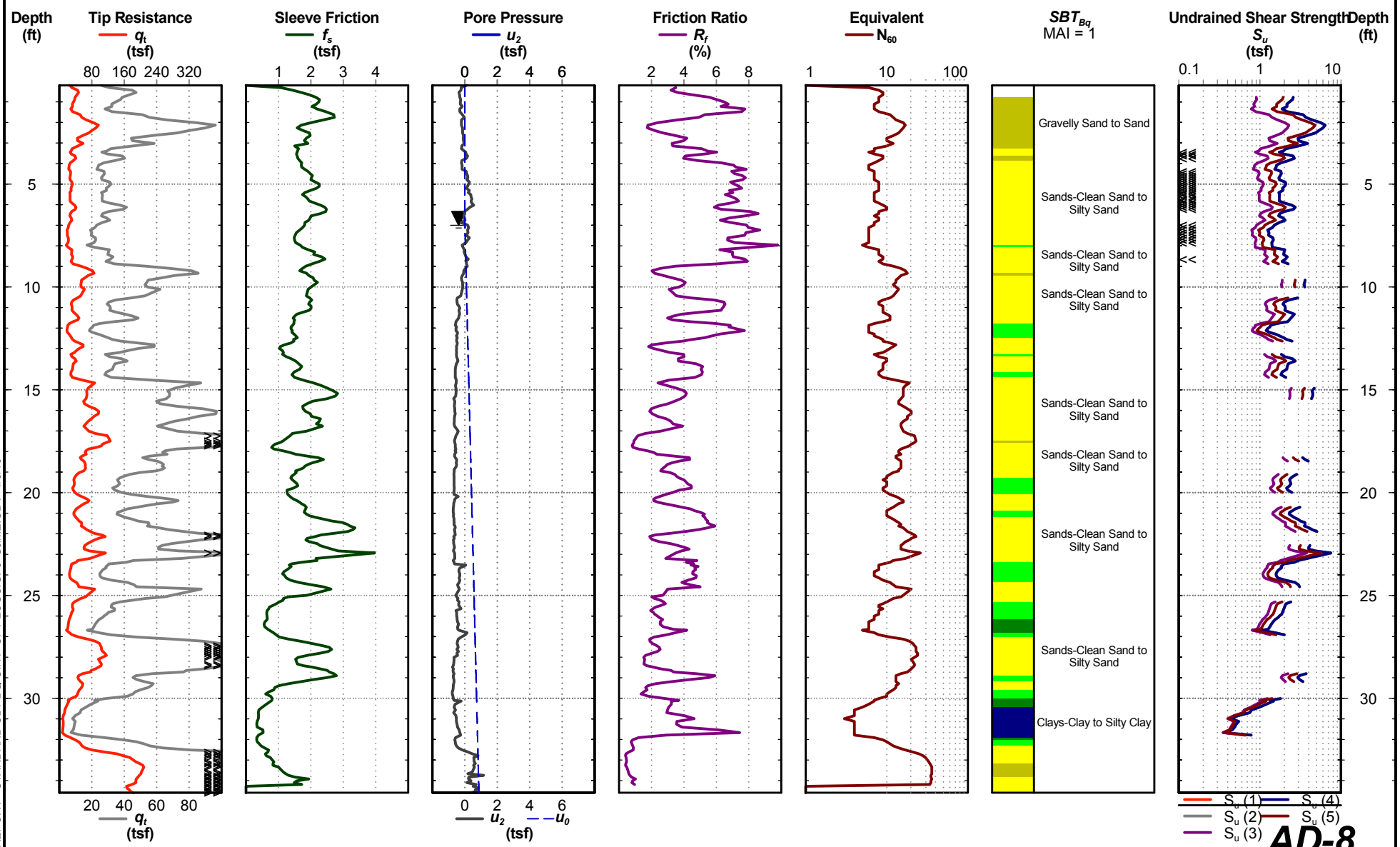
S&ME

Belews Creek Steam Station
Belews Creek, NC
S&ME Project No: 1356-09-029-4

Cone Penetration Test AD-8

Date: Mar. 29, 2010
Estimated Water Depth: 7 ft
Rig/Operator:

Total Depth: 34.6 ft
Termination Criteria:
Cone Size: 1.75



Electronic Filename: f29m1003c.ecp

CPT REPORT - STANDARD SBT BQ GINT CPT LOGS.GPJ S&ME.GDT 4/8/10

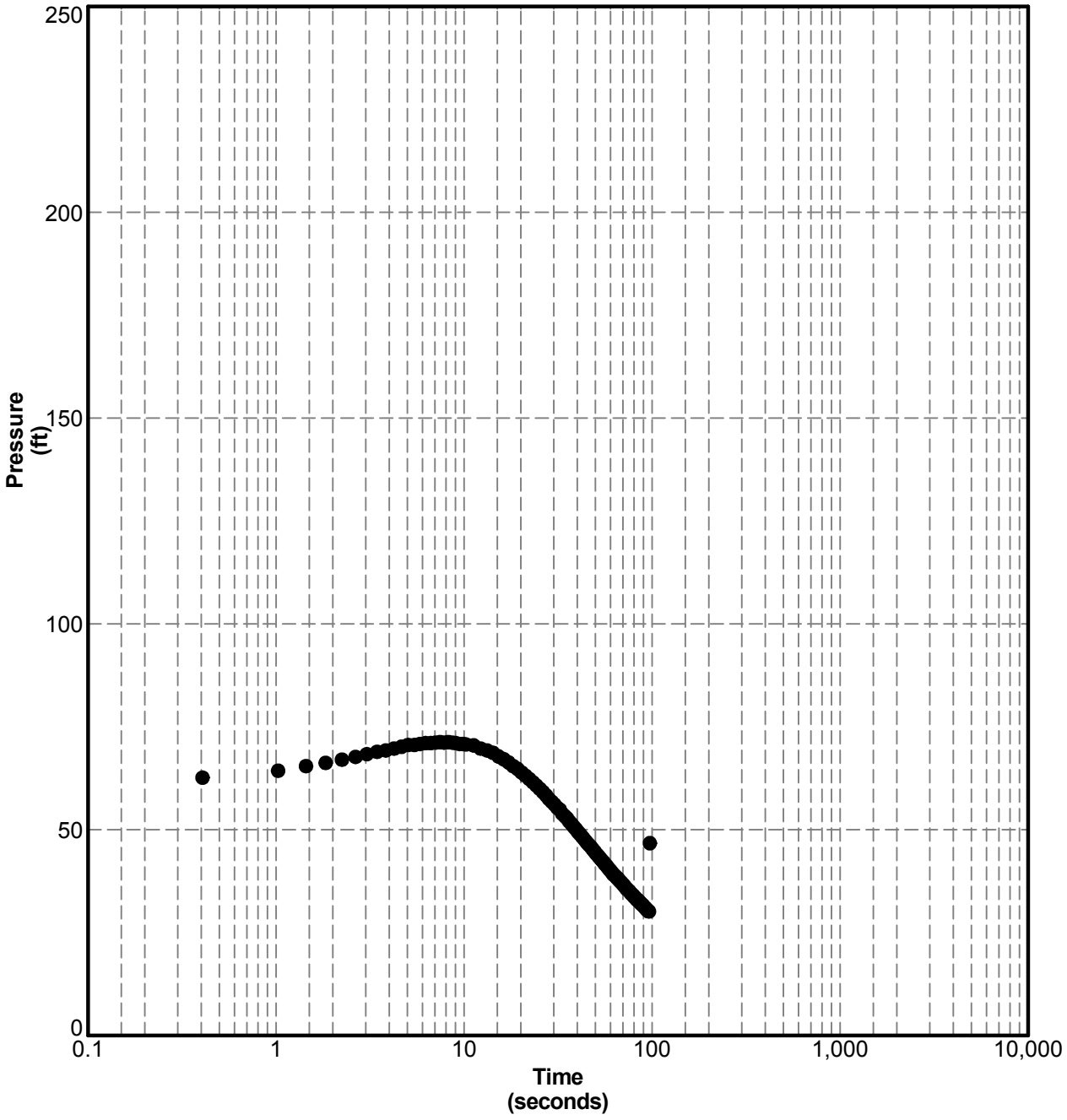
S&ME

Belews Creek Steam Station
Belews Creek, NC
S&ME Project No: 1356-09-029-4

Pore Pressure Dissipation

Date: Mar. 29, 2010
Estimated Water Depth: 21 ft
Rig/Operator:

Depth: 20.7 ft
Termination Criteria:
Cone Size: 1.75



CPT - PORE PRESSURE DISSIPATION CPT LOGS.GPJ S&ME.GDT 4/8/10

Electronic Filename: f29m1002d.21

AD-2

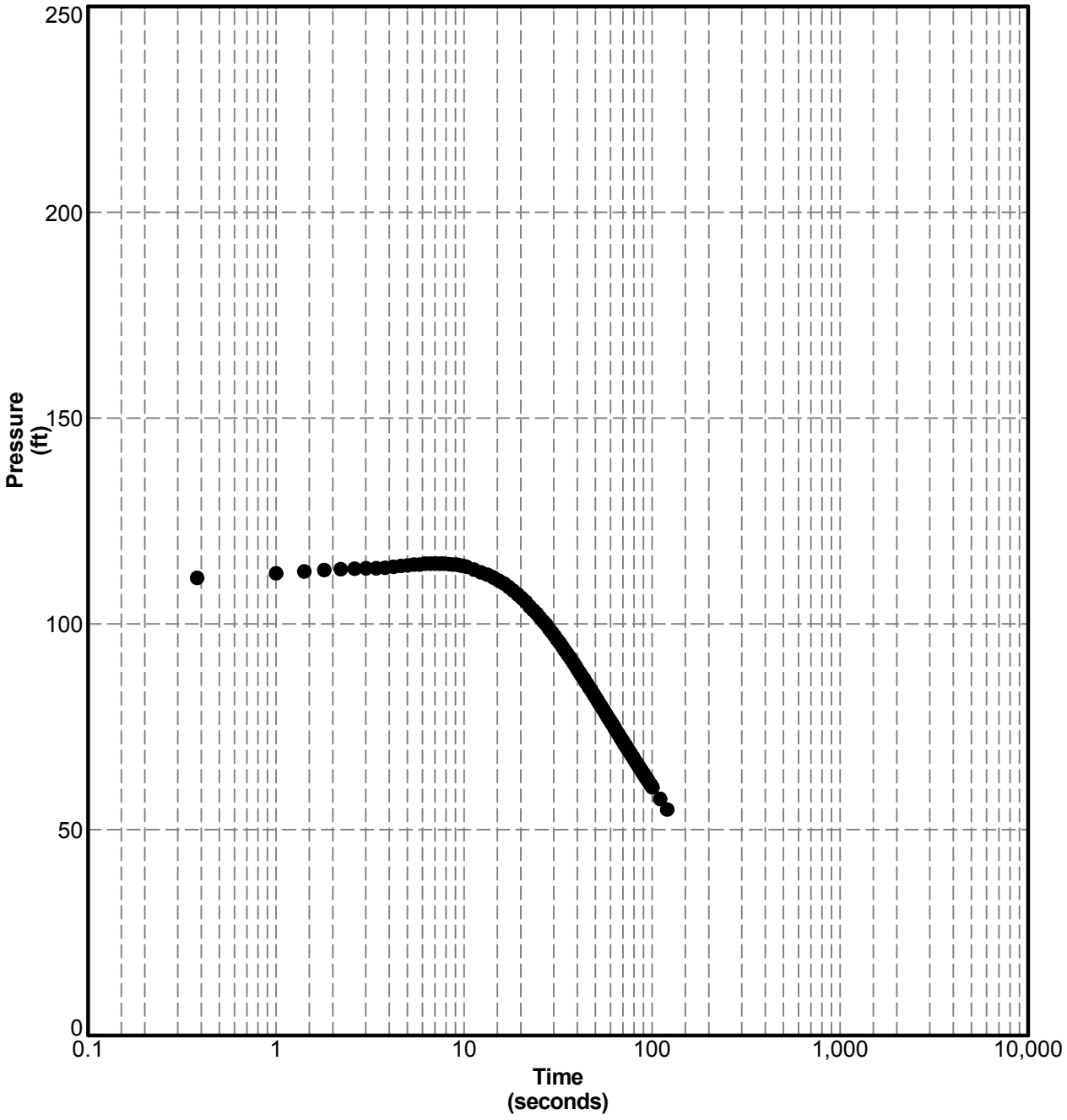
S&ME

Belews Creek Steam Station
Belews Creek, NC
S&ME Project No: 1356-09-029-4

Pore Pressure Dissipation

Date: Mar. 29, 2010
Estimated Water Depth: 21 ft
Rig/Operator:

Depth: 30.2 ft
Termination Criteria:
Cone Size: 1.75



CPT - PORE PRESSURE DISSIPATION CPT LOGS.GPJ S&ME.GDT 4/8/10

Electronic Filename: f29m1002d.30

AD-2

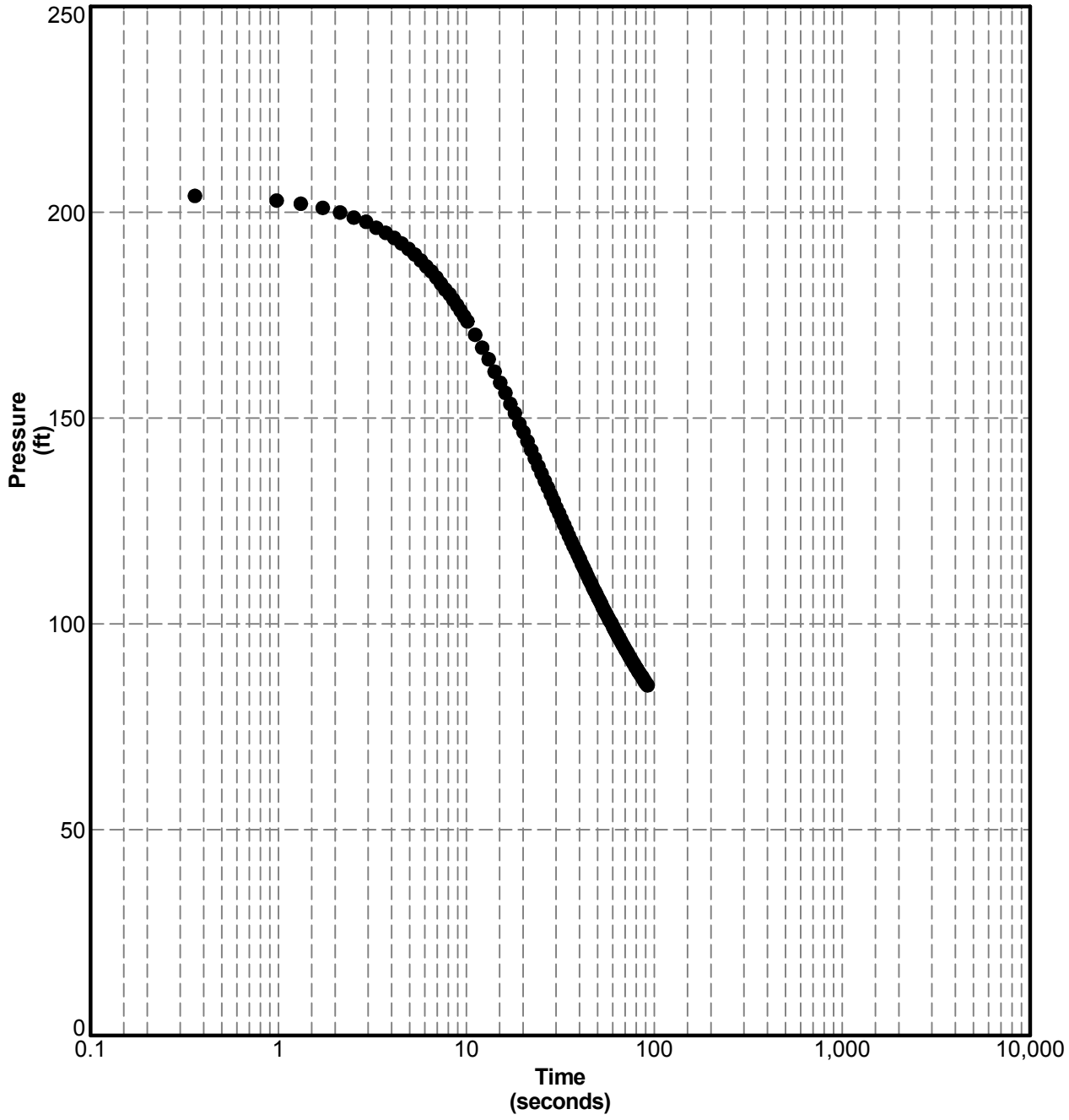
S&ME

Belews Creek Steam Station
Belews Creek, NC
S&ME Project No: 1356-09-029-4

Pore Pressure Dissipation

Date: Mar. 29, 2010
Estimated Water Depth: 21 ft
Rig/Operator:

Depth: 40.1 ft
Termination Criteria:
Cone Size: 1.75



CPT - PORE PRESSURE DISSIPATION CPT LOGS.GPJ S&ME.GDT 4/8/10

Electronic Filename: f29m1002d.40

AD-2

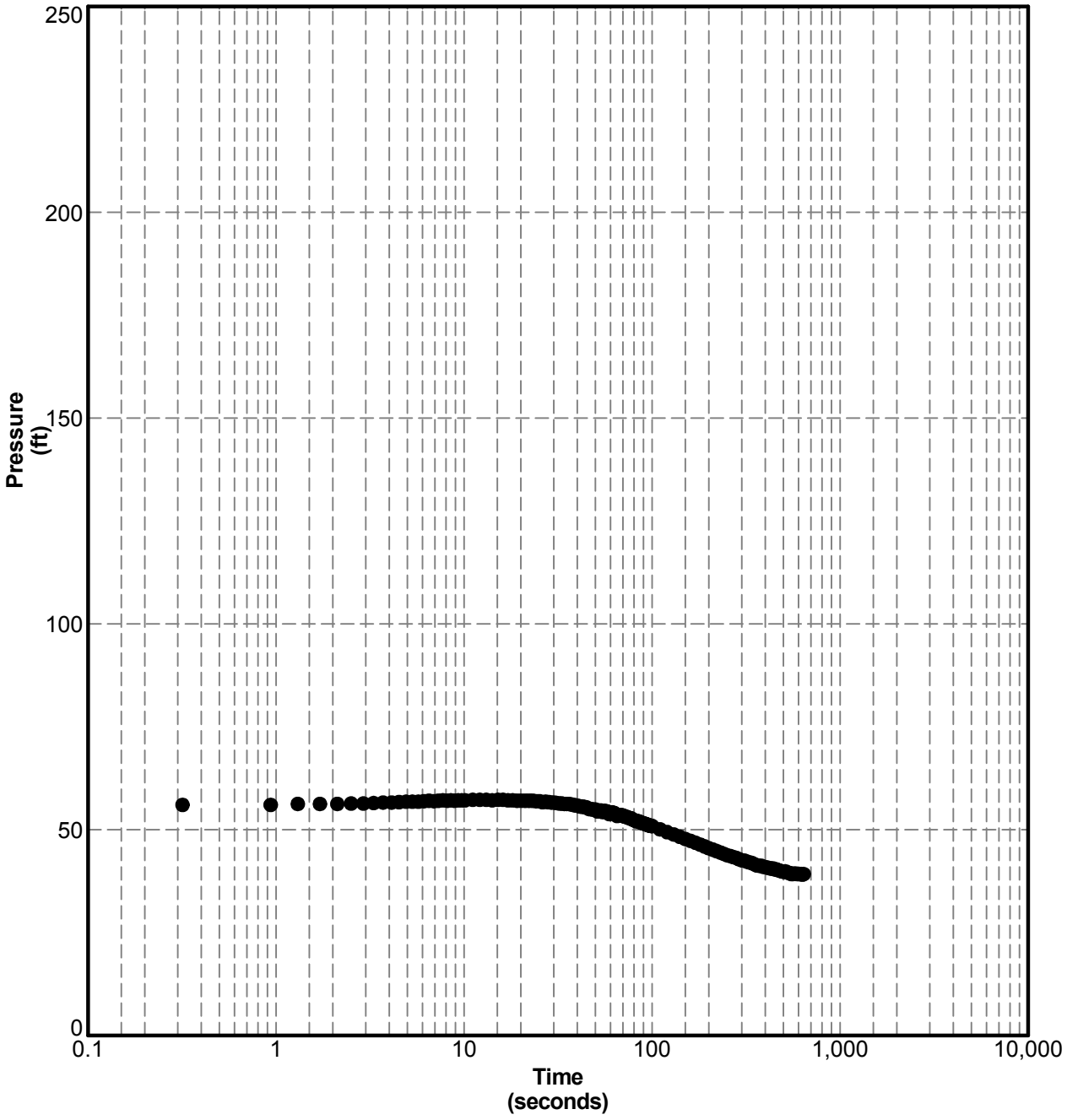
S&ME

Belews Creek Steam Station
Belews Creek, NC
S&ME Project No: 1356-09-029-4

Pore Pressure Dissipation

Date: Mar. 29, 2010
Estimated Water Depth: 21 ft
Rig/Operator:

Depth: 49.7 ft
Termination Criteria:
Cone Size: 1.75



CPT - PORE PRESSURE DISSIPATION CPT LOGS.GPJ S&ME.GDT 4/8/10

Electronic Filename: f29m1002d.50

AD-2

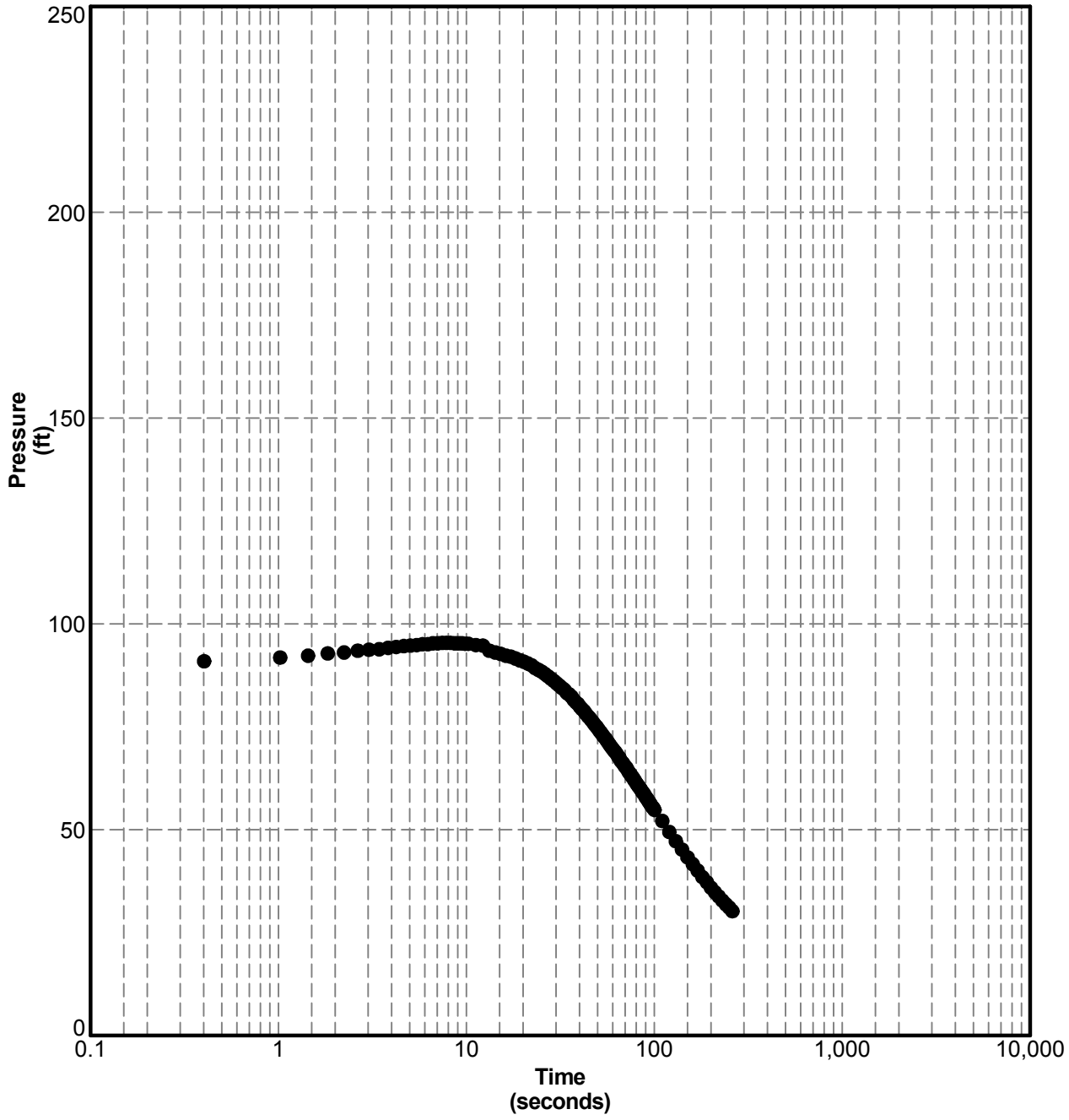
S&ME

Belews Creek Steam Station
Belews Creek, NC
S&ME Project No: 1356-09-029-4

Pore Pressure Dissipation

Date: Mar. 30, 2010
Estimated Water Depth: 25 ft
Rig/Operator:

Depth: 23.4 ft
Termination Criteria:
Cone Size: 1.75



CPT - PORE PRESSURE DISSIPATION CPT LOGS.GPJ S&ME.GDT 4/8/10

Electronic Filename: f30m1003d.23

AD-5

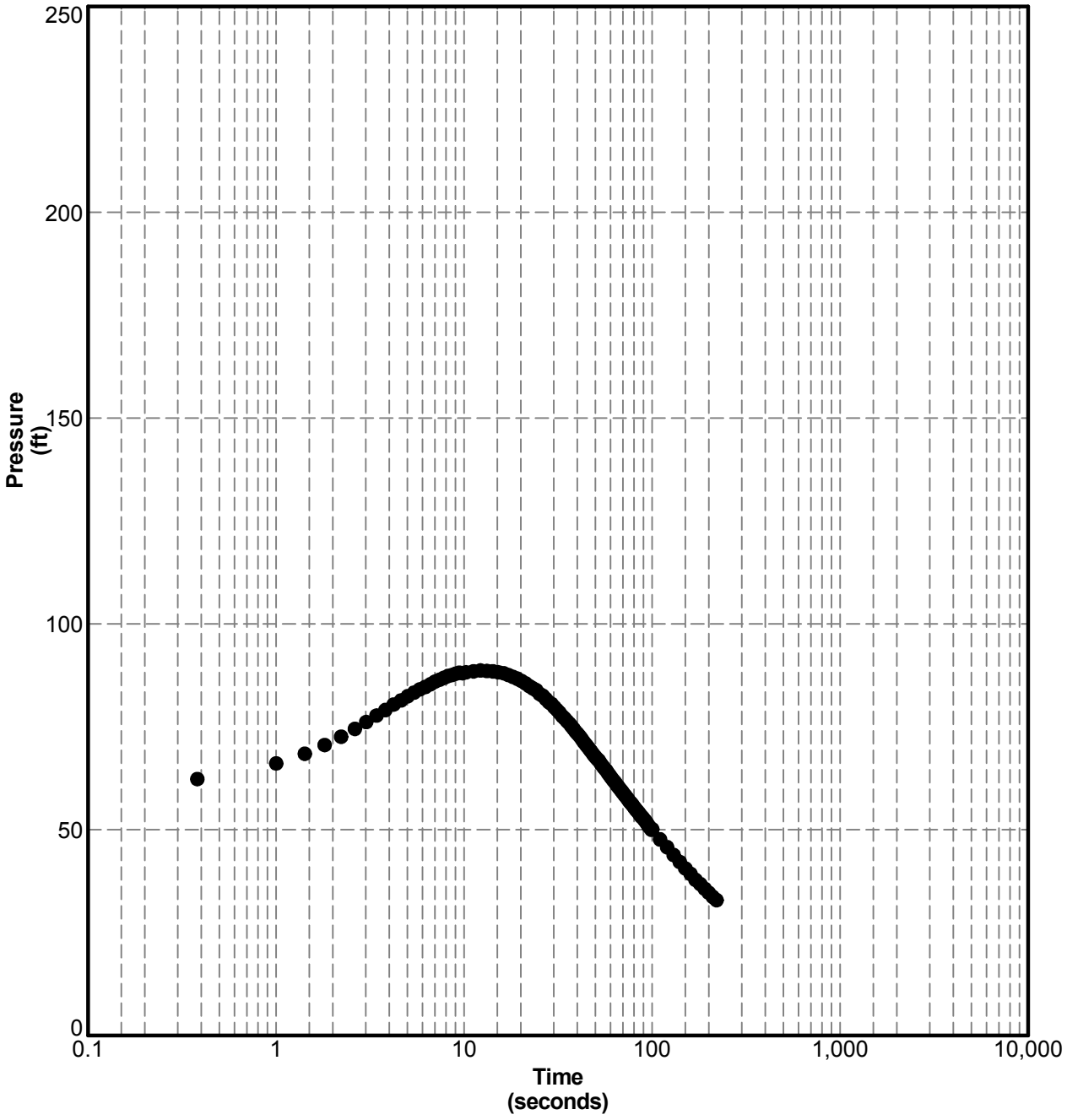
S&ME

Belews Creek Steam Station
Belews Creek, NC
S&ME Project No: 1356-09-029-4

Pore Pressure Dissipation

Date: Mar. 30, 2010
Estimated Water Depth: 25 ft
Rig/Operator:

Depth: 31.8 ft
Termination Criteria:
Cone Size: 1.75



CPT - PORE PRESSURE DISSIPATION CPT LOGS.GPJ S&ME.GDT 4/8/10

Electronic Filename: f30m1003d.32

AD-5

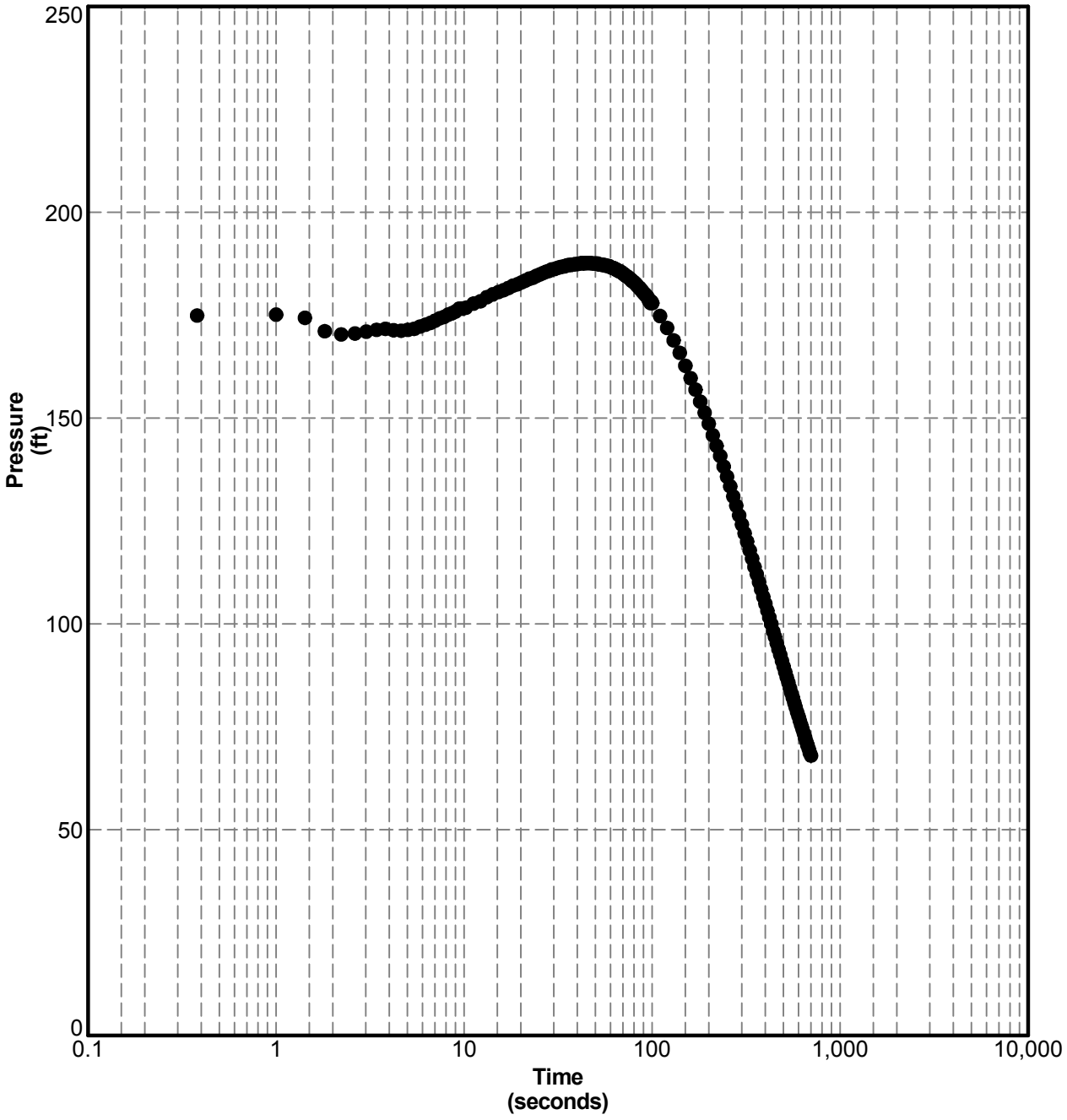
S&ME

Belews Creek Steam Station
Belews Creek, NC
S&ME Project No: 1356-09-029-4

Pore Pressure Dissipation

Date: Mar. 30, 2010
Estimated Water Depth: 25 ft
Rig/Operator:

Depth: 39.7 ft
Termination Criteria:
Cone Size: 1.75



CPT - PORE PRESSURE DISSIPATION CPT LOGS.GPJ S&ME.GDT 4/8/10

Electronic Filename: f30m1003d.40

AD-5

Shear Wave Velocity Calculations

Belews Creek Steam Station
Belews Creek, NC

Sounding ID: **AD-2**

Project Number: **1356-09-029 ph4**

Geophone Offset: 1.85 Feet

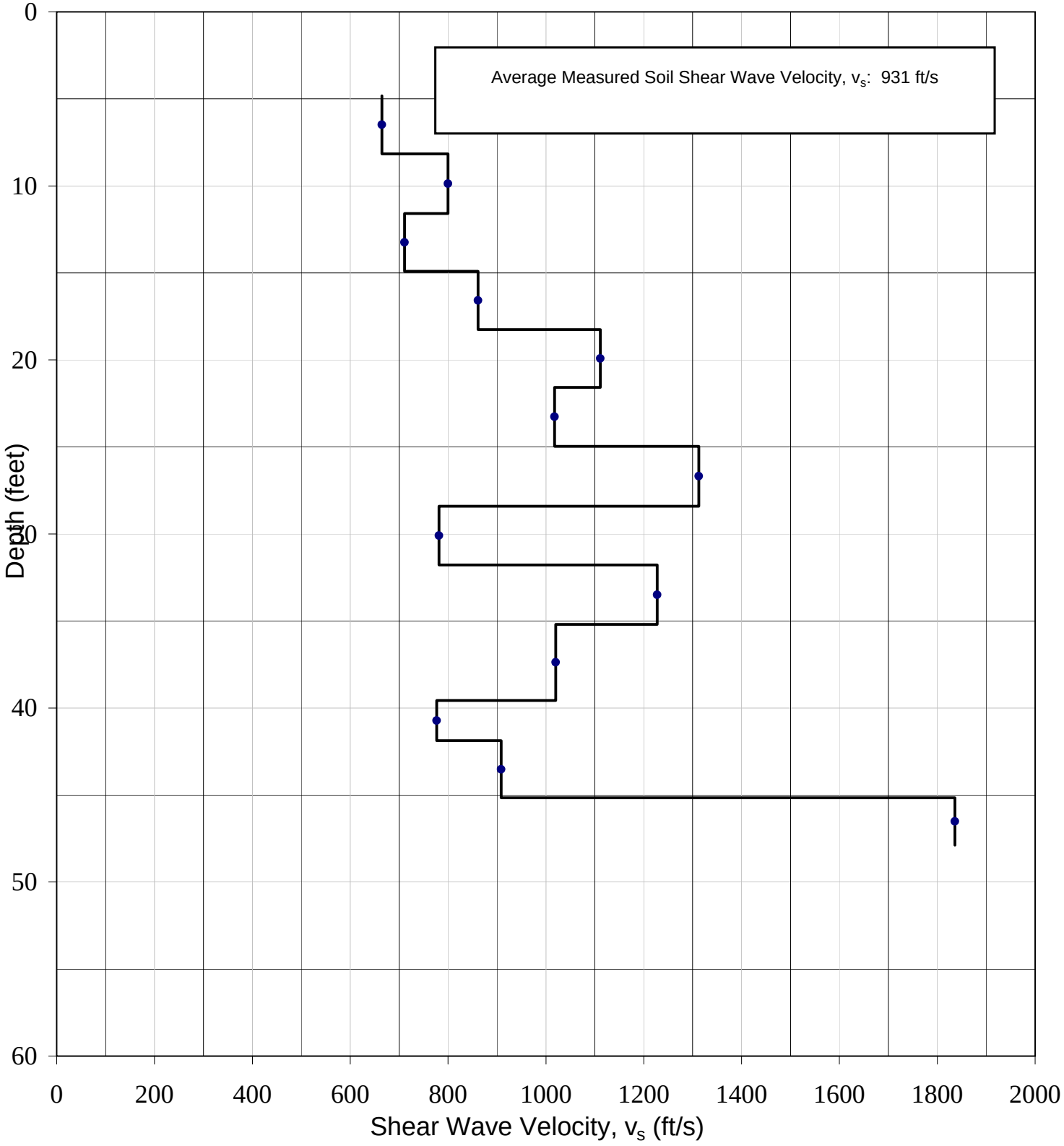
Source Offset: 8.00 Feet

Date: 3/29/10

Rig: ATV

Cone Tip Depth (feet)	Geophone Depth (feet)	Waveform Ray Path (feet)	Incremental Distance (feet)	Characteristic Arrival Time (seconds)	Incremental Time Interval (seconds)	Interval Velocity (ft/s)	Interval Depth (feet)	Interval Travel Time (seconds)
6.67	4.82	9.34	9.34	0.0228				
10.01	8.16	11.43	2.09	0.0259	0.0031	664.8	6.49	0.00502
13.44	11.59	14.08	2.66	0.0292	0.0033	799.8	9.88	0.00429
16.76	14.91	16.92	2.84	0.0332	0.0040	711.2	13.25	0.00467
20.10	18.25	19.93	3.01	0.0367	0.0035	861.3	16.58	0.00388
23.43	21.58	23.02	3.09	0.0395	0.0028	1111.0	19.92	0.00300
26.81	24.96	26.21	3.20	0.0426	0.0031	1017.7	23.27	0.00332
30.25	28.40	29.51	3.29	0.0451	0.0025	1312.6	26.68	0.00262
33.63	31.78	32.77	3.27	0.0493	0.0042	781.4	30.09	0.00433
37.05	35.20	36.10	3.33	0.0520	0.0027	1227.4	33.49	0.00279
41.41	39.56	40.36	4.26	0.0562	0.0042	1019.9	37.38	0.00427
43.73	41.88	42.64	2.28	0.0591	0.0029	776.9	40.72	0.00299
47.01	45.16	45.86	3.23	0.0627	0.0036	908.7	43.52	0.00361
49.73	47.88	48.54	2.68	0.0642	0.0015	1836.0	46.52	0.00148

Average Measured Soil Shear Wave Velocity, v_s (ft/s): 931



Shear Wave Velocity Profile	S&ME	Sounding ID:	AD-2	Drawn By:
Belews Creek Steam Station		Date:	3/29/10	Approved By:
Belews Creek, NC		Project Number:	1356-09-029 ph4	Figure:

Shear Wave Velocity Calculations

Belews Creek Steam Station
Belews Creek, NC

Sounding ID: **AD-5**

Project Number: **1356-09-029 ph4**

Geophone Offset: 1.85 Feet

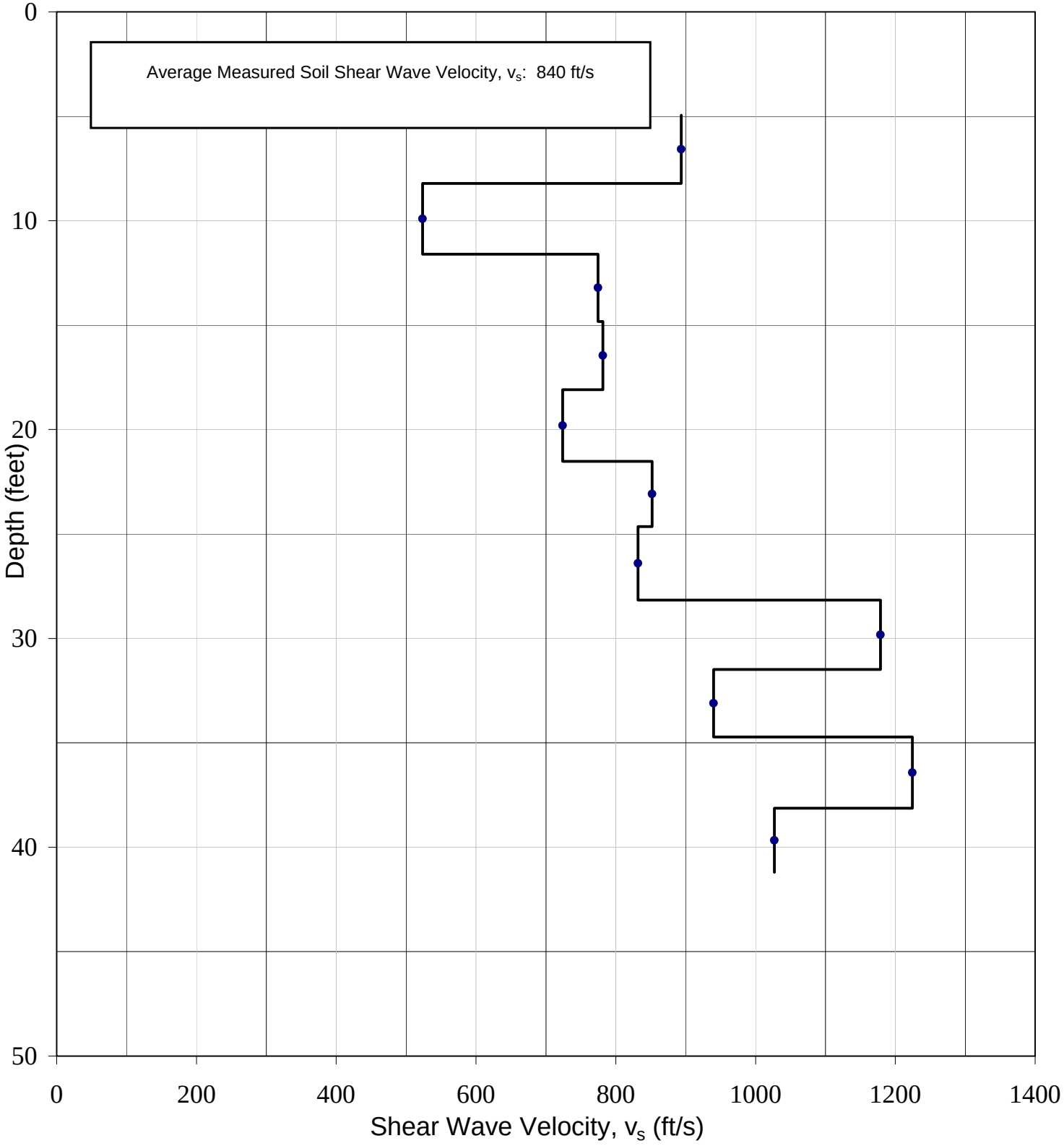
Source Offset: 8.00 Feet

Date: 3/30/10

Rig: ATV

Cone Tip Depth (feet)	Geophone Depth (feet)	Waveform Ray Path (feet)	Incremental Distance (feet)	Characteristic Arrival Time (seconds)	Incremental Time Interval (seconds)	Interval Velocity (ft/s)	Interval Depth (feet)	Interval Travel Time (seconds)
6.80	4.95	9.41	9.41	0.0318				
10.06	8.21	11.46	2.06	0.0341	0.0023	893.7	6.58	0.00365
13.45	11.60	14.09	2.63	0.0391	0.0050	523.5	9.91	0.00648
16.67	14.82	16.84	2.75	0.0426	0.0036	774.7	13.21	0.00416
19.94	18.09	19.78	2.94	0.0464	0.0038	781.5	16.46	0.00418
23.37	21.52	22.96	3.18	0.0508	0.0044	724.1	19.81	0.00474
26.50	24.65	25.92	2.96	0.0543	0.0035	852.1	23.09	0.00367
30.02	28.17	29.28	3.37	0.0583	0.0041	831.7	26.41	0.00423
33.34	31.49	32.49	3.21	0.0610	0.0027	1178.8	29.83	0.00282
36.57	34.72	35.63	3.14	0.0644	0.0033	939.9	33.11	0.00344
39.98	38.13	38.96	3.33	0.0671	0.0027	1224.4	36.43	0.00278
43.05	41.20	41.97	3.01	0.0700	0.0029	1027.1	39.67	0.00299

Average Measured Soil Shear Wave Velocity, v_s (ft/s): 840



Shear Wave Velocity Profile	S&ME	Sounding ID:	AD-5	Drawn By:
Belews Creek Steam Station		Date:	3/30/10	Approved By:
Belews Creek, NC		Project Number:	1356-09-029 ph4	Figure:

Job No.	1356-09-029
Sheet No.	of
Date	September 12, 2010
Job Name	Belews Creek Dams
Computed By	JSR
Subject	Estimation of Hydraulic Conductivity Based on Grain Size
Checked By	

Formula

Harleman et al (1963)

$$k = (6.54E\text{-}4)d^2$$

Where: k permeability (cm2)

d_{10} characteristic particle diameter (cm)

Conversion from permeability to hydraulic conductivity

$$K = k\,(pg/\mu)$$

Where:

- K Hydraulic conductivity (cm/sec)
- k permeability (cm^2)
- p fluid density 1.0 g/cm^3
- g gravitational constant 980 cm/s^2
- μ dynamic viscosity 0.01124 g/s*cm

Calculations

Sample Number: AD-10 **Geologic Unit:** Blanket Drain

Sample Depth: 23.5 -25 ft

Soil Classification: Tan Brown Micaceous Silty Fine to Coarse SAND (SM)

d10 (from grain size analysis): 0.0016 cm

constant = 6.54E-04

d^2 = 0.00000256 cm

p = 1 g/cm^3

g = 980 cm/s^2

μ = 0.01124 g/s*cm

k = $(6.54E\text{-}04)d^2$

k = 1.67E-09 cm^2

K = k (pg/μ)

K = 1.46E-04 cm/sec

Job No. 1356-09-029
Sheet No. of
Date September 12, 2010

Job Name Belews Creek Dams
Computed By JSR
Subject Estimation of Hydraulic Conductivity Based on Grain Size
Checked By

Sample Number: AD-9 **Geologic Unit:** Residuum
Sample Depth: 33.5 - 35 ft
Soil Classification: Tan Fine to Coarse SAND (SP-SM) with Silt
d10 (from grain size analysis): 0.0055 cm

constant = 6.54E-04 k = $(6.54E-04)d^2$
d^2 = 0.00003025 cm **k = 1.98E-08 cm^2**

p = 1 g/cm^3
g = 980 cm/s^2 K = k (pg/μ)
μ = 0.01124 g/s*cm **K = 1.72E-03 cm/sec**

Sample Number: AD-9 **Geologic Unit:** Residuum
Sample Depth: 35 - 36.5 ft
Soil Classification: Tan Micaceous Silty Fine to Coarse SAND (SM)
d10 (from grain size analysis): 0.002 cm

constant = 6.54E-04 k = $(6.54E-04)d^2$
d^2 = 0.000004 cm **k = 2.62E-09 cm^2**

p = 1 g/cm^3
g = 980 cm/s^2 K = k (pg/μ)
μ = 0.01124 g/s*cm **K = 2.28E-04 cm/sec**

Sample Number: AD-9 **Geologic Unit:** PWR
Sample Depth: 36.5 - 38 ft
Soil Classification: Orange Tan Silver Silty Fine to Coarse SAND (SM)
d10 (from grain size analysis): 0.002 cm

constant = 6.54E-04 k = $(6.54E-04)d^2$
d^2 = 0.000004 cm **k = 2.62E-09 cm^2**

p = 1 g/cm^3
g = 980 cm/s^2 K = k (pg/μ)
μ = 0.01124 g/s*cm **K = 2.28E-04 cm/sec**

Job No. 1356-09-029
Sheet No. of
Date September 12, 2010

Job Name Belews Creek Dams
Computed By JSR
Subject Estimation of Hydraulic Conductivity Based on Grain Size
Checked By

Sample Number: AD-7 **Geologic Unit:** Blanket Drain
Sample Depth: 13 - 14.5 ft
Soil Classification: Tan Silty Coarse to Fine Sand (SM)
d10 (from grain size analysis): 0.0035 cm

constant = 6.54E-04 k = $(6.54E-04)d^2$
d^2 = 0.00001225 cm **k = 8.01E-09 cm^2**

p = 1 g/cm^3
g = 980 cm/s^2 K = k (pg/μ)
μ = 0.01124 g/s*cm **K = 6.99E-04 cm/sec**

Sample Number: AD-4 **Geologic Unit:** Blanket Drain
Sample Depth: 15-16.5
Soil Classification: Brown Micaceous Coarse to Fine Sand (SM)
d10 (from grain size analysis): 0.00055 cm

constant = 6.54E-04 k = $(6.54E-04)d^2$
d^2 = 3.025E-07 cm **k = 1.98E-10 cm^2**

p = 1 g/cm^3
g = 980 cm/s^2 K = k (pg/μ)
μ = 0.01124 g/s*cm **K = 1.72E-05 cm/sec**

Sample Number: MD-9 **Geologic Unit:** Blanket Drain
Sample Depth: 58.5-60
Soil Classification: Tan Poorly Graded Sand with Silt (SP-SM)
d10 (from grain size analysis): 0.011 cm

constant = 6.54E-04 k = $(6.54E-04)d^2$
d^2 = 0.000121 cm **k = 7.91E-08 cm^2**

p = 1 g/cm^3
g = 980 cm/s^2 K = k (pg/μ)
μ = 0.01124 g/s*cm **K = 6.90E-03 cm/sec**

APPENDIX II

LABORATORY TEST DATA

Table L1 – Laboratory Test Data Summary
Table L1A – Summary of Laboratory Triaxial Test Data
Table L2 – Summary of Historic Duke Energy 1982 and 1983 Laboratory Test Data
Laboratory Test Data Sheets

Table L1 - Summary of Laboratory Test Data
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Boring No.	Sample Depth (ft)		Sample Type	Lithologic Unit	USCS Classification	Percent Passing No. 200	Atterberg Limits		Specific Gravity	Average Void Ratio	Average Natural Moisture Content	Average Dry Unit Weight	Average Moist Unit Weight	Vertical Hydraulic Conductivity
	From	To					LL	PI			(%)	(pcf)	(pcf)	k (cm/sec)
AD-1	16	18	UD	Residuum	ML	62.1	46	15		0.58	19.4	104.8	125.1	5.1×10^{-7}
AD-3	36	38	UD	Fill	ML	56.2	44	13		0.63	20.1	99.7	119.7	5.4×10^{-7}
AD-4	1	2.5	SS	Fill							24.2			
AD-4	3.5	5	SS	Fill							30.5			
AD-4	6	7.5	SS	Fill							27.0			
AD-4	7.5	9	SS	Fill							28.4			
AD-4	9	10.5	SS	Fill							27.3			
AD-4	10.5	12	SS	Fill							22.0			
AD-4	12	13.5	SS	Fill							23.1			
AD-4	13.5	15	SS	Fill							32.6			
AD-4	15	16.5	SS	Drain Blanket		27.7	NP	NP			5.3			
AD-4	16.5	18	SS	Fill							16.4			
AD-4	23.5	25	SS	Residuum							12.7			
AD-4	30	32	UD	Residuum	SM	34.3	32	5		0.57	17.1	105.6	123.7	
AD-6	1	2.5	SS	Fill							20.9			
AD-6	3.5	5	SS	Fill							20.5			
AD-6	6	7.5	SS	Fill							20.2			
AD-6	8.5	10	SS	Fill							21.4			
AD-6	13.5	15	SS	Fill							23.9			
AD-6	18.5	20	SS	Fill							29.0			
AD-6	23.5	25	SS	Fill							14.5			
AD-6	28.5	30	SS	Fill							11.4			
AD-6	30	32	UD	Fill	MH	65.2	57	25		0.72	20.4	96.3	115.9	

Table L1 - Summary of Laboratory Test Data
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Boring No.	Sample Depth (ft)		Sample Type	Lithologic Unit	USCS Classification	Percent Passing No. 200	Atterberg Limits		Specific Gravity	Average Void Ratio	Average Natural Moisture Content	Average Dry Unit Weight	Average Moist Unit Weight	Vertical Hydraulic Conductivity
	From	To					LL	PI			(%)	(pcf)	(pcf)	k (cm/sec)
AD-6	33.5	35	SS	Fill							28.4			
AD-6	38.5	40	SS	Fill							29.9			
AD-6	43.5	45	SS	Fill							14.5			
AD-6	48.5	50	SS	Residuum							26.9			
AD-6	53.5	55	SS	Residuum							18.4			
AD-6	58.5	60	SS	Residuum							12.1			
AD-7	1	2.5	SS	Fill							22.7			
AD-7	3.5	5	SS	Fill							26.2			
AD-7	6	7.5	SS	Fill							23.8			
AD-7	8.5	10	SS	Fill							22.0			
AD-7	10	11.5	SS	Fill							22.0			
AD-7	11.5	13	SS	Fill							13.7			
AD-7	13	14.5	SS	Drain Blanket		12.7					16.5			
AD-7	14.5	16	SS	Fill							20.5			
AD-7	16	17.5	SS	Residuum							13.9			
AD-9	1	2.5	SS	Fill							19.5			
AD-9	3.5	5	SS	Fill							21.7			
AD-9	8.5	10	SS	Fill							16.9			
AD-9	13.5	15	SS	Fill							18.3			
AD-9	16	18	UD	Fill	SM	44.1	36	10		0.54	17.7	107.3	126.3	3.5×10^{-5}
AD-9	18.5	20	SS	Fill							18.9			
AD-9	20	21.5	SS	Fill							23.3			
AD-9	21.5	23	SS	Fill							23.9			

Table L1 - Summary of Laboratory Test Data
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Boring No.	Sample Depth (ft)		Sample Type	Lithologic Unit	USCS Classification	Percent Passing No. 200	Atterberg Limits		Specific Gravity	Average Void Ratio	Average Natural Moisture Content	Average Dry Unit Weight	Average Moist Unit Weight	Vertical Hydraulic Conductivity
	From	To					LL	PI			(%)	(pcf)	(pcf)	k (cm/sec)
AD-9	23	24.5	SS	Drain Blanket							18.7			
AD-9	24.5	26	SS	Residuum							19.7			
AD-9	28.5	30	SS	Residuum							17.1			
AD-9	33.5	35	SS	Residuum		11.4					15.2			
AD-9	35	36.5	SS	Residuum		18.4	NP	NP			16.4			
AD-9	36.5	38	SS	Residuum		20.0					11.3			
AD-10	1	2.5	SS	Fill							27.6			
AD-10	3.5	5	SS	Fill							24.2			
AD-10	6	7.5	SS	Fill							27.5			
AD-10	8	9.5	SS	Fill							21.9			
AD-10	9.5	11	SS	Fill							13.7			
AD-10	11	12.5	SS	Fill							19.1			
AD-10	13.5	15	SS	Fill							23.5			
AD-10	18.5	20	SS	Fill							28.3			
AD-10	23.5	25	SS	Drain Blanket		21.2	NP	NP			16.4			

Notes:
SS = Split Spoon Sample (ASTM D-1586)
UD = Undisturbed Sample (ASTM D-1587)
BAG = Bulk Sample
NP = Non Plastic

Table L1A - Summary of Laboratory Triaxial Test Data
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Dam	Boring	Depth	Residual or Fill	Sample No.	Total Consolidation Stress σ_3 (ksf)	Total Normal Stress σ_1 (ksf)	Effective Consolidation Stress σ'_3 (ksf)	Effective Normal Stress σ'_1 (ksf)
ASH DIKE	AD-1	16-18	residual	1	0.72	8.37	0.45	3.7
	AD-1	16-18	residual	2	2.16	12.79	1.41	7.77
	AD-1	16-18	residual	3	1.44	12.19	1.63	8.04
	AD-3	36-38	fill	1	2.88	9.12	1.2	4.7
	AD-3	36-38	fill	2	7.2	14.32	3.3	8.9
	AD-3	36-38	fill	3	4.32	14.1	3	11
	AD-4	30-32	residual	1	1.44	5.56	0.55	2.9
	AD-4	30-32	residual	2	4.32	9.85	1.57	6.07
	AD-6	30-32	fill	1	2.16	6.59	0.69	3.61
	AD-6	30-32	fill	2	3.6	9.67	1.57	6.31
	AD-6	30-32	fill	3	5.76	11.37	2.4	7.5
	AD-9	16-18	fill	1	1.01	4.66	0.53	2.33
	AD-9	16-18	fill	2	3.02	8.16	1.31	5.07
MAIN DAM	MD-4	10-12	fill	1	0.72	3.34	0.5	2.01
	MD-4	10-12	fill	2	1.44	4.67	0.99	3.43
	MD-4	10-12	fill	3	2.16	4.96	1.09	3.45
	MD-4	20-22	fill	1	1.44	5.84	0.84	3.59
	MD-4	20-22	fill	2	2.88	8.22	1.61	5.51
	MD-4	20-22	fill	3	4.32	10.09	1.7	6.29
	MD-6	20-22	fill	1	1.44	7.59	0.98	4.34
	MD-6	20-22	fill	2	4.32	11.43	2.43	8.56
	MD-6	55-57	residual	1	7.2	12.51	2.39	7.63
	MD-6	55-57	residual	2	4.32	10.82	1.71	6.97
	MD-6	55-57	residual	3	2.88	5.42	1.12	3.58
	MD-8	28-30	fill	1	2.16	8.11	1.2	4.7
	MD-8	28-30	fill	2	5.76	16.27	2.6	10.1
	MD-8	28-30	fill	3	3.6	9.27	1.5	6
	MD-9	20-22	fill	1	1.44	6.99	0.84	3.6
	MD-9	20-22	fill	2	4.32	10.11	2.07	6.96
	MD-9	20-22	fill	3	2.88	8.62	1.38	5.54
	MD-10A	15-17	residual	1	1.01	2.97	0.55	1.89
	MD-10A	15-17	residual	2	3.02	6.47	1.25	4.27
	MD-10A	15-17	residual	3	2.02	4.87	0.91	3.37

Table L2 - Summary of Historic Duke Energy 1982 and 1983 Laboratory Test Data
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Boring No.	Sample Depth (ft)		Sample Type	Lithologic Unit	USCS Classification	Percent Passing No. 200	Atterberg Limits		Specific Gravity	Average Void Ratio	Average Natural Moisture Content	Average Dry Unit Weight	Average Moist Unit Weight	CU Triaxial			
														C_R	ϕ_R	C'	ϕ'
	From	To					LL	PI			(%)	(pcf)	(pcf)	(psf)	Deg	(psf)	Deg
A-4	4.6	6.9	UD	Fill	ML	61	NP	NP	2.66	0.815	27.3	91.4	116.4			100	35.0
A-4	13	15	UD	Fill	ML	67.1	NP	NP	2.65	0.796	26.4	92.2	116.5			0	39
A-4	15	17	UD	Fill	ML	66.1	NP	NP	2.68	0.756	25.6	95.4	119.8			0	34.5
A-4A	4	6	UD	Fill	ML	60.8	NP	NP	2.65	0.841	28.2	89.9	115.2			250	33
A-4A	6	8	UD	Fill	ML	66	NP	NP	2.65	0.782	26.1	92.5	116.7			0	34.5
A-4A	14	16	UD	Fill	ML	62.7	37	7	2.67	0.733	25.7	96.1	120.8			0	32.5
A-8A	13	16.5	UD	Residuum	SM	29	NP	NP	2.75	0.540	17.8	111.9	131.8			0	36
A-8A	20	22	UD	Residuum	SM	41	NP	NP	2.71	0.670	23.3	106.9	131.8			0	33
A-8A	23	26	UD	Residuum	SW-SM	9.5	NP	NP	2.65	0.526	19.2	108.3	129.1			0	38.5
A-9A	25	27	UD	Residuum	SM	40.6	NP	NP		0.651	21.0	103.6	125.3			0	33
A-12	9.7	11.7	UD	Fill	CH	65.4	55	35	2.71	0.598	19.2	106.6	127.1			0	34
A-13	15	17	UD	Fill	ML	32.8	NP	NP	2.81								
A-20A	12.9	14.9	UD	Fill	SM	35.5	NP	NP	2.75	0.660	21.0	103.5	125.2			800	29.5
A-20A	17	19.9	UD	Residuum	SP-GP	5.1	NP	NP									

Notes:
SS = Split Spoon Sample (ASTM D-1586)
UD = Undisturbed Sample (ASTM D-1587)
BAG = Bulk Sample
NP = Non Plastic

Form No. TR-D4318-T89-90
Revision No. 0
Revision Date: 11/20/07

Liquid Limit, Plastic Limit, and Plastic Index

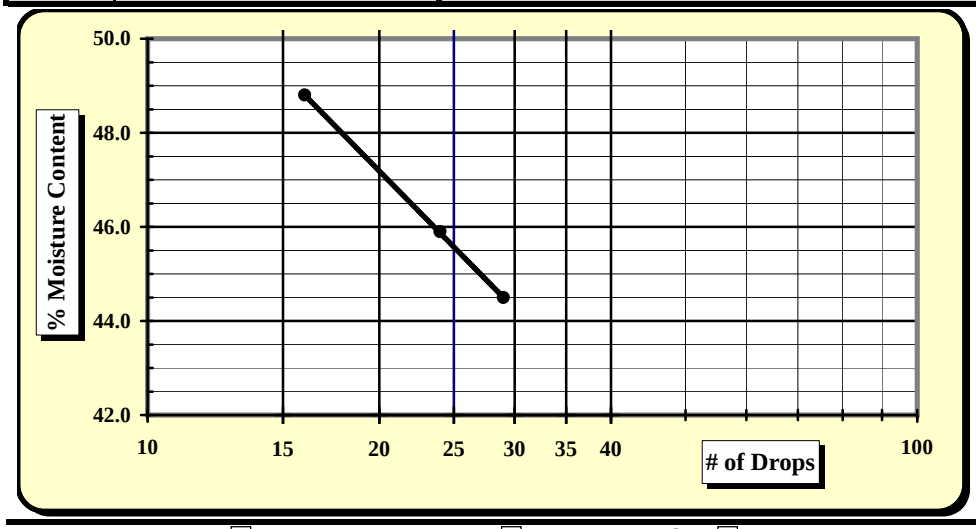
Another code *ASTM D 4318* ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐ ***Quality Assurance***

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s)	6/13-22/10
Client Name:	Duke Energy		
Client Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD-1	Sample #: Residual	Sample Date:
Location:		Offset:	Elevation: 16-18'
Sample Description:	Brown Orange Tan Fine to Coarse Sandy Silt (ML)		

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	3996	2/3/2010	Grooving tool	21587	2/28/2010
LL Apparatus	3611	10/20/2009	Grooving tool		
Oven	10844	9/4/2009	Grooving tool		

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	Omega	30	Cupid				9	BA	
A	Tare Weight	14.61	15.90	8.33				**13.93**	15.36	
B	Wet Soil Weight + A	25.36	26.52	16.84				21.54	21.53	
C	Dry Soil Weight + A	22.05	23.18	14.05				19.75	20.09	
D	Water Weight (B-C)	3.31	3.34	2.79				1.79	1.44	
E	Dry Soil Weight (C-A)	7.44	7.28	5.72				5.82	4.73	
F	% Moisture (D/E)*100	44.5%	45.9%	48.8%				30.8%	30.4%	
N	# OF DROPS	29	24	16				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							**30.6%**		



One Point Liquid Limit			
N	**Factor**	**N**	**Factor**
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☐

Liquid Limit	**46**
Plastic Limit	**31**
Plastic Index	**15**
Group Symbol	**ML**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *Estimate the % Retained on the #40 Sieve:*

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Karen Warner — *Technician Name* — *Date*
Jason Reeves — *Technical Responsibility* — *Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D422-2
Revision No. 0
Revision Date: 02/20/08

Particle Size Analysis of Soils

ASTM D 422

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	6/9-22/10
Client Name:	Duke Energy	Address:	3195 Pine Hall Road, Belews Creek, NC 27009
Boring #:	AD-1	Sample #:	Residual
Location:		Offset:	
Sample Description:	Brown Orange Tan Fine to Coarse Sandy Silt (ML)		

Pan #:		Beaker #:		**Apparent Relative Density (Assumed)**	**2.650**	
Hydrometer Jar #:						
Pan Tare Weight (grams):			**Moisture Content**	Hygroscopic	Natural	
Total Sample Air Dried Wt. + tare wt. (grams):	255.99		Tare #	55		
Weight of Total Sample Air Dried:	255.99	A	Tare Wt.	14.31		
Weight of Air Dried Hydrometer Sample (g):	50.03	B	Wet Wt. + A	24.65		
Total Sample Oven Dried:	251.92	C	Dry Wt. + A	24.48		
Hydrometer Sample Oven Dried (**W**):	49.21	D	Water Wt. (B-C)	0.17		
% Passing #10:	96.6%	E	Dry Wt. (C-A)	10.17		
Correction Factor a (Table 1):	1.00		% Moisture (100 x D/E)	1.67%		

Sieve	Retained Wt.	Percent Passing	
3.0"	0.0	Pan # (washed)	100.0%
1.5"	0.0		100.0%
1.0"	0.0		100.0%
3/4"	0.0		100.0%
1/2"	0.0		100.0%
3/8"	3.6	Soil Mortar	98.6%
#4	6.4		97.5%
#10	8.5	**100.0%**	96.6%
#20	0.7	98.7%	95.3%
#40	1.6	96.7%	93.4%
#60	4.0	91.9%	88.8%
#100	13.8	72.0%	69.5%
#200	17.6	64.3%	62.1%

Description of Sand & Gravel Particles — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Stirring Apparatus: A ☐ B ☐ Dispersion Time: 1 min. Sodium Hexametaphosphate: 40 g./ Liter

Balance: *ID No.* 3996 *Cal. Date:* 2/3/2010 Hydrometer: *ID No.* 3901 *Cal. Date:* 3/26/2010

Control Cylinder ☒ **Composite Correction** ☐ **Type:** **151H** ☐ **152H** ☒

Time	Temp.	Hydrometer	Corrections		Hydrometer	Percent Passing		Effective Depth	Table 3	Diameter
			Control Cylinder	Composite Correction		P(-#10) = (R x a / W) x 100	P (total) = P x % Passing #10			D = K x ((L/T)$^{1/2}$
T (Min.)	(0.5 °C)	Reading			R			L	K	
1	23.0	35.0	5.0		30.00	61.0%	58.9%	11.4	0.01317	0.04442
2	23.0	32.0	5.0		27.00	54.9%	53.0%	11.9	0.01317	0.03208
5	23.0	28.0	5.0		23.00	46.7%	45.2%	12.5	0.01317	0.02084
15	23.0	23.5	5.0		18.50	37.6%	36.3%	13.3	0.01317	0.01238
30	23.0	20.5	5.0		15.50	31.5%	30.4%	13.8	0.01317	0.00892
60	23.0	18.5	5.0		13.50	27.4%	26.5%	14.1	0.01317	0.00638
250	23.0	15.0	5.0		10.00	20.3%	19.6%	14.7	0.01317	0.00319
1440	21.0	14.0	5.5		8.50	17.3%	16.7%	14.9	0.01348	0.00137

References / Comments / Deviations ASTM D 422, D 2487, D 4318

Karen Warner	NICET 117900	Jason Reeves	Senior Engineer	
Technician Name	*Certification #*	*Technical Responsibility*	*Position*	*Date*

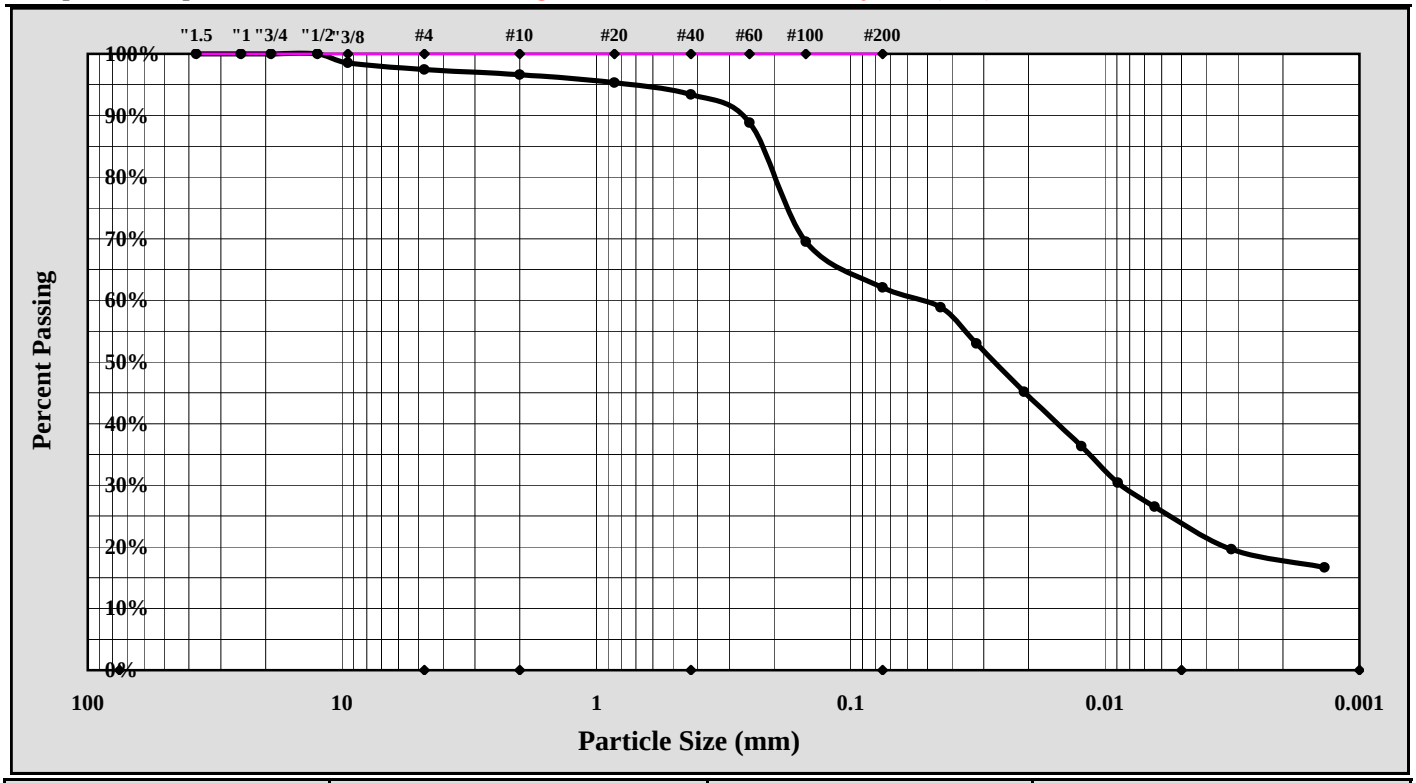
Particle Size Analysis of Soils

ASTM D422

Quality Assurance

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

S&ME Project #:	1356-09-029 Phase 04	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	6/9-22/10
Client Name:	Duke Energy		
Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD-1	Sample #: Residual	Sample Date:
Location:	Offset:		Elevation: 16-18'
Sample Description:	Brown Orange Tan Fine to Coarse Sandy Silt (ML)		



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm (#200)
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Maximum Particle Size:	#4	Gravel:	2.5%	Silt	38.1%
Silt & Clay (% Passing #200):	62.1%	Total Sand:	35.4%	Clay	24.0%
ent Relative Density (Assumed)	2.650	Moisture Content		Colloids	16.5%
Liquid Limit	46	Plastic Limit	31	Plastic Index	15
Coarse Sand:	0.9%	Medium Sand:	3.2%	Fine Sand:	31.3%

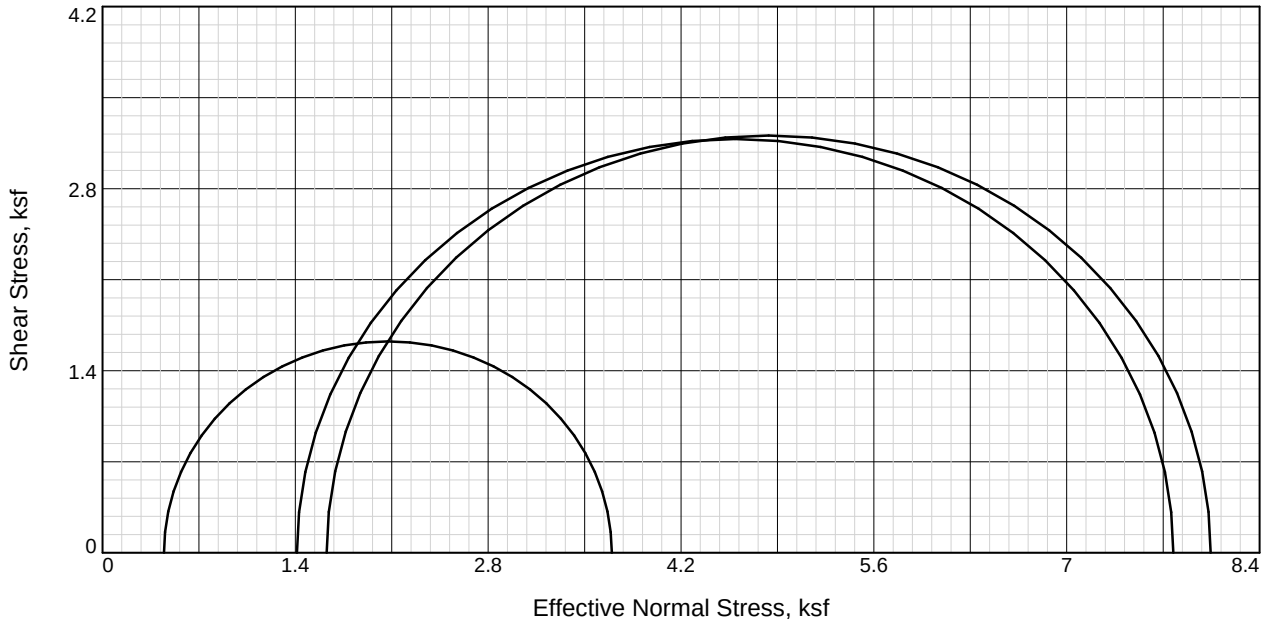
Description of Sand and Gravel — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

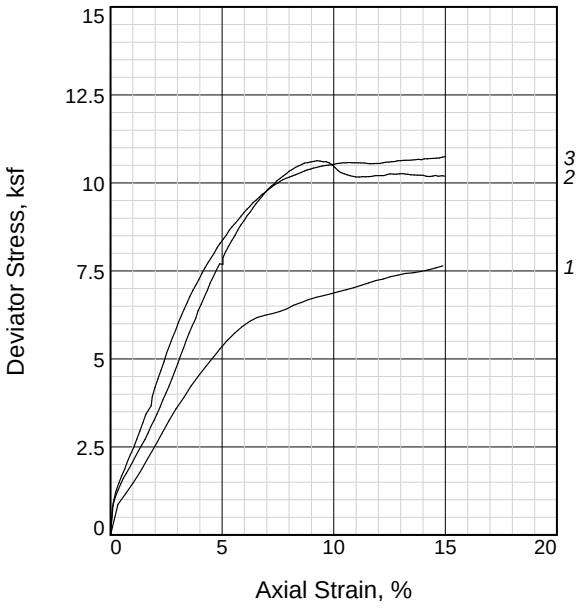
Apparatus B: Air Jet Dispersion — Dispersion Period: 1 min. Dispersing Agent: Sodium Hexametaphosphate: 40 g./ Liter

References / Comments / Deviations: ASTM D 4318, D 854, D 2487

Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.





Sample No.		1	2	3
Initial	Water Content, %	22.3	18.4	17.6
	Dry Density, pcf	103.9	103.0	107.6
	Saturation, %	99.5	80.3	86.8
	Void Ratio	0.5925	0.6056	0.5379
	Diameter, in.	2.860	2.864	2.855
	Height, in.	6.000	6.000	5.969
At Test	Water Content, %	21.9	19.7	19.3
	Dry Density, pcf	104.8	108.6	109.5
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.5790	0.5230	0.5102
	Diameter, in.	2.852	2.814	2.838
	Height, in.	5.983	5.896	5.933
Strain rate, in./min.		0.010	0.004	0.004
Back Pressure, ksf		8.64	10.08	10.08
Cell Pressure, ksf		9.36	12.24	11.52
Fail. Stress, ksf		3.25	6.36	6.42
Total Pore Pr., ksf		8.91	10.83	9.89
Ult. Stress, ksf				
Total Pore Pr., ksf				
$\bar{\sigma}_1$ Failure, ksf		3.70	7.77	8.04
$\bar{\sigma}_3$ Failure, ksf		0.45	1.41	1.63

Type of Test:
CU with Pore Pressures

Sample Type: Undisturbed

Description: Brown Orange Tan Coarse to Fine Sandy Silt (ML)

LL= 46 **PL=** 31 **PI=** 15

Assumed Specific Gravity= 2.65

Remarks: Effective Stress Shear Strengths Based on Maximum Principle Stress Ratio

Plate AD-1 (16-18)

Client: Duke Energy

Project: Duke Energy-Embankment Stability

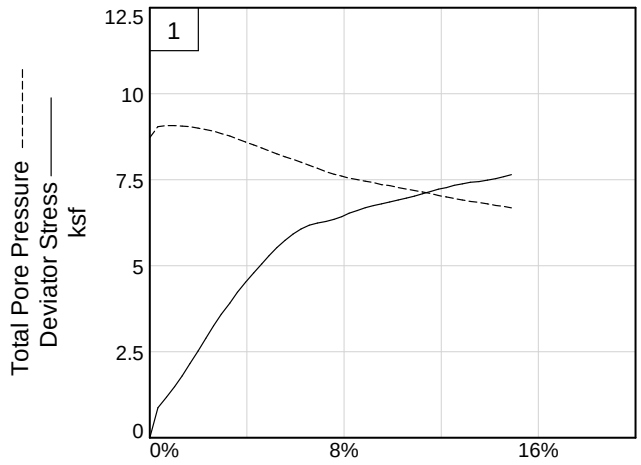
Sample Number: AD-1 Res **Depth:** 16-18'

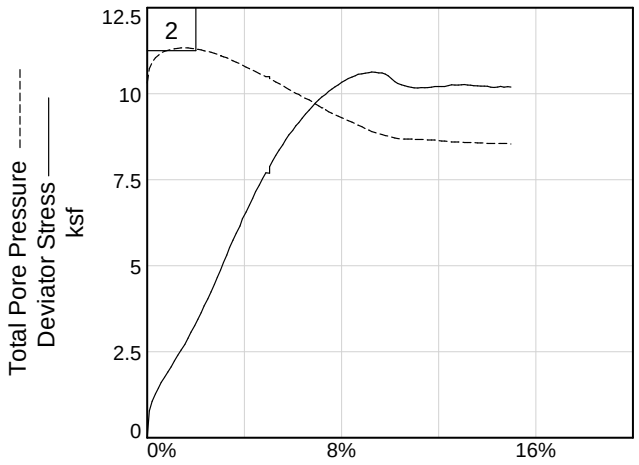
Proj. No.: 1356-09-029 Phase 04 **Date Sampled:**

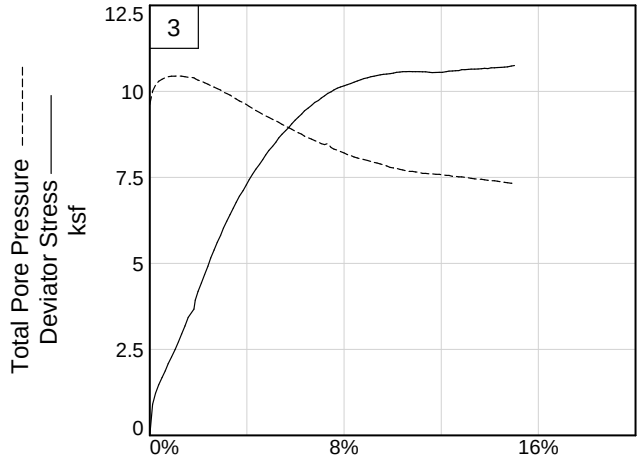
TRIAXIAL SHEAR TEST REPORT

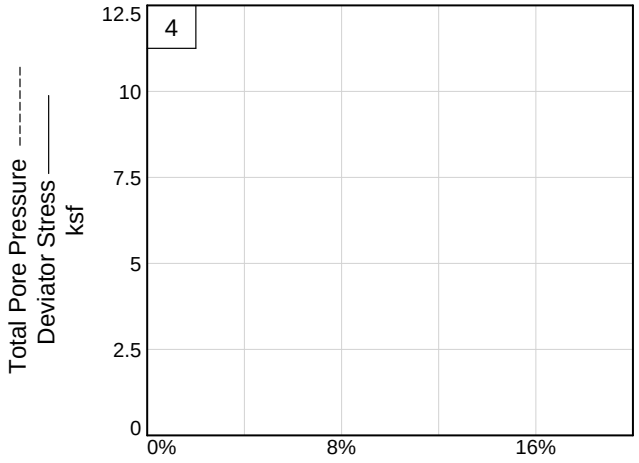
S & ME, INC.

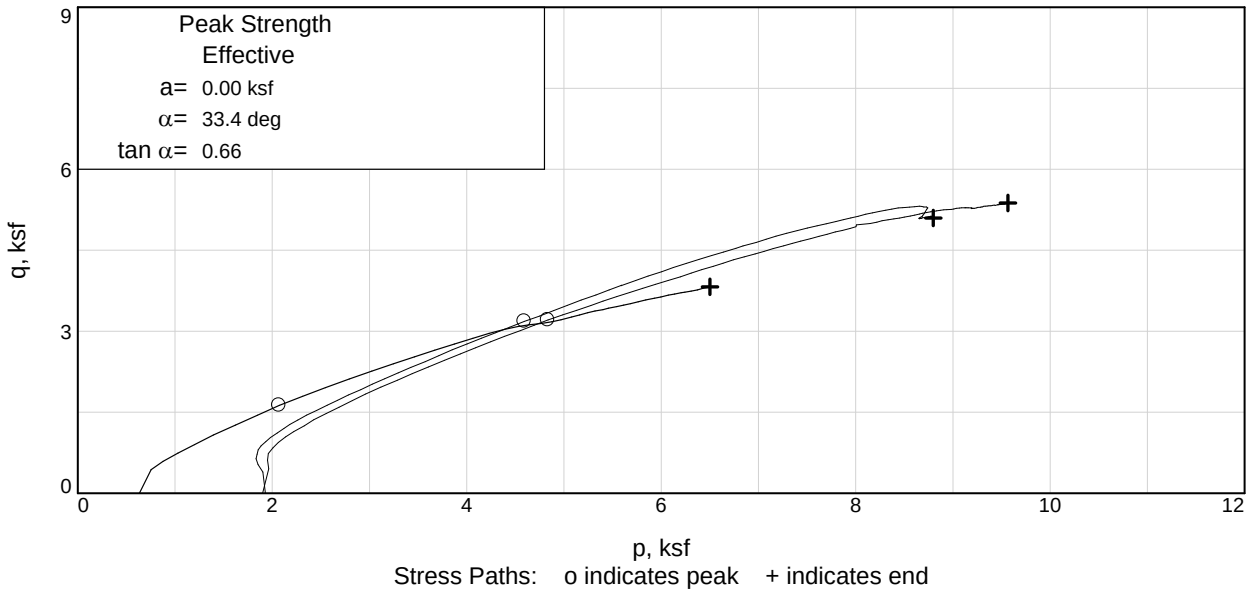
Tested By: KMW **Checked By:** JSR











Stress Paths: o indicates peak + indicates end

Client: Duke Energy
Project: Duke Energy-Embankment Stability
Depth: 16-18' **Sample Number:** AD-1 Res
Project No.: 1356-09-029 Phase 04 **Plate** AD-1 (16-18)

S & ME, INC.

Tested By: KMW **Checked By:** JSR

S&ME

Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter (Method "F")

Project #:	1356-09-029	Phase 04		Test Date(s):	6/16-17/10
Project Name:	Duke Energy - BCSS Embankment Stability			Report Date:	6/17/10
Client Name:	Duke Energy			Sample Date:	
Client Address:				Panel ID:	10
Boring #:	AD-1	Sample #: Residual	Depth: 16-18'	Perm Cell ID:	
Location:		Offset:	Sample Description: Brown Orange Tan Fine to Coarse Sandy Silt (ML)		
Liquid Limit:	46	Sp. Grav. (Assumed): 2.650	Sample Type:	Log #:	
Plastic Limit:	31	Plastic Index: 15	Percent Passing #200: 62.1	Maximum Particle Size:	

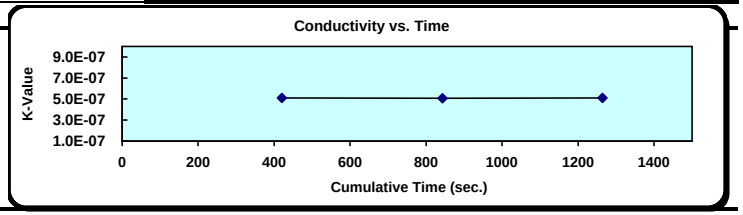
Initial Sample Conditions				Final Sample Conditions			
Length (cm):	15.161	Wet Density (PCF):	126.5	Length (cm):	15.161	Wet Density (PCF):	126.5
Diameter (cm):	7.253	Dry Density (PCF):	107.5	Diameter (cm):	7.25	Dry Density (PCF):	107.6
Area (cm^2)	41.31	Percent Saturation:	86.7	Area (cm^2)	41.31	Percent Saturation:	86.7
Volume (cm^3)	626.33			Volume (cm^3)	626.30	B-Parameter:	0.95
Wet weight (grams)	1269.1	Void Ratio:	0.538	Wet weight (grams)	1269.1	Void Ratio:	0.538
Dry Weight (grams)	1079.2	Porosity:	0.350	Dry Weight (grams)	1079.2	Porosity:	0.350
Percent Moisture:	17.6			Percent Moisture:	17.6		
Test Parameters:	Effective Consolidation Stress (psi):			Permeant Liquid Used:	Deaired Water	a_{in} (cm^2)	0.031416
Hg Equilibrium Level	1.990	Cell Pressure (psi):	80.0	Back Pressure (psi):	70.0	a_{out} (cm^2)	0.76712

Time (24-hr)			Temperature (°C)				Measurements						Initial Gradient	Final Gradient	K-Value (cm/sec)	
Start	End	Time (sec)	Initial	Final	Ave.	Factor	Rp1	Ra1	Rp2	Ra2	h1	h2			Uncorrected K-Value	Corrected K-Value
12:59	13:06	420	21.4	21.4	21.4	0.9670	7.50	1.89	6.30	1.89	70.5	55.4	4.65	3.66	5.28E-07	5.11E-07
1:12	1:19	423	21.4	21.4	21.4	0.9670	7.50	1.89	6.30	1.89	70.5	55.4	4.65	3.66	5.25E-07	5.07E-07
1:21	1:29	421	21.4	21.4	21.4	0.9670	7.50	1.89	6.30	1.89	70.5	55.4	4.65	3.66	5.27E-07	5.10E-07
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
Notes:	Permometer P700000 byTrautwein Soil Testing was used for permeation.											Averages:	0.93	0.73	5.27E-07	5.1E-07

References:

ASTM D 5084: Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

ASTM D 2216: Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass



Technician: Karen Warner

Technical Responsibility: Jason Reeves Position: Senior Engineer

signature

TRIAXIAL COMPRESSION TEST 7/16/2010

CU with Pore Pressures 12:13 PM

Date:
Client: Duke Energy
Project: Duke Energy-Embankment Stability
Project No.: 1356-09-029 Phase 04
Depth: 16-18' **Sample Number:** AD-1 Res
Description: Brown Orange Tan Coarse to Fine Sandy Silt (ML)
Remarks:
Type of Sample: Undisturbed
Assumed Specific Gravity=2.65 **LL=**46 **PL=**31 **PI=**15
Test Method: COE uniform strain

Parameters for Specimen No. 1

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	175.700			1079.400
Moisture content: Dry soil+tare, gms.	158.660			879.200
Moisture content: Tare, gms.	82.100			111.200
Moisture, %	22.3	22.2	21.9	26.1
Moist specimen weight, gms.	1285.00			
Diameter, in.	2.860	2.858	2.852	
Area, in.²	6.424	6.414	6.388	
Height, in.	6.000	5.995	5.983	
Net decrease in height, in.		0.005	0.012	
Wet Density, pcf	127.0	127.3	127.7	
Dry density, pcf	103.9	104.1	104.8	
Void ratio	0.5925	0.5886	0.5790	
Saturation, %	99.5	100.0	100.0	

Test Readings for Specimen No. 1

Consolidation cell pressure = 65.00 psi (9.36 ksf)
Consolidation back pressure = 60.00 psi (8.64 ksf)
Consolidation effective confining stress = 0.72 ksf
Strain rate, in./min. = 0.010
Fail. Stress = 3.25 ksf **at reading no.** 8

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
0	0.0020	15.300	0.0	0.0	0.00	0.63	0.63	1.00	60.60	0.63	0.00
1	0.0220	54.200	38.9	0.3	0.87	0.32	1.19	3.76	62.80	0.75	0.44
2	0.0430	67.900	52.6	0.7	1.18	0.29	1.47	5.09	63.00	0.88	0.59
3	0.0630	81.800	66.5	1.0	1.48	0.29	1.77	6.15	63.00	1.03	0.74
4	0.0820	96.200	80.9	1.3	1.80	0.30	2.10	6.95	62.90	1.20	0.90
5	0.1010	112.600	97.3	1.7	2.16	0.32	2.47	7.81	62.80	1.40	1.08
6	0.1210	129.400	114.1	2.0	2.52	0.36	2.88	8.00	62.50	1.62	1.26
7	0.1400	146.500	131.2	2.3	2.89	0.40	3.29	8.17	62.20	1.85	1.44
8	0.1590	163.400	148.1	2.6	3.25	0.45	3.70	8.28	61.90	2.07	1.63
9	0.1780	179.300	164.0	2.9	3.59	0.52	4.11	7.92	61.40	2.31	1.79
10	0.1990	194.700	179.4	3.3	3.91	0.59	4.50	7.62	60.90	2.55	1.96
11	0.2180	210.000	194.7	3.6	4.23	0.68	4.91	7.25	60.30	2.79	2.12
12	0.2380	224.100	208.8	3.9	4.52	0.76	5.28	6.92	59.70	3.02	2.26
13	0.2580	237.400	222.1	4.3	4.79	0.85	5.64	6.64	59.10	3.25	2.40
14	0.2780	250.300	235.0	4.6	5.05	0.94	5.99	6.40	58.50	3.46	2.53
15	0.2960	262.400	247.1	4.9	5.30	1.02	6.32	6.18	57.90	3.67	2.65
16	0.3150	274.000	258.7	5.2	5.53	1.11	6.64	5.98	57.30	3.87	2.76
17	0.3350	284.700	269.4	5.6	5.74	1.20	6.93	5.80	56.70	4.06	2.87
18	0.3550	294.500	279.2	5.9	5.92	1.27	7.19	5.67	56.20	4.23	2.96
19	0.3750	302.400	287.1	6.2	6.07	1.35	7.42	5.48	55.60	4.39	3.03
20	0.3950	308.600	293.3	6.6	6.18	1.44	7.62	5.29	55.00	4.53	3.09
21	0.4150	312.700	297.4	6.9	6.24	1.53	7.77	5.09	54.40	4.65	3.12
22	0.4360	316.100	300.8	7.3	6.29	1.63	7.92	4.86	53.70	4.77	3.14
23	0.4560	320.100	304.8	7.6	6.35	1.70	8.05	4.74	53.20	4.87	3.17
24	0.4750	324.800	309.5	7.9	6.43	1.76	8.18	4.66	52.80	4.97	3.21
25	0.4930	330.800	315.5	8.2	6.53	1.81	8.34	4.60	52.40	5.08	3.26
26	0.5130	335.600	320.3	8.5	6.60	1.86	8.46	4.56	52.10	5.16	3.30
27	0.5330	340.800	325.5	8.9	6.69	1.90	8.59	4.52	51.80	5.24	3.34
28	0.5530	345.100	329.8	9.2	6.75	1.94	8.69	4.47	51.50	5.32	3.37
29	0.5730	348.700	333.4	9.5	6.80	2.00	8.80	4.40	51.10	5.40	3.40
30	0.5930	352.700	337.4	9.9	6.85	2.03	8.89	4.38	50.90	5.46	3.43
31	0.6140	356.900	341.6	10.2	6.91	2.09	9.00	4.31	50.50	5.54	3.46
32	0.6340	360.800	345.5	10.6	6.97	2.13	9.10	4.27	50.20	5.61	3.48
33	0.6540	364.900	349.6	10.9	7.02	2.17	9.20	4.23	49.90	5.69	3.51
34	0.6740	369.700	354.4	11.2	7.09	2.22	9.31	4.20	49.60	5.76	3.55
35	0.6940	374.500	359.2	11.6	7.16	2.26	9.42	4.17	49.30	5.84	3.58
36	0.7130	379.100	363.8	11.9	7.23	2.32	9.54	4.12	48.90	5.93	3.61
37	0.7330	382.700	367.4	12.2	7.27	2.36	9.63	4.08	48.60	6.00	3.64
38	0.7520	387.400	372.1	12.5	7.34	2.40	9.74	4.05	48.30	6.07	3.67
39	0.7720	391.000	375.7	12.9	7.38	2.45	9.83	4.01	48.00	6.14	3.69
40	0.7920	394.900	379.6	13.2	7.43	2.49	9.92	3.98	47.70	6.20	3.71
41	0.8130	397.400	382.1	13.6	7.45	2.52	9.97	3.95	47.50	6.24	3.72
42	0.8340	401.100	385.8	13.9	7.49	2.56	10.05	3.92	47.20	6.31	3.74
43	0.8540	404.900	389.6	14.2	7.53	2.61	10.14	3.89	46.90	6.37	3.77
44	0.8740	409.300	394.0	14.6	7.59	2.64	10.22	3.88	46.70	6.43	3.79
45	0.8930	413.800	398.5	14.9	7.65	2.68	10.32	3.85	46.40	6.50	3.82

Parameters for Specimen No. 2

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	228.500			1353.300
Moisture content: Dry soil+tare, gms.	205.750			1108.200
Moisture content: Tare, gms.	81.840			74.640
Moisture, %	18.4	22.7	19.7	23.7
Moist specimen weight, gms.	1237.40			
Diameter, in.	2.864	2.861	2.814	
Area, in.²	6.442	6.429	6.219	
Height, in.	6.000	5.994	5.896	
Net decrease in height, in.		0.006	0.098	
Wet Density, pcf	122.0	126.8	130.1	
Dry density, pcf	103.0	103.3	108.6	
Void ratio	0.6056	0.6008	0.5230	
Saturation, %	80.3	100.0	100.0	

Test Readings for Specimen No. 2

Consolidation cell pressure = 85.00 psi (12.24 ksf)
Consolidation back pressure = 70.00 psi (10.08 ksf)
Consolidation effective confining stress = 2.16 ksf
Strain rate, in./min. = 0.004
Fail. Stress = 6.36 ksf **at reading no.** 30

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
0	0.0010	18.200	0.0	0.0	0.00	1.93	1.93	1.00	71.60	1.93	0.00
1	0.0060	52.000	33.8	0.1	0.78	1.51	2.29	1.52	74.50	1.90	0.39
2	0.0130	64.000	45.8	0.2	1.06	1.32	2.38	1.80	75.80	1.85	0.53
3	0.0210	73.500	55.3	0.3	1.28	1.20	2.47	2.07	76.70	1.83	0.64
4	0.0280	80.800	62.6	0.5	1.44	1.12	2.57	2.28	77.20	1.84	0.72
5	0.0350	88.100	69.9	0.6	1.61	1.05	2.66	2.53	77.70	1.86	0.80
6	0.0430	94.600	76.4	0.7	1.76	1.01	2.76	2.74	78.00	1.89	0.88
7	0.0510	101.400	83.2	0.8	1.91	0.98	2.89	2.95	78.20	1.93	0.96
8	0.0590	108.100	89.9	1.0	2.06	0.95	3.01	3.17	78.40	1.98	1.03
9	0.0670	115.700	97.5	1.1	2.23	0.94	3.17	3.39	78.50	2.05	1.12
10	0.0750	123.000	104.8	1.3	2.40	0.92	3.32	3.60	78.60	2.12	1.20
11	0.0830	129.700	111.5	1.4	2.55	0.91	3.45	3.81	78.70	2.18	1.27
12	0.0920	137.100	118.9	1.5	2.71	0.91	3.62	3.99	78.70	2.26	1.36
13	0.1000	145.200	127.0	1.7	2.89	0.91	3.80	4.19	78.70	2.35	1.45
14	0.1070	153.100	134.9	1.8	3.07	0.92	3.99	4.33	78.60	2.46	1.53
15	0.1160	161.600	143.4	2.0	3.26	0.94	4.19	4.48	78.50	2.56	1.63
16	0.1240	170.000	151.8	2.1	3.44	0.95	4.39	4.62	78.40	2.67	1.72
17	0.1320	178.800	160.6	2.2	3.64	0.96	4.60	4.77	78.30	2.78	1.82
18	0.1390	187.800	169.6	2.3	3.84	0.99	4.83	4.86	78.10	2.91	1.92
19	0.1480	197.100	178.9	2.5	4.04	1.01	5.05	5.01	78.00	3.03	2.02
20	0.1560	206.300	188.1	2.6	4.24	1.04	5.28	5.09	77.80	3.16	2.12
21	0.1640	216.200	198.0	2.8	4.46	1.07	5.52	5.18	77.60	3.29	2.23
22	0.1710	225.500	207.3	2.9	4.66	1.09	5.76	5.26	77.40	3.43	2.33
23	0.1790	235.100	216.9	3.0	4.87	1.14	6.01	5.28	77.10	3.57	2.44
24	0.1860	245.300	227.1	3.1	5.09	1.17	6.26	5.37	76.90	3.71	2.55
25	0.1940	255.300	237.1	3.3	5.31	1.20	6.51	5.44	76.70	3.85	2.66
26	0.2010	265.500	247.3	3.4	5.53	1.24	6.77	5.47	76.40	4.00	2.77

Test Readings for Specimen No. 2

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
27	0.2090	275.200	257.0	3.5	5.74	1.28	7.02	5.48	76.10	4.15	2.87
28	0.2170	284.700	266.5	3.7	5.94	1.32	7.27	5.49	75.80	4.30	2.97
29	0.2260	294.500	276.3	3.8	6.15	1.37	7.52	5.50	75.50	4.44	3.08
30	0.2320	304.200	286.0	3.9	6.36	1.41	7.77	5.51	75.20	4.59	3.18
31	0.2410	313.600	295.4	4.1	6.56	1.47	8.03	5.47	74.80	4.75	3.28
32	0.2490	323.200	305.0	4.2	6.77	1.51	8.28	5.47	74.50	4.89	3.38
33	0.2570	332.300	314.1	4.3	6.96	1.56	8.51	5.47	74.20	5.03	3.48
34	0.2640	341.700	323.5	4.5	7.16	1.60	8.75	5.48	73.90	5.18	3.58
35	0.2730	350.700	332.5	4.6	7.34	1.66	9.00	5.43	73.50	5.33	3.67
36	0.2810	359.600	341.4	4.7	7.53	1.70	9.23	5.43	73.20	5.46	3.76
37	0.2890	367.900	349.7	4.9	7.70	1.74	9.44	5.42	72.90	5.59	3.85
38	0.2980	367.900	349.7	5.0	7.69	1.74	9.43	5.41	72.90	5.59	3.84
39	0.2980	376.500	358.3	5.0	7.88	1.80	9.68	5.38	72.50	5.74	3.94
40	0.3050	384.500	366.3	5.2	8.04	1.84	9.89	5.36	72.20	5.87	4.02
41	0.3130	392.300	374.1	5.3	8.20	1.90	10.10	5.32	71.80	6.00	4.10
42	0.3210	400.000	381.8	5.4	8.36	1.94	10.30	5.30	71.50	6.12	4.18
43	0.3300	407.600	389.4	5.6	8.51	2.00	10.52	5.25	71.10	6.26	4.26
44	0.3370	414.800	396.6	5.7	8.66	2.06	10.72	5.21	70.70	6.39	4.33
45	0.3450	422.000	403.8	5.8	8.80	2.12	10.92	5.16	70.30	6.52	4.40
46	0.3540	428.500	410.3	6.0	8.93	2.17	11.11	5.11	69.90	6.64	4.47
47	0.3620	435.600	417.4	6.1	9.07	2.23	11.31	5.07	69.50	6.77	4.54
48	0.3690	440.100	421.9	6.2	9.16	2.26	11.42	5.05	69.30	6.84	4.58
49	0.3770	446.600	428.4	6.4	9.29	2.33	11.62	4.98	68.80	6.98	4.64
50	0.3850	452.700	434.5	6.5	9.41	2.38	11.78	4.96	68.50	7.08	4.70
51	0.3940	458.800	440.6	6.7	9.52	2.42	11.94	4.94	68.20	7.18	4.76
52	0.4020	464.400	446.2	6.8	9.63	2.48	12.11	4.89	67.80	7.29	4.81
53	0.4090	469.600	451.4	6.9	9.73	2.53	12.26	4.84	67.40	7.40	4.86
54	0.4170	474.500	456.3	7.1	9.82	2.59	12.41	4.79	67.00	7.50	4.91
55	0.4250	479.200	461.0	7.2	9.91	2.65	12.56	4.74	66.60	7.60	4.95
56	0.4340	483.300	465.1	7.3	9.98	2.71	12.69	4.69	66.20	7.70	4.99
57	0.4410	487.900	469.7	7.5	10.06	2.76	12.83	4.64	65.80	7.80	5.03
58	0.4490	491.700	473.5	7.6	10.13	2.81	12.94	4.61	65.50	7.87	5.07
59	0.4570	495.600	477.4	7.7	10.20	2.85	13.05	4.58	65.20	7.95	5.10
60	0.4650	499.100	480.9	7.9	10.26	2.89	13.15	4.54	64.90	8.02	5.13
61	0.4730	503.300	485.1	8.0	10.33	2.94	13.27	4.52	64.60	8.10	5.17
62	0.4810	506.400	488.2	8.1	10.38	2.98	13.36	4.48	64.30	8.17	5.19
63	0.4890	509.800	491.6	8.3	10.44	3.02	13.46	4.45	64.00	8.24	5.22
64	0.4980	512.700	494.5	8.4	10.49	3.07	13.55	4.42	63.70	8.31	5.24
65	0.5060	515.200	497.0	8.6	10.52	3.11	13.63	4.38	63.40	8.37	5.26
66	0.5130	517.900	499.7	8.7	10.57	3.15	13.72	4.35	63.10	8.44	5.28
67	0.5220	519.200	501.0	8.8	10.58	3.20	13.77	4.31	62.80	8.48	5.29
68	0.5300	521.000	502.8	9.0	10.60	3.25	13.85	4.26	62.40	8.55	5.30
69	0.5390	522.600	504.4	9.1	10.61	3.30	13.91	4.22	62.10	8.60	5.31
70	0.5460	524.100	505.9	9.2	10.63	3.34	13.97	4.18	61.80	8.66	5.32
71	0.5540	524.400	506.2	9.4	10.62	3.37	13.99	4.15	61.60	8.68	5.31
72	0.5630	524.400	506.2	9.5	10.60	3.40	14.00	4.12	61.40	8.70	5.30
73	0.5710	525.100	506.9	9.7	10.60	3.43	14.03	4.09	61.20	8.73	5.30

Test Readings for Specimen No. 2

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
74	0.5790	524.300	506.1	9.8	10.57	3.46	14.03	4.06	61.00	8.74	5.29
75	0.5860	522.600	504.4	9.9	10.52	3.47	13.99	4.03	60.90	8.73	5.26
76	0.5940	519.300	501.1	10.1	10.44	3.50	13.94	3.98	60.70	8.72	5.22
77	0.6020	516.100	497.9	10.2	10.35	3.53	13.88	3.93	60.50	8.70	5.18
78	0.6090	514.000	495.8	10.3	10.30	3.54	13.84	3.91	60.40	8.69	5.15
79	0.6180	513.100	494.9	10.5	10.26	3.56	13.82	3.88	60.30	8.69	5.13
80	0.6260	512.500	494.3	10.6	10.23	3.56	13.79	3.88	60.30	8.67	5.12
81	0.6340	512.000	493.8	10.7	10.21	3.56	13.76	3.87	60.30	8.66	5.10
82	0.6420	511.700	493.5	10.9	10.18	3.56	13.74	3.86	60.30	8.65	5.09
83	0.6490	511.700	493.5	11.0	10.17	3.57	13.74	3.85	60.20	8.66	5.09
84	0.6580	512.300	494.1	11.1	10.17	3.57	13.74	3.85	60.20	8.65	5.08
85	0.6660	513.600	495.4	11.3	10.18	3.57	13.75	3.85	60.20	8.66	5.09
86	0.6750	514.300	496.1	11.4	10.17	3.57	13.75	3.85	60.20	8.66	5.09
87	0.6820	515.200	497.0	11.6	10.18	3.59	13.76	3.84	60.10	8.68	5.09
88	0.6910	516.500	498.3	11.7	10.19	3.59	13.77	3.84	60.10	8.68	5.09
89	0.6990	518.200	500.0	11.8	10.21	3.59	13.79	3.85	60.10	8.69	5.10
90	0.7080	519.200	501.0	12.0	10.21	3.60	13.81	3.84	60.00	8.70	5.10
91	0.7160	519.900	501.7	12.1	10.21	3.61	13.82	3.82	59.90	8.72	5.10
92	0.7230	520.600	502.4	12.2	10.21	3.61	13.82	3.82	59.90	8.72	5.10
93	0.7320	522.900	504.7	12.4	10.24	3.63	13.87	3.82	59.80	8.75	5.12
94	0.7400	524.700	506.5	12.5	10.26	3.64	13.90	3.82	59.70	8.77	5.13
95	0.7480	525.100	506.9	12.7	10.25	3.64	13.89	3.81	59.70	8.77	5.13
96	0.7560	525.900	507.7	12.8	10.25	3.64	13.89	3.81	59.70	8.77	5.13
97	0.7640	527.100	508.9	12.9	10.26	3.64	13.90	3.82	59.70	8.77	5.13
98	0.7710	528.200	510.0	13.1	10.27	3.66	13.92	3.81	59.60	8.79	5.13
99	0.7790	528.300	510.1	13.2	10.25	3.66	13.91	3.80	59.60	8.78	5.13
100	0.7860	528.700	510.5	13.3	10.25	3.66	13.90	3.80	59.60	8.78	5.12
101	0.7940	528.800	510.6	13.4	10.23	3.66	13.89	3.80	59.60	8.77	5.12
102	0.8030	529.500	511.3	13.6	10.23	3.67	13.90	3.79	59.50	8.79	5.11
103	0.8110	529.800	511.6	13.7	10.22	3.67	13.89	3.78	59.50	8.78	5.11
104	0.8190	530.700	512.5	13.9	10.22	3.67	13.89	3.78	59.50	8.78	5.11
105	0.8270	531.300	513.1	14.0	10.22	3.69	13.90	3.77	59.40	8.79	5.11
106	0.8350	530.700	512.5	14.1	10.19	3.69	13.87	3.76	59.40	8.78	5.09
107	0.8430	531.200	513.0	14.3	10.18	3.69	13.87	3.76	59.40	8.78	5.09
108	0.8520	532.700	514.5	14.4	10.19	3.69	13.88	3.77	59.40	8.78	5.10
109	0.8590	534.400	516.2	14.6	10.21	3.69	13.90	3.77	59.40	8.79	5.11
110	0.8670	534.000	515.8	14.7	10.19	3.69	13.88	3.76	59.40	8.78	5.09
111	0.8760	535.700	517.5	14.8	10.20	3.69	13.89	3.77	59.40	8.79	5.10
112	0.8840	536.000	517.8	15.0	10.19	3.70	13.89	3.75	59.30	8.80	5.10

Parameters for Specimen No. 3

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	155.800			1353.300
Moisture content: Dry soil+tare, gms.	144.660			1108.200
Moisture content: Tare, gms.	81.430			74.640
Moisture, %	17.6	20.1	19.3	23.7
Moist specimen weight, gms.	1269.10			
Diameter, in.	2.855	2.852	2.838	
Area, in.²	6.402	6.389	6.325	
Height, in.	5.969	5.963	5.933	
Net decrease in height, in.		0.006	0.030	
Wet Density, pcf	126.5	129.6	130.6	
Dry density, pcf	107.6	107.9	109.5	
Void ratio	0.5379	0.5333	0.5102	
Saturation, %	86.8	100.0	100.0	

Test Readings for Specimen No. 3

Consolidation cell pressure = 80.00 psi (11.52 ksf)
Consolidation back pressure = 70.00 psi (10.08 ksf)
Consolidation effective confining stress = 1.44 ksf
Strain rate, in./min. = 0.004
Fail. Stress = 6.42 ksf **at reading no.** 25

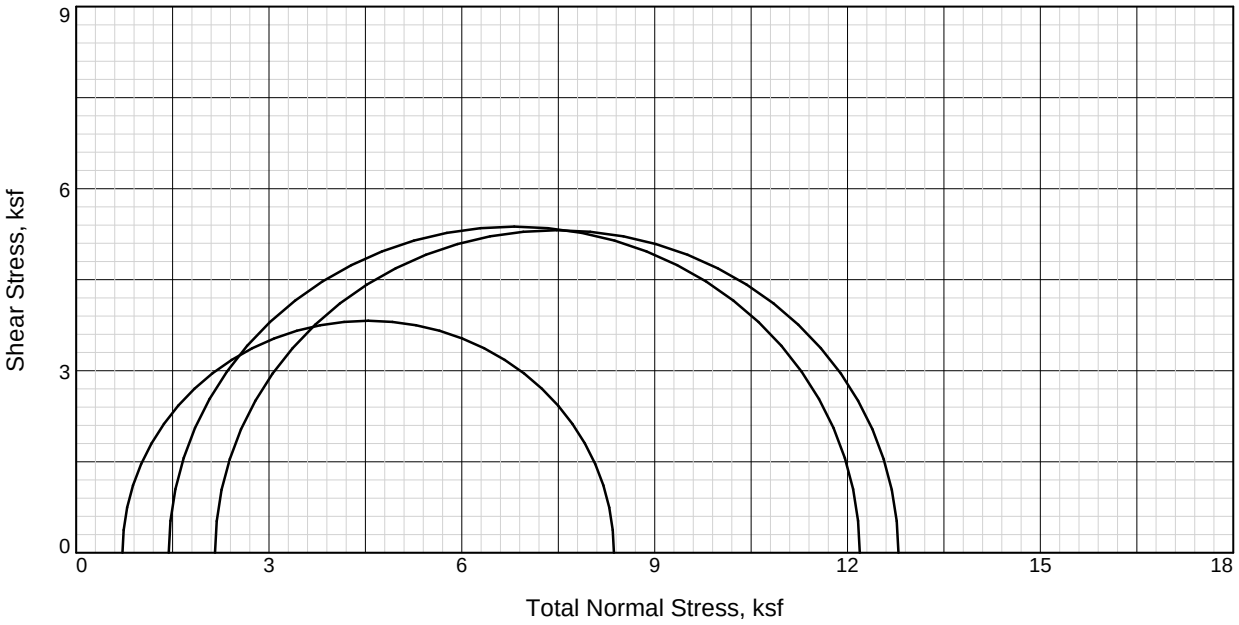
No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
0	0.0010	15.200	0.0	0.0	0.00	1.90	1.90	1.00	66.80	1.90	0.00
1	0.0080	54.900	39.7	0.1	0.90	1.51	2.41	1.60	69.50	1.96	0.45
2	0.0150	69.100	53.9	0.2	1.22	1.34	2.56	1.91	70.70	1.95	0.61
3	0.0230	80.100	64.9	0.4	1.47	1.22	2.70	2.20	71.50	1.96	0.74
4	0.0310	89.500	74.3	0.5	1.68	1.17	2.85	2.44	71.90	2.01	0.84
5	0.0390	98.200	83.0	0.6	1.88	1.12	3.00	2.67	72.20	2.06	0.94
6	0.0460	107.600	92.4	0.8	2.09	1.09	3.18	2.91	72.40	2.14	1.04
7	0.0540	116.300	101.1	0.9	2.28	1.08	3.36	3.11	72.50	2.22	1.14
8	0.0630	126.100	110.9	1.0	2.50	1.08	3.58	3.31	72.50	2.33	1.25
9	0.0710	136.100	120.9	1.2	2.72	1.07	3.79	3.55	72.60	2.43	1.36
10	0.0790	146.500	131.3	1.3	2.95	1.08	4.03	3.73	72.50	2.56	1.48
11	0.0870	157.100	141.9	1.4	3.18	1.09	4.28	3.91	72.40	2.69	1.59
12	0.0950	168.300	153.1	1.6	3.43	1.11	4.54	4.09	72.30	2.82	1.72
13	0.1090	179.500	164.3	1.8	3.67	1.12	4.80	4.27	72.20	2.96	1.84
14	0.1120	191.100	175.9	1.9	3.93	1.15	5.08	4.41	72.00	3.12	1.97
15	0.1190	202.800	187.6	2.0	4.19	1.20	5.38	4.50	71.70	3.29	2.09
16	0.1270	214.000	198.8	2.1	4.43	1.22	5.65	4.62	71.50	3.44	2.22
17	0.1350	225.300	210.1	2.3	4.68	1.27	5.94	4.69	71.20	3.60	2.34
18	0.1430	236.600	221.4	2.4	4.92	1.31	6.23	4.75	70.90	3.77	2.46
19	0.1500	247.700	232.5	2.5	5.16	1.35	6.51	4.81	70.60	3.93	2.58
20	0.1580	258.200	243.0	2.6	5.39	1.40	6.78	4.86	70.30	4.09	2.69
21	0.1660	268.700	253.5	2.8	5.61	1.44	7.05	4.90	70.00	4.25	2.81
22	0.1740	278.200	263.0	2.9	5.81	1.48	7.30	4.92	69.70	4.39	2.91
23	0.1810	288.000	272.8	3.0	6.02	1.54	7.56	4.91	69.30	4.55	3.01
24	0.1890	297.600	282.4	3.2	6.23	1.58	7.81	4.93	69.00	4.70	3.11
25	0.1970	306.700	291.5	3.3	6.42	1.63	8.04	4.94	68.70	4.84	3.21
26	0.2050	315.600	300.4	3.4	6.60	1.68	8.29	4.92	68.30	4.99	3.30

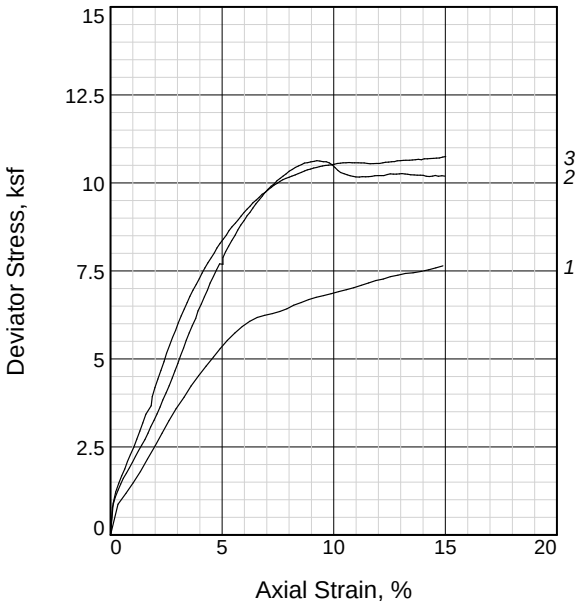
Test Readings for Specimen No. 3

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
27	0.2120	323.800	308.6	3.6	6.78	1.74	8.52	4.89	67.90	5.13	3.39
28	0.2200	332.300	317.1	3.7	6.95	1.80	8.75	4.86	67.50	5.28	3.48
29	0.2290	340.300	325.1	3.8	7.12	1.84	8.96	4.86	67.20	5.40	3.56
30	0.2370	348.300	333.1	4.0	7.28	1.90	9.18	4.83	66.80	5.54	3.64
31	0.2440	355.800	340.6	4.1	7.44	1.96	9.40	4.80	66.40	5.68	3.72
32	0.2520	363.200	348.0	4.2	7.59	2.02	9.60	4.76	66.00	5.81	3.79
33	0.2600	370.500	355.3	4.4	7.74	2.07	9.81	4.73	65.60	5.94	3.87
34	0.2690	377.700	362.5	4.5	7.88	2.13	10.01	4.70	65.20	6.07	3.94
35	0.2770	384.400	369.2	4.7	8.02	2.19	10.20	4.66	64.80	6.20	4.01
36	0.2840	391.200	376.0	4.8	8.15	2.23	10.38	4.65	64.50	6.31	4.08
37	0.2920	397.700	382.5	4.9	8.28	2.28	10.56	4.64	64.20	6.42	4.14
38	0.3010	404.000	388.8	5.1	8.40	2.33	10.74	4.60	63.80	6.54	4.20
39	0.3090	409.800	394.6	5.2	8.52	2.38	10.89	4.59	63.50	6.63	4.26
40	0.3160	416.300	401.1	5.3	8.65	2.42	11.07	4.57	63.20	6.74	4.32
41	0.3240	421.800	406.6	5.4	8.75	2.48	11.23	4.53	62.80	6.85	4.38
42	0.3330	427.500	412.3	5.6	8.86	2.53	11.40	4.50	62.40	6.97	4.43
43	0.3410	432.600	417.4	5.7	8.96	2.58	11.54	4.48	62.10	7.06	4.48
44	0.3480	437.800	422.6	5.8	9.06	2.62	11.68	4.46	61.80	7.15	4.53
45	0.3560	443.300	428.1	6.0	9.16	2.68	11.84	4.42	61.40	7.26	4.58
46	0.3640	448.100	432.9	6.1	9.25	2.72	11.97	4.40	61.10	7.35	4.63
47	0.3720	452.800	437.6	6.3	9.34	2.76	12.11	4.38	60.80	7.43	4.67
48	0.3790	457.700	442.5	6.4	9.43	2.82	12.26	4.34	60.40	7.54	4.72
49	0.3880	462.200	447.0	6.5	9.51	2.87	12.38	4.32	60.10	7.62	4.76
50	0.3960	466.500	451.3	6.7	9.59	2.91	12.50	4.30	59.80	7.70	4.80
51	0.4040	471.200	456.0	6.8	9.68	2.95	12.63	4.28	59.50	7.79	4.84
52	0.4130	474.700	459.5	6.9	9.74	3.00	12.73	4.25	59.20	7.86	4.87
53	0.4200	478.700	463.5	7.1	9.81	3.04	12.85	4.23	58.90	7.94	4.90
54	0.4280	482.400	467.2	7.2	9.87	3.07	12.94	4.22	58.70	8.00	4.94
55	0.4360	486.300	471.1	7.3	9.94	3.04	12.98	4.27	58.90	8.01	4.97
56	0.4440	489.300	474.1	7.5	9.99	3.15	13.14	4.17	58.10	8.15	4.99
57	0.4510	492.400	477.2	7.6	10.04	3.20	13.24	4.14	57.80	8.22	5.02
58	0.4590	495.500	480.3	7.7	10.09	3.23	13.32	4.13	57.60	8.27	5.05
59	0.4670	498.000	482.8	7.9	10.13	3.27	13.40	4.10	57.30	8.33	5.06
60	0.4760	500.400	485.2	8.0	10.16	3.31	13.47	4.07	57.00	8.39	5.08
61	0.4830	502.500	487.3	8.1	10.19	3.36	13.55	4.04	56.70	8.45	5.10
62	0.4920	505.000	489.8	8.3	10.23	3.38	13.61	4.02	56.50	8.50	5.11
63	0.5000	507.500	492.3	8.4	10.27	3.43	13.69	4.00	56.20	8.56	5.13
64	0.5080	509.900	494.7	8.5	10.30	3.46	13.76	3.98	56.00	8.61	5.15
65	0.5170	512.600	497.4	8.7	10.34	3.48	13.82	3.97	55.80	8.65	5.17
66	0.5240	514.800	499.6	8.8	10.37	3.50	13.87	3.96	55.70	8.69	5.19
67	0.5330	516.700	501.5	9.0	10.39	3.53	13.92	3.95	55.50	8.73	5.20
68	0.5410	519.000	503.8	9.1	10.43	3.56	13.98	3.93	55.30	8.77	5.21
69	0.5490	520.400	505.2	9.2	10.44	3.59	14.03	3.91	55.10	8.81	5.22
70	0.5560	522.100	506.9	9.4	10.46	3.60	14.06	3.91	55.00	8.83	5.23
71	0.5640	523.800	508.6	9.5	10.48	3.63	14.11	3.89	54.80	8.87	5.24
72	0.5720	525.300	510.1	9.6	10.50	3.66	14.15	3.87	54.60	8.91	5.25
73	0.5800	526.400	511.2	9.8	10.50	3.69	14.19	3.85	54.40	8.94	5.25

Test Readings for Specimen No. 3

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
74	0.5880	527.700	512.5	9.9	10.51	3.73	14.24	3.82	54.10	8.99	5.26
75	0.5960	529.200	514.0	10.0	10.53	3.74	14.27	3.81	54.00	9.01	5.26
76	0.6040	531.100	515.9	10.2	10.55	3.76	14.31	3.81	53.90	9.03	5.28
77	0.6120	532.300	517.1	10.3	10.56	3.79	14.35	3.79	53.70	9.07	5.28
78	0.6190	533.600	518.4	10.4	10.57	3.80	14.38	3.78	53.60	9.09	5.29
79	0.6270	534.400	519.2	10.6	10.57	3.83	14.40	3.76	53.40	9.12	5.29
80	0.6350	535.400	520.2	10.7	10.58	3.84	14.42	3.75	53.30	9.13	5.29
81	0.6430	535.900	520.7	10.8	10.57	3.84	14.42	3.75	53.30	9.13	5.29
82	0.6500	536.600	521.4	10.9	10.57	3.86	14.43	3.74	53.20	9.15	5.29
83	0.6590	537.500	522.3	11.1	10.57	3.87	14.45	3.73	53.10	9.16	5.29
84	0.6670	538.100	522.9	11.2	10.57	3.90	14.47	3.71	52.90	9.19	5.28
85	0.6750	538.900	523.7	11.4	10.57	3.90	14.47	3.71	52.90	9.19	5.28
86	0.6840	539.000	523.8	11.5	10.55	3.92	14.47	3.69	52.80	9.19	5.28
87	0.6910	539.300	524.1	11.6	10.55	3.92	14.46	3.69	52.80	9.19	5.27
88	0.7000	540.500	525.3	11.8	10.55	3.93	14.48	3.68	52.70	9.21	5.28
89	0.7080	541.400	526.2	11.9	10.55	3.93	14.48	3.68	52.70	9.21	5.28
90	0.7160	542.300	527.1	12.1	10.55	3.95	14.50	3.68	52.60	9.22	5.28
91	0.7250	544.100	528.9	12.2	10.57	3.96	14.53	3.67	52.50	9.25	5.29
92	0.7320	545.600	530.4	12.3	10.59	3.96	14.55	3.67	52.50	9.25	5.29
93	0.7400	546.600	531.4	12.5	10.59	3.99	14.58	3.66	52.30	9.28	5.30
94	0.7480	547.900	532.7	12.6	10.60	3.99	14.59	3.66	52.30	9.29	5.30
95	0.7560	548.900	533.7	12.7	10.61	4.00	14.61	3.65	52.20	9.31	5.30
96	0.7630	550.900	535.7	12.8	10.63	4.00	14.63	3.66	52.20	9.32	5.32
97	0.7710	551.800	536.6	13.0	10.63	4.02	14.65	3.65	52.10	9.33	5.32
98	0.7790	553.000	537.8	13.1	10.64	4.03	14.67	3.64	52.00	9.35	5.32
99	0.7860	554.100	538.9	13.2	10.65	4.05	14.69	3.63	51.90	9.37	5.32
100	0.7950	555.000	539.8	13.4	10.65	4.06	14.71	3.62	51.80	9.38	5.32
101	0.8030	556.200	541.0	13.5	10.65	4.08	14.73	3.61	51.70	9.40	5.33
102	0.8110	557.400	542.2	13.7	10.66	4.08	14.73	3.62	51.70	9.40	5.33
103	0.8190	558.800	543.6	13.8	10.67	4.09	14.76	3.61	51.60	9.42	5.34
104	0.8270	559.200	544.0	13.9	10.66	4.10	14.77	3.60	51.50	9.43	5.33
105	0.8350	561.300	546.1	14.1	10.69	4.12	14.80	3.59	51.40	9.46	5.34
106	0.8430	562.200	547.0	14.2	10.69	4.12	14.81	3.59	51.40	9.46	5.34
107	0.8510	563.400	548.2	14.3	10.69	4.13	14.83	3.59	51.30	9.48	5.35
108	0.8590	564.500	549.3	14.5	10.70	4.15	14.85	3.58	51.20	9.50	5.35
109	0.8670	565.800	550.6	14.6	10.71	4.16	14.87	3.57	51.10	9.51	5.35
110	0.8750	566.900	551.7	14.7	10.71	4.18	14.89	3.56	51.00	9.53	5.36
111	0.8840	569.100	553.9	14.9	10.73	4.19	14.92	3.56	50.90	9.56	5.37
112	0.8920	570.800	555.6	15.0	10.75	4.19	14.94	3.57	50.90	9.57	5.38





Sample No.		1	2	3
Initial	Water Content, %	22.3	18.4	17.6
	Dry Density, pcf	103.9	103.0	107.6
	Saturation, %	99.5	80.3	86.8
	Void Ratio	0.5925	0.6056	0.5379
	Diameter, in.	2.860	2.864	2.855
	Height, in.	6.000	6.000	5.969
At Test	Water Content, %	21.9	19.7	19.3
	Dry Density, pcf	104.8	108.6	109.5
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.5790	0.5230	0.5102
	Diameter, in.	2.852	2.814	2.838
	Height, in.	5.983	5.896	5.933
Strain rate, in./min.		0.010	0.004	0.004
Back Pressure, ksf		8.6	10.1	10.1
Cell Pressure, ksf		9.4	12.2	11.5
Fail. Stress, ksf		7.6	10.6	10.8
Total Pore Pr., ksf		6.7	8.9	7.3
Ult. Stress, ksf				
Total Pore Pr., ksf				
$\bar{\sigma}_1$ Failure, ksf		10.3	14.0	14.9
$\bar{\sigma}_3$ Failure, ksf		2.7	3.3	4.2

Type of Test:
CU with Pore Pressures

Sample Type: Undisturbed

Description: Brown Orange Tan Coarse to Fine Sandy Silt (ML)

LL= 46 **PL=** 31 **PI=** 15

Assumed Specific Gravity= 2.65

Remarks: Total stress shear strengths based on maximum deviator stess.

Plate AD-1 (16-18)

Client: Duke Energy

Project: Duke Energy-Embankment Stability

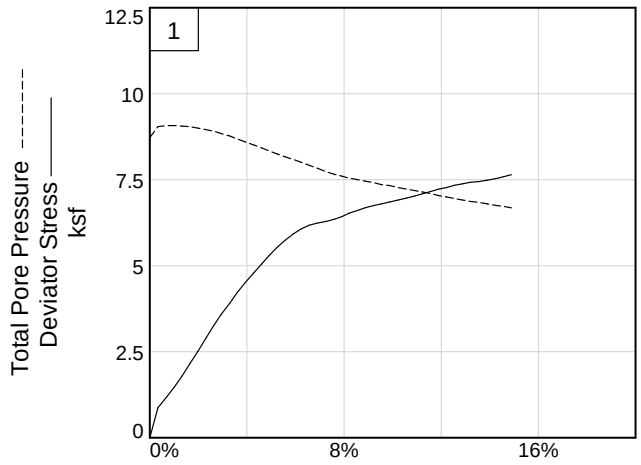
Sample Number: AD-1 Res **Depth:** 16-18'

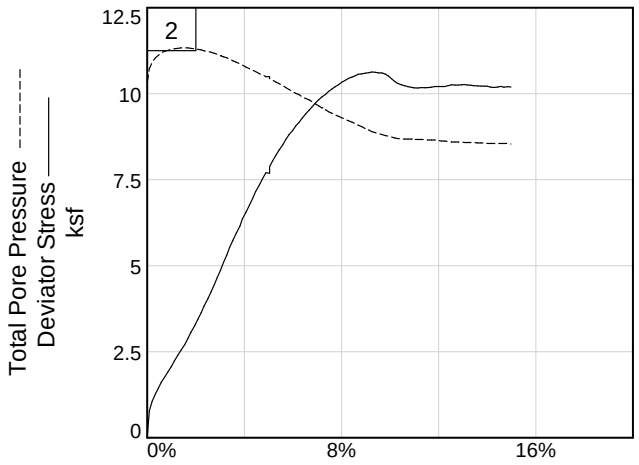
Proj. No.: 1356-09-029 Phase 04 **Date Sampled:**

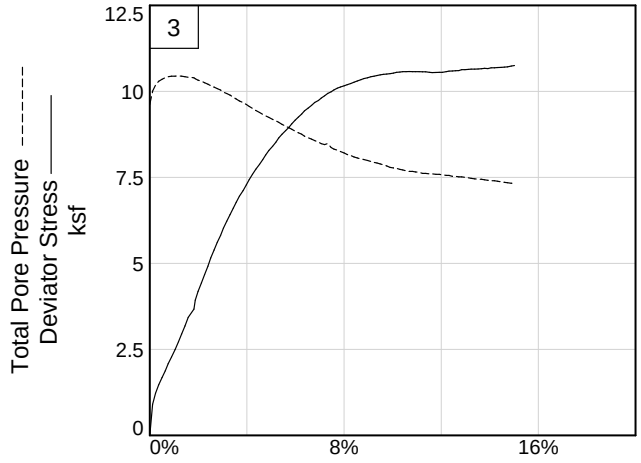
TRIAXIAL SHEAR TEST REPORT

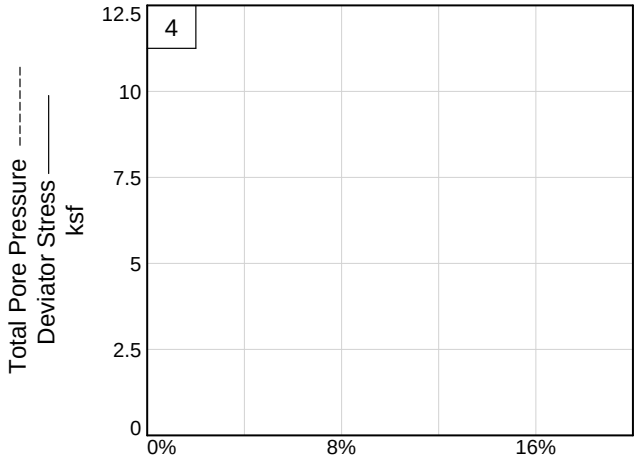
S & ME, INC.

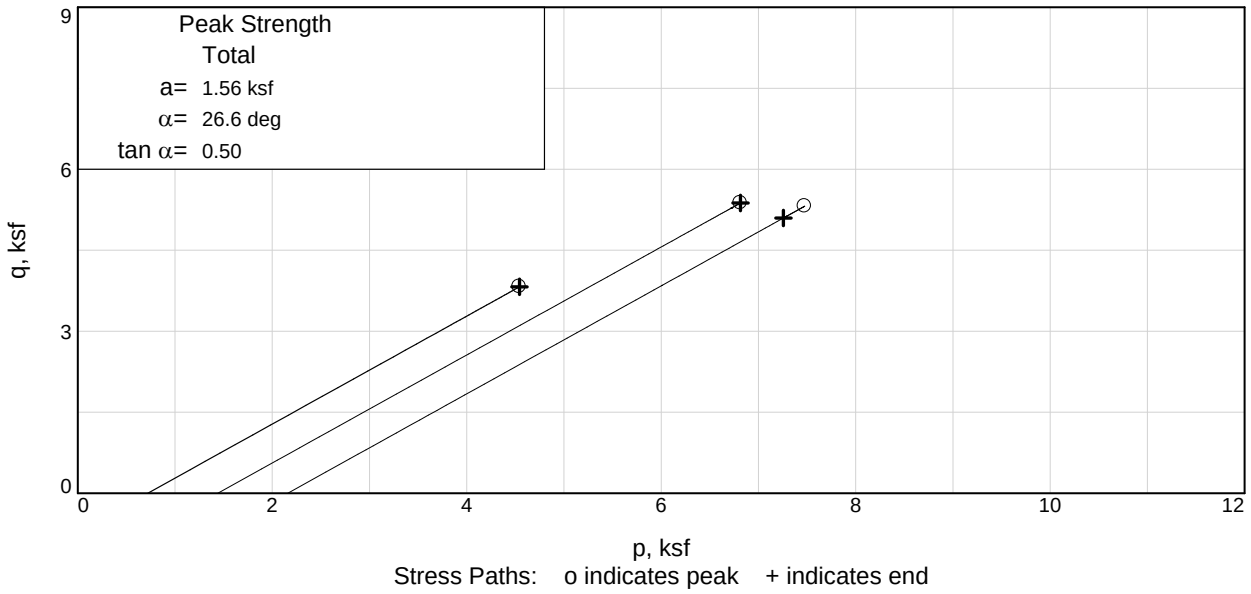
Tested By: KMW **Checked By:** JSR











Stress Paths: o indicates peak + indicates end

Client: Duke Energy

Project: Duke Energy-Embankment Stability

Depth: 16-18' **Sample Number:** AD-1 Res

Project No.: 1356-09-029 Phase 04 **Plate** AD-1 (16-18)

S & ME, INC.

Tested By: KMW **Checked By:** JSR

Form No. TR-D4318-T89-90
Revision No. 0
Revision Date: 11/20/07

Liquid Limit, Plastic Limit, and Plastic Index

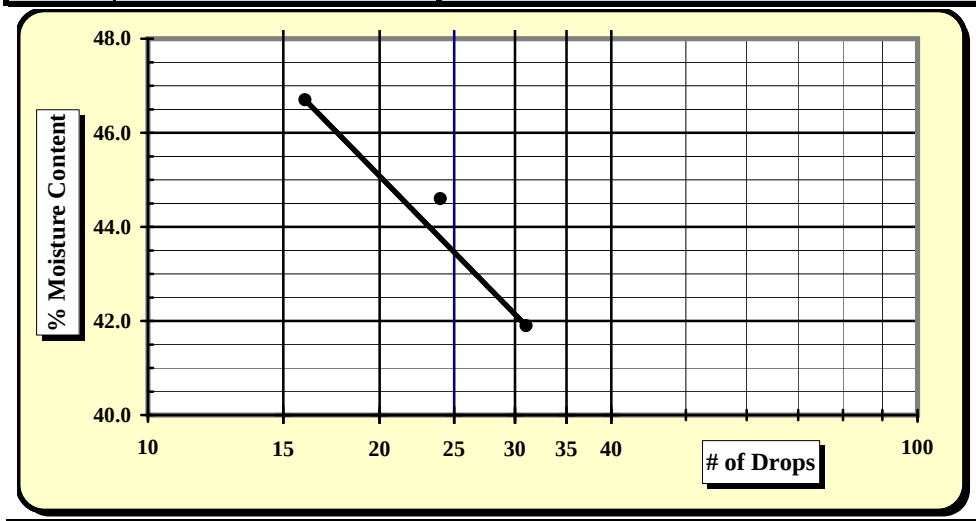
Another code *ASTM D 4318* ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐ ***Quality Assurance***

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	6/23/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s)	6/8-23/10
Client Name:	Duke Energy		
Client Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD-3	Sample #: Fill	Sample Date:
Location:		Offset:	Elevation: 36-38'
Sample Description:	Tan Orange Brown Fine to Coarse Sandy Silt (ML) w/Mica		

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	3996	2/3/2010	Grooving tool	21587	2/28/2010
LL Apparatus	3611	10/20/2009	Grooving tool		
Oven	10844	9/4/2009	Grooving tool		

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	P-4	55	13				SSS	25	
A	Tare Weight	15.92	14.34	13.99				**16.56**	14.35	
B	Wet Soil Weight + A	27.81	23.77	23.64				22.80	20.47	
C	Dry Soil Weight + A	24.30	20.86	20.57				21.35	19.03	
D	Water Weight (B-C)	3.51	2.91	3.07				1.45	1.44	
E	Dry Soil Weight (C-A)	8.38	6.52	6.58				4.79	4.68	
F	% Moisture (D/E)*100	41.9%	44.6%	46.7%				30.3%	30.8%	
N	# OF DROPS	31	24	16				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							**30.6%**		



One Point Liquid Limit			
N	**Factor**	**N**	**Factor**
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☐
Liquid Limit **44**
Plastic Limit **31**
Plastic Index **13**
Group Symbol **ML**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *Estimate the % Retained on the #40 Sieve:*

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Karen Warner — *Technician Name* — *Date*
Jason Reeves — *Technical Responsibility* — *Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D422-2
Revision No. 0
Revision Date: 02/20/08

Particle Size Analysis of Soils

ASTM D 422

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	1356-09-029 Phase 04	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	6/9-22/10
Client Name:	Duke Energy	Address:	3195 Pine Hall Road, Belews Creek, NC 27009
Boring #:	AD-3	Sample #:	Fill
Location:		Offset:	
Sample Description:	Tan Orange Brown Fine to Coarse Sandy Silt (ML) w/Mica		

Pan #:		Beaker #:		Apparent Relative Density	2.606		
Hydrometer Jar #:							
Pan Tare Weight (grams):			Moisture Content	Hygroscopic	Natural		
Total Sample Air Dried Wt. + tare wt. (grams):	229.15		Tare #	P-29			
Weight of Total Sample Air Dried:	229.15	A	Tare Wt.	15.76			
Weight of Air Dried Hydrometer Sample (g):	50.02	B	Wet Wt. + A	26.00			
Total Sample Oven Dried:	226.61	C	Dry Wt. + A	25.88			
Hydrometer Sample Oven Dried (**W**):	49.43	D	Water Wt. (B-C)	0.12			
% Passing #10:	94.6%	E	Dry Wt. (C-A)	10.12			
Correction Factor a (Table 1):	1.01		% Moisture (100 x D/E)	1.19%			

Sieve	Retained Wt.	Percent Passing	
3.0"	0.0	Pan # (washed)	100.0%
1.5"	0.0		100.0%
1.0"	0.0		100.0%
3/4"	0.0		100.0%
1/2"	0.0		100.0%
3/8"	0.0	Soil Mortar	100.0%
#4	4.5		98.0%
#10	12.2	**100.0%**	94.6%
#20	1.6	96.9%	91.7%
#40	3.8	92.2%	87.3%
#60	14.6	70.5%	66.7%
#100	17.1	65.4%	61.9%
#200	20.1	59.4%	56.2%

Description of Sand & Gravel Particles — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Stirring Apparatus: A ☐ B ☐ Dispersion Time: 1 min. Sodium Hexametaphosphate: 40 g./ Liter

Balance: *ID No.* 3996 *Cal. Date:* 2/3/2010 Hydrometer: *ID No.* 3901 *Cal. Date:* 3/26/2010

Control Cylinder ☒ **Composite Correction** ☐ **Type:** **151H** ☐ **152H** ☒

Time	Temp.	Hydrometer	Corrections		Hydrometer	Percent Passing		Effective Depth	Table 3	Diameter
			Control Cylinder	Composite Correction		P(-#10) = (R x a / W) x 100	P (total) = P x % Passing #10			D = K x ((L/T)$^{1/2}$
T (Min.)	(0.5 °C)	Reading			R			L	K	
1	24.0	31.0	5.0		26.00	53.1%	50.3%	12.0	0.01319	0.04574
2	24.0	29.5	5.0		24.50	50.1%	47.4%	12.3	0.01319	0.03267
5	24.0	25.0	5.0		20.00	40.9%	38.7%	13.0	0.01319	0.02128
15	24.0	21.5	5.0		16.50	33.7%	31.9%	13.6	0.01319	0.01255
30	23.5	18.0	5.0		13.00	26.6%	25.1%	14.2	0.01327	0.00912
60	23.5	16.0	5.0		11.00	22.5%	21.3%	14.5	0.01327	0.00652
250	23.0	14.5	5.5		9.00	18.4%	17.4%	14.8	0.01335	0.00325
1440	21.0	11.5	5.5		6.00	12.3%	11.6%	15.3	0.01366	0.00141

References / Comments / Deviations ASTM D 422, D 2487, D 4318

Karen Warner	NICET 117900	Jason Reeves	Senior Engineer	
Technician Name	*Certification #*	*Technical Responsibility*	*Position*	*Date*

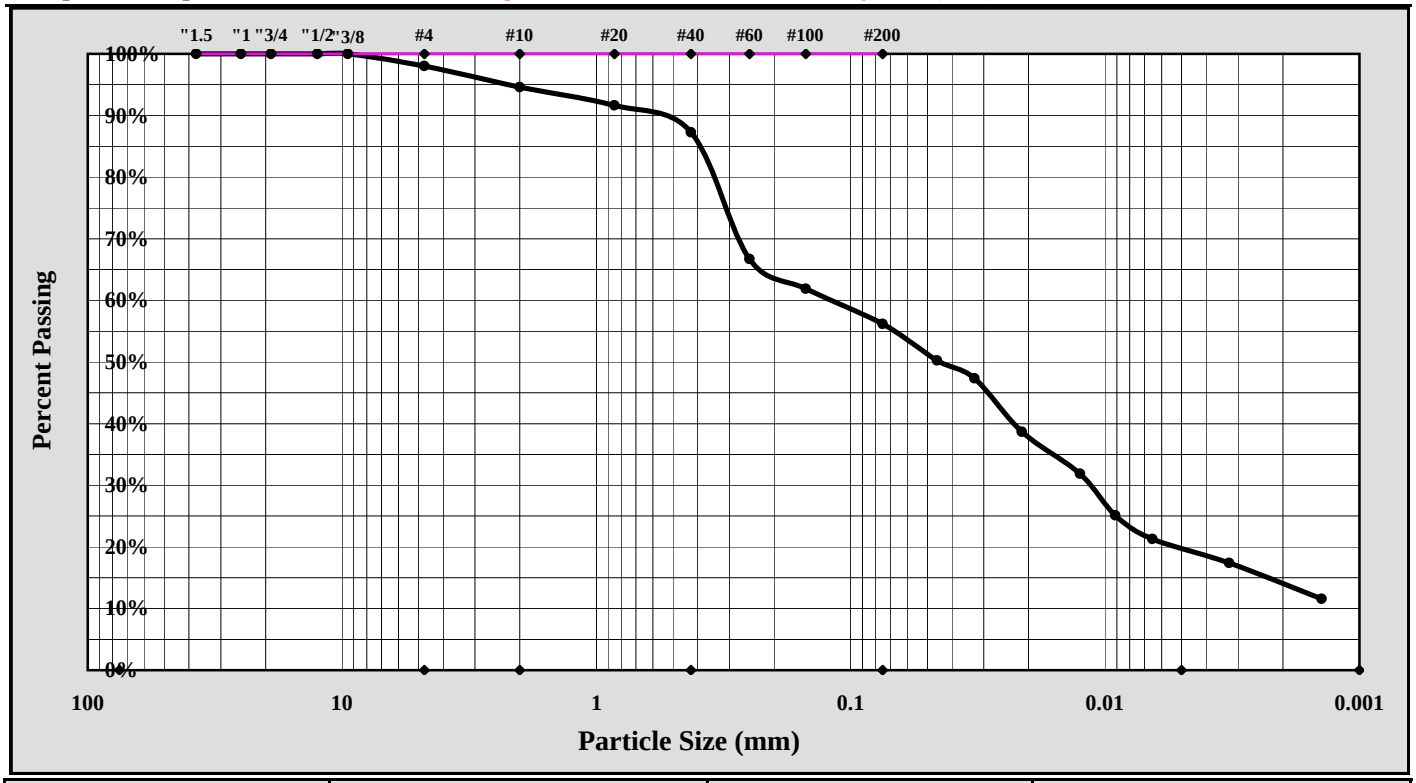
Particle Size Analysis of Soils

ASTM D422

Quality Assurance

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

S&ME Project #:	1356-09-029 Phase 04	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	6/9-22/10
Client Name:	Duke Energy		
Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD-3 Sample #: Fill	Sample Date:	
Location:	Offset:	Elevation:	36-38'
Sample Description:	Tan Orange Brown Fine to Coarse Sandy Silt (ML) w/Mica		



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm (#200)
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Maximum Particle Size:	#4	Gravel:	2.0%	Silt	36.7%
Silt & Clay (% Passing #200):	56.2%	Total Sand:	41.8%	Clay	19.5%
Apparent Relative Density	2.606	Moisture Content		Colloids	9.0%
Liquid Limit	44	Plastic Limit	31	Plastic Index	13
Coarse Sand:	3.4%	Medium Sand:	7.4%	Fine Sand:	31.1%

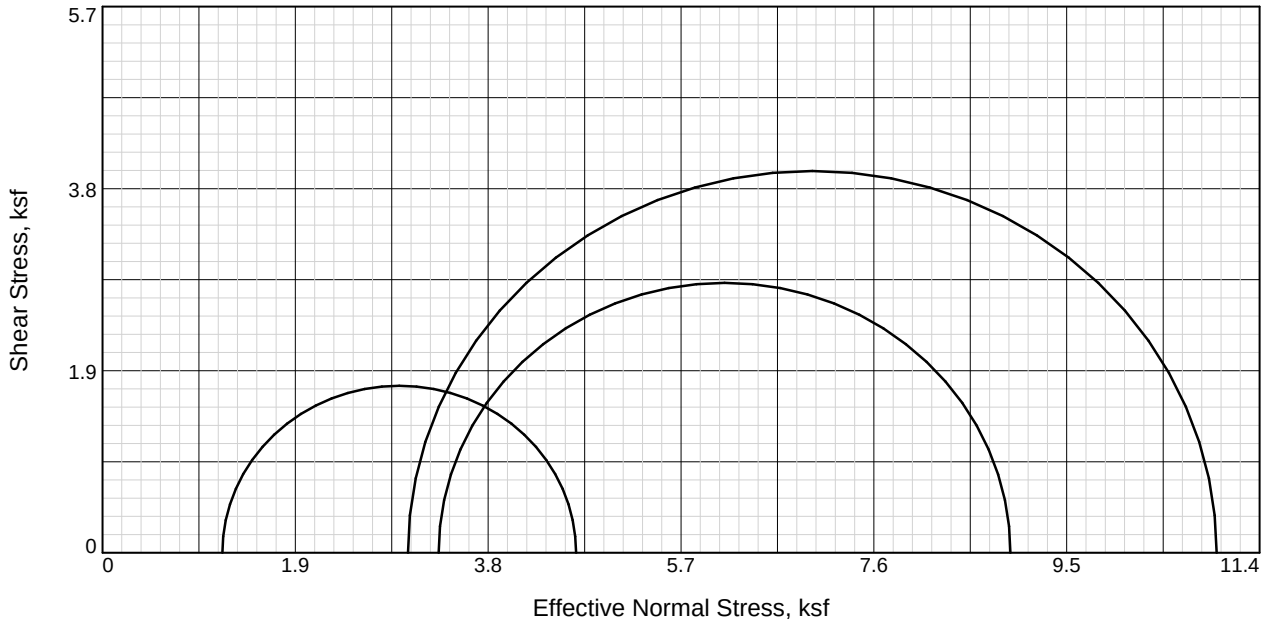
Description of Sand and Gravel: Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

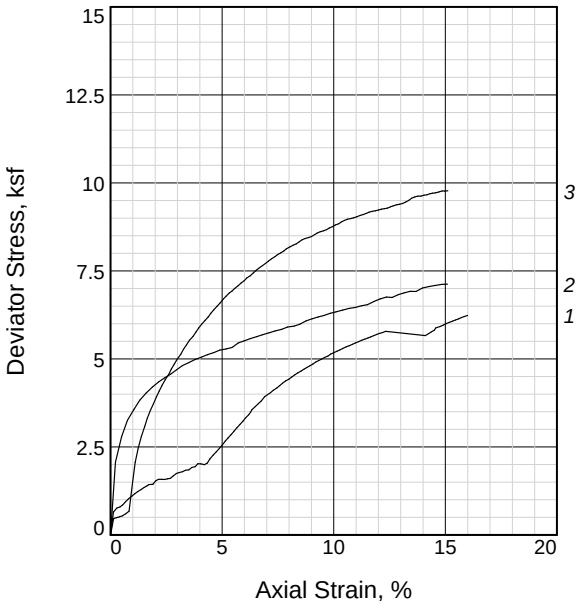
Apparatus B: Air Jet Dispersion — Dispersion Period: 1 min. — Dispersing Agent: Sodium Hexametaphosphate: 40 g./ Liter

References / Comments / Deviations: ASTM D 4318, D 854, D 2487

Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.





Sample No.		1	2	3
Initial	Water Content, %	21.2	17.4	21.8
	Dry Density, pcf	99.5	97.7	102.0
	Saturation, %	86.8	68.4	95.6
	Void Ratio	0.6354	0.6645	0.5954
	Diameter, in.	2.863	2.871	2.854
	Height, in.	5.969	6.031	5.969
At Test	Water Content, %	22.2	18.4	20.0
	Dry Density, pcf	103.0	109.9	106.9
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.5792	0.4805	0.5216
	Diameter, in.	2.830	2.760	2.809
	Height, in.	5.900	5.803	5.876
Strain rate, in./min.		0.004	0.008	0.004
Back Pressure, ksf		10.1	8.6	8.6
Cell Pressure, ksf		13.0	15.8	13.0
Fail. Stress, ksf		3.5	5.6	8.0
Total Pore Pr., ksf		11.8	12.5	10.0
Ult. Stress, ksf				
Total Pore Pr., ksf				
$\bar{\sigma}_1$ Failure, ksf		4.7	8.9	11.0
$\bar{\sigma}_3$ Failure, ksf		1.2	3.3	3.0

Type of Test:
CU with Pore Pressures

Sample Type: Undisturbed

Description: Tan Orange Brown Coarse to Fine Sandy Silt (ML) w/Mica

LL= 44 **PL=** 31 **PI=** 13

Specific Gravity= 2.606

Remarks: Effective Stress Shear Strengths Based on Maximum Principal Stress Ratio

Plate AD-3 (36-38)

Client: Duke Energy

Project: Duke Energy-Embankment Stability

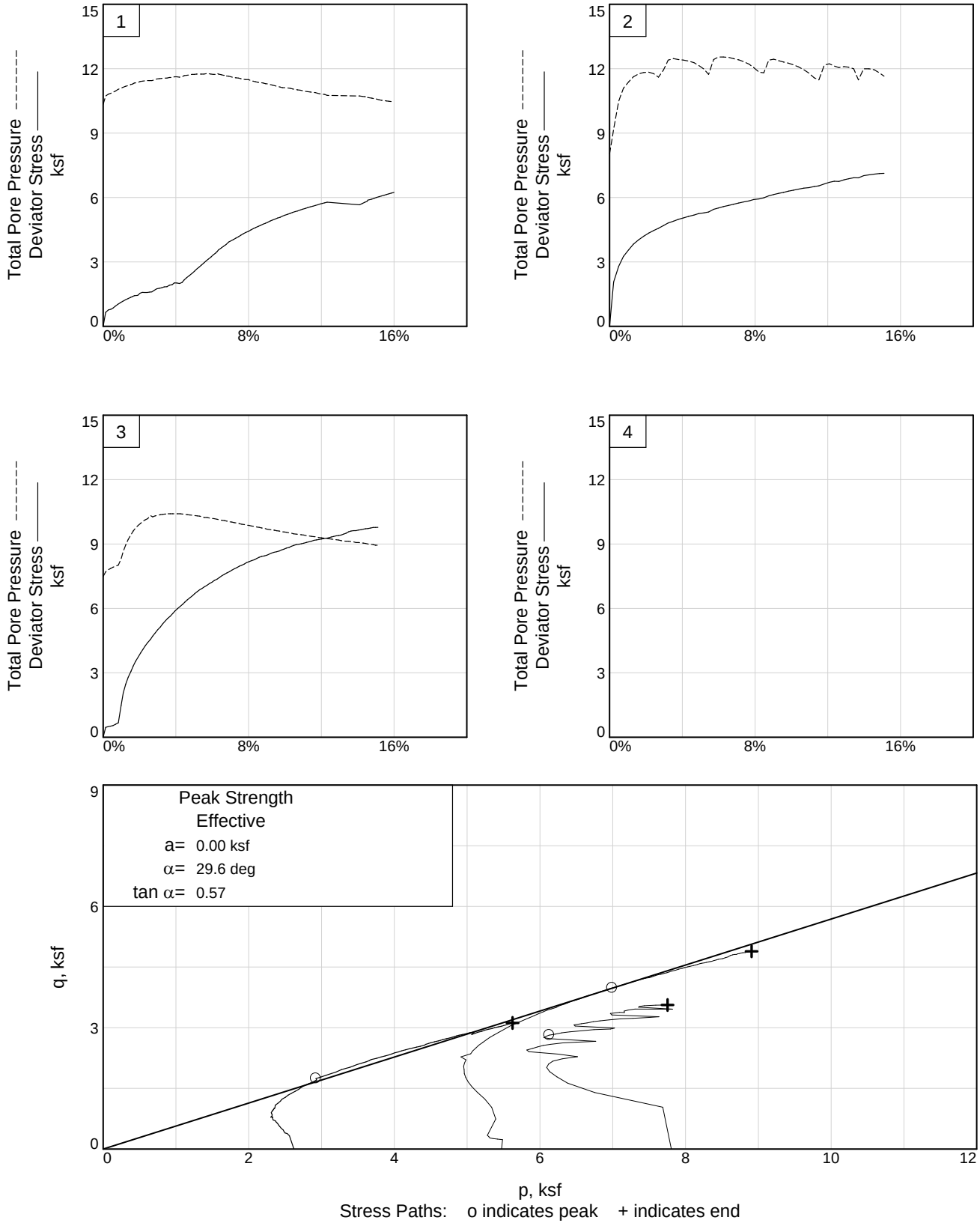
Sample Number: AD-3 Fill **Depth:** 36-38'

Proj. No.: 1356-09-029 Phase 04 **Date Sampled:**

TRIAXIAL SHEAR TEST REPORT

S & ME, INC.

Tested By: KMW **Checked By:** JSR



Client: Duke Energy

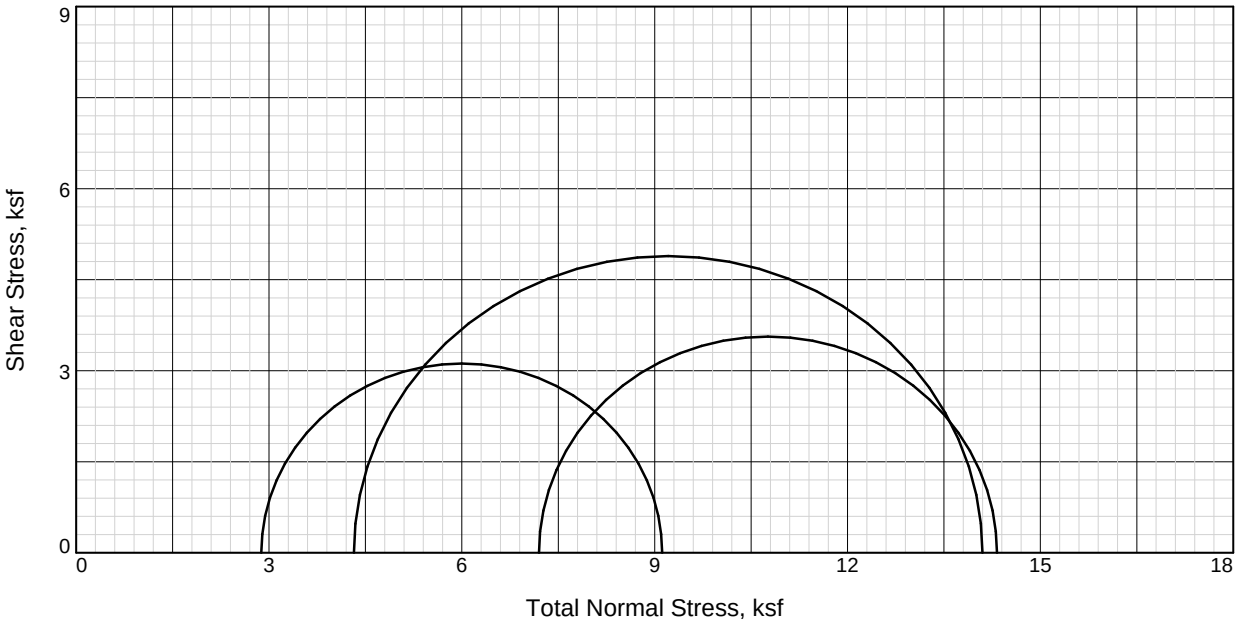
Project: Duke Energy-Embankment Stability

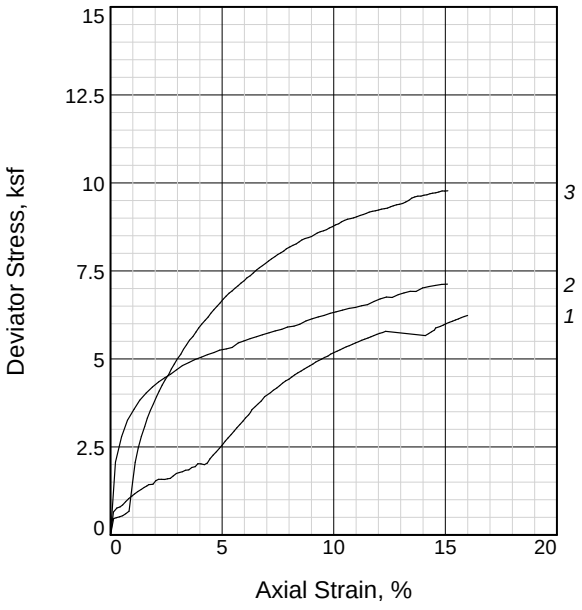
Depth: 36-38' **Sample Number:** AD-3 Fill

Project No.: 1356-09-029 Phase 04 **Plate** AD-3 (36-38)

S & ME, INC.

Tested By: KMW **Checked By:** JSR





Sample No.		1	2	3
Initial	Water Content, %	21.2	17.4	21.8
	Dry Density, pcf	99.5	97.7	102.0
	Saturation, %	86.8	68.4	95.6
	Void Ratio	0.6354	0.6645	0.5954
	Diameter, in.	2.863	2.871	2.854
	Height, in.	5.969	6.031	5.969
At Test	Water Content, %	22.2	18.4	20.0
	Dry Density, pcf	103.0	109.9	106.9
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.5792	0.4805	0.5216
	Diameter, in.	2.830	2.760	2.809
	Height, in.	5.900	5.803	5.876
Strain rate, in./min.		0.004	0.008	0.004
Back Pressure, ksf		10.1	8.6	8.6
Cell Pressure, ksf		13.0	15.8	13.0
Fail. Stress, ksf		6.2	7.1	9.8
Total Pore Pr., ksf		10.5	11.6	8.9
Ult. Stress, ksf				
Total Pore Pr., ksf				
$\bar{\sigma}_1$ Failure, ksf		8.7	11.3	13.8
$\bar{\sigma}_3$ Failure, ksf		2.5	4.2	4.0

Type of Test:
CU with Pore Pressures

Sample Type: Undisturbed

Description: Tan Orange Brown Coarse to Fine Sandy Silt (ML) w/Mica

LL= 44 **PL=** 31 **PI=** 13

Specific Gravity= 2.606

Remarks: Total Stress Shear Strengths Based on Maximum Deviator Stress

Plate AD-3 (36-38)

Client: Duke Energy

Project: Duke Energy-Embankment Stability

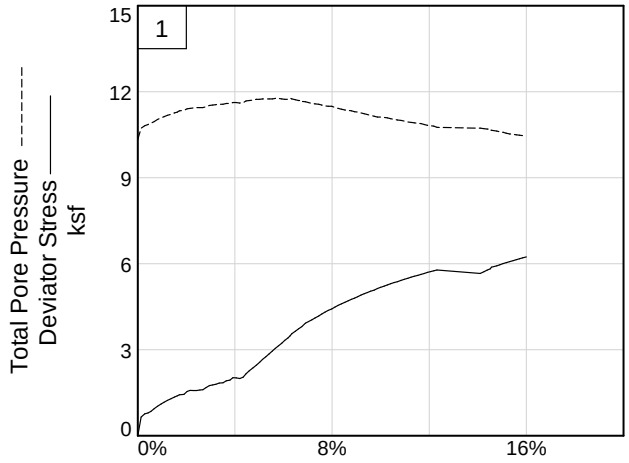
Sample Number: AD-3 Fill **Depth:** 36-38'

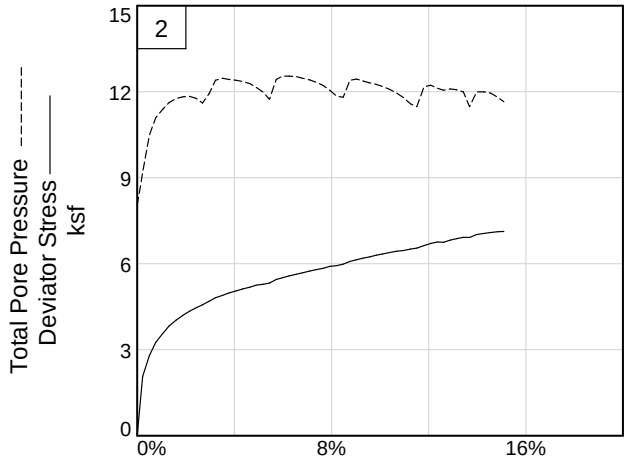
Proj. No.: 1356-09-029 Phase 04 **Date Sampled:**

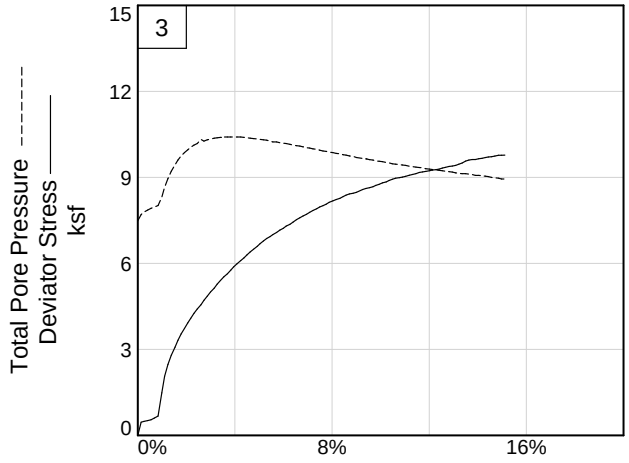
TRIAXIAL SHEAR TEST REPORT

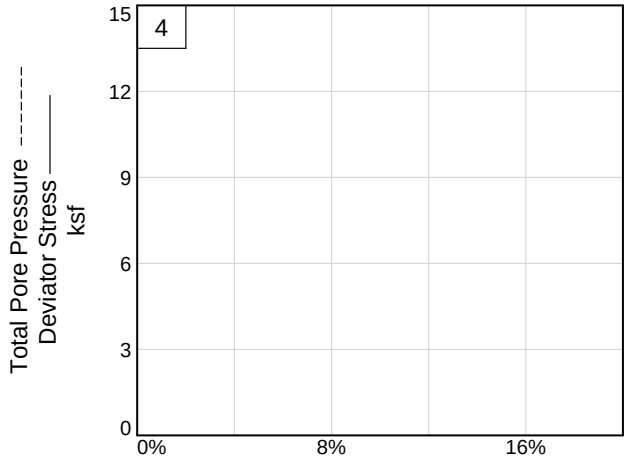
S & ME, INC.

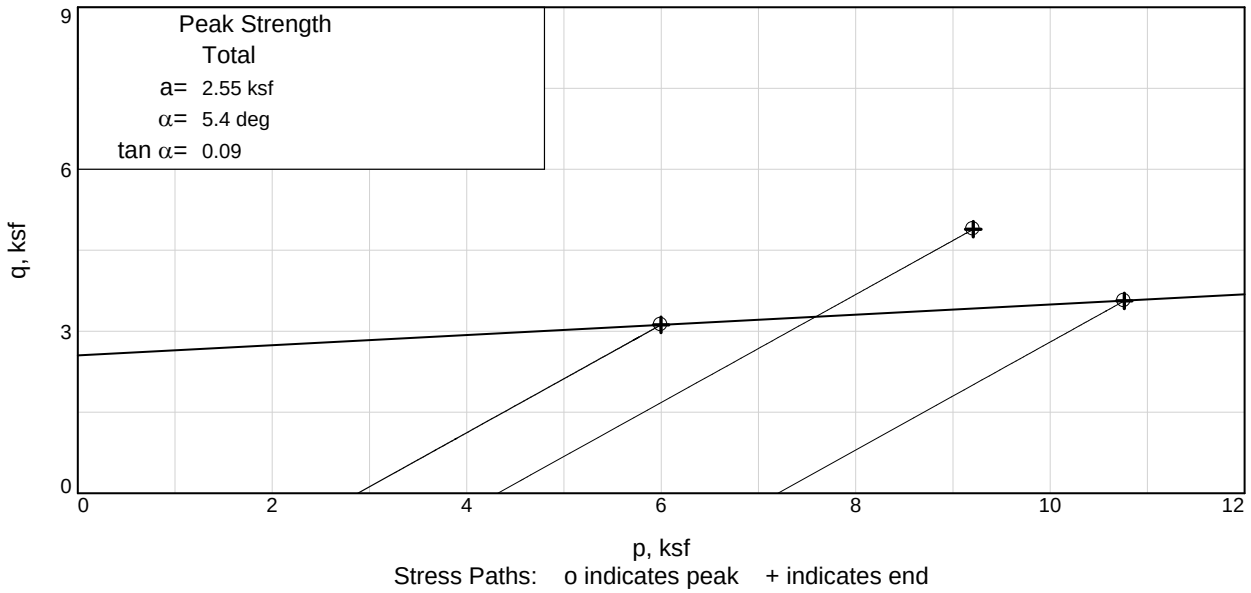
Tested By: KMW **Checked By:** JSR











Client: Duke Energy
Project: Duke Energy-Embankment Stability
Depth: 36-38' **Sample Number:** AD-3 Fill
Project No.: 1356-09-029 Phase 04 **Plate** AD-3 (36-38)

S & ME, INC.

Tested By: KMW **Checked By:** JSR

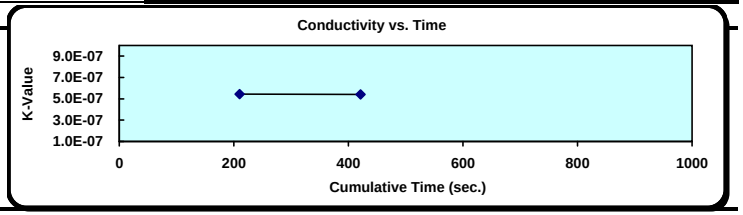
S&ME

Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter (Method "F")

Project #:	1356-09-029	Phase 04		Test Date(s):	6/18-19/20
Project Name:	Duke Energy - BCSS Embankment Stability			Report Date:	6/20/10
Client Name:	Duke Energy			Sample Date:	
Client Address:				Panel ID:	15
Boring #:	AD-3	Sample #: Fill	Depth: 36-38'	Perm Cell ID:	
Location:		Offset:	Sample Description: Tan Orange Brown Fine to Coarse Sandy Silt (ML) w/Mica		
Liquid Limit:	44	Sp. Grav. (Assumed): 2.606	Sample Type: Undisturbed	Log #:	
Plastic Limit:	31	Plastic Index: 13	Percent Passing #200: 56.2	Maximum Particle Size:	

Initial Sample Conditions				Final Sample Conditions			
Length (cm):	15.161	Wet Density (PCF):	124.2	Length (cm):	15.161	Wet Density (PCF):	124.2
Diameter (cm):	7.249	Dry Density (PCF):	102.0	Diameter (cm):	7.25	Dry Density (PCF):	102.0
Area (cm^2)	41.27	Percent Saturation:	95.5	Area (cm^2)	41.27	Percent Saturation:	95.5
Volume (cm^3)	625.75			Volume (cm^3)	625.72	B-Parameter:	0.96
Wet weight (grams)	1245.3	Void Ratio:	0.595	Wet weight (grams)	1245.3	Void Ratio:	0.595
Dry Weight (grams)	1022.4	Porosity:	0.373	Dry Weight (grams)	1022.4	Porosity:	0.373
Percent Moisture:	21.8			Percent Moisture:	21.8		
Test Parameters:	Effective Consolidation Stress (psi):		30.0	Permeant Liquid Used:	Deaired Water	a_{in} (cm^2)	0.031416
Hg Equilibrium Level	1.990	Cell Pressure (psi):	90.0	Back Pressure (psi):	60.0	a_{out} (cm^2)	0.76712

Time (24-hr)			Temperature (°C)				Measurements						Initial Gradient	Final Gradient	K-Value (cm/sec)	
Start	End	Time (sec)	Initial	Final	Ave.	Factor	Rp1	Ra1	Rp2	Ra2	h1	h2			Uncorrected K-Value	Corrected K-Value
12:39	12:42	210	23.1	23.1	23.1	0.9290	7.50	1.90	6.80	1.90	70.4	61.6	4.64	4.06	5.85E-07	5.44E-07
12:43	12:47	211	23.1	23.1	23.1	0.9290	7.50	1.90	6.80	1.89	70.4	61.7	4.64	4.07	5.82E-07	5.41E-07
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
					#DIV/0!	#DIV/0!					0.0	0.0	0.00	0.00		
Notes:	Permometer P700000 byTrautwein Soil Testing was used for permeation.											Averages:	0.62	0.54	5.84E-07	5.4E-07



References:

ASTM D 5084: Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

ASTM D 2216: Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

Technician: Karen Warner

Technical Responsibility: Jason Reeves Position: Senior Engineer

signature

TRIAXIAL COMPRESSION TEST 7/16/2010

CU with Pore Pressures 12:34 PM

Date:
Client: Duke Energy
Project: Duke Energy-Embankment Stability
Project No.: 1356-09-029 Phase 04
Depth: 36-38' **Sample Number:** AD-3 Fill
Description: Tan Orange Brown Coarse to Fine Sandy Silt (ML) w/Mica
Remarks:
Type of Sample: Undisturbed
Specific Gravity=2.606 **LL=**44 **PL=**31 **PI=**13
Test Method: COE uniform strain

Parameters for Specimen No. 1

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	201.900			1068.900
Moisture content: Dry soil+tare, gms.	180.980			877.300
Moisture content: Tare, gms.	82.100			86.800
Moisture, %	21.2	23.5	22.2	24.2
Moist specimen weight, gms.	1215.70			
Diameter, in.	2.863	2.850	2.830	
Area, in.²	6.438	6.377	6.289	
Height, in.	5.969	5.941	5.900	
Net decrease in height, in.		0.028	0.041	
Wet Density, pcf	120.5	124.6	125.9	
Dry density, pcf	99.5	100.9	103.0	
Void ratio	0.6354	0.6125	0.5792	
Saturation, %	86.8	100.0	100.0	

Test Readings for Specimen No. 1

Consolidation cell pressure = 90.00 psi (12.96 ksf)
Consolidation back pressure = 70.00 psi (10.08 ksf)
Consolidation effective confining stress = 2.88 ksf
Strain rate, in./min. = 0.004
Fail. Stress = 3.49 ksf **at reading no.** 47

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
0	0.0020	20.100	0.0	0.0	0.00	2.62	2.62	1.00	71.80	2.62	0.00
1	0.0100	48.700	28.6	0.1	0.65	2.23	2.89	1.29	74.50	2.56	0.33
2	0.0190	53.600	33.5	0.3	0.76	2.15	2.91	1.36	75.10	2.53	0.38
3	0.0270	55.000	34.9	0.4	0.80	2.10	2.90	1.38	75.40	2.50	0.40
4	0.0340	57.600	37.5	0.5	0.85	2.06	2.91	1.41	75.70	2.49	0.43
5	0.0420	61.600	41.5	0.7	0.94	2.00	2.95	1.47	76.10	2.47	0.47
6	0.0500	65.500	45.4	0.8	1.03	1.93	2.96	1.53	76.60	2.45	0.52
7	0.0590	69.100	49.0	1.0	1.11	1.87	2.98	1.59	77.00	2.43	0.56
8	0.0660	71.700	51.6	1.1	1.17	1.83	3.00	1.64	77.30	2.41	0.58
9	0.0740	74.600	54.5	1.2	1.23	1.79	3.02	1.69	77.60	2.40	0.62
10	0.0830	77.400	57.3	1.4	1.29	1.74	3.04	1.74	77.90	2.39	0.65
11	0.0910	79.900	59.8	1.5	1.35	1.70	3.05	1.79	78.20	2.37	0.67
12	0.0980	81.900	61.8	1.6	1.39	1.67	3.06	1.83	78.40	2.37	0.70
13	0.1030	83.600	63.5	1.7	1.43	1.63	3.06	1.88	78.70	2.34	0.71
14	0.1140	84.300	64.2	1.9	1.44	1.61	3.05	1.89	78.80	2.33	0.72
15	0.1220	88.900	68.8	2.0	1.54	1.56	3.10	1.99	79.20	2.33	0.77
16	0.1290	90.700	70.6	2.2	1.58	1.54	3.12	2.03	79.30	2.33	0.79
17	0.1370	90.700	70.6	2.3	1.58	1.53	3.11	2.03	79.40	2.32	0.79
18	0.1450	90.700	70.6	2.4	1.58	1.51	3.09	2.04	79.50	2.30	0.79
19	0.1530	91.600	71.5	2.6	1.60	1.51	3.11	2.06	79.50	2.31	0.80
20	0.1600	92.200	72.1	2.7	1.61	1.51	3.12	2.06	79.50	2.32	0.80
21	0.1680	95.600	75.5	2.8	1.68	1.48	3.16	2.13	79.70	2.32	0.84
22	0.1760	98.800	78.7	2.9	1.75	1.44	3.19	2.21	80.00	2.31	0.87
23	0.1840	100.000	79.9	3.1	1.77	1.43	3.20	2.24	80.10	2.31	0.89
24	0.1920	101.100	81.0	3.2	1.79	1.41	3.21	2.27	80.20	2.31	0.90
25	0.2000	103.200	83.1	3.4	1.84	1.40	3.24	2.32	80.30	2.32	0.92
26	0.2090	103.800	83.7	3.5	1.85	1.40	3.25	2.32	80.30	2.32	0.92
27	0.2170	107.100	87.0	3.6	1.92	1.37	3.29	2.40	80.50	2.33	0.96
28	0.2260	108.200	88.1	3.8	1.94	1.37	3.31	2.42	80.50	2.34	0.97
29	0.2330	112.100	92.0	3.9	2.02	1.34	3.36	2.51	80.70	2.35	1.01
30	0.2410	112.000	91.9	4.1	2.02	1.34	3.36	2.51	80.70	2.35	1.01
31	0.2500	111.100	91.0	4.2	2.00	1.35	3.35	2.47	80.60	2.35	1.00
32	0.2580	113.300	93.2	4.3	2.04	1.34	3.38	2.52	80.70	2.36	1.02
33	0.2650	119.100	99.0	4.5	2.17	1.28	3.45	2.69	81.10	2.36	1.08
34	0.2730	123.900	103.8	4.6	2.27	1.27	3.53	2.79	81.20	2.40	1.13
35	0.2820	128.600	108.5	4.7	2.37	1.25	3.62	2.89	81.30	2.44	1.18
36	0.2900	133.200	113.1	4.9	2.46	1.22	3.69	3.01	81.50	2.46	1.23
37	0.2980	138.000	117.9	5.0	2.56	1.22	3.79	3.09	81.50	2.51	1.28
38	0.3050	142.700	122.6	5.1	2.66	1.21	3.87	3.20	81.60	2.54	1.33
39	0.3130	147.200	127.1	5.3	2.76	1.21	3.97	3.28	81.60	2.59	1.38
40	0.3210	151.900	131.8	5.4	2.85	1.21	4.06	3.36	81.60	2.64	1.43
41	0.3290	156.800	136.7	5.5	2.96	1.21	4.17	3.44	81.60	2.69	1.48
42	0.3360	161.200	141.1	5.7	3.05	1.20	4.24	3.55	81.70	2.72	1.52
43	0.3440	165.600	145.5	5.8	3.14	1.20	4.33	3.63	81.70	2.76	1.57
44	0.3520	170.100	150.0	5.9	3.23	1.21	4.44	3.67	81.60	2.83	1.62
45	0.3590	174.800	154.7	6.1	3.33	1.22	4.55	3.72	81.50	2.89	1.66
46	0.3670	179.100	159.0	6.2	3.42	1.22	4.64	3.79	81.50	2.93	1.71

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
47	0.3720	182.500	162.4	6.3	3.49	1.18	4.67	3.95	81.80	2.92	1.74
48	0.3761	186.100	166.0	6.3	3.56	1.21	4.77	3.94	81.60	2.99	1.78
49	0.3849	190.500	170.4	6.5	3.65	1.24	4.89	3.95	81.40	3.06	1.82
50	0.3927	194.700	174.6	6.6	3.73	1.27	5.00	3.95	81.20	3.13	1.87
51	0.4004	198.300	178.2	6.8	3.80	1.30	5.10	3.94	81.00	3.20	1.90
52	0.4093	204.400	184.3	6.9	3.93	1.31	5.24	4.00	80.90	3.27	1.96
53	0.4248	210.300	190.2	7.2	4.04	1.37	5.41	3.96	80.50	3.39	2.02
54	0.4325	213.700	193.6	7.3	4.11	1.38	5.49	3.97	80.40	3.44	2.05
55	0.4415	217.200	197.1	7.4	4.18	1.40	5.57	3.99	80.30	3.49	2.09
56	0.4491	220.700	200.6	7.6	4.25	1.43	5.67	3.98	80.10	3.55	2.12
57	0.4568	224.100	204.0	7.7	4.31	1.45	5.77	3.96	79.90	3.61	2.16
58	0.4646	227.400	207.3	7.8	4.37	1.47	5.84	3.98	79.80	3.66	2.19
59	0.4734	230.100	210.0	8.0	4.42	1.47	5.89	4.01	79.80	3.68	2.21
60	0.4812	233.500	213.4	8.1	4.49	1.51	6.00	3.97	79.50	3.76	2.24
61	0.4889	236.700	216.6	8.3	4.55	1.54	6.09	3.95	79.30	3.82	2.28
62	0.4967	239.500	219.4	8.4	4.60	1.57	6.17	3.93	79.10	3.87	2.30
63	0.5055	242.400	222.3	8.5	4.66	1.60	6.25	3.91	78.90	3.93	2.33
64	0.5133	245.200	225.1	8.7	4.71	1.61	6.32	3.92	78.80	3.97	2.35
65	0.5210	247.900	227.8	8.8	4.76	1.63	6.38	3.92	78.70	4.01	2.38
66	0.5287	250.400	230.3	8.9	4.80	1.66	6.46	3.90	78.50	4.06	2.40
67	0.5365	253.200	233.1	9.1	4.85	1.67	6.52	3.91	78.40	4.10	2.43
68	0.5442	256.200	236.1	9.2	4.91	1.70	6.61	3.89	78.20	4.15	2.45
69	0.5520	258.800	238.7	9.3	4.96	1.73	6.68	3.87	78.00	4.21	2.48
70	0.5597	261.000	240.9	9.5	4.99	1.76	6.75	3.84	77.80	4.25	2.50
71	0.5675	263.600	243.5	9.6	5.04	1.79	6.83	3.82	77.60	4.31	2.52
72	0.5763	265.900	245.8	9.7	5.08	1.81	6.89	3.80	77.40	4.35	2.54
73	0.5840	269.000	248.9	9.9	5.14	1.84	6.98	3.79	77.20	4.41	2.57
74	0.5918	271.400	251.3	10.0	5.18	1.84	7.02	3.81	77.20	4.43	2.59
75	0.6006	273.800	253.7	10.1	5.22	1.86	7.08	3.81	77.10	4.47	2.61
76	0.6084	276.100	256.0	10.3	5.26	1.87	7.13	3.81	77.00	4.50	2.63
77	0.6161	278.500	258.4	10.4	5.30	1.90	7.20	3.79	76.80	4.55	2.65
78	0.6250	281.200	261.1	10.6	5.35	1.93	7.28	3.77	76.60	4.60	2.67
79	0.6327	282.900	262.8	10.7	5.37	1.94	7.32	3.76	76.50	4.63	2.69
80	0.6416	285.500	265.4	10.8	5.42	1.96	7.38	3.77	76.40	4.67	2.71
81	0.6493	287.700	267.6	11.0	5.46	1.99	7.44	3.75	76.20	4.71	2.73
82	0.6582	290.100	270.0	11.1	5.49	2.02	7.51	3.73	76.00	4.76	2.75
83	0.6659	292.300	272.2	11.3	5.53	2.03	7.56	3.72	75.90	4.80	2.77
84	0.6736	294.200	274.1	11.4	5.56	2.04	7.61	3.72	75.80	4.83	2.78
85	0.6825	296.400	276.3	11.5	5.60	2.06	7.66	3.72	75.70	4.86	2.80
86	0.6902	298.400	278.3	11.7	5.63	2.07	7.70	3.71	75.60	4.89	2.81
87	0.6980	300.500	280.4	11.8	5.66	2.10	7.77	3.69	75.40	4.93	2.83
88	0.7057	302.700	282.6	11.9	5.70	2.13	7.83	3.67	75.20	4.98	2.85
89	0.7135	304.500	284.4	12.1	5.73	2.15	7.87	3.67	75.10	5.01	2.86
90	0.7212	306.200	286.1	12.2	5.75	2.16	7.91	3.66	75.00	5.04	2.88
91	0.7290	308.200	288.1	12.3	5.78	2.20	7.99	3.63	74.70	5.10	2.89
92	0.8340	308.000	287.9	14.1	5.66	2.23	7.89	3.54	74.50	5.06	2.83
93	0.8429	311.500	291.4	14.3	5.72	2.25	7.97	3.55	74.40	5.11	2.86

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
94	0.8506	314.700	294.6	14.4	5.78	2.26	8.04	3.55	74.30	5.15	2.89
95	0.8584	317.600	297.5	14.5	5.82	2.29	8.11	3.54	74.10	5.20	2.91
96	0.8611	320.600	300.5	14.6	5.88	2.30	8.18	3.55	74.00	5.24	2.94
97	0.8739	323.800	303.7	14.8	5.93	2.33	8.26	3.54	73.80	5.30	2.96
98	0.8816	326.100	306.0	14.9	5.96	2.36	8.32	3.52	73.60	5.34	2.98
99	0.8893	328.700	308.6	15.0	6.00	2.38	8.38	3.53	73.50	5.38	3.00
100	0.8971	331.000	310.9	15.2	6.04	2.40	8.44	3.51	73.30	5.42	3.02
101	0.9059	333.400	313.3	15.3	6.07	2.43	8.51	3.50	73.10	5.47	3.04
102	0.9137	335.500	315.4	15.5	6.11	2.45	8.55	3.49	73.00	5.50	3.05
103	0.9214	337.700	317.6	15.6	6.14	2.46	8.60	3.49	72.90	5.53	3.07
104	0.9292	340.000	319.9	15.7	6.17	2.48	8.65	3.49	72.80	5.56	3.09
105	0.9369	342.100	322.0	15.8	6.20	2.49	8.70	3.49	72.70	5.59	3.10
106	0.9458	344.300	324.2	16.0	6.24	2.51	8.74	3.49	72.60	5.62	3.12

Parameters for Specimen No. 2

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	198.480			1409.200
Moisture content: Dry soil+tare, gms.	181.200			1175.500
Moisture content: Tare, gms.	82.120			160.770
Moisture, %	17.4	24.6	18.4	23.0
Moist specimen weight, gms.	1176.40			
Diameter, in.	2.871	2.857	2.760	
Area, in.²	6.474	6.411	5.984	
Height, in.	6.031	6.002	5.803	
Net decrease in height, in.		0.029	0.199	
Wet Density, pcf	114.8	123.5	130.1	
Dry density, pcf	97.7	99.2	109.9	
Void ratio	0.6645	0.6406	0.4805	
Saturation, %	68.4	100.0	100.0	

Test Readings for Specimen No. 2

Consolidation cell pressure = 110.00 psi (15.84 ksf)
Consolidation back pressure = 60.00 psi (8.64 ksf)
Consolidation effective confining stress = 7.20 ksf
Strain rate, in./min. = 0.008
Fail. Stress = 5.63 ksf **at reading no.** 24

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
0	0.0010	20.300	0.0	0.0	0.00	7.80	7.80	1.00	55.80	7.80	0.00
1	0.0140	106.500	86.2	0.2	2.07	6.65	8.72	1.31	63.80	7.69	1.03
2	0.0300	137.000	116.7	0.5	2.79	5.36	8.15	1.52	72.80	6.75	1.40
3	0.0450	156.700	136.4	0.8	3.26	4.75	8.01	1.69	77.00	6.38	1.63
4	0.0620	170.200	149.9	1.1	3.57	4.45	8.02	1.80	79.10	6.23	1.78
5	0.0770	181.500	161.2	1.3	3.83	4.22	8.05	1.91	80.70	6.13	1.91
6	0.0940	190.700	170.4	1.6	4.03	4.08	8.11	1.99	81.70	6.09	2.02
7	0.1100	198.200	177.9	1.9	4.20	4.02	8.22	2.05	82.10	6.12	2.10
8	0.1260	204.900	184.6	2.2	4.35	4.00	8.35	2.09	82.20	6.18	2.17
9	0.1420	210.500	190.2	2.4	4.47	4.08	8.54	2.10	81.70	6.31	2.23

Test Readings for Specimen No. 2

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
10	0.1570	215.300	195.0	2.7	4.57	4.23	8.80	2.08	80.60	6.52	2.28
11	0.1730	221.300	201.0	3.0	4.69	3.90	8.60	2.20	82.90	6.25	2.35
12	0.1880	227.000	206.7	3.2	4.81	3.44	8.26	2.40	86.10	5.85	2.41
13	0.2050	231.300	211.0	3.5	4.90	3.37	8.27	2.45	86.60	5.82	2.45
14	0.2200	235.500	215.2	3.8	4.98	3.41	8.40	2.46	86.30	5.90	2.49
15	0.2370	239.100	218.8	4.1	5.05	3.44	8.49	2.47	86.10	5.97	2.53
16	0.2530	242.900	222.6	4.3	5.12	3.48	8.61	2.47	85.80	6.05	2.56
17	0.2700	246.100	225.8	4.6	5.18	3.56	8.74	2.46	85.30	6.15	2.59
18	0.2850	249.700	229.4	4.9	5.25	3.69	8.94	2.42	84.40	6.31	2.62
19	0.3020	251.900	231.6	5.2	5.28	3.86	9.14	2.37	83.20	6.50	2.64
20	0.3170	254.400	234.1	5.4	5.33	4.10	9.43	2.30	81.50	6.77	2.66
21	0.3330	260.700	240.4	5.7	5.45	3.41	8.87	2.60	86.30	6.14	2.73
22	0.3480	263.900	243.6	6.0	5.51	3.30	8.81	2.67	87.10	6.05	2.76
23	0.3640	267.600	247.3	6.3	5.58	3.30	8.88	2.69	87.10	6.09	2.79
24	0.3810	270.800	250.5	6.5	5.63	3.31	8.95	2.70	87.00	6.13	2.82
25	0.3960	273.800	253.5	6.8	5.68	3.37	9.05	2.69	86.60	6.21	2.84
26	0.4130	277.300	257.0	7.1	5.75	3.43	9.17	2.68	86.20	6.30	2.87
27	0.4290	280.300	260.0	7.4	5.79	3.51	9.31	2.65	85.60	6.41	2.90
28	0.4460	283.200	262.9	7.7	5.84	3.63	9.47	2.61	84.80	6.55	2.92
29	0.4610	286.900	266.6	7.9	5.91	3.79	9.69	2.56	83.70	6.74	2.95
30	0.4780	289.000	268.7	8.2	5.93	4.00	9.94	2.48	82.20	6.97	2.97
31	0.4930	292.100	271.8	8.5	5.99	4.03	10.02	2.48	82.00	7.02	2.99
32	0.5090	297.300	277.0	8.8	6.08	3.44	9.52	2.77	86.10	6.48	3.04
33	0.5250	300.800	280.5	9.0	6.14	3.40	9.54	2.81	86.40	6.47	3.07
34	0.5410	304.200	283.9	9.3	6.20	3.47	9.67	2.79	85.90	6.57	3.10
35	0.5560	306.900	286.6	9.6	6.24	3.53	9.76	2.77	85.50	6.65	3.12
36	0.5720	310.600	290.3	9.8	6.30	3.59	9.88	2.76	85.10	6.73	3.15
37	0.5870	313.300	293.0	10.1	6.34	3.66	10.00	2.73	84.60	6.83	3.17
38	0.6040	316.600	296.3	10.4	6.39	3.76	10.15	2.70	83.90	6.95	3.19
39	0.6210	319.800	299.5	10.7	6.44	3.89	10.32	2.66	83.00	7.11	3.22
40	0.6370	321.900	301.6	11.0	6.46	4.05	10.51	2.60	81.90	7.28	3.23
41	0.6540	325.200	304.9	11.3	6.51	4.26	10.77	2.53	80.40	7.52	3.26
42	0.6690	327.600	307.3	11.5	6.54	4.36	10.91	2.50	79.70	7.63	3.27
43	0.6860	332.800	312.5	11.8	6.63	3.67	10.30	2.81	84.50	6.99	3.32
44	0.7020	337.300	317.0	12.1	6.71	3.61	10.32	2.86	84.90	6.97	3.35
45	0.7180	340.800	320.5	12.4	6.76	3.72	10.47	2.82	84.20	7.09	3.38
46	0.7330	341.200	320.9	12.6	6.75	3.79	10.53	2.78	83.70	7.16	3.37
47	0.7490	345.900	325.6	12.9	6.83	3.74	10.57	2.82	84.00	7.16	3.41
48	0.7640	349.300	329.0	13.1	6.88	3.77	10.65	2.82	83.80	7.21	3.44
49	0.7800	352.500	332.2	13.4	6.92	3.84	10.77	2.80	83.30	7.31	3.46
50	0.7950	353.300	333.0	13.7	6.92	4.36	11.28	2.59	79.70	7.82	3.46
51	0.8120	359.300	339.0	14.0	7.02	3.84	10.86	2.83	83.30	7.35	3.51
52	0.8290	362.400	342.1	14.3	7.06	3.84	10.90	2.84	83.30	7.37	3.53
53	0.8450	365.000	344.7	14.5	7.09	3.89	10.98	2.82	83.00	7.43	3.54
54	0.8620	367.600	347.3	14.8	7.12	4.03	11.15	2.77	82.00	7.59	3.56
55	0.8770	369.000	348.7	15.1	7.12	4.19	11.31	2.70	80.90	7.75	3.56

Parameters for Specimen No. 3

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	199.600			1166.900
Moisture content: Dry soil+tare, gms.	178.400			975.300
Moisture content: Tare, gms.	81.300			75.040
Moisture, %	21.8	22.3	20.0	21.3
Moist specimen weight, gms.	1245.30			
Diameter, in.	2.854	2.845	2.809	
Area, in.²	6.397	6.357	6.198	
Height, in.	5.969	5.950	5.876	
Net decrease in height, in.		0.019	0.074	
Wet Density, pcf	124.2	125.9	128.3	
Dry density, pcf	102.0	103.0	106.9	
Void ratio	0.5954	0.5802	0.5216	
Saturation, %	95.6	100.0	100.0	

Test Readings for Specimen No. 3

Consolidation cell pressure = 90.00 psi (12.96 ksf)
Consolidation back pressure = 60.00 psi (8.64 ksf)
Consolidation effective confining stress = 4.32 ksf
Strain rate, in./min. = 0.004
Fail. Stress = 7.97 ksf **at reading no.** 55

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
0	0.0000	20.300	0.0	0.0	0.00	5.47	5.47	1.00	52.00	5.47	0.00
1	0.0080	40.200	19.9	0.1	0.46	5.26	5.72	1.09	53.50	5.49	0.23
2	0.0150	41.500	21.2	0.3	0.49	5.17	5.66	1.10	54.10	5.42	0.25
3	0.0240	42.600	22.3	0.4	0.52	5.10	5.61	1.10	54.60	5.36	0.26
4	0.0320	43.900	23.6	0.5	0.55	5.04	5.59	1.11	55.00	5.31	0.27
5	0.0400	46.500	26.2	0.7	0.60	5.00	5.60	1.12	55.30	5.30	0.30
6	0.0490	49.700	29.4	0.8	0.68	4.94	5.62	1.14	55.70	5.28	0.34
7	0.0580	84.800	64.5	1.0	1.48	4.65	6.13	1.32	57.70	5.39	0.74
8	0.0650	110.100	89.8	1.1	2.06	4.31	6.37	1.48	60.10	5.34	1.03
9	0.0730	128.200	107.9	1.2	2.48	4.00	6.48	1.62	62.20	5.24	1.24
10	0.0810	142.400	122.1	1.4	2.80	3.74	6.54	1.75	64.00	5.14	1.40
11	0.0900	154.800	134.5	1.5	3.08	3.53	6.61	1.87	65.50	5.07	1.54
12	0.0970	165.500	145.2	1.7	3.32	3.36	6.67	1.99	66.70	5.01	1.66
13	0.1050	175.400	155.1	1.8	3.54	3.21	6.75	2.10	67.70	4.98	1.77
14	0.1130	184.000	163.7	1.9	3.73	3.10	6.83	2.20	68.50	4.96	1.87
15	0.1210	192.900	172.6	2.1	3.93	3.00	6.92	2.31	69.20	4.96	1.96
16	0.1280	200.100	179.8	2.2	4.09	2.91	7.00	2.40	69.80	4.95	2.04
17	0.1360	207.800	187.5	2.3	4.26	2.84	7.09	2.50	70.30	4.96	2.13
18	0.1440	214.900	194.6	2.5	4.41	2.78	7.19	2.59	70.70	4.98	2.21
19	0.1530	221.700	201.4	2.6	4.56	2.64	7.19	2.73	71.70	4.91	2.28
20	0.1600	228.800	208.5	2.7	4.71	2.69	7.41	2.75	71.30	5.05	2.36
21	0.1680	235.400	215.1	2.9	4.85	2.65	7.50	2.83	71.60	5.08	2.43
22	0.1760	242.200	221.9	3.0	5.00	2.62	7.62	2.91	71.80	5.12	2.50
23	0.1850	248.500	228.2	3.1	5.13	2.59	7.73	2.98	72.00	5.16	2.57
24	0.1920	255.000	234.7	3.3	5.27	2.58	7.85	3.05	72.10	5.21	2.64
25	0.2000	261.100	240.8	3.4	5.40	2.56	7.97	3.11	72.20	5.27	2.70
26	0.2080	267.100	246.8	3.5	5.53	2.55	8.08	3.17	72.30	5.31	2.77

Test Readings for Specimen No. 3

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
27	0.2170	272.300	252.0	3.7	5.64	2.55	8.19	3.21	72.30	5.37	2.82
28	0.2250	278.300	258.0	3.8	5.76	2.55	8.31	3.26	72.30	5.43	2.88
29	0.2320	283.800	263.5	3.9	5.88	2.55	8.43	3.31	72.30	5.49	2.94
30	0.2400	289.000	268.7	4.1	5.99	2.55	8.54	3.35	72.30	5.54	2.99
31	0.2490	294.300	274.0	4.2	6.10	2.55	8.64	3.39	72.30	5.60	3.05
32	0.2570	298.900	278.6	4.4	6.19	2.56	8.75	3.41	72.20	5.66	3.09
33	0.2640	304.000	283.7	4.5	6.30	2.58	8.87	3.44	72.10	5.73	3.15
34	0.2720	309.100	288.8	4.6	6.40	2.59	8.99	3.47	72.00	5.79	3.20
35	0.2800	313.800	293.5	4.8	6.49	2.61	9.10	3.49	71.90	5.85	3.25
36	0.2890	318.800	298.5	4.9	6.59	2.62	9.21	3.52	71.80	5.92	3.30
37	0.2960	323.500	303.2	5.0	6.69	2.64	9.32	3.54	71.70	5.98	3.34
38	0.3040	328.100	307.8	5.2	6.78	2.65	9.43	3.56	71.60	6.04	3.39
39	0.3120	332.500	312.2	5.3	6.87	2.66	9.53	3.58	71.50	6.10	3.43
40	0.3200	335.900	315.6	5.4	6.93	2.69	9.63	3.57	71.30	6.16	3.47
41	0.3270	339.500	319.2	5.6	7.00	2.72	9.72	3.57	71.10	6.22	3.50
42	0.3360	343.600	323.3	5.7	7.08	2.72	9.80	3.60	71.10	6.26	3.54
43	0.3440	347.700	327.4	5.9	7.16	2.75	9.91	3.60	70.90	6.33	3.58
44	0.3520	351.100	330.8	6.0	7.23	2.76	9.99	3.61	70.80	6.38	3.61
45	0.3590	355.100	334.8	6.1	7.30	2.78	10.08	3.63	70.70	6.43	3.65
46	0.3680	358.500	338.2	6.3	7.37	2.81	10.17	3.62	70.50	6.49	3.68
47	0.3760	362.600	342.3	6.4	7.44	2.84	10.28	3.62	70.30	6.56	3.72
48	0.3840	366.800	346.5	6.5	7.52	2.85	10.38	3.64	70.20	6.61	3.76
49	0.3920	370.400	350.1	6.7	7.59	2.87	10.46	3.65	70.10	6.66	3.80
50	0.4000	373.800	353.5	6.8	7.65	2.89	10.55	3.64	69.90	6.72	3.83
51	0.4080	377.000	356.7	6.9	7.71	2.92	10.64	3.64	69.70	6.78	3.86
52	0.4160	380.700	360.4	7.1	7.78	2.94	10.72	3.65	69.60	6.83	3.89
53	0.4240	384.300	364.0	7.2	7.85	2.97	10.81	3.65	69.40	6.89	3.92
54	0.4330	387.800	367.5	7.4	7.91	2.98	10.89	3.65	69.30	6.94	3.95
55	0.4400	391.000	370.7	7.5	7.97	3.01	10.98	3.65	69.10	6.99	3.98
56	0.4480	393.700	373.4	7.6	8.01	3.04	11.05	3.64	68.90	7.05	4.01
57	0.4560	396.700	376.4	7.8	8.07	3.05	11.12	3.64	68.80	7.09	4.03
58	0.4630	400.200	379.9	7.9	8.13	3.08	11.21	3.64	68.60	7.15	4.07
59	0.4720	403.300	383.0	8.0	8.18	3.10	11.28	3.64	68.50	7.19	4.09
60	0.4800	405.900	385.6	8.2	8.23	3.12	11.35	3.63	68.30	7.24	4.11
61	0.4890	408.600	388.3	8.3	8.27	3.14	11.41	3.63	68.20	7.27	4.14
62	0.4970	412.000	391.7	8.5	8.33	3.17	11.50	3.63	68.00	7.33	4.17
63	0.5040	414.900	394.6	8.6	8.38	3.18	11.56	3.63	67.90	7.37	4.19
64	0.5120	417.400	397.1	8.7	8.42	3.21	11.63	3.62	67.70	7.42	4.21
65	0.5210	419.300	399.0	8.9	8.45	3.23	11.67	3.62	67.60	7.45	4.22
66	0.5290	421.300	401.0	9.0	8.48	3.27	11.75	3.59	67.30	7.51	4.24
67	0.5440	427.100	406.8	9.3	8.58	3.30	11.87	3.60	67.10	7.59	4.29
68	0.5520	429.600	409.3	9.4	8.62	3.31	11.93	3.60	67.00	7.62	4.31
69	0.5610	431.500	411.2	9.5	8.64	3.34	11.98	3.59	66.80	7.66	4.32
70	0.5690	433.700	413.4	9.7	8.67	3.36	12.03	3.59	66.70	7.69	4.34
71	0.5760	436.500	416.2	9.8	8.72	3.38	12.11	3.58	66.50	7.74	4.36
72	0.5840	438.900	418.6	9.9	8.76	3.40	12.16	3.58	66.40	7.78	4.38
73	0.5920	441.900	421.6	10.1	8.81	3.41	12.22	3.58	66.30	7.82	4.40

Test Readings for Specimen No. 3

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
74	0.6010	444.300	424.0	10.2	8.84	3.44	12.29	3.57	66.10	7.86	4.42
75	0.6080	447.300	427.0	10.3	8.89	3.46	12.35	3.57	66.00	7.90	4.45
76	0.6160	449.900	429.6	10.5	8.93	3.48	12.42	3.56	65.80	7.95	4.47
77	0.6240	452.300	432.0	10.6	8.97	3.50	12.47	3.56	65.70	7.98	4.49
78	0.6330	454.000	433.7	10.8	8.99	3.51	12.50	3.56	65.60	8.01	4.50
79	0.6400	455.500	435.2	10.9	9.01	3.53	12.54	3.55	65.50	8.03	4.50
80	0.6480	457.500	437.2	11.0	9.04	3.54	12.58	3.55	65.40	8.06	4.52
81	0.6570	460.100	439.8	11.2	9.08	3.57	12.65	3.54	65.20	8.11	4.54
82	0.6650	462.100	441.8	11.3	9.10	3.59	12.69	3.54	65.10	8.14	4.55
83	0.6730	464.200	443.9	11.5	9.13	3.60	12.73	3.54	65.00	8.17	4.57
84	0.6810	466.800	446.5	11.6	9.17	3.61	12.79	3.54	64.90	8.20	4.59
85	0.6890	468.500	448.2	11.7	9.19	3.63	12.82	3.53	64.80	8.22	4.60
86	0.6970	470.100	449.8	11.9	9.21	3.66	12.87	3.52	64.60	8.26	4.61
87	0.7060	472.000	451.7	12.0	9.23	3.67	12.91	3.51	64.50	8.29	4.62
88	0.7130	473.600	453.3	12.1	9.25	3.69	12.94	3.51	64.40	8.31	4.63
89	0.7210	475.000	454.7	12.3	9.27	3.70	12.97	3.50	64.30	8.33	4.63
90	0.7290	476.600	456.3	12.4	9.29	3.72	13.00	3.50	64.20	8.36	4.64
91	0.7370	479.200	458.9	12.5	9.32	3.73	13.05	3.50	64.10	8.39	4.66
92	0.7440	481.100	460.8	12.7	9.35	3.74	13.09	3.50	64.00	8.42	4.68
93	0.7530	483.400	463.1	12.8	9.38	3.76	13.14	3.50	63.90	8.45	4.69
94	0.7610	484.900	464.6	13.0	9.40	3.77	13.17	3.49	63.80	8.47	4.70
95	0.7690	486.700	466.4	13.1	9.42	3.80	13.22	3.48	63.60	8.51	4.71
96	0.7770	489.500	469.2	13.2	9.46	3.82	13.28	3.48	63.50	8.55	4.73
97	0.7850	492.400	472.1	13.4	9.50	3.83	13.33	3.48	63.40	8.58	4.75
98	0.7930	496.400	476.1	13.5	9.57	3.83	13.40	3.50	63.40	8.61	4.78
99	0.8010	498.900	478.6	13.6	9.60	3.84	13.45	3.50	63.30	8.65	4.80
100	0.8090	500.700	480.4	13.8	9.62	3.86	13.48	3.49	63.20	8.67	4.81
101	0.8170	501.500	481.2	13.9	9.63	3.89	13.51	3.48	63.00	8.70	4.81
102	0.8250	503.600	483.3	14.0	9.65	3.89	13.54	3.48	63.00	8.71	4.83
103	0.8330	505.000	484.7	14.2	9.66	3.90	13.57	3.48	62.90	8.73	4.83
104	0.8410	507.200	486.9	14.3	9.69	3.92	13.61	3.47	62.80	8.76	4.85
105	0.8480	508.700	488.4	14.4	9.71	3.93	13.64	3.47	62.70	8.79	4.85
106	0.8560	510.000	489.7	14.6	9.72	3.96	13.68	3.45	62.50	8.82	4.86
107	0.8640	512.000	491.7	14.7	9.74	3.97	13.72	3.45	62.40	8.85	4.87
108	0.8730	514.300	494.0	14.9	9.77	3.99	13.76	3.45	62.30	8.87	4.89
109	0.8800	514.900	494.6	15.0	9.77	4.02	13.79	3.43	62.10	8.90	4.89
110	0.8880	516.100	495.8	15.1	9.78	4.02	13.80	3.43	62.10	8.91	4.89

Form No: TR-D2216-T265-1
Revision No. 0
Revision Date: 02/22/08

Laboratory Determination of Water Content

ASTM D 2216 ☑ *AASHTO T 265* ☐ ***Quality Assurance***

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	5/21/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	5/17-21/10
Client Name:	Duke Energy		
Client Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Sample by:	C. Withers	Sample Date(s):	3/30/10
Sampling Method:		Drill Rig :	

Method: **A (1%)** ☐ **B (0.1%)** ☑ *Balance ID.* *Calibration Date:*

Boring No.	Sample No.	Sample Depth	Tare #	Tare Weight	Tare Wt.+ Wet Wt	Tare Wt. + Dry Wt	Water Weight	Percent Moisture	Note
		ft. or m.		grams	grams	grams	grams	%	
AD4	1	1-2.5	72	74.77	297.71	254.34	43.37	**24.2%**	
AD4	2	3.5-5	JR	109.84	278.89	239.40	39.49	**30.5%**	
AD4	3	6-7.5	L-18	87.35	295.43	251.15	44.28	**27.0%**	
AD4	4	7.5-9	76	71.76	325.40	269.29	56.11	**28.4%**	
AD4	5	9-10.5	RT-1	86.17	281.00	239.22	41.78	**27.3%**	
AD4	6	10.5-12	SEJ	85.83	275.40	241.16	34.24	**22.0%**	
AD4	7	12-13.5	539	111.43	251.64	225.33	26.31	**23.1%**	
AD4	8	13.5-15	62	72.64	242.54	200.78	41.76	**32.6%**	
AD4	9	15-16.5	536	111.24	181.45	177.94	3.51	**5.3%**	
AD4	10	16.5-18	538	111.57	330.41	299.65	30.76	**16.4%**	
AD4	11	23.5-25	537	105.95	299.21	277.42	21.79	**12.7%**	

Notes / Deviations / References

ASTM D 2216: Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

Karen Warner		NICET 117900	
Technician Name	*Signature*	*Certification Type / No.*	*Date*
Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D4318-T89-90
Revision No. 0
Revision Date: 11/20/07

Liquid Limit, Plastic Limit, and Plastic Index

S&ME

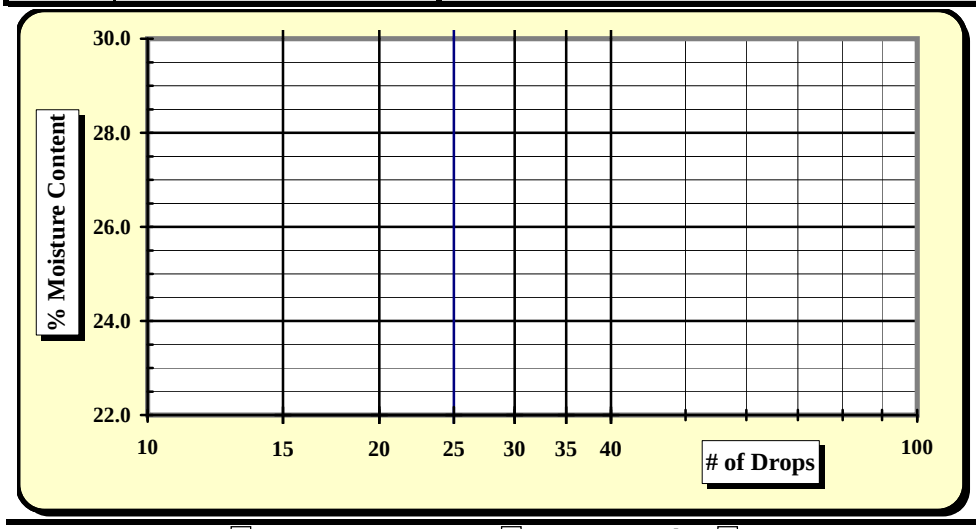
Another code *ASTM D 4318* ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐ ***Quality Assurance***

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	6/1/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s)	5/25-6/1/10
Client Name:	Duke Energy		
Client Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD4	Sample #: 9	Sample Date:
Location:		Offset:	Elevation: 15-16.5'
Sample Description:	Brown Micaceous Silty Fine to Coarse Sand (SM)		

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	20233	6/15/2009	Grooving tool	21587	2/28/2010
LL Apparatus	3611	10/20/2009	Grooving tool		
Oven	10844	9/4/2009	Grooving tool		

		Liquid Limit						Plastic Limit		
	Pan # / Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit			
N	**Factor**	**N**	**Factor**
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒
Liquid Limit
Plastic Limit
Plastic Index
Group Symbol **SM**

Multipoint Method ☐
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *Estimate the % Retained on the #40 Sieve:*

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Jason Clark — *Technician Name* — *Date*
Jason Reeves — *Technical Responsibility* — *Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D422-2
Revision No. 0
Revision Date: 02/20/08

Particle Size Analysis of Soils

ASTM D 422

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	1356-09-029 Phase 04	Report Date:	6/1/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	5/18-6/1/10
Client Name:	Duke Energy	Address:	3195 Pine Hall Road, Belews Creek, NC 27009
Boring #:	AD4	Sample #:	9
Location:		Offset:	
Sample Description:	Brown Micaceous Silty Fine to Coarse Sand (SM)		

Pan #:		Beaker #:		Apparent Relative Density	2.660	
Hydrometer Jar #:						
Pan Tare Weight (grams):			Moisture Content	Hygroscopic	Natural	
Total Sample Air Dried Wt. + tare wt. (grams):	147.94		Tare #	51		
Weight of Total Sample Air Dried:	147.94	A	Tare Wt.	15.74		
Weight of Air Dried Hydrometer Sample (g):	49.98	B	Wet Wt. + A	26.53		
Total Sample Oven Dried:	142.08	C	Dry Wt. + A	26.05		
Hydrometer Sample Oven Dried (**W**):	47.76	D	Water Wt. (B-C)	0.48		
% Passing #10:	88.5%	E	Dry Wt. (C-A)	10.31		
Correction Factor a (Table 1):	1.00		% Moisture (100 x D/E)	4.66%		

Sieve	Retained Wt.	Percent Passing	
3.0"	0.0	Pan # (washed)	100.0%
1.5"	0.0		100.0%
1.0"	0.0		100.0%
3/4"	0.0		100.0%
1/2"	0.0		100.0%
3/8"	0.0	Soil Mortar	100.0%
#4	5.9		95.9%
#10	16.3	**100.0%**	88.5%
#20	6.7	86.0%	76.1%
#40	17.4	63.6%	56.3%
#60	23.3	51.1%	45.3%
#100	27.4	42.7%	37.8%
#200	32.8	31.3%	27.7%

Description of Sand & Gravel Particles — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Stirring Apparatus: A ☐ B ☐ Dispersion Time: 1 min. Sodium Hexametaphosphate: 40 g./ Liter

Balance: *ID No.* 3996 *Cal. Date:* 2/3/2010 Hydrometer: *ID No.* 3901 *Cal. Date:* 3/26/2010

Control Cylinder ☒ **Composite Correction** ☐ **Type:** **151H** ☐ **152H** ☒

Time	Temp.	Hydrometer	Corrections		Hydrometer	Percent Passing		Effective Depth	Table 3	Diameter
			Control Cylinder	Composite Correction		P(-#10) = (R x a / W) x 100	P (total) = P x % Passing #10			D = K x ((L/T)$^{1/2}$
T (Min.)	(0.5 °C)	Reading			R			L	K	
1	23.5	17.5	4.5		13.00	27.2%	24.1%	14.2	0.01305	0.04911
2	23.5	15.5	4.5		11.00	23.0%	20.4%	14.5	0.01305	0.03513
5	23.5	13.5	4.5		9.00	18.8%	16.7%	14.8	0.01305	0.02247
15	23.5	12.0	4.5		7.50	15.7%	13.9%	15.1	0.01305	0.01308
30	23.5	10.5	4.5		6.00	12.6%	11.1%	15.3	0.01305	0.00932
60	23.5	10.0	4.5		5.50	11.5%	10.2%	15.4	0.01305	0.00661
250	23.5	8.5	4.5		4.00	8.4%	7.4%	15.6	0.01305	0.00326
1440	23.5	7.5	4.5		3.00	6.3%	5.6%	15.8	0.01305	0.00137

References / Comments / Deviations ASTM D 422, D 2487, D 4318

Karen Warner	NICET 117900	Jason Reeves	Senior Engineer	
Technician Name	*Certification #*	*Technical Responsibility*	*Position*	*Date*

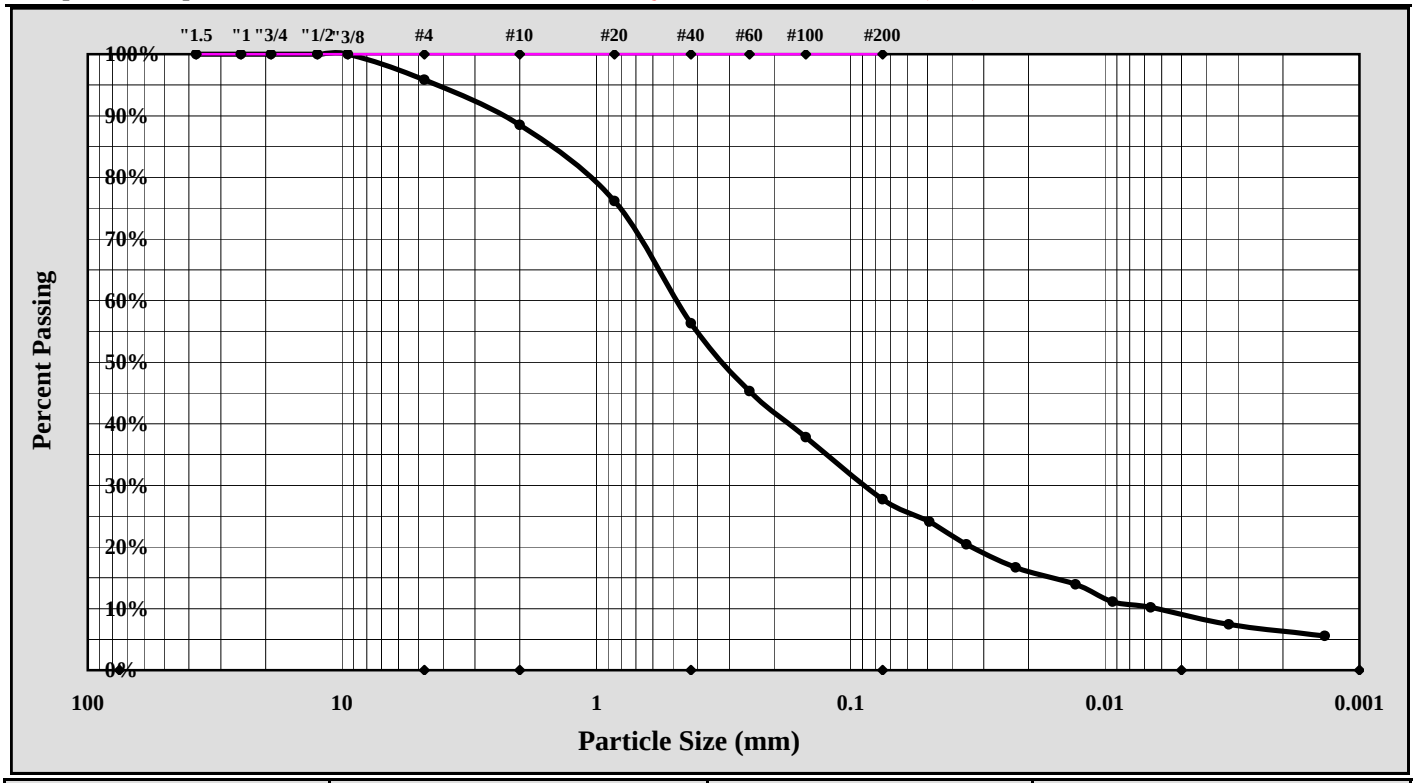
Particle Size Analysis of Soils

ASTM D422

Quality Assurance

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

S&ME Project #:	1356-09-029 Phase 04	Report Date:	6/1/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	5/18-6/1/10
Client Name:	Duke Energy		
Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD4	Sample #: 9	Sample Date:
Location:	Offset:		Elevation: 15-16.5'
Sample Description:	Brown Micaceous Silty Fine to Coarse Sand (SM)		



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm (#200)
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Maximum Particle Size:	#4	Gravel:	4.1%	Silt	18.2%
Silt & Clay (% Passing #200):	27.7%	Total Sand:	68.1%	Clay	9.5%
Apparent Relative Density	2.660	Moisture Content		Colloids	5.0%
Liquid Limit	NP	Plastic Limit	NP	Plastic Index	NP
Coarse Sand:	7.3%	Medium Sand:	32.2%	Fine Sand:	28.6%

Description of Sand and Gravel: Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Apparatus B: Air Jet Dispersion — Dispersion Period: 1 min. — Dispersing Agent: Sodium Hexametaphosphate: 40 g./ Liter

References / Comments / Deviations: ASTM D 4318, D 854, D 2487

Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D4318-T89-90
Revision No. 0
Revision Date: 11/20/07

Liquid Limit, Plastic Limit, and Plastic Index

Another code *ASTM D 4318* ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐ ***Quality Assurance***

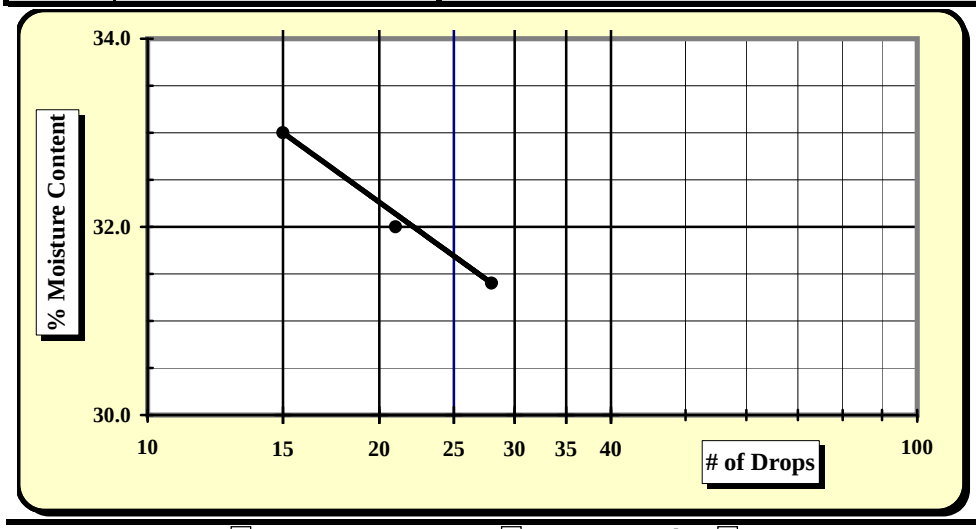
S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s)	6/14-22/10
Client Name:	Duke Energy		
Client Address:	3195 Pine Hall Road, Belews Creek, NC 27009		

Boring #:	AD-4	Sample #: Residual	Sample Date:
Location:		Offset:	Elevation: 30-32'
Sample Description:	Brown Tan Silty Fine to Coarse Sand (SM) w/Mica		

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	3996	2/3/2010	Grooving tool	21587	2/28/2010
LL Apparatus	3611	10/20/2009	Grooving tool		
Oven	10844	9/4/2009	Grooving tool		

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	29	13	11				52	55	
A	Tare Weight	15.90	13.97	13.83				15.70	14.31	
B	Wet Soil Weight + A	26.69	26.52	23.18				22.10	20.94	
C	Dry Soil Weight + A	24.11	23.48	20.86				20.71	19.53	
D	Water Weight (B-C)	2.58	3.04	2.32				1.39	1.41	
E	Dry Soil Weight (C-A)	8.21	9.51	7.03				5.01	5.22	
F	% Moisture (D/E)*100	31.4%	32.0%	33.0%				27.7%	27.0%	
N	# OF DROPS	28	21	15				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							**27.4%**		



One Point Liquid Limit			
N	**Factor**	**N**	**Factor**
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☐

Liquid Limit	**32**
Plastic Limit	**27**
Plastic Index	**5**
Group Symbol	**SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *Estimate the % Retained on the #40 Sieve:*

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Karen Warner — *Technician Name* — *Date*
Jason Reeves — *Technical Responsibility* — *Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D422-2
Revision No. 0
Revision Date: 02/20/08

Particle Size Analysis of Soils

ASTM D 422

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	1356-09-029 Phase 04	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	6/9-22/10
Client Name:	Duke Energy	Address:	3195 Pine Hall Road, Belews Creek, NC 27009
Boring #:	AD-4	Sample #:	Residual
Location:		Offset:	
Sample Description:	Brown Tan Silty Fine to Coarse Sand (SM) w/Mica		

Pan #:		Beaker #:		**Apparent Relative Density (Assumed)**		**2.650**	
Hydrometer Jar #:							
Pan Tare Weight (grams):				**Moisture Content**	Hygroscopic	Natural	
Total Sample Air Dried Wt. + tare wt. (grams):	333.53			Tare #	SSS		
Weight of Total Sample Air Dried:	333.53		A	Tare Wt.	16.54		
Weight of Air Dried Hydrometer Sample (g):	50.02		B	Wet Wt. + A	29.99		
Total Sample Oven Dried:	330.41		C	Dry Wt. + A	29.82		
Hydrometer Sample Oven Dried (**W**):	49.39		D	Water Wt. (B-C)	0.17		
% Passing #10:	73.9%		E	Dry Wt. (C-A)	13.28		
Correction Factor a (Table 1):	1.00			% Moisture (100 x D/E)	1.28%		

Sieve	Retained Wt.	Percent Passing	
3.0"	0.0	Pan # (washed)	100.0%
1.5"	0.0		100.0%
1.0"	0.0		100.0%
3/4"	0.0		100.0%
1/2"	0.0		100.0%
3/8"	21.9	Soil Mortar	93.4%
#4	52.0		84.2%
#10	86.4		**100.0%**
#20	5.6		88.6%
#40	10.7		78.4%
#60	15.4		68.7%
#100	23.3		52.9%
#200	26.4		46.5%

Description of Sand & Gravel Particles — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Stirring Apparatus: A ☐ B ☐ Dispersion Time: 1 min. Sodium Hexametaphosphate: 40 g./ Liter

Balance: *ID No.* 3996 *Cal. Date:* 2/3/2010 Hydrometer: *ID No.* 3901 *Cal. Date:* 3/26/2010

Control Cylinder ☒ **Composite Correction** ☐ **Type:** **151H** ☐ **152H** ☒

Time	Temp.	Hydrometer	Corrections		Hydrometer	Percent Passing		Effective Depth	Table 3	Diameter
			Control Cylinder	Composite Correction		P(-#10) = (R x a / W) x 100	P (total) = P x % Passing #10			D = K x $((L/T)^{1/2}$
T (Min.)	(0.5 °C)	Reading			R			L	K	
1	23.0	24.5	5.0		19.50	39.5%	29.2%	13.1	0.01317	0.04766
2	23.0	23.0	5.0		18.00	36.4%	26.9%	13.3	0.01317	0.03402
5	23.0	19.0	5.0		14.00	28.3%	20.9%	14.0	0.01317	0.02204
15	23.0	15.0	5.0		10.00	20.2%	15.0%	14.7	0.01317	0.01302
30	23.0	13.5	5.0		8.50	17.2%	12.7%	14.9	0.01317	0.00928
60	23.0	11.0	5.0		6.00	12.1%	9.0%	15.3	0.01317	0.00665
250	23.0	9.5	5.0		4.50	9.1%	6.7%	15.6	0.01317	0.00329
1440	21.0	9.0	5.5		3.50	7.1%	5.2%	15.7	0.01348	0.00141

References / Comments / Deviations ASTM D 422, D 2487, D 4318

Karen Warner	NICET 117900	Jason Reeves	Senior Engineer	
Technician Name	*Certification #*	*Technical Responsibility*	*Position*	*Date*

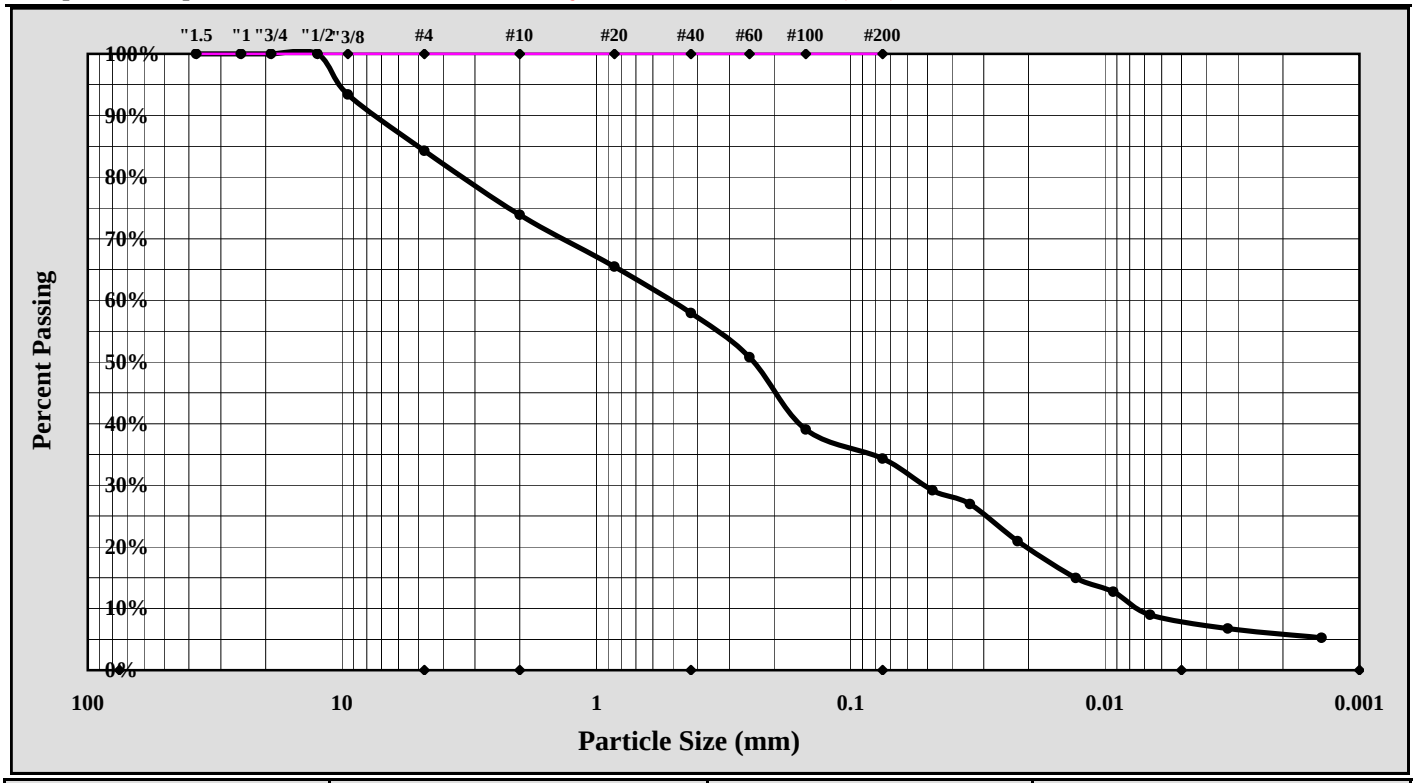
Particle Size Analysis of Soils

ASTM D422

Quality Assurance

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

S&ME Project #:	1356-09-029 Phase 04	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	6/9-22/10
Client Name:	Duke Energy		
Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD-4	Sample #: Residual	Sample Date:
Location:	Offset:		Elevation: 30-32'
Sample Description:	Brown Tan Silty Fine to Coarse Sand (SM) w/Mica		



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm (#200)
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Maximum Particle Size:	#4	Gravel:	15.8%	Silt	25.8%
Silt & Clay (% Passing #200):	34.3%	Total Sand:	49.9%	Clay	8.5%
ent Relative Density (Assumed)	2.650	Moisture Content		Colloids	5.0%
Liquid Limit	32	Plastic Limit	27	Plastic Index	5
Coarse Sand:	10.4%	Medium Sand:	15.9%	Fine Sand:	23.6%

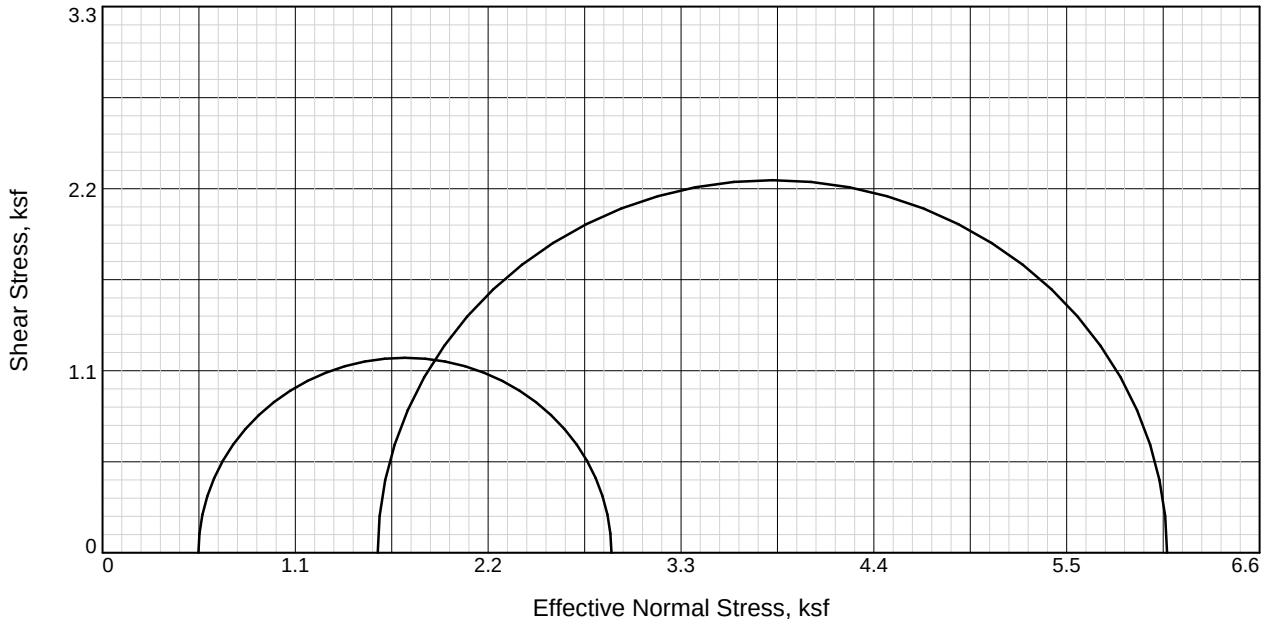
Description of Sand and Gravel — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

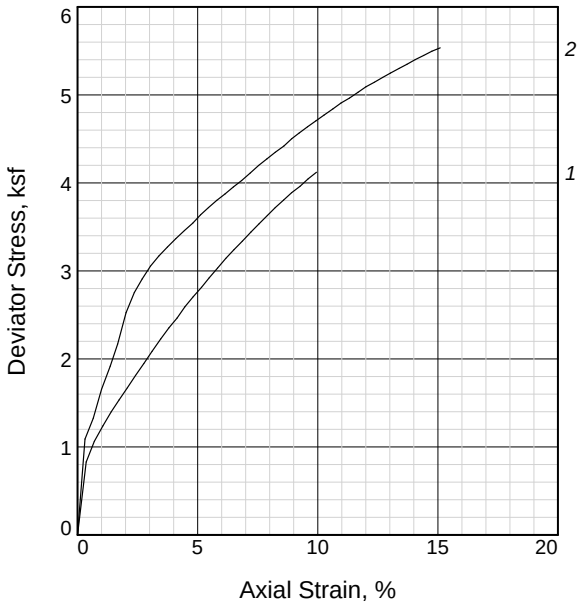
Apparatus B: Air Jet Dispersion — Dispersion Period: 1 min. Dispersing Agent: Sodium Hexametaphosphate: 40 g./ Liter

References / Comments / Deviations: ASTM D 4318, D 854, D 2487

Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.





Sample No.		1	2
Initial	Water Content, %	15.5	18.6
	Dry Density, pcf	108.4	102.8
	Saturation, %	78.0	81.0
	Void Ratio	0.5260	0.6087
	Diameter, in.	2.854	2.862
	Height, in.	5.969	5.938
At Test	Water Content, %	15.9	18.7
	Dry Density, pcf	116.3	110.7
	Saturation, %	100.0	100.0
	Void Ratio	0.4225	0.4951
	Diameter, in.	2.788	2.793
	Height, in.	5.832	5.796
Strain rate, in./min.		0.010	0.010
Back Pressure, ksf		10.08	10.08
Cell Pressure, ksf		11.52	14.40
Fail. Stress, ksf		2.36	4.50
Total Pore Pr., ksf		10.97	12.83
Ult. Stress, ksf			
Total Pore Pr., ksf			
$\bar{\sigma}_1$ Failure, ksf		2.90	6.07
$\bar{\sigma}_3$ Failure, ksf		0.55	1.57

Type of Test:
CU with Pore Pressures

Sample Type: Undisturbed

Description: Brown Tan Silty Coarse to Fine Sand (SM) w/Mica

LL= 32 **PL=** 27 **PI=** 5

Assumed Specific Gravity= 2.65

Remarks: Effective Stress Shear Strength Based on Maximum Principal Stress Ratio

Plate AD-4 (30-32)

Client: Duke Energy

Project: Duke Energy-Embankment Stability

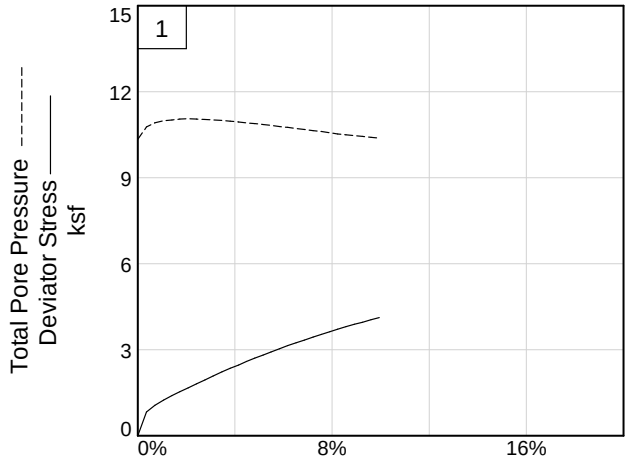
Sample Number: AD-4 Res **Depth:** 30-32'

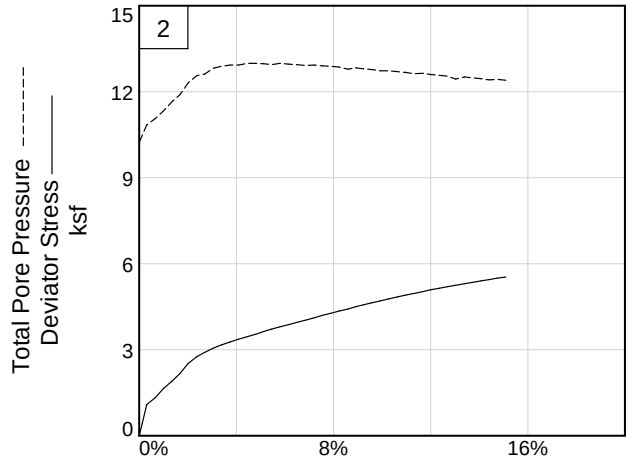
Proj. No.: 1356-09-029 Phase 04 **Date Sampled:**

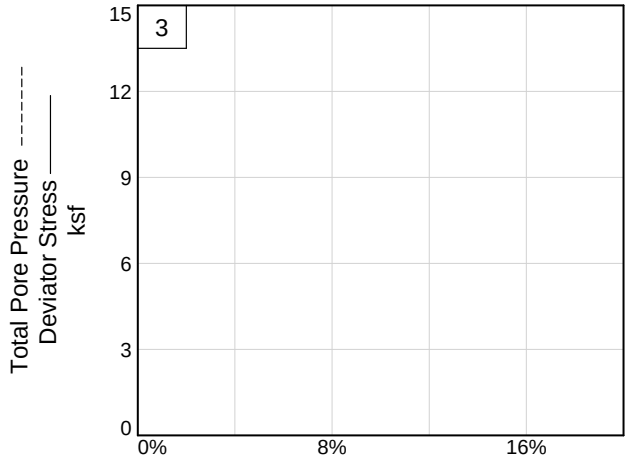
TRIAXIAL SHEAR TEST REPORT

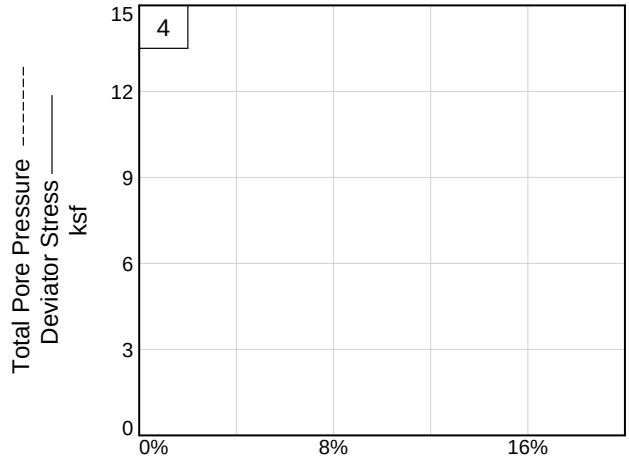
S & ME, INC.

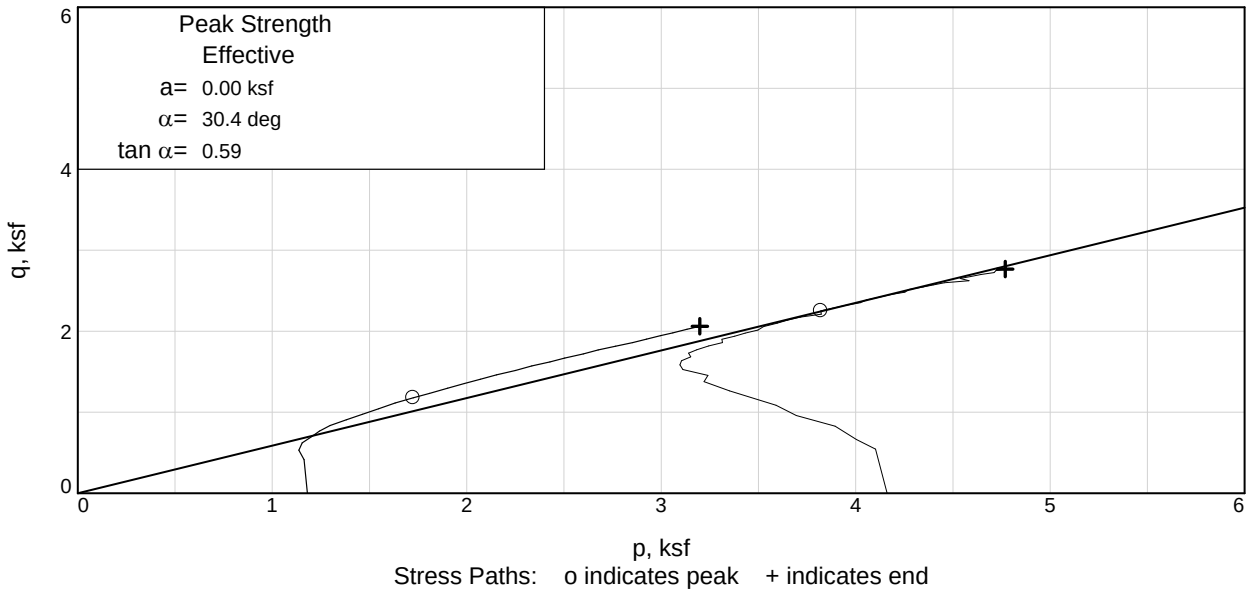
Tested By: KMW **Checked By:** JSR









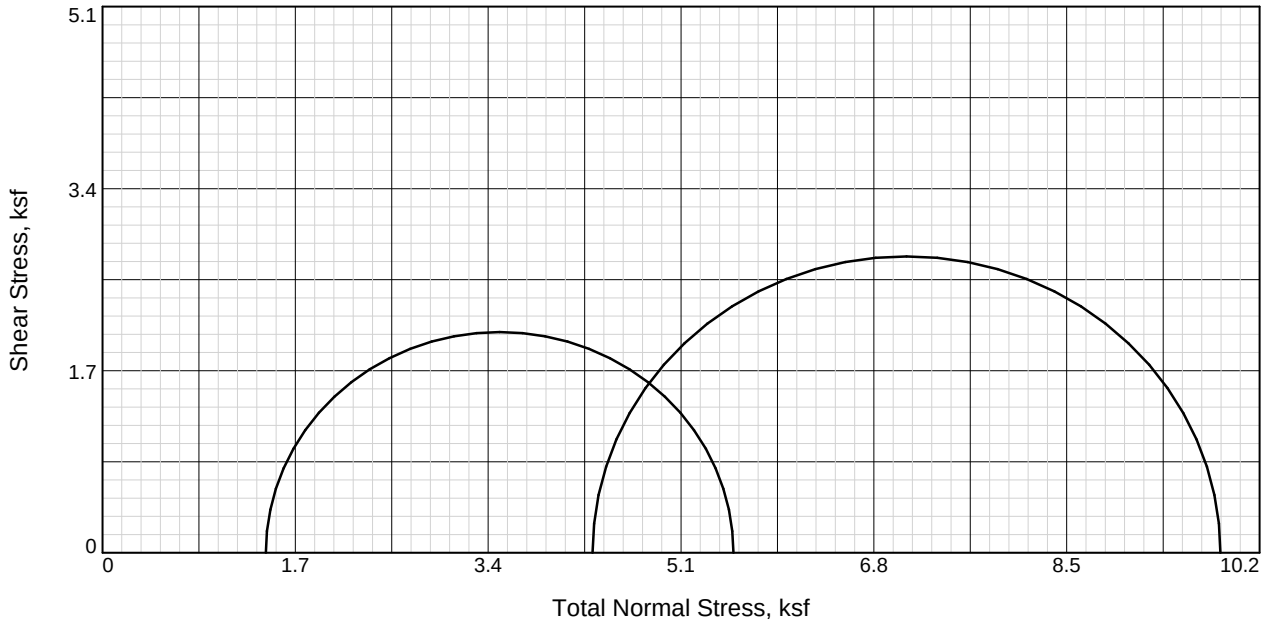


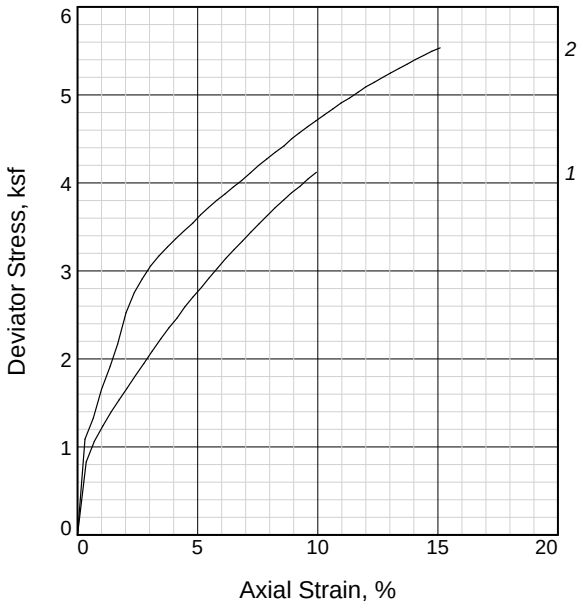
Stress Paths: o indicates peak + indicates end

Client: Duke Energy
Project: Duke Energy-Embankment Stability
Depth: 30-32' **Sample Number:** AD-4 Res
Project No.: 1356-09-029 Phase 04 **Plate** AD-4 (30-32)

S & ME, INC.

Tested By: KMW **Checked By:** JSR





Sample No.		1	2
Initial	Water Content, %	15.5	18.6
	Dry Density, pcf	108.4	102.8
	Saturation, %	78.0	81.0
	Void Ratio	0.5260	0.6087
	Diameter, in.	2.854	2.862
	Height, in.	5.969	5.938
At Test	Water Content, %	15.9	18.7
	Dry Density, pcf	116.3	110.7
	Saturation, %	100.0	100.0
	Void Ratio	0.4225	0.4951
	Diameter, in.	2.788	2.793
	Height, in.	5.832	5.796
Strain rate, in./min.		0.010	0.010
Back Pressure, ksf		10.08	10.08
Cell Pressure, ksf		11.52	14.40
Fail. Stress, ksf		4.12	5.53
Total Pore Pr., ksf		10.38	12.40
Ult. Stress, ksf			
Total Pore Pr., ksf			
$\bar{\sigma}_1$ Failure, ksf		5.26	7.54
$\bar{\sigma}_3$ Failure, ksf		1.14	2.00

Type of Test:
CU with Pore Pressures

Sample Type: Undisturbed

Description: Brown Tan Silty Coarse to Fine Sand (SM) w/Mica

LL= 32 **PL=** 27 **PI=** 5

Assumed Specific Gravity= 2.65

Remarks: Total Stress Shear Strength Based on Maximum Deviator Stress

Plate AD-4 (30-32)

Client: Duke Energy

Project: Duke Energy-Embankment Stability

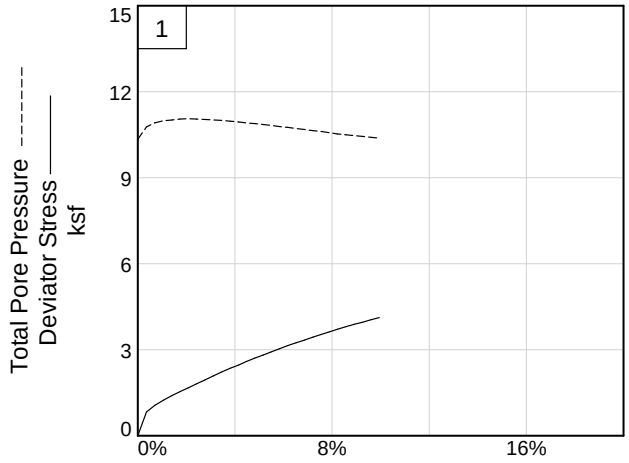
Sample Number: AD-4 Res **Depth:** 30-32'

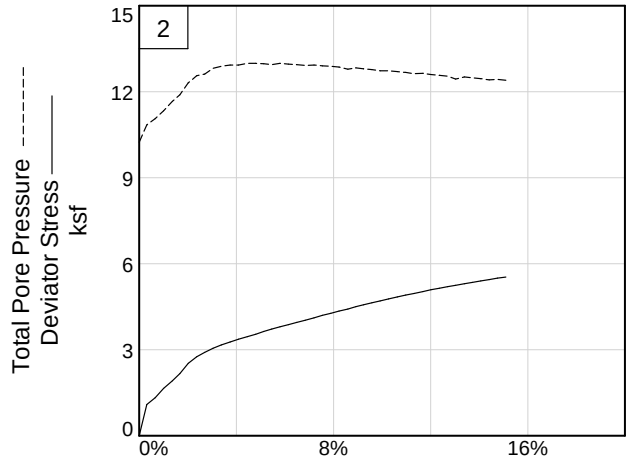
Proj. No.: 1356-09-029 Phase 04 **Date Sampled:**

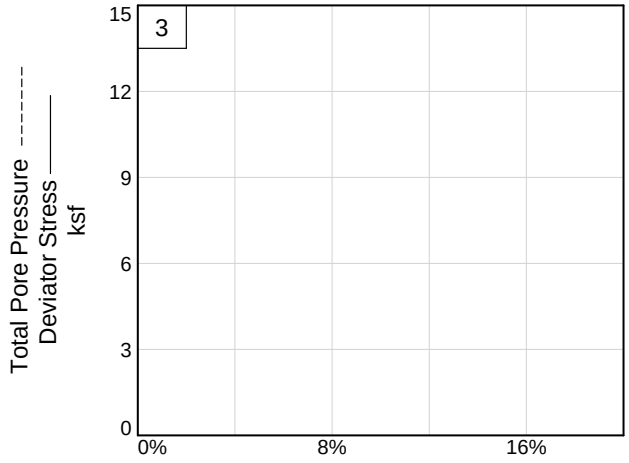
TRIAXIAL SHEAR TEST REPORT

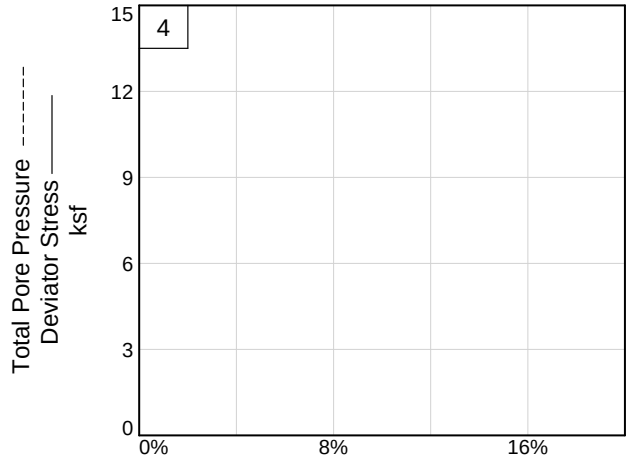
S & ME, INC.

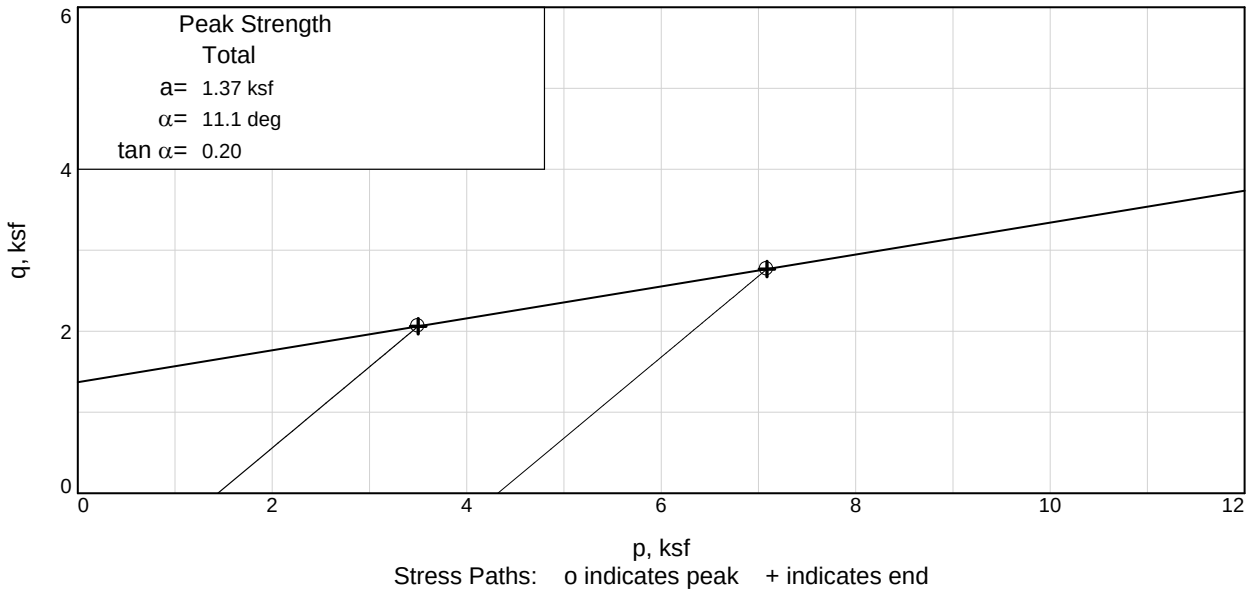
Tested By: KMW **Checked By:** JSR











Stress Paths: o indicates peak + indicates end

Client: Duke Energy
Project: Duke Energy-Embankment Stability
Depth: 30-32' **Sample Number:** AD-4 Res
Project No.: 1356-09-029 Phase 04 **Plate** AD-4 (30-32)

S & ME, INC.

Tested By: KMW **Checked By:** JSR

TRIAXIAL COMPRESSION TEST 7/16/2010

CU with Pore Pressures 12:41 PM

Date:
Client: Duke Energy
Project: Duke Energy-Embankment Stability
Project No.: 1356-09-029 Phase 04
Depth: 30-32' **Sample Number:** AD-4 Res
Description: Brown Tan Silty Coarse to Fine Sand (SM) w/Mica
Remarks:
Type of Sample: Undisturbed
Assumed Specific Gravity=2.65 **LL=**32 **PL=**27 **PI=**5
Test Method: COE uniform strain

Parameters for Specimen No. 1

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	234.820			1379.300
Moisture content: Dry soil+tare, gms.	214.310			1154.600
Moisture content: Tare, gms.	81.830			74.050
Moisture, %	15.5	19.6	15.9	20.8
Moist specimen weight, gms.	1254.90			
Diameter, in.	2.854	2.850	2.788	
Area, in.²	6.397	6.380	6.104	
Height, in.	5.969	5.961	5.832	
Net decrease in height, in.		0.008	0.129	
Wet Density, pcf	125.2	130.2	134.8	
Dry density, pcf	108.4	108.8	116.3	
Void ratio	0.5260	0.5199	0.4225	
Saturation, %	78.0	100.0	100.0	

Test Readings for Specimen No. 1

Consolidation cell pressure = 80.00 psi (11.52 ksf)
Consolidation back pressure = 70.00 psi (10.08 ksf)
Consolidation effective confining stress = 1.44 ksf
Strain rate, in./min. = 0.010
Fail. Stress = 2.36 ksf **at reading no.** 11

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
0	0.0040	18.600	0.0	0.0	0.00	1.18	1.18	1.00	71.80	1.18	0.00
1	0.0250	53.900	35.3	0.4	0.83	0.75	1.58	2.11	74.80	1.16	0.41
2	0.0450	64.000	45.4	0.7	1.06	0.60	1.67	2.76	75.80	1.14	0.53
3	0.0660	71.800	53.2	1.1	1.24	0.53	1.77	3.33	76.30	1.15	0.62
4	0.0860	78.800	60.2	1.4	1.40	0.50	1.90	3.78	76.50	1.20	0.70
5	0.1050	84.800	66.2	1.7	1.53	0.48	2.01	4.23	76.70	1.24	0.77
6	0.1250	91.000	72.4	2.1	1.67	0.46	2.13	4.63	76.80	1.30	0.84
7	0.1450	97.300	78.7	2.4	1.81	0.48	2.29	4.81	76.70	1.38	0.91
8	0.1650	103.500	84.9	2.8	1.95	0.49	2.44	4.98	76.60	1.46	0.97
9	0.1850	109.900	91.3	3.1	2.09	0.50	2.59	5.14	76.50	1.55	1.04
10	0.2060	116.400	97.8	3.5	2.23	0.52	2.75	5.30	76.40	1.63	1.11
11	0.2260	122.400	103.8	3.8	2.36	0.55	2.90	5.30	76.20	1.73	1.18
12	0.2460	127.600	109.0	4.1	2.46	0.58	3.04	5.28	76.00	1.81	1.23
13	0.2650	133.700	115.1	4.5	2.59	0.60	3.20	5.29	75.80	1.90	1.30
14	0.2850	139.200	120.6	4.8	2.71	0.63	3.34	5.27	75.60	1.99	1.35
15	0.3050	144.400	125.8	5.2	2.81	0.66	3.48	5.25	75.40	2.07	1.41
16	0.3240	149.700	131.1	5.5	2.92	0.69	3.61	5.23	75.20	2.15	1.46
17	0.3440	155.100	136.5	5.8	3.03	0.73	3.77	5.13	74.90	2.25	1.52
18	0.3640	160.600	142.0	6.2	3.14	0.76	3.91	5.12	74.70	2.33	1.57
19	0.3840	165.600	147.0	6.5	3.24	0.81	4.05	5.02	74.40	2.43	1.62
20	0.4040	170.500	151.9	6.9	3.34	0.84	4.17	5.00	74.20	2.50	1.67
21	0.4250	175.800	157.2	7.2	3.44	0.88	4.32	4.92	73.90	2.60	1.72
22	0.4450	180.800	162.2	7.6	3.54	0.91	4.44	4.90	73.70	2.68	1.77
23	0.4650	185.700	167.1	7.9	3.63	0.95	4.58	4.82	73.40	2.77	1.82
24	0.4840	190.400	171.8	8.2	3.72	0.99	4.71	4.74	73.10	2.85	1.86
25	0.5040	195.000	176.4	8.6	3.80	1.02	4.83	4.72	72.90	2.92	1.90
26	0.5240	199.600	181.0	8.9	3.89	1.05	4.94	4.70	72.70	3.00	1.94
27	0.5440	203.600	185.0	9.3	3.96	1.08	5.04	4.67	72.50	3.06	1.98
28	0.5640	208.400	189.8	9.6	4.05	1.11	5.16	4.65	72.30	3.13	2.02
29	0.5840	212.600	194.0	9.9	4.12	1.14	5.26	4.62	72.10	3.20	2.06

Parameters for Specimen No. 2

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	206.300			1352.500
Moisture content: Dry soil+tare, gms.	186.820			1144.100
Moisture content: Tare, gms.	82.080			84.700
Moisture, %	18.6	22.1	18.7	19.7
Moist specimen weight, gms.	1223.00			
Diameter, in.	2.862	2.848	2.793	
Area, in.²	6.433	6.373	6.126	
Height, in.	5.938	5.910	5.796	
Net decrease in height, in.		0.028	0.114	
Wet Density, pcf	122.0	127.4	131.3	
Dry density, pcf	102.8	104.3	110.7	
Void ratio	0.6087	0.5860	0.4951	
Saturation, %	81.0	100.0	100.0	

Test Readings for Specimen No. 2

Consolidation cell pressure = 100.00 psi (14.40 ksf)
Consolidation back pressure = 70.00 psi (10.08 ksf)
Consolidation effective confining stress = 4.32 ksf
Strain rate, in./min. = 0.010
Fail. Stress = 4.50 ksf **at reading no.** 26

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
0	0.0010	15.400	0.0	0.0	0.00	4.16	4.16	1.00	71.10	4.16	0.00
1	0.0190	61.900	46.5	0.3	1.09	3.56	4.65	1.31	75.30	4.10	0.54
2	0.0390	72.200	56.8	0.7	1.33	3.34	4.67	1.40	76.80	4.00	0.66
3	0.0590	86.500	71.1	1.0	1.65	3.07	4.72	1.54	78.70	3.89	0.83
4	0.0800	98.100	82.7	1.4	1.92	2.74	4.65	1.70	81.00	3.69	0.96
5	0.0980	109.300	93.9	1.7	2.17	2.51	4.68	1.87	82.60	3.59	1.09
6	0.1180	125.100	109.7	2.0	2.53	2.09	4.61	2.21	85.50	3.35	1.26
7	0.1380	135.400	120.0	2.4	2.75	1.84	4.60	2.49	87.20	3.22	1.38
8	0.1570	142.600	127.2	2.7	2.91	1.79	4.70	2.63	87.60	3.24	1.45
9	0.1770	149.400	134.0	3.0	3.05	1.58	4.64	2.93	89.00	3.11	1.53
10	0.1970	154.900	139.5	3.4	3.17	1.51	4.68	3.10	89.50	3.10	1.58
11	0.2180	160.000	144.6	3.7	3.27	1.47	4.74	3.23	89.80	3.10	1.64
12	0.2380	164.700	149.3	4.1	3.37	1.47	4.84	3.29	89.80	3.15	1.68
13	0.2590	169.400	154.0	4.5	3.46	1.41	4.87	3.45	90.20	3.14	1.73
14	0.2790	173.700	158.3	4.8	3.54	1.41	4.95	3.51	90.20	3.18	1.77
15	0.2980	178.500	163.1	5.1	3.64	1.43	5.06	3.55	90.10	3.24	1.82
16	0.3170	182.800	167.4	5.5	3.72	1.45	5.18	3.56	89.90	3.31	1.86
17	0.3370	187.100	171.7	5.8	3.80	1.41	5.21	3.69	90.20	3.31	1.90
18	0.3570	191.100	175.7	6.1	3.88	1.44	5.32	3.69	90.00	3.38	1.94
19	0.3770	195.300	179.9	6.5	3.95	1.45	5.41	3.72	89.90	3.43	1.98
20	0.3970	199.300	183.9	6.8	4.03	1.48	5.51	3.72	89.70	3.50	2.01
21	0.4180	204.000	188.6	7.2	4.11	1.47	5.58	3.80	89.80	3.53	2.06
22	0.4380	208.600	193.2	7.5	4.20	1.50	5.70	3.80	89.60	3.60	2.10
23	0.4580	212.700	197.3	7.9	4.27	1.51	5.78	3.83	89.50	3.65	2.14
24	0.4780	217.000	201.6	8.2	4.35	1.54	5.89	3.82	89.30	3.72	2.17
25	0.4990	221.100	205.7	8.6	4.42	1.61	6.03	3.74	88.80	3.82	2.21
26	0.5180	225.700	210.3	8.9	4.50	1.57	6.07	3.87	89.10	3.82	2.25

Test Readings for Specimen No. 2

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
27	0.5360	229.500	214.1	9.2	4.57	1.60	6.17	3.86	88.90	3.88	2.28
28	0.5560	233.600	218.2	9.6	4.64	1.63	6.27	3.85	88.70	3.95	2.32
29	0.5760	237.600	222.2	9.9	4.71	1.67	6.38	3.82	88.40	4.02	2.35
30	0.5960	241.600	226.2	10.3	4.77	1.67	6.44	3.86	88.40	4.06	2.39
31	0.6170	245.800	230.4	10.6	4.84	1.70	6.54	3.85	88.20	4.12	2.42
32	0.6370	250.000	234.6	11.0	4.91	1.73	6.64	3.84	88.00	4.18	2.45
33	0.6570	253.500	238.1	11.3	4.96	1.77	6.73	3.80	87.70	4.25	2.48
34	0.6780	257.700	242.3	11.7	5.03	1.76	6.79	3.86	87.80	4.27	2.52
35	0.6970	261.600	246.2	12.0	5.09	1.80	6.89	3.83	87.50	4.35	2.55
36	0.7170	265.100	249.7	12.4	5.14	1.83	6.97	3.81	87.30	4.40	2.57
37	0.7370	268.700	253.3	12.7	5.20	1.86	7.06	3.80	87.10	4.46	2.60
38	0.7560	272.100	256.7	13.0	5.25	1.96	7.21	3.68	86.40	4.58	2.62
39	0.7770	275.800	260.4	13.4	5.30	1.89	7.19	3.81	86.90	4.54	2.65
40	0.7960	279.100	263.7	13.7	5.35	1.92	7.26	3.79	86.70	4.59	2.67
41	0.8160	282.800	267.4	14.1	5.40	1.94	7.35	3.78	86.50	4.65	2.70
42	0.8360	286.200	270.8	14.4	5.45	1.99	7.44	3.74	86.20	4.71	2.72
43	0.8560	289.700	274.3	14.8	5.50	1.97	7.47	3.79	86.30	4.72	2.75
44	0.8760	292.700	277.3	15.1	5.53	2.00	7.54	3.77	86.10	4.77	2.77

Laboratory Determination of Water Content

ASTM D 2216 ☑ *AASHTO T 265* ☐ ***Quality Assurance***

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	5/20/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	5/19-20/10
Client Name:	Duke Energy		
Client Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Sample by:	C. Withers	Sample Date(s):	3/30/10
Sampling Method:		Drill Rig :	

Method: **A (1%)** ☐ **B (0.1%)** ☑ *Balance ID.* *Calibration Date:*

Boring No.	Sample No.	Sample Depth	Tare #	Tare Weight	Tare Wt.+ Wet Wt	Tare Wt. + Dry Wt	Water Weight	Percent Moisture	Note
		ft. or m.		grams	grams	grams	grams	%	
AD6	1	1-2.5	S-3	82.38	313.82	273.81	40.01	**20.9%**	
AD6	2	3.5-5	S-7	81.71	272.26	239.88	32.38	**20.5%**	
AD6	3	6-7.5	G-13	81.57	297.53	261.26	36.27	**20.2%**	
AD6	4	8.5-10	G-9	82.29	277.26	242.83	34.43	**21.4%**	
AD6	5	13.5-15	S-4	80.67	332.96	284.32	48.64	**23.9%**	
AD6	6	18.5-20	T-7	82.12	188.88	164.85	24.03	**29.0%**	
AD6	7	23.5-25	T-6	81.49	341.90	308.94	32.96	**14.5%**	
AD6	8	28.5-30	G-5	82.09	240.74	224.51	16.23	**11.4%**	
AD6	9	33.5-35	JAZZ	81.27	270.01	228.31	41.70	**28.4%**	
AD6	10	38.5-40	S-2	81.42	261.70	220.16	41.54	**29.9%**	
AD6	11	43.5-45	S-5	82.15	307.33	278.80	28.53	**14.5%**	
AD6	12	48.50-50	T-1	83.32	261.98	224.11	37.87	**26.9%**	
AD6	13	53.5-55	G-15	81.48	263.80	235.46	28.34	**18.4%**	
AD6	14	58.5-60	CHAD	82.88	320.59	294.98	25.61	**12.1%**	

Notes / Deviations / References

ASTM D 2216: Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

Karen Warner		NICET 117900	
Technician Name	*Signature*	*Certification Type / No.*	*Date*
Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D4318-T89-90
Revision No. 0
Revision Date: 11/20/07

Liquid Limit, Plastic Limit, and Plastic Index

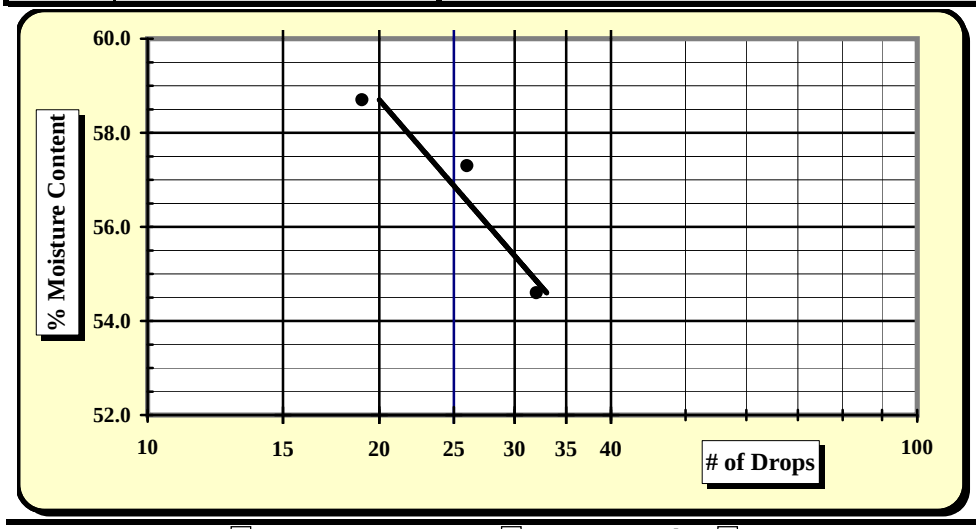
Another code *ASTM D 4318* ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐ ***Quality Assurance***

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s)	5/27-6/22/10
Client Name:	Duke Energy		
Client Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD-6	Sample #: Fill	Sample Date:
Location:		Offset:	Elevation: 30-32'
Sample Description:	Orange Tan Brown Fine to Coarse Sandy Clayey Silt (MH) w/Mica		

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	3996	2/3/2010	Grooving tool	21587	2/28/2010
LL Apparatus	3611	10/20/2009	Grooving tool		
Oven	10844	9/4/2009	Grooving tool		

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	50	KK	QQ				4	BA	
A	Tare Weight	15.77	16.02	16.85				13.99	15.35	
B	Wet Soil Weight + A	26.44	26.21	25.18				20.28	21.90	
C	Dry Soil Weight + A	22.67	22.50	22.10				18.76	20.33	
D	Water Weight (B-C)	3.77	3.71	3.08				1.52	1.57	
E	Dry Soil Weight (C-A)	6.90	6.48	5.25				4.77	4.98	
F	% Moisture (D/E)*100	54.6%	57.3%	58.7%				31.9%	31.5%	
N	# OF DROPS	32	26	19				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							**31.7%**		



One Point Liquid Limit			
N	**Factor**	**N**	**Factor**
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☐
Liquid Limit **57**
Plastic Limit **32**
Plastic Index **25**
Group Symbol **MH**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *Estimate the % Retained on the #40 Sieve:*

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Karen Warner — *Technician Name* — *Date*
Jason Reeves — *Technical Responsibility* — *Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D422-2
Revision No. 0
Revision Date: 02/20/08

Particle Size Analysis of Soils

ASTM D 422

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	1356-09-029 Phase 04	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	6/9-22/10
Client Name:	Duke Energy	Address:	3195 Pine Hall Road, Belews Creek, NC 27009
Boring #:	AD-6	Sample #:	Fill
Location:		Offset:	
Sample Description:	Orange Tan Brown Fine to Coarse Sandy Clayey Silt (MH) w/Mica		

Pan #:		Beaker #:		**Apparent Relative Density (Assumed)**		**2.650**	
Hydrometer Jar #:							
Pan Tare Weight (grams):				**Moisture Content**	Hygroscopic	Natural	
Total Sample Air Dried Wt. + tare wt. (grams):	295.84			Tare #	P-22		
Weight of Total Sample Air Dried:	295.84		A	Tare Wt.	15.86		
Weight of Air Dried Hydrometer Sample (g):	50.02		B	Wet Wt. + A	26.13		
Total Sample Oven Dried:	289.96		C	Dry Wt. + A	25.92		
Hydrometer Sample Oven Dried (**W**):	49.00		D	Water Wt. (B-C)	0.21		
% Passing #10:	97.1%		E	Dry Wt. (C-A)	10.06		
Correction Factor a (Table 1):	1.00			% Moisture (100 x D/E)	2.09%		

Sieve	Retained Wt.	Percent Passing	
3.0"	0.0	Pan # (washed)	100.0%
1.5"	0.0		100.0%
1.0"	0.0		100.0%
3/4"	0.0		100.0%
1/2"	0.0		100.0%
3/8"	2.8	Soil Mortar	99.0%
#4	5.1		98.2%
#10	8.5	**100.0%**	97.1%
#20	1.5	96.9%	94.1%
#40	3.2	93.4%	90.6%
#60	10.8	78.0%	75.7%
#100	13.1	73.3%	71.2%
#200	16.1	67.2%	65.2%

Description of Sand & Gravel Particles Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Stirring Apparatus: A ☐ B ☐ Dispersion Time: 1 min. Sodium Hexametaphosphate: 40 g./ Liter

Balance: *ID No.* 3996 *Cal. Date:* 2/3/2010 Hydrometer: *ID No.* 3901 *Cal. Date:* 3/26/2010

Control Cylinder ☒ **Composite Correction** ☐ **Type:** **151H** ☐ **152H** ☒

Time	Temp.	Hydrometer	Corrections		Hydrometer	Percent Passing		Effective Depth	Table 3	Diameter
			Control	Composite		P(-#10) =	P (total) =			D =
T (Min.)	(0.5 °C)	Reading	Cylinder	Correction	R	(R x a / W) x 100	P x % Passing #10	L	K	K x ((L/T)$^{1/2}$
1	25.0	34.0	4.5		29.50	60.2%	58.4%	11.5	0.01286	0.04353
2	25.0	31.0	4.5		26.50	54.1%	52.5%	11.9	0.01286	0.03143
5	24.5	27.0	4.5		22.50	45.9%	44.6%	12.6	0.01294	0.02054
15	24.5	24.5	4.5		20.00	40.8%	39.6%	13.0	0.01294	0.01205
30	24.5	23.0	5.0		18.00	36.7%	35.7%	13.3	0.01294	0.00863
60	24.0	21.5	5.0		16.50	33.7%	32.7%	13.6	0.01301	0.00619
250	23.0	20.0	5.5		14.50	29.6%	28.7%	13.9	0.01317	0.00311
1440	20.5	19.0	5.5		13.50	27.6%	26.7%	14.1	0.01357	0.00134

References / Comments / Deviations ASTM D 422, D 2487, D 4318

Karen Warner	NICET 117900	Jason Reeves	Senior Engineer	
Technician Name	*Certification #*	*Technical Responsibility*	*Position*	*Date*

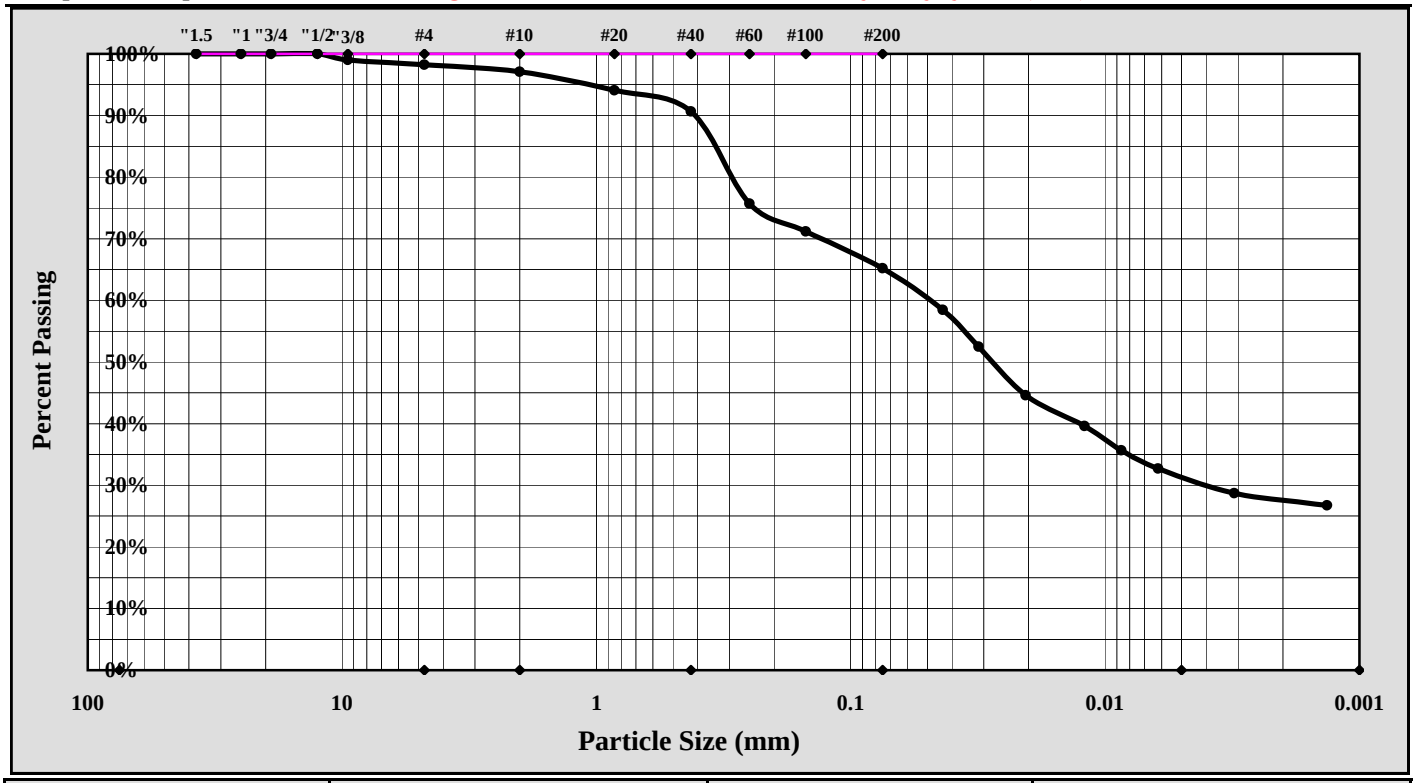
Particle Size Analysis of Soils

ASTM D422

Quality Assurance

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

S&ME Project #:	1356-09-029 Phase 04	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	6/9-22/10
Client Name:	Duke Energy		
Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD-6	Sample #: Fill	Sample Date:
Location:	Offset:		Elevation: 30-32'
Sample Description:	Orange Tan Brown Fine to Coarse Sandy Clayey Silt (MH) w/Mica		



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm (#200)
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Maximum Particle Size:	#4	Gravel:	1.8%	Silt	34.2%
Silt & Clay (% Passing #200):	65.2%	Total Sand:	33.0%	Clay	31.0%
ent Relative Density (Assumed)	2.650	Moisture Content		Colloids	27.0%
Liquid Limit	57	Plastic Limit	32	Plastic Index	25
Coarse Sand:	1.2%	Medium Sand:	6.4%	Fine Sand:	25.4%

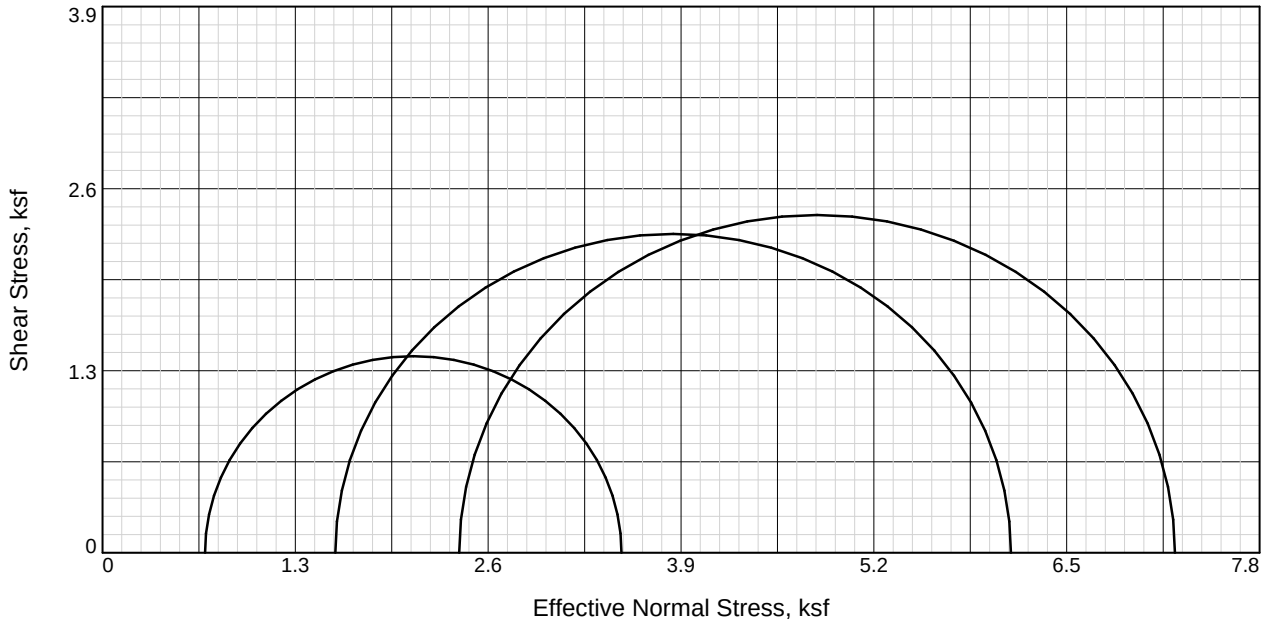
Description of Sand and Gravel — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

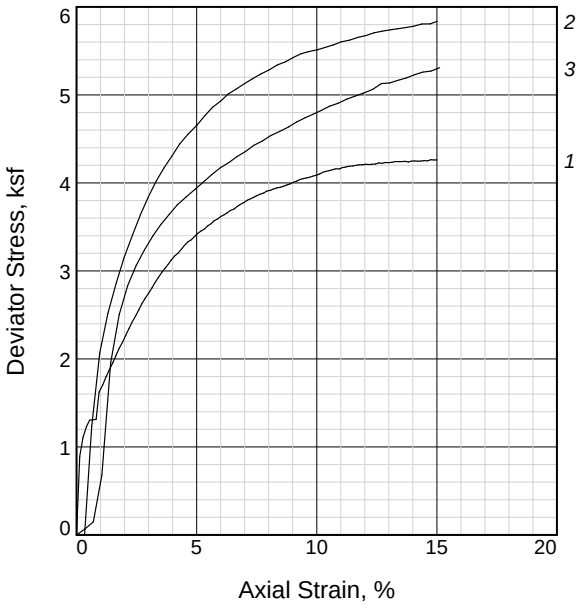
Apparatus B: Air Jet Dispersion — Dispersion Period: 1 min. Dispersing Agent: Sodium Hexametaphosphate: 40 g./ Liter

References / Comments / Deviations: ASTM D 4318, D 854, D 2487

Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.





Sample No.		1	2	3
Initial	Water Content, %	29.4	16.1	15.8
	Dry Density, pcf	89.9	100.7	98.4
	Saturation, %	92.7	66.2	61.5
	Void Ratio	0.8404	0.6429	0.6814
	Diameter, in.	2.864	2.861	2.865
	Height, in.	5.938	6.063	5.813
At Test	Water Content, %	30.5	25.7	21.9
	Dry Density, pcf	90.1	100.8	99.3
	Saturation, %	96.7	106.5	87.1
	Void Ratio	0.8367	0.6405	0.6667
	Diameter, in.	2.881	2.878	2.883
	Height, in.	5.857	5.982	5.691
Strain rate, in./min.		0.004	0.010	0.010
Back Pressure, ksf		10.08	8.64	8.64
Cell Pressure, ksf		12.24	12.24	14.40
Fail. Stress, ksf		2.81	4.55	4.82
Total Pore Pr., ksf		11.55	10.67	12.00
Ult. Stress, ksf				
Total Pore Pr., ksf				
$\bar{\sigma}_1$ Failure, ksf		3.50	6.12	7.23
$\bar{\sigma}_3$ Failure, ksf		0.69	1.57	2.40

Type of Test:
CU with Pore Pressures

Sample Type: Undisturbed

Description: Orange Tan Brown Coarse to Fine Sandy Clayey Silt (MH) w/Mica

LL= 57 **PL=** 32 **PI=** 25

Assumed Specific Gravity= 2.65

Remarks: Effective Stress Shear Strength Based on Maximum Principal Stress Ratio

Plate AD-6 (30-32)

Client: Duke Energy

Project: Duke Energy-Embankment Stability

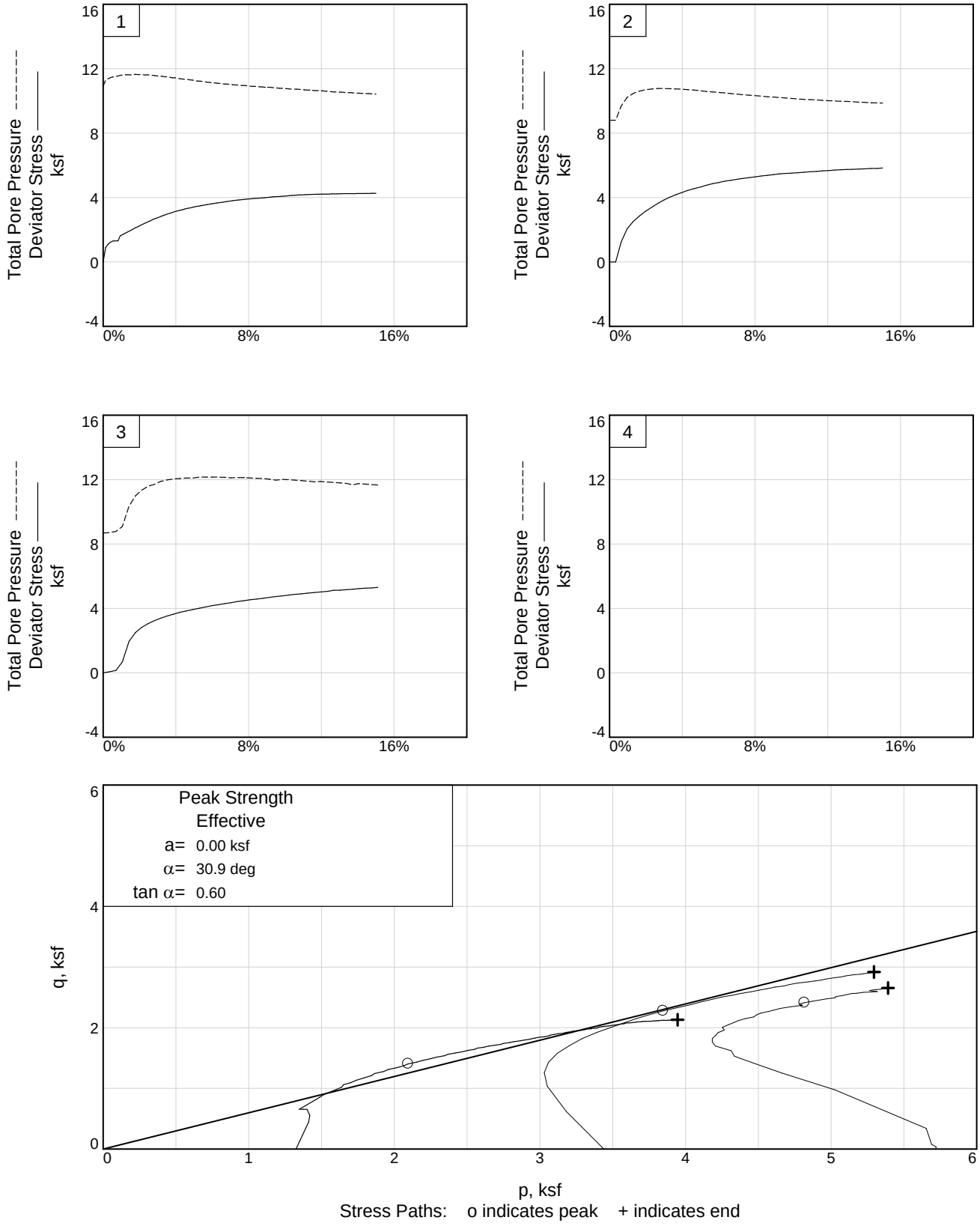
Sample Number: AD-6 Fill **Depth:** 30-32'

Proj. No.: 1356-09-029 Phase 04 **Date Sampled:**

TRIAXIAL SHEAR TEST REPORT

S & ME, INC.

Tested By: KMW **Checked By:** JSR



Client: Duke Energy

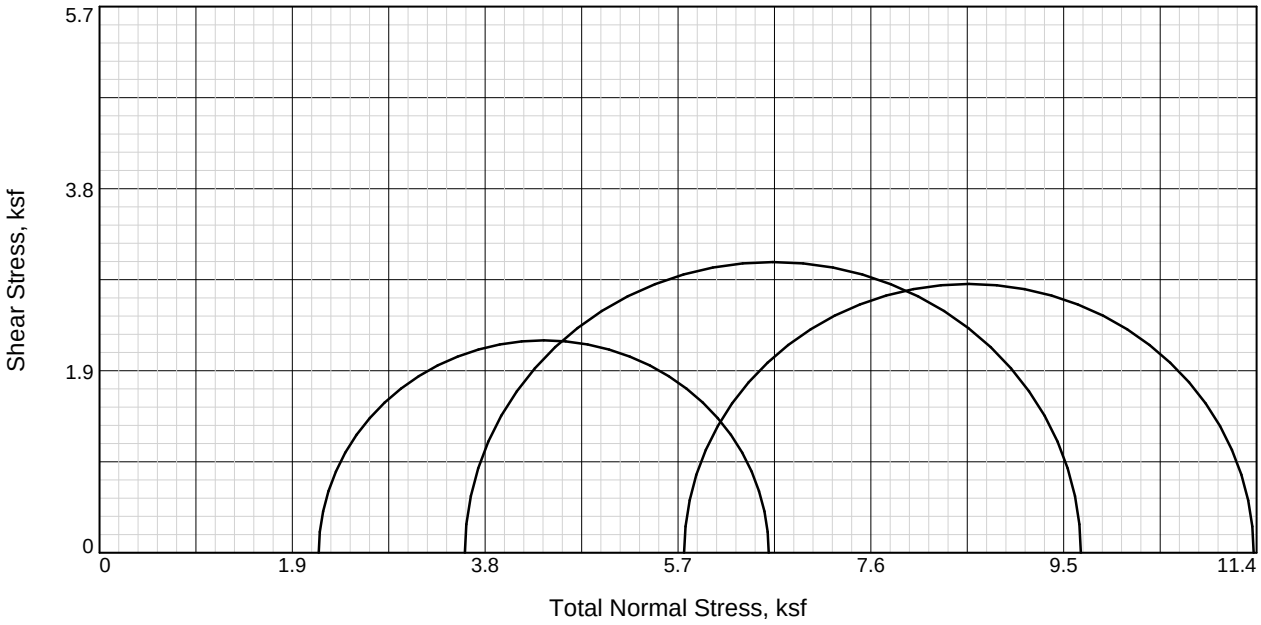
Project: Duke Energy-Embankment Stability

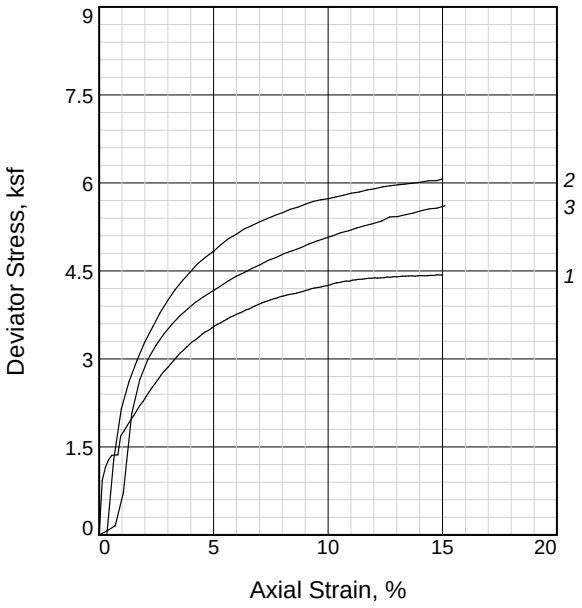
Depth: 30-32' **Sample Number:** AD-6 Fill

Project No.: 1356-09-029 Phase 04 **Plate** AD-6 (30-32)

S & ME, INC.

Tested By: KMW **Checked By:** JSR





Sample No.		1	2	3
Initial	Water Content, %	29.4	16.1	15.8
	Dry Density, pcf	89.9	100.7	98.4
	Saturation, %	92.7	66.2	61.5
	Void Ratio	0.8404	0.6429	0.6814
	Diameter, in.	2.864	2.861	2.865
	Height, in.	5.938	6.063	5.813
At Test	Water Content, %	28.9	21.8	21.8
	Dry Density, pcf	93.7	104.9	104.9
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.7658	0.5776	0.5770
	Diameter, in.	2.825	2.823	2.804
	Height, in.	5.857	5.982	5.691
Strain rate, in./min.		0.004	0.010	0.010
Back Pressure, ksf		10.08	8.64	8.64
Cell Pressure, ksf		12.24	12.24	14.40
Fail. Stress, ksf		4.43	6.07	5.61
Total Pore Pr., ksf		10.43	9.86	11.66
Ult. Stress, ksf				
Total Pore Pr., ksf				
$\bar{\sigma}_1$ Failure, ksf		6.25	8.45	8.35
$\bar{\sigma}_3$ Failure, ksf		1.81	2.38	2.74

Type of Test:
CU with Pore Pressures

Sample Type: Undisturbed

Description: Orange Tan Brown Coarse to Fine Sandy Clayey Silt (MH) w/Mica

LL= 57 **PL=** 32 **PI=** 25

Assumed Specific Gravity= 2.65

Remarks: Total Stress Shear Strength Based on Maximum Deviator Stress

Plate AD-6 (30-32)

Client: Duke Energy

Project: Duke Energy-Embankment Stability

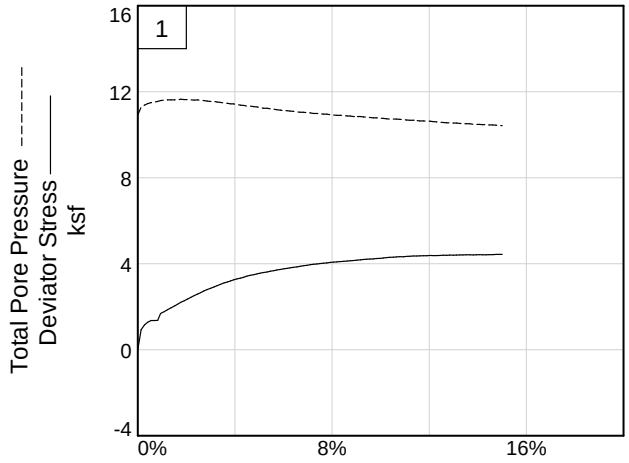
Sample Number: AD-6 Fill **Depth:** 30-32'

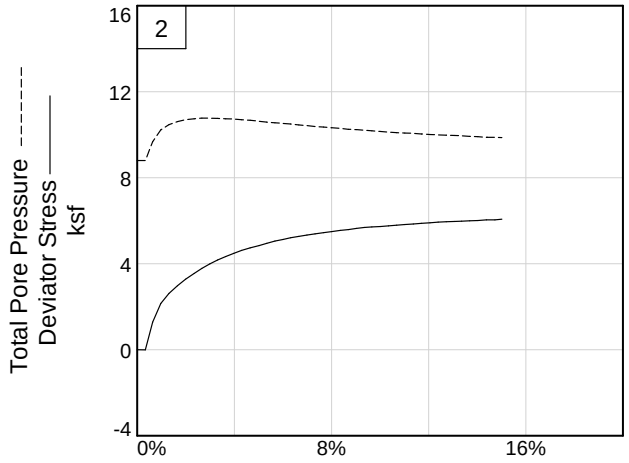
Proj. No.: 1356-09-029 Phase 04 **Date Sampled:**

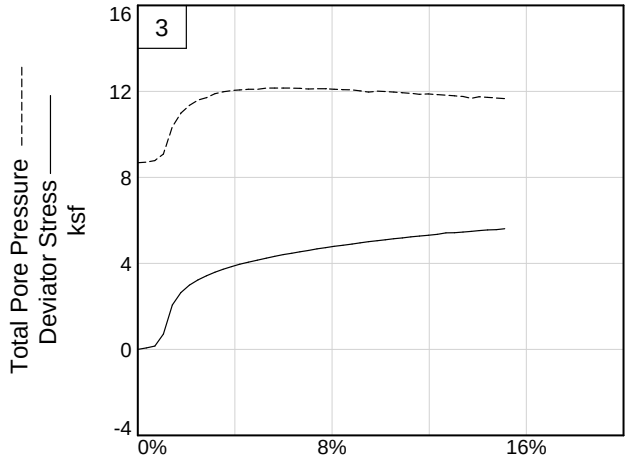
TRIAXIAL SHEAR TEST REPORT

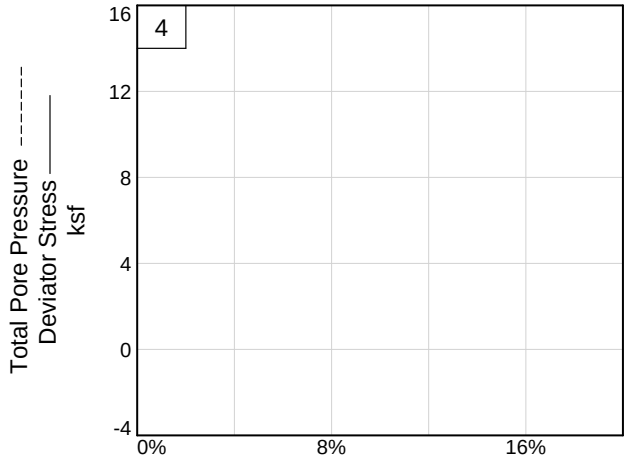
S & ME, INC.

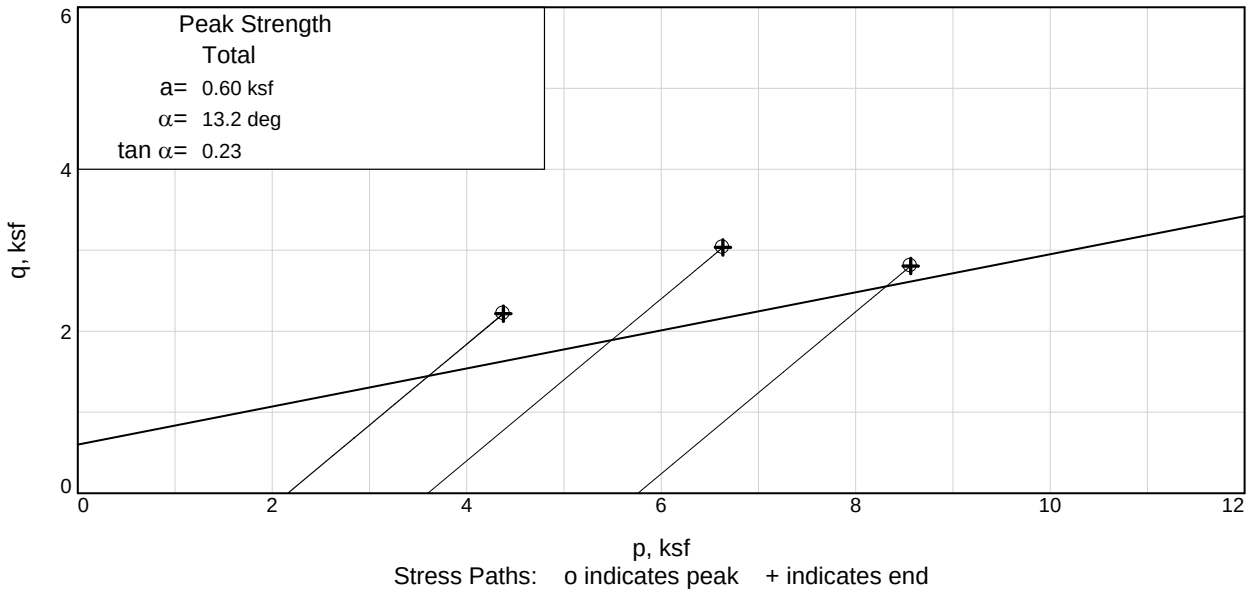
Tested By: KMW **Checked By:** JSR











Stress Paths: o indicates peak + indicates end

Client: Duke Energy
Project: Duke Energy-Embankment Stability
Depth: 30-32' **Sample Number:** AD-6 Fill
Project No.: 1356-09-029 Phase 04 **Plate** AD-6 (30-32)

S & ME, INC.

Tested By: KMW **Checked By:** JSR

TRIAXIAL COMPRESSION TEST 7/16/2010

CU with Pore Pressures 12:38 PM

Date:
Client: Duke Energy
Project: Duke Energy-Embankment Stability
Project No.: 1356-09-029 Phase 04
Depth: 30-32' **Sample Number:** AD-6 Fill
Description: Orange Tan Brown Coarse to Fine Sandy Clayey Silt (MH) w/Mica
Remarks:
Type of Sample: Undisturbed
Assumed Specific Gravity=2.65 **LL=**57 **PL=**32 **PI=**25
Test Method: COE uniform strain

Parameters for Specimen No. 1

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	214.840			798.200
Moisture content: Dry soil+tare, gms.	184.740			631.800
Moisture content: Tare, gms.	82.330			86.970
Moisture, %	29.4	31.6	28.9	30.5
Moist specimen weight, gms.	1167.90			
Diameter, in.	2.864	2.862	2.825	
Area, in.²	6.442	6.434	6.266	
Height, in.	5.938	5.934	5.857	
Net decrease in height, in.		0.004	0.077	
Wet Density, pcf	116.3	118.5	120.8	
Dry density, pcf	89.9	90.1	93.7	
Void ratio	0.8404	0.8367	0.7658	
Saturation, %	92.7	100.0	100.0	

Test Readings for Specimen No. 1

Consolidation cell pressure = 85.00 psi (12.24 ksf)
Consolidation back pressure = 70.00 psi (10.08 ksf)
Consolidation effective confining stress = 2.16 ksf
Strain rate, in./min. = 0.004
Fail. Stress = 2.92 ksf **at reading no.** 23

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
0	0.0010	20.100	0.0	0.0	0.00	1.32	1.32	1.00	75.80	1.32	0.00
1	0.0090	60.600	40.5	0.1	0.93	0.96	1.89	1.96	78.30	1.43	0.46
2	0.0170	70.500	50.4	0.3	1.16	0.86	2.02	2.34	79.00	1.44	0.58
3	0.0250	76.000	55.9	0.4	1.28	0.79	2.07	2.62	79.50	1.43	0.64
4	0.0330	79.500	59.4	0.5	1.36	0.75	2.11	2.81	79.80	1.43	0.68
5	0.0410	79.800	59.7	0.7	1.36	0.72	2.08	2.89	80.00	1.40	0.68
6	0.0490	80.000	59.9	0.8	1.37	0.69	2.06	2.98	80.20	1.37	0.68
7	0.0560	94.300	74.2	0.9	1.69	0.65	2.34	3.61	80.50	1.49	0.84
8	0.0650	98.200	78.1	1.1	1.78	0.63	2.41	3.80	80.60	1.52	0.89
9	0.0730	102.400	82.3	1.2	1.87	0.62	2.49	4.02	80.70	1.55	0.93
10	0.0810	106.200	86.1	1.4	1.95	0.62	2.57	4.15	80.70	1.59	0.98
11	0.0900	110.300	90.2	1.5	2.04	0.62	2.66	4.30	80.70	1.64	1.02
12	0.0970	113.800	93.7	1.6	2.12	0.62	2.74	4.42	80.70	1.68	1.06
13	0.1050	117.900	97.8	1.8	2.21	0.59	2.80	4.74	80.90	1.69	1.10
14	0.1130	121.000	100.9	1.9	2.27	0.60	2.88	4.76	80.80	1.74	1.14
15	0.1210	124.900	104.8	2.0	2.36	0.60	2.96	4.90	80.80	1.78	1.18
16	0.1290	128.700	108.6	2.2	2.44	0.62	3.06	4.94	80.70	1.84	1.22
17	0.1370	132.300	112.2	2.3	2.52	0.63	3.15	4.97	80.60	1.89	1.26
18	0.1450	135.600	115.5	2.5	2.59	0.62	3.21	5.18	80.70	1.91	1.29
19	0.1530	139.000	118.9	2.6	2.66	0.65	3.31	5.11	80.50	1.98	1.33
20	0.1600	142.300	122.2	2.7	2.73	0.65	3.38	5.22	80.50	2.01	1.37
21	0.1680	145.300	125.2	2.9	2.79	0.68	3.47	5.13	80.30	2.07	1.40
22	0.1770	148.400	128.3	3.0	2.86	0.69	3.55	5.14	80.20	2.12	1.43
23	0.1850	151.300	131.2	3.1	2.92	0.69	3.61	5.22	80.20	2.15	1.46
24	0.1920	154.100	134.0	3.3	2.98	0.72	3.70	5.14	80.00	2.21	1.49
25	0.2000	157.000	136.9	3.4	3.04	0.73	3.77	5.14	79.90	2.25	1.52
26	0.2090	160.200	140.1	3.6	3.11	0.76	3.87	5.07	79.70	2.32	1.55
27	0.2170	162.500	142.4	3.7	3.15	0.78	3.93	5.05	79.60	2.35	1.58
28	0.2250	165.000	144.9	3.8	3.20	0.81	4.01	4.97	79.40	2.41	1.60
29	0.2320	167.300	147.2	3.9	3.25	0.81	4.06	5.03	79.40	2.43	1.62
30	0.2400	169.600	149.5	4.1	3.30	0.84	4.13	4.95	79.20	2.48	1.65
31	0.2490	171.600	151.5	4.2	3.33	0.86	4.20	4.86	79.00	2.53	1.67
32	0.2570	173.800	153.7	4.4	3.38	0.88	4.26	4.85	78.90	2.57	1.69
33	0.2640	176.000	155.9	4.5	3.42	0.91	4.33	4.77	78.70	2.62	1.71
34	0.2720	178.000	157.9	4.6	3.46	0.91	4.37	4.81	78.70	2.64	1.73
35	0.2810	179.600	159.5	4.8	3.49	0.94	4.43	4.73	78.50	2.68	1.75
36	0.2890	181.600	161.5	4.9	3.53	0.95	4.48	4.71	78.40	2.71	1.76
37	0.2960	183.300	163.2	5.0	3.56	0.98	4.54	4.64	78.20	2.76	1.78
38	0.3040	184.900	164.8	5.2	3.59	1.01	4.60	4.56	78.00	2.80	1.80
39	0.3130	186.400	166.3	5.3	3.62	1.01	4.63	4.59	78.00	2.82	1.81
40	0.3210	188.300	168.2	5.5	3.65	1.04	4.69	4.52	77.80	2.86	1.83
41	0.3290	189.700	169.6	5.6	3.68	1.05	4.73	4.50	77.70	2.89	1.84
42	0.3360	191.400	171.3	5.7	3.71	1.08	4.79	4.44	77.50	2.94	1.86
43	0.3450	192.800	172.7	5.9	3.74	1.09	4.83	4.41	77.40	2.96	1.87
44	0.3530	194.400	174.3	6.0	3.76	1.12	4.89	4.35	77.20	3.01	1.88
45	0.3610	195.600	175.5	6.1	3.79	1.12	4.91	4.37	77.20	3.02	1.89
46	0.3680	196.800	176.7	6.3	3.81	1.14	4.94	4.35	77.10	3.04	1.90

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
47	0.3760	198.400	178.3	6.4	3.83	1.15	4.99	4.33	77.00	3.07	1.92
48	0.3850	199.500	179.4	6.6	3.85	1.18	5.03	4.26	76.80	3.11	1.93
49	0.3930	201.200	181.1	6.7	3.88	1.20	5.08	4.25	76.70	3.14	1.94
50	0.4000	202.500	182.4	6.8	3.91	1.20	5.10	4.27	76.70	3.15	1.95
51	0.4090	203.900	183.8	7.0	3.93	1.21	5.14	4.25	76.60	3.17	1.96
52	0.4170	205.400	185.3	7.1	3.96	1.22	5.18	4.23	76.50	3.20	1.98
53	0.4250	206.500	186.4	7.2	3.97	1.25	5.23	4.17	76.30	3.24	1.99
54	0.4330	207.600	187.5	7.4	3.99	1.25	5.24	4.19	76.30	3.25	2.00
55	0.4400	208.700	188.6	7.5	4.01	1.27	5.28	4.16	76.20	3.27	2.00
56	0.4490	209.900	189.8	7.6	4.03	1.28	5.31	4.14	76.10	3.30	2.01
57	0.4570	210.800	190.7	7.8	4.04	1.28	5.32	4.15	76.10	3.30	2.02
58	0.4650	212.200	192.1	7.9	4.06	1.31	5.38	4.10	75.90	3.34	2.03
59	0.4730	212.900	192.8	8.1	4.07	1.32	5.40	4.07	75.80	3.36	2.04
60	0.4810	213.900	193.8	8.2	4.09	1.34	5.43	4.05	75.70	3.38	2.04
61	0.4890	214.800	194.7	8.3	4.10	1.34	5.44	4.06	75.70	3.39	2.05
62	0.4980	215.600	195.5	8.5	4.11	1.34	5.45	4.07	75.70	3.39	2.06
63	0.5060	216.400	196.3	8.6	4.12	1.37	5.49	4.01	75.50	3.43	2.06
64	0.5130	217.300	197.2	8.7	4.14	1.37	5.50	4.02	75.50	3.44	2.07
65	0.5210	218.200	198.1	8.9	4.15	1.40	5.54	3.97	75.30	3.47	2.07
66	0.5300	219.500	199.4	9.0	4.17	1.40	5.57	3.98	75.30	3.48	2.08
67	0.5380	220.500	200.4	9.2	4.18	1.40	5.58	3.99	75.30	3.49	2.09
68	0.5450	221.600	201.5	9.3	4.20	1.41	5.61	3.98	75.20	3.51	2.10
69	0.5530	222.400	202.3	9.4	4.21	1.43	5.64	3.95	75.10	3.53	2.11
70	0.5610	223.100	203.0	9.6	4.22	1.44	5.66	3.93	75.00	3.55	2.11
71	0.5690	223.800	203.7	9.7	4.23	1.45	5.68	3.91	74.90	3.57	2.11
72	0.5760	224.700	204.6	9.8	4.24	1.45	5.69	3.92	74.90	3.57	2.12
73	0.5850	225.600	205.5	10.0	4.25	1.47	5.72	3.89	74.80	3.59	2.13
74	0.5930	226.600	206.5	10.1	4.27	1.48	5.75	3.88	74.70	3.62	2.13
75	0.6010	227.900	207.8	10.2	4.29	1.50	5.78	3.86	74.60	3.64	2.14
76	0.6080	228.700	208.6	10.4	4.30	1.51	5.81	3.84	74.50	3.66	2.15
77	0.6170	229.500	209.4	10.5	4.31	1.51	5.82	3.85	74.50	3.66	2.15
78	0.6250	230.400	210.3	10.7	4.32	1.51	5.83	3.86	74.50	3.67	2.16
79	0.6330	231.200	211.1	10.8	4.33	1.53	5.85	3.84	74.40	3.69	2.16
80	0.6420	231.500	211.4	10.9	4.33	1.54	5.87	3.81	74.30	3.70	2.16
81	0.6490	232.600	212.5	11.1	4.34	1.56	5.90	3.79	74.20	3.73	2.17
82	0.6570	233.200	213.1	11.2	4.35	1.57	5.92	3.77	74.10	3.74	2.17
83	0.6650	234.000	213.9	11.3	4.36	1.57	5.93	3.78	74.10	3.75	2.18
84	0.6740	234.500	214.4	11.5	4.36	1.58	5.94	3.75	74.00	3.76	2.18
85	0.6810	235.100	215.0	11.6	4.37	1.60	5.97	3.73	73.90	3.78	2.18
86	0.6900	235.900	215.8	11.8	4.38	1.60	5.97	3.74	73.90	3.79	2.19
87	0.6980	236.200	216.1	11.9	4.37	1.61	5.99	3.71	73.80	3.80	2.19
88	0.7060	236.900	216.8	12.0	4.38	1.61	6.00	3.72	73.80	3.80	2.19
89	0.7130	237.000	216.9	12.2	4.38	1.63	6.01	3.69	73.70	3.82	2.19
90	0.7210	237.500	217.4	12.3	4.38	1.64	6.02	3.67	73.60	3.83	2.19
91	0.7300	238.000	217.9	12.4	4.38	1.66	6.04	3.65	73.50	3.85	2.19
92	0.7380	239.000	218.9	12.6	4.40	1.67	6.07	3.63	73.40	3.87	2.20
93	0.7460	239.100	219.0	12.7	4.39	1.68	6.08	3.61	73.30	3.88	2.20

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
94	0.7530	239.900	219.8	12.8	4.40	1.68	6.09	3.61	73.30	3.89	2.20
95	0.7620	240.200	220.1	13.0	4.40	1.70	6.10	3.59	73.20	3.90	2.20
96	0.7700	240.800	220.7	13.1	4.41	1.70	6.10	3.59	73.20	3.90	2.20
97	0.7780	241.500	221.4	13.3	4.41	1.71	6.13	3.58	73.10	3.92	2.21
98	0.7850	241.800	221.7	13.4	4.41	1.73	6.14	3.55	73.00	3.93	2.21
99	0.7930	242.200	222.1	13.5	4.41	1.73	6.14	3.55	73.00	3.93	2.21
100	0.8020	242.700	222.6	13.7	4.42	1.73	6.14	3.56	73.00	3.94	2.21
101	0.8100	242.700	222.6	13.8	4.41	1.76	6.17	3.51	72.80	3.96	2.20
102	0.8170	243.500	223.4	13.9	4.42	1.76	6.18	3.52	72.80	3.97	2.21
103	0.8250	244.000	223.9	14.1	4.42	1.76	6.18	3.52	72.80	3.97	2.21
104	0.8330	244.200	224.1	14.2	4.42	1.77	6.19	3.49	72.70	3.98	2.21
105	0.8410	244.600	224.5	14.3	4.42	1.77	6.19	3.49	72.70	3.98	2.21
106	0.8480	245.200	225.1	14.5	4.42	1.79	6.21	3.48	72.60	4.00	2.21
107	0.8570	245.500	225.4	14.6	4.42	1.79	6.21	3.48	72.60	4.00	2.21
108	0.8650	246.500	226.4	14.8	4.44	1.80	6.24	3.46	72.50	4.02	2.22
109	0.8730	246.700	226.6	14.9	4.43	1.81	6.25	3.44	72.40	4.03	2.22
110	0.8800	247.100	227.0	15.0	4.43	1.81	6.25	3.44	72.40	4.03	2.22

Parameters for Specimen No. 2

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	204.480			1043.000
Moisture content: Dry soil+tare, gms.	187.470			844.600
Moisture content: Tare, gms.	81.600			73.880
Moisture, %	16.1	24.2	21.8	25.7
Moist specimen weight, gms.	1195.80			
Diameter, in.	2.861	2.860	2.823	
Area, in.²	6.429	6.422	6.257	
Height, in.	6.063	6.060	5.982	
Net decrease in height, in.		0.003	0.078	
Wet Density, pcf	116.9	125.2	127.7	
Dry density, pcf	100.7	100.8	104.9	
Void ratio	0.6429	0.6405	0.5776	
Saturation, %	66.2	100.0	100.0	

Test Readings for Specimen No. 2

Consolidation cell pressure = 85.00 psi (12.24 ksf)
Consolidation back pressure = 60.00 psi (8.64 ksf)
Consolidation effective confining stress = 3.60 ksf
Strain rate, in./min. = 0.010
Fail. Stress = 4.74 ksf **at reading no.** 14

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
0	0.0080	16.000	0.0	0.0	0.00	3.44	3.44	1.00	61.10	3.44	0.00
1	0.0280	15.800	-0.2	0.3	0.00	3.44	3.44	1.00	61.10	3.44	0.00
2	0.0460	72.200	56.2	0.6	1.29	2.56	3.85	1.50	67.20	3.21	0.64
3	0.0660	110.400	94.4	1.0	2.15	2.02	4.17	2.07	71.00	3.09	1.08
4	0.0860	131.200	115.2	1.3	2.62	1.77	4.39	2.48	72.70	3.08	1.31
5	0.1070	147.600	131.6	1.7	2.98	1.63	4.61	2.83	73.70	3.12	1.49
6	0.1270	161.600	145.6	2.0	3.28	1.54	4.83	3.13	74.30	3.18	1.64
7	0.1480	173.900	157.9	2.3	3.55	1.50	5.05	3.37	74.60	3.27	1.77
8	0.1670	184.900	168.9	2.7	3.78	1.47	5.25	3.58	74.80	3.36	1.89
9	0.1870	195.000	179.0	3.0	4.00	1.47	5.47	3.72	74.80	3.47	2.00
10	0.2060	203.700	187.7	3.3	4.18	1.48	5.66	3.82	74.70	3.57	2.09
11	0.2260	211.600	195.6	3.6	4.34	1.50	5.84	3.90	74.60	3.67	2.17
12	0.2460	218.800	202.8	4.0	4.48	1.51	5.99	3.96	74.50	3.75	2.24
13	0.2650	225.800	209.8	4.3	4.62	1.54	6.16	4.00	74.30	3.85	2.31
14	0.2860	231.800	215.8	4.6	4.74	1.57	6.31	4.02	74.10	3.94	2.37
15	0.3080	237.500	221.5	5.0	4.84	1.61	6.45	4.00	73.80	4.03	2.42
16	0.3270	243.300	227.3	5.3	4.95	1.66	6.61	3.99	73.50	4.13	2.48
17	0.3470	248.800	232.8	5.7	5.05	1.68	6.74	4.00	73.30	4.21	2.53
18	0.3670	253.000	237.0	6.0	5.13	1.71	6.84	3.99	73.10	4.28	2.56
19	0.3860	257.700	241.7	6.3	5.21	1.74	6.95	3.99	72.90	4.35	2.61
20	0.4060	261.300	245.3	6.7	5.27	1.79	7.06	3.95	72.60	4.42	2.63
21	0.4260	265.100	249.1	7.0	5.33	1.81	7.15	3.94	72.40	4.48	2.67
22	0.4460	268.700	252.7	7.3	5.39	1.86	7.25	3.90	72.10	4.55	2.69
23	0.4670	272.300	256.3	7.7	5.45	1.89	7.33	3.89	71.90	4.61	2.72
24	0.4870	275.500	259.5	8.0	5.49	1.92	7.41	3.87	71.70	4.66	2.75
25	0.5080	279.300	263.3	8.4	5.55	1.94	7.50	3.86	71.50	4.72	2.78
26	0.5280	282.000	266.0	8.7	5.59	1.99	7.58	3.81	71.20	4.78	2.79

Test Readings for Specimen No. 2

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
27	0.5480	285.500	269.5	9.0	5.64	2.00	7.64	3.82	71.10	4.82	2.82
28	0.5670	288.500	272.5	9.3	5.69	2.03	7.72	3.80	70.90	4.87	2.84
29	0.5860	290.700	274.7	9.7	5.71	2.06	7.77	3.77	70.70	4.91	2.86
30	0.6070	292.800	276.8	10.0	5.73	2.09	7.82	3.75	70.50	4.95	2.87
31	0.6270	295.200	279.2	10.3	5.76	2.12	7.88	3.72	70.30	5.00	2.88
32	0.6470	297.700	281.7	10.7	5.79	2.15	7.94	3.70	70.10	5.04	2.90
33	0.6670	300.500	284.5	11.0	5.83	2.16	7.99	3.70	70.00	5.07	2.91
34	0.6880	302.600	286.6	11.4	5.85	2.17	8.02	3.69	69.90	5.10	2.92
35	0.7080	305.300	289.3	11.7	5.88	2.20	8.08	3.67	69.70	5.14	2.94
36	0.7290	307.600	291.6	12.1	5.90	2.23	8.13	3.64	69.50	5.18	2.95
37	0.7490	310.300	294.3	12.4	5.93	2.25	8.18	3.64	69.40	5.21	2.97
38	0.7690	312.300	296.3	12.7	5.95	2.26	8.21	3.63	69.30	5.24	2.98
39	0.7890	314.300	298.3	13.1	5.97	2.28	8.24	3.62	69.20	5.26	2.98
40	0.8070	315.900	299.9	13.4	5.98	2.29	8.27	3.61	69.10	5.28	2.99
41	0.8270	317.800	301.8	13.7	5.99	2.32	8.31	3.59	68.90	5.32	3.00
42	0.8470	319.800	303.8	14.0	6.01	2.33	8.34	3.58	68.80	5.34	3.01
43	0.8680	322.400	306.4	14.4	6.04	2.36	8.40	3.56	68.60	5.38	3.02
44	0.8890	323.700	307.7	14.7	6.04	2.36	8.40	3.56	68.60	5.38	3.02
45	0.9060	326.300	310.3	15.0	6.07	2.38	8.45	3.55	68.50	5.41	3.03

Parameters for Specimen No. 3

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	231.680			1221.500
Moisture content: Dry soil+tare, gms.	211.180			1017.100
Moisture content: Tare, gms.	81.450			84.240
Moisture, %	15.8	25.2	21.8	21.9
Moist specimen weight, gms.	1120.80			
Diameter, in.	2.865	2.857	2.804	
Area, in.²	6.447	6.409	6.176	
Height, in.	5.813	5.796	5.691	
Net decrease in height, in.		0.017	0.105	
Wet Density, pcf	113.9	124.2	127.7	
Dry density, pcf	98.4	99.3	104.9	
Void ratio	0.6814	0.6667	0.5770	
Saturation, %	61.5	100.0	100.0	

Test Readings for Specimen No. 3

Consolidation cell pressure = 100.00 psi (14.40 ksf)
Consolidation back pressure = 60.00 psi (8.64 ksf)
Consolidation effective confining stress = 5.76 ksf
Strain rate, in./min. = 0.010
Fail. Stress = 5.10 ksf **at reading no.** 29

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
0	0.0150	20.200	0.0	0.0	0.00	5.72	5.72	1.00	60.30	5.72	0.00
1	0.0350	23.300	3.1	0.4	0.07	5.69	5.76	1.01	60.50	5.72	0.04
2	0.0550	27.000	6.8	0.7	0.16	5.62	5.77	1.03	61.00	5.69	0.08
3	0.0750	51.300	31.1	1.1	0.72	5.31	6.03	1.14	63.10	5.67	0.36
4	0.0960	110.100	89.9	1.4	2.07	4.05	6.11	1.51	71.90	5.08	1.03
5	0.1160	135.700	115.5	1.8	2.65	3.41	6.06	1.78	76.30	4.74	1.32
6	0.1360	151.300	131.1	2.1	2.99	3.05	6.04	1.98	78.80	4.55	1.50
7	0.1560	162.300	142.1	2.5	3.23	2.81	6.04	2.15	80.50	4.42	1.62
8	0.1760	171.400	151.2	2.8	3.43	2.69	6.12	2.27	81.30	4.41	1.71
9	0.1960	179.300	159.1	3.2	3.59	2.51	6.10	2.43	82.60	4.30	1.80
10	0.2150	186.000	165.8	3.5	3.73	2.42	6.15	2.54	83.20	4.28	1.86
11	0.2350	192.000	171.8	3.9	3.85	2.36	6.21	2.63	83.60	4.29	1.93
12	0.2540	197.700	177.5	4.2	3.96	2.33	6.30	2.70	83.80	4.32	1.98
13	0.2740	202.500	182.3	4.6	4.06	2.30	6.36	2.76	84.00	4.33	2.03
14	0.2950	207.300	187.1	4.9	4.15	2.30	6.45	2.80	84.00	4.38	2.07
15	0.3160	212.200	192.0	5.3	4.24	2.25	6.49	2.89	84.40	4.37	2.12
16	0.3360	217.000	196.8	5.6	4.33	2.25	6.58	2.93	84.40	4.41	2.16
17	0.3560	221.400	201.2	6.0	4.41	2.25	6.66	2.96	84.40	4.45	2.21
18	0.3760	225.000	204.8	6.3	4.47	2.25	6.72	2.99	84.40	4.48	2.24
19	0.3950	229.000	208.8	6.7	4.54	2.26	6.80	3.01	84.30	4.53	2.27
20	0.4150	232.600	212.4	7.0	4.60	2.29	6.89	3.01	84.10	4.59	2.30
21	0.4350	236.900	216.7	7.4	4.68	2.28	6.95	3.06	84.20	4.62	2.34
22	0.4550	240.100	219.9	7.7	4.73	2.28	7.01	3.08	84.20	4.64	2.37
23	0.4750	244.000	223.8	8.1	4.80	2.30	7.10	3.08	84.00	4.70	2.40
24	0.4960	247.200	227.0	8.5	4.85	2.32	7.16	3.09	83.90	4.74	2.42
25	0.5170	250.600	230.4	8.8	4.90	2.33	7.23	3.10	83.80	4.78	2.45
26	0.5360	254.300	234.1	9.2	4.96	2.38	7.33	3.09	83.50	4.86	2.48

Test Readings for Specimen No. 3

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
27	0.5560	257.600	237.4	9.5	5.01	2.43	7.44	3.06	83.10	4.94	2.50
28	0.5760	260.700	240.5	9.9	5.05	2.39	7.45	3.11	83.40	4.92	2.53
29	0.5950	263.700	243.5	10.2	5.10	2.40	7.50	3.12	83.30	4.95	2.55
30	0.6150	267.100	246.9	10.5	5.15	2.43	7.58	3.12	83.10	5.01	2.57
31	0.6350	269.800	249.6	10.9	5.19	2.46	7.65	3.11	82.90	5.06	2.59
32	0.6550	273.100	252.9	11.2	5.23	2.49	7.72	3.10	82.70	5.11	2.62
33	0.6750	275.900	255.7	11.6	5.27	2.53	7.80	3.08	82.40	5.17	2.64
34	0.6960	278.800	258.6	12.0	5.31	2.52	7.83	3.11	82.50	5.17	2.65
35	0.7170	282.000	261.8	12.3	5.35	2.55	7.90	3.10	82.30	5.22	2.68
36	0.7370	286.500	266.3	12.7	5.42	2.58	8.00	3.10	82.10	5.29	2.71
37	0.7570	287.900	267.7	13.0	5.43	2.61	8.03	3.08	81.90	5.32	2.71
38	0.7770	290.600	270.4	13.4	5.46	2.64	8.10	3.07	81.70	5.37	2.73
39	0.7960	293.000	272.8	13.7	5.49	2.72	8.21	3.02	81.10	5.47	2.74
40	0.8150	296.000	275.8	14.1	5.53	2.65	8.18	3.09	81.60	5.41	2.76
41	0.8350	298.700	278.5	14.4	5.56	2.68	8.24	3.08	81.40	5.46	2.78
42	0.8550	300.500	280.3	14.8	5.57	2.71	8.28	3.06	81.20	5.49	2.79
43	0.8750	303.700	283.5	15.1	5.61	2.74	8.35	3.05	81.00	5.54	2.81

Particle Size Analysis of Soils

ASTM D 422

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	6/1/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	5/20-6/1/10
Client Name:	Duke Energy	Address:	3195 Pine Hall Road, Belews Creek, NC 27009
Boring #:	AD7	Sample #:	7
Location:		Offset:	
Sample Description:	Tan Silty Fine to Coarse Sand (SM)		

Pan #:		Beaker #:		**Apparent Relative Density (Assumed)**		**2.650**	
Hydrometer Jar #:							
Pan Tare Weight (grams):				**Moisture Content**	Hygroscopic	Natural	
Total Sample Air Dried Wt. + tare wt. (grams):	193.43			Tare #	PO		
Weight of Total Sample Air Dried:	193.43		A	Tare Wt.	15.15		
Weight of Air Dried Hydrometer Sample (g):	100.00		B	Wet Wt. + A	25.76		
Total Sample Oven Dried:	189.41		C	Dry Wt. + A	25.51		
Hydrometer Sample Oven Dried (**W**):	97.64		D	Water Wt. (B-C)	0.25		
% Passing #10:	87.9%		E	Dry Wt. (C-A)	10.36		
Correction Factor a (Table 1):	1.00			% Moisture (100 x D/E)	2.41%		

Sieve	Retained Wt.	Percent Passing	
3.0"	0.0	Pan # (washed)	100.0%
1.5"	0.0		100.0%
1.0"	0.0		100.0%
3/4"	0.0		100.0%
1/2"	0.0		100.0%
3/8"	1.7	Soil Mortar	99.1%
#4	9.6		95.0%
#10	22.9	**100.0%**	87.9%
#20	17.4	82.2%	72.3%
#40	47.5	51.4%	45.2%
#60	69.9	28.5%	25.0%
#100	78.6	19.5%	17.1%
#200	83.5	14.5%	12.7%

Description of Sand & Gravel Particles Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Stirring Apparatus: A ☐ B ☐ Dispersion Time: 1 min. Sodium Hexametaphosphate: 40 g./ Liter

Balance: *ID No.* 3996 *Cal. Date:* 2/3/2010 Hydrometer: *ID No.* 3901 *Cal. Date:* 3/26/2010

Control Cylinder ☒ **Composite Correction** ☐ **Type:** **151H** ☐ **152H** ☒

Time	Temp.	Hydrometer	Corrections		Hydrometer	Percent Passing		Effective Depth	Table 3	Diameter
			Control Cylinder	Composite Correction		P(-#10) = (R x a / W) x 100	P (total) = P x % Passing #10			D = K x ((L/T)$^{1/2}$
T (Min.)	(0.5 °C)	Reading			R			L	K	
1	24.5	17.5	4.5		13.00	13.3%	11.7%	14.2	0.01294	0.04868
2	24.5	15.5	4.5		11.00	11.3%	9.9%	14.5	0.01294	0.03482
5	24.5	13.0	4.5		8.50	8.7%	7.7%	14.9	0.01294	0.02233
15	24.5	11.0	4.5		6.50	6.7%	5.9%	15.2	0.01294	0.01303
30	24.5	10.0	4.5		5.50	5.6%	5.0%	15.4	0.01294	0.00927
60	24.5	9.5	4.5		5.00	5.1%	4.5%	15.5	0.01294	0.00657
250	24.5	9.0	4.5		4.50	4.6%	4.1%	15.6	0.01294	0.00323
1440	23.5	7.5	4.5		3.00	3.1%	2.7%	15.8	0.01309	0.00137

References / Comments / Deviations ASTM D 422, D 2487, D 4318

Karen Warner	NICET 117900	Jason Reeves	Senior Engineer	
Technician Name	*Certification #*	*Technical Responsibility*	*Position*	*Date*

Form No. TR-D422-3
Revision No. 0
Revision Date: 02/20/08

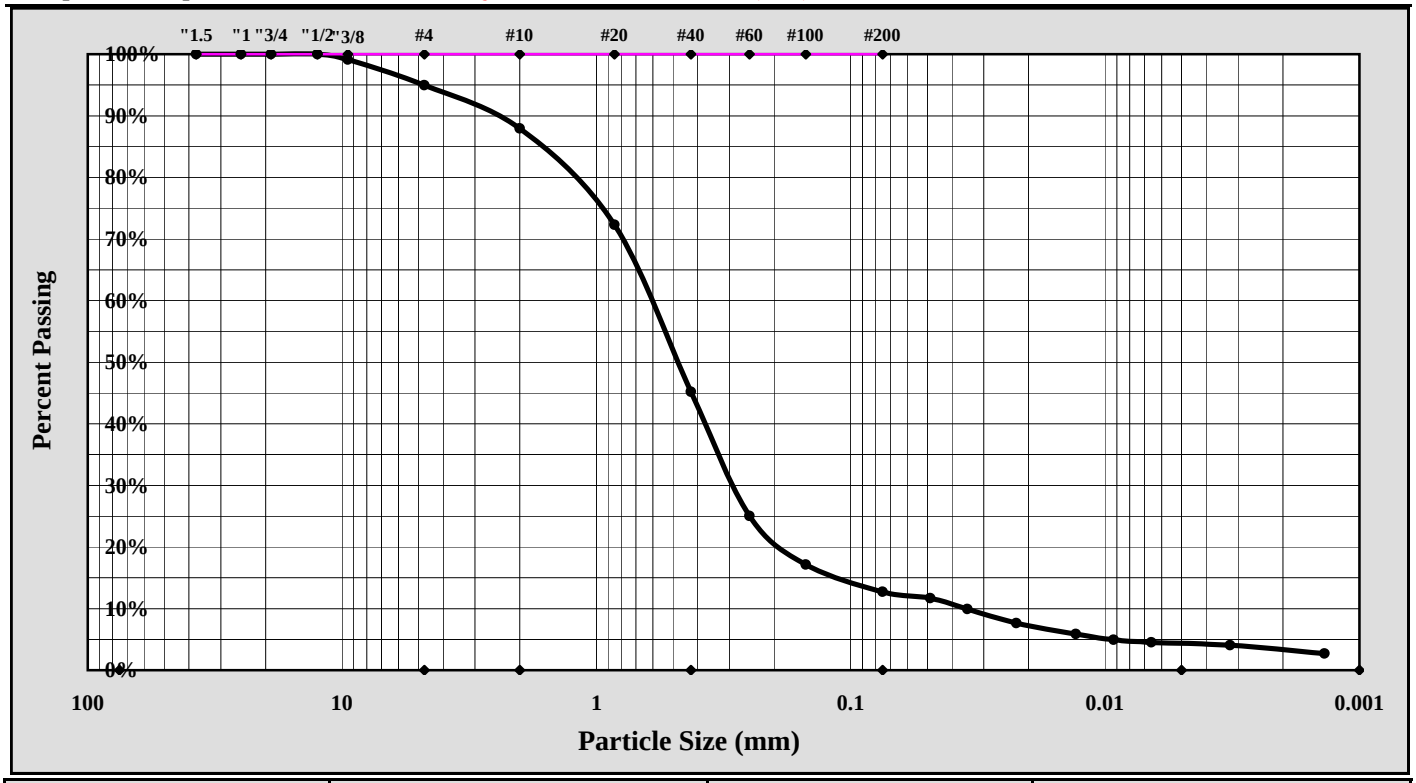
Particle Size Analysis of Soils

ASTM D422

Quality Assurance

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

S&ME Project #:	1356-09-029 Phase 04	Report Date:	6/1/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	5/20-6/1/10
Client Name:	Duke Energy		
Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD7	Sample #: 7	Sample Date:
Location:		Offset:	Elevation: 13-14.5'
Sample Description:	Tan Silty Fine to Coarse Sand (SM)		



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm (#200)
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Maximum Particle Size:	#4	Gravel:	5.0%	Silt	8.2%
Silt & Clay (% Passing #200):	12.7%	Total Sand:	82.2%	Clay	4.5%
ent Relative Density (Assumed)	2.650	Moisture Content		Colloids	3.0%
Liquid Limit	ND	Plastic Limit	ND	Plastic Index	ND
Coarse Sand:	7.0%	Medium Sand:	42.7%	Fine Sand:	32.5%

Description of Sand and Gravel — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Apparatus B: Air Jet Dispersion — Dispersion Period: 1 min. Dispersing Agent: Sodium Hexametaphosphate: 40 g./ Liter

References / Comments / Deviations: ASTM D 4318, D 854, D 2487

Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No: TR-D2216-T265-1
Revision No. 0
Revision Date: 02/22/08

Laboratory Determination of Water Content

ASTM D 2216 ☑ *AASHTO T 265* ☐ ***Quality Assurance***

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	5/21/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	5/17-21/10
Client Name:	Duke Energy		
Client Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Sample by:	C. Withers	Sample Date(s):	3/30/10
Sampling Method:		Drill Rig :	

Method: **A (1%)** ☐ **B (0.1%)** ☑ *Balance ID.* *Calibration Date:*

Boring No.	Sample No.	Sample Depth	Tare #	Tare Weight	Tare Wt.+ Wet Wt	Tare Wt. + Dry Wt	Water Weight	Percent Moisture	Note
		ft. or m.		grams	grams	grams	grams	%	
AD9	1	1-2.5	S-3	82.34	256.76	228.27	28.49	**19.5%**	
AD9	2	3.5-5	T-4	81.62	258.67	227.11	31.56	**21.7%**	
AD9	3	8.5-10	G-3	81.55	292.52	262.04	30.48	**16.9%**	
AD9	4	13.5-15	G-12	82.87	283.13	252.09	31.04	**18.3%**	
AD9	5	18.5-20	G-1	83.07	270.05	240.32	29.73	**18.9%**	
AD9	6	20-21.5	G-15	81.45	292.66	252.81	39.85	**23.3%**	
AD9	7	21.5-23	T-1	83.30	363.28	309.25	54.03	**23.9%**	
AD9	8	23-24.5	S-5	82.14	288.22	255.69	32.53	**18.7%**	
AD9	9	24.5-26	PAUL	81.83	291.29	256.75	34.54	**19.7%**	
AD9	10	28.5-30	S-2	81.43	295.05	263.89	31.16	**17.1%**	
AD9	11	33.5-35	G-13	81.63	182.56	169.23	13.33	**15.2%**	
AD9	12	35-36.5	S-7	81.73	190.47	175.14	15.33	**16.4%**	
AD9	13	36.5-38	G-5	82.10	170.25	161.33	8.92	**11.3%**	

Notes / Deviations / References

ASTM D 2216: Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

Karen Warner		NICET 117900	
Technician Name	*Signature*	*Certification Type / No.*	*Date*
Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D4318-T89-90
Revision No. 0
Revision Date: 11/20/07

Liquid Limit, Plastic Limit, and Plastic Index

Another code *ASTM D 4318* ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐ ***Quality Assurance***

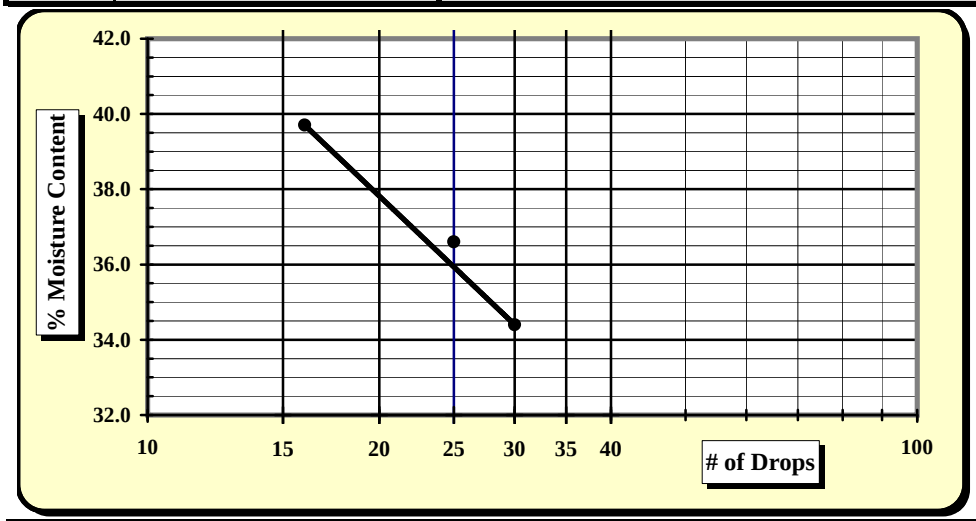
S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s)	5/26-6/22/10
Client Name:	Duke Energy		
Client Address:	3195 Pine Hall Road, Belews Creek, NC 27009		

Boring #:	AD-9	Sample #: Fill	Sample Date:
Location:		Offset:	Elevation: 16-18'
Sample Description:	Orange Brown Micaceous Silty Coarse to Fine Sand (SM)		

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	3996	2/3/2010	Grooving tool	21587	2/28/2010
LL Apparatus	3611	10/20/2009	Grooving tool		
Oven	10844	9/4/2009	Grooving tool		

Pan #		Liquid Limit						Plastic Limit		
	Tare #:	Rocky	111	Ron				Bugs	Phi	
A	Tare Weight	14.55	14.50	8.41				14.63	14.62	
B	Wet Soil Weight + A	25.46	24.46	19.18				20.97	20.63	
C	Dry Soil Weight + A	22.67	21.79	16.12				19.64	19.39	
D	Water Weight (B-C)	2.79	2.67	3.06				1.33	1.24	
E	Dry Soil Weight (C-A)	8.12	7.29	7.71				5.01	4.77	
F	% Moisture (D/E)*100	34.4%	36.6%	39.7%				26.5%	26.0%	
N	# OF DROPS	30	25	16				*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*							**26.3%**		



One Point Liquid Limit			
N	**Factor**	**N**	**Factor**
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☐
Liquid Limit **36**
Plastic Limit **26**
Plastic Index **10**
Group Symbol **SM**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *Estimate the % Retained on the #40 Sieve:*

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Karen Warner — *Technician Name* — *Date*
Jason Reeves — *Technical Responsibility* — *Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D422-2
Revision No. 0
Revision Date: 02/20/08

Particle Size Analysis of Soils

ASTM D 422

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	6/9-22/10
Client Name:	Duke Energy	Address:	3195 Pine Hall Road, Belews Creek, NC 27009
Boring #:	AD-9	Sample #:	Fill
Location:		Offset:	
Sample Description:	Orange Brown Micaceous Silty Coarse to Fine Sand (SM)		

Pan #:		Beaker #:		**Apparent Relative Density (Assumed)**		**2.650**	
Hydrometer Jar #:							
Pan Tare Weight (grams):				**Moisture Content**	Hygroscopic	Natural	
Total Sample Air Dried Wt. + tare wt. (grams):	153.49			Tare #	40		
Weight of Total Sample Air Dried:	153.49		A	Tare Wt.	15.79		
Weight of Air Dried Hydrometer Sample (g):	50.03		B	Wet Wt. + A	26.59		
Total Sample Oven Dried:	153.49		C	Dry Wt. + A	26.59		
Hydrometer Sample Oven Dried (**W**):	50.03		D	Water Wt. (B-C)	0.00		
% Passing #10:	86.9%		E	Dry Wt. (C-A)	10.80		
Correction Factor a (Table 1):	1.00			% Moisture (100 x D/E)	0.00%		

Sieve	Retained Wt.	Percent Passing	
3.0"	0.0	Pan # (washed)	100.0%
1.5"	0.0		100.0%
1.0"	0.0		100.0%
3/4"	0.0		100.0%
1/2"	0.0		100.0%
3/8"	0.0	Soil Mortar	100.0%
#4	7.8		94.9%
#10	20.2	**100.0%**	86.9%
#20	4.6	90.9%	79.0%
#40	7.7	84.6%	73.5%
#60	16.8	66.4%	57.7%
#100	20.5	59.0%	51.3%
#200	24.6	50.7%	44.1%

Description of Sand & Gravel Particles — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Stirring Apparatus: A ☐ B ☐ Dispersion Time: 1 min. Sodium Hexametaphosphate: 40 g./ Liter

Balance: *ID No.* 3996 *Cal. Date:* 2/3/2010 Hydrometer: *ID No.* 3901 *Cal. Date:* 3/26/2010

Control Cylinder ☒ **Composite Correction** ☐ **Type:** **151H** ☐ **152H** ☒

Time	Temp.	Hydrometer	Corrections		Hydrometer	Percent Passing		Effective Depth	Table 3	Diameter
			Control Cylinder	Composite Correction		P(-#10) = (R x a / W) x 100	P (total) = P x % Passing #10			D = K x $((L/T)^{1/2}$
T (Min.)	(0.5 °C)	Reading			R			L	K	
1	25.0	27.0	4.5		22.50	45.0%	39.1%	12.6	0.01286	0.04566
2	25.0	24.0	4.5		19.50	39.0%	33.9%	13.1	0.01286	0.03291
5	24.5	20.5	4.5		16.00	32.0%	27.8%	13.7	0.01294	0.02139
15	24.5	18.5	5.0		13.50	27.0%	23.4%	14.1	0.01294	0.01253
30	24.0	17.0	5.0		12.00	24.0%	20.8%	14.3	0.01301	0.00899
60	24.0	16.0	5.0		11.00	22.0%	19.1%	14.5	0.01301	0.00639
250	23.0	14.5	5.5		9.00	18.0%	15.6%	14.8	0.01317	0.00321
1440	21.0	12.5	5.5		7.00	14.0%	12.2%	15.1	0.01348	0.00138

References / Comments / Deviations ASTM D 422, D 2487, D 4318

Karen Warner	NICET 117900	Jason Reeves	Senior Engineer	
Technician Name	*Certification #*	*Technical Responsibility*	*Position*	*Date*

Form No. TR-D422-3
Revision No. 0
Revision Date: 02/20/08

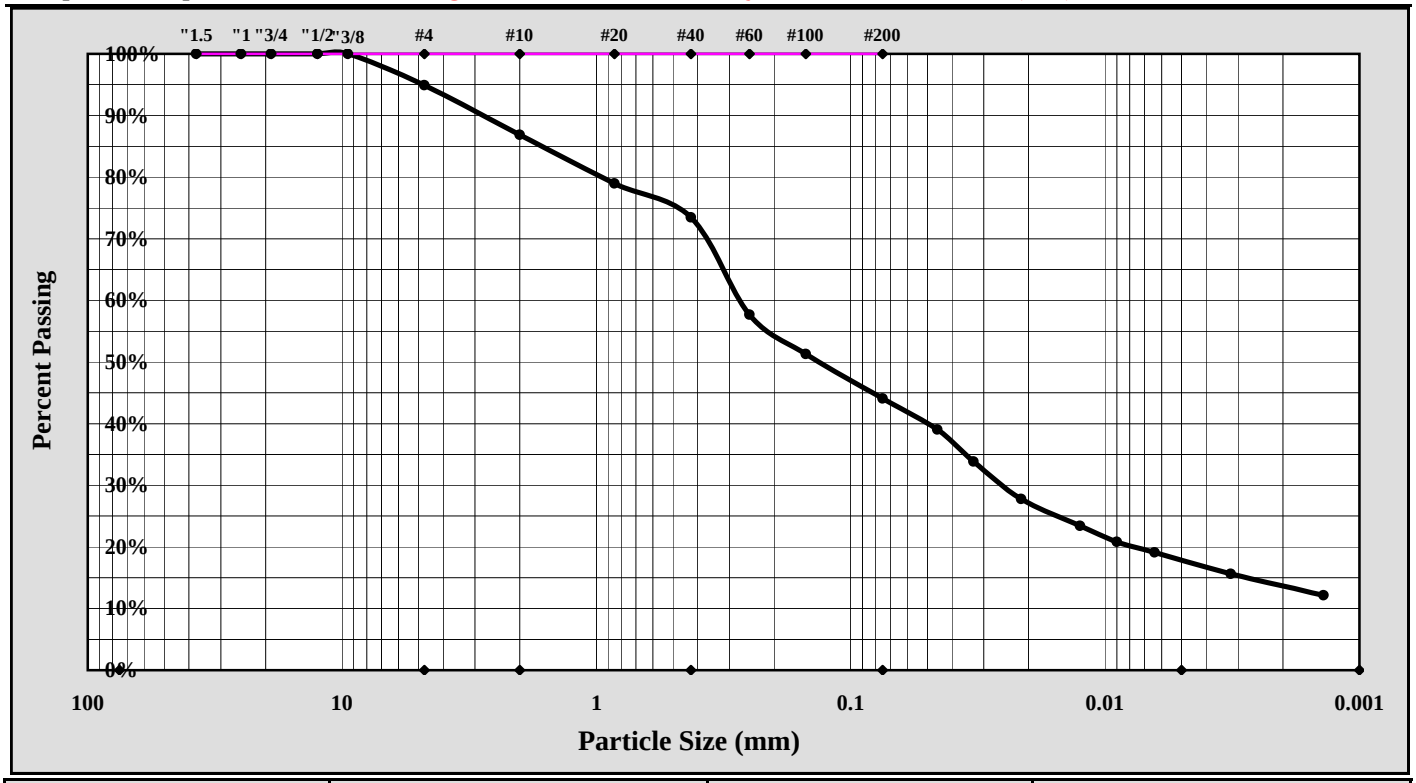
Particle Size Analysis of Soils

ASTM D422

Quality Assurance

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

S&ME Project #:	1356-09-029 Phase 04	Report Date:	6/22/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	6/9-22/10
Client Name:	Duke Energy		
Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD-9	Sample #: Fill	Sample Date:
Location:	Offset:		Elevation: 16-18'
Sample Description:	Orange Brown Micaceous Silty Coarse to Fine Sand (SM)		



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm (#200)
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Maximum Particle Size:	#4	Gravel:	5.1%	Silt	26.1%
Silt & Clay (% Passing #200):	44.1%	Total Sand:	50.8%	Clay	18.0%
ent Relative Density (Assumed)	2.650	Moisture Content		Colloids	12.0%
Liquid Limit	36	Plastic Limit	26	Plastic Index	10
Coarse Sand:	8.0%	Medium Sand:	13.4%	Fine Sand:	29.4%

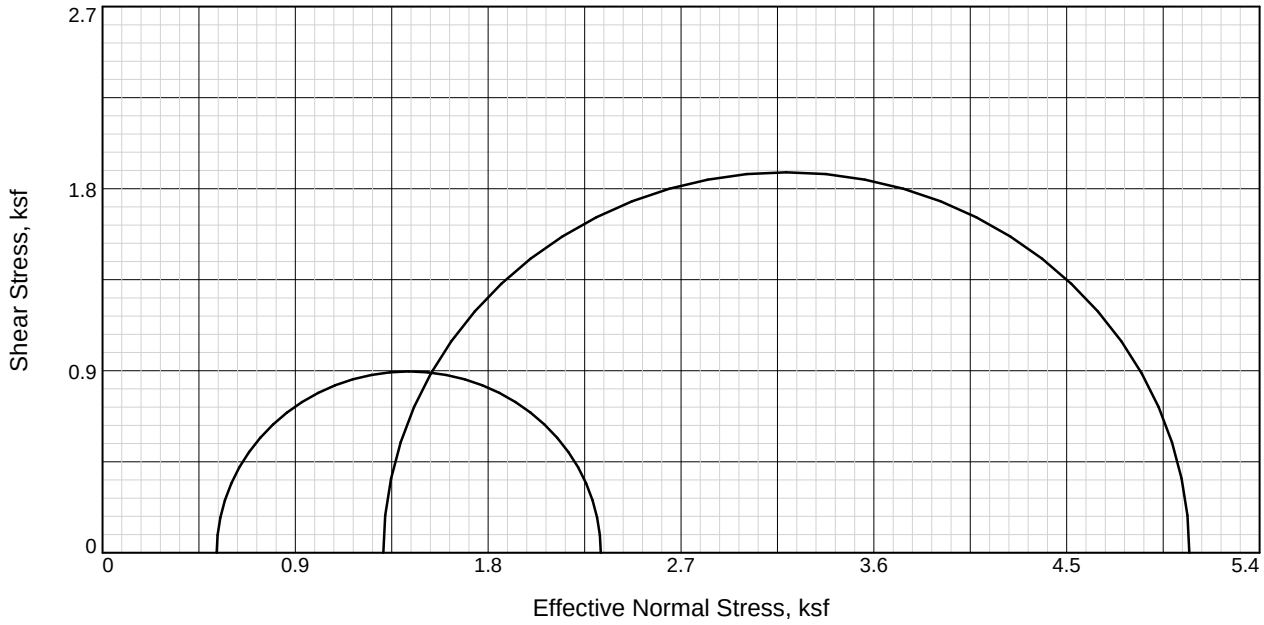
Description of Sand and Gravel — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

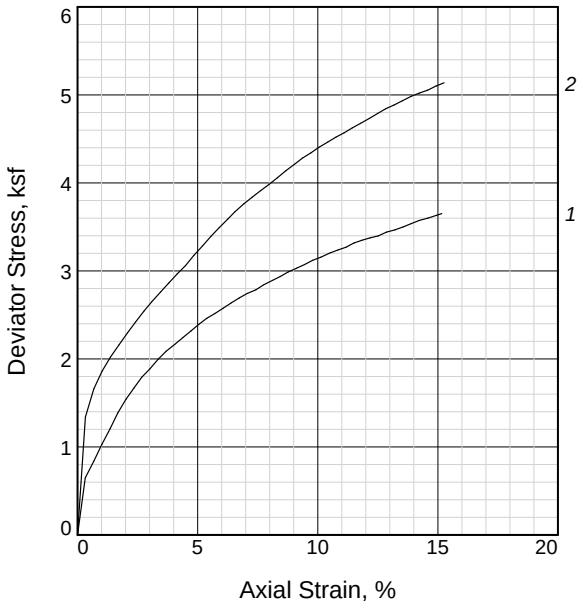
Apparatus B: Air Jet Dispersion — Dispersion Period: 1 min. Dispersing Agent: Sodium Hexametaphosphate: 40 g./ Liter

References / Comments / Deviations: ASTM D 4318, D 854, D 2487

Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.





Sample No.		1	2
Initial	Water Content, %	17.1	18.3
	Dry Density, pcf	106.7	107.9
	Saturation, %	82.4	91.1
	Void Ratio	0.5512	0.5327
	Diameter, in.	2.866	2.861
	Height, in.	5.969	5.875
At Test	Water Content, %	18.9	16.8
	Dry Density, pcf	110.3	114.5
	Saturation, %	100.0	100.0
	Void Ratio	0.5001	0.4454
	Diameter, in.	2.834	2.805
	Height, in.	5.903	5.762
Strain rate, in./min.		0.010	0.010
Back Pressure, ksf		10.08	8.64
Cell Pressure, ksf		11.09	11.66
Fail. Stress, ksf		1.79	3.76
Total Pore Pr., ksf		10.56	10.35
Ult. Stress, ksf			
Total Pore Pr., ksf			
$\bar{\sigma}_1$ Failure, ksf		2.33	5.07
$\bar{\sigma}_3$ Failure, ksf		0.53	1.31

Type of Test:
CU with Pore Pressures

Sample Type: Undisturbed

Description: Orange Brown Micaceous Silty Coarse to Fine Sand (SM)

LL= 36 **PL=** 26 **PI=** 10

Specific Gravity= 2.65

Remarks: Effective Stress Shear Strengths Based on Maximum Principal Stress Ratio

Plate AD-9 (16-18)

Client: Duke Energy

Project: Duke Energy-Embankment Stability

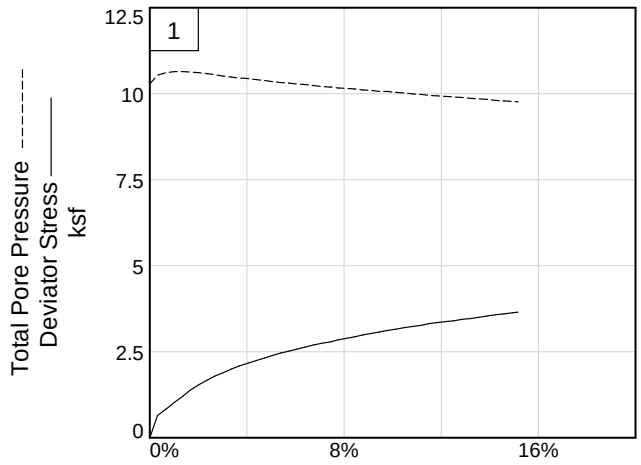
Sample Number: AD-9 Fill **Depth:** 16-18'

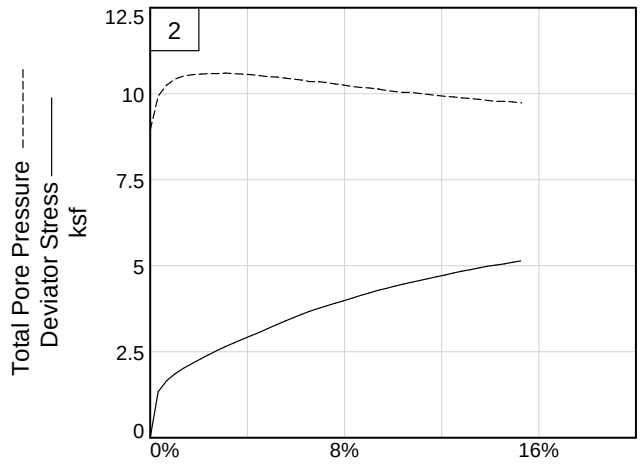
Proj. No.: 1356-09-029 Phase 04 **Date Sampled:**

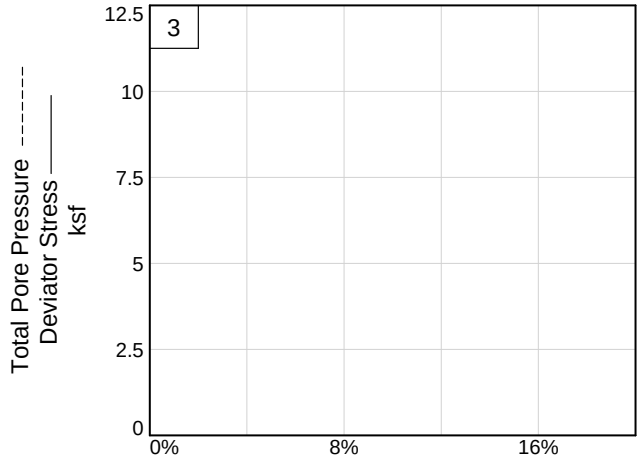
TRIAXIAL SHEAR TEST REPORT

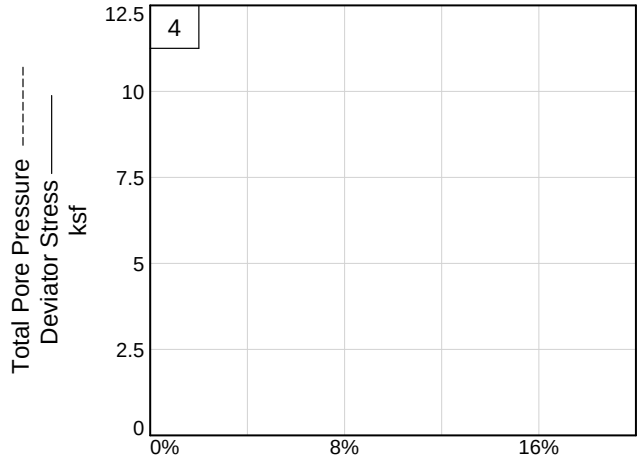
S & ME, INC.

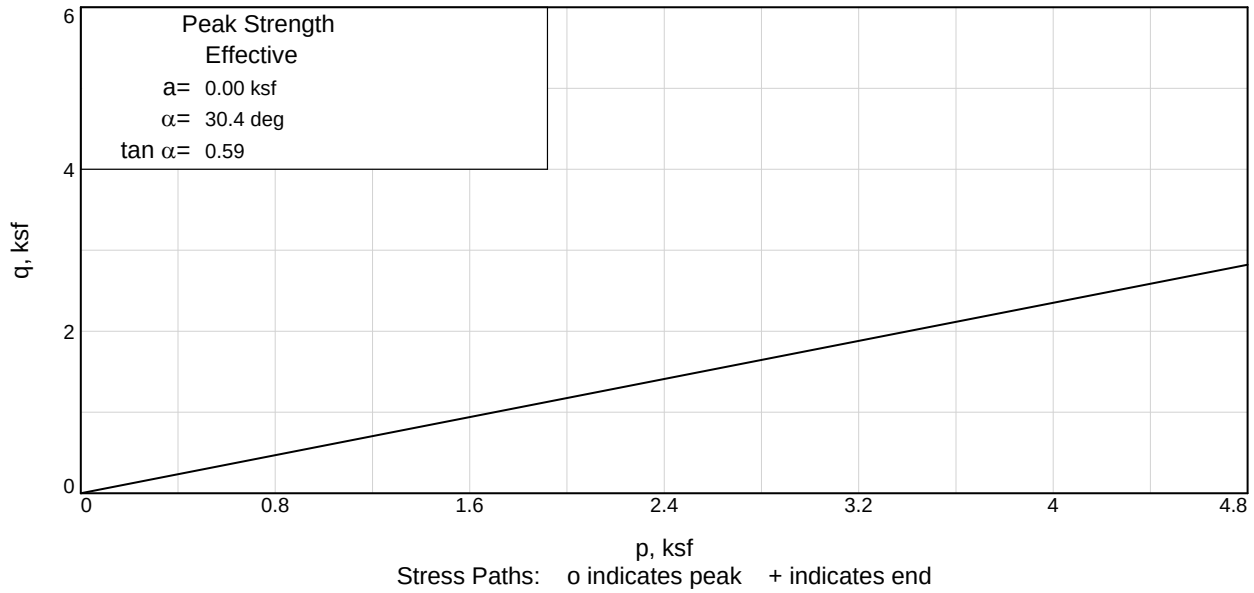
Tested By: KMW **Checked By:** JSR











Stress Paths: o indicates peak + indicates end

Client: Duke Energy
Project: Duke Energy-Embankment Stability
Depth: 16-18' **Sample Number:** AD-9 Fill
Project No.: 1356-09-029 Phase 04 **Plate** AD-9 (16-18)

S & ME, INC.

Tested By: KMW **Checked By:** JSR

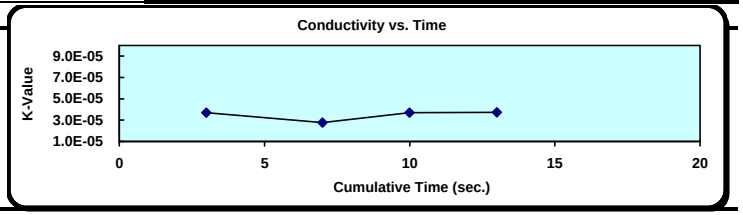
S&ME

Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter (Method "F")

Project #:	1356-09-029 Phase 04	Test Date(s):	6/3-4/10
Project Name:	Duke Energy - BCSS Embankment Stability	Report Date:	6/4/10
Client Name:		Sample Date:	
Client Address:		Panel ID:	8
Boring #:	AD-9 Sample #: Fill Depth: 16-18'	Perm Cell ID:	
Location:	Offset: Sample Description: Orange Brown Micaceous Silty Coarse to Fine Sand (SM)		
Liquid Limit:	36 Sp. Grav. (Assumed): 2.650 Sample Type: Undisturbed	Log #:	
Plastic Limit:	26 Plastic Index: 10 Percent Passing #200: 44.1	Maximum Particle Size:	

Initial Sample Conditions				Final Sample Conditions			
Length (cm):	15.161	Wet Density (PCF):	124.9	Length (cm):	15.161	Wet Density (PCF):	124.9
Diameter (cm):	7.280	Dry Density (PCF):	106.7	Diameter (cm):	7.28	Dry Density (PCF):	106.7
Area (cm^2)	41.62	Percent Saturation:	82.3	Area (cm^2)	41.62	Percent Saturation:	82.3
Volume (cm^3)	631.02			Volume (cm^3)	630.99	B-Parameter:	0.97
Wet weight (grams)	1262.8	Void Ratio:	0.551	Wet weight (grams)	1262.8	Void Ratio:	0.551
Dry Weight (grams)	1078.4	Porosity:	0.355	Dry Weight (grams)	1078.4	Porosity:	0.355
Percent Moisture:	17.1			Percent Moisture:	17.1		
Test Parameters:	Effective Consolidation Stress (psi):		7.0	Permeant Liquid Used:	Deaired Water	a_{in} (cm^2)	0.031416
Hg Equilibrium Level	1.990	Cell Pressure (psi):	77.0	Back Pressure (psi):	70.0	a_{out} (cm^2)	0.76712

Time (24-hr)			Temperature (°C)				Measurements						Initial Gradient	Final Gradient	K-Value (cm/sec)	
Start	End	Time (sec)	Initial	Final	Ave.	Factor	Rp1	Ra1	Rp2	Ra2	h1	h2			Uncorrected K-Value	Corrected K-Value
12:55	12:55	3	23.8	23.8	23.8	0.9140	7.50	1.90	6.80	1.90	70.4	61.6	4.64	4.06	4.06E-05	3.71E-05
12:56	12:56	4	23.8	23.8	23.8	0.9140	7.50	1.90	6.80	1.90	70.4	61.6	4.64	4.06	3.05E-05	2.78E-05
12:57	12:57	3	23.8	23.8	23.8	0.9140	7.50	1.90	6.80	1.90	70.4	61.6	4.64	4.06	4.06E-05	3.71E-05
12:58	12:58	3	23.8	23.7	23.8	0.9151	7.50	1.90	6.80	1.90	70.4	61.6	4.64	4.06	4.06E-05	3.72E-05
Notes: Permometer P700000 byTrautwein Soil Testing was used for permeation.													***Averages:***	***4.64***	***4.06***	***3.81E-05***	***3.5E-05***



References:

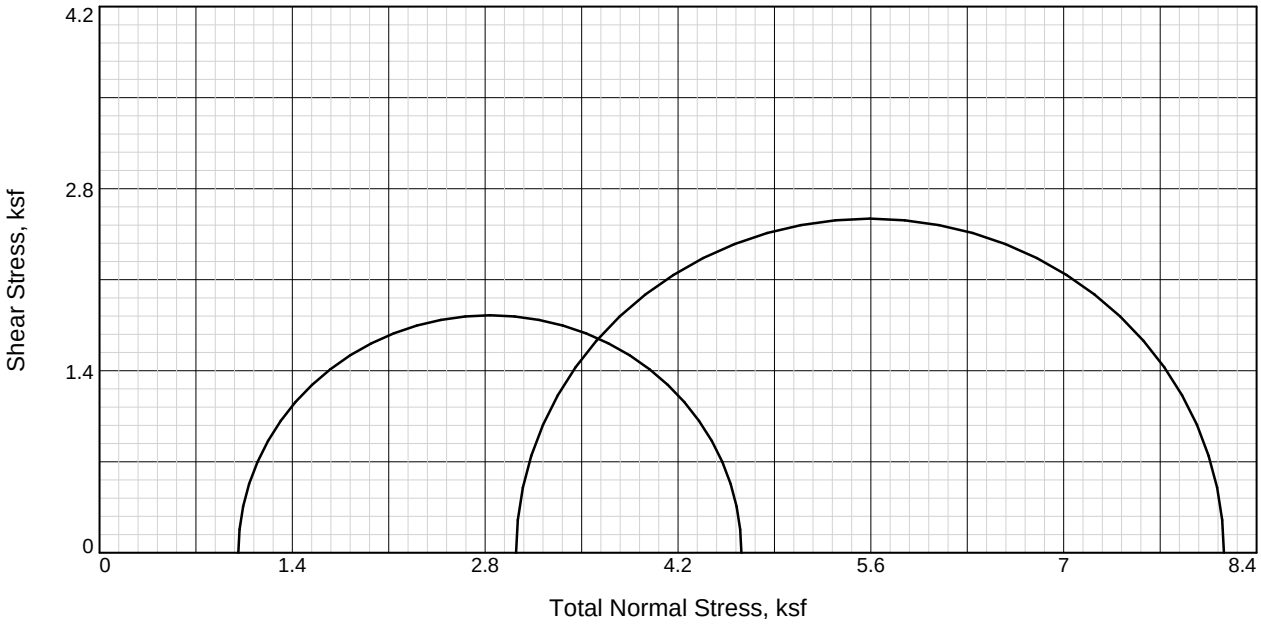
ASTM D 5084: Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

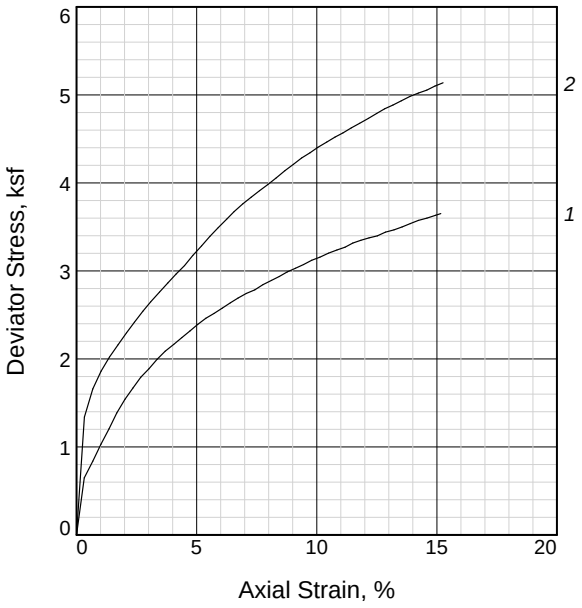
ASTM D 2216: Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

Technician: Karen Warner

Technical Responsibility: Jason Reeves Position: Senior Engineer

signature





Sample No.		1	2
Initial	Water Content, %	17.1	18.3
	Dry Density, pcf	106.7	107.9
	Saturation, %	82.4	91.1
	Void Ratio	0.5512	0.5327
	Diameter, in.	2.866	2.861
	Height, in.	5.969	5.875
At Test	Water Content, %	18.9	16.8
	Dry Density, pcf	110.3	114.5
	Saturation, %	100.0	100.0
	Void Ratio	0.5001	0.4454
	Diameter, in.	2.834	2.805
	Height, in.	5.903	5.762
Strain rate, in./min.		0.010	0.010
Back Pressure, ksf		10.08	8.64
Cell Pressure, ksf		11.09	11.66
Fail. Stress, ksf		3.65	5.14
Total Pore Pr., ksf		9.76	9.73
Ult. Stress, ksf			
Total Pore Pr., ksf			
$\bar{\sigma}_1$ Failure, ksf		4.98	7.07
$\bar{\sigma}_3$ Failure, ksf		1.32	1.93

Type of Test:
CU with Pore Pressures

Sample Type: Undisturbed

Description: Orange Brown Micaceous Silty Coarse to Fine Sand (SM)

LL= 36 **PL=** 26 **PI=** 10

Specific Gravity= 2.65

Remarks: Total Stress Shear Strengths Based on Maximum Deviator Stress

Plate AD-9 (16-18)

Client: Duke Energy

Project: Duke Energy-Embankment Stability

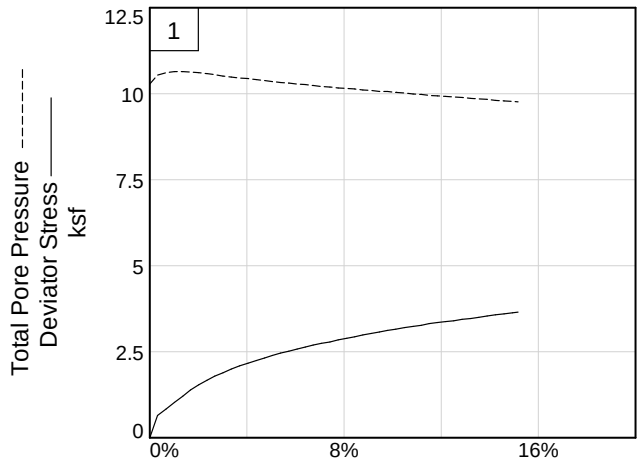
Sample Number: AD-9 Fill **Depth:** 16-18'

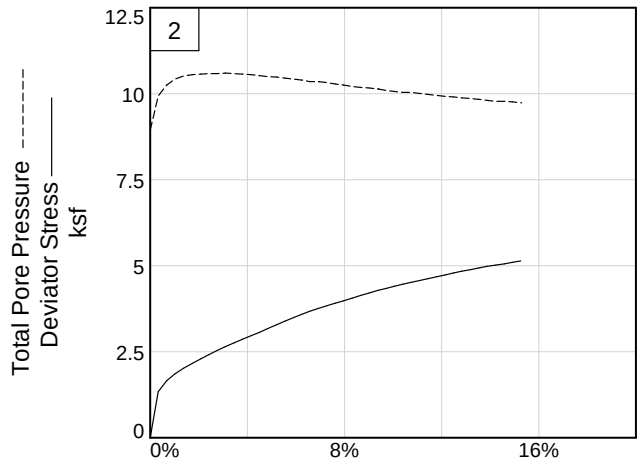
Proj. No.: 1356-09-029 Phase 04 **Date Sampled:**

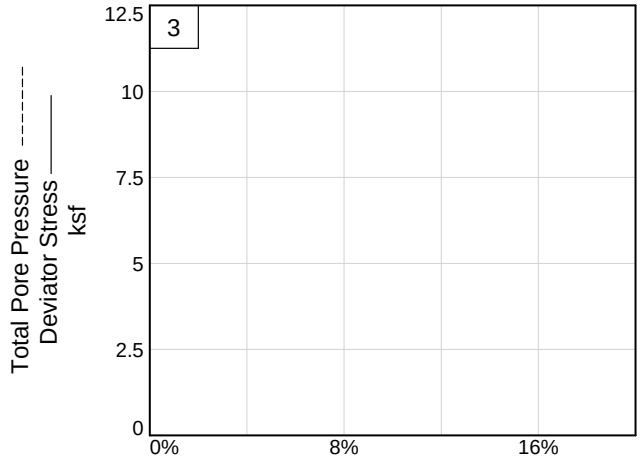
TRIAXIAL SHEAR TEST REPORT

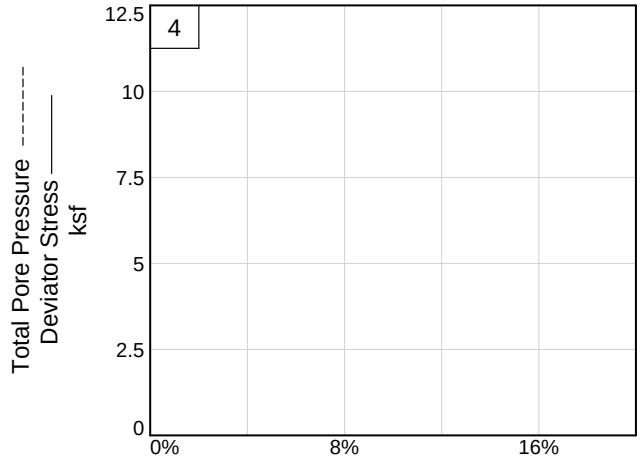
S & ME, INC.

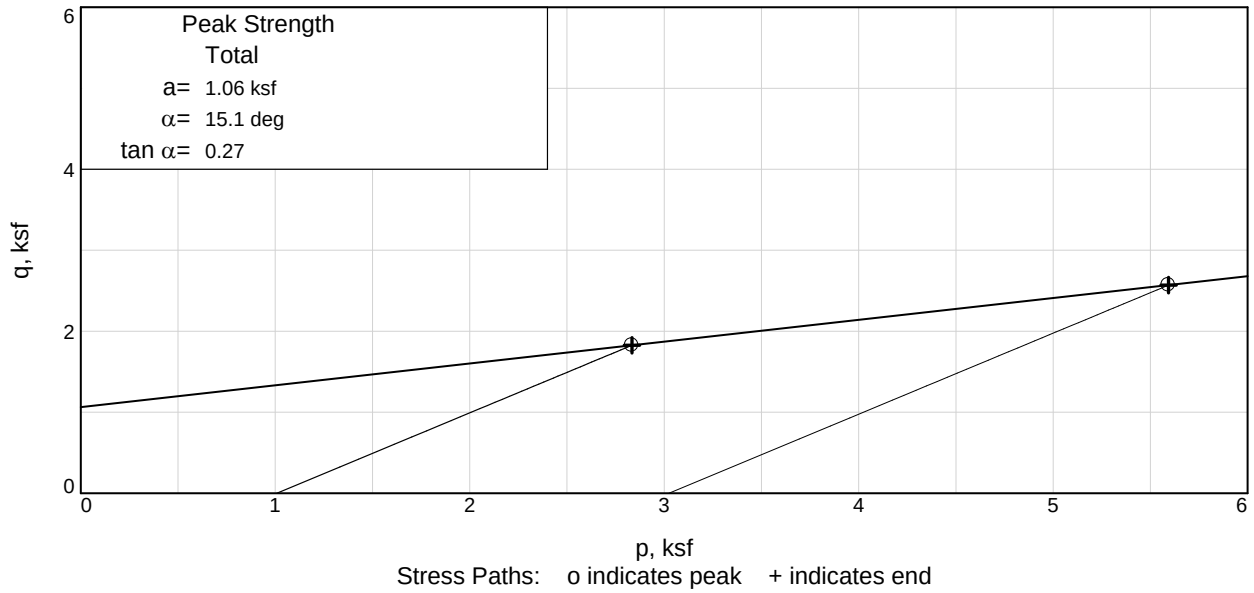
Tested By: KMW **Checked By:** JSR











Stress Paths: o indicates peak + indicates end

Client: Duke Energy
Project: Duke Energy-Embankment Stability
Depth: 16-18' **Sample Number:** AD-9 Fill
Project No.: 1356-09-029 Phase 04 **Plate** AD-9 (16-18)

S & ME, INC.

Tested By: KMW **Checked By:** JSR

TRIAXIAL COMPRESSION TEST 7/16/2010

CU with Pore Pressures 10:49 AM

Date:
Client: Duke Energy
Project: Duke Energy-Embankment Stability
Project No.: 1356-09-029 Phase 04
Depth: 16-18' **Sample Number:** AD-9 Fill
Description: Orange Brown Micaceous Silty Coarse to Fine Sand (SM)
Remarks:
Type of Sample: Undisturbed
Specific Gravity=2.65 **LL=**36 **PL=**26 **PI=**10
Test Method: COE uniform strain

Parameters for Specimen No. 1

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	253.960			1364.300
Moisture content: Dry soil+tare, gms.	228.690			1143.550
Moisture content: Tare, gms.	81.260			74.380
Moisture, %	17.1	19.9	18.9	20.6
Moist specimen weight, gms.	1262.80			
Diameter, in.	2.866	2.852	2.834	
Area, in.²	6.451	6.389	6.309	
Height, in.	5.969	5.940	5.903	
Net decrease in height, in.		0.029	0.037	
Wet Density, pcf	124.9	129.8	131.1	
Dry density, pcf	106.7	108.2	110.3	
Void ratio	0.5512	0.5286	0.5001	
Saturation, %	82.4	100.0	100.0	

Test Readings for Specimen No. 1

Consolidation cell pressure = 77.00 psi (11.09 ksf)
Consolidation back pressure = 70.00 psi (10.08 ksf)
Consolidation effective confining stress = 1.01 ksf
Strain rate, in./min. = 0.010
Fail. Stress = 1.79 ksf **at reading no.** 8

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
0	0.0030	20.100	0.0	0.0	0.00	0.81	0.81	1.00	71.40	0.81	0.00
1	0.0220	48.600	28.5	0.3	0.65	0.55	1.20	2.19	73.20	0.87	0.32
2	0.0430	57.100	37.0	0.7	0.84	0.48	1.31	2.77	73.70	0.89	0.42
3	0.0630	65.700	45.6	1.0	1.03	0.45	1.48	3.31	73.90	0.96	0.52
4	0.0830	73.700	53.6	1.4	1.21	0.45	1.65	3.70	73.90	1.05	0.60
5	0.1020	81.900	61.8	1.7	1.39	0.46	1.85	4.01	73.80	1.15	0.69
6	0.1220	89.000	68.9	2.0	1.54	0.48	2.02	4.24	73.70	1.25	0.77
7	0.1420	95.100	75.0	2.4	1.67	0.50	2.18	4.32	73.50	1.34	0.84
8	0.1610	100.800	80.7	2.7	1.79	0.53	2.33	4.36	73.30	1.43	0.90
9	0.1810	105.400	85.3	3.0	1.89	0.58	2.46	4.28	73.00	1.52	0.94
10	0.2010	110.600	90.5	3.4	2.00	0.60	2.60	4.30	72.80	1.60	1.00
11	0.2210	115.100	95.0	3.7	2.09	0.63	2.72	4.30	72.60	1.68	1.04
12	0.2420	119.000	98.9	4.0	2.17	0.65	2.81	4.34	72.50	1.73	1.08
13	0.2620	122.900	102.8	4.4	2.24	0.68	2.92	4.31	72.30	1.80	1.12
14	0.2820	126.700	106.6	4.7	2.32	0.71	3.02	4.29	72.10	1.86	1.16
15	0.3010	130.500	110.4	5.0	2.39	0.73	3.13	4.26	71.90	1.93	1.20
16	0.3210	134.100	114.0	5.4	2.46	0.76	3.23	4.23	71.70	1.99	1.23
17	0.3410	137.100	117.0	5.7	2.52	0.78	3.30	4.24	71.60	2.04	1.26
18	0.3610	140.300	120.2	6.1	2.58	0.81	3.38	4.20	71.40	2.10	1.29
19	0.3810	143.600	123.5	6.4	2.64	0.82	3.46	4.21	71.30	2.14	1.32
20	0.4000	146.600	126.5	6.7	2.69	0.85	3.54	4.17	71.10	2.20	1.35
21	0.4200	149.500	129.4	7.1	2.75	0.88	3.62	4.13	70.90	2.25	1.37
22	0.4410	151.900	131.8	7.4	2.79	0.89	3.68	4.12	70.80	2.29	1.39
23	0.4610	155.200	135.1	7.8	2.84	0.92	3.77	4.09	70.60	2.34	1.42
24	0.4820	158.000	137.9	8.1	2.89	0.94	3.83	4.09	70.50	2.38	1.45
25	0.5010	160.600	140.5	8.4	2.94	0.95	3.89	4.09	70.40	2.42	1.47
26	0.5210	163.700	143.6	8.8	2.99	0.98	3.97	4.05	70.20	2.47	1.50
27	0.5410	166.200	146.1	9.1	3.03	0.99	4.02	4.05	70.10	2.51	1.52
28	0.5610	168.800	148.7	9.5	3.07	1.02	4.10	4.01	69.90	2.56	1.54
29	0.5810	171.700	151.6	9.8	3.12	1.02	4.14	4.05	69.90	2.58	1.56
30	0.6010	174.000	153.9	10.1	3.16	1.05	4.21	4.00	69.70	2.63	1.58
31	0.6220	176.800	156.7	10.5	3.20	1.07	4.27	4.00	69.60	2.67	1.60
32	0.6430	179.200	159.1	10.8	3.24	1.09	4.33	3.96	69.40	2.71	1.62
33	0.6630	181.400	161.3	11.2	3.27	1.11	4.38	3.95	69.30	2.74	1.64
34	0.6820	184.300	164.2	11.5	3.32	1.14	4.45	3.92	69.10	2.80	1.66
35	0.7020	186.500	166.4	11.8	3.35	1.15	4.50	3.91	69.00	2.83	1.67
36	0.7220	188.500	168.4	12.2	3.38	1.17	4.54	3.89	68.90	2.85	1.69
37	0.7420	190.300	170.2	12.5	3.40	1.18	4.58	3.88	68.80	2.88	1.70
38	0.7620	193.100	173.0	12.9	3.44	1.20	4.64	3.88	68.70	2.92	1.72
39	0.7830	195.100	175.0	13.2	3.47	1.22	4.69	3.83	68.50	2.96	1.73
40	0.8030	197.500	177.4	13.6	3.50	1.24	4.74	3.83	68.40	2.99	1.75
41	0.8230	200.100	180.0	13.9	3.54	1.25	4.79	3.82	68.30	3.02	1.77
42	0.8430	202.700	182.6	14.2	3.57	1.28	4.86	3.79	68.10	3.07	1.79
43	0.8640	204.800	184.7	14.6	3.60	1.30	4.90	3.78	68.00	3.10	1.80
44	0.8850	207.200	187.1	14.9	3.63	1.31	4.94	3.77	67.90	3.13	1.82
45	0.8980	208.700	188.6	15.2	3.65	1.32	4.98	3.76	67.80	3.15	1.83

Parameters for Specimen No. 2

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	248.800			1141.500
Moisture content: Dry soil+tare, gms.	223.020			954.400
Moisture content: Tare, gms.	82.270			86.100
Moisture, %	18.3	19.9	16.8	21.5
Moist specimen weight, gms.	1266.10			
Diameter, in.	2.861	2.858	2.805	
Area, in.²	6.429	6.416	6.181	
Height, in.	5.875	5.869	5.762	
Net decrease in height, in.		0.006	0.107	
Wet Density, pcf	127.7	129.8	133.7	
Dry density, pcf	107.9	108.3	114.5	
Void ratio	0.5327	0.5280	0.4454	
Saturation, %	91.1	100.0	100.0	

Test Readings for Specimen No. 2

Consolidation cell pressure = 81.00 psi (11.66 ksf)
Consolidation back pressure = 60.00 psi (8.64 ksf)
Consolidation effective confining stress = 3.02 ksf
Strain rate, in./min. = 0.010
Fail. Stress = 3.76 ksf **at reading no.** 20

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
0	0.0010	22.400	0.0	0.0	0.00	2.72	2.72	1.00	62.10	2.72	0.00
1	0.0200	80.100	57.7	0.3	1.34	1.73	3.07	1.78	69.00	2.40	0.67
2	0.0400	94.100	71.7	0.7	1.66	1.41	3.07	2.18	71.20	2.24	0.83
3	0.0600	103.100	80.7	1.0	1.86	1.24	3.10	2.50	72.40	2.17	0.93
4	0.0800	110.400	88.0	1.4	2.02	1.15	3.17	2.76	73.00	2.16	1.01
5	0.1010	116.900	94.5	1.7	2.16	1.11	3.27	2.95	73.30	2.19	1.08
6	0.1210	123.100	100.7	2.1	2.30	1.09	3.39	3.10	73.40	2.24	1.15
7	0.1400	128.700	106.3	2.4	2.42	1.08	3.50	3.24	73.50	2.29	1.21
8	0.1600	134.600	112.2	2.8	2.54	1.08	3.62	3.35	73.50	2.35	1.27
9	0.1790	139.700	117.3	3.1	2.65	1.07	3.71	3.49	73.60	2.39	1.32
10	0.2000	145.100	122.7	3.5	2.76	1.08	3.84	3.56	73.50	2.46	1.38
11	0.2200	150.200	127.8	3.8	2.86	1.09	3.96	3.62	73.40	2.53	1.43
12	0.2400	155.200	132.8	4.1	2.97	1.11	4.07	3.67	73.30	2.59	1.48
13	0.2600	160.000	137.6	4.5	3.06	1.14	4.20	3.69	73.10	2.67	1.53
14	0.2800	165.700	143.3	4.8	3.18	1.17	4.34	3.72	72.90	2.75	1.59
15	0.3010	171.200	148.8	5.2	3.29	1.18	4.47	3.78	72.80	2.82	1.64
16	0.3210	176.600	154.2	5.6	3.39	1.21	4.60	3.80	72.60	2.91	1.70
17	0.3410	181.700	159.3	5.9	3.49	1.24	4.73	3.82	72.40	2.98	1.75
18	0.3610	186.700	164.3	6.2	3.59	1.27	4.86	3.83	72.20	3.06	1.79
19	0.3790	191.200	168.8	6.6	3.67	1.31	4.98	3.80	71.90	3.15	1.84
20	0.4000	195.900	173.5	6.9	3.76	1.31	5.07	3.87	71.90	3.19	1.88
21	0.4200	200.100	177.7	7.3	3.84	1.34	5.18	3.87	71.70	3.26	1.92
22	0.4400	204.200	181.8	7.6	3.91	1.38	5.29	3.83	71.40	3.34	1.96
23	0.4600	208.100	185.7	8.0	3.98	1.41	5.39	3.82	71.20	3.40	1.99
24	0.4800	212.400	190.0	8.3	4.06	1.45	5.51	3.79	70.90	3.48	2.03
25	0.5010	217.000	194.6	8.7	4.14	1.48	5.62	3.79	70.70	3.55	2.07
26	0.5210	221.100	198.7	9.0	4.21	1.50	5.71	3.81	70.60	3.60	2.11

Test Readings for Specimen No. 2

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress ksf	Minor Eff. Stress ksf	Major Eff. Stress ksf	1:3 Ratio	Pore Press. psi	P ksf	Q ksf
27	0.5410	225.300	202.9	9.4	4.28	1.53	5.81	3.81	70.40	3.67	2.14
28	0.5610	228.900	206.5	9.7	4.34	1.57	5.91	3.77	70.10	3.74	2.17
29	0.5800	232.600	210.2	10.0	4.40	1.60	6.00	3.76	69.90	3.80	2.20
30	0.6010	236.300	213.9	10.4	4.46	1.63	6.09	3.74	69.70	3.86	2.23
31	0.6210	239.900	217.5	10.8	4.52	1.63	6.15	3.78	69.70	3.89	2.26
32	0.6400	243.000	220.6	11.1	4.57	1.66	6.23	3.76	69.50	3.94	2.28
33	0.6600	246.600	224.2	11.4	4.63	1.68	6.31	3.75	69.30	4.00	2.31
34	0.6800	250.000	227.6	11.8	4.68	1.71	6.39	3.73	69.10	4.05	2.34
35	0.7010	253.700	231.3	12.1	4.73	1.74	6.48	3.72	68.90	4.11	2.37
36	0.7210	257.400	235.0	12.5	4.79	1.76	6.55	3.73	68.80	4.15	2.40
37	0.7400	260.900	238.5	12.8	4.84	1.79	6.63	3.71	68.60	4.21	2.42
38	0.7600	263.900	241.5	13.2	4.88	1.80	6.68	3.71	68.50	4.24	2.44
39	0.7800	267.300	244.9	13.5	4.93	1.83	6.76	3.70	68.30	4.30	2.47
40	0.8010	270.800	248.4	13.9	4.98	1.86	6.84	3.68	68.10	4.35	2.49
41	0.8210	273.700	251.3	14.2	5.02	1.89	6.91	3.66	67.90	4.40	2.51
42	0.8410	276.400	254.0	14.6	5.05	1.89	6.94	3.68	67.90	4.41	2.53
43	0.8610	279.800	257.4	14.9	5.10	1.90	7.00	3.68	67.80	4.45	2.55
44	0.8800	282.700	260.3	15.3	5.14	1.93	7.07	3.66	67.60	4.50	2.57

Form No. TR-D422-2
Revision No. 0
Revision Date: 02/20/08

Particle Size Analysis of Soils

ASTM D 422

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	1356-09-029 Phase 04	Report Date:	6/1/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	5/20-6/1/10
Client Name:	Duke Energy	Address:	3195 Pine Hall Road, Belews Creek, NC 27009
Boring #:	AD9	Sample #:	11
Location:		Offset:	
Sample Description:	Tan Micaceous Silty Fine to Coarse Sand (SM)		

Pan #:		Beaker #:		Apparent Relative Density (Assumed)	2.650	
Hydrometer Jar #:						
Pan Tare Weight (grams):			Moisture Content	Hygroscopic	Natural	
Total Sample Air Dried Wt. + tare wt. (grams):	192.99		Tare #	27		
Weight of Total Sample Air Dried:	192.99	A	Tare Wt.	13.91		
Weight of Air Dried Hydrometer Sample (g):	100.00	B	Wet Wt. + A	25.71		
Total Sample Oven Dried:	192.99	C	Dry Wt. + A	25.71		
Hydrometer Sample Oven Dried (**W**):	100.00	D	Water Wt. (B-C)	0.00		
% Passing #10:	89.3%	E	Dry Wt. (C-A)	11.80		
Correction Factor a (Table 1):	1.00		% Moisture (100 x D/E)	0.00%		

Sieve	Retained Wt.	Percent Passing	
3.0"	0.0	Pan # (washed)	100.0%
1.5"	0.0		100.0%
1.0"	0.0		100.0%
3/4"	0.0		100.0%
1/2"	0.0		100.0%
3/8"	3.0	Soil Mortar	98.4%
#4	9.5		95.1%
#10	20.7	**100.0%**	89.3%
#20	15.4	84.7%	75.6%
#40	44.1	55.9%	49.9%
#60	67.8	32.2%	28.8%
#100	78.9	21.2%	18.9%
#200	87.3	12.7%	11.4%

Description of Sand & Gravel Particles — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Stirring Apparatus: A ☐ B ☐ Dispersion Time: 1 min. Sodium Hexametaphosphate: 40 g./ Liter

Balance: *ID No.* 3996 *Cal. Date:* 2/3/2010 Hydrometer: *ID No.* 3901 *Cal. Date:* 3/26/2010

Control Cylinder ☒ **Composite Correction** ☐ **Type:** **151H** ☐ **152H** ☒

Time	Temp.	Hydrometer	Corrections		Hydrometer	Percent Passing		Effective Depth	Table 3	Diameter
			Control Cylinder	Composite Correction		P(-#10) = (R x a / W) x 100	P (total) = P x % Passing #10			D = K x ((L/T)$^{1/2}$
T (Min.)	(0.5 °C)	Reading			R			L	K	
1	24.5	15.0	4.5		10.50	10.5%	9.4%	14.6	0.01294	0.04938
2	24.5	13.5	4.5		9.00	9.0%	8.0%	14.8	0.01294	0.03521
5	24.5	11.0	4.5		6.50	6.5%	5.8%	15.2	0.01294	0.02257
15	24.5	10.0	4.5		5.50	5.5%	4.9%	15.4	0.01294	0.01310
30	24.5	8.5	4.5		4.00	4.0%	3.6%	15.6	0.01294	0.00934
60	24.5	8.0	4.5		3.50	3.5%	3.1%	15.7	0.01294	0.00662
250	24.5	7.0	4.5		2.50	2.5%	2.2%	15.9	0.01294	0.00326
1440	23.5	6.0	4.5		1.50	1.5%	1.3%	16.0	0.01309	0.00138

References / Comments / Deviations ASTM D 422, D 2487, D 4318

Karen Warner	NICET 117900	Jason Reeves	Senior Engineer	
Technician Name	*Certification #*	*Technical Responsibility*	*Position*	*Date*

Form No. TR-D422-3
Revision No. 0
Revision Date: 02/20/08

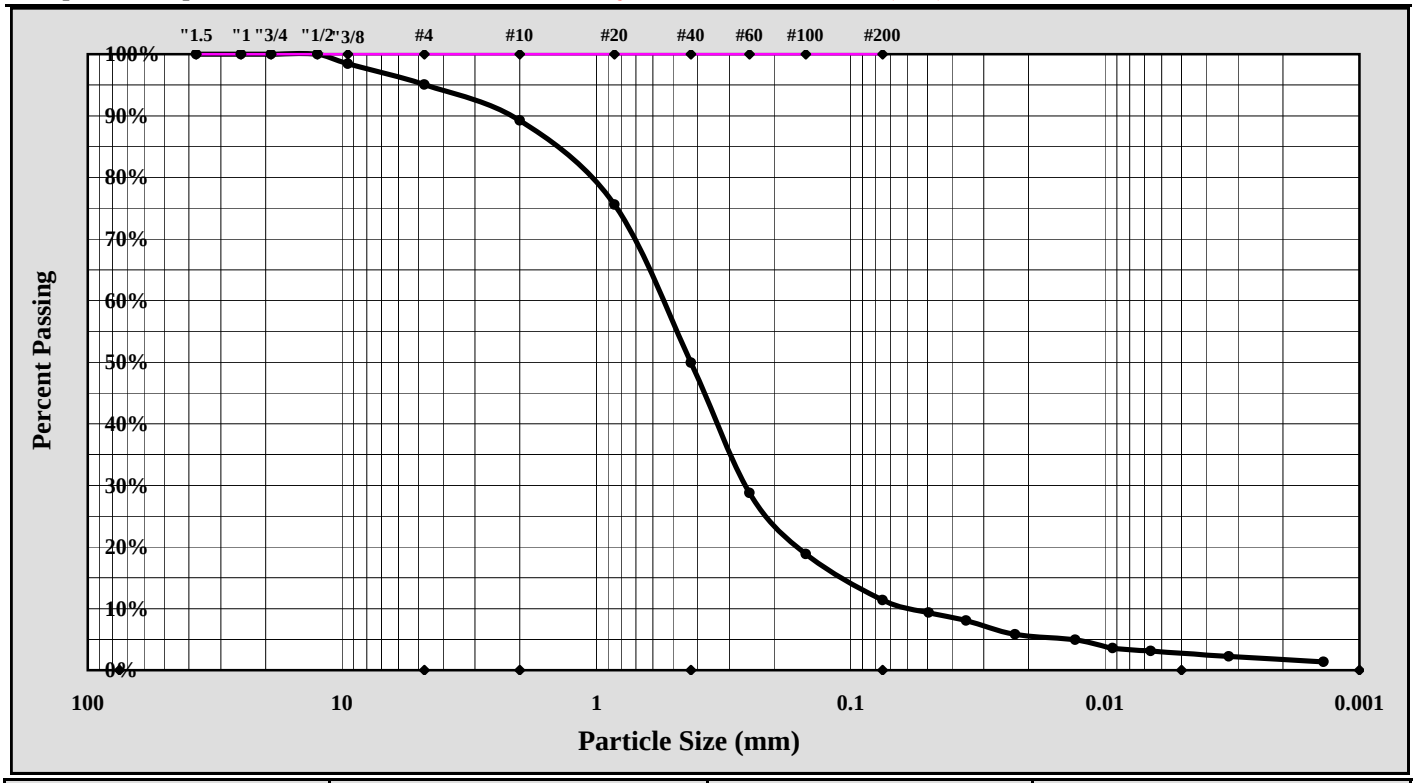
Particle Size Analysis of Soils

ASTM D422

Quality Assurance

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

S&ME Project #:	1356-09-029 Phase 04	Report Date:	6/1/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	5/20-6/1/10
Client Name:	Duke Energy		
Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD9	Sample #: 11	Sample Date:
Location:		Offset:	Elevation: 33.5-35'
Sample Description:	Tan Micaceous Silty Fine to Coarse Sand (SM)		



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm (#200)
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Maximum Particle Size:	#4	Gravel:	4.9%	Silt	8.4%
Silt & Clay (% Passing #200):	11.4%	Total Sand:	83.7%	Clay	3.0%
ent Relative Density (Assumed)	2.650	Moisture Content		Colloids	1.0%
Liquid Limit	ND	Plastic Limit	ND	Plastic Index	ND
Coarse Sand:	5.8%	Medium Sand:	39.3%	Fine Sand:	38.6%

Description of Sand and Gravel — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Apparatus B: Air Jet Dispersion — Dispersion Period: 1 min. Dispersing Agent: Sodium Hexametaphosphate: 40 g./ Liter

References / Comments / Deviations: ASTM D 4318, D 854, D 2487

Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D4318-T89-90
Revision No. 0
Revision Date: 11/20/07

Liquid Limit, Plastic Limit, and Plastic Index

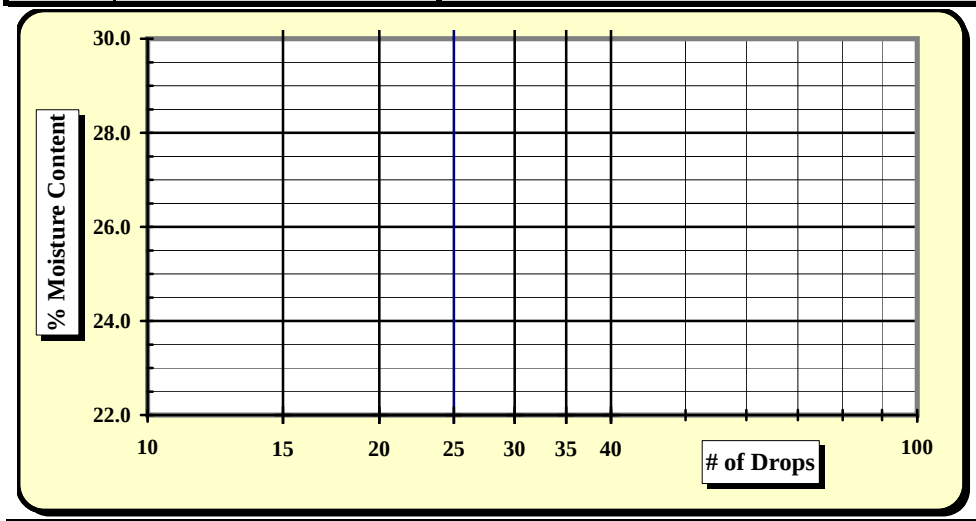
Another code *ASTM D 4318* ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐ ***Quality Assurance***

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	6/1/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s)	5/25-6/1/10
Client Name:	Duke Energy		
Client Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD9	Sample #: 12	Sample Date:
Location:		Offset:	Elevation: 35-36.5'
Sample Description:	Tan Micaceous Silty Fine to Coarse Sand (SM)		

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	20233	6/15/2009	Grooving tool	21587	2/28/2010
LL Apparatus	3611	10/20/2009	Grooving tool		
Oven	10844	9/4/2009	Grooving tool		

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit			
N	**Factor**	**N**	**Factor**
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒
Liquid Limit
Plastic Limit
Plastic Index
Group Symbol **SM**

Multipoint Method ☐
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *Estimate the % Retained on the #40 Sieve:*

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Jason Clark — *Technician Name* — *Date*
Jason Reeves — *Technical Responsibility* — *Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D422-2
Revision No. 0
Revision Date: 02/20/08

Particle Size Analysis of Soils

ASTM D 422

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	1356-09-029 Phase 04	Report Date:	6/1/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	5/20-6/1/10
Client Name:	Duke Energy	Address:	3195 Pine Hall Road, Belews Creek, NC 27009
Boring #:	AD9	Sample #:	12
Location:		Offset:	
Sample Description:	Tan Micaceous Silty Fine to Coarse Sand (SM)		

Pan #:		Beaker #:		**Apparent Relative Density (Assumed)**	**2.650**	
Hydrometer Jar #:						
Pan Tare Weight (grams):			**Moisture Content**	Hygroscopic	Natural	
Total Sample Air Dried Wt. + tare wt. (grams):	206.87		Tare #	SSS		
Weight of Total Sample Air Dried:	206.87	A	Tare Wt.	16.56		
Weight of Air Dried Hydrometer Sample (g):	50.00	B	Wet Wt. + A	27.95		
Total Sample Oven Dried:	206.33	C	Dry Wt. + A	27.91		
Hydrometer Sample Oven Dried (**W**):	49.82	D	Water Wt. (B-C)	0.04		
% Passing #10:	74.3%	E	Dry Wt. (C-A)	11.35		
Correction Factor a (Table 1):	1.00		% Moisture (100 x D/E)	0.35%		

Sieve	Retained Wt.	Percent Passing	
3.0"	0.0	Pan # (washed)	100.0%
1.5"	0.0		100.0%
1.0"	0.0		100.0%
3/4"	0.0		100.0%
1/2"	0.0		100.0%
3/8"	3.8	Soil Mortar	98.1%
#4	20.9		89.9%
#10	53.1	**100.0%**	74.3%
#20	12.7	74.6%	55.4%
#40	22.1	55.6%	41.3%
#60	27.7	44.4%	33.0%
#100	31.9	35.9%	26.7%
#200	37.5	24.7%	18.4%

Description of Sand & Gravel Particles — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Stirring Apparatus: A ☐ B ☐ Dispersion Time: 1 min. Sodium Hexametaphosphate: 40 g./ Liter

Balance: *ID No.* 3996 *Cal. Date:* 2/3/2010 Hydrometer: *ID No.* 3901 *Cal. Date:* 3/26/2010

Control Cylinder ☒ **Composite Correction** ☐ **Type:** **151H** ☐ **152H** ☒

Time	Temp.	Hydrometer	Corrections		Hydrometer	Percent Passing		Effective Depth	Table 3	Diameter
			Control Cylinder	Composite Correction		P(-#10) = (R x a / W) x 100	P (total) = P x % Passing #10			D = K x ((L/T)$^{1/2}$
T (Min.)	(0.5 °C)	Reading			R			L	K	
1	24.5	15.0	4.5		10.50	21.1%	15.7%	14.6	0.01294	0.04938
2	24.5	13.0	4.5		8.50	17.1%	12.7%	14.9	0.01294	0.03531
5	24.5	11.5	4.5		7.00	14.0%	10.4%	15.1	0.01294	0.02251
15	24.5	10.0	4.5		5.50	11.0%	8.2%	15.4	0.01294	0.01310
30	24.5	8.5	4.5		4.00	8.0%	6.0%	15.6	0.01294	0.00934
60	24.5	8.0	4.5		3.50	7.0%	5.2%	15.7	0.01294	0.00662
250	24.5	7.5	4.5		3.00	6.0%	4.5%	15.8	0.01294	0.00325
1440	23.5	6.5	4.5		2.00	4.0%	3.0%	16.0	0.01309	0.00138

References / Comments / Deviations ASTM D 422, D 2487, D 4318

Jennifer Olsen	NICET 117926	Jason Reeves	Senior Engineer	
Technician Name	*Certification #*	*Technical Responsibility*	*Position*	*Date*

Form No. TR-D422-3
Revision No. 0
Revision Date: 02/20/08

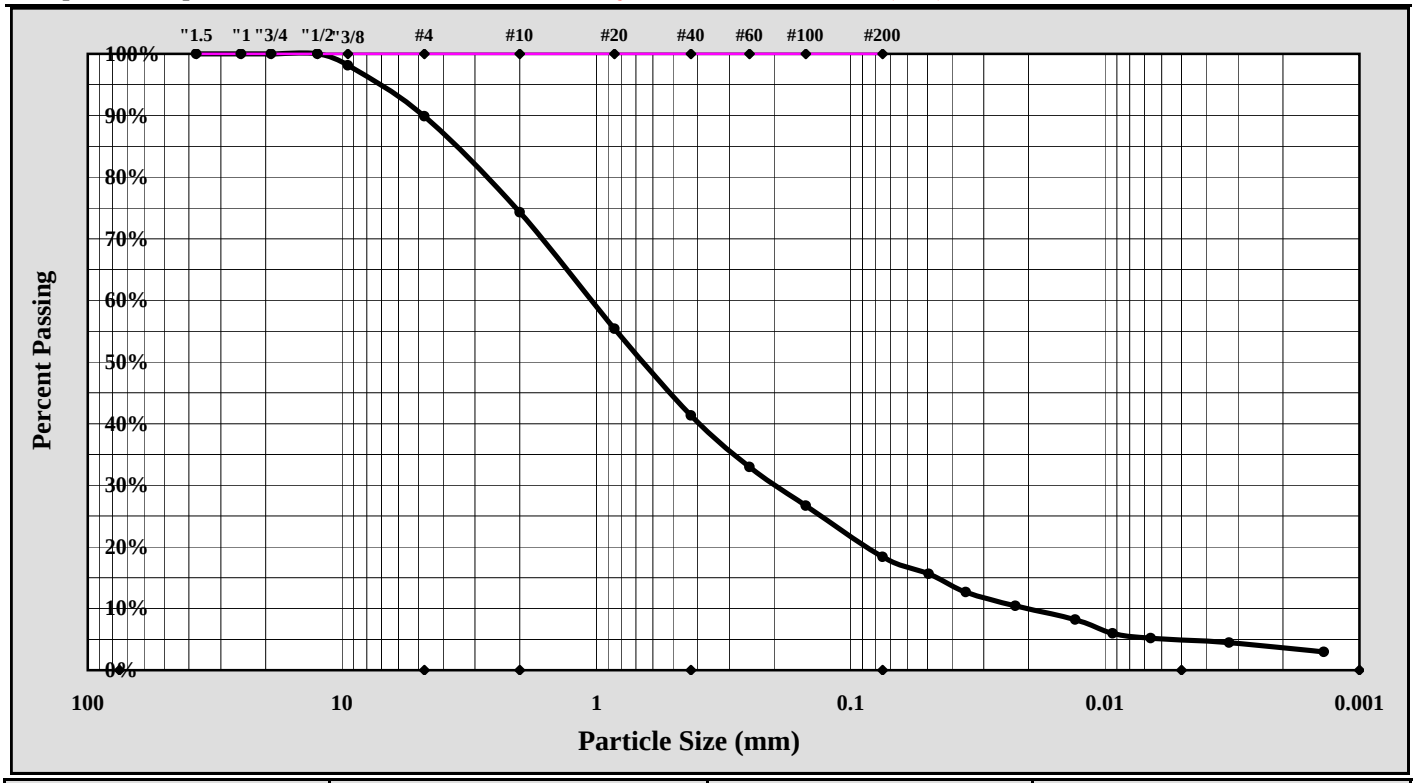
Particle Size Analysis of Soils

ASTM D422

Quality Assurance

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

S&ME Project #:	1356-09-029 Phase 04	Report Date:	6/1/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	5/20-6/1/10
Client Name:	Duke Energy		
Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD9	Sample #: 12	Sample Date:
Location:	Offset:		Elevation: 35-36.5'
Sample Description:	Tan Micaceous Silty Fine to Coarse Sand (SM)		



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm (#200)
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Maximum Particle Size:	#4	Gravel:	10.1%	Silt	13.4%
Silt & Clay (% Passing #200):	18.4%	Total Sand:	71.5%	Clay	5.0%
ent Relative Density (Assumed)	2.650	Moisture Content		Colloids	3.5%
Liquid Limit	NP	Plastic Limit	NP	Plastic Index	NP
Coarse Sand:	15.6%	Medium Sand:	33.0%	Fine Sand:	23.0%

Description of Sand and Gravel — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Apparatus B: Air Jet Dispersion — Dispersion Period: 1 min. Dispersing Agent: Sodium Hexametaphosphate: 40 g./ Liter

References / Comments / Deviations: ASTM D 4318, D 854, D 2487

Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Form No. TR-D422-2
Revision No. 0
Revision Date: 02/20/08

Particle Size Analysis of Soils

ASTM D 422

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	1356-09-029 Phase 04	Report Date:	
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	
Client Name:	Duke Energy	Address:	3195 Pine Hall Road, Belews Creek, NC 27009
Boring #:	AD9	Sample #:	13
Location:		Offset:	ND
Sample Description:	Orange Tan Silty Fine to Coarse Sand (SM)		

Pan #:		Beaker #:		**Apparent Relative Density (Assumed)**		**2.650**	
Hydrometer Jar #:							
Pan Tare Weight (grams):				**Moisture Content**	Hygroscopic	Natural	
Total Sample Air Dried Wt. + tare wt. (grams):	154.16			Tare #	29		
Weight of Total Sample Air Dried:	154.16		A	Tare Wt.	14.15		
Weight of Air Dried Hydrometer Sample (g):	100.00		B	Wet Wt. + A	24.97		
Total Sample Oven Dried:	153.36		C	Dry Wt. + A	24.90		
Hydrometer Sample Oven Dried (**W**):	99.35		D	Water Wt. (B-C)	0.07		
% Passing #10:	79.6%		E	Dry Wt. (C-A)	10.75		
Correction Factor a (Table 1):	1.00			% Moisture (100 x D/E)	0.65%		

Sieve	Retained Wt.	Percent Passing	
3.0"	0.0	Pan # (washed)	100.0%
1.5"	0.0		100.0%
1.0"	0.0		100.0%
3/4"	0.0		100.0%
1/2"	0.0		100.0%
3/8"	0.0	Soil Mortar	100.0%
#4	10.7		93.0%
#10	31.2	**100.0%**	79.6%
#20	20.2	79.6%	63.4%
#40	40.4	59.4%	47.3%
#60	53.6	46.1%	36.7%
#100	62.6	37.0%	29.5%
#200	74.4	25.2%	20.0%

Description of Sand & Gravel Particles — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Stirring Apparatus: A ☐ B ☐ Dispersion Time: 1 min. Sodium Hexametaphosphate: 40 g./ Liter

Balance: *ID No.* 3996 *Cal. Date:* 2/3/2010 Hydrometer: *ID No.* 3901 *Cal. Date:* 3/26/2010

Control Cylinder ☒ **Composite Correction** ☐ **Type:** **151H** ☐ **152H** ☒

Time	Temp.	Hydrometer	Corrections		Hydrometer	Percent Passing		Effective Depth	Table 3	Diameter
			Control Cylinder	Composite Correction		P(-#10) = (R x a / W) x 100	P (total) = P x % Passing #10			D = K x $((L/T)^{1/2}$
T (Min.)	(0.5 °C)	Reading			R			L	K	
1	24.5	25.0	4.5		20.50	20.6%	16.4%	12.9	0.01294	0.04652
2	24.5	22.0	4.5		17.50	17.6%	14.0%	13.4	0.01294	0.03351
5	24.5	18.0	4.5		13.50	13.6%	10.8%	14.1	0.01294	0.02171
15	24.5	14.5	4.5		10.00	10.1%	8.0%	14.7	0.01294	0.01279
30	24.5	13.0	4.5		8.50	8.6%	6.8%	14.9	0.01294	0.00912
60	24.5	12.0	4.5		7.50	7.5%	6.0%	15.1	0.01294	0.00648
250	24.5	9.5	4.5		5.00	5.0%	4.0%	15.5	0.01294	0.00322
1440	23.5	8.0	4.5		3.50	3.5%	2.8%	15.7	0.01309	0.00137

References / Comments / Deviations ASTM D 422, D 2487, D 4318

Karen Warner	NICET 117900	Jason Reeves	Senior Engineer	
Technician Name	*Certification #*	*Technical Responsibility*	*Position*	*Date*

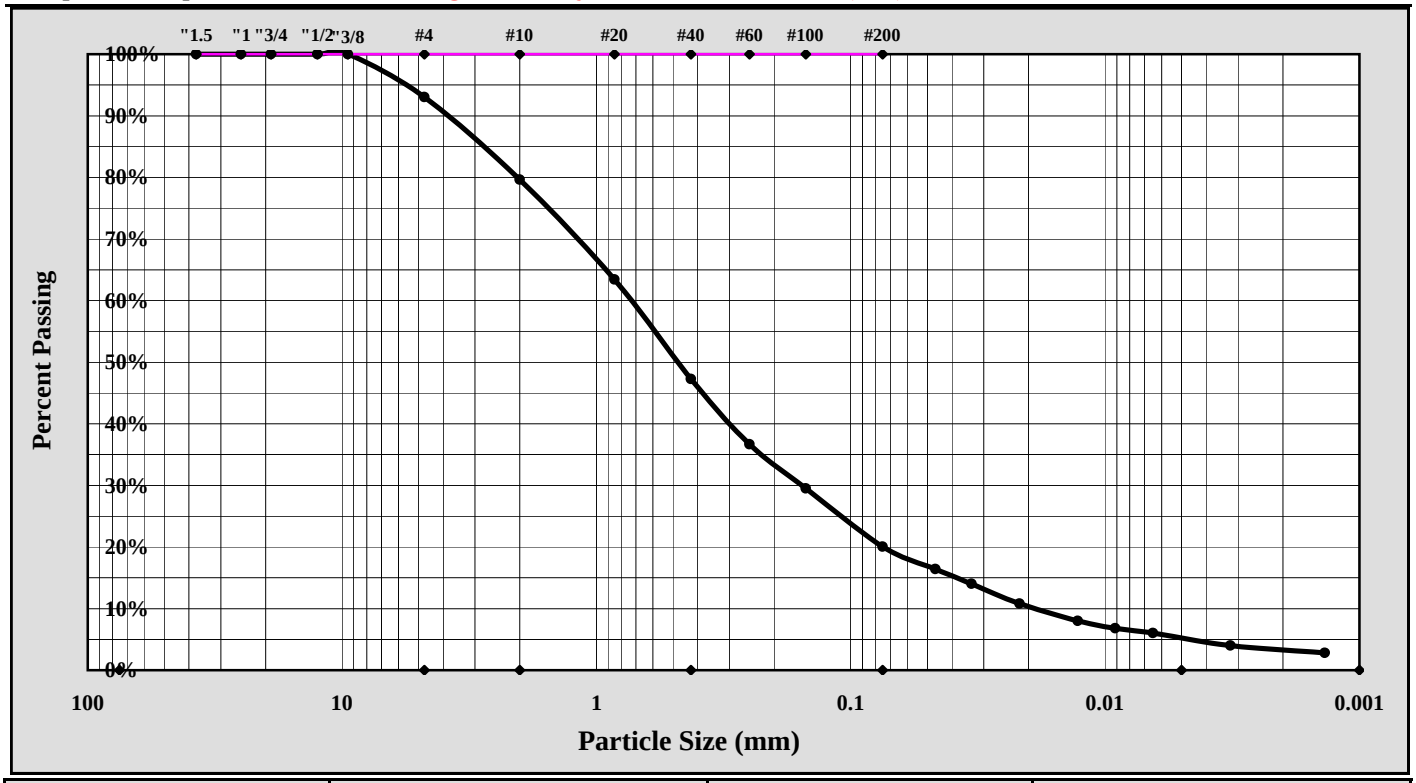
Particle Size Analysis of Soils

ASTM D422

Quality Assurance

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

S&ME Project #:	1356-09-029 Phase 04	Report Date:	
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	
Client Name:	Duke Energy		
Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD9	Sample #: 13	Sample Date:
Location:		Offset: ND	Elevation: 36.5-38'
Sample Description:	Orange Tan Silty Fine to Coarse Sand (SM)		



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm (#200)
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Maximum Particle Size:	#4	Gravel:	7.0%	Silt	15.0%
Silt & Clay (% Passing #200):	20.0%	Total Sand:	73.0%	Clay	5.0%
ent Relative Density (Assumed)	2.650	Moisture Content		Colloids	4.0%
Liquid Limit	ND	Plastic Limit	ND	Plastic Index	ND
Coarse Sand:	13.4%	Medium Sand:	32.4%	Fine Sand:	27.2%

Description of Sand and Gravel: Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Apparatus B: Air Jet Dispersion — Dispersion Period: 1 min. — Dispersing Agent: Sodium Hexametaphosphate: 40 g./ Liter

References / Comments / Deviations: ASTM D 4318, D 854, D 2487

Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Laboratory Determination of Water Content

ASTM D 2216 ☑ *AASHTO T 265* ☐ ***Quality Assurance***

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #: **1356-09-029 Phase 04** **0** Report Date: 5/21/10

Project Name: Duke Energy - BCSS Embankment Stability

Boring No.	Sample No.	Sample Depth	Tare #	Tare Weight	Tare Wt.+ Wet Wt	Tare Wt. + Dry Wt	Water Weight	Percent Moisture	Note
		ft. or m.		grams	grams	grams	grams	%	
AD10	1	1-2.5'	G-2	82.35	267.32	227.35	39.97	**27.6%**	1
AD10	2	3.5-5'	CHAD	82.86	290.63	250.18	40.45	**24.2%**	2
AD10	3	6-7.5'	T-7	82.15	271.03	230.25	40.78	**27.5%**	
AD10	4	8-9.5'	T-6	81.53	258.31	226.56	31.75	**21.9%**	
AD10	5	9.5-11'	JAZZ	81.26	256.08	234.96	21.12	**13.7%**	
AD10	6	11-12.5'	G-9	82.27	222.49	199.96	22.53	**19.1%**	
AD10	7	13.5-15'	S-4	80.67	290.90	250.96	39.94	**23.5%**	
AD10	8	18.5-20'	POT	113.30	240.15	212.14	28.01	**28.3%**	
AD10	9	23.5-25'	FISH	104.75	198.76	185.53	13.23	**16.4%**	

Notes / Deviations / References

Form No. TR-D4318-T89-90
Revision No. 0
Revision Date: 11/20/07

Liquid Limit, Plastic Limit, and Plastic Index

S&ME

Another code *ASTM D 4318* ☒ *AASHTO T 89* ☐ *AASHTO T 90* ☐ ***Quality Assurance***

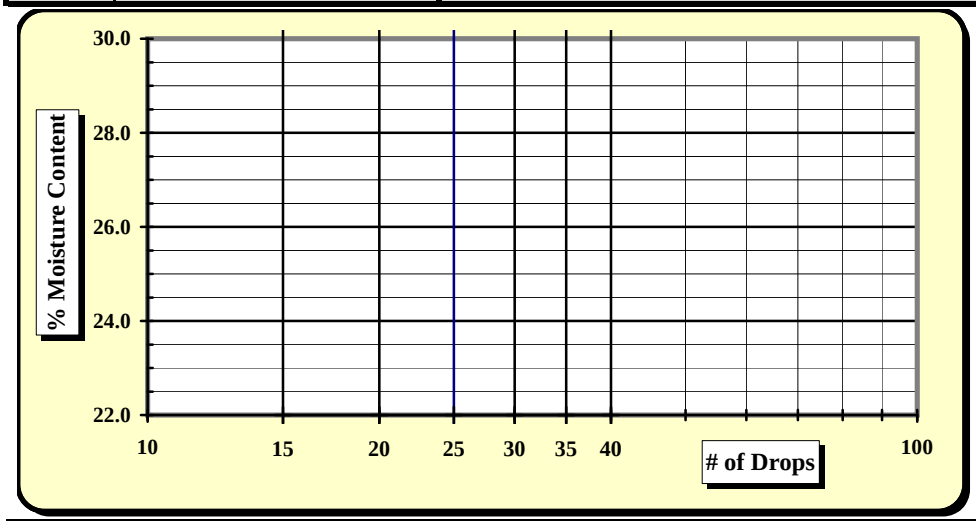
S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	6/1/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s)	5/25-6/1/10
Client Name:	Duke Energy		
Client Address:	3195 Pine Hall Road, Belews Creek, NC 27009		

Boring #:	AD10	Sample #: 9	Sample Date:
Location:		Offset:	Elevation: 23.5-25'
Sample Description:	Tan Gray Micaceous Silty Fine to Coarse Sand (SM)		

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	20233	6/15/2009	Grooving tool	21587	2/28/2010
LL Apparatus	3611	10/20/2009	Grooving tool		
Oven	10844	9/4/2009	Grooving tool		

		Liquid Limit						Plastic Limit		
Pan #	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by ASTM D 2216*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit			
N	**Factor**	**N**	**Factor**
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic	☒
Liquid Limit	
Plastic Limit	
Plastic Index	
Group Symbol	**SM**
Multipoint Method	☐
One-point Method	☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ *Estimate the % Retained on the #40 Sieve:*

Notes / Deviations / References:

ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Jason Clark — *Technician Name* — *Date*

Jason Reeves — *Technical Responsibility* — *Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

Particle Size Analysis of Soils

ASTM D 422

S&ME

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

Project #:	**1356-09-029 Phase 04**	Report Date:	6/1/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	5/20-6/1/10
Client Name:	Duke Energy	Address:	3195 Pine Hall Road, Belews Creek, NC 27009
Boring #:	AD10	Sample #:	9
Location:		Offset:	
Sample Description:	Tan Gray Micaceous Silty Fine to Coarse Sand (SM)		

Pan #:		Beaker #:		**Apparent Relative Density (Assumed)**		**2.650**	
Hydrometer Jar #:							
Pan Tare Weight (grams):				**Moisture Content**	Hygroscopic	Natural	
Total Sample Air Dried Wt. + tare wt. (grams):	156.82			Tare #	VV		
Weight of Total Sample Air Dried:	156.82		A	Tare Wt.	16.04		
Weight of Air Dried Hydrometer Sample (g):	50.00		B	Wet Wt. + A	26.93		
Total Sample Oven Dried:	156.17		C	Dry Wt. + A	26.88		
Hydrometer Sample Oven Dried (**W**):	49.77		D	Water Wt. (B-C)	0.05		
% Passing #10:	89.8%		E	Dry Wt. (C-A)	10.84		
Correction Factor a (Table 1):	1.00			% Moisture (100 x D/E)	0.46%		

Sieve	Retained Wt.	Percent Passing	
3.0"	0.0	Pan # (washed)	100.0%
1.5"	0.0		100.0%
1.0"	0.0		100.0%
3/4"	0.0		100.0%
1/2"	0.0		100.0%
3/8"	0.0	Soil Mortar	100.0%
#4	6.2		96.0%
#10	16.0	**100.0%**	89.8%
#20	6.2	87.5%	78.6%
#40	17.7	64.4%	57.8%
#60	27.8	44.1%	39.6%
#100	32.9	34.0%	30.5%
#200	38.0	23.6%	21.2%

Description of Sand & Gravel Particles Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Stirring Apparatus: A ☐ B ☐ Dispersion Time: 1 min. Sodium Hexametaphosphate: 40 g./ Liter

Balance: *ID No.* 3996 *Cal. Date:* 2/3/2010 Hydrometer: *ID No.* 3901 *Cal. Date:* 3/26/2010

Control Cylinder ☒ **Composite Correction** ☐ **Type:** **151H** ☐ **152H** ☒

Time	Temp.	Hydrometer	Corrections		Hydrometer	Percent Passing		Effective Depth	Table 3	Diameter
			Control	Composite		P(-#10) =	P (total) =			D =
T (Min.)	(0.5 °C)	Reading	Cylinder	Correction	R	(R x a / W) x 100	P x % Passing #10	L	K	K x ((L/T)$^{1/2}$
1	24.5	15.0	4.5		10.50	21.1%	18.9%	14.6	0.01294	0.04938
2	24.5	13.0	4.5		8.50	17.1%	15.3%	14.9	0.01294	0.03531
5	24.5	11.0	4.5		6.50	13.1%	11.7%	15.2	0.01294	0.02257
15	24.5	9.5	4.5		5.00	10.0%	9.0%	15.5	0.01294	0.01314
30	24.5	8.5	4.5		4.00	8.0%	7.2%	15.6	0.01294	0.00934
60	24.5	8.0	4.5		3.50	7.0%	6.3%	15.7	0.01294	0.00662
250	24.5	7.0	4.5		2.50	5.0%	4.5%	15.9	0.01294	0.00326
1440	24.5	6.0	4.5		1.50	3.0%	2.7%	16.0	0.01294	0.00137

References / Comments / Deviations ASTM D 422, D 2487, D 4318

Karen Warner	NICET 117900	Jason Reeves	Senior Engineer	
Technician Name	*Certification #*	*Technical Responsibility*	*Position*	*Date*

Form No. TR-D422-3
Revision No. 0
Revision Date: 02/20/08

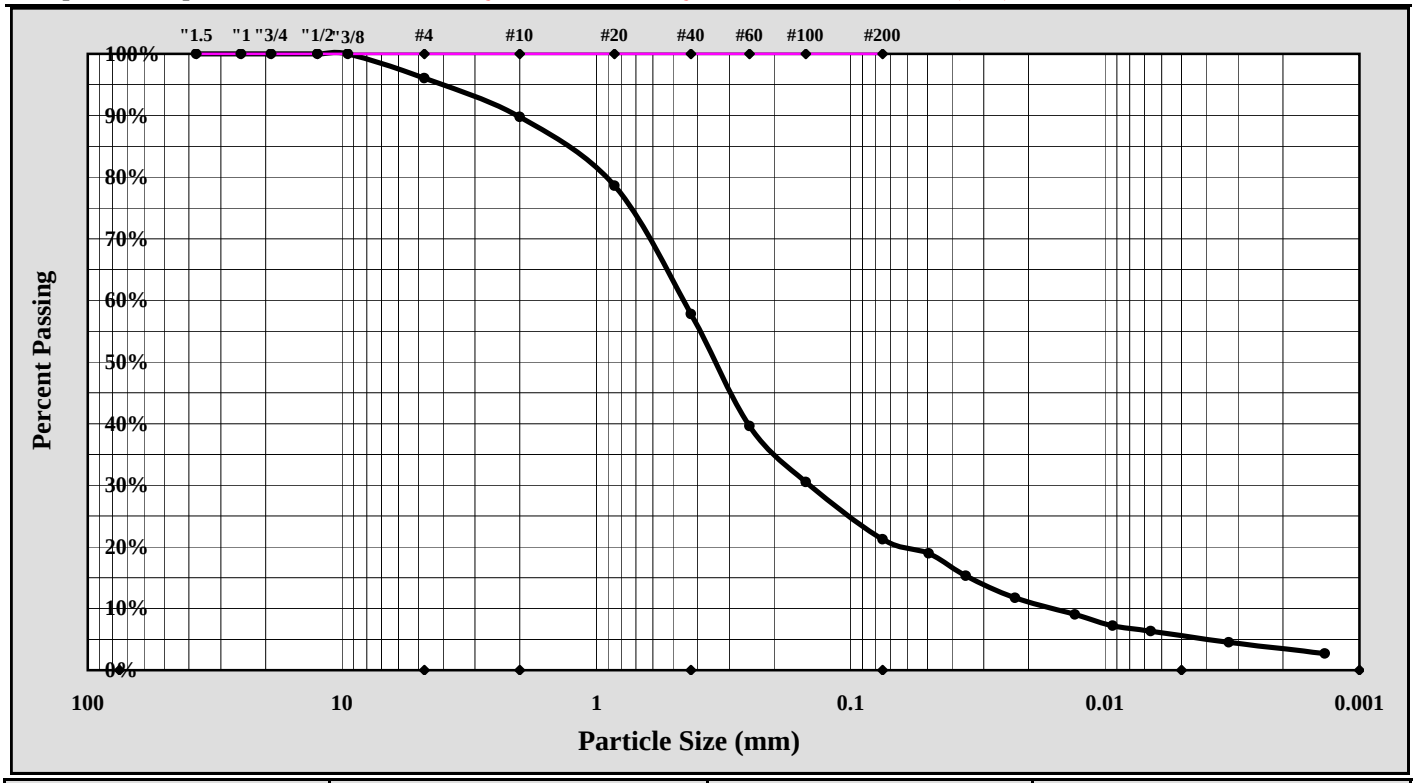
Particle Size Analysis of Soils

ASTM D422

Quality Assurance

S&ME, Inc. ~ 9751 Southern Pine Boulevard ~ Charlotte, NC 28273

S&ME Project #:	1356-09-029 Phase 04	Report Date:	6/1/10
Project Name:	Duke Energy - BCSS Embankment Stability	Test Date(s):	5/20-6/1/10
Client Name:	Duke Energy		
Address:	3195 Pine Hall Road, Belews Creek, NC 27009		
Boring #:	AD10	Sample #: 9	Sample Date:
Location:	Offset:		Elevation: 23.5-25'
Sample Description:	Tan Gray Micaceous Silty Fine to Coarse Sand (SM)		



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm (#200)
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Maximum Particle Size:	#4	Gravel:	4.0%	Silt	15.7%
Silt & Clay (% Passing #200):	21.2%	Total Sand:	74.8%	Clay	5.5%
ent Relative Density (Assumed)	2.650	Moisture Content		Colloids	2.5%
Liquid Limit	NP	Plastic Limit	NP	Plastic Index	NP
Coarse Sand:	6.2%	Medium Sand:	32.0%	Fine Sand:	36.5%

Description of Sand and Gravel — Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☐ Weathered & Friable ☐

Apparatus B: Air Jet Dispersion — Dispersion Period: 1 min. Dispersing Agent: Sodium Hexametaphosphate: 40 g./ Liter

References / Comments / Deviations: ASTM D 4318, D 854, D 2487

Jason Reeves		Senior Engineer	
Technical Responsibility	*Signature*	*Position*	*Date*

This report shall not be reproduced, except in full, without the written approval of S&ME, Inc.

APPENDIX III

WATER LEVELS

Table WL1 – Water Levels in Existing Instrumentation – Ash Dike Station 7+25
Table WL2 – Water Levels in Existing Instrumentation – Ash Dike Station 10+00
Table WL3 – Water Levels in Existing Instrumentation – Ash Dike Station 12+00
Historic Water Levels for Piezometers P34, P39, P59, and P61
Flow Through Ash Dike Horizontal Drains

Table WL1 - Water Levels in Existing Instrumentation - Ash Dike Station 7+25
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Description	Top of Casing Elevation (feet)	Source	Water Depth (feet)	Source	Water Elevation (feet)	Top of Screen Elevation (feet)	Bottom of Screen Elevation (feet)	Source
OW-78	773.4	2010 Duke Energy survey	22.62	February 2010 monitoring event	750.78	767.4	739.3	Note 2
P-79	773.36	2010 Duke Energy survey	52.10	February 2010 monitoring event	721.26	691.8	686.8	Note 1
OW-81	723.31	2010 Duke Energy survey	7.72	February 2010 monitoring event	715.59	717.3	710.0	Note 2
P-82	723.34	2010 Duke Energy survey	26.46	February 2010 monitoring event	696.88	697.5	692.5	Note 1
OW-80	723.24	2010 Duke Energy survey	4.52	February 2010 monitoring event	718.72	717.2	715.0	Note 2
P-83	723.06	2010 Duke Energy survey	40.62	February 2010 monitoring event	682.44	674.2	669.2	Note 1
OW-69	723.14	2010 Duke Energy survey	38 AND DRY	February 2010 monitoring event	DRY	717.1	685.1	Note 2
P-44	710.18	2010 Duke Energy survey	7.55	February 2010 monitoring event	702.63	666.5	661.5	Note 1
P-45	710.2	2010 Duke Energy survey	29.10	February 2010 monitoring event	681.10	697.5	692.5	Note 1
OW-84	695.29	2010 Duke Energy survey	3.61	February 2010 monitoring event	691.68	689.3	684.0	Note 2
OW-85	683.27	2010 Duke Energy survey	3.96	February 2010 monitoring event	679.31	677.3	675.1	Note 2

Note 1: Screen interval calculated by assuming a five foot screen length (typical piezometer detail on Duke Energy Drawing No. BC-1037-2) centered around the centerline of porous tube (elevation shown on Duke Energy Drawing No. BC-1037-4 Rev 4)

Note 2: Screen interval calculated by assuming top of screen is 6 feet below ground surface and the bottom of screen is at the elevation of the lowest point of drill holes (elevation shown on Duke Energy Drawing No. BC-1037-4 Rev 4)

Table WL2 - Water Levels in Existing Instrumentation - Ash Dike Station 10+00
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Description	Top of Casing Elevation (feet)	Source	Water Depth (feet)	Source	Water Elevation (feet)	Top of Screen Elevation (feet)	Bottom of Screen Elevation (feet)	Source
OW-53	771.35	2010 Duke Energy survey	27.02	February 2010 monitoring event	744.33	765.4	722.0	Note 2
P-57	729.64	2010 Duke Energy survey	35	February 2010 monitoring event	694.64	680.5	675.5	Note 1
P-58	729.65	2010 Duke Energy survey	17.7	February 2010 monitoring event	711.95	709.5	704.5	Note 1
P-54	729.5	assumed	31.96	February 2010 monitoring event	697.54	645.5	640.5	Note 1
P-55	729.5	2010 Duke Energy survey	27.42	February 2010 monitoring event	702.08	709.5	704.5	Note 1
OW-56	729.46	2010 Duke Energy survey	8.34	February 2010 monitoring event	721.12	723.5	639.0	Note 2
P-59	688.43	2010 Duke Energy survey	17.9	February 2010 monitoring event	670.53	643.5	638.5	Note 1
P-60	688.51	2010 Duke Energy survey	18.94	February 2010 monitoring event	669.57	671.5	666.5	Note 1
P-61	688.41	2010 Duke Energy survey	17.77	February 2010 monitoring event	670.64	659.5	654.5	Note 1
OW-62	688.42	2010 Duke Energy survey	6.77	February 2010 monitoring event	681.65	682.4	649.0	Note 2

Note 1: Screen interval calculated by assuming a five foot screen length (typical piezometer detail on Duke Energy Drawing No. BC-1037-2) centered around the centerline of porous tube (elevation shown on Duke Energy Drawing No. BC-1037-4 Rev 4)

Note 2: Screen interval calculated by assuming top of screen is 6 feet below ground surface and the bottom of screen is at the elevation of the lowest point of drill holes (elevation shown on Duke Energy Drawing No. BC-1037-4 Rev 4)

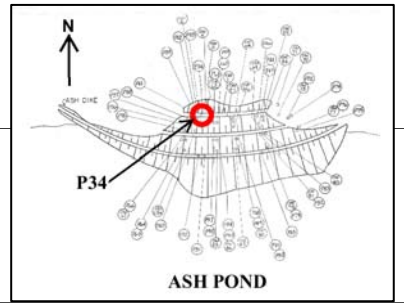
Table WL3 - Water Levels in Existing Instrumentation - Ash Dike Station 12+00
Belews Creek Ash Dike
S&ME Project No. 1356-09-029

Description	Top of Casing Elevation (feet)	Source	Water Depth (feet)	Source	Water Elevation (feet)	Top of Screen Elevation (feet)	Bottom of Screen Elevation (feet)	Source
OW-63A	773.29	2010 Duke Energy survey	26.67	February 2010 monitoring event	746.62	767.3	727.0	Note 2
P-64	730.01	2010 Duke Energy survey	35.92	February 2010 monitoring event	694.09	675.5	670.5	Note 1
P-65	730.01	2010 Duke Energy survey	4.73	February 2010 monitoring event	725.28	708.5	703.5	Note 1
P-66	730.26	2010 Duke Energy survey	7.03	February 2010 monitoring event	723.23	702.5	697.5	Note 1
OW-67	730.24	2010 Duke Energy survey	9.62	February 2010 monitoring event	720.62	724.2	691.0	Note 2
P-35	717.18	2010 Duke Energy survey	7.32	February 2010 monitoring event	709.86	709.6	704.6	Note 1
P-36	696.43	interpolated from 2010 Duke Energy survey (may be broken)	20.37	February 2010 monitoring event	676.06	674.1	669.1	Note 1
P-37	688.21	2010 Duke Energy survey	11.64	February 2010 monitoring event	676.57	680.3	675.3	Note 1
P-39	667.19	2010 Duke Energy survey	8.61	February 2010 monitoring event	658.58	658.4	653.4	Note 1

Note 1: Screen interval calculated by assuming a five foot screen length (typical piezometer detail on Duke Energy Drawing No. BC-1037-2) centered around the centerline of porous tube (elevation shown on Duke Energy Drawing No. BC-1037-4 Rev 4)

Note 2: Screen interval calculated by assuming top of screen is 6 feet below ground surface and the bottom of screen is at the elevation of the lowest point of drill holes (elevation shown on Duke Energy Drawing No. BC-1037-4 Rev 4)

Ash Dike - P34



Elevation (feet)

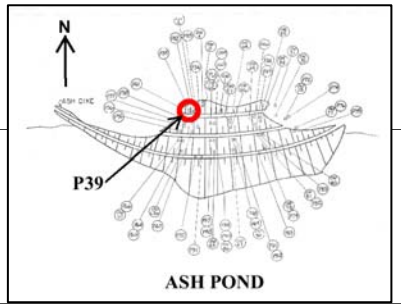
680
670
660
650
640
630

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

P34 P34 - 12-mo. Avg.

Ash Dike - P39



Elevation (feet)

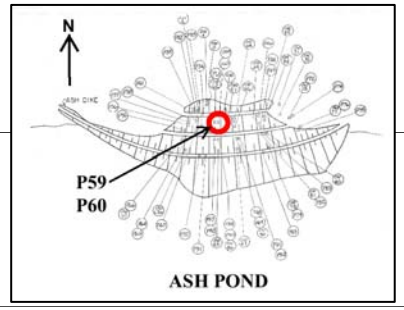
675
665
655
645
635
625

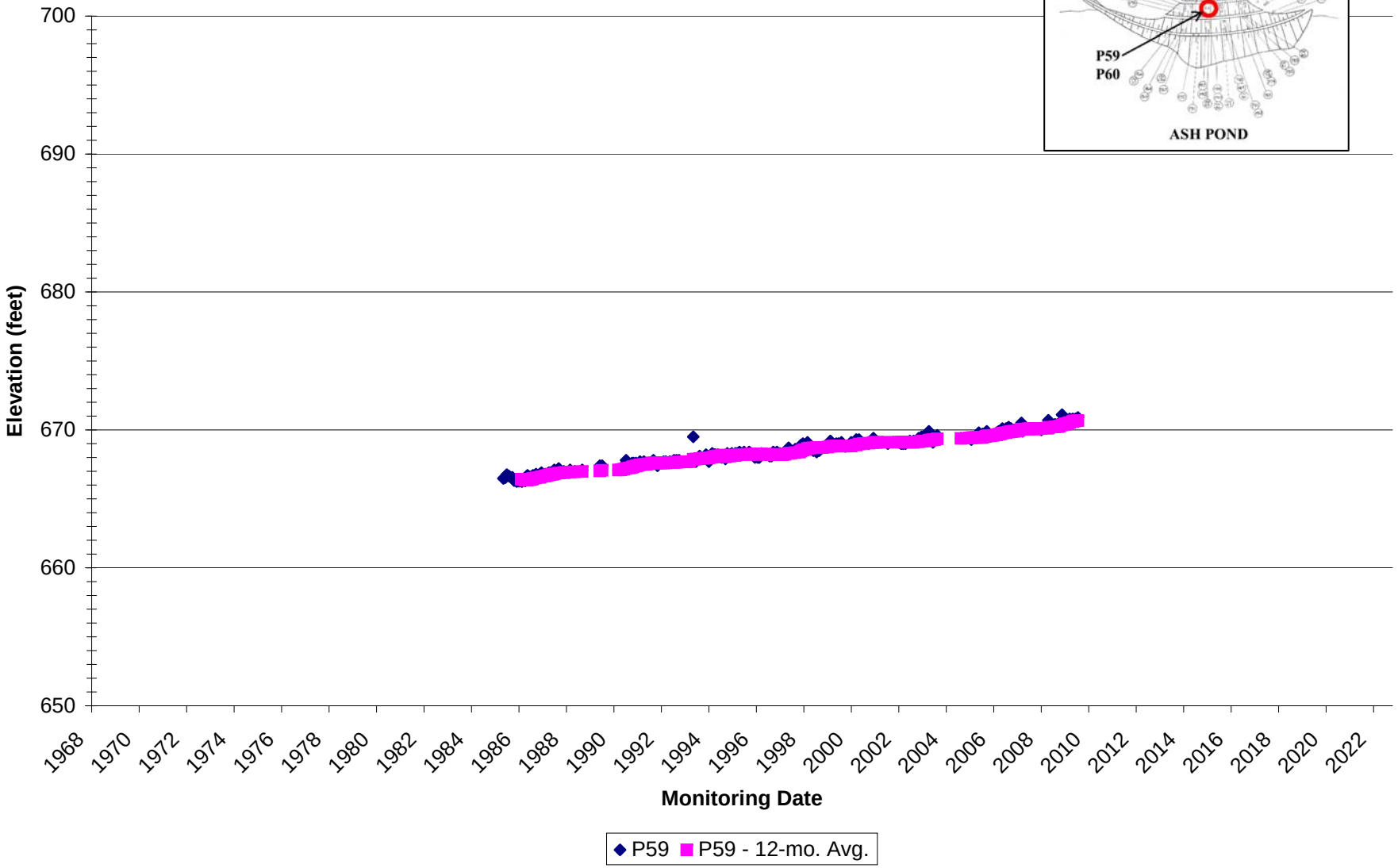
1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

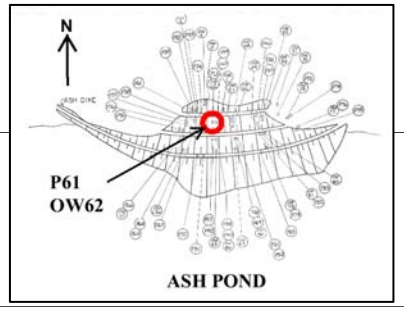
◆ P39 ■ P39 - 12-mo. Avg.

Ash Dike - P59


N
P59
P60
ASH POND


700
690
680
670
660
650
Elevation (feet)
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Monitoring Date
P59
P59 - 12-mo. Avg.

Ash Dike - P61



Elevation (feet)

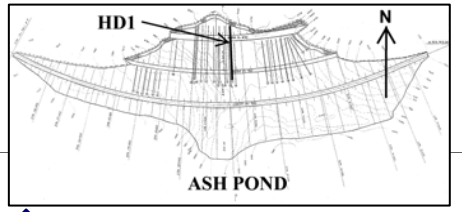
700
690
680
670
660
650

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

◆ P61 ■ P61 - 12-mo. Avg.

Ash Dike - HD1



Flow Rate (gpm)

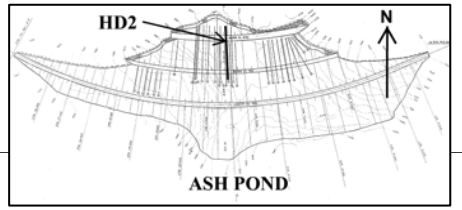
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

◆ HD1 ■ HD1 - 12-mo. Avg.

Ash Dike - HD2



Flow Rate (gpm)

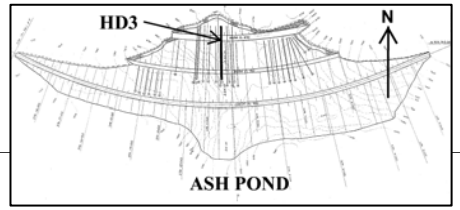
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

HD2 HD2 - 12-mo. Avg.

Ash Dike - HD3



Flow Rate (gpm)

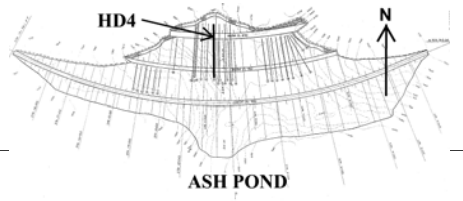
0.25
0.20
0.15
0.10
0.05
0.00

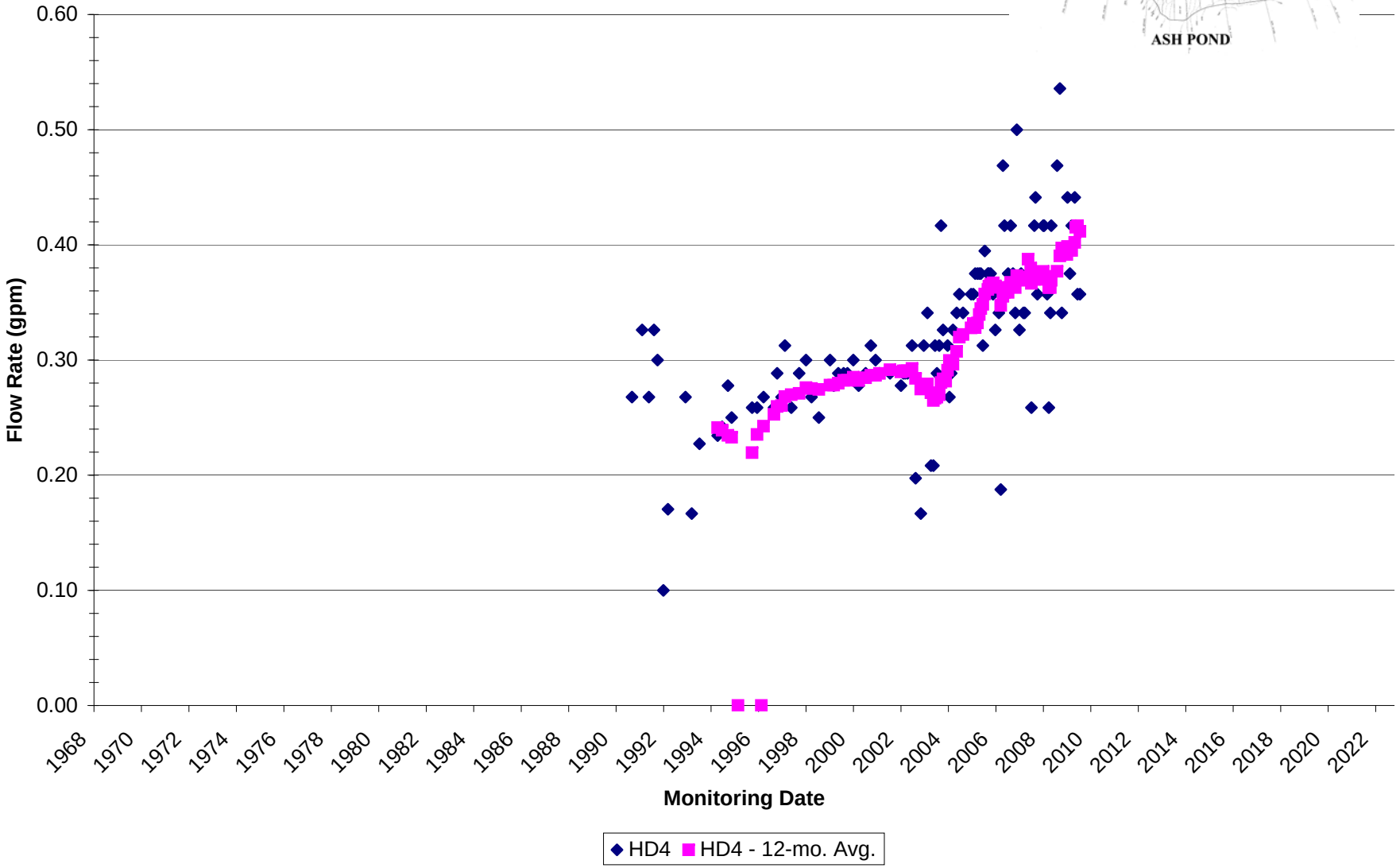
1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

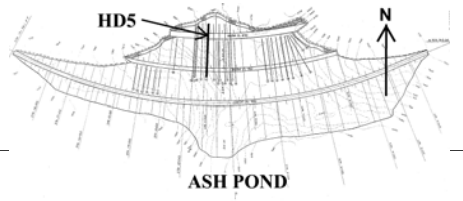
HD3 HD3 - 12-mo. Avg.

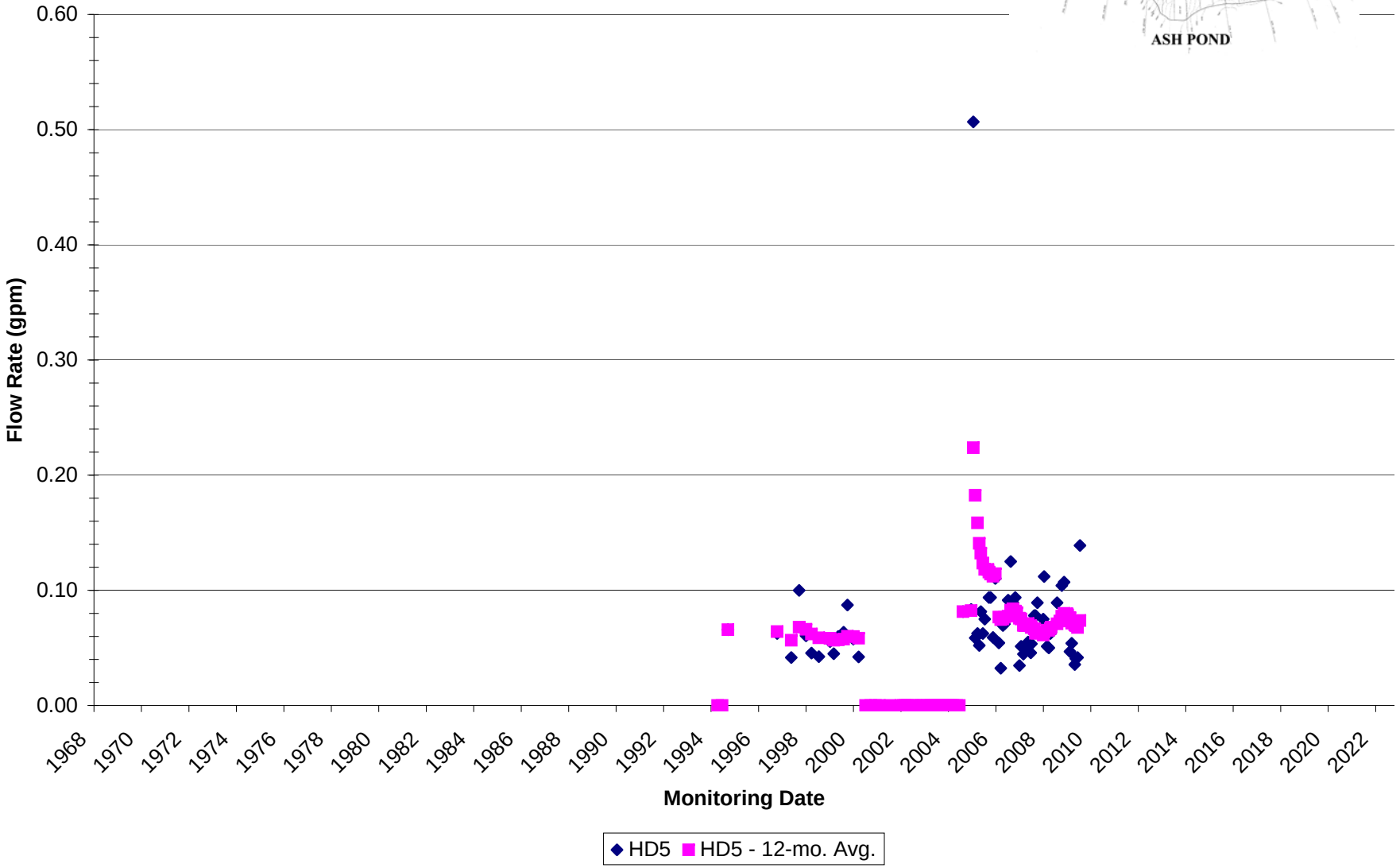
Ash Dike - HD4


HD4
N
ASH POND

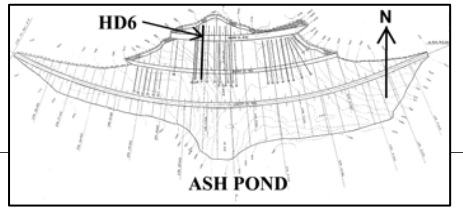

0.60
0.50
0.40
0.30
0.20
0.10
0.00
Flow Rate (gpm)
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Monitoring Date
HD4
HD4 - 12-mo. Avg.

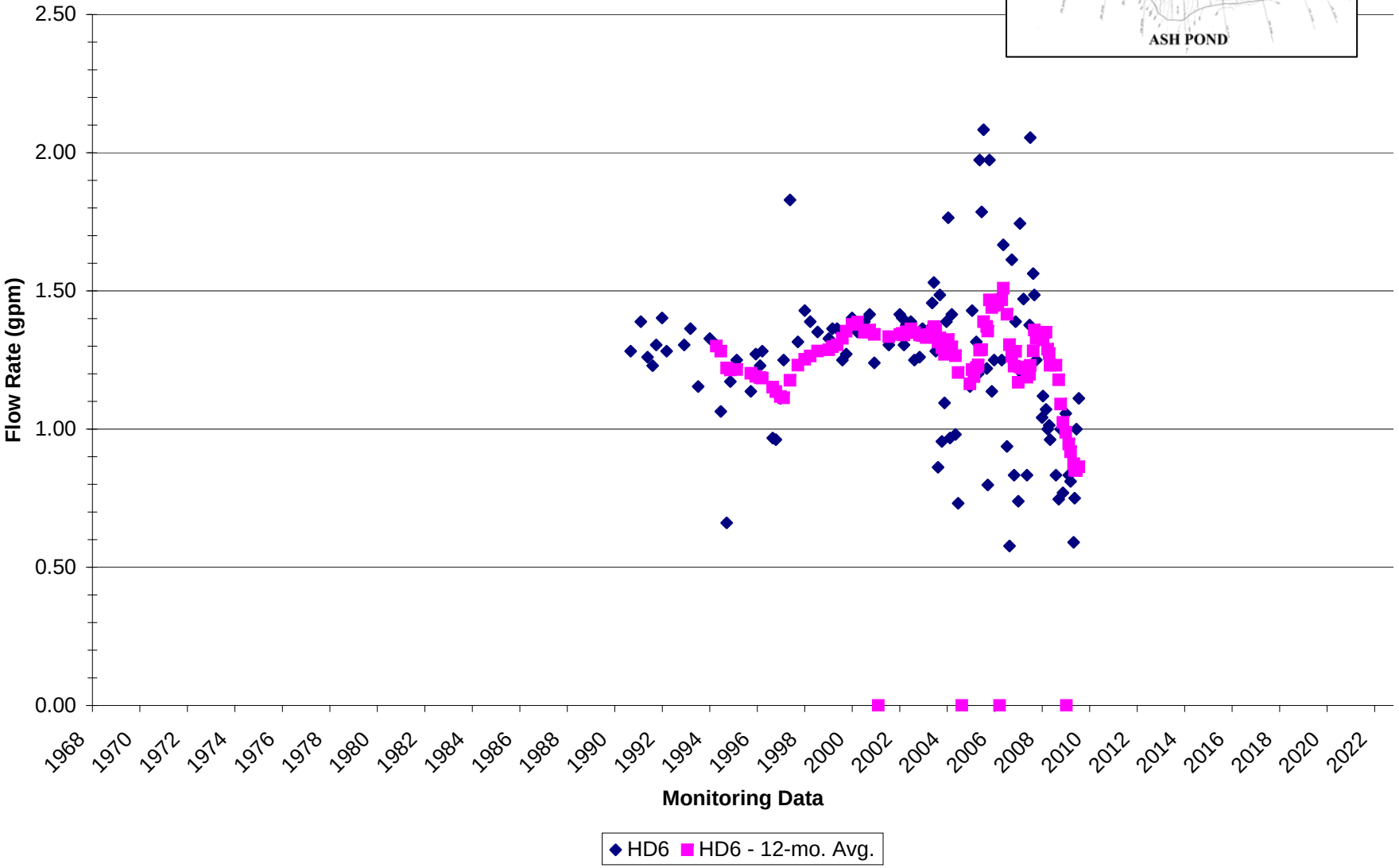
Ash Dike - HD5


HD5
N
ASH POND

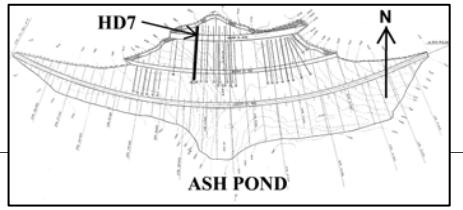

0.60
0.50
0.40
0.30
0.20
0.10
0.00
Flow Rate (gpm)
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Monitoring Date
HD5
HD5 - 12-mo. Avg.

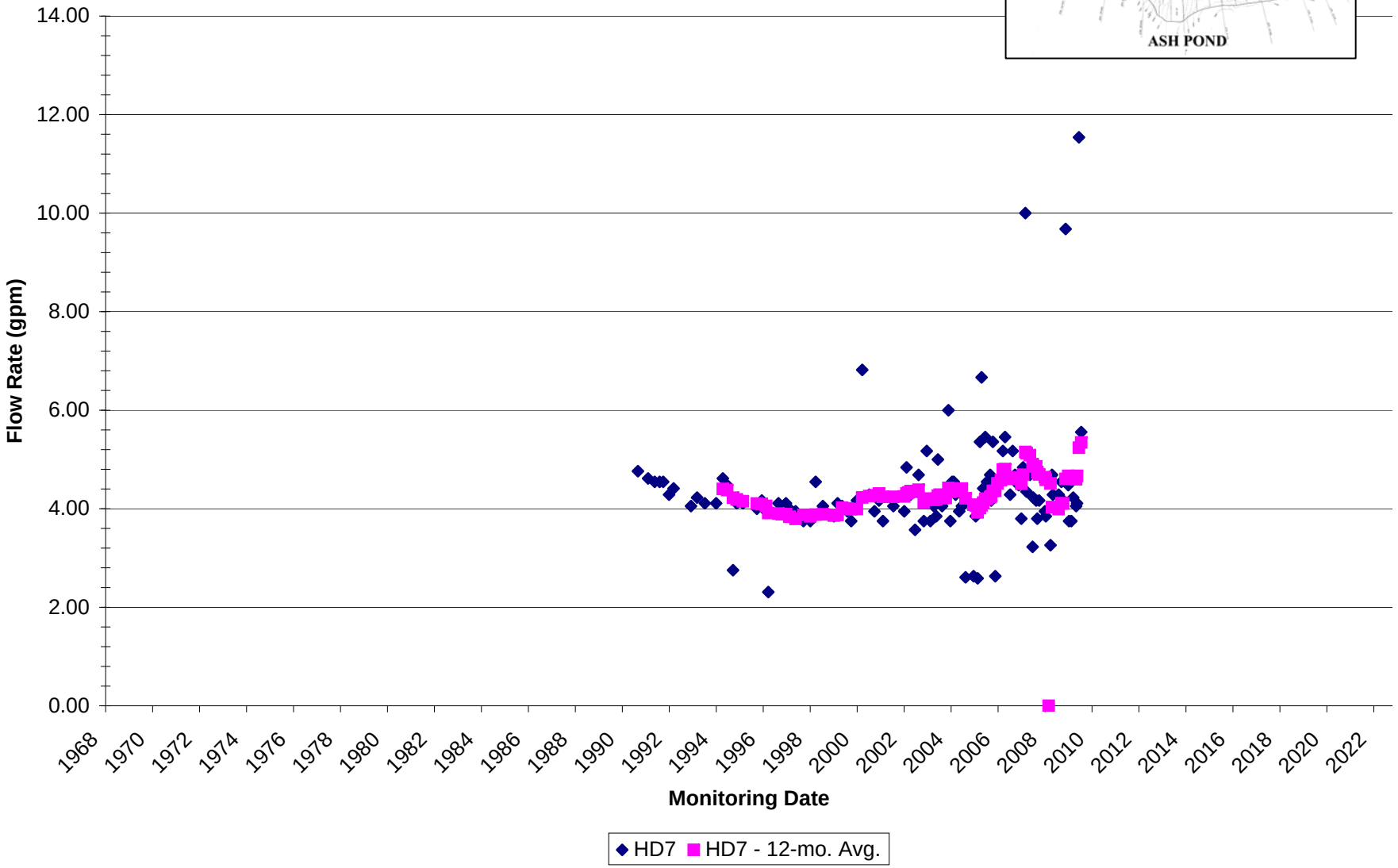
Ash Dike - HD6


HD6
N
ASH POND

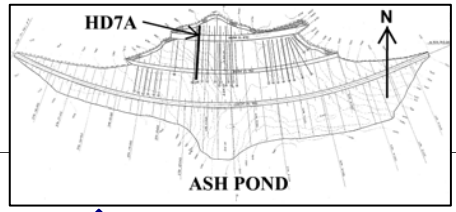

Flow Rate (gpm)
2.50
2.00
1.50
1.00
0.50
0.00
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Monitoring Data
HD6
HD6 - 12-mo. Avg.

Ash Dike - HD7


HD7
N
ASH POND


14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Flow Rate (gpm)
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Monitoring Date
HD7
HD7 - 12-mo. Avg.

Ash Dike - HD7A



Flow Rate (gpm)

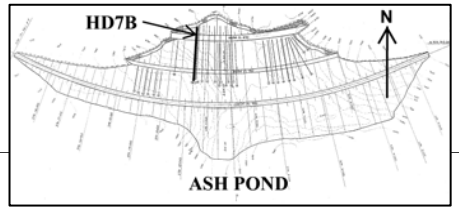
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

HD7A
HD7A - 12-mo. Avg.

Ash Dike - HD7B



Flow Rate (gpm)

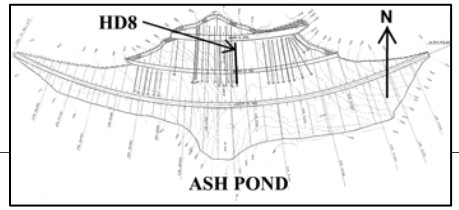
25.00
20.00
15.00
10.00
5.00
0.00

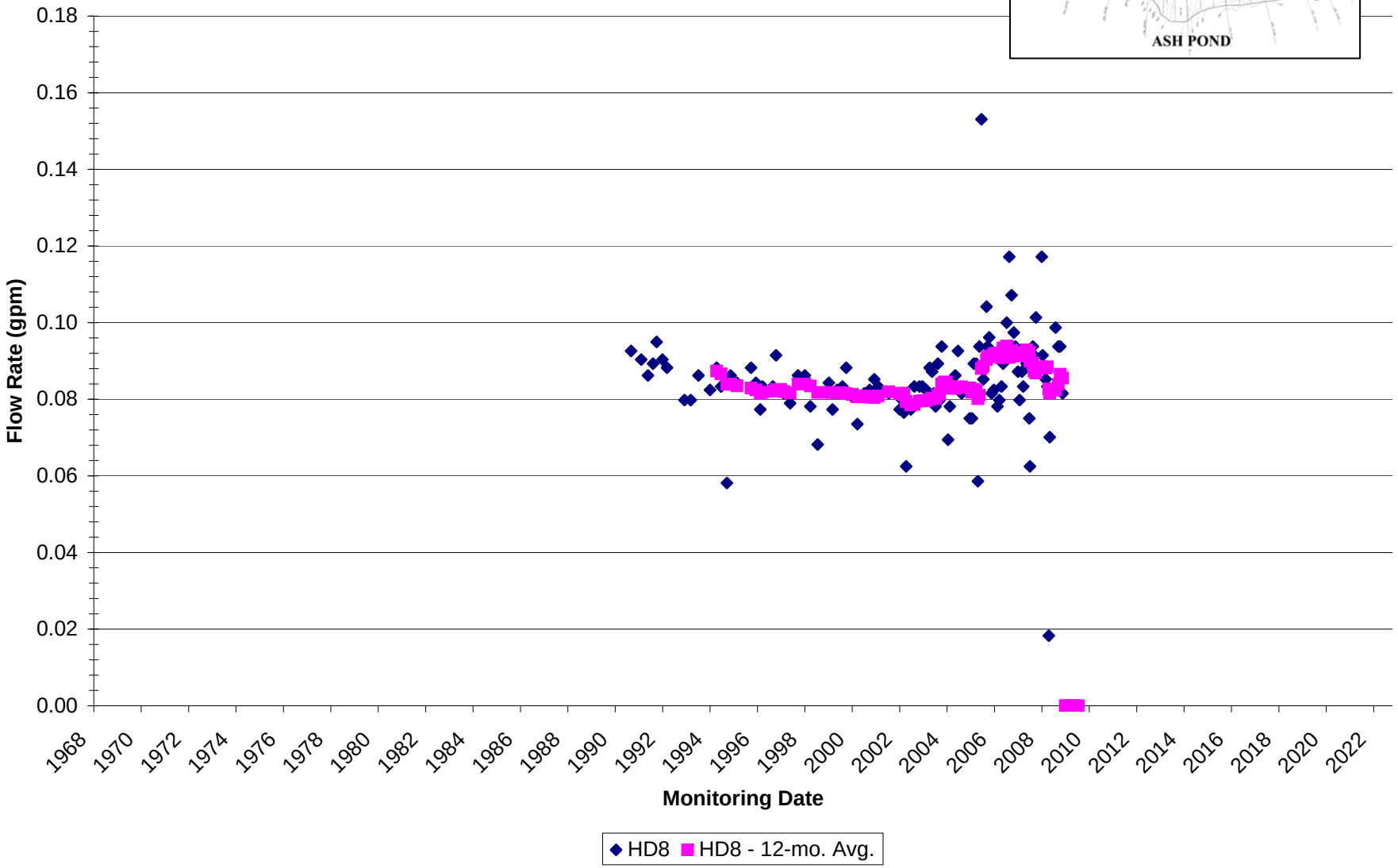
1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

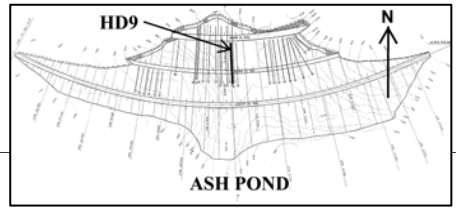
HD7B HD7B - 12-mo. Avg.

Ash Dike - HD8


HD8
N
ASH POND


0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Flow Rate (gpm)
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Monitoring Date
HD8
HD8 - 12-mo. Avg.

Ash Dike - HD9



Flow Rate (gpm)

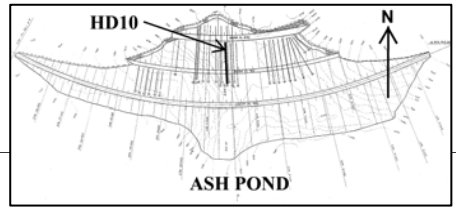
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

◆ HD9 ■ HD9 - 12-mo. Avg.

Ash Dike - HD10



Flow Rate (gpm)

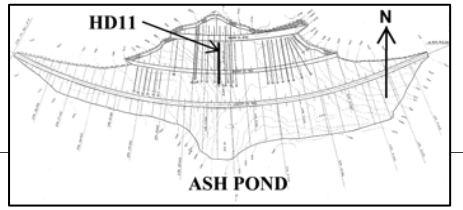
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

HD10 HD10 - 12-mo. Avg.

Ash Dike - HD11



Flow Rate (gpm)

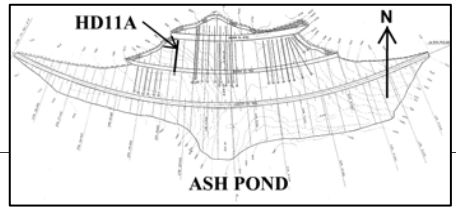
0.12
0.10
0.08
0.06
0.04
0.02
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

◆ HD11 ■ HD11 - 12-mo. Avg.

Ash Dike - HD11A



Flow Rate (gpm)

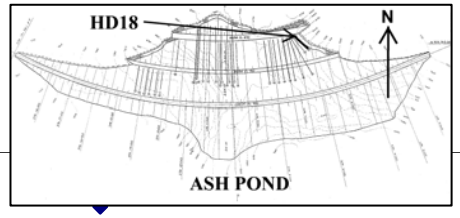
30.00
25.00
20.00
15.00
10.00
5.00
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

HD11A
HD11A - 12-mo. Avg.

Ash Dike - HD18



Flow Rate (gpm)

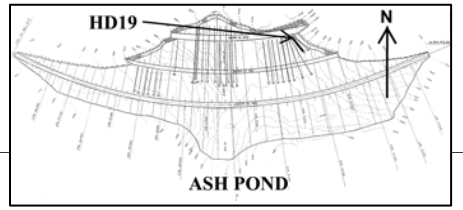
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

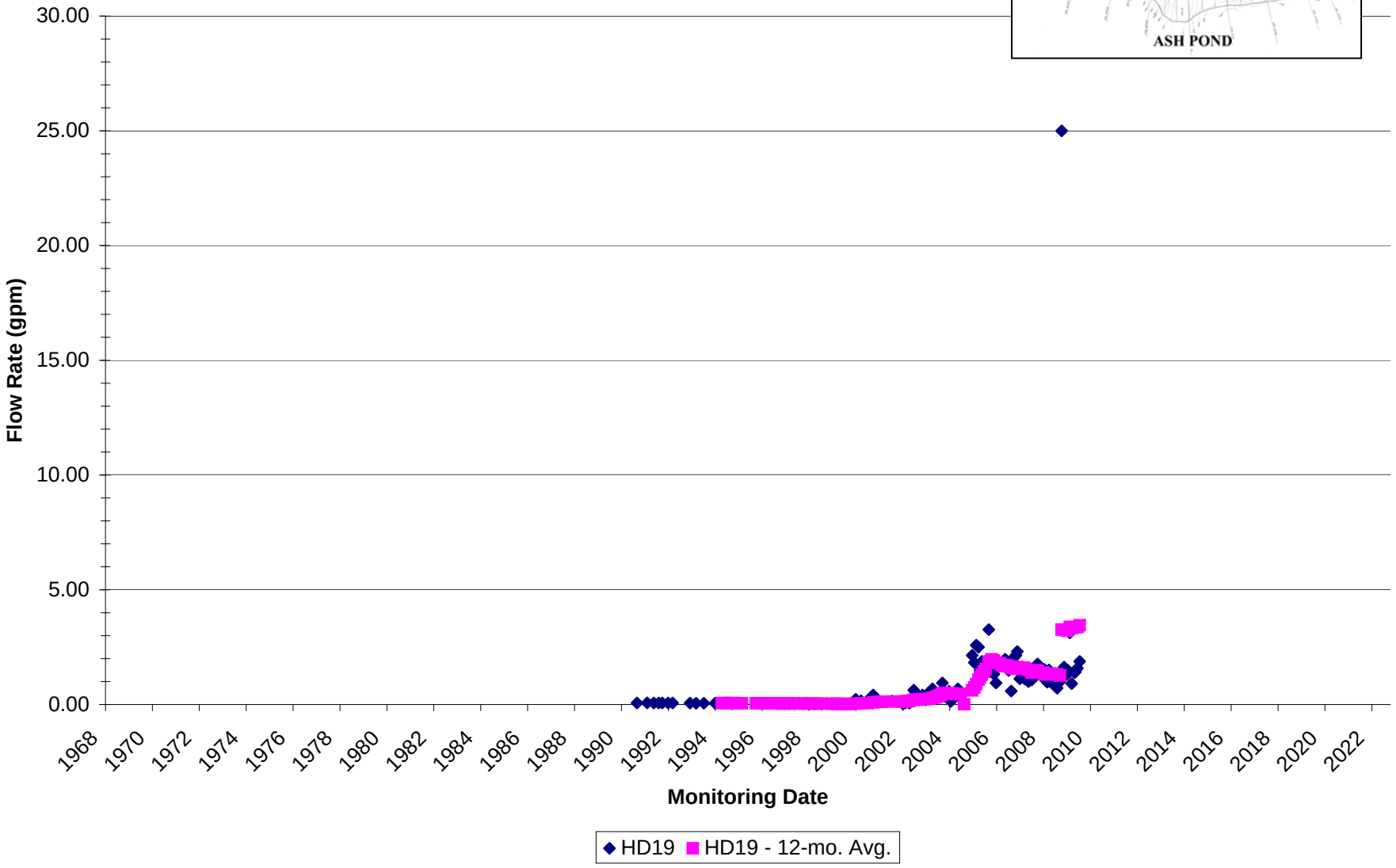
1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

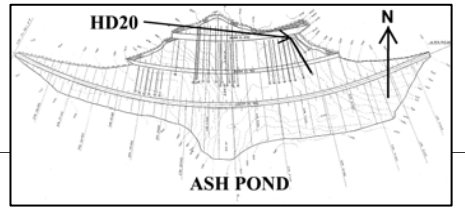
◆ HD18 ■ HD18 - 12-mo. Avg.

Ash Dike - HD19





Ash Dike - HD20



Flow Rate (gpm)

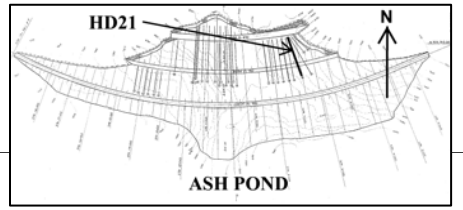
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

◆ HD20 ■ HD20 - 12-mo. Avg.

Ash Dike - HD21



Flow Rate (gpm)

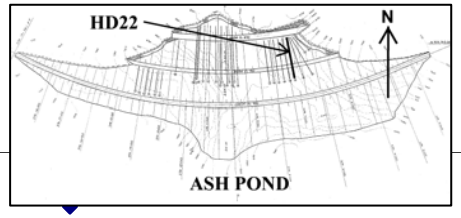
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

HD21 HD21 - 12-mo. Avg.

Ash Dike - HD22



Flow Rate (gpm)

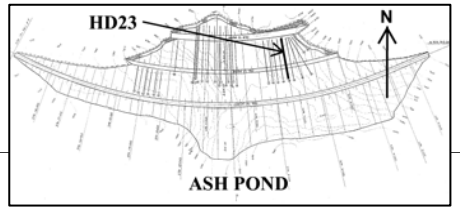
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

HD22 HD22 - 12-mo. Avg.

Ash Dike - HD23



Flow Rate (gpm)

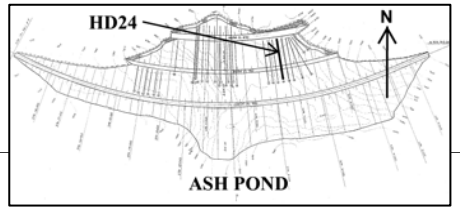
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

◆ HD23 ■ HD23 - 12-mo. Avg.

Ash Dike - HD24



Flow Rate (gpm)

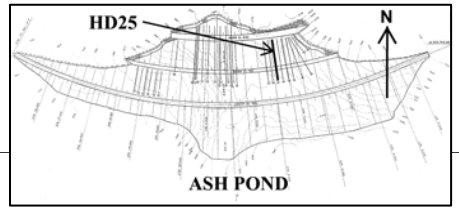
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

HD24 HD24 - 12-mo. Avg.

Ash Dike - HD25



Flow Rate (gpm)

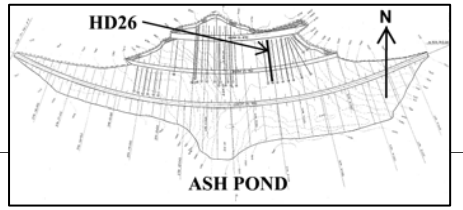
0.30
0.25
0.20
0.15
0.10
0.05
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

HD25 HD25 - 12-mo. Avg.

Ash Dike - HD26



Flow Rate (gpm)

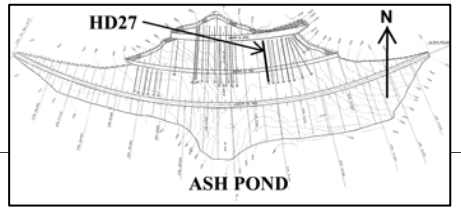
0.25
0.20
0.15
0.10
0.05
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

HD26 HD26 - 12-mo. Avg.

Ash Dike - HD27



Flow Rate (gpm)

0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022

Monitoring Date

HD27 HD27 - 12-mo. Avg.

APPENDIX IV

CALCULATIONS

Seismic Coefficient
Liquefaction Potential Analysis
Seepage and Slope Stability Analyses

OBJECTIVE:

S&ME is conducting liquefaction and slope stability analyses for the Belews Lake dam and ash dike at Belews Creek Steam Station. This calculation estimates a design dam crest acceleration and a design seismic coefficient for various pseudo-static slope stability analyses and liquefaction screening analyses.

METHOD:

In a pseudo-static analysis, the cyclic loading generated by an earthquake is simplified to one horizontal force, which is represented by a seismic coefficient. The seismic coefficient is taken as the acceleration (expressed as a fraction of gravity) of the potential failure mass. A different seismic coefficient is estimated at various depths of interest, including at bedrock; at the ground surface; at the top of the embankment; and at points along the embankment slope.

The seismic coefficient at bedrock, also called the peak horizontal ground acceleration (PHGA), is estimated by using an online interactive mapping feature developed by the United States Geologic Survey (USGS). The seismic coefficient at the ground surface, also called free-field acceleration, is then estimated by using published correlations between the PHGA and free-field acceleration. Likewise, the acceleration at the embankment crest is estimated from published correlations with the free-field acceleration, and accelerations at points of interest along the embankment slope is estimated from published correlations with the acceleration at the top of the embankment.

CALCULATIONS:

1. Estimate the seismic coefficient at bedrock (peak horizontal ground acceleration, PHGA)

The method for estimating the peak horizontal ground acceleration (PHGA) is described in paragraph 5.h.(2) of the USACE publication ER-1110-2-1806, *Earthquake Design and Evaluation for Civil Works Projects* (Reference 1). Specifically, the probabilistic seismic hazard analysis (PSHA) method, described in paragraph 5.h.(2)(b) will be used to estimate the PHGA.

The PSHA approach provides "an assessment of the likelihood that ground motions will occur during the specified time period." For the purposes of this analysis, the Maximum Design Earthquake (MDE) was considered to be the seismic event with a probability of exceedance equal to 2 percent in 50 years.

The approximate coordinates for the Belews Lake dam and ash dike were located from Google Earth imagery and averaged, as shown in the following table:

TABLE 1: AVERAGE COORDINATES

	North		West	
	Ash Dike	Main Dam	Ash Dike	Main Dam
Degrees	36	36	80	80
Minutes	17	19	4	1
Seconds	39.1	11.61	23.6	27.36
Composite	36.294	36.320	80.073	80.024
AVERAGE	**36.307**		**80.049**	

The averaged coordinates were input into an online interactive software, displaying the 2002 USGS hazard maps (Reference 2). According to the output of the online software, the peak horizontal ground acceleration (PHGA) at bedrock with a 2 percent probability of exceedance in 50 years was estimated to be approximately 0.1 times the acceleration due to gravity (0.1 g).

2. Categorize the site based on shear wave velocity

Soil test borings performed in 1969 prior to embankment construction, provided by Duke Energy, indicate that existing soils generally consist of residual and alluvial silty sands, sandy silts, and sands with N-values ranging from approximately 2 to 15 blows per foot (bpf). Historic construction documents indicate that the alluvial soils below the Ash Dike and Main Dam were excavated during embankment construction. Also, softer near-surface soils were generally excavated to residual soils having SPT N-values of 12 bpf or greater, or weathered rock, below the Ash Dike. The existing soils are generally underlain by partially weathered rock (PWR), and hard rock. According to Seed et al (Reference 3), shear wave velocity may be estimated from the following equation:

$$v_s = 220 N_{60}^{0.17} D^{0.2}$$

Where:

v_s = shear wave velocity (fps);

N_{60} = N-value measured in SPT test delivering 60% of the free-fall energy to the drill rods; and

D = depth of soil in feet.

S&ME assumed a representative subsurface stratigraphy and shear wave velocities to calculate the average shear wave velocity of the upper 30 meters of material (VS_{30}), as shown in the table below:

TABLE 2: AVERAGE SHEAR WAVE VELOCITY

Depth (feet)	Thickness (feet)	Average Depth (feet)	Stratigraphy	Description	Average N-Value	Shear Wave Velocity (ft/s)
0-15	15	7.5	Residuum	sand/silty sand/sandy silt	20	548
15-25	10	20	PWR	rock with weathered rock seams	100	876
25-35	10	30	Rock	hard rock	-	1500
35-45	10	40	Rock	hard rock	-	2000
45-100	55	72.5	Rock	hard rock	-	4000
					VS_{30} (ft/s)	**2720**
					VS_{30} (m/s)	**829**

Based on an average shear wave velocity of 829 m/s, the NEHRP site classification is “rock”, as shown in Reference 4.

3. Estimate the seismic coefficient at the ground surface (free-field acceleration)

The seismic coefficient at the ground surface was estimated using a relationship described by the Federal Highway Administration, as shown in Reference 4. As calculated in Step 2, the NEHRP site classification is “rock”, therefore the free-field acceleration is the same as the PHGA calculated in Step 1, approximately 0.1 g.

4. Estimate the seismic coefficient at the crest of the embankment

The seismic coefficient at the crest of the embankment was estimated using a relationship described by the Federal Highway Administration, as shown in Reference 4. Based on a free-field acceleration of 0.1 g, estimated in Step 3, the seismic coefficient at the top of the embankment was estimated to be 0.36 g.

5. Estimate the seismic coefficient at depths of interest along the embankment

Assuming that one meter of seismic deformation is allowable, the seismic coefficient (k) is assumed to be one half the maximum acceleration as described by Hynes and Franklin (1984) and referenced by the FHWA (Reference 4). The maximum seismic acceleration at depths of interest along the embankment was estimated using a relationship described by Makdisi and Seed (1977) as shown in Reference 5. The relationship between the depth of interest from the top of the embankment (y) and the total height of the embankment (h) versus seismic coefficient is summarized in Table 3.

TABLE 3: SEISMIC COEFFICIENT AT DEPTHS OF INTEREST

y/h	k_{max}/u_{max}	Maximum Horizontal Acceleration at Crest of Embankment $\{u_{max}\}$ (%g)	Maximum Horizontal Acceleration at Depth of Interest $\{a_{max}\}$ (%g)	Seismic Coefficient at Depth of Interest* {k} (%g)
1	0.35	0.36	0.13	0.06
0.9	0.37	0.36	0.13	0.07
0.8	0.41	0.36	0.15	0.07
0.7	0.48	0.36	0.17	0.09
0.6	0.52	0.36	0.19	0.09
0.5	0.60	0.36	0.22	0.11
0.4	0.70	0.36	0.25	0.13
0.3	0.79	0.36	0.28	0.14
0.2	0.88	0.36	0.32	0.16
0.1	0.93	0.36	0.33	0.17
0	1.00	0.36	0.36	0.18

*A seismic coefficient equal to one-half of the maxium horizontal acceleration is assumed based on an allowable embankment deformation of up to one meter.

During pseudo-static global stability analyses, the depth of interest will be assumed to be at the base of the failure slip surface.

CONCLUSIONS AND RECOMMENDATIONS:

In this analysis, seismic coefficients were calculated for use in different pseudo-static slope stability and liquefaction screening analyses. In a liquefaction analysis, the analysis will be conducted on materials encountered within the embankment and foundation soils. Therefore, the free-field acceleration seismic coefficient (0.10 g) should be used during liquefaction analyses at the toe of the embankment, and the seismic coefficients from Table 3 should be used to calculate the acceleration at different heights within the embankment to evaluate the liquefaction potential of embankment soils.

During stability analyses of the embankment, the ratio of the depth of interest corresponding with the base of the failure slip surface “y” versus the height of the embankment “h” should be used to obtain the seismic coefficient from Table 3.

REFERENCES:

1. United States Army Corps of Engineers, "Earthquake Design and Evaluation for Civil Works Projects," ER-1110-2-1806, July 31, 1995.
2. United States Geological Survey, "National Seismic Hazard Maps," 2002.
3. Seed, H. Bolton et. al., "Moduli and Damping Factors for Dynamic Analyses of Cohesionless Soils", 1986.
4. Federal Highway Administration, "Geotechnical Engineering Circular No. 3: Design Guidance: Geotechnical Earthquake Engineering for Highways: Volume 1 – Design Principles," May, 1997.
5. Makdisi, F. and H. Bolton Seed. "A Simplified Procedure for Estimating Earthquake-Induced Deformations in Dams and Embankments," August 1977.

REFERENCE 1

United States Army Corps of Engineers, "Earthquake Design and Evaluation for Civil Works Projects," ER-1110-2-1806, July 31, 1995.

which requires special expertise and substantial judgment to be effective. In many instances, the project team should augment the inhouse staff with technical experts to ensure independent review of the methodology and results, to add credibility to the results, and to ensure public acceptance of the conclusions. Such experts should be drawn from the fields of geology, seismology, and structural and geotechnical earthquake engineering. These experts may be from within the U.S. Army Corps of Engineers, other government agencies, universities, or the private sector. Technical experts should be included in the early team planning sessions to assist in identifying the scope of earthquake problems, selecting approaches and criteria, reviewing results, and selecting interim and final seismic parameters. The experts shall participate with the team in meetings and provide memoranda of concurrence and summary advice which shall be a part of the formal record of design or evaluation.

h. Standard and site-specific studies. Seismic studies should include the seismotectonic, geologic, site, geotechnical, and structural investigations required to select the design ground motions, and to determine the foundation and structural response for the earthquake events applicable at the project site. Further guidance on the design and analysis requirements are provided in Appendices B-F.

(1) Standard seismic studies are based on existing generic seismological studies, available site data and information, and simplified methods of evaluation developed for similar projects or structures. Generally, standard studies use preliminary values of the ground motions obtained from published seismic zone maps, a preliminary structural analysis, and a simplified assessment of soil liquefaction and deformation to determine if seismic loadings control the design, and to set the scope of any proposed site-specific studies. Standard methods and data in the referenced guidance are useful for preliminary and screening investigations in all seismic zones, and may be satisfactory for final design or evaluation in seismic zones 1 or 2A.

(2) Site-specific studies involve the use of actual site and structural conditions in evaluating the project hazards and the response of project features to seismic loading. Detailed field exploration and testing programs should be carefully planned and executed. Geologic studies should describe the seismotectonic province, characterize the site, and investigate all faults that can affect the site. Seismologic investigations should describe the earthquake history, earthquake recurrence relationship, and the strong motion records to be used in design or evaluation. Special emphasis should be placed on identifying all geological, seismological, and geotechnical parameters necessary to encompass the design and response of foundations and structures. Structural investigations should accurately account for all relevant factors which affect the seismic hazard at the specific site and the actual dynamic behavior of the structure, including damping and ductility of the structural systems. Geotechnical investigations should determine the types and spatial distribution of foundation and embankment maturate and the engineering properties of soil and rock. Propagation of the ground motion through the foundation and embankment, liquefaction potential of foundation and embankment soils, stability of natural and artificial slopes, and estimates of deformations should also be determined. The final results of site-specific studies are used as a basis for making design or evaluation decisions and for designing any remedial measures. Site-specific studies should be conducted for all zone 3 and 4 projects, and for zone 2A and 2B projects for which earthquake loadings control the design. There are two general approaches for conducting site-specific seismic hazard analyses, which are described below:

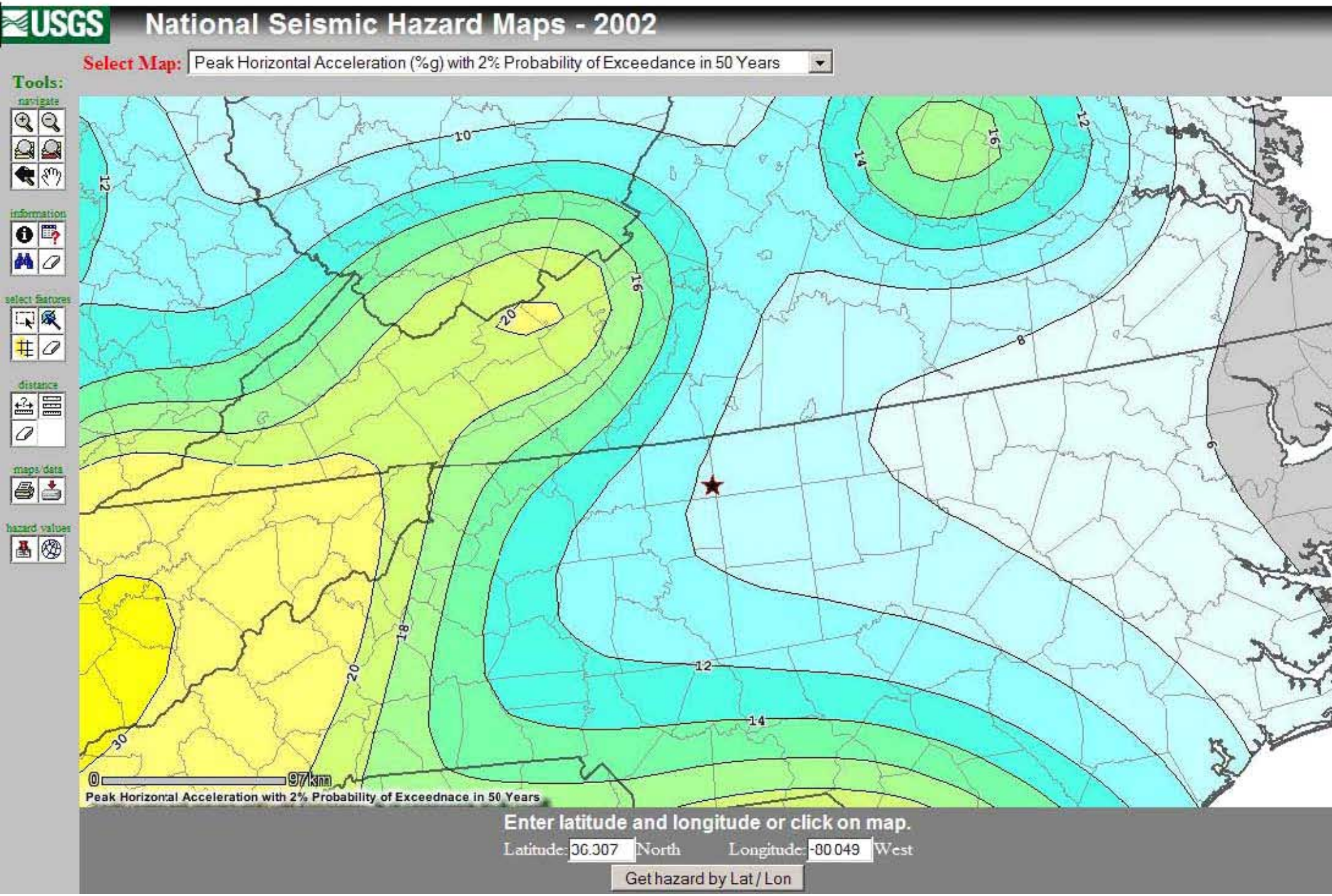
(a) Deterministic seismic hazard analysis (DSHA). The DSHA approach uses the known seismic sources sufficiently near the site and available historical seismic and geological data to generate discrete, single-valued events or models of ground motion at the site. Typically one or more earthquakes are specified by magnitude and location with respect to the site. Usually the earthquakes are assumed to occur on the portion of the source closest to the site. The site ground motions are estimated deterministically, given the magnitude, source-to-site distance, and site condition.

(b) Probabilistic seismic hazard analysis (PSHA). The PSHA approach uses the elements of the DSHA and adds an assessment of the likelihood that ground motions will occur during the specified time period. The probability or frequency of occurrence of different magnitude earthquakes on each significant seismic source and inherent uncertainties are directly accounted for in the analysis. The results of a PSHA are used to select the site ground motions based on the probability of exceedance of a given magnitude during the service life of the structure or for a given return period.

REFERENCE 2

United States Geological Survey, "National Seismic Hazard Maps,"

May 13, 2008.


USGS
National Seismic Hazard Maps - 2002
Select Map:
Peak Horizontal Acceleration (%g) with 2% Probability of Exceedance in 50 Years
Tools:
navigate
information
select features
distance
maps/data
hazard values
10
12
14
16
20
8
6
18
30
0
97km
Peak Horizontal Acceleration with 2% Probability of Exceednace in 50 Years
Enter latitude and longitude or click on map.
Latitude: 36.307 North
Longitude: -80.049 West
Get hazard by Lat / Lon

REFERENCE 3

Seed, H. Bolton et. al., "Moduli and Damping Factors for Dynamic Analyses of Cohesionless Soils", 1986.

S&ME

the soil, having a value of 1 for alluvial deposits and 1.3 for diluvial deposits; and F_2 = a factor, depending on the nature of the soil as shown in Table 2.

Thus for sands and sandy gravel deposits, the average value of F_1 is about 1.15 and the average value of F_2 is close to 1.1 so that the product of F_1F_2 is typically very close to 1.25. Converting the results to fps units and U.S. practice in the measurement of N values, Eq. 2 reduces to

$$v_s = 220N_{60}^{0.17}D^{0.2} \text{ fps} \quad \ldots\ldots (3)$$

where N_{60} = N-value measured in SPT test delivering 60% of the theoretical free-fall energy to the drill rods; and D = depth of soil in feet.

Actually, due to the small power of N_j in the original equation, the difference in SPT N-values can be neglected for all practical purposes.

$$\text{Since} \quad G_{max} = \frac{\gamma}{g} v_s^2 \quad \ldots\ldots (4)$$

Eq. 3 provides a correlation between G_{max} and SPT N-value, based on field test data as follows. Assuming γ = 120 pcf, substitution of Eq. 3 in Eq. 4 leads to

$$G_{max} = 180 \times 10^3 \cdot N_{60}^{0.34} \cdot D^{0.4} \text{ psf} \quad \ldots\ldots (5)$$

If the water table is at a relatively shallow depth below the ground surface, the effective stress at depths below 10 ft may be expressed approximately by

$$\sigma_0' \simeq 62.5D \text{ psf} \quad \ldots\ldots (6)$$

$$\text{Thus} \quad D \simeq \frac{\sigma_0'}{62.5 \text{ ft}} \quad \ldots\ldots (7)$$

Substituting Eq. 7 into Eq. 5 leads to

$$G_{max} \simeq 35 \times 1{,}000 N_{60}^{0.34} (\sigma_0')^{0.4} \text{ psf} \quad \ldots\ldots (8)$$

Noting that $N = N_1/C_N$ leads to

$$G_{max} \simeq 35 \times 1{,}000 (N_1)_{60}^{0.34} \frac{(\sigma_0')^{0.4}}{C_N^{0.34}} \text{ psf} \quad \ldots\ldots (9)$$

It can readily be shown that with a high degree of accuracy for effective stresses up to 6,000 psf

TABLE 3.—Values of $(K_2)_{max}$ for Various N_1 Values

$(N_1)_{60}$ (1)	$(K_2)_{max}$ (2)
5	34
8	40
10	43
18	52
28	61
44	71

REFERENCE 4

Federal Highway Administration, "Geotechnical Engineering Circular No. 3: Design Guidance: Geotechnical Earthquake Engineering for Highways: Volume 1 – Design Principles," May, 1997.

Amplification of the spectral acceleration may occur at soil sites in any earthquake at frequencies around the resonant frequency of the soil deposit. Some of the most significant damage in recent earthquakes (e.g., building damage in Mexico City in the 1985 earthquake and damage to freeway structures in the Loma Prieta earthquake of 1989) has occurred in situations where the predominant frequencies of the bedrock motions and the resonant frequencies of both the local soil deposit and the overlying structure all fell within the same range.

Table 3. NEHRP site classification (after Borcherdt, 1994, reprinted by permission of ATC).

NEHRP Site Classification	Average Shear Wave Velocity
Special Study[1]	Less than 100 m/s
Soft	100 to 200 m/s
Medium Stiff	200 to 375 m/s
Stiff	375 to 700 m/s
Rock	Greater than 700 m/s

Note: [1] Special study soils also include liquefiable soils, quick and highly sensitive clays, peats, highly organic clays, very high plasticity clays (PI>75), and soft soil deposits more than 37 m thick.

4.7 SELECTION OF REPRESENTATIVE TIME HISTORIES

Earthquake time histories may be required for input to both seismic site response analyses (see chapter 6) and seismic deformation analyses (see chapter 7). There are several procedures that can be used to select earthquake ground motions at a site. These procedures include:

- selection of motions previously recorded for similar site conditions during a similar earthquake and at distances comparable to those under consideration;
- selection of generic, publicly available synthetic ground motions generated to represent an event of the target magnitude;
- estimation of a *target spectrum* (a spectrum representative of the design magnitude, site-to-source distance, and local geology (soil or rock) using either an attenuation relationship or a code or standard) and then selection of recorded or synthetic time histories whose special ordinates are either comparable to or envelope those of the target spectrum for the period range of interest; or
- use of simulation techniques to generate a project-specific synthetic time history, starting from the source and propagating the appropriate wave forms to the site to

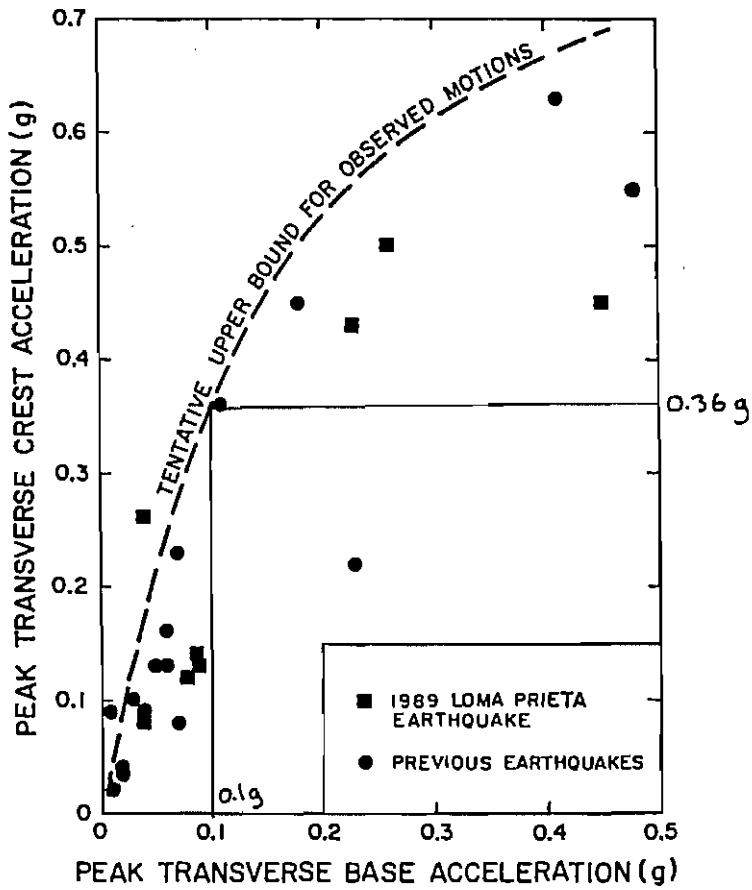


Figure 47. Comparisons of peak base and crest accelerations recorded at earth dams (Harder, 1991).

The free-field soft soil site amplification curve presented in figure 46 and the embankment response observational data presented in figure 47 may be used in a simplified three- or four-step site response analysis procedure to account for the influence of local soil conditions and earthen embankments on the peak ground acceleration at a project site. The three- or four-step procedure is as follows:

Step 1: *Classify the site*. Using table 3 (Borcherdt; 1994), classify the site as a Special Study, soft, medium stiff, stiff, or rock on the basis of the average shear wave velocity for the top 30 meters of soil.

Step 2: *Estimate the hypothetical free-field bedrock acceleration at the site.* Using one of the methods discussed in chapter 3, estimate the free-field peak ground acceleration at a hypothetical bedrock outcrop at the project site.

importance of earthquake magnitude in determining the seismic coefficient. Unfortunately, this definition provides no guidance on selection of an appropriate value for k_s, for earthquakes with peak acceleration levels less than 0.75 g.

Other investigators have attempted to relate the seismic coefficient to the peak horizontal ground acceleration without considering earthquake magnitude. Figure 51 shows the results of Newmark seismic deformation analyses performed by Hynes and Franklin (1984) using 348 strong motion records (all soil/rock conditions; $4.5 < M_w < 7.4$) and 6 synthetic records. Based upon this data and their experience with seismic response analyses of slopes and embankments, Hynes and Franklin (1984) concluded that slopes and embankments designed with a yield acceleration k_y equal to half the peak ground acceleration a_{max} (i.e., a factor of safety of 1.0 for $k_s = 0.5 \cdot a_{max}/g$) would experience permanent seismic deformations, u, of less than one meter in any earthquake, even for embankments where amplification of peak accelerations by a factor of three occurs. In the absence of amplification, or if amplification is taken into account in determining the peak acceleration, the Hynes and Franklin "upper bound" curve presented in figure 51 suggests that deformations will be less than 0.3 m for yield accelerations greater than or equal to one-half the peak acceleration for all cases. Therefore, based upon the work of Hynes and Franklin, it appears that a value of k_s equal to $0.5 \cdot k_{max}/g$ will limit permanent seismic deformations to less than 0.3 m, where k_{max} is peak horizontal average acceleration of the potential failure mass. The value of k_{max} can be estimated using the methods presented in chapter 6 of this document.

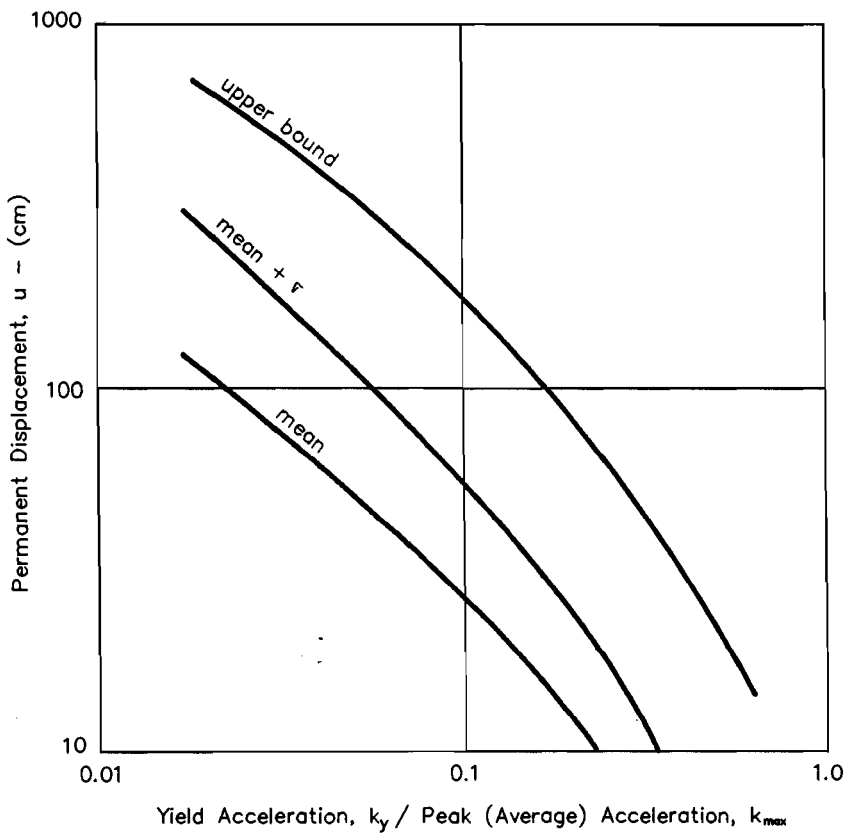


Figure 51. Permanent seismic deformation chart (Hynes and Franklin, 1984, reprinted by permission of U.S. Army Engineer Waterways Experiment Station).

REFERENCE 5

Makdisi, F. and H. Bolton Seed. "A Simplified Procedure for Estimating Earthquake-Induced Deformations in Dams and Embankments," August 1977.

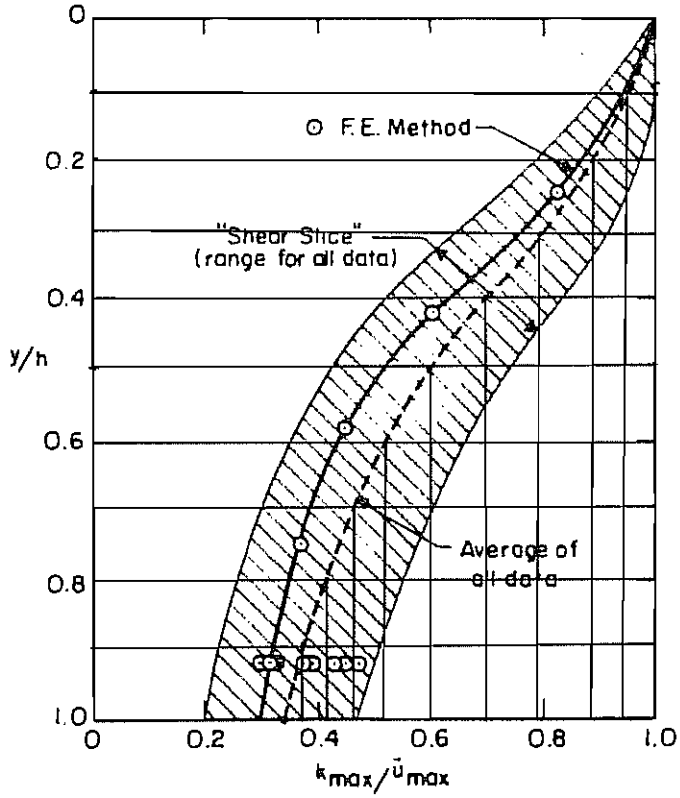


FIG. 9 VARIATION OF "MAXIMUM ACCELERATION RATIO" WITH DEPTH OF SLIDING MASS

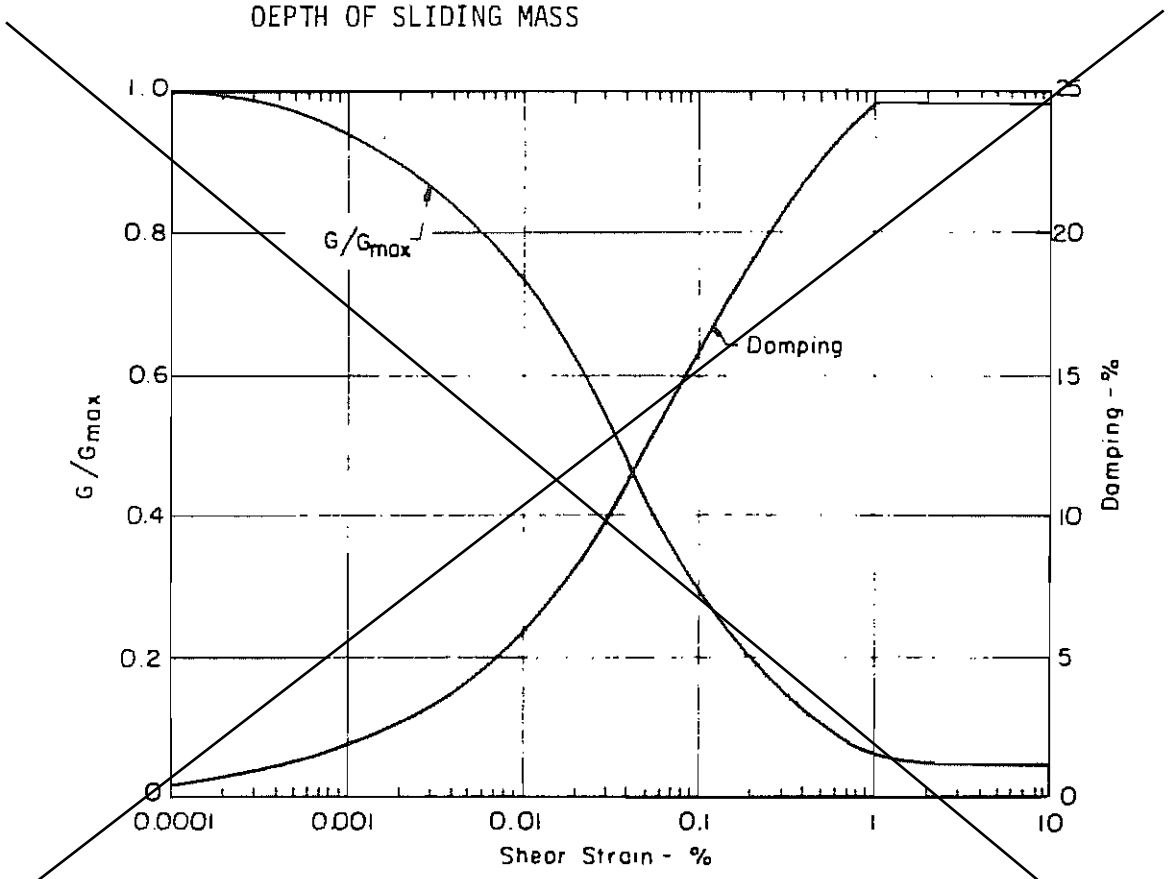


FIG. 10 SHEAR MODULUS AND DAMPING CHARACTERISTICS USED IN RESPONSE COMPUTATIONS

OBJECTIVE:

Evaluate the liquefaction potential of subgrade soils at the Belews Creek Ash Dike.

METHOD:

In order to evaluate the liquefaction potential of the dam embankment and foundation soils, the cyclic stress ratio induced by a seismic event (CSR_{EQ}) was compared to the cyclic resistance ratio (CRR) of subgrade soils developed from standard penetration test (SPT) data. The method used to evaluate liquefaction potential is in general accordance with that proposed by Youd et al. (2001) and is generally referred to as the "Simplified Method" originally proposed by Seed and included as Reference 1. The procedures outlined within these documents was coded into a spreadsheet and evaluated for various boring locations.

A total of three soil test borings performed within the embankment were evaluated for liquefaction potential as shown on the S&ME Field Test Location Plan.

Design Criteria

The design criterion of a factor of safety against liquefaction of 1.2 was used for the analysis.

Factor of Safety

The factor of safety of liquefaction was estimated using Equation 1 (Youd et al., 2001).

$$FS_{Liquefaction} = \left(\frac{CRR_{7.5}}{CSR_{EQ}}\right) * MSF * K_{\sigma} > 1.2 \qquad \text{(Equation 1)}$$

Where:

$FS_{Liquefaction}$ = factor of safety against liquefaction failure;

$CRR_{7.5}$ = cyclic resistance ratio developed from SPT data;

CSR_{EQ} = cyclic stress ratio induced by a seismic event;

MSF = magnitude scaling factor; and,

K_{σ} = overburden correction factor.

A lower-bound MSF relationship recommended by Youd et al. (2001) was used and is shown below.

$$MSF = \left(\frac{10^{2.24}}{M_w^{2.56}} \right) \quad \text{(Equation 2)}$$

Where M_w = Moment magnitude.

A moment magnitude, M_w, of 7.3 was used for the design event based on the de-aggregation plot from USGS (Reference 2).

The overburden correction factor (K_σ) was estimated with the relationship recommended by Youd et al. (2001).

$$K_\sigma = \left(\frac{\sigma_{vo}'}{P_a} \right)^{(f-1)} \quad \text{(Equation 3)}$$

Where:

σ_{vo}'= effective vertical stress (kPa);

P_a = atmospheric pressure (kPa); and,

f = ranges from 0.7-0.8 for relative densities ranging from 40% to 60% and from 0.6 to 0.7 for relative densities ranging from 60% to 80% respectively.

Evaluation of CSR_{EQ}

The cyclic stress ratio induced by a seismic event (CSR_{EQ}) was estimated using Equation 4.

$$CSR_{EQ} = 0.65 * \frac{a_{max}}{g} * r_d * \left(\frac{\sigma_{vo}}{\sigma'_{vo}} \right) \quad \text{(Equation 4)}$$

Where:

a_{max} = peak ground surface acceleration(m/s^2);

g = acceleration of gravity (m/s^2);

r_d = stress reduction factor;

σ_{vo} = total vertical stress (kPa); and

σ'_{vo}= effective vertical stress (kPa).

Evaluation of a_{max}

The peak horizontal ground acceleration (PHGA) was estimated to be 0.1g based on near surface rock conditions. The amplified maximum horizontal acceleration at the crest of embankment, U_{max}, was conservatively estimated to be 0.36g using the Harder (1991) relationship outlined in FHWA (1997). The horizontal acceleration with depth within the embankment and foundation soils was estimated by multiplying U_{max} times estimated acceleration reduction ratio, k_{max} / U_{max} from Makdisi and Seed (1977) based on estimated depths over total embankment height (y/h) ratios. A detailed discussion of the site specific peak ground acceleration is provided in the companion calculation package Seismic Coefficient.

Evaluation of r_d

Equation 5, presented within Youd et al. (2001), was used to estimate the stiffness reduction factor at varying depths, z.

$$r_d = \frac{(1.000 - 0.4113z^{0.5} + .04052z + 0.001753z^{1.5})}{(1.000 - 0.4177z^{0.5} + 0.05729z - 0.006205z^{1.5} + 0.001210z^{2})} \qquad \text{(Equation 5)}$$

Equation 5 is typically used for depths < 23 m.

Evaluation of $\left(\frac{\sigma_{vo}}{\sigma'_{vo}}\right)$

The total and effective vertical stresses used in evaluation of CSR_{EQ} were evaluated based on depth, assumed unit weight, and water table elevation.

Evaluation of CRR

The cyclic resistance ratio CRR of subgrade soils was evaluated in general accordance with the method recommended by Youd et al. (2001). This involved normalizing the measured standard penetration resistance, N_m, to a correction factors to a blow count normalized to an overburden pressure of approximately 100kPa and a hammer energy ratio of 60% $(N_1)_{60}$ by applying corrections, based on hammer energy ratio, borehole diameter, rod length, sampler type, and overburden stress. This is shown in the equations below.

$$(N_1)_{60} = N_m * C_E * C_B * C_R * C_S * C_N \quad \text{(Equation 6)}$$

Where:

$(N_1)_{60}$ = N_m normalized to an overburden pressure100kPa and a hammer energy ratio of 60%;

N_m = the measured standard penetration resistance;

C_E = correction factor for hammer energy ratio, 1.3 is used as the drill rig used an autohammer;

C_B = borehole diameter correction factor, 1.05 is used for a 6-inch diameter borehole;

C_R = correction factor for rod length, where C_R = 0.75 for rod length less than 3 meters, C_R = 0.8 for rod length between 3 and 4 meters, C_R = 0.85 for rod length between 4 and 6 meters, C_R = 0.95 for rod length between 6 and 10 meters, and C_R = 1.0 for rod length between 10 and 30 meters;

C_S = correction factor for sampler type where 1.0 is used as the drill rig used a standard sampler; and,

C_N = correction factor for overburden stress where:

$$C_N = \frac{2.2}{\left(1.2 + \frac{\sigma'_{vo}}{P_a}\right)} \quad \text{(Equation 7)}$$

Where P_a = atmospheric pressure.

Once N_m is normalized and corrected to $(N_1)_{60}$, corrections are applied based on fines content to estimate the equivalent clean sand value $(N_1)_{60cs}$. This is shown in the equations below.

$$(N_1)_{60cs} = \alpha + \beta * (N_1)_{60} \quad \text{(Equation 8)}$$

Where:

$(N_1)_{60cs}$ = clean sand equivalent value of $(N_1)_{60}$ corrected for fines content;

α and β = coefficients determined from the following relationships:

$$\alpha = 0 \quad \text{for FC} \leq 5\% \quad \text{(Equation 9)}$$

$$\alpha = e^{(1.76 - 190*(FC^2))} \quad \text{for } 5\% < \text{FC} < 35 \quad \text{(Equation 10)}$$

$$\alpha = 5.0 \quad \text{for FC} \geq 35\% \quad \text{(Equation 11)}$$

$$\beta = 1.0 \quad \text{for FC} \leq 5\% \quad \text{(Equation 12)}$$

$$\beta = \left(0.99 + \frac{FC^{1.5}}{1000}\right) \quad \text{for } 5\% < \text{FC} < 35\% \quad \text{(Equation 13)}$$

$$\beta = 1.2 \quad \text{for FC} \geq 35\% \quad \text{(Equation 14)}$$

The fines contents of the soils evaluated were estimated based on laboratory grain-size analysis results representative of the soil types encountered. The estimated fines contents were typically greater than 35 percent.

Evaluation of CSR_{EQ}

Equation 15, presented below, was used to determine the cyclic resistance ratio for magnitude 7.5 ($CRR_{7.5}$) earthquakes.

$$CSR_{EQ} = \left(\frac{1}{34 - (N_1)_{60}}\right) + \left(\frac{(N_1)_{60}}{135}\right) + \left(\frac{50}{10 * (N_1)_{60} + 45]^2}\right) + \left(\frac{1}{200}\right) \quad \text{(Equation 15)}$$

Since the soils contained fines contents, the $(N_1)_{60cs}$ values were substituted for $(N_1)_{60}$ in Equation 15. Soils with corrected $(N_1)_{60cs}$ values greater than 30 are not considered liquefiable per Youd et al (2001).

CALCULATIONS:

MS Excel was used to evaluate $FS_{Liquefaction}$ for a number of SPTs performed on the Belews Creek Ash Dike. Calculations are presented in spreadsheets attached to this calculation package.

RESULTS:

Results indicate factors of safety against liquefaction greater than 1.2 for the borings evaluated with the exception of two soil layers in Boring AD-9 from 35 to 36.5 feet and AD-12 from 1 to 2.5 feet. Boring AD-9 indicated an N_{Field} –value of 4 from 35 to 36.5 feet. This material consists of residual soils located between residual soils and PWR and can likely be attributed to sampling disturbance. Residual soils derived from parent bedrock materials in the Piedmont of which the site is a part are not considered to be liquefiable.

Analysis for Boring AD-12 from 1 to 2.5 indicated a safety factor of 1.09. This layer was above the water table and is not considered liquefiable. In general, compacted earth fills are not considered to be liquefiable, particularly based on the relatively low design acceleration for the site of 0.1 g.

DISCUSSION:

The minimum FS for data points below the water table exceeded 1.2 with the exception of Boring AD-9 from 35 to 36.5 feet. This consisted of residual soil and is not considered to be liquefiable. Therefore, liquefaction within the existing embankment is considered to be unlikely.

ATTACHMENTS:

1. Liquefaction Spreadsheets.

REFERENCES:

1. Youd et al, (2001) "Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils". ASCE Journal of Geotechnical and Geoenvironmental Engineering.
2. United States Geological Survey, "PSH Deaggregation on NEHRP BC Rock", 2008.

ATTACHMENT 1

Liquefaction Spreadsheets

SPT LIQUEFACTION POTENTIAL CALCULATION SHEET

* Areas of user input are shaded in green
* Data needed for user calculation are in red

Project Information

Date: Sep-10
Site: Belews Creek Ash Dike
Location: Walnut Cove, NC
Project No.: 1356-09-029

Boring: AD-4
GW Depth: 25.9 ft
GW Depth: 7.9 m

Quake Parameters

M_w: 7.3
MSF^1: 1.07 (lower bound)
MSF^2: 1.09 (upper bound)
a: 0.1 %g
U_{max} [10]: 0.36 %g
height (ft): 130
vertical distance to crest (ft): 50

Hammer Parameters

ER: 78 %
C_E: 1.3
C_B: 1.05
C_S: 1.0

General Parameters

γ_{soil}: 121 lb/ft^3
γ_{soil}: 19.0 kN/m^2
γ_{water}: 62.4 lb/ft^3
γ_{water}: 9.8 kN/m^2
Pa: 101.33 kPa

Liquefaction Likliehood Classification

Almost Certain to liquefy ("certain")
Very likely to liquefy ("very likely")
Liquefaction and no liquefaction are equally likely ("fifty-fifty")
Unlikely to liquefy ("unlikely")
Almost Certain that it will not liquefy ("none")

USCS	Layer top		bottom	z (ft)	z (m)	N_m	% Fines	y/h	k_{max}/U_{max} [11]	σ_{vo} (kPa)	σ'_{vo} (kPa)	r_d [3]	CSR [4]	C_N [5]	C_R [6]	$(N_1)_{60}$	$(N_1)_{60cs}$ [7]	$CRR_{7.5}$ [8]	D_r	f	K_σ	CRR (correct.)	fos	Liq? (by FOS def'n)	Liq Prob [9]	Liq Likelihood
ML	1.0	-	2.5	1.8	0.5	11	59	0.40	0.7	10.1	10.1	1.00	0.16	1.69	0.75	19	28	0.364	87	0.60	1.00	0.39	2.39	no	0.02	none
ML	3.5	-	5.0	4.3	1.3	8	59	0.42	0.7	24.6	24.6	0.99	0.16	1.52	0.75	12	20	0.215	59	0.70	1.00	0.23	1.42	no	0.12	none
ML	6.0	-	7.5	6.8	2.1	12	59	0.44	0.7	39.1	39.1	0.99	0.16	1.38	0.75	17	25	0.300	65	0.68	1.00	0.32	1.99	no	0.04	none
ML	7.5	-	9.0	8.3	2.5	8	59	0.45	0.6	47.8	47.8	0.98	0.14	1.31	0.75	11	18	0.191	50	0.75	1.00	0.20	1.48	no	0.10	none
SM	9.0	-	10.5	9.8	3.0	11	27	0.46	0.6	56.5	56.5	0.98	0.14	1.25	0.75	14	20	0.220	56	0.72	1.00	0.24	1.71	no	0.07	none
CL	10.5	-	12.0	11.3	3.4	13	59	0.47	0.6	65.2	65.2	0.98	0.14	1.19	0.80	17	25	0.297	59	0.70	1.00	0.32	2.32	no	0.02	none
ML	12.0	-	13.5	12.8	3.9	10	59	0.48	0.6	73.9	73.9	0.97	0.14	1.13	0.80	12	20	0.214	50	0.75	1.00	0.23	1.68	no	0.07	none
SM	13.5	-	15.0	14.3	4.3	13	27	0.49	0.6	82.6	82.6	0.97	0.14	1.09	0.85	16	23	0.257	56	0.72	1.00	0.28	2.02	no	0.04	none
SM	15.0	-	16.5	15.8	4.8	20	27	0.51	0.6	91.3	91.3	0.97	0.14	1.04	0.85	24	32	0.682	68	0.66	1.00	0.73	5.38	no	0.00	none
ML	16.5	-	18.0	17.3	5.3	17	59	0.52	0.6	100.0	100.0	0.96	0.14	1.00	0.85	20	29	0.395	61	0.70	1.00	0.43	3.14	no	0.01	none
SM	23.5	-	25.0	24.3	7.4	31	27	0.57	0.52	140.6	140.6	0.94	0.11	0.84	0.95	34	n/a	n/a	76	0.62	0.88	n/a	n/a	no	n/a	none
SM	28.5	-	30.0	29.3	8.9	20	27	0.61	0.52	169.6	159.6	0.92	0.12	0.79	0.95	20	28	0.355	59	0.71	0.88	0.33	2.78	no	0.01	none
SM	33.5	-	35.0	34.3	10.4	51	34	0.65	0.52	198.6	173.6	0.90	0.12	0.75	1.00	52	n/a	n/a	92	0.60	0.81	n/a	n/a	no	n/a	none
SM	38.5	-	40.0	39.3	12.0	51	34	0.69	0.48	227.6	187.6	0.86	0.12	0.72	1.00	50	n/a	n/a	90	0.60	0.78	n/a	n/a	no	n/a	none
SM	43.5	-	43.8	43.7	13.3	100	34	0.72	0.48	253.1	200.0	0.82	0.12	0.69	1.00	94	n/a	n/a	124	0.60	0.76	n/a	n/a	no	n/a	none
SM	48.5	-	48.8	48.7	14.8	100	34	0.76	0.41	282.1	214.0	0.77	0.10	0.66	1.00	90	n/a	n/a	122	0.60	0.74	n/a	n/a	no	n/a	none

SPT LIQUEFACTION POTENTIAL CALCULATION SHEET

* Areas of user input are shaded in green
* Data needed for user calculation are in red

Project Information

Date: Sep-10
Site: Belews Creek Ash Dike
Location: Walnut Cove, NC
Project No.: 1356-09-029

Quake Parameters

M_w: 7.3
MSF^1: 1.07 (lower bound)
MSF^2: 1.09 (upper bound)
a: 0.1 %g
U_{max} ^{10}: 0.36 %g
height (ft): 130
vertical distance to crest (ft): 100

Hammer Parameters

ER: 78 %
C_E: 1.3
C_B: 1.05
C_S: 1.0

General Parameters

γ_{soil}: 121 lb/ft^3
γ_{soil}: 19.0 kN/m^2
γ_{water}: 62.4 lb/ft^3
γ_{water}: 9.8 kN/m^2
Pa: 101.33 kPa

Liquefaction Likliehood Classification

Almost Certain to liquefy ("certain")
Very likely to liquefy ("very likely")
Liquefaction and no liquefaction are equally likely ("fifty-fifty")
Unlikely to liquefy ("unlikely")
Almost Certain that it will not liquefy ("none")

Boring: AD-9
GW Depth: 6.9 ft
GW Depth: 2.1 m

USCS	Layer top		Layer bottom	z (ft)	z (m)	N_m	% Fines	y/h	k_{max}/U_{max} [11]	σ_{vo} (kPa)	σ'_{vo} (kPa)	r_d [3]	CSR [4]	C_N [5]	C_R [6]	$(N_1)_{60}$	$(N_1)_{60cs}$ [7]	$CRR_{7.5}$ [8]	D_r	f	K_σ	CRR (correct.)	fos	Liq? (by FOS def'n)	Liq Prob [9]	Liq Likelihood
ML	1.0	-	2.5	1.8	0.5	15	59	0.78	0.41	10.1	10.1	1.00	0.10	1.69	0.75	26	36	n/a	101	0.60	1.00	n/a	n/a	no	n/a	none
ML	3.5	-	5.0	4.3	1.3	12	59	0.80	0.41	24.6	24.6	0.99	0.10	1.52	0.75	19	27	0.351	73	0.64	1.00	0.38	3.95	no	0.00	none
ML	8.5	-	10.0	9.3	2.8	17	59	0.84	0.41	53.6	46.6	0.98	0.11	1.32	0.75	23	33	0.940	74	0.63	1.00	1.01	9.30	no	0.00	none
ML	13.5	-	15.0	14.3	4.3	21	59	0.88	0.37	82.6	60.6	0.97	0.11	1.22	0.85	30	41	n/a	77	0.62	1.00	n/a	n/a	no	n/a	none
SM	18.5	-	20.0	19.3	5.9	11	45	0.92	0.37	111.6	74.7	0.96	0.12	1.13	0.85	14	22	0.246	53	0.74	1.00	0.26	2.13	no	0.03	none
CL	20.0	-	21.5	20.8	6.3	8	59	0.93	0.37	120.3	78.9	0.95	0.13	1.11	0.95	11	19	0.201	44	0.78	1.00	0.21	1.70	no	0.07	none
ML	21.5	-	23.0	22.3	6.8	11	59	0.94	0.37	129.0	83.1	0.95	0.13	1.08	0.95	15	24	0.266	51	0.74	1.00	0.28	2.23	no	0.03	none
SM	23.0	-	24.5	23.8	7.2	14	45	0.95	0.35	137.7	87.3	0.95	0.12	1.06	0.95	19	28	0.374	57	0.71	1.00	0.40	3.28	no	0.01	none
SM	24.5	-	26.0	25.3	7.7	15	45	0.96	0.35	146.4	91.5	0.94	0.12	1.04	0.95	20	29	0.424	58	0.71	1.00	0.45	3.69	no	0.00	none
ML	28.5	-	30.0	29.3	8.9	21	59	0.99	0.35	169.6	102.8	0.92	0.12	0.99	0.95	27	37	n/a	67	0.66	1.00	n/a	n/a	no	n/a	none
SM	33.5	-	35.0	34.3	10.4	53	45	1.03	0.35	198.6	116.8	0.90	0.12	0.93	1.00	67	n/a	n/a	103	0.60	0.94	n/a	n/a	no	n/a	none
SM	35.0	-	36.5	35.8	10.9	4	45	1.04	0.35	207.3	121.0	0.89	0.12	0.91	1.00	5	11	0.122	28	0.80	0.97	0.13	1.01	YES	0.30	unlikely
SM	36.5	-	36.9	36.7	11.2	100	45	1.05	0.35	212.8	123.7	0.88	0.12	0.90	1.00	123	n/a	n/a	140	0.60	0.92	n/a	n/a	no	n/a	none
SM	38.0	-	38.4	38.2	11.6	100	45	1.06	0.35	221.5	127.9	0.87	0.12	0.89	1.00	121	n/a	n/a	139	0.60	0.91	n/a	n/a	no	n/a	none

S&ME

SPT LIQUEFACTION POTENTIAL CALCULATION SHEET

* Areas of user input are shaded in green
* Data needed for user calculation are in red

Project Information

Date: Sep-10
Site: Belews Creek Ash Dike
Location: Walnut Cove, NC
Project No.: 1356-09-029

Boring: AD-12
GW Depth: 44.6 ft
GW Depth: 13.6 m

Quake Parameters

M_w: 7.3
MSF^1: 1.07 (lower bound)
MSF^2: 1.09 (upper bound)
a: 0.1 %g
U_{max} [10]: 0.36 %g
height (ft): 130
vertical distance to crest (ft): 0

Hammer Parameters

ER: 78 %
C_E: 1.3
C_B: 1.05
C_S: 1.0

General Parameters

γ_{soil}: 121 lb/ft^3
γ_{soil}: 19.0 kN/m^2
γ_{water}: 62.4 lb/ft^3
γ_{water}: 9.8 kN/m^2
Pa: 101.33 kPa

Liquefaction Likliehood Classification

Almost Certain to liquefy ("certain")
Very likely to liquefy ("very likely")
Liquefaction and no liquefaction are equally likely ("fifty-fifty")
Unlikely to liquefy ("unlikely")
Almost Certain that it will not liquefy ("none")

USCS	Layer top		Layer bottom	z (ft)	z (m)	N_m	% Fines	y/h	k_{max}/U_{max} [11]	σ_{vo} (kPa)	σ'_{vo} (kPa)	r_d [3]	CSR [4]	C_N [5]	C_R [6]	$(N_1)_{60}$	$(N_1)_{60cs}$ [7]	$CRR_{7.5}$ [8]	D_r	*f*	K_σ	CRR (correct.)	fos	Liq? (by FOS def'n)	Liq Prob [9]	Liq Likelihood
SM	1.0	-	2.5	1.8	0.5	8	45	0.01	1	10.1	10.1	1.00	0.23	1.69	0.75	14	22	0.237	74	0.63	1.00	0.25	1.09	no	0.26	unlikely
ML	3.5	-	5.0	4.3	1.3	16	59	0.03	1	24.6	24.6	0.99	0.23	1.52	0.75	25	35	n/a	84	0.60	1.00	n/a	n/a	no	n/a	none
SM	8.5	-	10.0	9.3	2.8	18	45	0.07	1	53.6	53.6	0.98	0.23	1.27	0.75	23	33	1.259	73	0.63	1.00	1.35	5.88	no	0.00	none
SM	13.5	-	15.0	14.3	4.3	21	45	0.11	0.93	82.6	82.6	0.97	0.21	1.09	0.85	26	37	n/a	71	0.65	1.00	n/a	n/a	no	n/a	none
SM	18.5	-	20.0	19.3	5.9	22	45	0.15	0.93	111.6	111.6	0.96	0.21	0.95	0.85	24	34	n/a	67	0.66	0.97	n/a	n/a	no	n/a	none
SM	23.5	-	25.0	24.3	7.4	32	45	0.19	0.88	140.6	140.6	0.94	0.19	0.84	0.95	35	n/a	n/a	77	0.62	0.88	n/a	n/a	no	n/a	none
SM	28.5	-	30.0	29.3	8.9	22	45	0.23	0.88	169.6	169.6	0.92	0.19	0.76	0.95	22	31	0.559	61	0.70	0.86	0.51	2.69	no	0.01	none
ML	33.5	-	35.0	34.3	10.4	18	59	0.26	0.79	198.6	198.6	0.90	0.17	0.69	1.00	17	25	0.299	53	0.74	0.84	0.27	1.62	no	0.08	none
ML	38.5	-	40.0	39.3	12.0	18	59	0.30	0.79	227.6	227.6	0.86	0.16	0.63	1.00	16	24	0.268	51	0.74	0.81	0.23	1.47	no	0.11	none
ML	43.5	-	45.0	44.3	13.5	19	59	0.34	0.79	256.5	256.5	0.81	0.15	0.58	1.00	15	23	0.260	51	0.75	0.79	0.22	1.47	no	0.11	none
ML	48.5	-	50.0	49.3	15.0	19	59	0.38	0.7	285.5	271.6	0.76	0.13	0.56	1.00	15	22	0.249	50	0.75	0.78	0.21	1.59	no	0.08	none
ML	53.5	-	55.0	54.3	16.5	22	59	0.42	0.7	314.5	285.7	0.71	0.13	0.54	1.00	16	25	0.283	53	0.73	0.76	0.23	1.80	no	0.06	none
ML	58.5	-	60.0	59.3	18.1	21	59	0.46	0.6	343.5	299.7	0.67	0.11	0.52	1.00	15	23	0.257	51	0.74	0.76	0.21	1.95	no	0.04	none
ML	63.5	-	65.0	64.3	19.6	20	59	0.49	0.6	372.5	313.7	0.63	0.10	0.51	1.00	14	22	0.237	50	0.75	0.76	0.19	1.83	no	0.05	none
ML	68.5	-	70.0	69.3	21.1	21	59	0.53	0.6	401.5	327.8	0.60	0.10	0.49	1.00	14	22	0.241	50	0.75	0.74	0.19	1.87	no	0.05	none
ML	73.5	-	75.0	74.3	22.6	32	59	0.57	0.52	430.5	341.8	0.57	0.09	0.48	1.00	21	30	0.466	61	0.69	0.69	0.34	3.92	no	0.00	none
SM	78.5	-	80.0	79.3	24.2	32	45	0.61	0.52	459.5	355.9	0.55	0.09	0.46	1.00	20	29	0.422	61	0.70	0.68	0.31	3.56	no	0.01	none
SM	83.5	-	85.0	84.3	25.7	33	45	0.65	0.48	488.5	369.9	0.53	0.08	0.45	1.00	20	29	0.424	61	0.69	0.67	0.31	3.85	no	0.00	none
SM	88.5	-	90.0	89.3	27.2	23	45	0.69	0.48	517.4	383.9	0.52	0.08	0.44	1.00	14	21	0.234	51	0.75	0.71	0.18	2.27	no	0.03	none
ML	93.5	-	95.0	94.3	28.7	9	59	0.73	0.48	546.4	398.0	0.51	0.08	0.42	1.00	5	11	0.124	31	0.80	0.76	0.10	1.29	no	0.16	unlikely
SM	98.5	-	98.9	98.7	30.1	100	45	0.76	0.41	572.2	410.5	0.50	0.07	0.41	1.00	57	n/a	n/a	104	0.60	0.57	n/a	n/a	no	n/a	none
SM	103.5	-	103.9	103.7	31.6	100	45	0.80	0.41	601.2	424.5	0.49	0.07	0.40	1.00	55	n/a	n/a	103	0.60	0.56	n/a	n/a	no	n/a	none

REFERENCE 1

Youd et al, (2001) "Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils". ASCE Journal of Geotechnical and Geoenvironmental Engineering.

S&ME

Preface

Evaluation of soil liquefaction resistance is an important aspect of geotechnical engineering practice. To update and enhance criteria that are routinely applied in practice, workshops were convened in 1996 and 1998 to gain consensus from 20 experts on updates and augmentations that should be made to standard procedures that have evolved over the past 30 years. At the outset, the goal was to develop this state-of-the-art summary of consensus recommendations. A commitment was also made to those who participated in the workshops that all would be listed as co-authors. Unfortunately, the previous publication of this summary paper (April 2001) listed only the co-chairs of the workshop, Profs. Youd and Idriss, as authors; the remaining workshop participants were acknowledged in a footnote. In order to correct this error and to fully acknowledge and credit those who significantly contributed to the work, this paper is being republished in its entirety, at the request of the journal's editors, with all the participants named as co-authors. All further reference to this paper should be to this republication. The previous publication should no longer be cited. Also, several minor errors are corrected in this republication.

LIQUEFACTION RESISTANCE OF SOILS: SUMMARY REPORT FROM THE 1996 NCEER AND 1998 NCEER/NSF WORKSHOPS ON EVALUATION OF LIQUEFACTION RESISTANCE OF SOILS[a]

By T. L. Youd,[1] Chair, Member, ASCE, I. M. Idriss,[2] Co-Chair, Fellow, ASCE, Ronald D. Andrus,[3] Ignacio Arango,[4] Gonzalo Castro,[5] John T. Christian,[6] Richardo Dobry,[7] W. D. Liam Finn,[8] Leslie F. Harder Jr.,[9] Mary Ellen Hynes,[10] Kenji Ishihara,[11] Joseph P. Koester,[12] Sam S. C. Liao,[13] William F. Marcuson III,[14] Geoffrey R. Martin,[15] James K. Mitchell,[16] Yoshiharu Moriwaki,[17] Maurice S. Power,[18] Peter K. Robertson,[19] Raymond B. Seed,[20] and Kenneth H. Stokoe II[21]

ABSTRACT: Following disastrous earthquakes in Alaska and in Niigata, Japan in 1964, Professors H. B. Seed and I. M. Idriss developed and published a methodology termed the ''simplified procedure'' for evaluating liquefaction resistance of soils. This procedure has become a standard of practice throughout North America and much of the world. The methodology which is largely empirical, has evolved over years, primarily through summary papers by H. B. Seed and his colleagues. No general review or update of the procedure has occurred, however, since 1985, the time of the last major paper by Professor Seed and a report from a National Research Council workshop on liquefaction of soils. In 1996 a workshop sponsored by the National Center for Earthquake Engineering Research (NCEER) was convened by Professors T. L. Youd and I. M. Idriss with 20 experts to review developments over the previous 10 years. The purpose was to gain consensus on updates and augmentations to the simplified procedure. The following topics were reviewed and recommendations developed: (1) criteria based on standard penetration tests; (2) criteria based on cone penetration tests; (3) criteria based on shear-wave velocity measurements; (4) use of the Becker penetration test for gravelly soil; (4) magnitude scaling factors; (5) correction factors for overburden pressures and sloping ground; and (6) input values for earthquake magnitude and peak acceleration. Probabilistic and seismic energy analyses were reviewed but no recommendations were formulated.

[a]This Summary Report, originally published in April 2001, is being republished so that the contribution of all workshop participants as authors can be officially recognized. The original version listed only two authors, plus a list of 19 workshop participants. This was incorrect; all 21 individuals should have been identified as authors. ASCE deeply regrets the error.

[1]Prof., Brigham Young Univ., Provo, UT 84602.
[2]Prof., Univ. of California at Davis, Davis, CA 95616.
[3]Prof., Clemson Univ., Clemson, SC 29634-0911; formerly, Nat. Inst. of Standards and Technol., Gaithersburg, MD.
[4]Bechtel Corp., San Francisco, CA 94119-3965.
[5]PhD, GEI Consultants, Inc., Winchester, MA 01890.
[6]PhD, Engrg. Consultant, Waban, MA 02468-1103.
[7]Prof., Rensselaer Polytechnic Inst., Troy, NY 12180.
[8]Prof., Univ. of British Columbia, Vancouver, BC, Canada.
[9]California Dept. of Water Resour., Sacramento, CA 94236-0001.
[10]U.S. Army Engr. Wtrwy. Experiment Station, Vicksburg, MS 39180.
[11]Prof., Sci. Univ. of Tokyo, Tokyo, Japan.
[12]U.S. Army Engr. Wtrwy. Experiment Station, Vicksburg, MS 39180.
[13]Parsons Brinckerhoff, Boston, MA 02116.
[14]PhD, U.S. Army Engr. Wtrwy. Experiment Station, Vicksburg, MS 39180.
[15]Prof., Univ. of Southern California, Los Angeles, CA 90089-2531.
[16]Prof., Virginia Polytechnic Inst., Blacksburg, VA 24061.
[17]PhD, Prin., Geomatrix Consultants, Santa Ana, CA 94612.
[18]Geomatrix Consultants, Oakland, CA 94612.
[19]Prof., Univ. of Alberta, Edmonton, Alberta, Canada.
[20]Prof., Univ. of California, Berkeley, CA 94720.
[21]Prof., Univ. of Texas at Austin, Austin, TX 78712.

Note. Discussion open until March 1, 2002. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on January 18, 2000; revised November 14, 2000. This paper is part of the ***Journal of Geotechnical and Geoenvironmental Engineering***, Vol. 127, No. 10, October, 2001. ©ASCE, ISSN 1090-0241/01/0010-0817–0833/$8.00 + $.50 per page. Paper No. 22223.

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

INTRODUCTION

Over the past 25 years a methodology termed the ''simplified procedure'' has evolved as a standard of practice for evaluating the liquefaction resistance of soils. Following disastrous earthquakes in Alaska and in Niigata, Japan in 1964, Seed and Idriss (1971) developed and published the basic ''simplified procedure.'' That procedure has been modified and improved periodically since that time, primarily through landmark papers by Seed (1979), Seed and Idriss (1982), and Seed et al. (1985). In 1985, Professor Robert V. Whitman convened a workshop on behalf of the National Research Council (NRC) in which 36 experts and observers thoroughly reviewed the state-of-knowledge and the state-of-the-art for assessing liquefaction hazard. That workshop produced a report (NRC 1985) that has become a widely used standard and reference for liquefaction hazard assessment. In January 1996, T. L. Youd and I. M. Idriss convened a workshop of 20 experts to update the simplified procedure and incorporate research findings from the previous decade. This paper summarizes recommendations from that workshop (Youd and Idriss 1997).

To keep the workshop focused, the scope of the workshop was limited to procedures for evaluating liquefaction resistance of soils under level to gently sloping ground. In this context, liquefaction refers to the phenomena of seismic generation of large pore-water pressures and consequent softening of granular soils. Important postliquefaction phenomena, such as residual shear strength, soil deformation, and ground failure, were beyond the scope of the workshop.

The simplified procedure was developed from empirical evaluations of field observations and field and laboratory test data. Field evidence of liquefaction generally consisted of surficial observations of sand boils, ground fissures, or lateral spreads. Data were collected mostly from sites on level to gently sloping terrain, underlain by Holocene alluvial or fluvial sediment at shallow depths (<15 m). The original procedure was verified for, and is applicable only to, these site conditions. Similar restrictions apply to the implementation of the updated procedures recommended in this report.

Liquefaction is defined as the transformation of a granular material from a solid to a liquefied state as a consequence of increased pore-water pressure and reduced effective stress (Marcuson 1978). Increased pore-water pressure is induced by the tendency of granular materials to compact when subjected to cyclic shear deformations. The change of state occurs most readily in loose to moderately dense granular soils with poor drainage, such as silty sands or sands and gravels capped by or containing seams of impermeable sediment. As liquefaction occurs, the soil stratum softens, allowing large cyclic deformations to occur. In loose materials, the softening is also accompanied by a loss of shear strength that may lead to large shear deformations or even flow failure under moderate to high shear stresses, such as beneath a foundation or sloping ground. In moderately dense to dense materials, liquefaction leads to transient softening and increased cyclic shear strains, but a tendency to dilate during shear inhibits major strength loss and large ground deformations. A condition of cyclic mobility or cyclic liquefaction may develop following liquefaction of moderately dense granular materials. Beneath gently sloping to flat ground, liquefaction may lead to ground oscillation or lateral spread as a consequence of either flow deformation or cyclic mobility. Loose soils also compact during liquefaction and reconsolidation, leading to ground settlement. Sand boils may also erupt as excess pore water pressures dissipate.

CYCLIC STRESS RATIO (CSR) AND CYCLIC RESISTANCE RATIO (CRR)

Calculation, or estimation, of two variables is required for evaluation of liquefaction resistance of soils: (1) the seismic demand on a soil layer, expressed in terms of CSR; and (2) the capacity of the soil to resist liquefaction, expressed in terms of CRR. The latter variable has been termed the cyclic stress ratio or the cyclic stress ratio required to generate liquefaction, and has been given different symbols by different writers. For example, Seed and Harder (1990) used the symbol CSR_ℓ, Youd (1993) used the symbol CSRL, and Kramer (1996) used the symbol CSR_L to denote this ratio. To reduce confusion and to better distinguish induced cyclic shear stresses from mobilized liquefaction resistance, the capacity of a soil to resist liquefaction is termed the CRR in this report. This term is recommended for engineering practice.

EVALUATION OF CSR

Seed and Idriss (1971) formulated the following equation for calculation of the cyclic stress ratio:

$$\text{CSR} = (\tau_{av}/\sigma'_{vo}) = 0.65(a_{max}/g)(\sigma_{vo}/\sigma'_{vo})r_d \quad (1)$$

where a_{max} = peak horizontal acceleration at the ground surface generated by the earthquake (discussed later); g = acceleration of gravity; σ_{vo} and σ'_{vo} are total and effective vertical overburden stresses, respectively; and r_d = stress reduction coefficient. The latter coefficient accounts for flexibility of the soil profile. The workshop participants recommend the following minor modification to the procedure for calculation of CSR.

For routine practice and noncritical projects, the following equations may be used to estimate average values of r_d (Liao and Whitman 1986b):

$$r_d = 1.0 - 0.00765z \quad \text{for } z \le 9.15 \text{ m} \quad (2a)$$

$$r_d = 1.174 - 0.0267z \quad \text{for } 9.15 \text{ m} < z \le 23 \text{ m} \quad (2b)$$

where z = depth below ground surface in meters. Some investigators have suggested additional equations for estimating r_d at greater depths (Robertson and Wride 1998), but evaluation of liquefaction at these greater depths is beyond the depths where the simplified procedure is verified and where routine applications should be applied. Mean values of r_d calculated from (2) are plotted in Fig. 1, along with the mean and range of values proposed by Seed and Idriss (1971). The workshop participants agreed that for convenience in programming spreadsheets and other electronic aids, and to be consistent with past practice, r_d values determined from (2) are suitable for use in routine engineering practice. The user should understand, however, that there is considerable variability in the

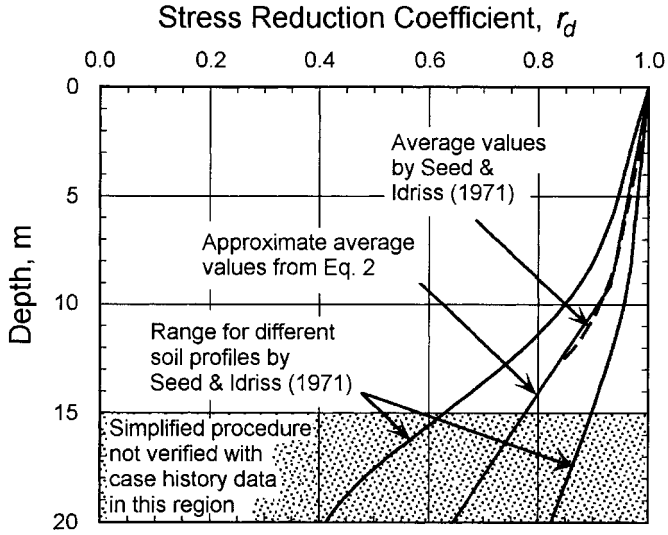


FIG. 1. r_d versus Depth Curves Developed by Seed and Idriss (1971) with Added Mean-Value Lines Plotted from Eq. (2)

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

flexibility and thus r_d at field sites, that r_d calculated from (2) are the mean of a wide range of possible r_d, and that the range of r_d increases with depth (Golesorkhi 1989).

For ease of computation, T. F. Blake (personal communication, 1996) approximated the mean curve plotted in Fig. 1 by the following equation:

$$r_d = \frac{(1.000 - 0.4113z^{0.5} + 0.04052z + 0.001753z^{1.5})}{(1.000 - 0.4177z^{0.5} + 0.05729z - 0.006205z^{1.5} + 0.001210z^2)} \quad (3)$$

where z = depth beneath ground surface in meters. Eq. (3) yields essentially the same values for r_d as (2), but is easier to program and may be used in routine engineering practice.

I. M. Idriss [Transportation Research Board (TRB) (1999)] suggested a new procedure for determining magnitude-dependent values of r_d. Application of these r_d require use of a corresponding set of magnitude scaling factors that are compatible with the new r_d. Because these r_d were developed after the workshop and have not been independently evaluated by other experts, the workshop participants chose not to recommend the new factors at this time.

EVALUATION OF LIQUEFACTION RESISTANCE (CRR)

A major focus of the workshop was on procedures for evaluating liquefaction resistance. A plausible method for evaluating CRR is to retrieve and test undisturbed soil specimens in the laboratory. Unfortunately, in situ stress states generally cannot be reestablished in the laboratory, and specimens of granular soils retrieved with typical drilling and sampling techniques are too disturbed to yield meaningful results. Only through specialized sampling techniques, such as ground freezing, can sufficiently undisturbed specimens be obtained. The cost of such procedures is generally prohibitive for all but the most critical projects. To avoid the difficulties associated with sampling and laboratory testing, field tests have become the state-of-practice for routine liquefaction investigations.

Several field tests have gained common usage for evaluation of liquefaction resistance, including the standard penetration test (SPT), the cone penetration test (CPT), shear-wave velocity measurements (V_s), and the Becker penetration test (BPT). These tests were discussed at the workshop, along with associated criteria for evaluating liquefaction resistance. The participants made a conscientious attempt to correlate liquefaction resistance criteria from each of the various field tests to provide generally consistent results, no matter which test is applied. SPTs and CPTs are generally preferred because of the more extensive databases and past experience, but the other tests may be applied at sites underlain by gravelly sediment or where access by large equipment is limited. Primary advantages and disadvantages of each test are listed in Table 1.

SPT

Criteria for evaluation of liquefaction resistance based on the SPT have been rather robust over the years. Those criteria are largely embodied in the CSR versus $(N_1)_{60}$ plot reproduced in Fig. 2. $(N_1)_{60}$ is the SPT blow count normalized to an overburden pressure of approximately 100 kPa (1 ton/sq ft) and a hammer energy ratio or hammer efficiency of 60%. The normalization factors for these corrections are discussed in the section entitled Other Corrections. Fig. 2 is a graph of calculated CSR and corresponding $(N_1)_{60}$ data from sites where liquefaction effects were or were not observed following past earthquakes with magnitudes of approximately 7.5. CRR curves on this graph were conservatively positioned to separate regions with data indicative of liquefaction from regions with data indicative of nonliquefaction. Curves were developed for granular soils with the fines contents of 5% or less, 15%, and 35% as shown on the plot. The CRR curve for fines contents <5% is the basic penetration criterion for the simplified procedure and is referred to hereafter as the ''SPT clean-sand base curve.'' The CRR curves in Fig. 2 are valid only for magnitude 7.5 earthquakes. Scaling factors to adjust CRR curves to other magnitudes are addressed in a later section of this report.

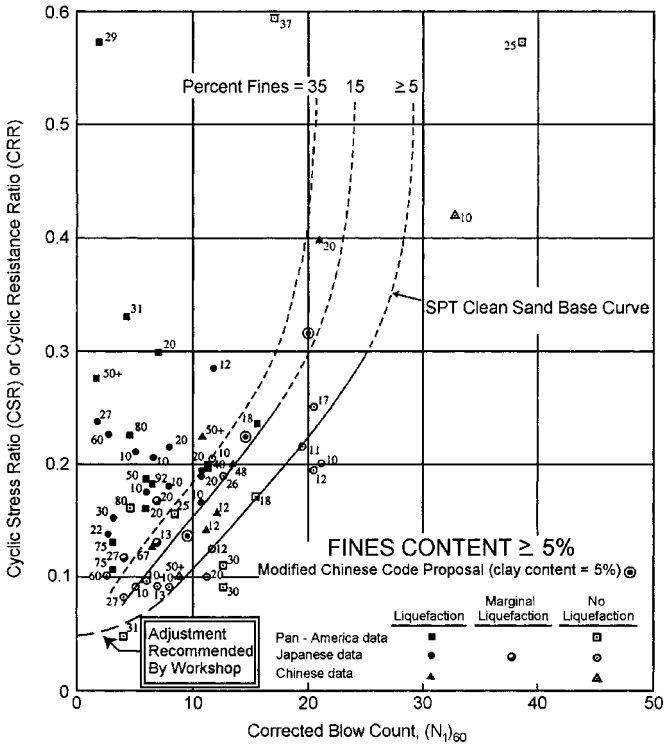


FIG. 2. SPT Clean-Sand Base Curve for Magnitude 7.5 Earthquakes with Data from Liquefaction Case Histories (Modified from Seed et al. 1985)

SPT Clean-Sand Base Curve

Several changes to the SPT criteria are recommended by the workshop participants. The first change is to curve the trajec-

TABLE 1. Comparison of Advantages and Disadvantages of Various Field Tests for Assessment of Liquefaction Resistance

Feature	Test Type			
	SPT	CPT	V_s	BPT
Past measurements at liquefaction sites	Abundant	Abundant	Limited	Sparse
Type of stress-strain behavior influencing test	Partially drained, large strain	Drained, large strain	Small strain	Partially drained, large strain
Quality control and repeatability	Poor to good	Very good	Good	Poor
Detection of variability of soil deposits	Good for closely spaced tests	Very good	Fair	Fair
Soil types in which test is recommended	Nongravel	Nongravel	All	Primarily gravel
Soil sample retrieved	Yes	No	No	No
Test measures index or engineering property	Index	Index	Engineering	Index

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

tory of the clean-sand base curve at low $(N_1)_{60}$ to a projected intercept of about 0.05 (Fig. 2). This adjustment reshapes the clean-sand base curve to achieve greater consistency with CRR curves developed for the CPT and shear-wave velocity procedures. Seed and Idriss (1982) projected the original curve through the origin, but there were few data to constrain the curve in the lower part of the plot. A better fit to the present empirical data is to bow the lower end of the base curve as indicated in Fig. 2.

At the University of Texas, A. F. Rauch (personal communication, 1998), approximated the clean-sand base curve plotted in Fig. 2 by the following equation:

$$\mathrm{CRR}_{7.5} = \frac{1}{34 - (N_1)_{60}} + \frac{(N_1)_{60}}{135} + \frac{50}{[10 \cdot (N_1)_{60} + 45]^2} - \frac{1}{200} \quad (4)$$

This equation is valid for $(N_1)_{60} < 30$. For $(N_1)_{60} \geq 30$, clean granular soils are too dense to liquefy and are classed as nonliquefiable. This equation may be used in spreadsheets and other analytical techniques to approximate the clean-sand base curve for routine engineering calculations.

Influence of Fines Content

In the original development, Seed et al. (1985) noted an apparent increase of CRR with increased fines content. Whether this increase is caused by an increase of liquefaction resistance or a decrease of penetration resistance is not clear. Based on the empirical data available, Seed et al. developed CRR curves for various fines contents reproduced in Fig. 2. A revised correction for fines content was developed by workshop attendees to better fit the empirical database and to better support computations with spreadsheets and other electronic computational aids.

The workshop participants recommend (5) and (6) as approximate corrections for the influence of fines content (FC) on CRR. Other grain characteristics, such as soil plasticity, may affect liquefaction resistance as well as fines content, but widely accepted corrections for these factors have not been developed. Hence corrections based solely on fines content should be used with engineering judgment and caution. The following equations were developed by I. M. Idriss with the assistance of R. B. Seed for correction of $(N_1)_{60}$ to an equivalent clean sand value, $(N_1)_{60cs}$:

$$(N_1)_{60cs} = \alpha + \beta(N_1)_{60} \quad (5)$$

where α and β = coefficients determined from the following relationships:

$$\alpha = 0 \quad \text{for FC} \leq 5\% \quad (6a)$$

$$\alpha = \exp[1.76 - (190/\mathrm{FC}^2)] \quad \text{for } 5\% < \mathrm{FC} < 35\% \quad (6b)$$

$$\alpha = 5.0 \quad \text{for FC} \geq 35\% \quad (6c)$$

$$\beta = 1.0 \quad \text{for FC} \leq 5\% \quad (7a)$$

$$\beta = [0.99 + (\mathrm{FC}^{1.5}/1{,}000)] \quad \text{for } 5\% < \mathrm{FC} < 35\% \quad (7b)$$

$$\beta = 1.2 \quad \text{for FC} \geq 35\% \quad (7c)$$

These equations may be used for routine liquefaction resistance calculations. A back-calculated curve for a fines content of 35% is essentially congruent with the 35% curve plotted in Fig. 2. The back-calculated curve for a fines contents of 15% plots to the right of the original 15% curve.

Other Corrections

Several factors in addition to fines content and grain characteristics influence SPT results, as noted in Table 2. Eq. (8) incorporates these corrections

TABLE 2. Corrections to SPT (Modified from Skempton 1986) as Listed by Robertson and Wride (1998)

Factor	Equipment variable	Term	Correction
Overburden pressure	—	C_N	$(P_a/\sigma'_{vo})^{0.5}$
Overburden pressure	—	C_N	$C_N \leq 1.7$
Energy ratio	Donut hammer	C_E	0.5–1.0
Energy ratio	Safety hammer	C_E	0.7–1.2
Energy ratio	Automatic-trip Donut-type hammer	C_E	0.8–1.3
Borehole diameter	65–115 mm	C_B	1.0
Borehole diameter	150 mm	C_B	1.05
Borehole diameter	200 mm	C_B	1.15
Rod length	<3 m	C_R	0.75
Rod length	3–4 m	C_R	0.8
Rod length	4–6 m	C_R	0.85
Rod length	6–10 m	C_R	0.95
Rod length	10–30 m	C_R	1.0
Sampling method	Standard sampler	C_S	1.0
Sampling method	Sampler without liners	C_S	1.1–1.3

$$(N_1)_{60} = N_m C_N C_E C_B C_R C_S \quad (8)$$

where N_m = measured standard penetration resistance; C_N = factor to normalize N_m to a common reference effective overburden stress; C_E = correction for hammer energy ratio (ER); C_B = correction factor for borehole diameter; C_R = correction factor for rod length; and C_S = correction for samplers with or without liners.

Because SPT *N*-values increase with increasing effective overburden stress, an overburden stress correction factor is applied (Seed and Idriss 1982). This factor is commonly calculated from the following equation (Liao and Whitman 1986a):

$$C_N = (P_a/\sigma'_{\mathrm{vo}})^{0.5} \quad (9)$$

where C_N normalizes N_m to an effective overburden pressure σ'_{vo} of approximately 100 kPa (1 atm) P_a. C_N should not exceed a value of 1.7 [A maximum value of 2.0 was published in the National Center for Earthquake Engineering Research (NCEER) workshop proceedings (Youd and Idriss 1997), but later was reduced to 1.7 by consensus of the workshop participants] Kayen et al. (1992) suggested the following equation, which limits the maximum C_N value to 1.7, and in these writers' opinion, provides a better fit to the original curve specified by Seed and Idriss (1982):

$$C_N = 2.2/(1.2 + \sigma'_{\mathrm{vo}}/P_a) \quad (10)$$

Either equation may be used for routine engineering applications.

The effective overburden pressure σ'_{vo} applied in (9) and (10) should be the overburden pressure at the time of drilling and testing. Although a higher ground-water level might be used for conservatism in the liquefaction resistance calculations, the C_N factor must be based on the stresses present at the time of the testing.

The C_N correction factor was derived from SPT performed in test bins with large sand specimens subjected to various confining pressures (Gibbs and Holtz 1957; Marcuson and Bieganousky 1997a,b). The results of several of these tests are reproduced in Fig. 3 in the form of C_N curves versus effective overburden stress (Castro 1995). These curves indicate considerable scatter of results with no apparent correlation of C_N with soil type or gradation. The curves from looser sands, however, lie in the lower part of the C_N range and are reasonably approximated by (9) and (10) for low effective overburden pressures [200 kPa (<2 tsf)]. The workshop participants endorsed the use of (9) for calculation of C_N, but acknowledged that for overburden pressures >200 kPa (2 tsf) the results are uncertain. Eq. (10) provides a better fit for overburden

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

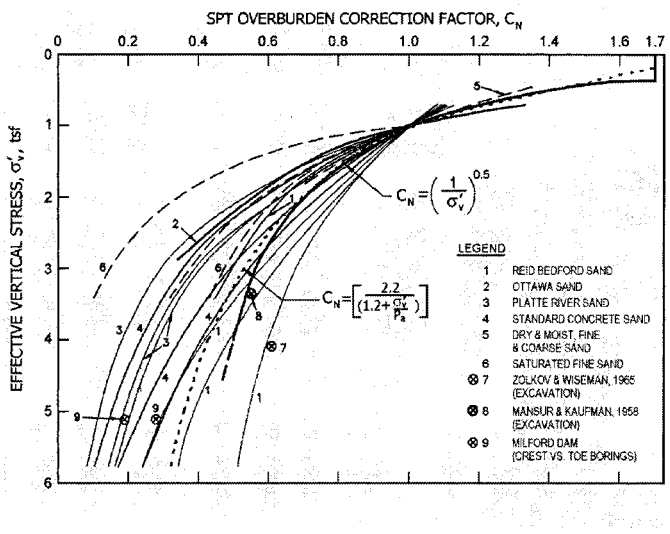


FIG. 3. C_N Curves for Various Sands Based on Field and Laboratory Test Data along with Suggested C_N Curve Determined from Eqs. (9) and (10) (Modified from Castro 1995)

pressures up to 300 kPa (3 tsf). For pressures >300 kPa (3 tsf), the uncertainty is so great that (9) should not be applied. At these high pressures, which are generally below the depth for which the simplified procedure has been verified, C_N should be estimated by other means.

Another important factor is the energy transferred from the falling hammer to the SPT sampler. An ER of 60% is generally accepted as the approximate average for U.S. testing practice and as a reference value for energy corrections. The ER delivered to the sampler depends on the type of hammer, anvil, lifting mechanism, and the method of hammer release. Approximate correction factors (C_E = ER/60) to modify the SPT results to a 60% energy ratio for various types of hammers and anvils are listed in Table 2. Because of variations in drilling and testing equipment and differences in testing procedures, a rather wide range in the energy correction factor C_E has been observed as noted in the table. Even when procedures are carefully monitored to conform to established standards, such as ASTM D 1586-99, some variation in C_E may occur because of minor variations in testing procedures. Measured energies at a single site indicate that variations in energy ratio between blows or between tests in a single borehole typically vary by as much as 10%. The workshop participants recommend measurement of the hammer energy frequently at each site where the SPT is used. Where measurements cannot be made, careful observation and notation of the equipment and procedures are required to estimate a C_E value for use in liquefaction resistance calculations. Use of good-quality testing equipment and carefully controlled testing procedures conforming to ASTM D 1586-99 will generally yield more consistent energy ratios and C_E with values from the upper parts of the ranges listed in Table 2.

Skempton (1986) suggested and Robertson and Wride (1998) updated correction factors for rod lengths <10 m, borehole diameters outside the recommended interval (65–125 mm), and sampling tubes without liners. Range for these correction factors are listed in Table 2. For liquefaction resistance calculations and rod lengths <3 m, a C_R of 0.75 should be applied as was done by Seed et al. (1985) in formulating the simplified procedure. Although application of rod-length correction factors listed in Table 2 will give more precise $(N_1)_{60}$ values, these corrections may be neglected for liquefaction resistance calculations for rod lengths between 3 and 10 m because rod-length corrections were not applied to SPT test data from these depths in compiling the original liquefaction case history databases. Thus rod-length corrections are implicitly incorporated into the empirical SPT procedure.

A final change recommended by workshop participants is the use of revised magnitude scaling factors rather than the original Seed and Idriss (1982) factors to adjust CRR for earthquake magnitudes other than 7.5. Magnitude scaling factors are addressed later in this report.

CPT

A primary advantage of the CPT is that a nearly continuous profile of penetration resistance is developed for stratigraphic interpretation. The CPT results are generally more consistent and repeatable than results from other penetration tests listed in Table 1. The continuous profile also allows a more detailed definition of soil layers than the other tools listed in the table. This stratigraphic capability makes the CPT particularly advantageous for developing liquefaction-resistance profiles. Interpretations based on the CPT, however, must be verified with a few well-placed boreholes preferably with standard penetration tests, to confirm soil types and further verify liquefaction-resistance interpretations.

Fig. 4 provides curves prepared by Robertson and Wride (1998) for direct determination of CRR for clean sands (FC $\leq$ 5%) from CPT data. This figure was developed from CPT case history data compiled from several investigations, including those by Stark and Olson (1995) and Suzuki et al. (1995). The chart, valid for magnitude 7.5 earthquakes only, shows calculated cyclic resistance ratio plotted as a function of dimensionless, corrected, and normalized CPT resistance q_{c1N} from sites where surface effects of liquefaction were or were not observed following past earthquakes. The CRR curve conservatively separates regions of the plot with data indicative of liquefaction from regions indicative of nonliquefaction.

Based on a few misclassified case histories from the 1989 Loma Prieta earthquake, I. M. Idriss suggested that the clean sand curve in Fig. 4 should be shifted to the right by 10–15%. However, a majority of workshop participants supported a curve in its present position, for three reasons. First, a purpose of the workshop was to recommend criteria that yield roughly equivalent CRR for the field tests listed in Table 1. Shifting the base curve to the right makes the CPT criteria generally more conservative. For example, for $(N_1)_{60} > 5$, q_{c1N}:$(N_1)_{60}$ ra-

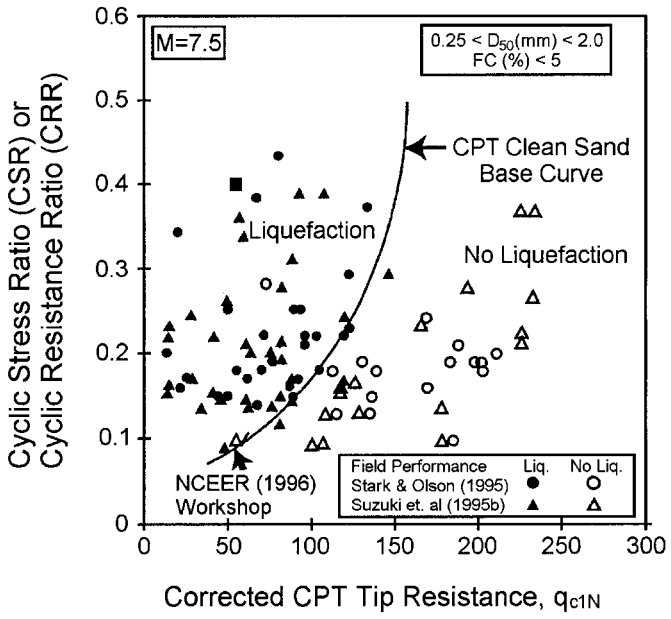


FIG. 4. Curve Recommended for Calculation of CRR from CPT Data along with Empirical Liquefaction Data from Compiled Case Histories (Reproduced from Robertson and Wride 1998)

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

tios between the two clean-sand base curves, plotted in Figs. 4 and 2, respectively, range from 5 to 8—values that are slightly higher than those expected for clean sands. Shifting the CPT base curve to the right by 10 to 15% would increase those ratios to unusually high values ranging from 6 to 9. Second, base curves, such as those plotted in Figs. 2 and 4, were intended to be conservative, but not necessarily to encompass every data point on the plot. Thus the presence of a few points beyond the base curve should be allowable. Finally, several studies have confirmed that the CPT criteria in Fig. 4 are generally conservative. Robertson and Wride (1998) verified these criteria against SPT and other data from sites they investigated. Gilstrap and Youd (1998) compared calculated liquefaction resistances against field performance at 19 sites and concluded that the CPT criteria correctly predicted the occurrence or nonoccurrence of liquefaction with >85% reliability.

The clean-sand base curve in Fig. 4 may be approximated by the following equation (Robertson and Wride 1998):

$$\text{If } (q_{c1N})_{cs} < 50 \quad \text{CRR}_{7.5} = 0.833[(q_{c1N})_{cs}/1{,}000] + 0.05 \tag{11a}$$

$$\text{If } 50 \leq (q_{c1N})_{cs} < 160 \quad \text{CRR}_{7.5} = 93[(q_{c1N})_{cs}/1{,}000]^3 + 0.08 \tag{11b}$$

where $(q_{c1N})_{cs}$ = clean-sand cone penetration resistance normalized to approximately 100 kPa (1 atm).

Normalization of Cone Penetration Resistance

The CPT procedure requires normalization of tip resistance using (12) and (13). This transformation yields normalized, dimensionless cone pentration resistance q_{c1N}

$$q_{c1N} = C_Q(q_c/P_a) \tag{12}$$

where

$$C_Q = (P_a/\sigma'_{vo})^n \tag{13}$$

and where C_Q = normalizing factor for cone penetration resistance; P_a = 1 atm of pressure in the same units used for σ'_{vo}; n = exponent that varies with soil type; and q_c = field cone penetration resistance measured at the tip. At shallow depths C_Q becomes large because of low overburden pressure; however, values >1.7 should not be applied. As noted in the following paragraphs, the value of the exponent n varies from 0.5 to 1.0, depending on the grain characteristics of the soil (Olsen 1997).

The CPT friction ratio (sleeve resistance f_s divided by cone tip resistance q_c) generally increases with increasing fines content and soil plasticity, allowing rough estimates of soil type and fines content to be determined from CPT data. Robertson and Wride (1998) constructed the chart reproduced in Fig. 5 for estimation of soil type. The boundaries between soil types 2–7 can be approximated by concentric circles and can be used to account for effects of soil characteristics on q_{c1N} and CRR. The radius of these circles, termed the soil behavior type index I_c is calculated from the following equation:

$$I_c = [(3.47 - \log Q)^2 + (1.22 + \log F)^2]^{0.5} \tag{14}$$

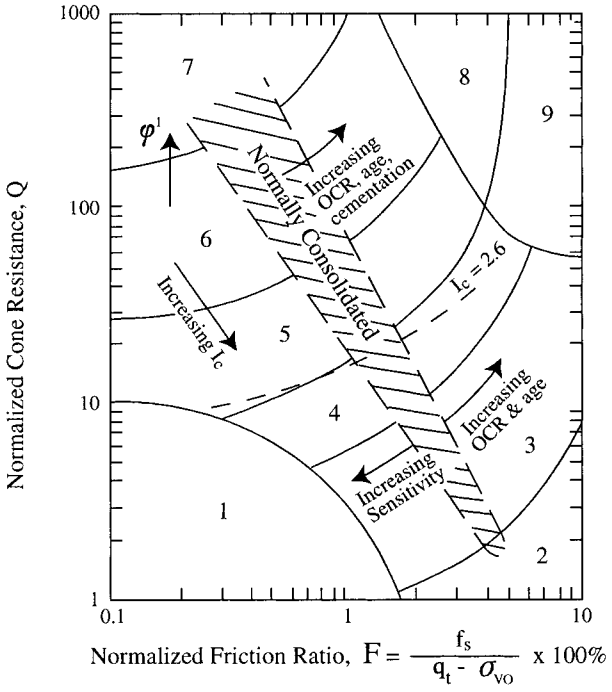
where

$$Q = [(q_c - \sigma_{vo})/P_a][(P_a/\sigma'_{vo})^n] \tag{15}$$

and

$$F = [f_s/(q_c - \sigma_{vo})] \times 100\% \tag{16}$$

The soil behavior chart in Fig. 5 was developed using an exponent n of 1.0, which is the appropriate value for clayey soil types. For clean sands, however, an exponent value of 0.5 is more appropriate, and a value intermediate between 0.5 and



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand*
9. Very stiff, fine grained*

Heavily overconsolidated or cemented

FIG. 5. CPT-Based Soil Behavior-Type Chart Proposed by Robertson (1990)

1.0 would be appropriate for silts and sandy silts. Robertson and Wride recommended the following procedure for calculating the soil behavior type index I_c. The first step is to differentiate soil types characterized as clays from soil types characterized as sands and silts. This differentiation is performed by assuming an exponent n of 1.0 (characteristic of clays) and calculating the dimensionless CPT tip resistance Q from the following equation:

$$Q = [(q_c - \sigma_{vo})/P_a][P_a/\sigma'_{vo}]^{1.0} = [(q_c - \sigma_{vo})/\sigma'_{vo}] \tag{17}$$

If the I_c calculated with an exponent of 1.0 is >2.6, the soil is classified as clayey and is considered too clay-rich to liquefy, and the analysis is complete. However, soil samples should be retrieved and tested to confirm the soil type and liquefaction resistance. Criteria such as the Chinese criteria might be applied to confirm that the soil is nonliquefiable. The so-called Chinese criteria, as defined by Seed and Idriss (1982), specify that liquefaction can only occur if all three of the following conditions are met:

1. The clay content (particles smaller than 5 μ) is <15% by weight.
2. The liquid limit is <35%.
3. The natural moisture content is >0.9 times the liquid limit.

If the calculated I_c is <2.6, the soil is most likely granular in nature, and therefore C_q and Q should be recalculated using an exponent n of 0.5. I_c should then be recalculated using (14). If the recalculated I_c is <2.6, the soil is classed as nonplastic and granular. This I_c is used to estimate liquefaction resistance, as noted in the next section. However, if the recalculated I_c is

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

>2.6, the soil is likely to be very silty and possibly plastic. In this instance, q_{c1N} should be recalculated from (12) using an intermediate exponent n of 0.7 in (13). I_c is then recalculated from (14) using the recalculated value for q_{c1N}. This intermediate I_c is then used to calculate liquefaction resistance. In this instance, a soil sample should be retrieved and tested to verify the soil type and whether the soil is liquefiable by other criteria, such as the Chinese criteria.

Because the relationship between I_c and soil type is approximate, the consensus of the workshop participants is that all soils with an I_c of 2.4 or greater should be sampled and tested to confirm the soil type and to test the liquefiability with other criteria. Also, soil layers characterized by an $I_c > 2.6$, but with a normalized friction ratio $F < 1.0\%$ (region 1 of Fig. 5) may be very sensitive and should be sampled and tested. Although not technically liquefiable according to the Chinese criteria, such sensitive soils may suffer softening and strength loss during earthquake shaking.

Calculation of Clean-Sand Equivalent Normalized Cone Penetration Resistance ($q_{c1N})_{cs}$

The normalized penetration resistance (q_{c1N}) for silty sands is corrected to an equivalent clean sand value $(q_{c1N})_{cs}$, by the following relationship:

$$(q_{c1N})_{cs} = K_c q_{c1N} \tag{18}$$

where K_c, the correction factor for grain characteristics, is defined by the following equation (Robertson and Wride 1998):

$$\text{for } I_c \leq 1.64 \quad K_c = 1.0 \tag{19a}$$

$$\text{for } I_c > 1.64 \quad K_c = -0.403I_c^4 + 5.581I_c^3 - 21.63I_c^2 + 33.75I_c - 17.88 \tag{19b}$$

The K_c curve defined by (19) is plotted in Fig. 6. For $I_c > 2.6$, the curve is shown as a dashed line, indicating that soils in this range of I_c are most likely too clay-rich or plastic to liquefy.

With an appropriate I_c and K_c, (11) and (19) can be used to calculate $CRR_{7.5}$. To adjust CRR to magnitudes other than 7.5, the calculated $CRR_{7.5}$ is multiplied by an appropriate magnitude scaling factor. The same magnitude scaling factors are used with CPT data as with SPT data. Magnitude scaling factors are discussed in a later section of this report.

Olsen (1997) and Suzuki et al. (1995) Procedures

Olsen (1997), who pioneered many of the techniques for assessing liquefaction resistance from CPT soundings, suggested a somewhat different procedure for calculating CRR from CPT data. Reasons for recommending the Robertson and Wride (1998) procedure over that of Olsen are the ease of application and the ease with which relationships can be quantified for computer-aided calculations. Results from Olsen's procedure, however, are consistent with results from the procedure proposed here for shallow (<15 m deep) sediment beneath level to gently sloping terrain. Olsen (1997) noted that almost any CPT normalization technique will give results consistent with his normalization procedure for soil layers in the 3–15 m depth range. For deeper layers, significant differences may develop between the two procedures. Those depths are also beyond the depth for which the simplified procedure has been verified. Hence any procedure based on the simplified procedure yields rather uncertain results at depths >15 m.

Suzuki et al. (1995) also developed criteria for evaluating CRR from CPT data. Those criteria are slightly more conservative than those of Robertson and Wride (1998) and were considered by the latter investigators in developing the criteria recommended herein.

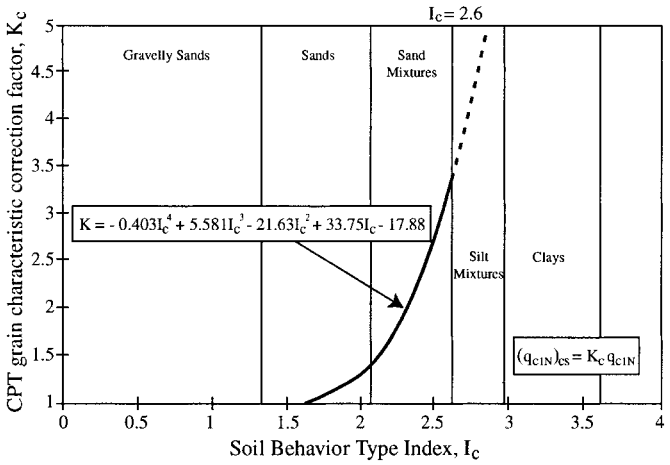


FIG. 6. Grain-Characteristic Correction Factor K_c for Determination of Clean-Sand Equivalent CPT Resistance (Reproduced from Robertson and Wride 1998)

Correction of Cone Penetration Resistance for Thin Soil Layers

Theoretical as well as laboratory studies indicate that CPT tip resistance is influenced by softer soil layers above or below the cone tip. As a result, measured CPT tip resistance is smaller in thin layers of granular soils sandwiched between softer layers than in thicker layers of the same granular soil. The amount of the reduction of penetration resistance in soft layers is a function of the thickness of the softer layer and the stiffness of the stiffer layers.

Using a simplified elastic solution, Vreugdenhil et al. (1994) developed a procedure for estimating the thick-layer equivalent cone penetration resistance of thin stiff layers lying within softer strata. The correction applies only to thin stiff layers embedded within thick soft layers. Because the corrections have a reasonable trend, but appear rather large, Robertson and Fear (1995) recommended conservative corrections from the $q_{cA}/q_{cB} = 2$ curve sketched in Fig. 7.

Further analysis of field data by Gonzalo Castro and Peter Robertson for the NCEER workshop indicates that corrections based on the $q_{cA}/q_{cB} = 2$ curve may still be too large and not adequately conservative. They suggested, and the workshop participants agreed, that the lower bound of the range of field data plotted by G. Castro in Fig. 7 provides more conservative K_H values that should be used until further field studies and analyses indicate that higher values are viable. The equation for the lower bound of the field curve is

$$K_H = 0.25[((H/d_c)/17) - 1.77]^2 + 1.0 \tag{20}$$

where H = thickness of the interbedded layer in mm; q_{cA} and q_{cB} = cone resistances of the stiff and soft layers, respectively; and d_c = diameter of the cone in mm (Fig. 7).

V_s

Andrus and Stokoe (1997, 2000) developed liquefaction resistance criteria from field measurements of shear wave velocity V_s. The use of V_s as a field index of liquefaction resistance is soundly based because both V_s and CRR are similarly, but not proportionally, influenced by void ratio, effective confining stresses, stress history, and geologic age. The advantages of using V_s include the following: (1) V_s measurements are possible in soils that are difficult to penetrate with CPT and SPT or to extract undisturbed samples, such as gravelly soils, and at sites where borings or soundings may not be permitted; (2) V_s is a basic mechanical property of soil materials, directly related to small-strain shear modulus; and (3) the

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

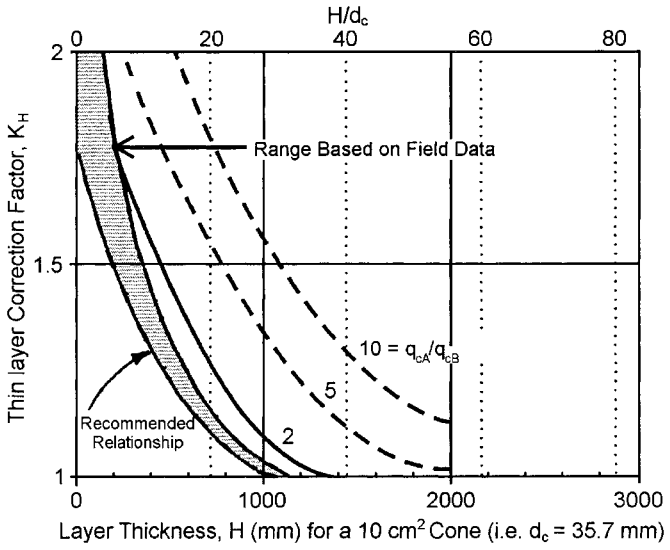


FIG. 7. Thin-Layer Correction Factor K_H for Determination of Equivalent Thick-Layer CPT Resistance (Modified from Robertson and Fear 1995)

small-strain shear modulus is a parameter required in analytical procedures for estimating dynamic soil response and soil-structure interaction analyses.

Three concerns arise when using V_s for liquefaction-resistance evaluations: (1) seismic wave velocity measurements are made at small strains, whereas pore-water pressure buildup and the onset of liquefaction are medium- to high-strain phenomena; (2) seismic testing does not provide samples for classification of soils and identification of nonliquefiable soft clay-rich soils; and (3) thin, low V_s strata may not be detected if the measurement interval is too large. Therefore the preferred practice is to drill sufficient boreholes and conduct in situ tests to detect and delineate thin liquefiable strata, nonliquefiable clay-rich soils, and silty soils above the ground-water table that might become liquefiable should the water table rise. Other tests, such as the SPT or CPT, are needed to detect liquefiable weakly cemented soils that may have high V_s values.

V_s Criteria for Evaluating Liquefaction Resistance

Following the traditional procedures for correcting penetration resistance to account for overburden stress, V_s is also corrected to a reference overburden stress using the following equation (Sykora 1987; Kayen et al. 1992; Robertson et al. 1992):

$$V_{s1} = V_s \left(\frac{P_a}{\sigma'_{vo}}\right)^{0.25} \tag{21}$$

where V_{s1} = overburden-stress corrected shear wave velocity; P_a = atmospheric pressure approximated by 100 kPa (1 TSF); and σ'_{vo} = initial effective vertical stress in the same units as P_a. Eq. (21) implicitly assumes a constant coefficient of earth pressure K'_o which is approximately 0.5 for sites susceptible to liquefaction. Application of (21) also implicitly assumes that V_s is measured with both the directions of particle motion and wave propagation polarized along principal stress directions and that one of those directions is vertical (Stokoe et al. 1985).

Fig. 8 compares seven CRR-V_{s1} curves. The ''best fit'' curve by Tokimatsu and Uchida (1990) was determined from laboratory cyclic triaxial test results for various sands with <10% fines and 15 cycles of loading. The more conservative ''lower bound'' curve for Tokimatsu and Uchida's laboratory test results is also shown as a lower bound for liquefaction occurrences. The bounding curve by Robertson et al. (1992) was developed using field performance data from sites in Imperial Valley, Calif., along with data from four other sites. The curves by Kayen et al. (1992) and Lodge (1994) are from sites that did and did not liquefy during the 1989 Loma Prieta earthquake. Andrus and Stokoe's (1997) curve was developed for uncemented, Holocene-age soils with 5% or less fines using field performance data from 20 earthquakes and over 50 measurement sites. Andrus and Stokoe (2000) revised this curve based on new information and an expanded database that includes 26 earthquakes and more than 70 measurement sites.

Andrus and Stokoe (1997) proposed the following relationship between CRR and V_{s1}:

$$\text{CRR} = a\left(\frac{V_{s1}}{100}\right)^2 + b\left(\frac{1}{V^*_{s1} - V_{s1}} - \frac{1}{V^*_{s1}}\right) \tag{22}$$

where V^*_{s1} = limiting upper value of V_{s1} for liquefaction occurrence; and a and b are curve fitting parameters. The first parenthetical term of (22) is based on a modified relationship

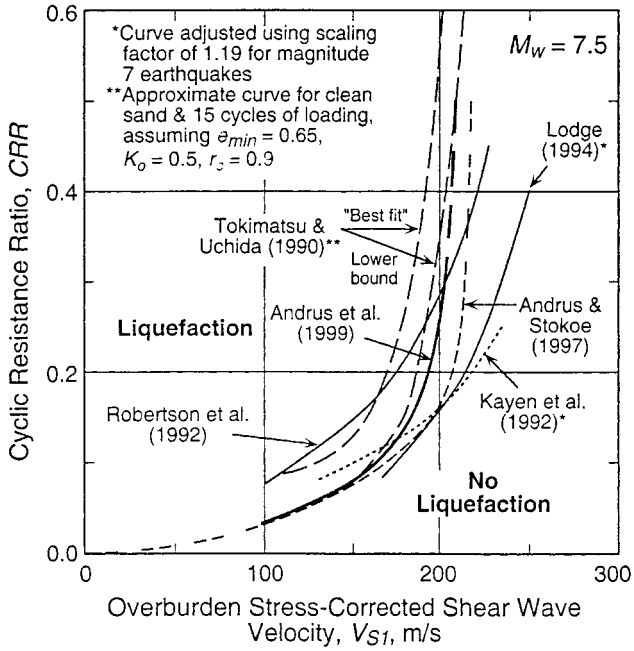


FIG. 8. Comparison of Seven Relationships between Liquefaction Resistance and Overburden Stress-Corrected Shear Wave Velocity for Granular Soils

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

between V_{s1} and CSR for constant average cyclic shear strain suggested by R. Dobry (personal communication to R. D. Andrus, 1996). The second parenthetical term is a hyperbola with a small value at low V_{s1}, and a very large value as V_{s1} approaches V_{s1}^*, a constant limiting velocity for liquefaction of soils.

CRR versus V_{s1} curves recommended for engineering practice by Andrus and Stokoe (2000) for magnitude 7.5 earthquakes and uncemented Holocene-age soils with various fines contents are reproduced in Fig. 9. Also plotted and presented in Fig. 9 are points calculated from liquefaction case history information for magnitude 5.9–8.3 earthquakes. The three curves shown were determined through an iterative process of varying the values of a and b until nearly all the points indicative of liquefaction were bounded by the curves with the least number of nonliquefaction points plotted in the liquefaction region. The final values of a and b used to draw the curves were 0.022 and 2.8, respectively. Values of V_{s1}^* were assumed to vary linearly from 200 m/s for soils with fines content of 35% to 215 m/s for soils with fines content of 5% or less.

The recommended curves shown in Fig. 9 are dashed above CRR of 0.35 to indicate that field-performance data are limited in that range. Also, they do not extend much below 100 m/s, because there are no field data to support extending them to the origin. The calculated CRR is 0.033 for a V_{s1} of 100 m/s. This minimal CRR value is generally consistent with intercept CRR values assumed for the CPT and SPT procedures. Eq. (22) can be scaled to other magnitude values through use of magnitude scaling factors. These factors are discussed in a later section of this paper.

BPT

Liquefaction resistance of nongravelly soils has been evaluated primarily through CPT and SPT, with occasional V_s measurements. CPT and SPT measurements, however, are not generally reliable in gravelly soils. Large gravel particles may interfere with the normal deformation of soil materials around the penetrometer and misleadingly increase penetration resistance. Several investigators have employed large-diameter penetrometers to surmount these difficulties; the Becker penetration test (BPT) in particular has become one of the more effectively and widely used larger tools. The BPT was developed in Canada in the late 1950s and consists of a 168-mm diameter, 3-m-long double-walled casing driven into the ground with a double-acting diesel-driven pile hammer. The hammer impacts are applied at the top of the casing and peneration is continuous. The Becker penetration resistance is defined as the number of blows required to drive the casing through an increment of 300 mm.

The BPT has not been standardized, and several different types of equipment and procedures have been used. There are currently very few liquefaction sites from which BPT data have been obtained. Thus the BPT cannot be directly correlated with field behavior, but rather through estimating equivalent SPT N-values from BPT data and then applying evaluation procedures based on the SPT. This indirect method introduces substantial additional uncertainty into the calculated CRR.

To provide uniformity, Harder and Seed (1986) recommended newer AP-1000 drill rigs equipped with supercharged diesel hammers, 168-mm outside diameter casing, and a plugged bit. From several sites where both BPT and SPT tests were conducted in parallel soundings, Harder and Seed (1986) developed a preliminary correlation between Becker and standard penetration resistance [Fig. 10(a)]. Additional comparative data compiled since 1986 are plotted in Fig. 10(b). The original Harder and Seed correlation curve (solid line) is drawn in Fig. 10(b) along with dashed curves representing 20% over- and underpredictions of SPT blow counts. These plots indicate that SPT blow counts can be roughly estimated

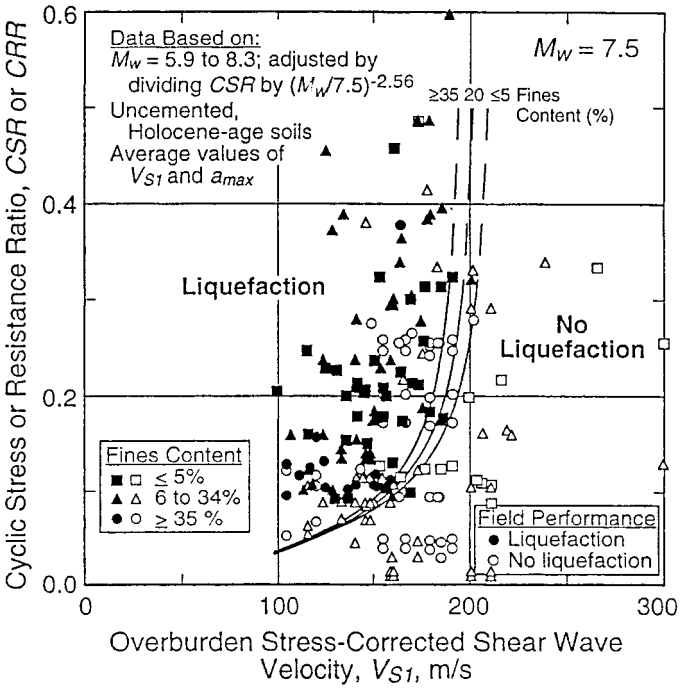


FIG. 9. Liquefaction Relationship Recommended for Clean, Uncemented Soils with Liquefaction Data from Compiled Case Histories (Reproduced from Andrus and Stokoe 2000)

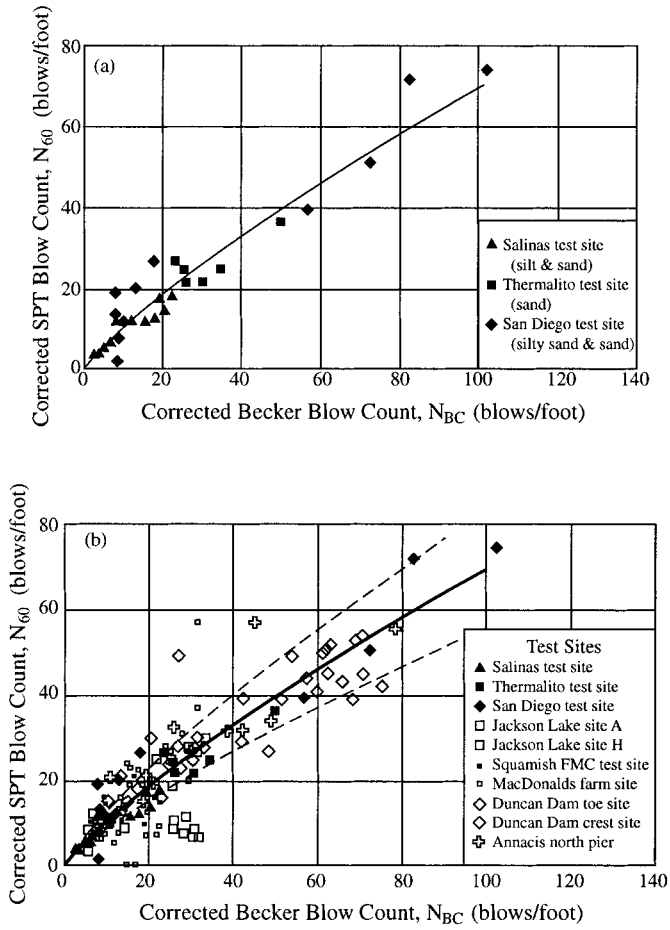


FIG. 10. Correlation between Corrected Becker Penetration Resistance N_{BC} and Corrected SPT Resistance N_{60}: (a) Harder and Seed (1986); (b) Data from Additional Sites (Reproduced from Harder 1997)

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

from BPT measurements. These plots indicate that although SPT blow counts can be roughly estimated from BPT measurements, there can be considerable uncertainty for calculating liquefaction resistance because the data scatter is greatest in the range of greatest importance [*N*-values of 0–30 blows/300 mm (ft)].

A major source of variation in BPT blow counts is deviations in hammer energy. Rather than measuring hammer energy directly, Harder and Seed (1986) monitored bounce-chamber pressures and found that uniform combustion conditions (e.g., full throttle with a supercharger) correlated rather well with variations in Becker blow count. From this information, Harder and Seed developed an energy correction procedure based on measured bounce-chamber pressure.

Direct measurement of transmitted hammer energy could provide a more theoretically rigorous correction for Becker hammer efficiency. Sy and Campanella (1994) and Sy et al. (1995) instrumented a small length of Becker casing with strain gauges and accelerometers to measure transferred energy. They analyzed the recorded data with a pile-driving analyzer to determine strain, force, acceleration, and velocity. The transferred energy was determined by time integration of force times velocity. They were able to verify many of the variations in hammer energy previously identified by Harder and Seed (1986), including effects of variable throttle settings and energy transmission efficiencies of various drill rigs. However, they were unable to reduce the amount of scatter and uncertainty in converting BPT blow counts to SPT blow counts. Because the Sy and Campanella procedure requires considerably more effort than monitoring of bounce-chamber pressure without producing greatly improved results, the workshop participants agreed that the bounce-chamber technique is adequate for routine practice.

Friction along the driven casing also influences penetration resistance. Harder and Seed (1986) did not directly evaluate the effect of casing friction; hence, the correlation in Fig. 10(b) intrinsically incorporates an unknown amount of casing friction. However, casing friction remains a concern for depths >30 m and for measurement of penetration resistance in soft soils underlying thick deposits of dense soil. Either of these circumstances could lead to greater casing friction than is intrinsically incorporated in the Harder and Seed correlation.

The following procedures are recommended for routine practice: (1) the BPT should be conducted with newer AP-1000 drill rigs equipped with supercharged diesel hammers to drive plugged 168-mm outside diameter casing; (2) bounce-chamber pressures should be monitored and adjustments made to measured BPT blow counts to account for variations in diesel hammer combustion efficiency—for most routine applications, correlations developed by Harder and Seed (1986) may be used for these adjustments; and (3) the influence of some casing friction is indirectly accounted for in the Harder and Seed BPT-SPT correlation. This correlation, however, has not been verified and should not be used for depths >30 m or for sites with thick dense deposits overlying loose sands or gravels. For these conditions, mudded boreholes may be needed to reduce casing friction, or specially developed local correlations or sophisticated wave-equation analyses may be applied to quantify frictional effects.

MAGNITUDE SCALING FACTORS (MSFs)

The clean-sand base or CRR curves in Figs. 2 (SPT), 4 (CPT), and 10 (V_{s1}) apply only to magnitude 7.5 earthquakes. To adjust the clean-sand curves to magnitudes smaller or larger than 7.5, Seed and Idriss (1982) introduced correction factors termed "magnitude scaling factors (MSFs)." These factors are used to scale the CRR base curves upward or downward on CRR versus $(N_1)_{60}$, q_{c1N}, or V_{s1} plots. Conversely, magnitude weighting factors, which are the inverse of magnitude scaling factors, may be applied to correct CSR for magnitude. Either correcting CRR via magnitude scaling factors, or correcting CSR via magnitude weighting factors, leads to the same final result. Because the original papers by Seed and Idriss were written in terms of magnitude scaling factors, the use of magnitude scaling factors is continued in this report.

To illustrate the influence of magnitude scaling factors on calculated hazard, the equation for factor of safety (FS) against liquefaction is written in terms of CRR, CSR, and MSF as follows:

$$FS = (CRR_{7.5}/CSR)MSF \tag{23}$$

where CSR = calculated cyclic stress ratio generated by the earthquake shaking; and $CRR_{7.5}$ = cyclic resistance ratio for magnitude 7.5 earthquakes. $CRR_{7.5}$ is determined from Fig. 2 or (4) for SPT data, Fig. 4 or (11) for CPT data, or Fig. 9 or (22) for V_{s1} data.

Seed and Idriss (1982) Scaling Factors

Because of the limited amount of field liquefaction data available in the 1970s, Seed and Idriss (1982) were unable to adequately constrain bounds between liquefaction and non-liquefaction regions on CRR plots for magnitudes other than 7.5. Consequently, they developed a set of MSF from average numbers of loading cycles for various earthquake magnitudes and laboratory test results. A representative curve developed by these investigators, showing the number of loading cycles required to generate liquefaction for a given CSR, is reproduced in Fig. 11. The average number of loading cycles for various magnitudes of earthquakes are also noted on the plot. The initial set of magnitude scaling factors was derived by dividing CSR values on the representative curve for the number of loading cycles corresponding to a given earthquake magnitude by the CSR for 15 loading cycles (equivalent to a magnitude 7.5 earthquake). These scaling factors are listed in column 2 of Table 3 and are plotted in Fig. 12. These MSFs have been routinely applied in engineering practice since their introduction in 1982.

Revised Idriss Scaling Factors

In preparing his H. B. Seed Memorial Lecture, I. M. Idriss reevaluated the data that he and the late Professor Seed used to calculate the original (1982) magnitude scaling factors. In so doing, Idriss replotted the data on a log-log plot and suggested that the data should plot as a straight line. He noted, however, that one outlying point had strongly influenced the original analysis, causing the original plot to be nonlinear and characterized by unduly low MSF values for magnitudes <7.5. Based on this reevaluation, Idriss defined a revised set of magnitude scaling factors listed in column 3 of Table 3 and plotted

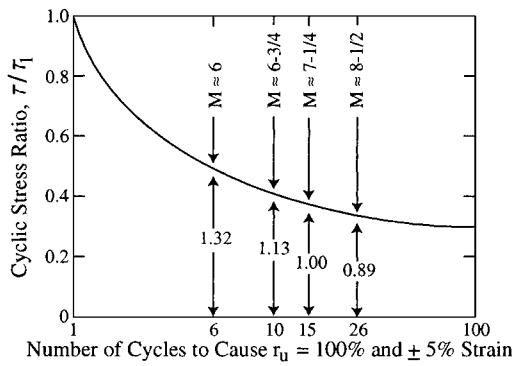


FIG. 11. Representative Relationship between CSR and Number of Cycles to Cause Liquefaction (Reproduced from Seed and Idriss 1982)

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

TABLE 3. Magnitude Scaling Factor Values Defined by Various Investigators (Youd and Noble 1997a)

Magnitude, M	Seed and Idriss (1982)	Idriss[a]	Ambraseys (1988)	Arango (1996) Distance based	Arango (1996) Energy based	Andrus and Stokoe (1997)	Youd and Noble (1997b) P_L < 20%	Youd and Noble (1997b) P_L < 32%	Youd and Noble (1997b) P_L < 50%
5.5	1.43	2.20	2.86	3.00	2.20	2.8	2.86	3.42	4.44
6.0	1.32	1.76	2.20	2.00	1.65	2.1	1.93	2.35	2.92
6.5	1.19	1.44	1.69	1.60	1.40	1.6	1.34	1.66	1.99
7.0	1.08	1.19	1.30	1.25	1.10	1.25	1.00	1.20	1.39
7.5	1.00	1.00	1.00	1.00	1.00	1.00	—	—	1.00
8.0	0.94	0.84	0.67	0.75	0.85	0.8?	—	—	0.73?
8.5	0.89	0.72	0.44	—	—	0.65?	—	—	0.56?

Note: ? = Very uncertain values.
[a]1995 Seed Memorial Lecture, University of California at Berkeley (I. M. Idriss, personal communication to T. L. Youd, 1997).

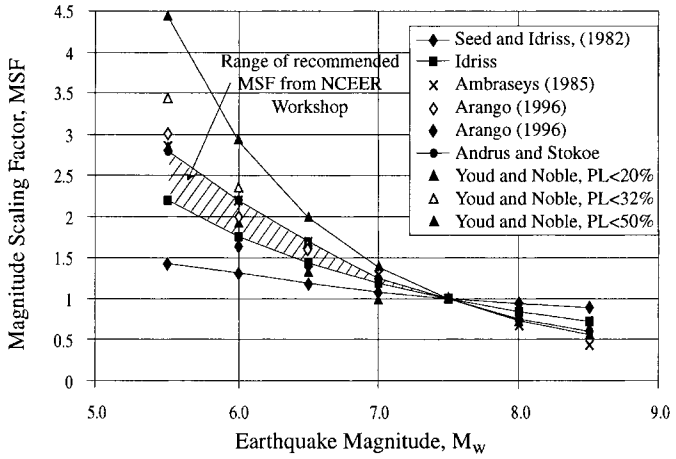


FIG. 12. Magnitude Scaling Factors Derived by Various Investigators (Reproduced from Youd and Noble 1997a)

in Fig. 12. The revised MSFs are defined by the following equation:

$$\text{MSF} = 10^{2.24}/M_w^{2.56} \tag{24}$$

The workshop participants recommend these revised scaling factors as a lower bound for MSF values.

The revised scaling factors are significantly higher than the original scaling factors for magnitudes <7.5 and somewhat lower than the original factors for magnitudes >7.5. Relative to the original scaling factors, the revised factors lead to a reduced calculated liquefaction hazard for magnitudes <7.5, but increase calculated hazard for magnitudes >7.5.

Ambraseys (1988) Scaling Factors

Field performance data collected since the 1970s for magnitudes <7.5 indicate that the original Seed and Idriss (1982) scaling factors are overly conservative. For example, Ambraseys (1988) analyzed liquefaction data compiled through the mid-1980s and plotted calculated cyclic stress ratios for sites that did or did not liquefy versus $(N_1)_{60}$. From these plots, Ambraseys developed empirical exponential equations that define CRR as a function of $(N_1)_{60}$ and moment magnitude M_w. By holding the value of $(N_1)_{60}$ constant in the equations and taking the ratio of CRR determined for various magnitudes of earthquakes to the CRR for magnitude 7.5 earthquakes, Ambraseys derived the magnitude scaling factors listed in column 4 of Table 3 and plotted in Fig. 12. For magnitudes <7.5, the MSFs suggested by Ambraseys are significantly larger than both the original factors developed by Seed and Idriss (column 2, Table 3) and the revised factors suggested by Idriss (column 3). Because they are based on observational data, these factors have validity for estimating liquefaction hazard; however, they have not been widely used in engineering practice.

For magnitudes >7.5, Ambraseys factors are significantly lower and much more conservative than the original (Seed and Idriss 1982) and Idriss's revised scaling factors. Because there are few data to constrain Ambraseys' scaling factors for magnitudes >7.5, they are not recommended for hazard evaluation for large earthquakes.

Arango (1996) Scaling Factors

Arango (1996) developed two sets of magnitude scaling factors. The first set (column 5, Table 3) is based on furthest observed liquefaction effects from the seismic energy source, the estimated average peak accelerations at those distant sites, and the seismic energy required to cause liquefaction. The second set (column 6, Table 3) was developed from energy concepts and the relationship derived by Seed and Idriss (1982) between numbers of significant stress cycles and earthquake magnitude. The MSFs listed in column 5 are similar in value (within about 10%) to the MSFs of Ambraseys (column 4), and the MSFs listed in column 6 are similar in value (within about 10%) to the revised MSFs proposed by Idriss (column 3).

Andrus and Stokoe (1997) Scaling Factors

From their studies of liquefaction resistance as a function of shear wave velocity V_s Andrus and Stokoe (1997) drew bounding curves and developed (22) for calculating CRR from V_s for magnitude 7.5 earthquakes. These investigators drew similar bounding curves for sites where surface effects of liquefaction were or were not observed for earthquakes with magnitudes of 6, 6.5, and 7. The positions of the CRR curves were visually adjusted on each graph until a best-fit bound was obtained. Magnitude scaling factors were then estimated by taking the ratio of CRR for a given magnitude to the CRR for magnitude 7.5 earthquakes. These MSFs are quantified by the following equation:

$$\text{MSF} = (M_w/7.5)^{-2.56} \tag{25}$$

MSFs for magnitudes <6 and >7.5 were extrapolated from this equation. The derived MSFs are listed in column 7 of Table 3, and plotted in Fig. 12. For magnitudes <7.5, the MSFs proposed by Andrus and Stokoe are rather close in value (within about 5%) to the MSFs proposed by Ambraseys. For magnitudes >7.5, the Andrus and Stokoe MSFs are slightly smaller than the revised MSFs proposed by Idriss.

Youd and Noble (1997a) Scaling Factors

Youd and Noble (1997a) used a probabilistic or logistic analysis to analyze case history data from sites where effects of liquefaction were or were not reported following past earthquakes. This analysis yielded the following equation, which

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

was updated after publication of the NCEER proceedings (Youd and Idriss 1997):

$$\text{Logit}(P_L) = \ln(P_L/(1 - P_L)) = -7.0351 + 2.1738M_w - 0.2678(N_1)_{60cs} + 3.0265 \ln \text{CRR} \quad (26)$$

where P_L = probability that liquefaction occurred; $1 - P_L$ = probability that liquefaction did not occur; and $(N_1)_{60cs}$ = corrected equivalent clean-sand blow count. For magnitudes <7.5, Youd and Noble recommended direct application of this equation to calculate the CRR for a given probability of liquefaction. In lieu of direct application, Youd and Noble defined three sets of MSFs for use with the simplified procedure. These MSFs are for probabilities of liquefaction occurrence <20, 32, and 50%, respectively, and are defined by the following equations:

$$\text{Probability } P_L < 20\% \quad \text{MSF} = 10^{3.81}/M^{4.53} \text{ for } M_w < 7 \quad (27)$$

$$\text{Probability } P_L < 32\% \quad \text{MSF} = 10^{3.74}/M^{4.33} \text{ for } M_w < 7 \quad (28)$$

$$\text{Probability } P_L < 50\% \quad \text{MSF} = 10^{4.21}/M^{4.81} \text{ for } M_w < 7.75 \quad (29)$$

New Recommendation by Idriss

I. M. Idriss (TRB 1999) proposed a new set of MSFs that are compatible with, and are only to be used with, the magnitude-dependent r_d that he also proposed. These new MSFs have lower values than the revised MSFs listed in Table 3, but slightly higher values than the original Seed and Idriss (1982) MSFs. Because the proposed r_d and associated MSFs have not been published and the factors have not been independently verified, the workshop participants chose not to recommend the new r_d or MSFs at this time.

Recommendations for Engineering Practice

The workshop participants reviewed the MSFs listed in Table 3, and all but one (S. S. C. Liao) agree that the original factors were too conservative and that increased MSFs are warranted for engineering practice for magnitudes <7.5. Rather than recommending a single set of factors, the workshop participants suggest a range of MSFs from which the engineer is allowed to choose factors that are requisite with the acceptable risk for any given application. For magnitudes <7.5, the lower bound for the recommended range is the new MSF proposed by Idriss [column 3 in Table 3, or (23)]. The suggested upper bound is the MSF proposed by Andrus and Stokoe [column 7 in Table 3, or (26)]. The upper-bound values are consistent with MSFs suggested by Ambraseys (1988), Arango (1996), and Youd and Noble (1997a) for $P_L < 20\%$.

For magnitudes >7.5, the new factors recommended by Idriss [column 3 in Table 3; (25)] should be used for engineering practice. These new factors are smaller than the original Seed and Idriss (1982) factors, hence their application leads to increased calculated liquefaction hazard compared to the original factors. Because there are only a few well-documented liquefaction case histories for earthquakes with magnitudes >8, MSFs in that range are poorly constrained by field data. Thus the workshop participants agreed that the greater conservatism embodied in the revised MSF by Idriss (column 3, Table 3) should be recommended for engineering practice.

CORRECTIONS FOR HIGH OVERBURDEN STRESSES, STATIC SHEAR STRESSES, AND AGE OF DEPOSIT

Correction factors K_σ and K_α were developed by Seed (1983) to extrapolate the simplified procedure to larger overburden pressure and static shear stress conditions than those embodied in the case history data set from which the simplified procedure was derived. As noted previously, the simplified procedure was developed and validated only for level to gently sloping sites (low static shear stress) and depths less than about 15 m (low overburden pressures). Thus applications using K_σ and K_α are beyond routine practice and require specialized expertise. Because these factors were discussed at the workshop and some new information was developed, recommendations from those discussions are included here. These recommendations, however, apply mostly to liquefaction hazard analyses of embankment dams and other large structures. These factors are applied by extending (23) to include K_σ and K_α as follows:

$$\text{FS} = (\text{CRR}_{7.5}/\text{CSR}) \cdot \text{MSF} \cdot K_\sigma \cdot K_\alpha \quad (30)$$

K_σ Correction Factor

Cyclically loaded laboratory test data indicate that liquefaction resistance increases with increasing confining stress. The rate of increase, however, is nonlinear. To account for the nonlinearity between CRR and effective overburden pressure, Seed (1983) introduced the correction factor K_σ to extrapolate the simplified procedure to soil layers with overburden pressures >100 kPa. Cyclically loaded, isotropically consolidated triaxial compression tests on sand specimens were used to measure CRR for high-stress conditions and develop K_σ values. By taking the ratio of CRR for various confining pressures to the CRR determined for approximately 100 kPa (1 atm) Seed (1983) developed the original K_σ correction curve. Other investigators have added data and suggested modifications to better define K_σ for engineering practice. For example, Seed and Harder (1990) developed the clean-sand curve reproduced in Fig. 13. Hynes and Olsen (1999) compiled and analyzed an enlarged data set to provide guidance and formulate equations for selecting K_σ values (Fig. 14). The equation they derived for calculating K_σ is

$$K_\sigma = (\sigma'_{vo}/P_a)^{(f-1)} \quad (31)$$

where σ'_{vo}, effective overburden pressure; and P_a, atmospheric pressure, are measured in the same units; and f is an exponent that is a function of site conditions, including relative density, stress history, aging, and overconsolidation ratio. The workshop participants considered the work of previous investigators and recommend the following values for f (Fig. 15). For relative densities between 40 and 60%, $f = 0.7–0.8$; for relative densities between 60 and 80%, $f = 0.6–0.7$. Hynes and Olsen recommended these values as minimal or conservative esti-

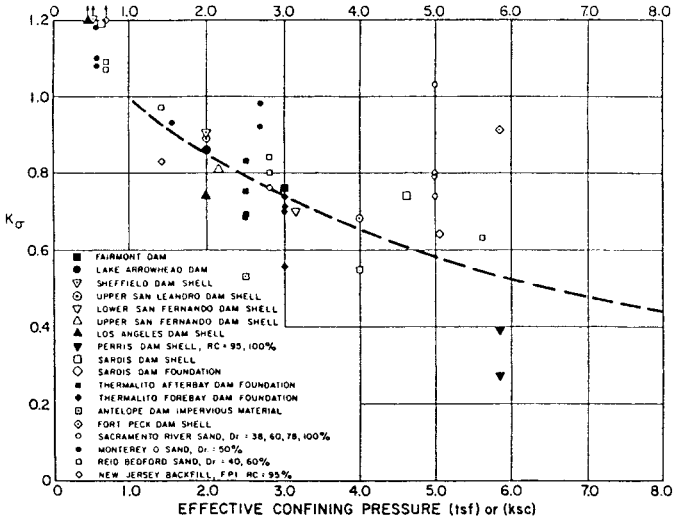


FIG. 13. K_σ-Values Determined by Various Investigators (Reproduced from Seed and Harder 1990)

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

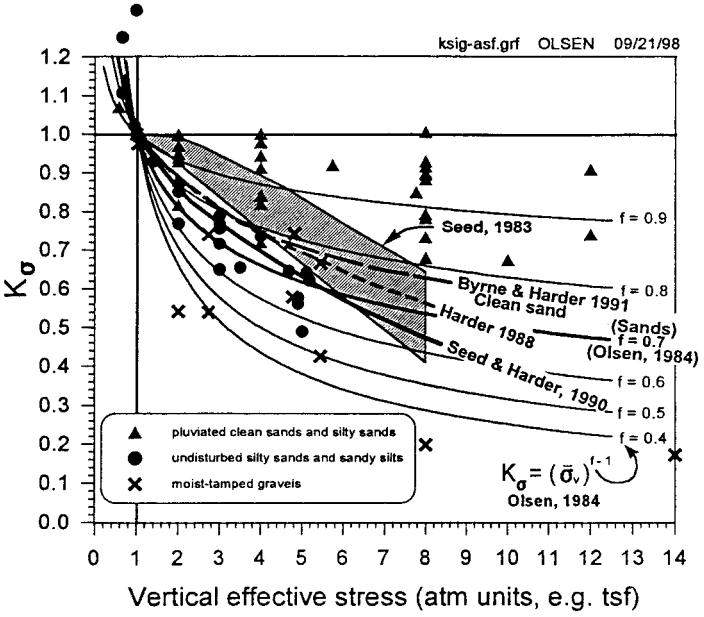


FIG. 14. Laboratory Data and Compiled K_σ Curves (Reproduced from Hynes and Olsen 1999)

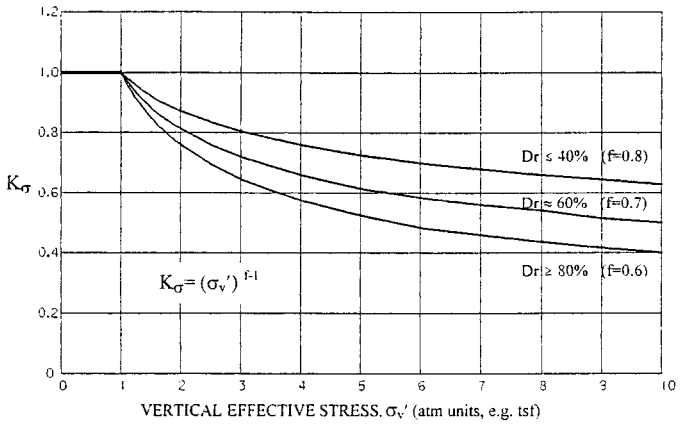


FIG. 15. Recommended Curves for Estimating K_σ for Engineering Practice

mates of K_σ for use in engineering practice for both clean and silty sands, and for gravels. The workshop participants concurred with this recommendation.

K_α Correction Factor for Sloping Ground

The liquefaction resistance of dilative soils (moderately dense to dense granular materials under low confining stress) increases with increased static shear stress. Conversely, the liquefaction resistance of contractive soils (loose soils and moderately dense soils under high confining stress) decreases with increased static shear stresses. To incorporate the effect of static shear stresses on liquefaction resistance, Seed (1983) introduced a correction factor K_α. To generate values for this factor, Seed normalized the static shear stress τ_{st} acting on a plane with respect to the effective vertical stress σ'_{vo} yielding a parameter α, where

$$\alpha = \tau_{st}/\sigma'_{vo} \tag{32}$$

Cyclically loaded triaxial compression tests were then used to empirically determine values of the correction factor K_α as a function of α.

For the NCEER workshop, Harder and Boulanger (1997) reviewed past publications, test results, and analyses of K_α. They noted that a wide range of K_α values have been proposed, indicating a lack of convergence and a need for continued research. The workshop participants agreed with this assessment. Although curves relating K_α to α have been published (Harder and Boulanger 1997), these curves should not be used by nonspecialists in geotechnical earthquake engineering or in routine engineering practice.

Influence of Age of Deposit

Several investigators have noted that liquefaction resistance of soils increases with age. For example, Seed (1979) observed significant increases in liquefaction resistance with aging of reconstituted sand specimens tested in the laboratory. Increases of as much as 25% in cyclic resistance ratio were noted between freshly constituted and 100-day-old specimens. Youd and Hoose (1977) and Youd and Perkins (1978) noted that liquefaction resistance increases markedly with geologic age. Sediments deposited within the past few thousand years are generally much more susceptible to liquefaction than older Holocene sediments; Pleistocene sediments are even more resistant; and pre-Pleistocene sediments are generally immune to liquefaction. Although qualitative time-dependent increases have been documented as noted above, few quantitative data have been collected. In addition, the factors causing increased liquefaction resistance with age are poorly understood. Consequently, verified correction factors for age have not been developed.

In the absence of quantitative correction factors, engineering judgment is required to estimate the liquefaction resistance of sediments more than a few thousand years old. For deeply buried sediments dated as more than a few thousand years old, some knowledgeable engineers have omitted application of the K_σ factor as partial compensation for the unquantified, but substantial increase of liquefaction resistance with age. For man-made structures, such as thick fills and embankment dams, aging effects are minimal, and corrections for age should not be applied in calculating liquefaction resistance.

SEISMIC FACTORS

Application of the simplified procedure for evaluating liquefaction resistance requires estimates of two ground motion parameters—earthquake magnitude and peak horizontal ground acceleration. These factors characterize duration and intensity of ground shaking, respectively. The workshop addressed the following questions with respect to selection of magnitude and peak acceleration values for liquefaction resistance analyses.

Earthquake Magnitude

Records from recent earthquakes, such as 1979 Imperial Valley, 1988 Armenia, 1989 Loma Prieta, 1994 Northridge, and 1995 Kobe, indicate that the relationship between duration and magnitude is rather uncertain and that factors other than magnitude also influence duration. For example, unilateral faulting, in which rupture begins at one end of the fault and propagates to the other, usually produces longer shaking duration for a given magnitude than bilateral faulting, in which slip begins near the midpoint on the fault and propagates in both directions simultaneously. Duration also generally increases with distance from the seismic energy source and may vary with tectonic province, site conditions, and bedrock topography (basin effects).

Question: Should correction factors be developed to adjust duration of shaking to account for the influence of earthquake source mechanism, fault rupture mode, distance from the energy source, basin effects, etc.?

Answer: Faulting characteristics and variations in shaking duration are difficult to predict in advance of an earthquake

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

event. The influence of distance generally is of secondary importance within the range of distances to which damaging liquefaction effects commonly develop. Basin effects are not yet sufficiently predictable to be adequately accounted for in engineering practice. Thus the workshop participants recommend continued use of the generally conservative relationship between magnitude and duration that is embodied in the simplified procedure.

Question: An important difference between eastern U.S. earthquakes and western U.S. earthquakes is that eastern ground motions are generally richer in high-frequency energy and thus could generate more significant stress cycles and equivalently longer durations than western earthquakes of the same magnitude. Is a correction needed to account for higher frequencies of motions generated by eastern U.S. earthquakes?

Answer: The high-frequency motions of eastern earthquakes are generally limited to near-field rock sites. High-frequency motions attenuate or are damped out rather quickly as they propagate through soil layers. This filtering action reduces the high-frequency energy at soil sites and thus reduces differences in numbers of significant loading cycles. Because liquefaction occurs only within soil strata, duration differences on soil sites between eastern and western earthquakes are not likely to be great. Without more instrumentally recorded data from which differences in ground motion characteristics can be quantified, there is little basis for the development of additional correction factors for eastern localities.

Another difference between eastern and western U.S. earthquakes is that strong ground motions generally propagate to greater distances in the east than in the west. By applying present state-of-the-art procedures for estimating peak ground acceleration at eastern sites, differences in amplitudes of ground motions between western and eastern earthquakes are properly taken into account.

Question: Which magnitude scale should be used for selection of earthquake magnitudes for liquefaction resistance analyses?

Answer: Seismologists commonly calculate earthquake magnitudes using five different scales: (1) local or Richter magnitude M_L; (2) surface-wave magnitude M_s; (3) short-period body-wave magnitude m_b; (4) long-period body-wave magnitude m_B; and (5) moment magnitude M_w. Moment magnitude, the scale most commonly used for engineering applications, is the scale preferred for calculation of liquefaction resistance. As Fig. 16 shows, magnitudes from other scales may be substituted directly for M_w within the following limitations—$M_L < 6$, $m_B < 7.5$, and $6 < M_s < 8$—m_b, a scale commonly used for eastern U.S. earthquakes, may be used for magnitudes between 5 and 6, provided m_b values are corrected to equivalent M_w values. The curves plotted in Fig. 16 may be used for this adjustment (Idriss 1985).

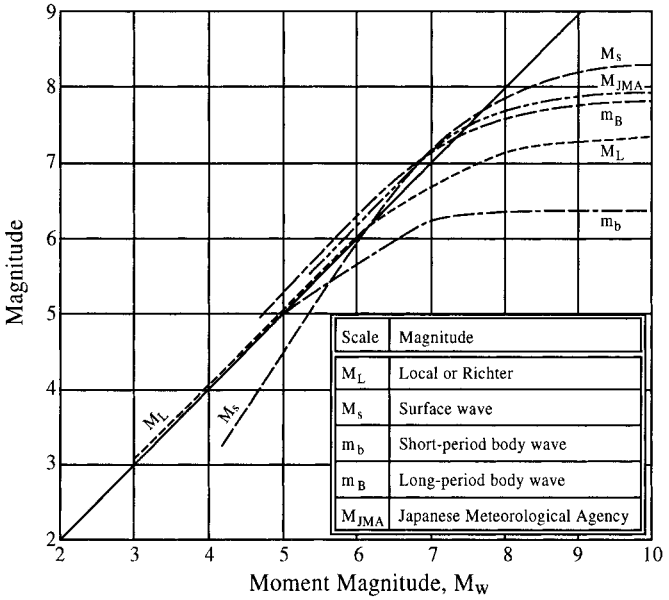


FIG. 16. Relationship between Moment M_w and Other Magnitude Scales (Reproduced from Heaton et al., Unpublished Report, 1982)

Peak Acceleration

In the simplified procedure, peak horizontal acceleration a_{max} is used to characterize the intensity of ground shaking. To provide guidance for estimation of a_{max}, the workshop addressed the following questions.

Question: What procedures are preferred for estimating a_{max} at potentially liquefiable sites?

Answer: The following methods, in order of preference, may be used for estimating a_{max}:

1) The preferred method for estimating a_{max} is through empirical correlations of a_{max} with earthquake magnitude, distance from the seismic energy source, and local site conditions. Several correlations have been published for estimating a_{max} for sites on bedrock or stiff to moderately stiff soils. Preliminary attenuation relationships have also been developed for a limited range of soft soil sites (Idriss 1991). Selection of an attenuation relationship should be based on such factors as region of the country, type of faulting, and site condition.

2) For soft sites and other soil profiles that are not compatible with available attenuation relationships, a_{max} may be estimated from local site response analyses. Computer programs such as SHAKE and DESRA may be used for these calculations (Schnabel et al. 1972; Finn et al. 1977). Input ground motions in the form of recorded accelerograms are preferable to synthetic records. Accelerograms derived from white noise should be avoided. A suite of plausible earthquake records should be used in the analysis, including as many as feasible from earthquakes with similar magnitudes, source distances, etc.

3) The third and least desirable method for estimating peak ground acceleration is through amplification ratios, such as those developed by Idriss (1990, 1991) and Seed et al. (1994). These factors use a multiplier or ratio by which bedrock outcrop motions are amplified to estimate surface motions at soil sites. Because amplification ratios are influenced by strain level, earthquake magnitude, and frequency content, caution and considerable engineering judgment are required in the application of these relationships.

Question: Which peak acceleration should be used: (1) the largest horizontal acceleration recorded on a three-component accelerogram; (2) the geometric mean (square root of the product) of the two maximum horizontal components; or (3) a vectorial combination of horizontal accelerations?

Answer: According to I. M. Idriss (oral discussion at NCEER workshop, 1996), where recorded motions were available, the larger of the two horizontal peak components of acceleration was used in the compilation of data used to derive the original simplified procedure. Where recorded values were not available, which was the circumstance for most sites, peak acceleration values were estimated from attenuation relationships based on the geometric mean of the two orthogonal peak horizontal accelerations. In nearly all instances where recorded motions were used, the peaks from the two horizontal records were approximately equal. Thus where a single peak was used, the peak and the geometric mean of the two peaks were about the same value. Based on this information, the workshop participants concurred that use of the geometric mean is consistent with the development of the procedure and is preferred for use in engineering practice. However, use of the larger of

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

the two orthogonal peak accelerations yields a larger estimate of a_{max}, is conservative, and is allowable. Vectorial accelerations are seldom calculated and should not be used. Peak vertical accelerations are generally much smaller than peak horizontal accelerations and are ignored for calculation of liquefaction resistance.

Question: Liquefaction usually develops at soil sites where ground motion amplification may occur and where sediment may soften, reducing motions as excess pore pressure develop. How should investigators account for these factors in estimating peak acceleration?

Answer: The recommended procedure is to calculate or estimate the a_{max} that would occur at the site in the absence of increased pore pressure or the onset of liquefaction. That peak acceleration incorporates the influence of site amplification, but neglects the influence of excess pore-water pressure.

Question: Should high-frequency spikes (periods <0.1 s) in acceleration records be considered or ignored?

Answer: In general, short-duration, high-frequency acceleration spikes are too short in duration to generate significant instability or deformation of granular structures, and should be ignored. By using attenuation relationships for estimation of peak acceleration, as noted above, high-frequency spikes are essentially ignored because few high-frequency peaks are incorporated in databases from which attenuation the relationships were derived. Similarly, ground response analyses programs such as SHAKE and DESRA generally attenuate or filter out high-frequency spikes, reducing their influence. Where amplification ratios are used, engineering judgment should be used to determine which bedrock acceleration is to be amplified.

ENERGY-BASED CRITERIA AND PROBABILISTIC ANALYSES

The workshop considered two additional topics: (1) liquefaction resistance criteria based on seismic energy passing through a liquefiable layer (Kayen and Mitchell 1997; Youd et al. 1997), and probabilistic analyses of case history data (Liao et al. 1988; Youd and Noble 1997b). Although probabilistic or risk analyses have been made for some localities and critical facilities, the workshop participants concluded that probabilistic procedures are still under development and not sufficiently formulated for routine engineering practice. Similarly, new energy-based criteria need to be independently tested before recommendations can be made for general practice. The workshop participants recommend that research and development continue on both of these relatively new and potentially useful procedures.

CONCLUSIONS

The participants in the NCEER workshop reviewed the state-of-the-art for evaluating liquefaction resistance and recommend several augmentations to that procedure. Specific recommendations, including procedures and equations, are listed in each section of this summary paper. Consensus conclusions from the workshop are:

1. Four field tests are recommended for routine evaluation of liquefaction resistance—the cone penetration test (CPT), the standard penetration test (SPT), shear-wave velocity (V_s) measurements, and for gravelly sites the Becker penetration test (BPT). Criteria for each test were reviewed and revised to incorporate recent developments and to achieve consistency between resistances calculated from the various tests. Each test has its advantages and limitations (Table 1). the CPT provides the most detailed soil stratigraphy and robust field-data based liquefaction resistance curves now available. CPT testing should always be accompanied by soil sampling for validation of soil type identification. The SPT has a longer record of application and provides disturbed soil samples from which fines content and other grain characteristics can be determined. Measured shear-wave velocities provide fundamental information on small-strain soil behavior that is useful beyond analyses of liquefaction resistance. V_s is also applicable at sites, such as landfills and gravelly sediments, where CPT and SPT soundings may not be possible or reliable. The BPT test is recommended only for gravelly sites and requires use of rough correlations between BPT and SPT, making the results less certain than other tests. Where possible, two or more test procedures should be applied to assure adequate definition of soil stratigraphy and a consistent evaluation of liquefaction resistance.
2. The magnitude scaling factors originally derived by Seed and Idriss (1982) are overly conservative for earthquakes with magnitudes <7.5. A range of scaling factors is recommended for engineering practice, the lower end of the range being the new MSF recommended by Idriss (column 3, Table 3), and the upper end of the range being the MSF suggested by Andrus and Stokoe (column 7, Table 3). These MSFs are defined by (25) and (26), respectively. For magnitudes >7.5, the new factors by Idriss (column 3, Table 3) should be used. These factors, which are more conservative than the original Seed and Idriss (1982) factors, should be applied.
3. The K_σ factors suggested by Seed and Harder (1990) appear to be overly conservative for some soils and field conditions. The workshop participants recommend K_σ values defined by the curves in Fig. 14 or (31). Because K_σ values are usually applied to depths greater than those verified for the simplified procedure, special expertise is generally required for their application.
4. Procedures for evaluation of liquefaction resistance beneath sloping ground or embankments (slopes greater than about 6%) have not been developed to a level allowable for routine use. Special expertise is required for evaluation of liquefaction resistance beneath sloping ground.
5. Moment magnitude M_w should be used for liquefaction resistance calculations. Magnitude, as used in the simplified procedure, is a measure of the duration of strong ground shaking. The present magnitude criteria are conservative and should not be corrected for source mechanism, style of faulting, distance from the energy source, subsurface bedrock topography (basin effect), or tectonic region (eastern versus western U.S. earthquakes).
6. The peak acceleration a_{max} applied in the procedure is the peak horizontal acceleration that would occur at ground surface in the absence of pore pressure increases or liquefaction. Attenuation relationships compatible with soil conditions at a site should be applied in estimating a_{max}. Relationships based on the geometric mean of the peak horizontal accelerations are preferred, but use of relationships based on peak horizontal acceleration is allowable and conservative. Where site conditions are incompatible with existing attenuation relationships, site-specific response calculations, using programs such as SHAKE or DESRA, should be used. The least preferable technique is application of amplification factors.

ACKNOWLEDGMENTS

Financial support for the January 1996 workshop was provided by the NCEER. Support for a second workshop in August 1998 was provided by both NCEER and the National Science Foundation. Brigham Young

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

University graduate students Steven Noble, Samuel Gilstrap, and Curt Peterson, assisted in organizing and conducting the workshops.

REFERENCES

Ambraseys, N. N. (1988). ''Engineering seismology.'' *Earthquake Engrg. and Struct. Dynamics*, 17, 1–105.

Andrus, R. D., and Stokoe, K. H., II (1997). ''Liquefaction resistance based on shear wave velocity.'' *Proc., NCEER Workshop on Evaluation of Liquefaction Resistance of Soils*, Nat. Ctr. for Earthquake Engrg. Res., State Univ. of New York at Buffalo, 89–128.

Andrus, R. D., and Stokoe, K. H., II (2000). ''Liquefaction resistance of soils from shear-wave velocity.'' *J. Geotech. and Geoenvir. Engrg.*, ASCE, 126(11), 1015–1025.

Arango, I. (1996). ''Magnitude scaling factors for soil liquefaction evaluations.'' *J. Geotech. Engrg.*, ASCE, 122(11), 929–936.

ASTM. (2000). ''Annual book of ASTM standards.'' *04.08, D 1586-99*, West Conshohocken, Pa.

Castro, G. (1995). ''Empirical methods in liquefaction evaluation.'' Primer Ciclo d Conferencias Internationales, Leonardo Zeevaert, Universidad Nacional Autonoma de Mexico, Mexico City.

Finn, W. D. L., Martin, G. R., and Lee, K. W. (1977). ''An effective stress model for liquefaction.'' *J. Geotech. Engrg Div.*, ASCE, 103(6), 517—533.

Gibbs, H. J., and Holtz, W. G. (1957). ''Research on determining the density of sand by spoon penetration testing.'' *Proc., 4th Int. Conf. on Soil Mech. and Found. Engrg.*, Vol. I, 35–39.

Gilstrap, S. D., and Youd, T. L. (1998). ''CPT based liquefaction resistance analyses using case histories.'' *Tech. Rep. CEG-90-01*, Dept. of Civ. and Envir. Engrg., Brigham Young University, Provo, Utah.

Golesorkhi, R. (1989). ''Factors influencing the computational determination of earthquake-induced shear stresses in sandy soils.'' PhD dissertation, University of California at Berkeley.

Harder, L. F., Jr. (1988). ''Use of penetration tests to determine the cyclic loading resistance of gravelly soils during earthquake shaking.'' PhD dissertation, University of California at Berkeley.

Harder, L. F., Jr. (1997). ''Application of the Becker Penetration test for evaluating the liquefaction potential of gravelly soils.'' *Proc., NCEER Workshop on Evaluation of Liquefaction Resistance of Soils*, National Center for Engineering Research, Buffalo, 129–148.

Harder, L. F., Jr., and Boulanger, R. W. (1997). ''Application of K_σ and K_α correction factors.'' *Proc., NCEER Workshop on Evaluation of Liquefaction Resistance of Soils*, Nat. Ctr. for Earthquake Engrg. Res., State Univ. of New York at Buffalo, 167–190.

Harder, L. F., Jr., and Seed, H. B. (1986). ''Determination of penetration resistance for coarse-grained soils using the Becker hammer drill.'' *Rep. UCB/EERC-86/06*, Earthquake Engrg. Res. Ctr., University of California at Berkeley.

Hynes, M. E., and Olsen, R. S. (1999). ''Influence of confining stress on liquefaction resistance.'' *Proc., Int. Workshop on Phys. and Mech. of Soil Liquefaction*, Balkema, Rotterdam, The Netherlands, 145–152.

Idriss, I. M. (1985). ''Evaluating seismic risk in engineering practice.'' *Proc., 11th Int. Conf. on Soil Mech. and Found. Engrg.*, Vol. 1, 255–320.

Idriss, I. M. (1990). ''Response of soft soil sites during earthquakes.'' *Proc., H. Bolton Seed Memorial Symp.*, Vol. 2, BiTech Publishers, Ltd., Vancouver, 273–290.

Idriss, I. M. (1991). ''Earthquake ground motions at soft soil sites.'' *Proc., 2nd Int. Conf. on Recent Adv. in Geotech. Earthquake Engrg. and Soil Dyn.*, Vol. 3, 2265–2271.

Kayen, R. E., and Mitchell, J. K. (1997). ''Assessment of liquefaction potential during earthquakes by Arias intensity.'' *J. Geotech and Geoenvir. Engrg.*, ASCE, 123(12), 1162–1174.

Kayen, R. E., Mitchell, J. K., Seed, R. B., Lodge, A., Nishio, S., and Coutinho, R. (1992). ''Evaluation of SPT-, CPT-, and shear wave-based methods for liquefaction potential assessment using Loma Prieta data.'' *Proc., 4th Japan-U.S. Workshop on Earthquake-Resistant Des. of Lifeline Fac. and Countermeasures for Soil Liquefaction*, Vol. 1, 177–204.

Kramer S. L. (1996). *Geotechnical earthquake engineering*, Prentice-Hall, Englewood Cliffs, N.J., 653.

Liao, S., and Whitman, R. V. (1986a). ''Overburden correction factors for SPT in sand.'' *J. Geotech. Engrg.*, ASCE, 112(3), 373–377.

Liao, S. S. C., Veneziano, D., and Whitman, R. V. (1988). ''Regression models for evaluating liquefaction probability.'' *J. Geotech. Engrg.*, ASCE, 114(4), 389–411.

Liao, S. S. C., and Whitman, R. V. (1986b). ''Catalogue of liquefaction and non-liquefaction occurrences during earthquakes.'' *Res. Rep.*, Dept. of Civ. Engrg., Massachusetts Institute of Technology, Cambridge, Mass.

Lodge, A. L. (1994). ''Shear wave velocity measurements for subsurface characterization.'' PhD dissertation, University of California at Berkeley.

Marcuson, W. F., III (1978). ''Definition of terms related to liquefaction.'' *J. Geotech. Engrg. Div.*, ASCE, 104(9), 1197–1200.

Marcuson, W. F., III, and Bieganousky, W. A. (1977a). ''Laboratory standard penetration tests on fine sands.'' *J. Geotech. Engrg. Div.*, ASCE, 103(6), 565–588.

Marcuson, W. F., III, and Bieganousky, W. A. (1977b). ''SPT and relative density in coarse sands.'' *J. Geotech. Engrg. Div.*, ASCE, 103(11), 1295–1309.

National Research Council (NRC). (1985). *Liquefaction of soils during earthquakes*, National Academy Press, Washington, D.C.

Olsen, R. S. (1984). ''Liquefaction analysis using the cone penetrometer test (CPT).'' *Proc., 8th World Conf. on Earthquake Engrg.*, Vol. 3, 247–254.

Olsen, R. S. (1997). ''Cyclic liquefaction based on the cone penetration test.'' *Proc., NCEER Workshop on Evaluation of Liquefaction Resistance of Soils*, Nat. Ctr. for Earthquake Engrg. Res., State Univ. of New York at Buffalo, 225–276.

Robertson, P. K. (1990). ''Soil classification using CPT.'' *Can. Geotech. J.*, Ottawa, 27(1), 151–158.

Robertson, P. K., and Fear, C. E. (1995). ''Liquefaction of sands and its evaluation.'' *Proc., 1st Int. Conf. on Earthquake Geotech. Engrg.*

Robertson, P. K., Woeller, D. J., and Finn, W. D. (1992). ''Seismic cone penetration test for evaluating liquefaction potential under cyclic loading.'' *Can. Geotech. J.*, Ottawa, 29, 686–695.

Robertson, P. K., and Wride, C. E. (1998). ''Evaluating cyclic liquefaction potential using the cone penetration test.'' *Can. Geotech. J.*, Ottawa, 35(3), 442–459.

Schnabel, P. B., Lysmer, J., and Seed, H. B. (1972). ''A computer program for earthquake response analysis of horizontally layered sites.'' *Rep. No. EERC 72-12*, University of California at Berkeley.

Seed, H. B. (1979). ''Soil liquefaction and cyclic mobility evaluation for level ground during earthquakes.'' *J. Geotech. Engrg. Div.*, ASCE, 105(2), 201–255.

Seed, H. B. (1983). ''Earthquake-resistant design of earth dams.'' *Proc., Symp. Seismic Des. of Earth Dams and Caverns*, ASCE, New York, 41–64.

Seed, H. B., and Idriss, I. M. (1971). ''Simplified procedure for evaluating soil liquefaction potential.'' *J. Geotech. Engrg. Div.*, ASCE, 97(9), 1249–1273.

Seed, R. B., Dickenson, S. E., Rau, G. A., White, R. K., and Mok, C. M. (1994). ''Site effects on strong shaking and seismic risk: Recent developments and their impact on seismic design codes and practice.'' *Proc., Struct. Congr. II*, Vol. 1, ASCE, New York, 573–578.

Seed, R. B., and Harder, L. F., Jr. (1990). ''SPT-based analysis of cyclic pore pressure generation and undrained residual strength.'' *Proc., H. Bolton Seed Memorial Symp.*, BiTech Publishers Ltd., Vancouver, 351–376.

Seed, H. B., and Idriss, I. M. (1982). ''Ground motions and soil liquefaction during earthquakes.'' Earthquake Engineering Research Institute Monograph, Oakland, Calif.

Seed, H. B., Tokimatsu, K., Harder, L. F., and Chung, R. M. (1985). ''The influence of SPT procedures in soil liquefaction resistance evaluations.'' *J. Geotech. Engrg.*, ASCE, 111(12), 1425–1445.

Skempton, A. K. (1986). ''Standard penetration test procedures and the effects in sands of overburden pressure, relative density, particle size, aging, and overconsolidation.'' *Géotechnique*, London, 36(3), 425–447.

Stark, T. D., and Olson, S. M. (1995). ''Liquefaction resistance using CPT and field case histories.'' *J. Geotech. Engrg.*, ASCE, 121(12), 856–869.

Stokoe, K. H., II, Lee, S. H. H., and Knox, D. P. (1985). ''Shear moduli measurements under true triaxial stresses.'' *Advances in the art of testing under cyclic conditions*, ASCE, New York, 166–185.

Suzuki, Y., Tokimatsu, K., Koyamada, K., Taya, Y., and Kubota, Y. (1995). ''Field correlation of soil liquefaction based on CPT data.'' *Proc., Int. Symp. on Cone Penetration Testing*, Vol. 2, 583–588.

Sy, A., and Campanella, R. G. (1994). ''Becker and standard penetration tests (BPT-SPT) correlations with consideration of casing friction.'' *Can. Geotech. J.*, Ottawa, 31, 343–356.

Sy, A., Campanella, R. G., and Stewart, R. A. (1995). ''BPT-SPT correlations for evaluation of liquefaction resistance in gravelly soils.'' *Proc., Spec. Session on Dyn. Properties of Gravelly Soil*, ASCE, New York.

Sykora, D. W. (1987). ''Creation of a data base of seismic shear wave velocities for correlation analysis.'' *Geotech. Lab. Misc. Paper GL-87-26*, U.S. Army Engr. Waterways Experiment Station, Vicksburg, Miss.

Transportation Research Board (TRB). (1999). ''TRB workshop on new approaches to liquefaction analysis.'' *Publ. No. FHWA-RD-99-165*, Federal Highway Administration, Washington, D.C. (on CD-ROM).

Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

Tokimatsu, K., and Uchida, A. (1990). ''Correlation between liquefaction resistance and shear wave velocity.'' *Soils and Found.*, Tokyo, 30(2), 33–42.
Vreugdenhil, R., Davis, R., and Berrill, J. (1994). ''Interpretation of cone penetration results in multilayered soils.'' *Int. J. Numer. and Analytical Methods in Geomech.*, 18, 585–599.
Youd, T. L. (1993). ''Liquefaction-induced lateral spread displacement.'' *NCEL Tech. Note N-1862*, U.S. Navy, Port Hueneme, Calif., 44.
Youd, T. L., and Hoose, S. N. (1977). ''Liquefaction susceptibility and geologic setting.'' *Proc., 6th World Conf. on Earthquake Engrg.*, Vol. 3, Prentice-Hall, Englewood Cliffs, N.J., 2189–2194.
Youd, T. L., and Idriss, I. M., eds. (1997). *Proc., NCEER Workshop on Evaluation of Liquefaction Resistance of Soils*, Nat. Ctr. for Earthquake Engrg. Res., State Univ. of New York at Buffalo.
Youd, T. L., Kayen, R. E., and Mitchell, J. K. (1997). ''Liquefaction criteria based on energy content of seismograms.'' *Proc., NCEER Workshop on Evaluation of Liquefaction Resistance of Soils*, Nat. Ctr. for Earthquake Engrg. Res., State Univ. of New York at Buffalo, 217–224.
Youd, T. L., and Noble, S. K. (1997a). ''Magnitude scaling factors.'' *Proc., NCEER Workshop on Evaluation of Liquefaction Resistance of Soils*, Nat. Ctr. for Earthquake Engrg. Res., State Univ. of New York at Buffalo, 149–165.
Youd, T. L., and Noble, S. K. (1997b). ''Liquefaction criteria based on statistical and probabilistic analyses.'' *Proc., NCEER Workshop on Evaluation of Liquefaction Resistance of Soils*, Nat. Ctr. for Earthquake Engrg. Res., State Univ. of New York at Buffalo, 201–215.
Youd, T. L., and Perkins, D. M. (1978). ''Mapping of liquefaction-induced ground failure potential.'' *J. Geotech. Engrg. Div.*, ASCE, 104(4), 433–446.

NOTATION

The following symbols are used in this paper:

a, b = curve fitting parameters for use with V_s criteria for evaluating liquefaction resistance;
$a_{\max}$ = peak horizontal acceleration at ground surface;
C_B = correction factor for borehole diameter;
C_E = correction factor for hammer energy;
C_N = correction factor for overburden pressure applied to SPT;
C_Q = correction factor for overburden pressure applied to CPT;
C_R = correction factor for drilling rod length;
C_S = correction factor for split spoon sampler without liners;
$\mathrm{CRR}_{7.5}$ = cyclic resistance ratio for $M_w = 7.5$ earthquakes;
d_c = diameter of CPT tip;
F = normalized friction ratio;
f = exponent estimated from site conditions used in calculation of K_σ;
f_s = sleeve friction measured with CPT;
g = acceleration of gravity;
H = thickness of thin granular layer between softer sediment layers;
I_c = soil behavior type index for use with CPT liquefaction criteria;
K_c = correction factor for grain characteristics applied to CPT;
K_H = thin-layer correction factor for use with CPT;
K_α = correction factor for soil layers subjected to large static shear stresses;
K_σ = correction factor for soil layers subjected to large static normal stresses;
M_L = local or Richter magnitude of earthquake;
M_s = surface-wave magnitude of earthquake;
M_w = moment magnitude of earthquake;
m_B = long period body-wave magnitude of earthquake;
m_b = short period body-wave magnitude of earthquake;
N_m = measured standard penetration resistance;
$(N_1)_{60}$ = corrected standard penetration resistance;
$(N_1)_{60cs}$ = $(N_1)_{60}$ adjusted to equivalent clean-sand value;
n = exponent used in normalizing CPT resistance for overburden stress;
P_a = atmospheric pressure, approximately 100 kPa;
P_L = probability of liquefaction;
Q = normalized and dimensionless cone penetration resistance;
q_{c1N} = normalized cone penetration resistance;
$(q_{c1N})_{cs}$ = normalized cone penetration resistance adjusted to equivalent clean-sand value;
r_d = stress reduction coefficient to account for flexibility in soil profile;
V_s = measured shear-wave velocity;
V_{s1} = overburden-stress corrected shear-wave velocity;
V_{s1}^* = limiting upper value of V_{s1} for liquefaction occurrences;
z = depth below ground surface (m);
α, β = coefficients, that are functions of fines content, used to correct $(N_1)_{60}$ to $(N_1)_{60cs}$;
σ'_{vo} = effective overburden pressure;
τ_{av} = average horizontal shear stress acting on soil layer during shaking generated by given earthquake; and
τ_{st} = static shear stress acting on soil element due to gravitational forces.

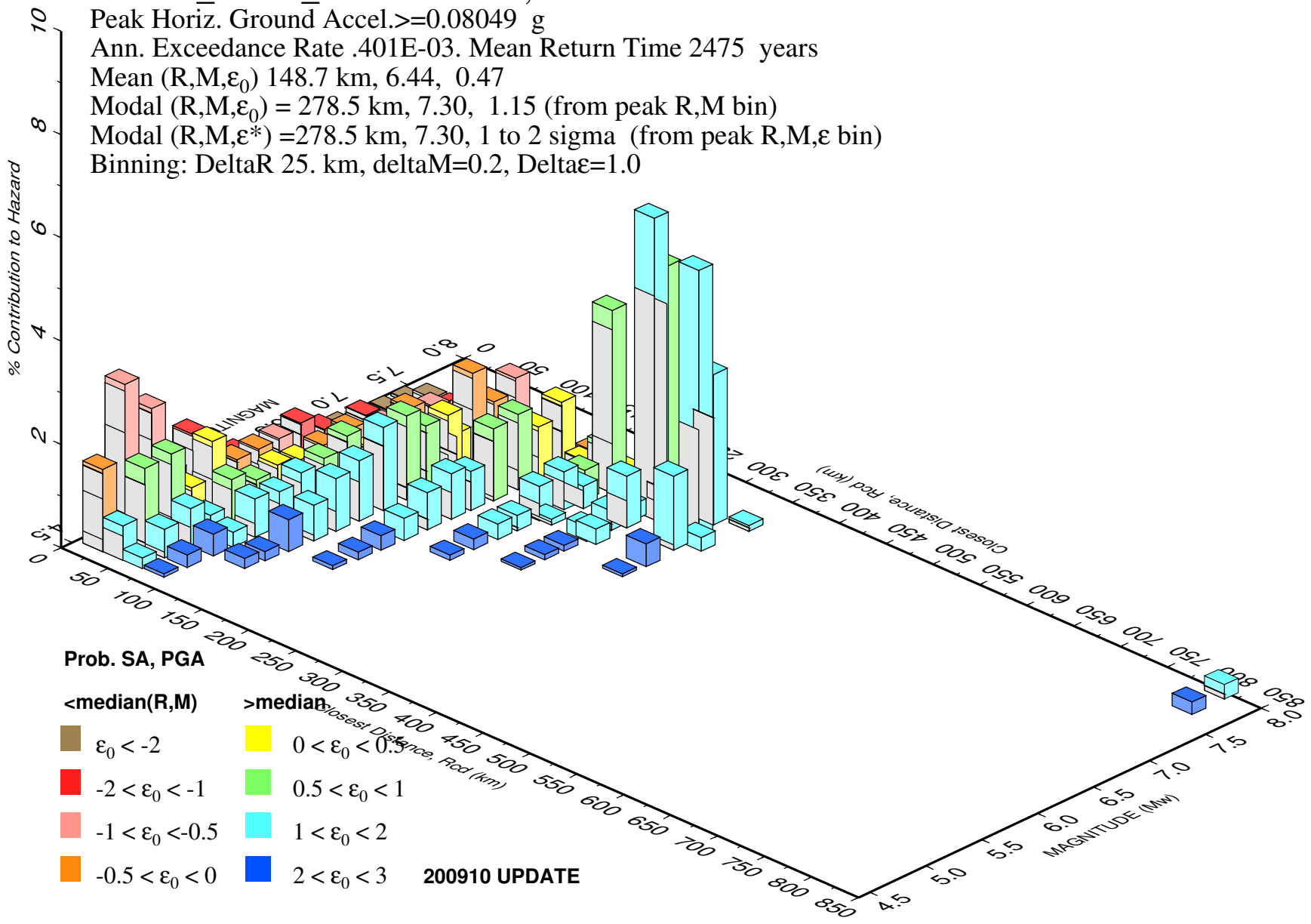
Downloaded 12 Aug 2009 to 208.216.231.17. Redistribution subject to ASCE license or copyright; see http://pubs.asce.org/copyright

REFERENCE 2

United States Geological Survey, "PSH Deaggregation on NEHRP BC Rock", 2008.

PSH Deaggregation on NEHRP BC rock
Belews_Creek_St 80.049º W, 36.307 N.

Peak Horiz. Ground Accel.>=0.08049 g
Ann. Exceedance Rate .401E-03. Mean Return Time 2475 years
Mean (R,M,ε_0) 148.7 km, 6.44, 0.47
Modal (R,M,ε_0) = 278.5 km, 7.30, 1.15 (from peak R,M bin)
Modal (R,M,ε*) =278.5 km, 7.30, 1 to 2 sigma (from peak R,M,ε bin)
Binning: DeltaR 25. km, deltaM=0.2, Deltaε=1.0



OBJECTIVE:

Perform seepage and slope stability analyses of the existing Ash Dike at Duke Energy's Belews Creek Steam Station. Seepage and/or stability analyses were performed for the following conditions: steady-state (static) normal pool, steady-state (static) pool from the 100-year storm event, steady-state (static) pool elevation of 760, steady-state (static) pool elevation of 745.63, pseudo-static with steady state seepage, and rapid drawdown.

SUMMARY:

Slope stability analyses for the Ash Dike indicate that minimum factor of safety requirements for the steady-state seepage conditions are less than current NCDENR safety factor requirements. Slope stability results for the pseudo-static and rapid drawdown conditions indicate that the safety factor requirements are met.

CALCULATIONS:

1. Determine target minimum safety factors for analyses

State and federal regulations were consulted to select target minimum safety factors, summarized below in Table 1.

TABLE 1: TARGET MINIMUM SAFETY FACTORS

Condition	Minimum Safety Factor			Selected Safety Factor
	NCDENR (Ref. 1)	USACE (Ref. 2)	USCS (NRCS) (Ref. 3)	
Steady-State Seepage	1.5	1.5	1.5	**1.5**
Pseudo-Static with Steady State Seepage	-	1.0	1.1	**1.0***
Surcharge Pool	-	1.4	-	**1.4**
Rapid Drawdown	1.25	1.1	1.2	**1.25**

*Refer to Section 4 of this calculation for a discussion of pseudo-static safety factors

2. Evaluate subsurface exploration data to compose representative cross-sections

S&ME developed three representative cross-sections of the Ash Dike for analyses. The cross-section locations were located at Ash Dike Stations 7+25, 10+00, and 12+00, and generally correspond with the tallest section and abutment sections of the dam where subsurface information was available.

2.1. Stratigraphy

During cross-section stratigraphy development, S&ME used information provided by Duke Energy including boring logs, drawings, and survey information. S&ME also used information collected during the subsurface exploration conducted in 2010 as part of this study. Please refer to the Appendices for figures showing cross-

section locations, figures showing the generalized cross-sections, descriptions of materials encountered, boring logs, and laboratory test results.

2.2. Water Levels

During development of water levels at the cross-section locations, S&ME used information provided by Duke Energy including drawings, survey information, and piezometer and observation well water level measurements collected during the February 2010 monitoring event. The normal pool elevation was assumed to be at 750.95 feet Mean Sea Level (M.S.L), which was the water surface elevation at the time of the February 2010 monitoring event.

The normal pool water surface elevation (750.95) was used during seepage and stability analyses for the steady-state and pseudo-static conditions. Seepage and stability analyses were also performed at pool elevations of 751.4 feet (the 100-year storm elevation), 760 feet, and 745.63 feet (the elevation of the invert of the outlet structure). A drawdown from elevation 750.95 feet to 745.63 feet was modeled corresponding to the invert of the outlet structure.

3. Estimate soil parameters for usage in seepage and slope stability analyses

Three generalized critical slope stability cross-sections were generated. The generalized cross-sections consist of five (5) material types: embankment fill, blanket drain, residuum, partially weathered rock (PWR), and rock. Rock was modeled as an impenetrable material. For the remainder of the soil or material types, the following soil parameters were estimated: unit weight, effective stress cohesion and friction angle, total stress cohesion and friction angle, and hydraulic conductivity.

3.1. Estimate unit weight for usage in slope stability analyses

Most of the material types are predominantly below the phreatic surface and therefore were modeled with saturated unit weights. However, the embankment fill consisted of materials above and below the phreatic surface. The fill material below the phreatic surface was modeled with a saturated unit weight and the material above the phreatic surface was modeled with a moist unit weight. Based on laboratory testing and our experience, the moist unit weights shown below were selected for use in the stability analyses.

TABLE 2: MATERIAL UNIT WEIGHTS

Material	γ_{sat} (pcf)	γ_{moist} (pcf)	Comments
Embankment Fill	123	121	
Blanket Drain	120	-	
Residuum	124	-	
PWR	140	-	
Rock	-	-	Impenetrable
Water	62.4	-	

3.2. Estimate shear stress parameters for usage in slope stability analyses

Consolidated-undrained (CU) triaxial testing was performed on relatively undisturbed Shelby tube samples of fill and residuum collected from the Ash Dike during the 2010 geotechnical exploration as summarized in Table L-1. In addition the results of previous CU triaxial tests performed by Duke Energy in1982 and 1983 were reviewed. This data is summarized in Table L-2 of this study.

Based on the testing, soil correlations, and our experience, the shear stress parameters shown in Table 3 of this calculation package were selected for use in the stability analyses.

TABLE 3: DESIGN MATERIAL SHEAR STRENGTHS

Material	Steady State and Surcharge Pool			Pseudo-Static		Rapid Drawdown			
	Effective Stress			Total Stress		Effective Stress		Total Stress	
	c' (ksf)	ϕ' (degrees)	τ* (ksf)	c_R (ksf)	ϕ_R (degrees)	c' (ksf)	ϕ' (degrees)	c_R (ksf)	ϕ_R (degrees)
Embankment Fill	-	-	$\tau = -0.0733\sigma'^{2}_{N} + 0.9021\sigma'_{N}$	1.3	12.5	0	38	1.3	12.5
Blanket Drain	0	36	-	0	36	0	36	-	-
Residuum	-	-	$\tau = -0.1078\sigma'^{2}_{N} + 1.1063\sigma'_{N}$	1.4	11.3	0	36	-	-
PWR	1.0	38	-	1.0	38	1.0	38	-	-
Rock	-	-	-	-	-	-	-	-	-

* The effective shear strengths for the embankment fill and residuum were represented using a curvilinear envelope as a function of the effective normal stress.

3.2.1. Discussion of rapid draw down shear stress parameters and methodology

The dam embankment fill material generally consists of sandy silt, silty sand, silty clay, and clayey silt with estimated permeabilities of less than $1x10^{-4}$ cm/s. Therefore, per Corps guidelines, the embankment fill was assumed to exhibit undrained behavior during rapid drawdown conditions. CU test "total stress" envelope data was used to develop the undrained strength envelope based on the Army Corps of Engineers procedures as summarized below.

The rapid draw down condition was analyzed using the general methodology of the US Army Corps of Engineers (3-Stage Method). The first stage computes effective and normal consolidation stresses along the base of each failure slice, assuming soil strengths and pore water pressures are equal to the steady-state seepage normal and shear stresses [Reference 2, pages G-2 – G-4].

The second stage uses the relationship between undrained shear strength and effective normal stress to calculate a modified strength envelope with y-intercept d and slope of Ψ [Reference 2, Figure G-3]. This undrained shear strength envelope corresponds to the isotropic consolidation case (K_c = 1). The undrained shear strength envelope can be calculated at follows:

$$d_{Kc=1} = c_R \frac{\cos\phi_R \cos\phi'}{1-\sin\phi_R}$$

$$\Psi_{Kc=1} = \arctan\frac{\sin\phi_R \cos\phi'}{1-\sin\phi_R}$$

Where: c_R = total stress cohesion intercept from CU test
ϕ_R = total stress friction angle from CU test
ϕ' = effective (drained) friction angle

The effective stress envelope corresponds to the maximum possible consolidation ratio ($K_c = K_f$). A composite shear strength envelope is created from the $K_c = 1$ case and the $K_c = K_f$ case [Reference 2, Figure G-4]. For each slice, the principal stress ratio is calculated and the undrained shear strength is linearly interpolated from the composite shear strength envelope. Slope stability is then calculated using the interpolated undrained shear strength values for each slice [Reference 2, pages G-4 – G-8].

The third stage compares the undrained shear strength calculated in stage 2 with the drained shear strength for each slice. The lower of these values for each slice are used to compute the slope stability safety factor for the third and final slope stability analysis [Reference 2, pages G-8 – G-9].

3.3. Estimate permeability parameters for usage in seepage analysis

Initial permeability parameters were estimated based on field and laboratory test results, then calibrated for each cross-section to develop a pore water pressure distribution that reasonably matched the total head (water level elevation) measurements taken during the February 2010 monitoring event.

Pore pressure dissipation tests conducted during CPT soundings on in-situ embankment fill materials indicated higher permeabilities than vertical laboratory flexible permeability testing performed on relatively undisturbed Shelby tube samples collected during soil test borings (S&ME Ref. 5 and 6). Based on this observation, the embankment fill was assumed to have a higher horizontal permeability (k_h) than vertical permeability (k_v). The relationship between horizontal and vertical permeabilities (k_v/k_h) was defined as the "k ratio" during seepage analyses. A k ratio less than 1 indicates a higher horizontal permeability than vertical permeability.

For each cross-section, the permeability and k ratio of the soil and material parameters were calibrated to approximate the total head values indicated by piezometers and observation wells measured during the February 2010 monitoring event. Thus, the permeability parameters vary slightly between cross-sections. The permeability parameters shown below were selected for use in the seepage analyses.

TABLE 4: HYDRAULIC CONDUCTIVITIES						
Material	Station 7+25		Station 10+00		Station 12+00	
	k_h (cm/sec)	k_v/k_h ratio	k_h (cm/sec)	k_v/k_h ratio	k_h (cm/sec)	k_v/k_h ratio
Embankment Fill	1.0 E-06	0.08	1.0 E-06	0.1	3.0 E-06	0.1
Blanket Drain	1.0 E-04	1	1.0 E-04	1	1.0 E-04	1
Residuum	1.0 E-04	0.1	1.0 E-04	1	1.0 E-05	1
PWR	1.0 E-05	0.1	1.0 E-05	1	1.0 E-05	1
Rock	1.0 E-07	0.1	1.0 E-05	1	-	-

4. Estimate peak ground acceleration for pseudo-static analyses

Pseudo-static analyses of the cross-sections were performed as a screening analysis to evaluate the potential for slope instability or excessive deformation as a result of seismic loading from an earthquake. The pseudo-static analysis method is considered conservative, and is well-accepted in practice. It is a screening-level analysis, in that it indicates whether there is a need for more rigorous analysis or not. As long as the minimum pseudo-static factor of safety is 1.0 or greater, then the dam slope is not expected to experience a significant slope failure or deformation in excess of 1 meter, and more rigorous analysis is generally not required.

For a pseudo-static analysis, the cyclic loading or shaking generated by an earthquake is represented by a horizontal force applied to each slice of the potential failure mass. A factor of safety for the slope stability is calculated as with the static analysis with the inclusion of this lateral force acting on the slope material. A seismic coefficient, *k*, that is expressed as a fraction or percentage of gravity is used in the slope stability analysis to calculate the horizontal force that is applied. The seismic coefficient is determined based on a reference ground acceleration that is chosen based on the design earthquake and the method used for the pseudo-static analyses.

The seismic coefficient was assumed to be 0.06 g, as calculated in the companion "Seismic Coefficient" (S&ME, Ref. 8) calculation package. This is slightly conservative when compared to the Hynes-Griffin Franklin method referenced in Duncan and Wright, 2005 (Ref. 4) that uses a coefficient equal to one half of the base rock motion, or 0.05 g.

5. Seepage Analyses

Seepage analyses for the dam were performed for the cross-sections using GeoStudio's SEEP/W 2007, version 7.17 computer program (Reference 7). During seepage analyses, the portions of the phreatic surface were modeled as zero pressure lines and/or points to approximate the phreatic surface observed in the monitoring wells and observed site conditions. Seepage input parameters (permeability and "k ratio") were then calibrated for each section to approximate observed total head conditions as measured in the piezometers and observation wells during the February 2010 monitoring event. Calibration was considered to be complete upon reasonable agreement of calculated head conditions versus measured head conditions.

Following calibration of the seepage model, a pore pressure condition less than hydrostatic conditions was observed in the embankment fill above the blanket drain as previously described by others, and as indicated by the total head contours skewing down and toward the upstream direction. S&ME believes that this condition is consistent with a partially functioning blanket drain, where the drain is permeable enough to provide some drainage within the embankment but not draw down the water surface globally as assumed in the design slope stability analyses. It is also likely due to the inferred anisotropic soil permeability conditions resulting from compaction of the fill materials. The reduced hydrostatic condition results in pore pressure conditions generally less than the hydrostatic condition.

6. Slope Stability Analyses

Slope stability analyses were evaluated by Spenser's method using GeoStudio's SLOPE/W 2007, version 7.17 computer program (Reference 7). Stability analyses were performed for the following conditions: steady-state (static) normal pool, steady-state (static) pool from the 100-year storm event, steady-state (static) pool elevation of 760, steady-state (static) pool elevation of 745.63, pseudo-static with steady state seepage, and rapid drawdown. Refer to the attached graphical results of the slope stability analyses for each condition modeled.

6.1. Steady-State, 100-year Pool, 760 Pool, and 745.63 Pool Conditions

Estimated consolidated, effective stress conditions were used to model the steady-state, 100-year pool, 760 pool, and 745.63 pool conditions. For each of these conditions, the downstream face of the dam was analyzed for slope stability assuming global failure and localized failures within the upper and lower portions of the embankment.

The results of the analyses are presented at the end of this calculation and by cross-section in Tables 5.1 through 5.3.

TABLE 5.1: SLOPE STABILITY RESULTS - EFFECTIVE STRESS STATION 7+25			
Condition Analyzed	**Calculated Safety Factor**	**Minimum Target Safety Factor**	**SF Criteria Met**
Steady State - Global (WSEL = 750.95)	1.58	1.5	Yes
Steady State - Upper (WSEL = 750.95)	1.96	1.5	Yes
Steady State - Lower (WSEL = 750.95)	1.55	1.5	Yes
100-yr Storm - Global (WSEL = 751.4)	1.58	1.4	Yes
100-yr Storm - Upper (WSEL = 751.4)	1.97	1.4	Yes
100-yr Storm - Lower (WSEL = 751.4)	1.55	1.4	Yes
Surcharge Pool - Global (WSEL = 760)	1.51	1.4	Yes
Surcharge Pool - Upper (WSEL = 760)	1.57	1.4	Yes
Surcharge Pool - Lower (WSEL = 760)	1.36*	1.4	Yes
Lowered Pool - Lower (WSEL = 745.63)	1.63	1.5	Yes

*Calculated safety factor rounds up to minimum target safety factor.

TABLE 5.2: SLOPE STABILITY RESULTS - EFFECTIVE STRESS STATION 10+00			
Steady State - Global (WSEL = 750.95)	1.46*	1.5	Yes
Steady State - Upper (WSEL = 750.95)	2.08	1.5	Yes
Steady State - Lower (WSEL = 750.95)	1.79	1.5	Yes
100-yr Storm - Global (WSEL = 751.4)	1.46	1.4	Yes
100-yr Storm - Upper (WSEL = 751.4)	2.08	1.4	Yes
100-yr Storm - Lower (WSEL = 751.4)	1.79	1.4	Yes
Surcharge Pool - Global (WSEL = 760)	1.42	1.4	Yes
Surcharge Pool - Upper (WSEL = 760)	1.72	1.4	Yes
Surcharge Pool - Lower (WSEL = 760)	1.46	1.4	Yes
Lowered Pool - Lower (WSEL = 745.63)	1.83	1.5	Yes

*Calculated safety factor rounds up to minimum target safety factor.

TABLE 5.3: SLOPE STABILITY RESULTS - EFFECTIVE STRESS STATION 12+00			
Steady State - Global (WSEL = 750.95)	1.51	1.5	Yes
Steady State - Upper (WSEL = 750.95)	2.06	1.5	Yes
Steady State - Lower (WSEL = 750.95)	**1.37**	1.5	**No**
100-yr Storm - Global (WSEL = 751.4)	1.52	1.4	Yes
100-yr Storm - Upper (WSEL = 751.4)	2.09	1.4	Yes
100-yr Storm - Lower (WSEL = 751.4)	1.37*	1.4	Yes
Surcharge Pool - Global (WSEL = 760)	**1.33**	1.4	**No**
Surcharge Pool - Upper (WSEL = 760)	1.92	1.4	Yes
Surcharge Pool - Lower (WSEL = 760)	**1.05**	1.4	**No**
Lowered Pool - Lower (WSEL = 745.63)	1.47*	1.5	No

*Calculated safety factor rounds up to minimum target safety factor.

6.2. Pseudostatic Condition

For the pseudo-static analyses, soils that are saturated or near saturated are assumed to behave in an undrained manner during the rapid earthquake loading. For the cross sections analyzed for the subject dike, portions of the embankment were above the water level. However, in most cases the entire soil unit was modeled as being undrained rather than splitting the material into two parts based on the location of the assumed water level. Materials assumed to be undrained during seismic loading included the embankment fill and residual soils.

Very free-draining materials (i.e. permeabilities of $1x10^{-4}$ cm/s or les) such as an open-graded aggregate drain can be assumed to remain in a drained state during the earthquake due to their free draining character even if under the water table. This was assumed to be the case with the remaining materials.

The undrained shear strength of the soils were represented by using the "R-envelope" from the CU triaxial tests as shown in the Appendices. Use of the CU R-envelope to represent undrained shear strength is not precisely correct from a soil mechanics perspective, but it is conservative and is well-established by precedent. Duncan and Wright include a concise description of this method in their book "Soil Strength and Slope Stability" (2005). The undrained shear strength of soils is typically highly dependant on the stresses the soil has been allowed to consolidate under in the past. Use of the R-envelope is a method to approximately relate the available undrained shear strength of the soil to steady-state seepage and stress conditions present in the soil before the earthquake in a single-stage analysis. The water table is included in the analysis so the program can compute pore water pressures and determine the strengths based on effective stresses using the R-envelope.

The results of the analyses are presented at the end of this calculation and in Table 6.

TABLE 6: SLOPE STABILITY RESULTS - PSEUDOSTATIC

Station	Condition Analyzed	Calculated Safety Factor	Minimum Target Safety Factor	SF Criteria Met
7+25	Pseudostatic - Global	1.25	1.0	Yes
7+25	Pseudostatic - Upper	1.63	1.0	Yes
7+25	Pseudostatic - Lower	1.99	1.0	Yes
10+00	Pseudostatic - Global	1.13	1.0	Yes
10+00	Pseudostatic - Upper	1.94	1.0	Yes
10+00	Pseudostatic - Lower	1.49	1.0	Yes
12+00	Pseudostatic - Global	1.17	1.0	Yes
12+00	Pseudostatic - Upper	1.75	1.0	Yes
12+00	Pseudostatic - Lower	1.69	1.0	Yes

6.3 Rapid draw down condition

The rapid draw down condition was modeled by SLOPE/W assuming the water surface dropped from the normal pool elevation of 750.95 feet during the February 2010 monitoring event to an elevation of 745.63 feet which represents the invert of the outlet pipe. The upstream rapid drawdown condition was analyzed using the general methodology of the US Army Corps of Engineers (3-Stage Method) [Reference 2] using the SLOPE/W program. The results of the rapid drawdown analysis are summarized in the following table:

TABLE 7: SLOPE STABILITY RESULTS - RAPID DRAWDOWN

Station	Condition Analyzed	Calculated Safety Factor	Minimum Target Safety Factor	SF Criteria Met
7+25	Upstream	1.47	1.25	Yes
10+00	Upstream	1.34	1.25	Yes
12+00	Upstream	1.45	1.25	Yes

CONCLUSIONS:

The slope stability analyses indicate a calculated safety factor of 1.37 for the downstream steady-state seepage condition along the lower portion of Station 12+00, which is less than the NCDENR minimum safety factor of 1.5. The calculated safety factor may be indicative of local instability in the vicinity of the lower portion of the embankment around Station 12+00, which is consistent with current and historical observations. Stability analyses indicate that lowering the water table to 745.63 may yield a safety factor of 1.47 for the same area.

The downstream pseudo-static and upstream rapid drawdown slope stability analyses indicated minimum safety factors greater than 1.0 and 1.25, respectively. Therefore, the embankment is stable for those conditions.

REFERENCES:

1. "North Carolina Adminsitrative Code - Title 15A Department of Environment and Natural Resources of Subchapter 2K - Dam Safety." North Carolina Department of Environmental and Natural Resources, June 15, 1980.

2. "Engineering and Design – Slope Stability." EM 1110-2-1902, United States Army Corps of Engineers, October 31, 2003.

3. "Earth Dams and Reservoirs." Technical Release No. 60, U.S. Department of Agriculture Soil Conservation Service Engineering Division, October 1985.

4. J.M. Duncan and S.G. Wright, "Soil Strength and Slope Stability", John Wiley and Sons, Inc., 2005

5. S&ME Boring Logs, 2010.

6. S&ME Laboratory Test Results, 2010

7. S&ME SEEP/W and SLOPE/W Output, 2010

8. S&ME Seismic Coefficient Calculation Package

REFERENCE 1

"North Carolina Adminsitrative Code - Title 15A Department of Environment and Natural Resources of Subchapter 2K - Dam Safety." North Carolina Department of Environmental and Natural Resources, June 15, 1980.

included in the analysis. The flow net and seepage analysis shall be documented in the final design report, as required by .0201(d)(4) of this Section.
(d) Piezometers for confirming the location of the phreatic surface assumed for seepage and slope stability analyses should be considered by the design engineer for class A and class B dams and shall be required for class C dams. Where piezometers are required, their design, depths, and locations shall be provided as required in .0201(d) and .0212(b) of this Section.

History Note: Statutory Authority G.S. 143-215.26; 143-215.27; 143-215.31;
Eff. June 15, 1980.

.0208 STRUCTURAL STABILITY AND SLOPE PROTECTION
(a) Design and construction of dams to assure structural stability shall be consistent with modern engineering practice. The scope and degree of precision that will be required for a specific project will depend on the conditions of the site and the damage potential of the proposed structure. Consideration in design for structural stability shall include, but are not necessarily limited to, the following:
(1) the hazard potential of the dam under present downstream conditions and under conditions which would likely develop during the life of the reservoir;
(2) foundation bearing capacity, compressibility, and permeability; the extent and reliability of the site investigation; and the predictability of the site and foundation conditions;
(3) the reliability of construction materials, such as borrow soils, in terms of sufficient volume to complete construction without unanticipated interruption and in terms of predictability of physical properties such as strength, permeability, and compressibility;
(4) durability of construction materials;
(5) construction conditions at the site;
(6) the degree of quality control to be exercised during construction;
(7) pore pressure build-up during construction;
(8) the rate of filling the reservoir and the rate of possible reservoir drawdown;
(9) tailwater conditions and the impact of tailwater drawdown;
(10) possible effects of landslides and subsurface solution activity on the structural stability of the dam and spillway structures;
(11) the extent of piezometers and other devices which will be used to monitor the completed dam and the degree of access for inspections.
(b) Slope stability analyses should be considered by the design engineer for all embankment dams and may be required for class B and class C dams. Where slope stability analyses are required, documentation in the final design report shall include the design cross section(s) showing the soil parameters assumed for analysis, the location of the phreatic surface assumed for analysis, stability computations, and the location and computed safety factor(s) for the most critical circle(s) or failure wedge(s). A minimum factor of safety of 1.5 for slope stability for normal loading conditions, and 1.25 for quick drawdown conditions and for construction conditions, shall be required unless the design engineer provides a thoroughly documented basis for using other safety factors.
(c) Foundation bearing capacity and sliding base analyses should be considered for all dams and may be required for class B and C dams. Where bearing capacity or sliding base analyses are required, documentation of assumptions, computations, and safety factors shall be included in the final design report. A minimum factor of safety against bearing capacity and sliding wedge failure of 2.0 shall be required unless the design engineer provides a thoroughly documented basis for using other safety factors.

REFERENCE 2

"Engineering and Design – Slope Stability." EM 1110-2-1902, United States Army Corps of Engineers, October 31, 2003.

Table 3-1
Minimum Required Factors of Safety: New Earth and Rock-Fill Dams

Analysis Condition[1]	Required Minimum Factor of Safety	Slope
End-of-Construction (including staged construction)[2]	1.3	Upstream and Downstream
Long-term (Steady seepage, maximum storage pool, spillway crest or top of gates)	1.5	Downstream
Maximum surcharge pool[3]	1.4	Downstream
Rapid drawdown	1.1-1.3[4,5]	Upstream

[1] For earthquake loading, see ER 1110-2-1806 for guidance. An Engineer Circular, "Dynamic Analysis of Embankment Dams," is still in preparation.

[2] For embankments over 50 feet high on soft foundations and for embankments that will be subjected to pool loading during construction, a higher minimum end-of-construction factor of safety may be appropriate.

[3] Pool thrust from maximum surcharge level. Pore pressures are usually taken as those developed under steady-state seepage at maximum storage pool. However, for pervious foundations with no positive cutoff steady-state seepage may develop under maximum surcharge pool.

[4] Factor of safety (FS) to be used with improved method of analysis described in Appendix G.

[5] FS = 1.1 applies to drawdown from maximum surcharge pool; FS = 1.3 applies to drawdown from maximum storage pool.

For dams used in pump storage schemes or similar applications where rapid drawdown is a routine operating condition, higher factors of safety, e.g., 1.4-1.5, are appropriate. If consequences of an upstream failure are great, such as blockage of the outlet works resulting in a potential catastrophic failure, higher factors of safety should be considered.

(1) During construction of embankments, materials should be examined to ensure that they are consistent with the materials on which the design was based. Records of compaction, moisture, and density for fill materials should be compared with the compaction conditions on which the undrained shear strengths used in stability analyses were based.

(2) Particular attention should be given to determining if field compaction moisture contents of cohesive materials are significantly higher or dry unit weights are significantly lower than values on which design strengths were based. If so, undrained (UU, Q) shear strengths may be lower than the values used for design, and end-of-construction stability should be reevaluated. Undisturbed samples of cohesive materials should be taken during construction and unconsolidated-undrained (UU, Q) tests should be performed to verify end-of-construction stability.

d. Pore water pressure. Seepage analyses (flow nets or numerical analyses) should be performed to estimate pore water pressures for use in long-term stability computations. During operation of the reservoir, especially during initial filling and as each new record pool is experienced, an appropriate monitoring and evaluation program must be carried out. This is imperative to identify unexpected seepage conditions, abnormally high piezometric levels, and unexpected deformations or rates of deformations. As the reservoir is brought up and as higher pools are experienced, trends of piezometric levels versus reservoir stage can be used to project piezometric levels for maximum storage and maximum surcharge pool levels. This allows comparison of anticipated actual performance to the piezometric levels assumed during original design studies and analysis. These projections provide a firm basis to assess the stability of the downstream slope of the dam for future maximum loading conditions. If this process indicates that pore water pressures will be higher than those used in design stability analyses, additional analyses should be performed to verify long-term stability.

e. Loads on slopes. Loads imposed on slopes, such as those resulting from structures, vehicles, stored materials, etc. should be accounted for in stability analyses.

The stress σ'_c is the effective normal stress, or consolidation stress, on the slip surface before drawdown.

b. Second-stage shear strengths. Once the effective consolidation stresses have been calculated from the first-stage computations, shear strengths are estimated for the second stage. The shear strengths are estimated from a "composite," bilinear shear strength envelope. The envelope represents the lower bound of the R and S strength envelopes.

(1) The R envelope is determined by plotting a circle using the effective minor principal stress during consolidation, σ'_{3c}, and the principal stress difference at failure, $(\sigma_1 - \sigma_3)_f$, as shown in Figure G-1, together with the corresponding R envelope. Figure G-1a shows the envelope using conventional axes ($\sigma - \tau$); while Figure G-1b shows the envelope on a modified diagram of $(\sigma_1 - \sigma_3)_f$ versus σ_3. Neither envelope is a valid Mohr-Coulomb envelope, because they are plotted using one stress that existed during consolidation, σ'_{3c}, and another stress that existed at failure, $(\sigma_1 - \sigma_3)_f$. Accordingly, this envelope is not consistent with the fundamental principles of soil mechanics. It is empirical and should only be used in empirical procedures like the 1970 procedure for rapid drawdown.

(2) The composite envelope used to determine the shear strengths for the second-stage computations is shown in Figure G-2. The envelope represents the lower bound of the empirical R envelope described above, and the effective stress S envelope. Shear strengths are determined for the second-stage computations using the effective normal stress calculated for the first stage (from Equation G-1) and the composite envelope shown in Figure G-2. Shear strengths are determined in this manner for each slice whose base lies in material that does not drain freely.

c. Second-stage computations. The second-stage computations are performed to calculate the stability immediately after drawdown. For materials that do not drain freely the shear strengths are determined in the manner described in G-2b. These strengths are assigned as values of cohesion, c, with ϕ equal to zero. For materials that drain freely, effective stress shear strength parameters, c' and ϕ', are used, and appropriate pore water pressures are prescribed. The pore water pressures for free-draining materials should represent the values after drawdown has occurred and steady-state seepage has been established at the new lower water level. The pore water pressures for materials which do not drain freely are set equal to zero. If a portion of the slope remains submerged after drawdown, the external water pressures acting on the submerged part of the slope are calculated and applied as external loads to the surface of the slope.

G-3. Improved Method for Rapid Drawdown – Background

This method was developed by Lowe and Karafiath (1960), and modified by Wright and Duncan (1987) and Duncan, Wright, and Wong (1990). The method involves either two or three separate slope stability calculations for each trial slip surface. The first computation is the same as that for the Corps of Engineers' 1970 procedure and is used to calculate the effective stresses to which the soil is consolidated before drawdown. The second set of computations is performed using undrained shear strengths corresponding to the effective consolidation stresses calculated in the first stage. If the drained shear strength is less than the undrained shear strength for any slices, a third set of calculations is performed, using drained shear strengths for those slices. The factor of safety from the last stage (the second or third stage) is the factor of safety after rapid drawdown.

a. First-stage computations. The first-stage computations are the same as those for the Corps of Engineers' 1970 method. However, in addition to computing the consolidation normal stress on the base of each slice, σ'_c, the shear stress at consolidation, τ_c, is also calculated for each slice. The shear stress at consolidation is calculated by dividing the shear force (S) on the base of the slice by the length of the base, i.e.,

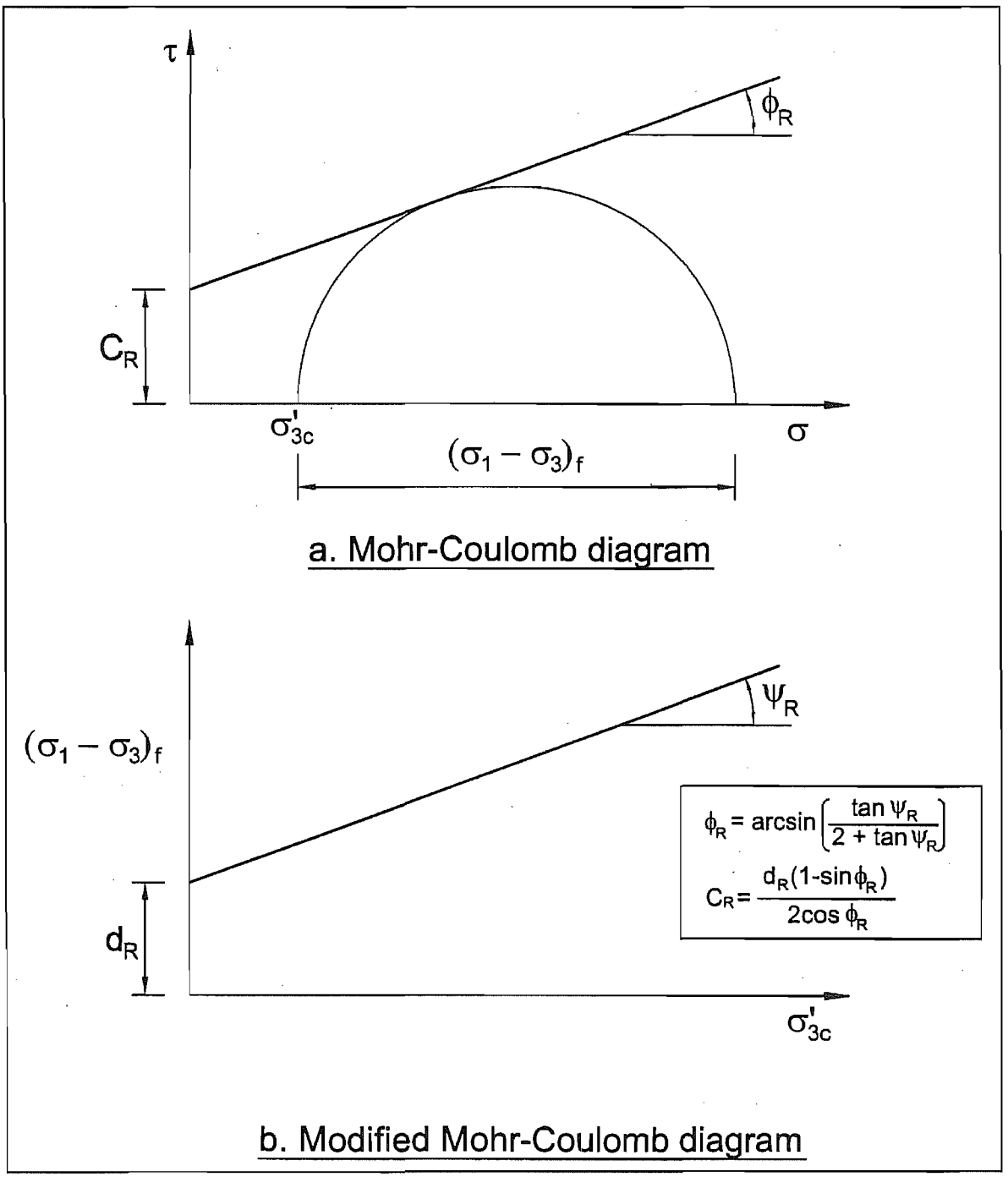


Figure G-1. R Shear strength envelope used in Corps of Engineers' (1970) method for rapid drawdown

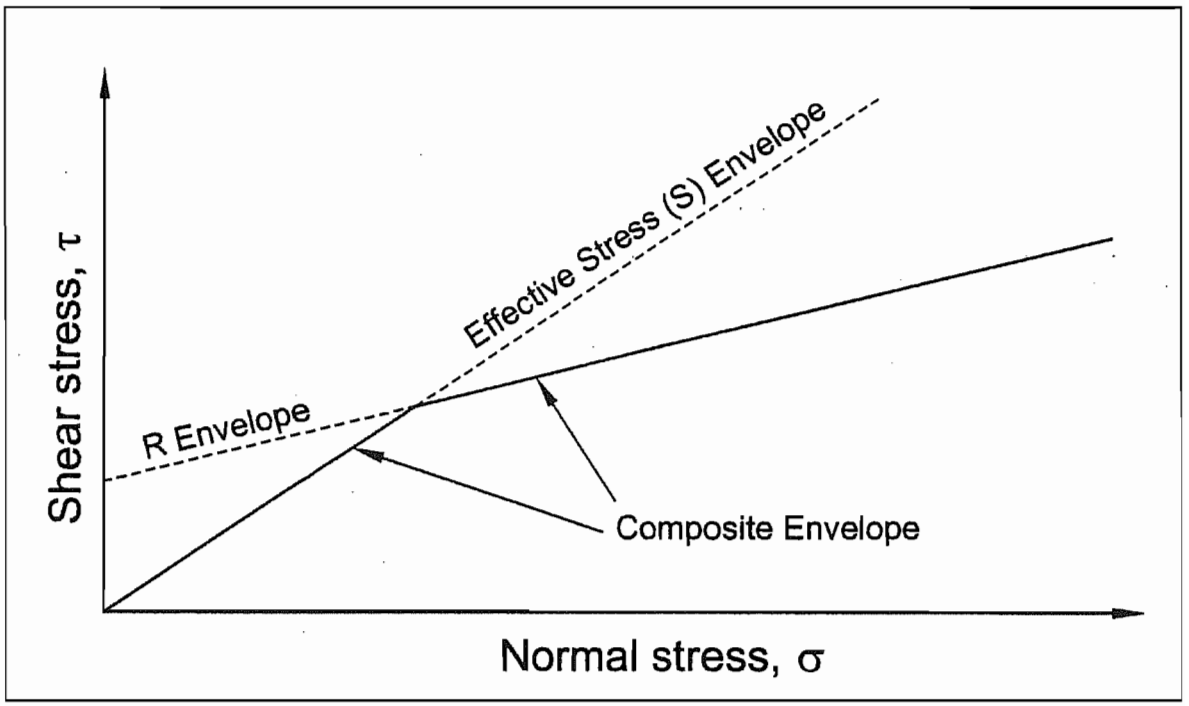


Figure G-2. Composite shear strength envelope used in Corps of Engineers' (1970) method for rapid drawdown

$$\tau_c = \frac{S}{\Delta \ell} \tag{G-2}$$

b. Second-stage shear strengths. Two shear strength relationships are used to evaluate shear strengths for the second-stage computations.

(1) The first is the relationship between undrained shear strength (shear stress on the failure plane at failure), τ_{ff}, and effective normal stress on the failure plane during consolidation, σ'_{fc}. This relationship can be determined directly from the results of isotropically consolidated-undrained (CU or R) tests, or it can be calculated from the strength parameters, c_R and ϕ_R, that are determined from the R envelope shown in Figure G-1.

(a) To determine the relationship between τ_{ff} and σ'_{fc} directly from the results of isotropically consolidated-undrained triaxial compression tests, the shear stress on the failure plane at failure, τ_{ff}, is plotted versus the effective stress on the failure plane at consolidation, σ'_{fc}. The values of τ_{ff} and σ'_{fc} are calculated using the following equations:

$$\tau_{ff} = \frac{(\sigma_1 - \sigma_3)_f}{2} \cos \phi' \tag{G-3}$$

and

$$\sigma'_{fc} = \sigma'_{3c} \tag{G-4}$$

where

$(\sigma_1 - \sigma_3)_f$ = principal stress difference at failure

ϕ' = effective stress angle of internal friction

σ'_{3c} = CU test consolidation pressure

σ'_{fc} is equal to σ'_{3c} because the consolidation pressure is the same on all planes in an isotropic consolidated undrained triaxial test.

(b) An example relationship of τ_{ff} vs. σ'_{fc} is shown in Figure G-3. The intercept and slope of this envelope are designated, $d_{K_c=1}$ and $\psi_{K_c=1}$. If values of τ_{ff} and σ'_{fc} are determined directly from the CU test results, the values of $d_{K_c=1}$ and $\psi_{K_c=1}$ are determined by drawing a line through the data and measuring the intercept and the slope as indicated in Figure G-3.

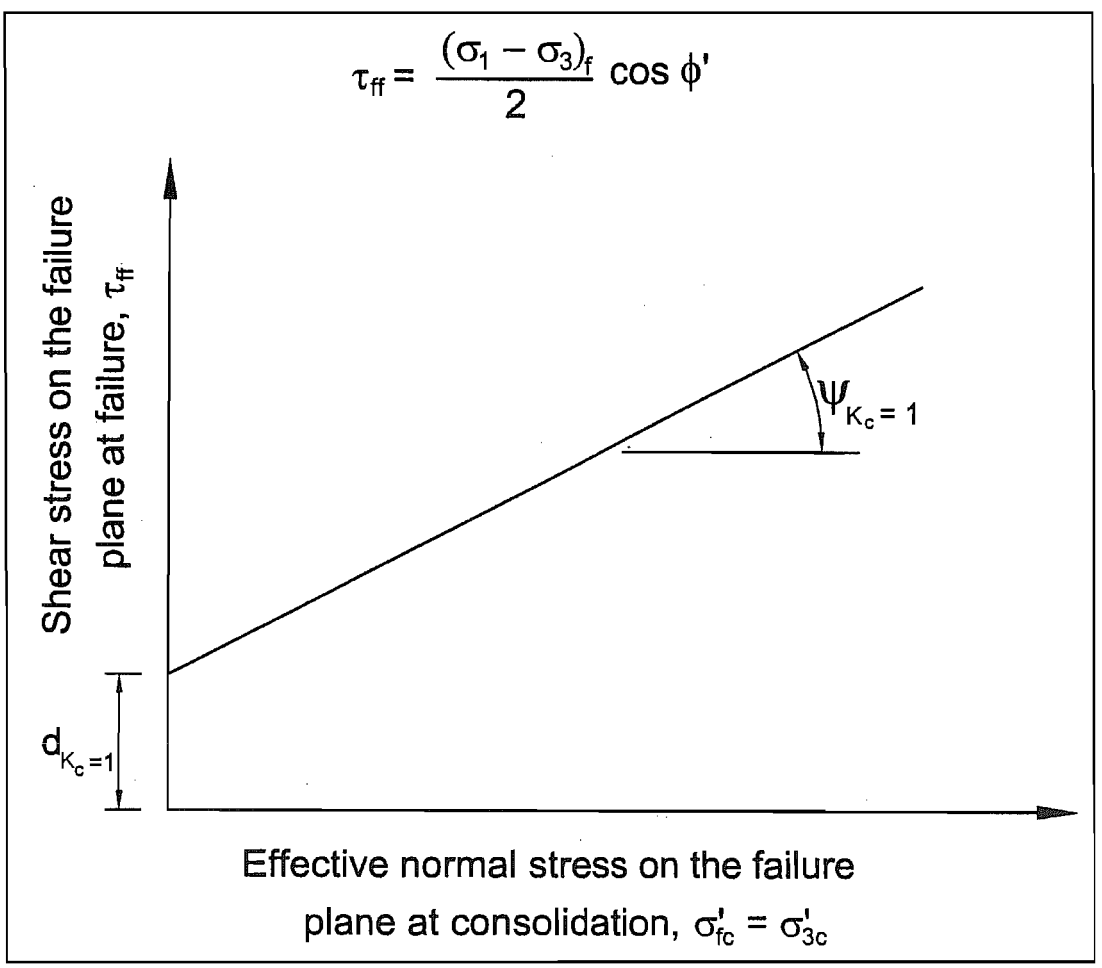


Figure G-3. τ_{ff} vs σ'_{fc} Shear strength envelope from isotropically consolidated undrained (CU or R) triaxial compression tests

(c) The values of $d_{K_c=1}$ and $\psi_{K_c=1}$ are related to the intercept and slope (c_R and ϕ_R) of the R-envelope shown in Figure G-1 and can be computed if c_R and ϕ_R have been evaluated. The relationships between the parameters $d_{K_c=1}$ and $\psi_{K_c=1}$ and the parameters c_R and ϕ_R are follows:

$$d_{K_c=1} = c_R \left(\frac{\cos \phi_R \cos \phi'}{1 - \sin \phi_R} \right) \tag{G-5}$$

$$\psi_{K_c=1} = \tan^{-1} \left(\frac{\sin \phi_R \cos \phi'}{1 - \sin \phi_R} \right) \tag{G-6}$$

(2) The other shear strength relationship needed for the second-stage computations is the effective stress envelope. Although this envelope is for drained strengths, it may also be viewed as an envelope representing the undrained shear strength of soil that is consolidated to stresses that bring the soil to failure before any undrained loading is applied. In this case, no additional load can be applied in undrained shear before the soil fails. In such a test, the stresses at failure are the same as those at consolidation.

(a) The two shear strength envelopes that are used to determine undrained shear strengths for the second-stage stability computations are shown in Figure G-4. Both envelopes represent relationships between undrained shear strength, τ_{ff}, and effective consolidation pressure on the failure plane, σ'_{fc}.

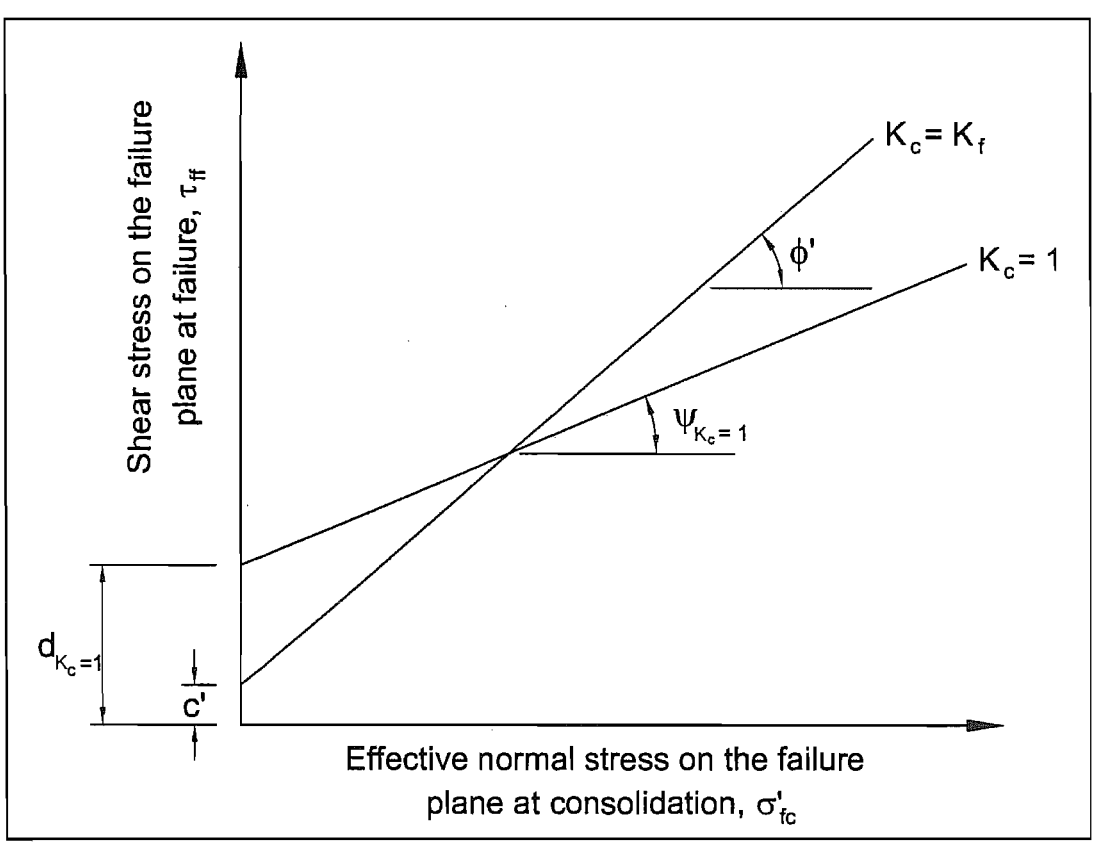


Figure G-4. τ_{ff} vs σ'_{fc} Shear strength envelope used for improved procedure for rapid drawdown analysis

(b) The two envelopes shown in Figure G-4 correspond to the extreme possible values of the ratio of $\sigma'_{1c}/\sigma'_{3c} = K_c$. As discussed above, one of the envelopes corresponds to isotropic consolidation, or $K_c = 1$, and the other corresponds to the maximum possible ratio, or $K_c = \sigma'_{1f}/\sigma'_{3f} = K_f$. The undrained shear strengths needed for the second-stage stability analyses are interpolated between these envelopes, using the value of K_c for each slice determined from the first stage computations as the basis for interpolating between the envelopes.

(c) As noted above, the values of K_c ranges from 1.0 to K_f. If $c' = 0$, the value of K_f is given by the following equation:

$$K_f = \frac{1+\sin\ \phi'}{1-\sin\ \phi'} \tag{G-7}$$

If c' is not equal to zero, the value of K_f varies with the effective consolidation pressure σ'_{fc}, as shown by the following equation:

$$K_f = \frac{(\sigma'_{fc}+c'\cos\ \phi')(1+\sin\ \phi')}{(\sigma'_{fc}-c'\cos\ \phi')(1-\sin\ \phi')} \tag{G-8}$$

(3) The following steps are used to compute undrained shear strength values for each slice using the stresses σ'_c and τ_c from the first-stage computations:

(a) Compute undrained shear strengths from the two shear strength envelopes shown in Figure G-3. The shear strengths are computed using the effective consolidation stress, σ'_c, as follows:

$$\tau_{(ff-K_c=1)} = d_{(K_c=1)} + \sigma'_c \tan(\psi_{K_c=1}) \tag{G-9}$$

$$\tau_{(ff-K_c=K_f)} = c' + \sigma'_c \tan(\phi') \tag{G-10}$$

(b) Compute the effective principal consolidation stress ratio at failure, K_f, from Equation G-7 or G-8.

(c) Calculate the principal stress ratio at consolidation, K_c, for the stresses on the base of the slice,

$$K_c = \frac{\sigma'_c + \tau_c \dfrac{\sin\ \phi'+1}{\cos\ \phi'}}{\sigma'_c + \tau_c \dfrac{\sin\ \phi'-1}{\cos\ \phi'}} \tag{G-11}$$

where the stresses σ'_c and τ_c are those from the first-stage computations.

Equation G-11 is derived by assuming that the orientation of the principal stresses during consolidation is the same as at failure, as suggested by Lowe and Karafiath (1960).

(d) Calculate, by linear interpolation between the two values of shear strength determined in Step a, the undrained shear strength, τ_{ff}, for the slice. The undrained shear strength is calculated using the following equation:

$$\tau_{ff} = \frac{(K_f - K_c)\tau_{ff-K_c=1} + (K_c - 1)\tau_{ff-K_c=K_f}}{K_f - 1} \quad \text{(G-12)}$$

c. Second-stage computations. The second-stage computations are performed to calculate stability immediately after drawdown, assuming that all low-permeability materials are undrained. The low-permeability materials are assigned undrained shear strength values calculated from Equation G-12, with ϕ set equal to zero. Effective stress shear strength parameters are used for materials that drain freely, and appropriate pore water pressures are prescribed. The pore water pressures for free-draining materials are those after drawdown has occurred and steady-state seepage has been reestablished. The pore water pressures in the low-permeability materials are set equal to zero. If a portion of the slope remains submerged after drawdown, the external water pressures acting on the submerged part of the slope are calculated and applied as external loads to the surface of the slope.

d. Strengths for third-stage computations. Once the second-stage computations have been completed, each slice is examined to determine if the drained strength would be less than the undrained strength determined from Equation G-12. The drained shear strength is estimated as follows:

(1) The total normal stress on the base of each slice is calculated by dividing the normal force, N, calculated in the second-stage computations by the length of the base, i.e.,

$$\sigma = \frac{N}{\Delta \ell} \quad \text{(G-13)}$$

(2) An approximate value of the drained effective stress, σ'_d, after steady-state seepage is reestablished is computed by subtracting the pore water pressure from the total stress, i.e.,

$$\sigma'_d = \sigma - u \quad \text{(G-14)}$$

where σ is the total normal stress calculated in Equation G-13.

Because the total normal stress is based on the second-stage computations, it is not necessarily the same as the total normal stress that would exist after drainage has occurred. However, it should not be much different, and it is reasonable to assume that it is the same for the purpose of these analyses. The pore water pressure, u, in Equation G-14 should be the pore water pressure after steady-state seepage is reestablished following drawdown. The pore water pressure is not the same as the pore water pressure used in the first-stage computations.

(3) The drained shear strength is estimated using the effective stress calculated in Equation G-14 and the effective stress shear strength parameters, c' and ϕ', which are the same as those used in the first-stage computations. The drained shear strength, s_d, is calculated from:

$$s_d = c' + \sigma'_d \tan(\phi') \quad \text{(G-15)}$$

(4) The drained shear strength calculated in Equation G-15 is compared to the value of undrained shear strength for this slice that was used in the second-stage computations. If the drained shear strength is greater than the undrained shear strength for all slices where the undrained shear strength was used previously, then no further computations are required. In that case, the factor of safety after rapid drawdown is equal to the factor of safety calculated for the second stage. If for any slice the drained shear strength is less than the undrained shear strength used for the second-stage computations, a third-stage computation is performed. For

those slices where the drained shear strength is less than the undrained shear strength, the effective stress drained shear strength parameters, c' and ϕ', are assigned to those slices for the third-stage computations. Pore water pressures are assigned based on the reestablished steady-state seepage conditions. For those slices where the undrained shear strength is less than the estimated drained shear strength, the same undrained shear strengths used for the second-stage computations are used for the third stage.

e. Third-stage computations. The third-stage stability computations are performed using the same conditions as for the second-stage computations, except for those materials where drained strengths are lower than undrained strengths. For those slices the drained strength parameters and appropriate pore water pressures are used, as noted above. The factor of safety after rapid drawdown is equal to the factor of safety calculated for the third stage. If the third-stage computations are not required, the factor of safety after rapid drawdown is equal to the factor of safety calculated for the second stage.

G-4. Example Problems

Three examples of rapid drawdown stability analyses of the slope shown in Figure G-5 are presented in the following sections. The slope is homogeneous, with the shear strength properties indicated in the table shown in Figure G-5. The unit weight of soil is 135 pcf. The unit weight is assumed to be the same above and below the water levels and does not change as a result of drawdown. Drawdown is from a maximum pool level of 103 feet to a minimum pool of 24 feet.

a. All computations are performed for the circular slip surface shown in Figure G-6. The soil mass above the trial slip surface is subdivided into 12 slices. The slip surface is not the critical slip surface.

b. For simplicity in the example calculations, it was assumed that the piezometric line was horizontal at the elevation of the maximum pool. Similarly, after drawdown and reestablishment of steady-state seepage, the piezometric line was assumed to be horizontal at the reservoir level after drawdown. In many slopes it would be appropriate to perform seepage analyses to determine the pore water pressures before and after drawdown.

c. In the following sections, three analyses are presented. The first uses the Corps of Engineers' 1970 procedure (USACE 1970) for rapid drawdown, and the Modified Swedish Method for the stability calculations. The second uses the improved (and recommended) procedure for rapid drawdown and the Simplified Bishop Method for the stability calculations. The third uses the improved procedure for rapid drawdown, and the Modified Swedish Method for stability calculations, with side force inclinations determined using Spencer's Method.

G-5. U.S. Army Corps of Engineers' 1970 Procedure - Example

The first analysis uses the U.S. Army Corps of Engineers' 1970 procedure (USACE 1970) for rapid drawdown analyses. Although the improved method described in Section G-3 is recommended, the 1970 method has been used for design of many dams, and it may be necessary to use this method to check those older designs. Stability calculations for the 1970 method were performed using the Modified Swedish Method and the 1970 recommendations regarding the inclination of interslice forces. This was done for consistency with the original procedure as described in the earlier manual, although Spencer's Method is currently recommended. The interslice forces are assumed to be parallel to the average embankment slope. The average embankment slope is 2.84 (horizontal) to 1 (vertical), yielding an interslice force inclination of 19.4 degrees measured from the horizontal.

REFERENCE 3

"Earth Dams and Reservoirs." Technical Release No. 60, U.S. Department of Agriculture Soil Conservation Service Engineering Division, October 1985.

Table 5-2 Slope stability criteria

Design condition	Primary assumption	Remarks	Shear strength to be used	Minimum safety factor
1. End of construction (upstream or downstream slope)	Zones of the embankment or layers of the foundation are expected to develop significant pore pressures during construction	Embankment soils that are slowly permeable should be tested at water contents that are as wet as likely during construction (usually wet of optimum) Saturated slowly permeable foundation soils that are not predicted to fully consolidate during construction Permeable embankment zones and/or foundation strata	UU – includes triaxial UU tests, unconfined compression (qu) tests, and field vane shear tests CU' or CD	1.4 for failure surfaces extending into foundation layers 1.3 for embankments on stronger foundations where the failure surface is located entirely in the embankment
2. Rapid drawdown (upstream slope)	Drawdown from the highest normal pool to the lowest ungated outlet	Consider failure surfaces both within the embankment and extending into the foundation	Lowest shear strength from a composite envelope of CU and CD envelopes (fig. 5-1)	1.2 1.1 for infinite slope analysis
3. Steady seepage without seismic forces (downstream slope)	Phreatic line developed from pool at the principal spillway crest Uplift pressure simulated by phreatic line developed from auxiliary spillway crest applied to saturated embankment and foundation soils	Consider failure surfaces both within the embankment and extending into the foundation	Lowest shear strength from a composite envelope of CU and (CU+CD)/2 envelopes (fig. 5-2)	1.5 1.1 for infinite slope analysis
4. Steady seepage with seismic forces (downstream slope)	Phreatic line developed from principal spillway crest with no uplift	Consider failure surfaces both within the embankment and extending into the foundation	Lowest shear strength from a composite envelope of CU and (CU+CD)/2 envelopes (fig. 5-2)	1.1

REFERENCE 4

J.M. Duncan and S.G. Wright, "Soil Strength and Slope Stability", John Wiley and Sons, Inc., 2005

not necessary. However, drainage *after* the earthquake could adversely affect stability and should be considered as discussed in the final section of this chapter.

Simplified procedure (*R* envelope and single-stage analysis). Although the two-stage analysis procedure described above is the proper way to perform a pseudostatic analysis for a slope, analyses are sometimes performed using a simple single-stage procedure. In the single-stage procedure the *R* shear strength envelope is used. The *R envelope*, as it is called in U.S. Army Corps of Engineers' terminology, is obtained by plotting results of consolidated–undrained triaxial tests as shown on the Mohr–Coulomb diagram in Figure 10.4. In this diagram circles are plotted as follows: The minor principal stress is the effective stress, σ'_{3c}, *at consolidation;* the diameter of the circle is the principal stress difference *at failure*, $\sigma_{1f} - \sigma_{3f}$. Because the two stresses used to plot the circles (σ'_{3c} and $\sigma_{1f} - \sigma_{3f}$) exist at different times during a test, the circles are not actually Mohr circles—a Mohr's circle represents the state of stress at a point *at an instant in time* (e.g., at consolidation or at failure). Similarly the *R* envelope drawn on such a diagram is not actually a Mohr–Coulomb failure envelope. However, the envelope that is drawn on such a diagram is often quite similar to the corresponding τ_{ff} vs. σ'_{fc} envelope that is plotted from consolidated–undrained tests described in Chapter 9. To illustrate the similarities between the *R* and τ_{ff} vs. σ'_{fc} envelopes, the two envelopes are plotted in Figure 10.5 for four different soils. The four soils and properties are summarized in Table 10.3. It can be seen that the *R* envelope in each case plots below the τ_{ff} vs. σ'_{fc} envelope. There may be other cases where the *R* envelope lies above the τ_{ff} vs. σ'_{fc} envelope.

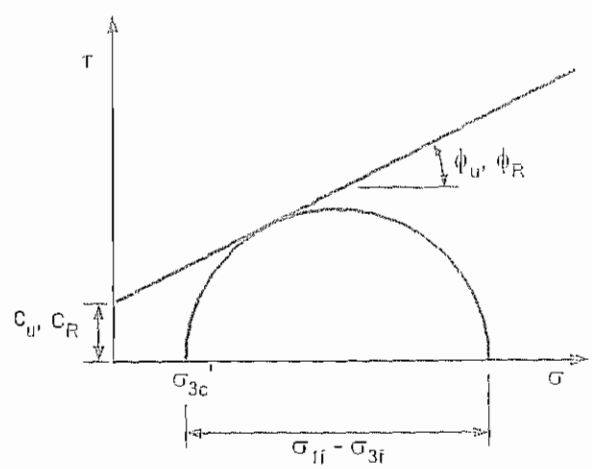


Figure 10.4 *R* (total stress) undrained shear strength envelope plotted from consolidated–undrained triaxial compression tests.

In the simplified pseudostatic procedure a single set of computations is performed for each trial slip surface using the appropriate seismic coefficient and the intercept and slope (c_R and ϕ_R) of the *R* envelope as Mohr–Coulomb shear strength parameters. In this simplified approach it is important to use the proper pore water pressures: The *R* envelope in this case is being used as an envelope approximating the relationship between the undrained shear strength ($\approx\tau_{ff}$) and effective consolidation pressure ($\approx\sigma'_{fc}$). Thus, pore water pressures equal to those during consolidation (e.g., for steady-state seepage) should be used in the computations.[1]

To illustrate the differences between the simple single-stage procedure using the *R* envelope and the more rigorous two-stage procedure such as the one described earlier, a pseudostatic slope stability analysis was performed for the slope shown in Figure 10.6. A seismic coefficient of 0.15 was used and computations were performed for the slope with both dry (zero pore water pressure) and fully submerged conditions prior to earthquake loading. Computations were performed using each of the four different sets of soil strength properties shown in Figure 10.4 and Table 10.3. Results of the computations are summarized in Table 10.4 and plotted in Figure 10.7. In all cases the factor of safety computed by the simpler procedure is less than the factor of safety computed by the more rigorous two-stage procedure. The factor of safety from the single-stage procedure varies between about 80 and 90% of the value from the two-stage analysis.

Recapitulation

- Unconsolidated–undrained tests performed on undisturbed or laboratory compacted specimens can be used to determine the shear strength for pseudostatic analyses of *existing slopes* or *new slopes at the end of construction.*
- To determine the shear strength for *new slopes after the slope has reached consolidated equilibrium,* shear strengths are determined using consolidated–undrained testing procedures and analyses are performed as two-stage analyses using procedures similar to those used for rapid drawdown.

[1] Although the *R* envelope is called a *total stress envelope* in many texts (Terzaghi and Peck, 1967; Peck et al., 1974; Wu, 1976; Sowers, 1979; Dunn et al., 1980; Holtz and Kovacs, 1981; Lee et al., 1983; McCarty, 1993; Liu and Evett, 2001; Abramson et al., 2002; Das, 2002), when the envelope is used in pseudostatic slope stability computations, effective stresses and appropriate pore water pressures must be used.

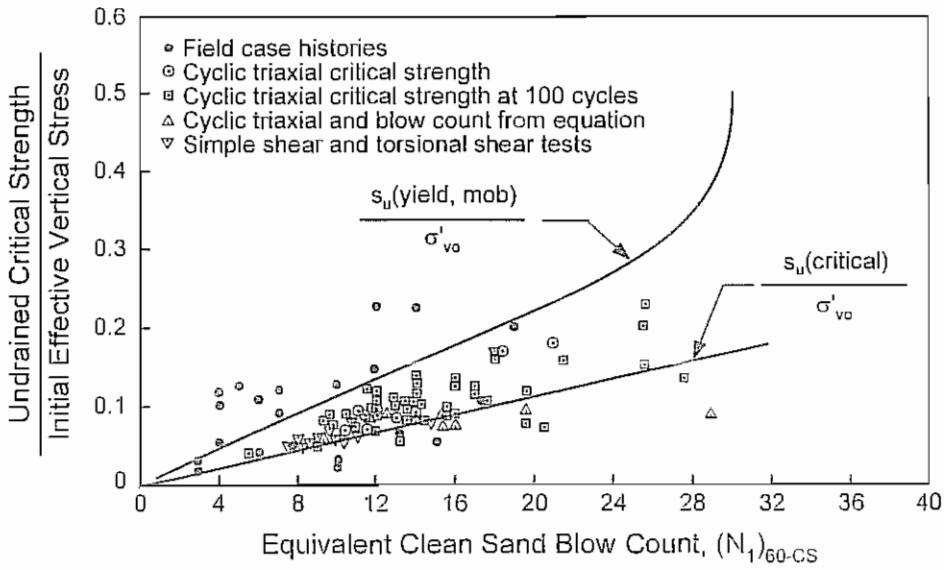


Figure 10.9 Relationship between undrained critical strength ratio and equivalent clean sand blow count. (From Stark and Mesri, 1992.)

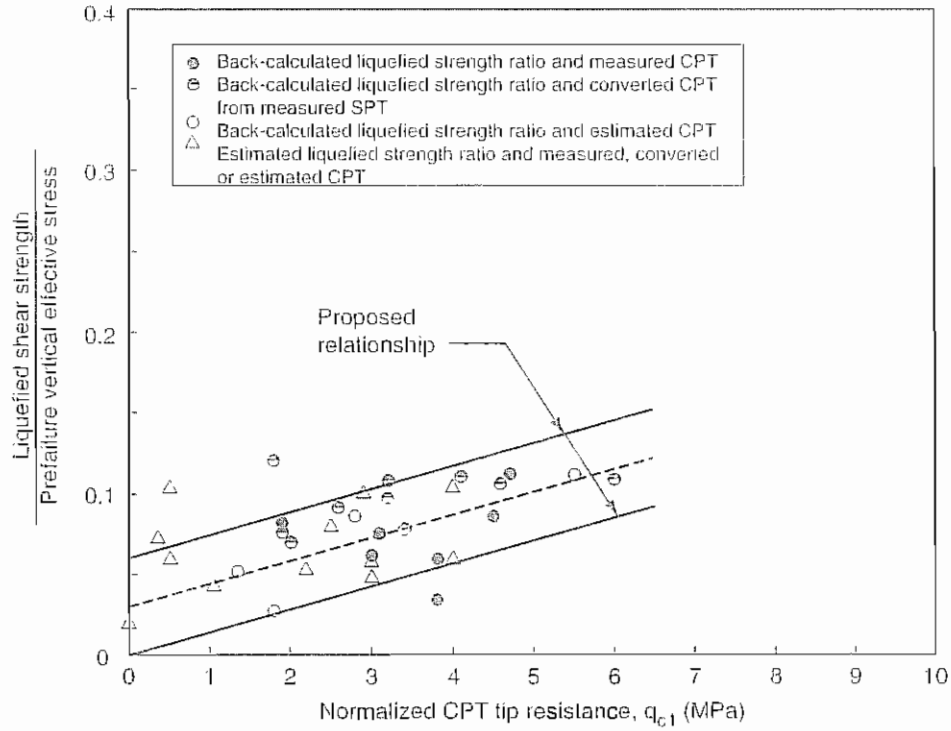


Figure 10.10 Liquefied strength ratio relationship based on normalized CPT tip resistance. (After Olson and Stark, 2002.)

REFERENCE 7

S&ME SEEP/W and SLOPE/W Output, 2010

ASH DIKE SECTION STA. 7+25

Seepage Analysis – Static Condition

Seepage Analysis Flow Net – Static Condition

Static Slope Stability Analysis – Global

Static Slope Stability Analysis – Upper

Static Slope Stability Analysis – Lower

Seepage Analysis - Pool from 100-year Slope Storm Event

Pool from 100-year Slope Storm Event Stability Analysis – Global

Pool from 100-year Slope Storm Event Stability Analysis – Upper

Pool from 100-year Storm Event Slope Stability Analysis – Lower

Seepage Analysis - Surcharge Pool = 760

Surcharge Pool = 760 Slope Stability Analysis – Global

Surcharge Pool = 760 Slope Stability Analysis – Upper

Surcharge Pool = 760 Slope Stability Analysis – Lower

Pseudostatic Slope Stability Analysis – Global

Pseudostatic Slope Stability Analysis – Upper

Pseudostatic Slope Stability Analysis – Lower

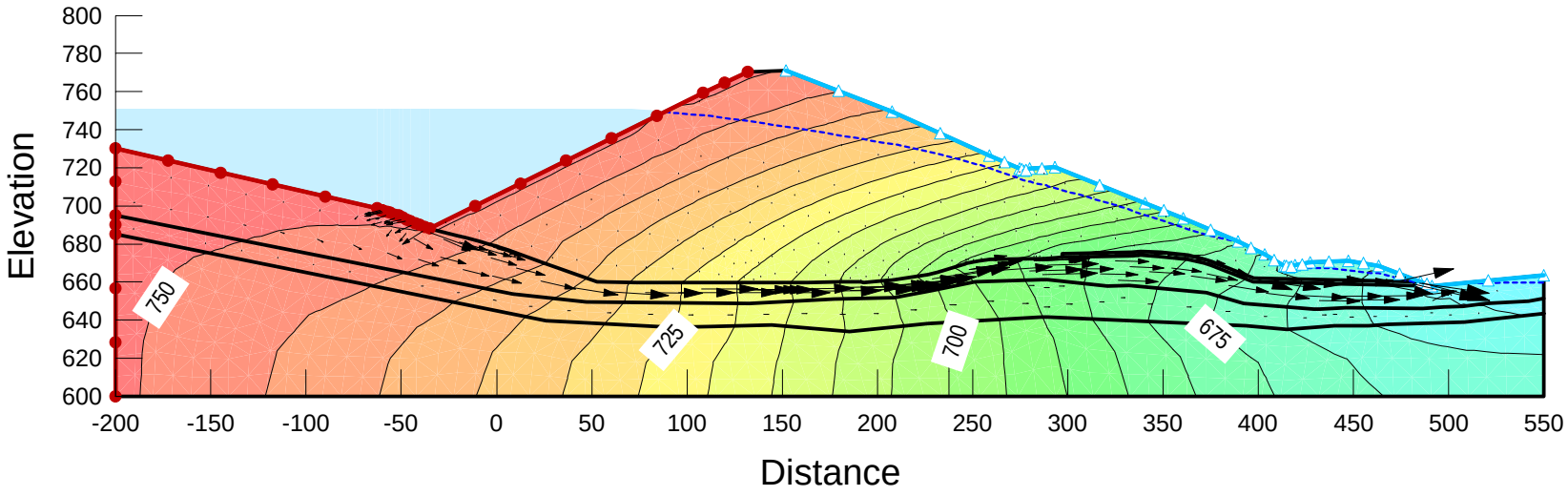
Rapid Drawdown Stability Analysis

Seepage Analysis - Water Surface Elevation = 745.63

Water Surface Elevation = 745.63 Slope Stability Analysis – Lower

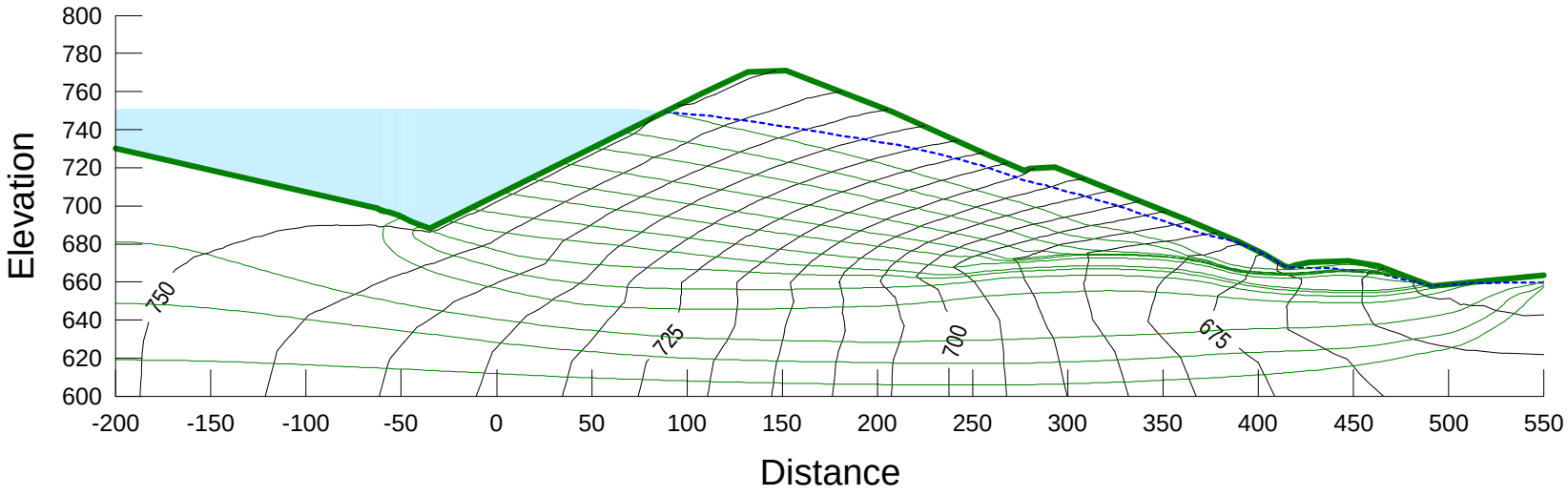
Name: Seepage Analysis - Static Condition
Description: Ash Dike Section Sta. 7+25

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 1e-6 K-Ratio: 0.08 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 0.1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 0.1 K-Direction: 0
Name: Rock Model: Saturated / Unsaturated K-Function: 1e-7 K-Ratio: 0.1 K-Direction: 0



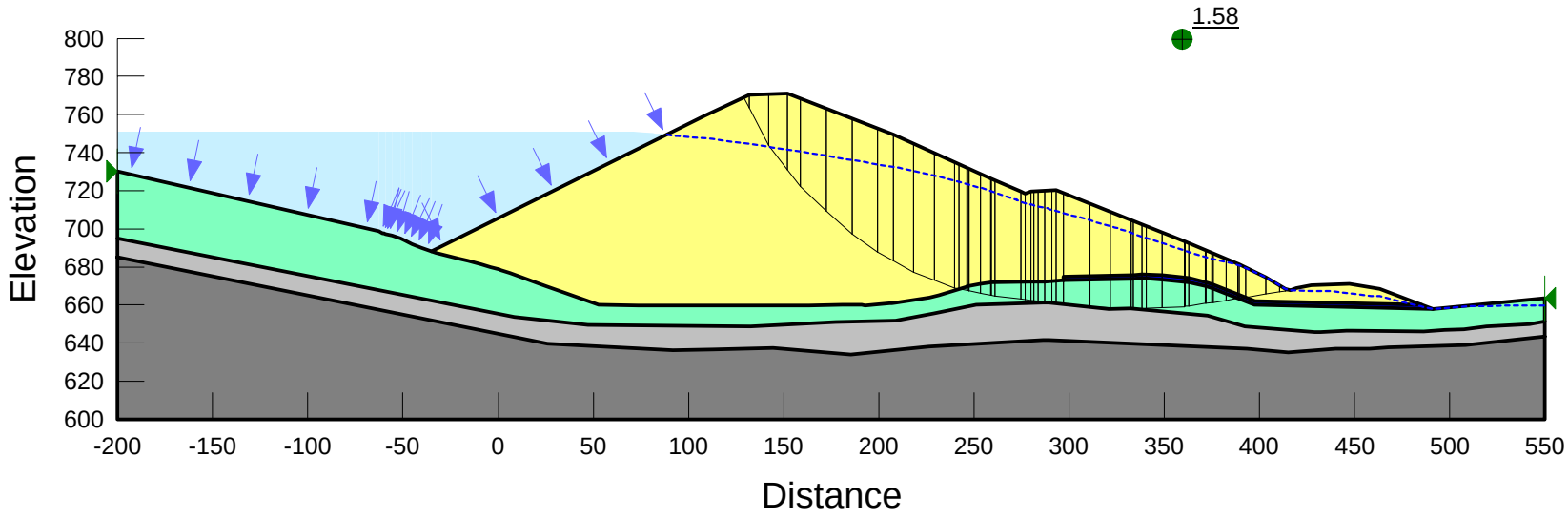
Name: Seepage Analysis - Static Condition
Description: Ash Dike Section Sta. 7+25

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 1e-6 K-Ratio: 0.08 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 0.1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 0.1 K-Direction: 0
Name: Rock Model: Saturated / Unsaturated K-Function: 1e-7 K-Ratio: 0.1 K-Direction: 0



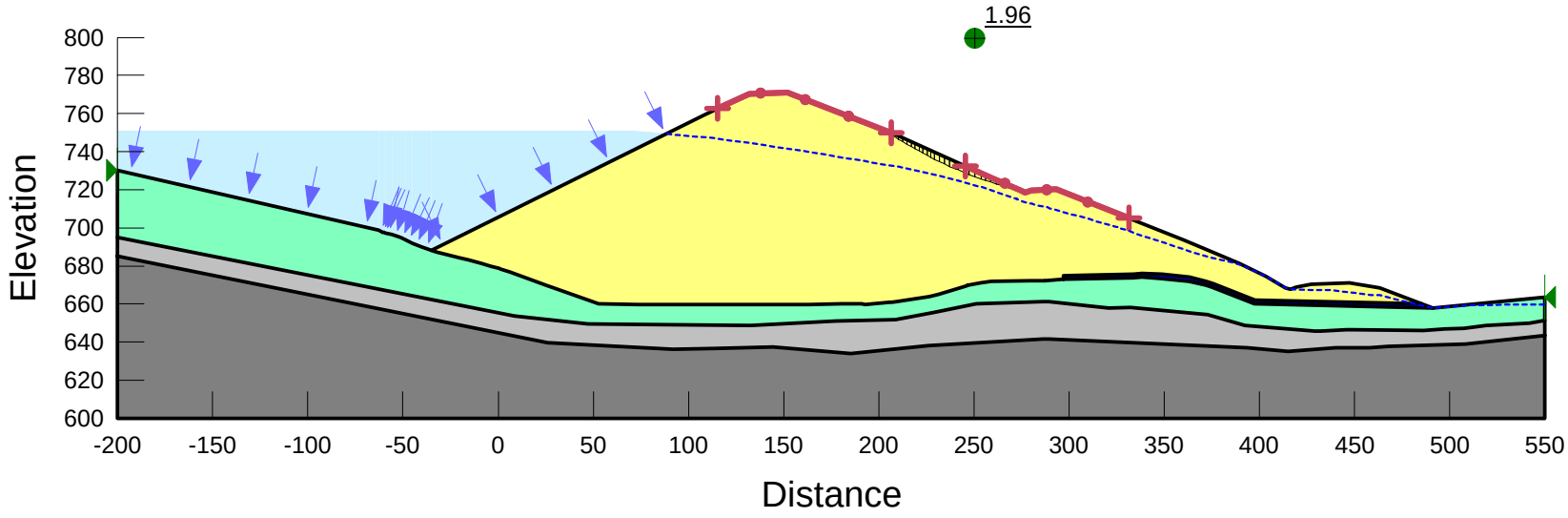
Name: Static Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 7+25

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



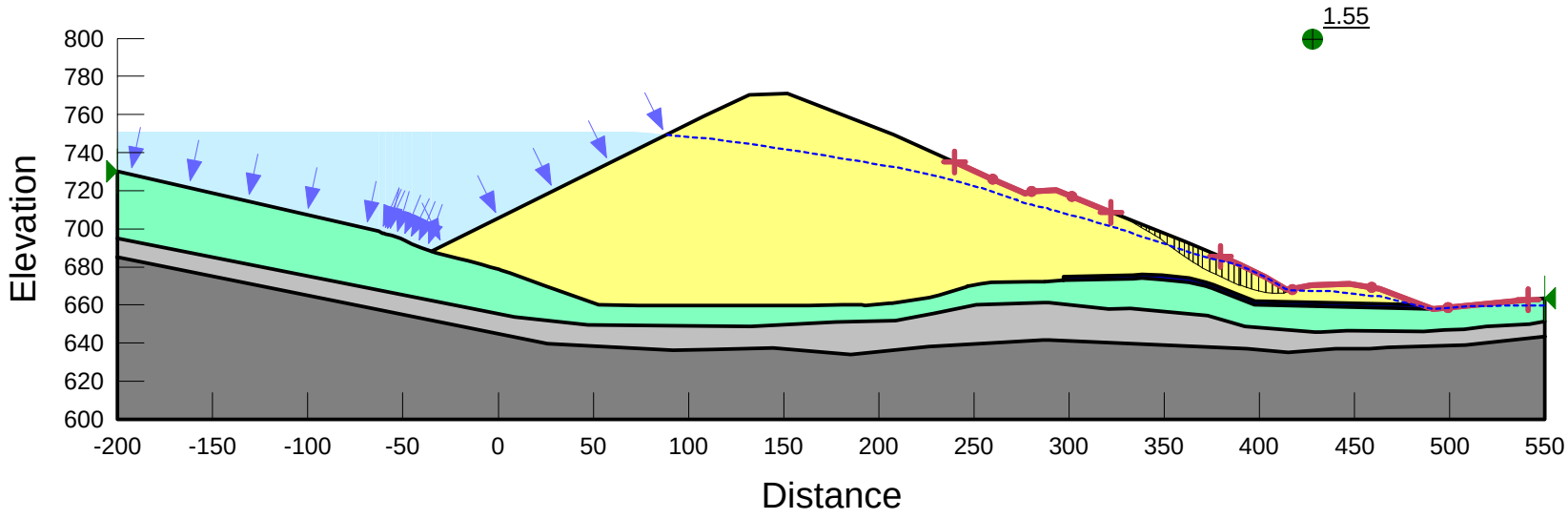
Name: Static Slope Stability Analysis - Upper
Description: Ash Dike Section Sta. 7+25

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



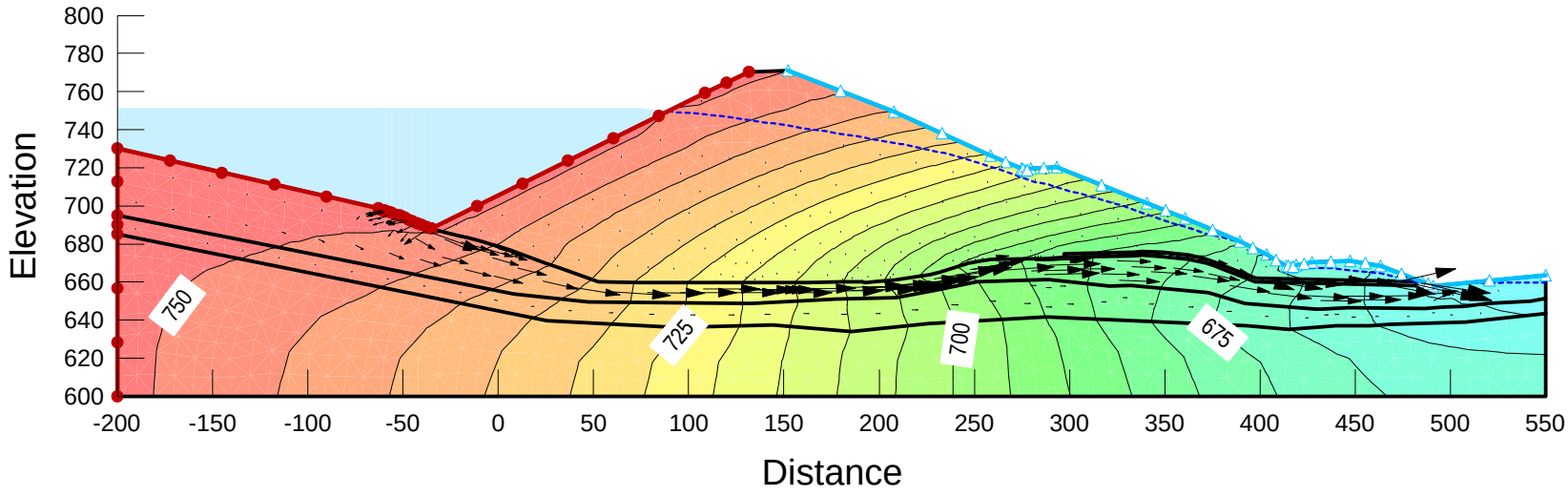
Name: Static Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 7+25

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



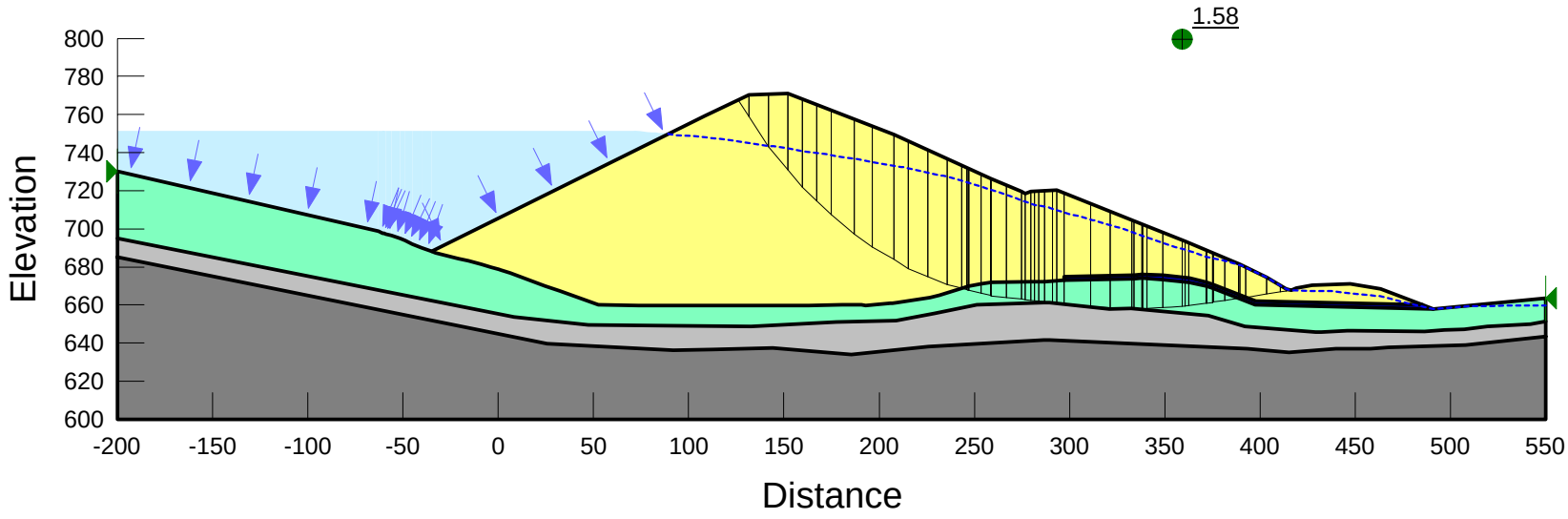
Name: Seepage Analysis - Pool from 100-yr Storm Event Condition
Description: Ash Dike Section Sta. 7+25
Pool from 100-yr Storm Event = 751.4

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 1e-6 K-Ratio: 0.08 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 0.1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 0.1 K-Direction: 0
Name: Rock Model: Saturated / Unsaturated K-Function: 1e-7 K-Ratio: 0.1 K-Direction: 0



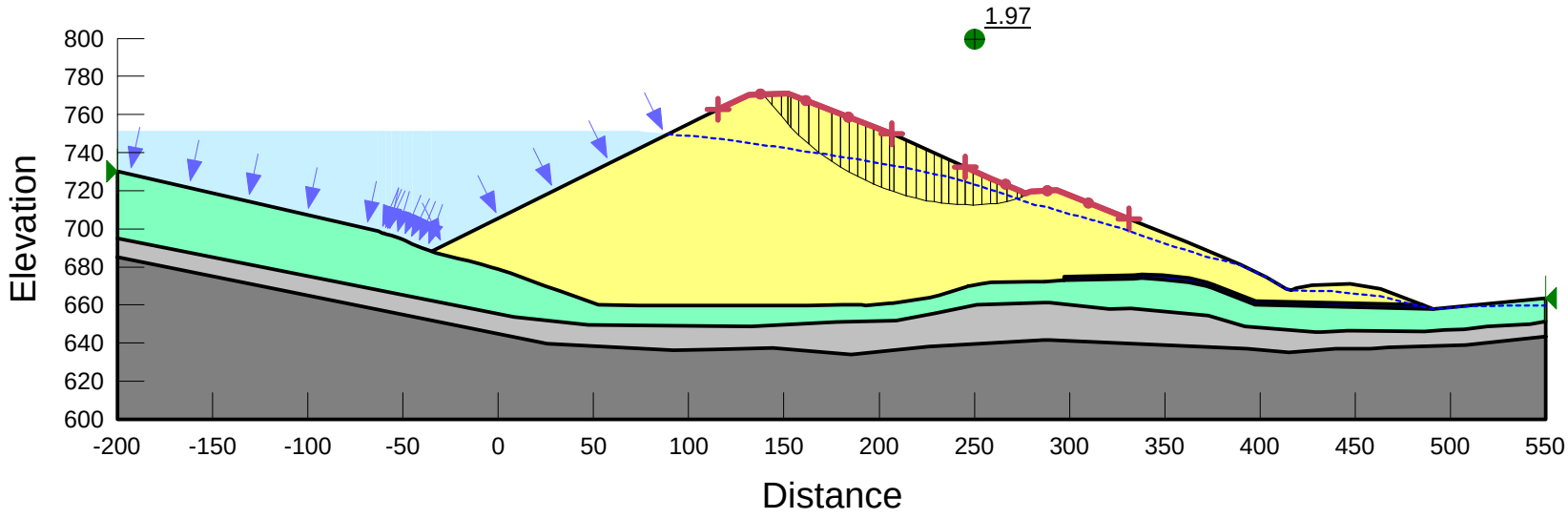
Name: Pool from 100-yr Storm Event Condition Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 7+25
Pool from 100-yr Storm Event = 751.4

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



Name: Pool from 100-yr Storm Event Condition Slope Stability Analysis - Upper
Description: Ash Dike Section Sta. 7+25
Pool from 100-yr Storm Event = 751.4

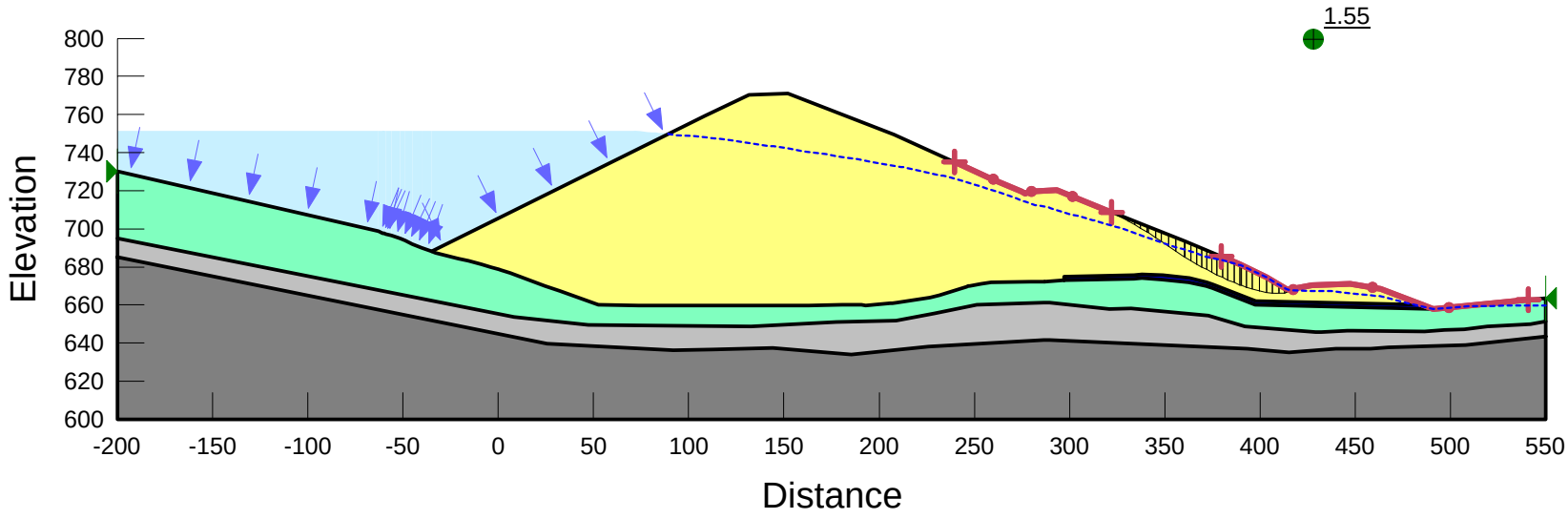
Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



Name: Pool from 100-yr Storm Event Condition Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 7+25

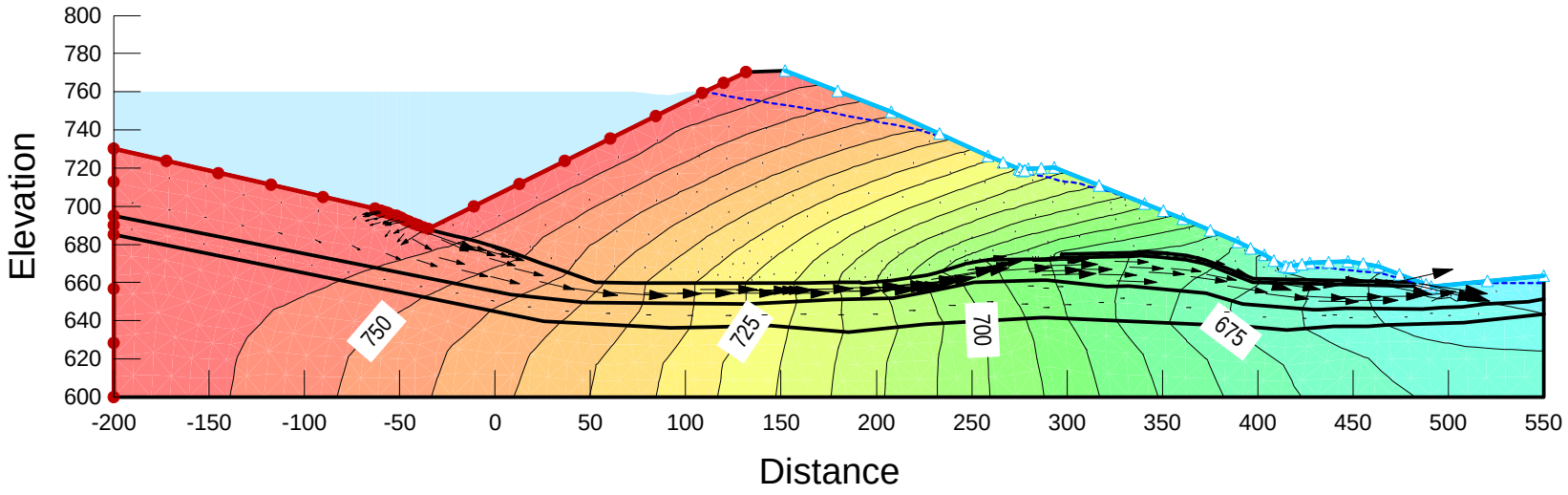
Pool from 100-yr Storm Event = 751.4

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



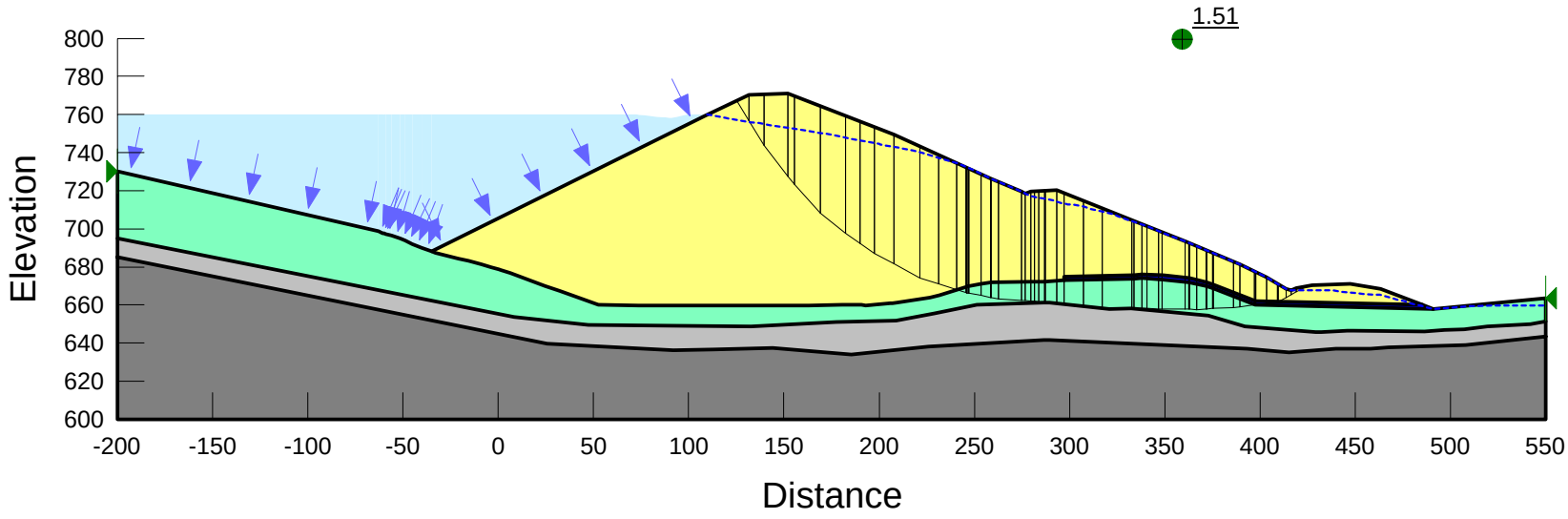
Name: Seepage Analysis - Surcharge Pool Condition
Description: Ash Dike Section Sta. 7+25
Surcharge Pool = 760

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 1e-6 K-Ratio: 0.08 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 0.1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 0.1 K-Direction: 0
Name: Rock Model: Saturated / Unsaturated K-Function: 1e-7 K-Ratio: 0.1 K-Direction: 0



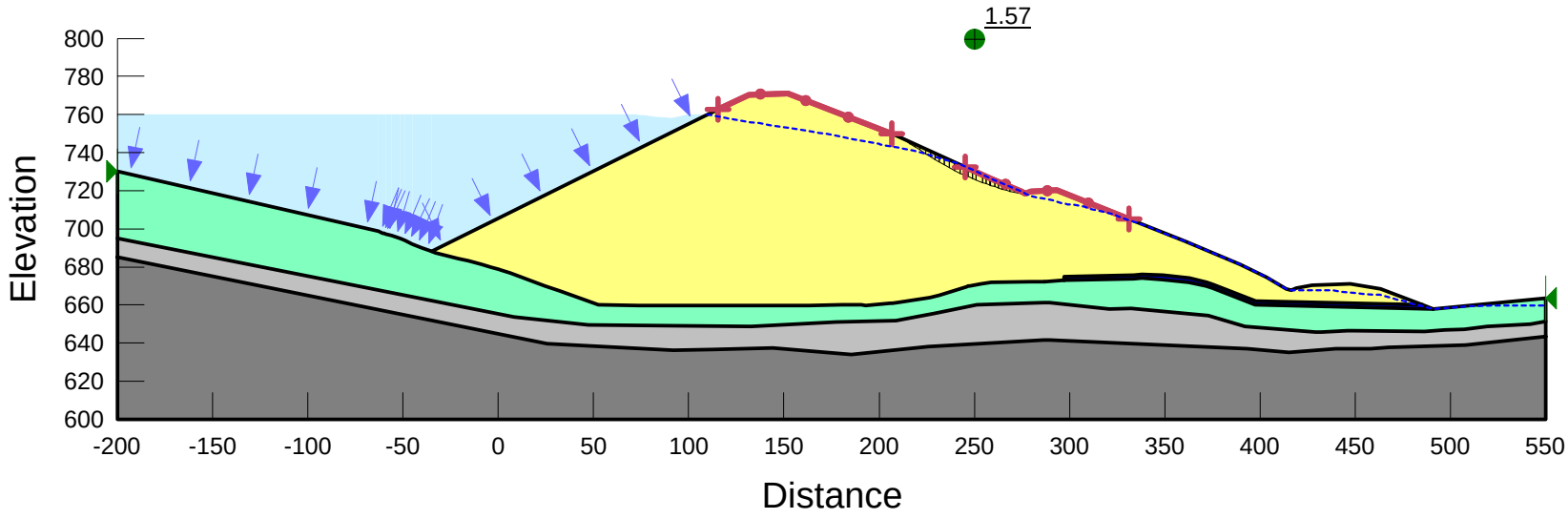
Name: Surcharge Pool Condition Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 7+25
Surcharge Pool = 760

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



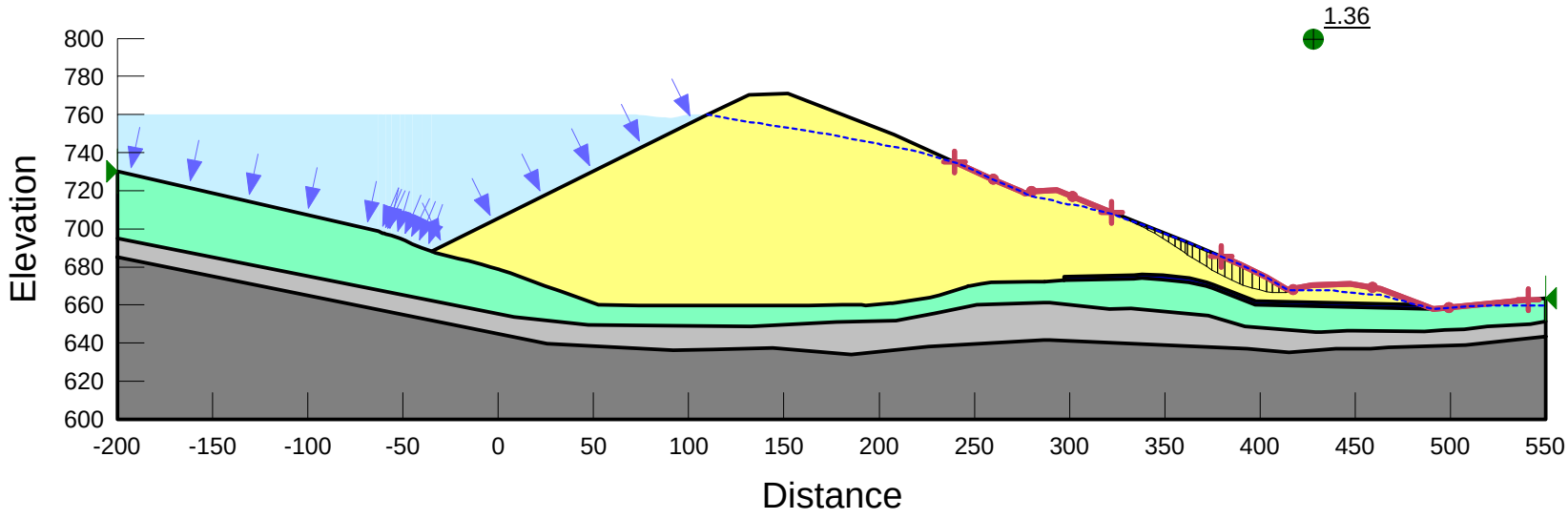
Name: Surcharge Pool Condition Slope Stability Analysis - Upper
Description: Ash Dike Section Sta. 7+25
Surcharge Pool = 760

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



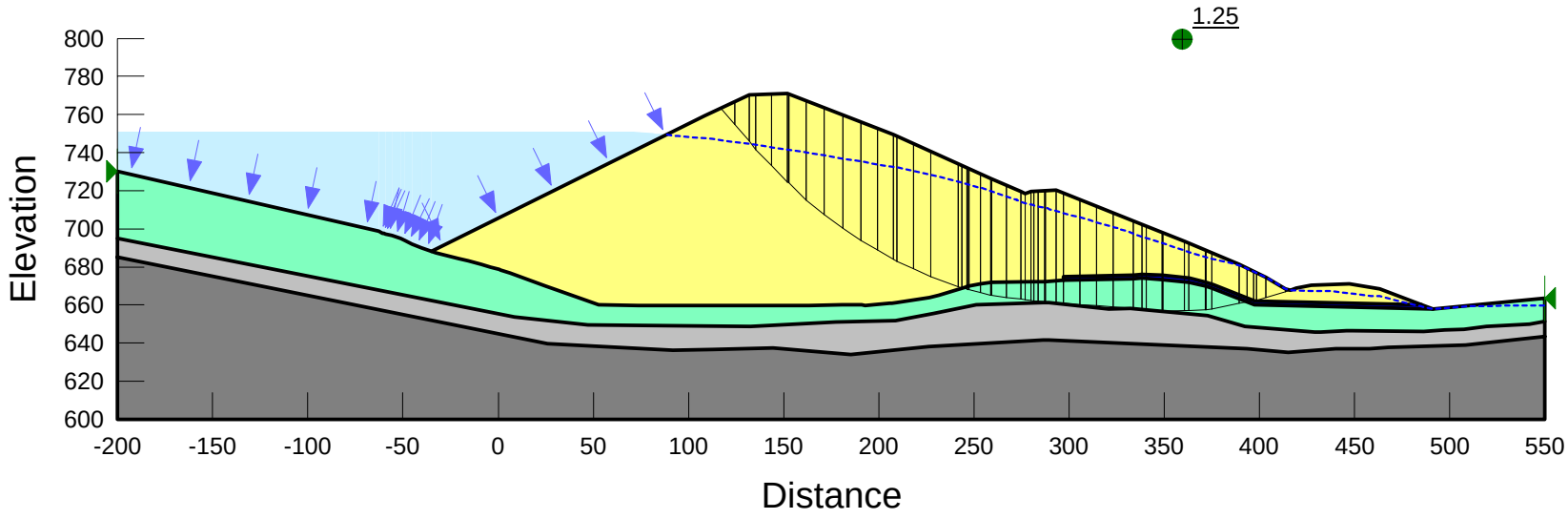
Name: Surcharge Pool Condition Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 7+25
Surcharge Pool = 760

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



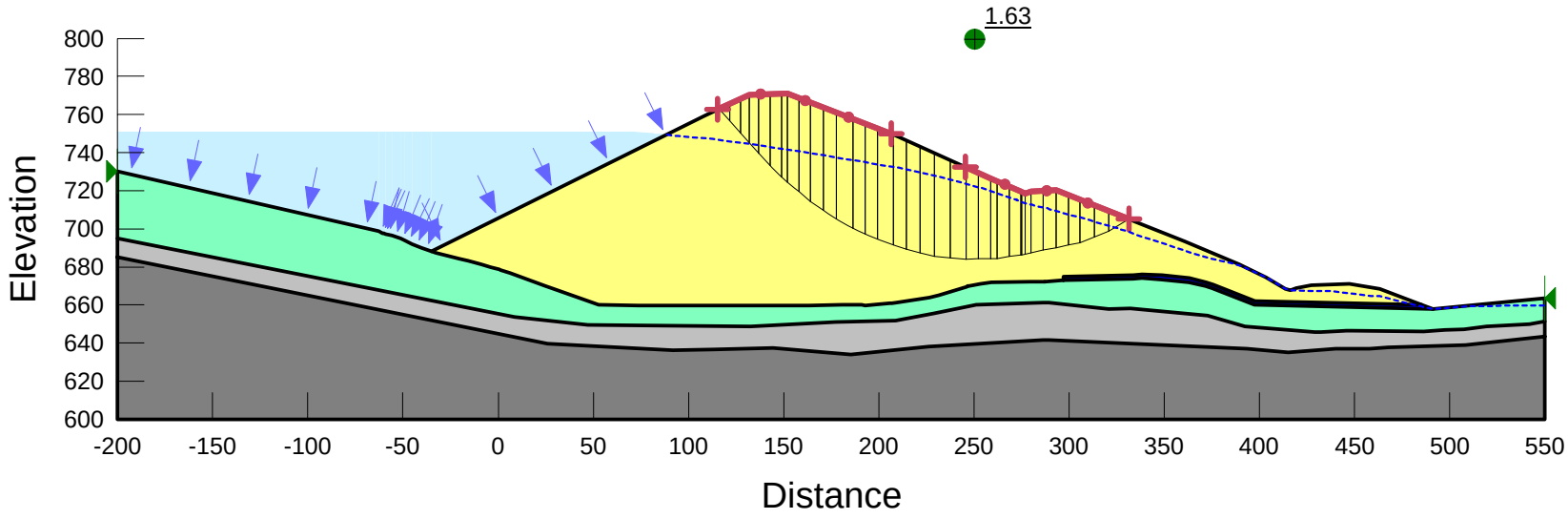
Name: Pseudostatic Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 7+25
Seismic Coefficient "k" = 0.06 g

Name: Embankment Fill - Ash Dike Model: Mohr-Coulomb Unit Weight: 123 Unit Wt. Above Water Table: 121 Cohesion: 1300 Phi: 12.5 Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Mohr-Coulomb Unit Weight: 124 Cohesion: 1400 Phi: 11.3 Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



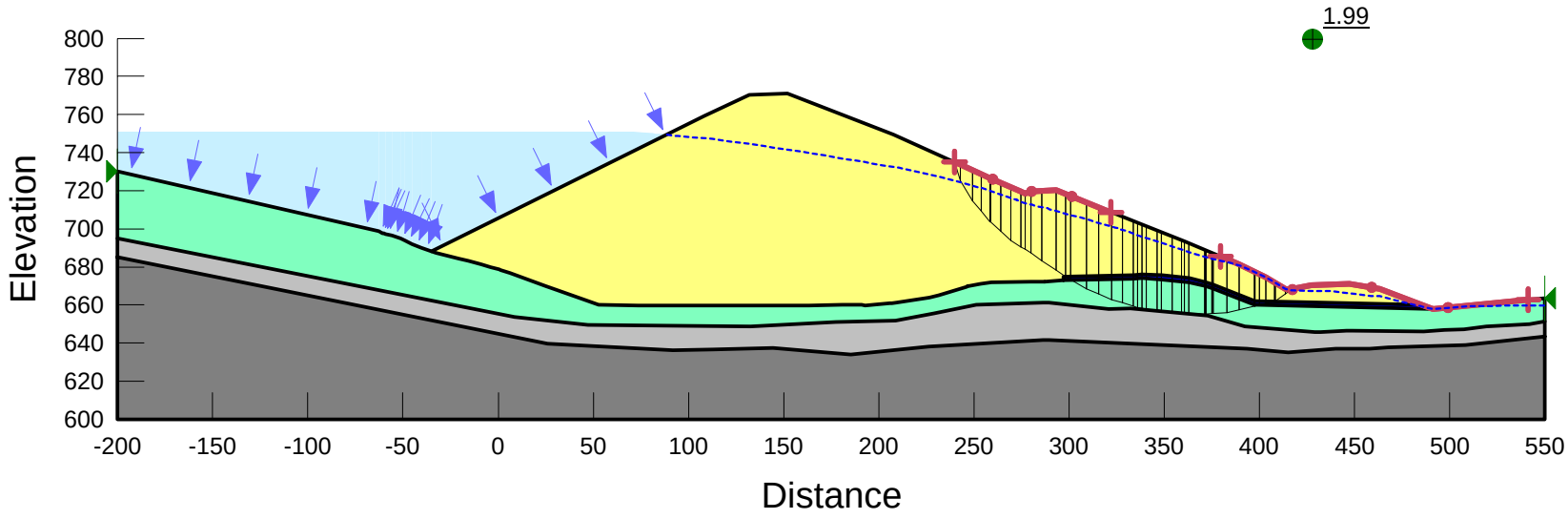
Name: Pseudostatic Slope Stability Analysis - Upper
Description: Ash Dike Section Sta. 7+25
Seismic Coefficient "k" = 0.06 g

Name: Embankment Fill - Ash Dike Model: Mohr-Coulomb Unit Weight: 123 Unit Wt. Above Water Table: 121 Cohesion: 1300 Phi: 12.5 Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Mohr-Coulomb Unit Weight: 124 Cohesion: 1400 Phi: 11.3 Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



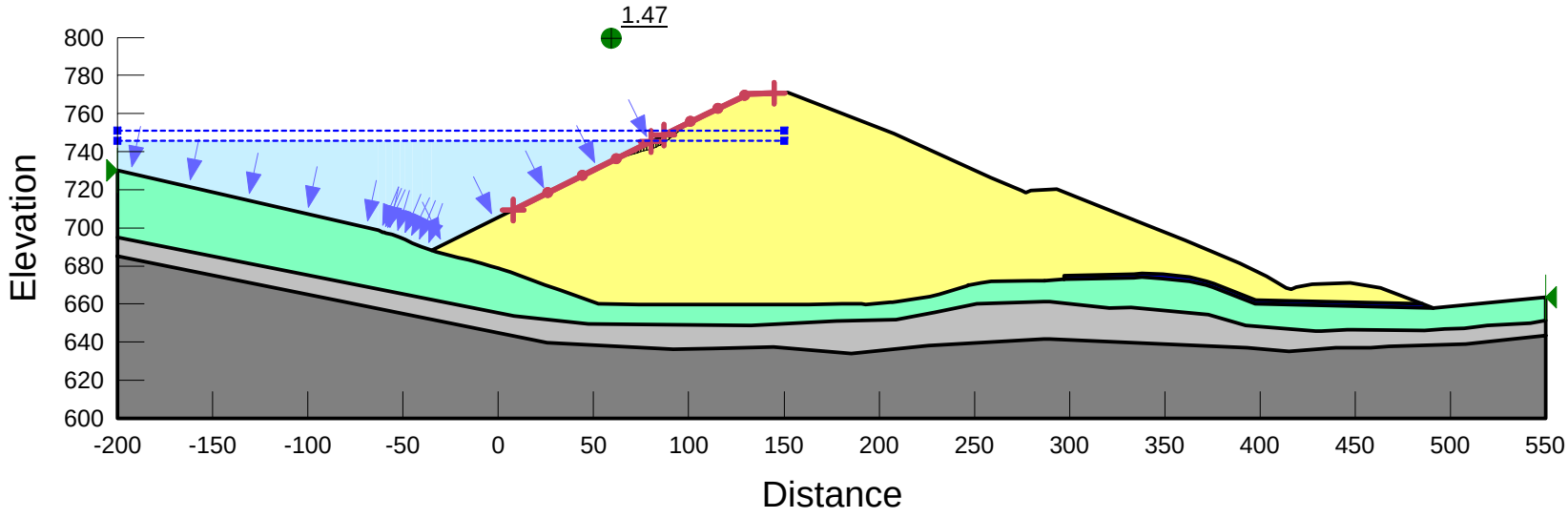
Name: Pseudostatic Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 7+25
Seismic Coefficient "k" = 0.06 g

Name: Embankment Fill - Ash Dike Model: Mohr-Coulomb Unit Weight: 123 Unit Wt. Above Water Table: 121 Cohesion: 1300 Phi: 12.5 Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Mohr-Coulomb Unit Weight: 124 Cohesion: 1400 Phi: 11.3 Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



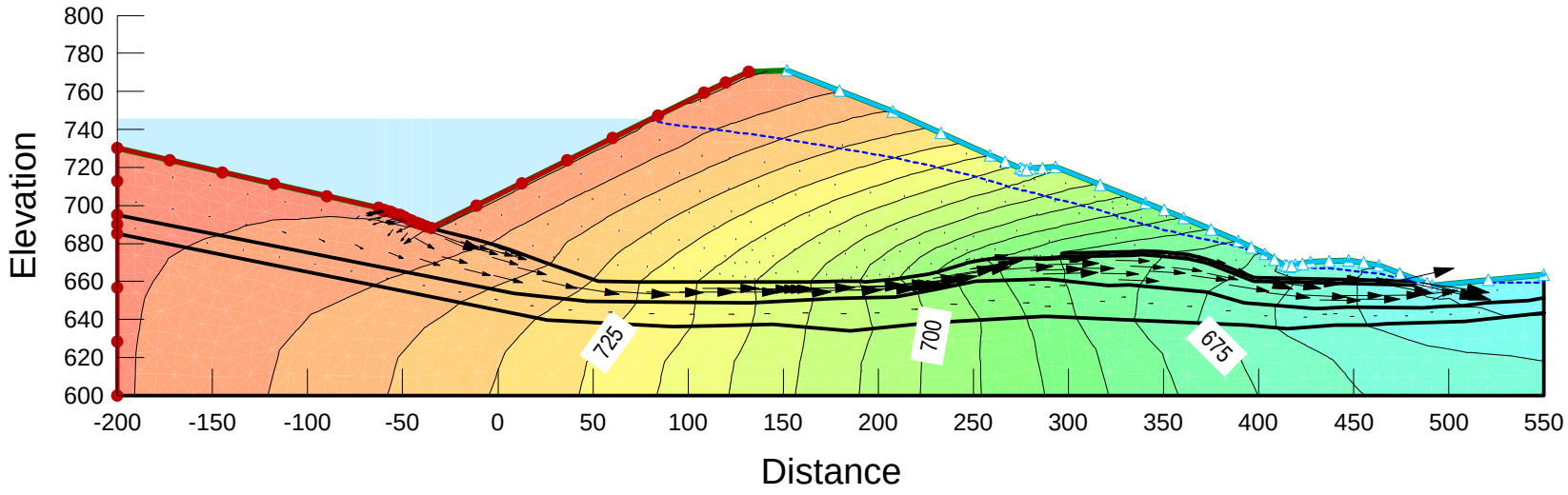
Name: Rapid Drawdown Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 7+25
Pool Drawdown from 750.95 to 745.63

Name: Embankment Fill - Ash Dike Model: Mohr-Coulomb Unit Weight: 123 pcf Unit Wt. Above Water Table: 121 pcf Cohesion: 0 psf Phi: 38 ° Phi-B: 0 °
Drawdown Total Cohesion: 1300 psf Drawdown Total Phi: 12.5 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 36 ° Phi-B: 0 ° Drawdown Total Cohesion: 0 psf Drawdown Total Phi: 0 °
Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Residuum Model: Mohr-Coulomb Unit Weight: 124 pcf Cohesion: 0 psf Phi: 36 ° Phi-B: 0 ° Drawdown Total Cohesion: 0 psf Drawdown Total Phi: 0 °
Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 pcf Cohesion: 1000 psf Phi: 38 ° Phi-B: 0 ° Drawdown Total Cohesion: 0 psf Drawdown Total Phi: 0 °
Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Rock Model: Bedrock (Impenetrable) Piezometric Line: 1 Piezometric Line After Drawdown: 2



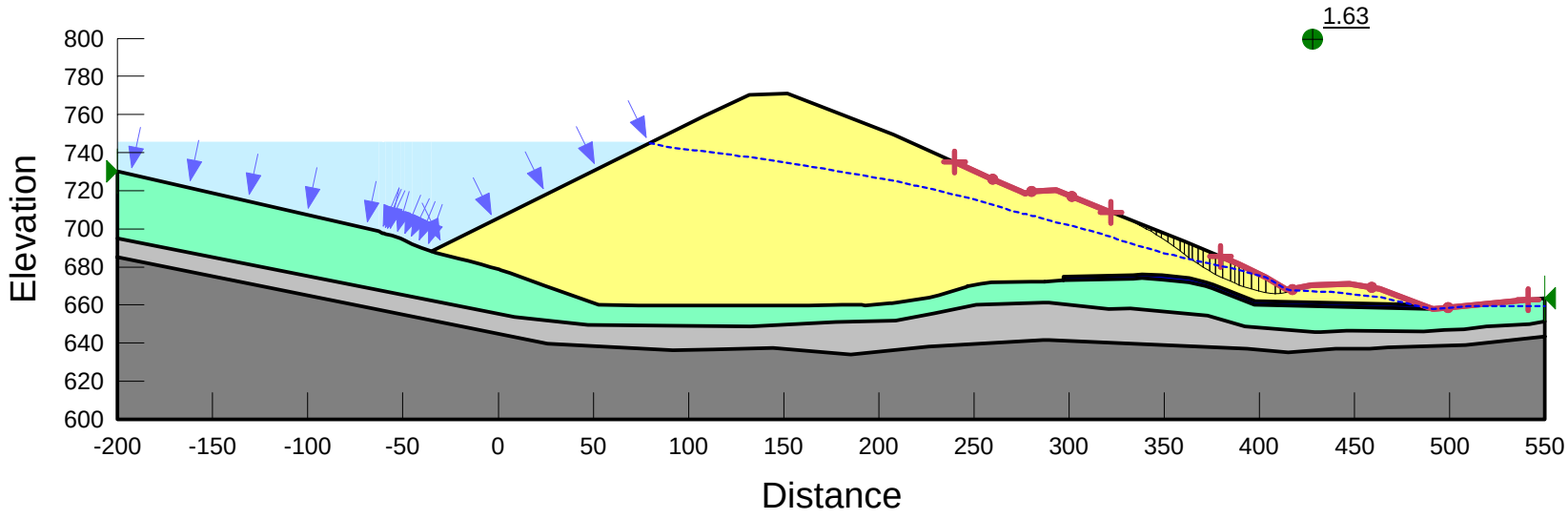
Name: Seepage Analysis - Static Condition
Description: Ash Dike Section Sta. 7+25
Water Surface Elevation = 745.63

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 1e-6 K-Ratio: 0.08 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 0.1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 0.1 K-Direction: 0
Name: Rock Model: Saturated / Unsaturated K-Function: 1e-7 K-Ratio: 0.1 K-Direction: 0



Name: Static Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 7+25
Water Surface Elevation = 745.63

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



Seepage Analysis - Static Condition

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 250
Last Edited By: Cedric Ruhl
Date: 9/12/2010
Time: 3:32:11 PM
File Name: AD 7+25 Static.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 7+25\
Last Solved Date: 9/12/2010
Last Solved Time: 7:22:36 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Mass(M) Units: lbs
Mass Flux Units: lbs/sec
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Seepage Analysis - Static Condition

Description: Ash Dike Section Sta. 7+25
Kind: SEEP/W
Method: Steady-State
Settings
  Include Air Flow: No
Control
  Apply Runoff: Yes
Convergence
  Convergence Type: Gauss Point K
  Convergence Settings
    Maximum Number of Iterations: 500
    Tolerance: 0.01
    Maximum Change in K: 0.1
    Rate of Change in K: 1.02
    Minimum Change in K: 0.0001
  Equation Solver: Parallel Direct
  Potential Seepage Max # of Reviews: 10
Time
  Starting Time: 0 sec
  Duration: 0 sec
  Ending Time: 0 sec

Materials

Embankment Fill - Ash Dike
Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-6
K-Ratio: 0.08
K-Direction: 0 °

Blanket Drain
Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

Residuum
Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 0.1
K-Direction: 0 °

PWR
Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 0.1
K-Direction: 0 °

Rock
Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-7
K-Ratio: 0.1
K-Direction: 0 °

Boundary Conditions

Water Elevation
Type: Head (H) 750.95

Potential Seepage Face
Review: true
Type: Total Flux (Q) 0

K Functions

1e-4
Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-006
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-006)

Data Point: (10000, 3.28e-006)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

1e-5

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-007
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-007)
Data Point: (10000, 3.28e-007)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

1e-6

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-008
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-008)
Data Point: (10000, 3.28e-008)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

1e-7

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-009
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-009)
Data Point: (10000, 3.28e-009)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20

Residual Water Content: 0 ft³/ft³

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	34075.396
Region 2	PWR	1,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,4,5,6,7,8,9,10, 11,12,13,14,15,16,17,18	9426.3413
Region 3	Residuum	43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23,22,21,20,19,44,45,46,47,48, 49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78, 79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106	13036.297
Region 4	Blanket Drain	53,52,51,50,49,48,47,46,45,107,108,109,110,111,112,113,114,115	386.71559
Region 5	Embankment Fill - Ash Dike	96,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,107,108, 109,110,111,112,113,114,115,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73, 74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90, 91,92,93,94,95	26903.486

Lines

	Start Point	End Point	Hydraulic Boundary
Line 1	1	2	
Line 2	2	3	
Line 3	3	4	Water Elevation
Line 4	4	5	
Line 5	5	6	
Line 6	6	7	
Line 7	7	8	
Line 8	8	9	
Line 9	9	10	
Line 10	10	11	
Line 11	11	12	
Line 12	12	13	
Line 13	13	14	
Line 14	14	15	
Line 15	15	16	
Line 16	16	17	
Line 17	17	18	
Line 18	18	1	
Line 19	1	19	
Line 20	19	20	
Line 21	20	21	
Line 22	21	22	
Line 23	22	23	
Line 24	23	24	
Line 25	24	25	
Line 26	25	26	
Line 27	26	27	
Line 28	27	28	
Line 29	28	29	
Line 30	29	30	
Line 31	30	31	
Line 32	31	32	
Line 33	32	33	
Line 34	33	34	
Line 35	34	35	
Line 36	35	36	

Line 37	36	37	
Line 38	37	38	
Line 39	38	39	
Line 40	39	40	
Line 41	40	41	
Line 42	41	42	
Line 43	42	43	
Line 44	43	4	Water Elevation
Line 45	19	44	
Line 46	44	45	Potential Seepage Face
Line 47	45	46	
Line 48	46	47	
Line 49	47	48	
Line 50	48	49	
Line 51	49	50	
Line 52	50	51	
Line 53	51	52	
Line 54	52	53	
Line 55	54	55	
Line 56	55	56	
Line 57	56	57	
Line 58	57	58	
Line 59	58	59	
Line 60	59	60	
Line 61	60	61	
Line 62	61	62	
Line 63	62	63	
Line 64	63	64	
Line 65	64	65	
Line 66	65	66	
Line 67	66	67	
Line 68	67	68	
Line 69	68	69	
Line 70	69	70	
Line 71	70	71	
Line 72	71	72	
Line 73	72	73	
Line 74	73	74	
Line 75	74	75	
Line 76	75	76	
Line 77	76	77	
Line 78	77	78	
Line 79	78	79	
Line 80	79	80	
Line 81	80	81	
Line 82	81	82	
Line 83	82	83	
Line 84	83	84	
Line 85	84	85	
Line 86	85	86	
Line 87	86	87	
Line 88	87	88	
Line 89	88	89	
Line 90	89	90	
Line 91	90	91	
Line 92	91	92	

Line 93	92	93	
Line 94	93	94	
Line 95	94	95	
Line 96	95	96	
Line 97	96	97	Water Elevation
Line 98	97	98	Water Elevation
Line 99	98	99	Water Elevation
Line 100	99	100	Water Elevation
Line 101	100	101	Water Elevation
Line 102	101	102	Water Elevation
Line 103	102	103	Water Elevation
Line 104	103	104	Water Elevation
Line 105	104	105	Water Elevation
Line 106	105	106	Water Elevation
Line 107	106	43	Water Elevation
Line 108	45	107	Potential Seepage Face
Line 109	107	108	
Line 110	108	109	
Line 111	109	110	
Line 112	110	111	
Line 113	111	112	
Line 114	112	113	
Line 115	113	114	
Line 116	114	115	
Line 117	115	53	
Line 118	96	116	Water Elevation
Line 119	116	117	Water Elevation
Line 120	117	118	
Line 121	118	119	Potential Seepage Face
Line 122	119	120	Potential Seepage Face
Line 123	120	121	Potential Seepage Face
Line 124	121	122	Potential Seepage Face
Line 125	122	123	Potential Seepage Face
Line 126	123	124	Potential Seepage Face
Line 127	124	125	Potential Seepage Face
Line 128	125	126	Potential Seepage Face
Line 129	126	127	Potential Seepage Face
Line 130	127	128	Potential Seepage Face
Line 131	128	129	Potential Seepage Face
Line 132	129	130	Potential Seepage Face
Line 133	130	131	Potential Seepage Face
Line 134	131	132	Potential Seepage Face
Line 135	132	133	Potential Seepage Face
Line 136	133	134	Potential Seepage Face
Line 137	134	107	Potential Seepage Face
Line 138	145	129	
Line 139	130	146	
Line 140	146	45	
Line 141	136	142	
Line 142	54	53	
Line 143	142	143	
Line 144	145	141	

Points

	X (ft)	Y (ft)
Point 1	550	643.3647
Point 2	550	600
Point 3	-200	600
Point 4	-200	685.0056
Point 5	25.7426	639.8508
Point 6	91.76715	636.2084
Point 7	112.72756	636.8157
Point 8	144.31997	637.4228
Point 9	185.32938	634.0833
Point 10	226.03496	638.03
Point 11	286.43432	641.4313
Point 12	289.43432	641.4313
Point 13	393.36363	637.2024
Point 14	415.19395	635.1409
Point 15	439.94649	637.2024
Point 16	457.99521	637.0306
Point 17	467.62118	637.7177
Point 18	508.09452	638.9222
Point 19	550	651.4496
Point 20	541.85333	649.8496
Point 21	519.17903	648.9358
Point 22	507.29329	647.1084
Point 23	497.05329	646.7429
Point 24	486.26473	646.1946
Point 25	448.8202	646.3468
Point 26	445.8202	646.3468
Point 27	432.09654	645.6083
Point 28	429.09654	645.6083
Point 29	392.26512	648.7703
Point 30	372.67616	654.6019
Point 31	332.30566	658.2393
Point 32	320.81182	657.9134
Point 33	289.43432	661.3487
Point 34	286.43432	661.3487
Point 35	251.23197	660
Point 36	228.7977	655.5246
Point 37	208.7887	651.8887
Point 38	177.46155	650.8788
Point 39	132.71487	648.6501
Point 40	88.65473	649.0541
Point 41	47.13084	649.4536
Point 42	8.32553	653.6954
Point 43	-200	694.96
Point 44	550	663.7246
Point 45	491.0095	658
Point 46	397.28134	660.0031
Point 47	374.91191	668.8368
Point 48	371.51592	670.0031
Point 49	362.7539	671.9827
Point 50	348.62646	673.5045
Point 51	338.09036	674.0216
Point 52	333.85513	673.6933
Point 53	297	673
Point 54	287.01309	672.4149
Point 55	283.72072	672.2682

Point 56	281.59335	672.1034
Point 57	279.83536	672.109
Point 58	258.98922	672.0388
Point 59	253.56482	671.1927
Point 60	247.40234	670.0146
Point 61	247.26941	670.0031
Point 62	246.63553	669.8069
Point 63	246.16446	669.7002
Point 64	231.4451	665.1625
Point 65	226.53674	663.8916
Point 66	209.08388	661.3512
Point 67	206.98054	660.9301
Point 68	205.71863	660.7488
Point 69	197.06118	660.0031
Point 70	192.85524	659.8323
Point 71	190.78124	659.9884
Point 72	181.39906	659.9468
Point 73	180.62914	659.9453
Point 74	163.16856	659.8467
Point 75	150.51799	659.8602
Point 76	142.43782	659.8635
Point 77	136.27384	659.8581
Point 78	133.58851	659.8636
Point 79	125.91382	659.8612
Point 80	121.0177	659.8562
Point 81	112.81162	659.8501
Point 82	100.06337	659.8179
Point 83	82.77777	659.8878
Point 84	73.65349	659.9169
Point 85	52.60684	660.0031
Point 86	32.32465	667.4898
Point 87	24.66721	670.0031
Point 88	6.2574	676.8635
Point 89	1.34452	678.2221
Point 90	0.42547	678.5441
Point 91	-3.82065	680.0031
Point 92	-8.82539	681.236
Point 93	-15.65178	683.1294
Point 94	-20.77908	684.2188
Point 95	-32.86093	687.3698
Point 96	-34.93861	688.0985
Point 97	-40.36917	690.0031
Point 98	-45.11248	692.0506
Point 99	-48.98865	693.9255
Point 100	-51.44979	694.9538
Point 101	-55.94949	696.3254
Point 102	-59.28317	697.087
Point 103	-60.04348	697.4401
Point 104	-60.64641	697.6906
Point 105	-62.85537	698.6024
Point 106	-200	730
Point 107	485.27751	660.123
Point 108	397.68249	661.995
Point 109	375.60439	670.7136
Point 110	372.06274	671.93
Point 111	363.08245	673.9589

Point 112	348.78271	675.4992
Point 113	338.06199	676.0254
Point 114	333.73698	675.6902
Point 115	297	675
Point 116	108.3899	759.37
Point 117	131.7264	770.44
Point 118	151.9611	771.04
Point 119	207.564	749.65
Point 120	258.5547	726.54
Point 121	274.704	719.62
Point 122	276.8231	718.56
Point 123	279.7673	719.5
Point 124	293.2405	720.41
Point 125	340.5962	701.24
Point 126	360.5184	693.26
Point 127	389.4693	681.17
Point 128	403.4468	674.58
Point 129	413.5669	668.6
Point 130	416.3662	667.66
Point 131	419.0419	668.73
Point 132	427.1289	670.25
Point 133	447.3202	671.17
Point 134	463.2535	668.28
Point 135	-200	750.95
Point 136	91.4571	750.95
Point 137	419.5191	668.8197
Point 138	273.1677	674.2
Point 139	326.0094	666.5
Point 140	326.0094	697.5
Point 141	353.1828	689.29
Point 142	153.2026	750.78
Point 143	272.4756	715.59
Point 144	326.0094	702.63
Point 145	381.8396	679.31
Point 146	439.6323	668.8197

Static Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 251
Last Edited By: Cedric Ruhl
Date: 9/12/2010
Time: 7:27:37 PM
File Name: AD 7+25 Static.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 7+25\
Last Solved Date: 9/12/2010
Last Solved Time: 7:27:57 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Static Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 7+25
Kind: SLOPE/W
Parent: Seepage Analysis - Static Condition
Method: Spencer
Settings
- PWP Conditions Source: Parent Analysis

Slip Surface
- Direction of movement: Left to Right
- Use Passive Mode: No
- Slip Surface Option: Auto-Search
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: Yes
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced
- Number of Slices: 30
- Optimization Tolerance: 0.01
- Minimum Slip Surface Depth: 3 ft
- Optimization Maximum Iterations: 2000
- Optimization Convergence Tolerance: 1e-007
- Starting Optimization Points: 8

Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Shear/Normal Fn.
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Strength Function: Ash Dike Fill
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Shear/Normal Fn.
Unit Weight: 124 pcf
Strength Function: Ash Dike Res
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Rock

Model: Bedrock (Impenetrable)

Slip Surface Limits

Left Coordinate: (-200, 730) ft
Right Coordinate: (550, 663.7246) ft

Shear/Normal Strength Functions

Ash Dike Fill

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)

Data Point: (500, 433)
Data Point: (1000, 829)
Data Point: (1500, 1188)
Data Point: (2000, 1511)
Data Point: (2500, 1797)
Data Point: (3000, 2047)
Data Point: (3500, 2259)
Data Point: (4000, 2436)
Data Point: (4500, 2575)
Data Point: (5000, 2678)
Data Point: (5500, 2744)
Data Point: (6000, 2774)
Data Point: (20000, 2800)

Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Ash Dike Res

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 526)
Data Point: (1000, 999)
Data Point: (1500, 1417)
Data Point: (2000, 1781)
Data Point: (2500, 2092)
Data Point: (3000, 2349)
Data Point: (3500, 2552)
Data Point: (4000, 2700)
Data Point: (4500, 2795)
Data Point: (5000, 2837)
Data Point: (20000, 3500)

Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	34075.396
Region 2	PWR	1,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	9426.3413

Region 3	Residuum	43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23,22,21,20,19,44,45,46,47, 48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76, 77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103, 104,105,106	13036.297
Region 4	Blanket Drain	53,52,51,50,49,48,47,46,45,107,108,109,110,111,112,113,114,115	386.71559
Region 5	Embankment Fill - Ash Dike	96,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,107, 108,109,110,111,112,113,114,115,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70, 71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95	26903.486

Points

	X (ft)	Y (ft)
Point 1	550	643.3647
Point 2	550	600
Point 3	-200	600
Point 4	-200	685.0056
Point 5	25.7426	639.8508
Point 6	91.76715	636.2084
Point 7	112.72756	636.8157
Point 8	144.31997	637.4228
Point 9	185.32938	634.0833
Point 10	226.03496	638.03
Point 11	286.43432	641.4313
Point 12	289.43432	641.4313
Point 13	393.36363	637.2024
Point 14	415.19395	635.1409
Point 15	439.94649	637.2024
Point 16	457.99521	637.0306
Point 17	467.62118	637.7177
Point 18	508.09452	638.9222
Point 19	550	651.4496
Point 20	541.85333	649.8496
Point 21	519.17903	648.9358
Point 22	507.29329	647.1084
Point 23	497.05329	646.7429
Point 24	486.26473	646.1946
Point 25	448.8202	646.3468
Point 26	445.8202	646.3468
Point 27	432.09654	645.6083
Point 28	429.09654	645.6083
Point 29	392.26512	648.7703
Point 30	372.67616	654.6019
Point 31	332.30566	658.2393
Point 32	320.81182	657.9134
Point 33	289.43432	661.3487
Point 34	286.43432	661.3487
Point 35	251.23197	660
Point 36	228.7977	655.5246
Point 37	208.7887	651.8887
Point 38	177.46155	650.8788
Point 39	132.71487	648.6501
Point 40	88.65473	649.0541
Point 41	47.13084	649.4536
Point 42	8.32553	653.6954

Point 43	-200	694.96
Point 44	550	663.7246
Point 45	491.0095	658
Point 46	397.28134	660.0031
Point 47	374.91191	668.8368
Point 48	371.51592	670.0031
Point 49	362.7539	671.9827
Point 50	348.62646	673.5045
Point 51	338.09036	674.0216
Point 52	333.85513	673.6933
Point 53	297	673
Point 54	287.01309	672.4149
Point 55	283.72072	672.2682
Point 56	281.59335	672.1034
Point 57	279.83536	672.109
Point 58	258.98922	672.0388
Point 59	253.56482	671.1927
Point 60	247.40234	670.0146
Point 61	247.26941	670.0031
Point 62	246.63553	669.8069
Point 63	246.16446	669.7002
Point 64	231.4451	665.1625
Point 65	226.53674	663.8916
Point 66	209.08388	661.3512
Point 67	206.98054	660.9301
Point 68	205.71863	660.7488
Point 69	197.06118	660.0031
Point 70	192.85524	659.8323
Point 71	190.78124	659.9884
Point 72	181.39906	659.9468
Point 73	180.62914	659.9453
Point 74	163.16856	659.8467
Point 75	150.51799	659.8602
Point 76	142.43782	659.8635
Point 77	136.27384	659.8581
Point 78	133.58851	659.8636
Point 79	125.91382	659.8612
Point 80	121.0177	659.8562
Point 81	112.81162	659.8501
Point 82	100.06337	659.8179
Point 83	82.77777	659.8878
Point 84	73.65349	659.9169
Point 85	52.60684	660.0031
Point 86	32.32465	667.4898
Point 87	24.66721	670.0031
Point 88	6.2574	676.8635
Point 89	1.34452	678.2221
Point 90	0.42547	678.5441
Point 91	-3.82065	680.0031
Point 92	-8.82539	681.236
Point 93	-15.65178	683.1294
Point 94	-20.77908	684.2188
Point 95	-32.86093	687.3698
Point 96	-34.93861	688.0985

Point 97	-40.36917	690.0031
Point 98	-45.11248	692.0506
Point 99	-48.98865	693.9255
Point 100	-51.44979	694.9538
Point 101	-55.94949	696.3254
Point 102	-59.28317	697.087
Point 103	-60.04348	697.4401
Point 104	-60.64641	697.6906
Point 105	-62.85537	698.6024
Point 106	-200	730
Point 107	485.27751	660.123
Point 108	397.68249	661.995
Point 109	375.60439	670.7136
Point 110	372.06274	671.93
Point 111	363.08245	673.9589
Point 112	348.78271	675.4992
Point 113	338.06199	676.0254
Point 114	333.73698	675.6902
Point 115	297	675
Point 116	108.3899	759.37
Point 117	131.7264	770.44
Point 118	151.9611	771.04
Point 119	207.564	749.65
Point 120	258.5547	726.54
Point 121	274.704	719.62
Point 122	276.8231	718.56
Point 123	279.7673	719.5
Point 124	293.2405	720.41
Point 125	340.5962	701.24
Point 126	360.5184	693.26
Point 127	389.4693	681.17
Point 128	403.4468	674.58
Point 129	413.5669	668.6
Point 130	416.3662	667.66
Point 131	419.0419	668.73
Point 132	427.1289	670.25
Point 133	447.3202	671.17
Point 134	463.2535	668.28
Point 135	-200	750.95
Point 136	91.4571	750.95
Point 137	419.5191	668.8197
Point 138	273.1677	674.2
Point 139	326.0094	666.5
Point 140	326.0094	697.5
Point 141	353.1828	689.29
Point 142	153.2026	750.78
Point 143	272.4756	715.59
Point 144	326.0094	702.63
Point 145	381.8396	679.31
Point 146	439.6323	668.8197

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.58	(361.008, 1000.8)	159.4434	(128.821, 769.062)	(416.289, 667.686)
2	354	1.67	(361.008, 1000.8)	338.847	(118.481, 764.157)	(437.647, 670.729)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	130.27375	766.2817	-1006.8475	175.19609	151.72215	4.4745e-006
2	Optimized	136.91175	753.57785	-435.43264	870.82955	689.69147	37
3	Optimized	147.0291	737.3704	207.03309	2307.8719	1201.7014	367
4	Optimized	155.4452	726.6477	587.08812	3068.9241	1419.6357	367
5	Optimized	165.5887	715.71395	932.1546	4101.6523	1343.8706	775
6	Optimized	179.0585	703.21545	1276.2009	4948.8925	1300.1355	1020
7	Optimized	192.56885	692.57795	1527.6382	5915.9231	1219.9489	1324
8	Optimized	203.4164	685.54785	1656.9598	6522.5179	1002.2961	1648
9	Optimized	212.9005	680.0683	1723.7183	6674.5306	1019.8583	1648
10	Optimized	223.6278	674.97685	1753.1707	7359.5621	336.3805	2414
11	Optimized	234.4094	670.9604	1718.0568	7262.9122	332.68837	2414
12	Optimized	240.9725	668.7066	1647.08	7763.6848	11.359801	2762.9
13	Optimized	244.15465	668.03995	1638.2122	7679.2416	267.01073	2616
14	Optimized	246.4	667.56955	1651.5197	7616.5172	263.65015	2616
15	Optimized	246.95245	667.4538	1654.4673	7601.1306	262.83979	2616
16	Optimized	250.4171	666.728	1681.1065	7504.1126	257.3742	2616
17	Optimized	256.05975	665.5459	1723.9215	7346.1193	248.49857	2616
18	Optimized	258.77195	664.9777	1738.0906	7270.5944	244.53413	2616
19	Optimized	260.02125	664.716	1744.081	7239.0268	242.87409	2616
20	Optimized	267.87865	663.74255	1728.6396	7323.1643	247.27543	2616
21	Optimized	275.76355	662.86775	1702.4983	7015.1428	234.81645	2616
22	Optimized	278.2952	662.58685	1694.683	7041.5712	236.33001	2616
23	Optimized	280.6803	662.32225	1687.2463	7137.2821	240.88908	2616
24	Optimized	282.657	662.10295	1681.0229	7179.8892	243.04737	2616
25	Optimized	285.3669	661.8023	1672.417	7238.4864	246.01772	2616
26	Optimized	289.00395	661.3988	1660.7961	7316.9983	250.00154	2616
27	Optimized	292.11765	661.05545	1650.8596	7390.8646	253.70559	2616
28	Optimized	295.12025	660.728	1641.0479	7348.6345	252.27272	2616
29	Optimized	303.97375	659.76245	1612.1629	7030.182	239.47396	2616
30	Optimized	316.22385	658.80945	1572.6773	6814.6822	231.69422	2616
31	Optimized	327.0557	658.4144	1513.5244	6325.4491	404.20393	2417
32	Optimized	333.1741	658.19125	1479.3622	6048.2078	383.78517	2417
33	Optimized	335.9456	658.09015	1462.5366	5922.1342	847.3262	1940
34	Optimized	339.3752	658.0737	1435.5988	6065.0524	388.87627	2417
35	Optimized	344.68945	658.3526	1376.9585	5755.95	832.01099	1940
36	Optimized	354.65055	658.8754	1273.5878	5168.8927	1153.0285	1516
37	Optimized	360.6747	659.1916	1205.9658	4808.3388	1066.3193	1516
38	Optimized	361.79245	659.3431	1188.7714	5051.777	1143.4677	1516
39	Optimized	367.1349	660.1393	1104.4391	4632.7971	1044.4105	1516
40	Optimized	371.7893	660.83295	1033.7165	4257.6821	1308.92	1131
41	Optimized	373.4873	661.08605	1010.7132	4120.2664	1262.4689	1131
42	Optimized	375.25815	661.35	984.63382	3976.1284	1537.6174	807
43	Optimized	379.0547	661.9158	927.89779	3659.6766	1404.1244	807
44	Optimized	385.58475	662.91795	828.93889	3128.3043	1430.2268	537
45	Optimized	389.0669	663.46965	773.18291	2704.0049	1402.8243	0
46	Optimized	391.0099	663.7775	732.6477	2522.7879	1300.613	0
47	Optimized	397.99865	664.8848	591.16895	1881.9439	926.76455	111

48	Optimized	407.07745	666.32325	287.2332	951.10547	525.78262	37
49	Optimized	412.1375	667.10015	126.18825	355.75306	198.80619	5.8333e-006
50	Optimized	414.9281	667.4938	41.3734	96.455491	47.701826	7.3916e-007

Slices of Slip Surface: 354

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	354	125.10355	757.72905	-566.19577	721.7899	571.65301	37
2	354	136.7851	746.83505	-131.09412	1907.9889	1232.5391	219
3	354	146.90245	738.24345	171.06181	2766.6177	1297.775	547
4	354	157.5214	729.9409	439.25477	3455.2571	1278.7884	775
5	354	168.642	721.92805	669.79823	3931.1637	1382.8227	775
6	354	179.76255	714.57155	850.43665	4350.0359	1238.8607	1020
7	354	190.8831	707.82185	999.33823	4716.976	1316.0465	1020
8	354	202.0037	701.63775	1106.9759	5029.9473	1388.7347	1020
9	354	212.66305	696.19905	1179.552	5246.5378	1130.6274	1324
10	354	222.8612	691.43865	1225.2894	5368.8	1151.9014	1324
11	354	233.05935	687.08195	1236.4578	5445.6623	1170.1643	1324
12	354	243.2575	683.1123	1223.9648	5477.9595	1182.6161	1324
13	354	253.45565	679.51535	1183.7016	5466.1348	1190.522	1324
14	354	262.59205	676.58285	1119.1008	5431.4342	1198.8343	1324
15	354	270.6667	674.2404	1083.1291	5382.7017	1195.2868	1324
16	354	275.76355	672.8481	1068.5	5332.2238	1185.3208	1324
17	354	277.74535	672.3389	1062.2806	5382.348	1200.9844	1324
18	354	279.21745	671.9683	1064.455	5500.1844	842.79123	1940
19	354	280.6803	671.60875	1075.1584	5584.0777	378.75133	2417
20	354	282.657	671.13315	1087.6559	5674.488	385.29604	2417
21	354	285.3669	670.50335	1103.4749	5796.4183	394.20945	2417
22	354	290.1268	669.4603	1126.06	6004.8889	409.82392	2417
23	354	295.12025	668.42155	1148.7076	6115.0821	417.17778	2417
24	354	303.12285	666.98715	1178.4291	5982.503	403.54446	2417
25	354	315.3685	665.093	1200.1641	5746.2549	381.87376	2417
26	354	327.61415	663.65415	1198.8057	5443.7093	806.5342	1940
27	354	335.8995	662.887	1184.3623	5207.3666	764.37321	1940
28	354	339.3291	662.64505	1172.5943	5097.6368	1161.8309	1516
29	354	344.68945	662.36645	1148.5939	4912.5057	1114.1355	1516
30	354	354.65055	662.059	1098.3356	4533.4885	1394.6614	1131
31	354	361.63615	661.95095	1052.6038	4240.565	1294.3024	1131
32	354	367.1349	662.03225	1006.8748	3971.4939	1523.8035	807
33	354	371.7893	662.1202	968.96894	3733.1588	1420.7836	807
34	354	373.4873	662.1814	955.87534	3640.695	1379.9876	807
35	354	375.25815	662.2485	939.90245	3543.8235	1338.406	807
36	354	382.53685	662.70455	862.44934	3106.0269	1395.5263	537
37	354	391.62365	663.34145	751.5462	2414.2396	1208.0175	0
38	354	398.6124	664.0768	621.37594	1887.9846	909.41338	111
39	354	408.50685	665.33315	316.51378	953.73856	504.67798	37
40	354	414.96655	666.2754	150.45408	269.77767	103.33582	7.7325e-007
41	354	417.70405	666.72825	75.668	229.69011	133.3852	-1.9094e-006
42	354	423.0854	667.70885	-15.60371	316.7908	274.34506	-3.928e-006
43	354	432.38775	669.5958	-162.99494	164.61215	142.55632	-2.0401e-006

Seepage Analysis - Pool from 100-yr Storm Event Condition

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 262
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 11:27:12 AM
File Name: AD 7+25 100 Year.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 7+25\
Last Solved Date: 9/13/2010
Last Solved Time: 11:27:17 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Mass(M) Units: lbs
Mass Flux Units: lbs/sec
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Seepage Analysis - Pool from 100-yr Storm Event Condition

Description: Ash Dike Section Sta. 7+25 Pool from 100-yr Storm Event = 751.4
Kind: SEEP/W
Method: Steady-State
Settings
    Include Air Flow: No
Control
    Apply Runoff: Yes
Convergence
    Convergence Type: Gauss Point K
    Convergence Settings
        Maximum Number of Iterations: 500
        Tolerance: 0.01
        Maximum Change in K: 0.1
        Rate of Change in K: 1.02
        Minimum Change in K: 0.0001
    Equation Solver: Parallel Direct
    Potential Seepage Max # of Reviews: 10
Time

Starting Time: 0 sec
Duration: 0 sec
Ending Time: 0 sec

Materials

Embankment Fill - Ash Dike

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-6
K-Ratio: 0.08
K-Direction: 0 °

Blanket Drain

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

Residuum

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 0.1
K-Direction: 0 °

PWR

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 0.1
K-Direction: 0 °

Rock

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-7
K-Ratio: 0.1
K-Direction: 0 °

Boundary Conditions

Water Elevation = 751.4

Type: Head (H) 751.4

Potential Seepage Face

Review: true
Type: Total Flux (Q) 0

K Functions

1e-4

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-006
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-006)
Data Point: (10000, 3.28e-006)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-5

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-007
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-007)
Data Point: (10000, 3.28e-007)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-6

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-008
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-008)
Data Point: (10000, 3.28e-008)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-7

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-009
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-009)
Data Point: (10000, 3.28e-009)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

Regions

	Material	Points	Area (ft^2)
Region 1	Rock	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	34075.396
Region 2	PWR	1,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	9426.3413
Region 3	Residuum	43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23,22,21,20,19,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106	13036.297
Region 4	Blanket Drain	53,52,51,50,49,48,47,46,45,107,108,109,110,111,112,113,114,115	386.71559
Region 5	Embankment Fill - Ash Dike	96,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,107,108,109,110,111,112,113,114,115,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95	26903.486

Lines

	Start Point	End Point	Hydraulic Boundary
Line 1	1	2	
Line 2	2	3	
Line 3	3	4	Water Elevation = 751.4
Line 4	4	5	
Line 5	5	6	
Line 6	6	7	
Line 7	7	8	
Line 8	8	9	
Line 9	9	10	
Line 10	10	11	
Line 11	11	12	
Line 12	12	13	
Line 13	13	14	
Line 14	14	15	
Line 15	15	16	
Line 16	16	17	
Line 17	17	18	
Line 18	18	1	

Line 19	1	19	
Line 20	19	20	
Line 21	20	21	
Line 22	21	22	
Line 23	22	23	
Line 24	23	24	
Line 25	24	25	
Line 26	25	26	
Line 27	26	27	
Line 28	27	28	
Line 29	28	29	
Line 30	29	30	
Line 31	30	31	
Line 32	31	32	
Line 33	32	33	
Line 34	33	34	
Line 35	34	35	
Line 36	35	36	
Line 37	36	37	
Line 38	37	38	
Line 39	38	39	
Line 40	39	40	
Line 41	40	41	
Line 42	41	42	
Line 43	42	43	
Line 44	43	4	Water Elevation = 751.4
Line 45	19	44	
Line 46	44	45	Potential Seepage Face
Line 47	45	46	
Line 48	46	47	
Line 49	47	48	
Line 50	48	49	
Line 51	49	50	
Line 52	50	51	
Line 53	51	52	
Line 54	52	53	
Line 55	54	55	
Line 56	55	56	
Line 57	56	57	
Line 58	57	58	
Line 59	58	59	
Line 60	59	60	
Line 61	60	61	
Line 62	61	62	
Line 63	62	63	
Line 64	63	64	
Line 65	64	65	
Line 66	65	66	
Line 67	66	67	
Line 68	67	68	
Line 69	68	69	
Line 70	69	70	

Line 71	70	71	
Line 72	71	72	
Line 73	72	73	
Line 74	73	74	
Line 75	74	75	
Line 76	75	76	
Line 77	76	77	
Line 78	77	78	
Line 79	78	79	
Line 80	79	80	
Line 81	80	81	
Line 82	81	82	
Line 83	82	83	
Line 84	83	84	
Line 85	84	85	
Line 86	85	86	
Line 87	86	87	
Line 88	87	88	
Line 89	88	89	
Line 90	89	90	
Line 91	90	91	
Line 92	91	92	
Line 93	92	93	
Line 94	93	94	
Line 95	94	95	
Line 96	95	96	
Line 97	96	97	Water Elevation = 751.4
Line 98	97	98	Water Elevation = 751.4
Line 99	98	99	Water Elevation = 751.4
Line 100	99	100	Water Elevation = 751.4
Line 101	100	101	Water Elevation = 751.4
Line 102	101	102	Water Elevation = 751.4
Line 103	102	103	Water Elevation = 751.4
Line 104	103	104	Water Elevation = 751.4
Line 105	104	105	Water Elevation = 751.4
Line 106	105	106	Water Elevation = 751.4
Line 107	106	43	Water Elevation = 751.4
Line 108	45	107	Potential Seepage Face
Line 109	107	108	
Line 110	108	109	
Line 111	109	110	
Line 112	110	111	
Line 113	111	112	
Line 114	112	113	
Line 115	113	114	
Line 116	114	115	
Line 117	115	53	
Line 118	96	116	Water Elevation = 751.4
Line 119	116	117	Water Elevation = 751.4
Line 120	117	118	
Line 121	118	119	Potential Seepage Face
Line 122	119	120	Potential Seepage Face

Line 123	120	121	Potential Seepage Face
Line 124	121	122	Potential Seepage Face
Line 125	122	123	Potential Seepage Face
Line 126	123	124	Potential Seepage Face
Line 127	124	125	Potential Seepage Face
Line 128	125	126	Potential Seepage Face
Line 129	126	127	Potential Seepage Face
Line 130	127	128	Potential Seepage Face
Line 131	128	129	Potential Seepage Face
Line 132	129	130	Potential Seepage Face
Line 133	130	131	Potential Seepage Face
Line 134	131	132	Potential Seepage Face
Line 135	132	133	Potential Seepage Face
Line 136	133	134	Potential Seepage Face
Line 137	134	107	Potential Seepage Face
Line 138	145	129	
Line 139	130	146	
Line 140	146	45	
Line 141	136	142	
Line 142	54	53	
Line 143	142	143	
Line 144	145	141	

Points

	X (ft)	Y (ft)
Point 1	550	643.3647
Point 2	550	600
Point 3	-200	600
Point 4	-200	685.0056
Point 5	25.7426	639.8508
Point 6	91.76715	636.2084
Point 7	112.72756	636.8157
Point 8	144.31997	637.4228
Point 9	185.32938	634.0833
Point 10	226.03496	638.03
Point 11	286.43432	641.4313
Point 12	289.43432	641.4313
Point 13	393.36363	637.2024
Point 14	415.19395	635.1409
Point 15	439.94649	637.2024
Point 16	457.99521	637.0306
Point 17	467.62118	637.7177
Point 18	508.09452	638.9222
Point 19	550	651.4496
Point 20	541.85333	649.8496
Point 21	519.17903	648.9358
Point 22	507.29329	647.1084
Point 23	497.05329	646.7429
Point 24	486.26473	646.1946
Point 25	448.8202	646.3468
Point 26	445.8202	646.3468

Point 27	432.09654	645.6083
Point 28	429.09654	645.6083
Point 29	392.26512	648.7703
Point 30	372.67616	654.6019
Point 31	332.30566	658.2393
Point 32	320.81182	657.9134
Point 33	289.43432	661.3487
Point 34	286.43432	661.3487
Point 35	251.23197	660
Point 36	228.7977	655.5246
Point 37	208.7887	651.8887
Point 38	177.46155	650.8788
Point 39	132.71487	648.6501
Point 40	88.65473	649.0541
Point 41	47.13084	649.4536
Point 42	8.32553	653.6954
Point 43	-200	694.96
Point 44	550	663.7246
Point 45	491.0095	658
Point 46	397.28134	660.0031
Point 47	374.91191	668.8368
Point 48	371.51592	670.0031
Point 49	362.7539	671.9827
Point 50	348.62646	673.5045
Point 51	338.09036	674.0216
Point 52	333.85513	673.6933
Point 53	297	673
Point 54	287.01309	672.4149
Point 55	283.72072	672.2682
Point 56	281.59335	672.1034
Point 57	279.83536	672.109
Point 58	258.98922	672.0388
Point 59	253.56482	671.1927
Point 60	247.40234	670.0146
Point 61	247.26941	670.0031
Point 62	246.63553	669.8069
Point 63	246.16446	669.7002
Point 64	231.4451	665.1625
Point 65	226.53674	663.8916
Point 66	209.08388	661.3512
Point 67	206.98054	660.9301
Point 68	205.71863	660.7488
Point 69	197.06118	660.0031
Point 70	192.85524	659.8323
Point 71	190.78124	659.9884
Point 72	181.39906	659.9468
Point 73	180.62914	659.9453
Point 74	163.16856	659.8467
Point 75	150.51799	659.8602
Point 76	142.43782	659.8635
Point 77	136.27384	659.8581
Point 78	133.58851	659.8636

Point 79	125.91382	659.8612
Point 80	121.0177	659.8562
Point 81	112.81162	659.8501
Point 82	100.06337	659.8179
Point 83	82.77777	659.8878
Point 84	73.65349	659.9169
Point 85	52.60684	660.0031
Point 86	32.32465	667.4898
Point 87	24.66721	670.0031
Point 88	6.2574	676.8635
Point 89	1.34452	678.2221
Point 90	0.42547	678.5441
Point 91	-3.82065	680.0031
Point 92	-8.82539	681.236
Point 93	-15.65178	683.1294
Point 94	-20.77908	684.2188
Point 95	-32.86093	687.3698
Point 96	-34.93861	688.0985
Point 97	-40.36917	690.0031
Point 98	-45.11248	692.0506
Point 99	-48.98865	693.9255
Point 100	-51.44979	694.9538
Point 101	-55.94949	696.3254
Point 102	-59.28317	697.087
Point 103	-60.04348	697.4401
Point 104	-60.64641	697.6906
Point 105	-62.85537	698.6024
Point 106	-200	730
Point 107	485.27751	660.123
Point 108	397.68249	661.995
Point 109	375.60439	670.7136
Point 110	372.06274	671.93
Point 111	363.08245	673.9589
Point 112	348.78271	675.4992
Point 113	338.06199	676.0254
Point 114	333.73698	675.6902
Point 115	297	675
Point 116	108.3899	759.37
Point 117	131.7264	770.44
Point 118	151.9611	771.04
Point 119	207.564	749.65
Point 120	258.5547	726.54
Point 121	274.704	719.62
Point 122	276.8231	718.56
Point 123	279.7673	719.5
Point 124	293.2405	720.41
Point 125	340.5962	701.24
Point 126	360.5184	693.26
Point 127	389.4693	681.17
Point 128	403.4468	674.58
Point 129	413.5669	668.6
Point 130	416.3662	667.66

Point 131	419.0419	668.73
Point 132	427.1289	670.25
Point 133	447.3202	671.17
Point 134	463.2535	668.28
Point 135	-200	750.95
Point 136	91.4571	750.95
Point 137	419.5191	668.8197
Point 138	273.1677	674.2
Point 139	326.0094	666.5
Point 140	326.0094	697.5
Point 141	353.1828	689.29
Point 142	153.2026	750.78
Point 143	272.4756	715.59
Point 144	326.0094	702.63
Point 145	381.8396	679.31
Point 146	439.6323	668.8197

Pool from 100-yr Storm Event Condition Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 262
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 11:27:12 AM
File Name: AD 7+25 100 Year.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 7+25\
Last Solved Date: 9/13/2010
Last Solved Time: 11:28:32 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Pool from 100-yr Storm Event Condition Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 7+25 Pool from 100-yr Storm Event = 751.4
Kind: SLOPE/W
Parent: Seepage Analysis - Pool from 100-yr Storm Event Condition
Method: Spencer
Settings
    PWP Conditions Source: Parent Analysis
Slip Surface
    Direction of movement: Left to Right
    Use Passive Mode: No
    Slip Surface Option: Auto-Search
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: Yes
    Tension Crack
        Tension Crack Option: (none)
FOS Distribution
    FOS Calculation Option: Constant
Advanced
    Number of Slices: 30
    Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 3 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Shear/Normal Fn.
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Strength Function: Ash Dike Fill
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Shear/Normal Fn.
Unit Weight: 124 pcf
Strength Function: Ash Dike Res
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Rock

Model: Bedrock (Impenetrable)

Slip Surface Limits

Left Coordinate: (-200, 730) ft
Right Coordinate: (550, 663.7246) ft

Shear/Normal Strength Functions

Ash Dike Fill

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress

Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 433)
Data Point: (1000, 829)
Data Point: (1500, 1188)
Data Point: (2000, 1511)
Data Point: (2500, 1797)
Data Point: (3000, 2047)
Data Point: (3500, 2259)
Data Point: (4000, 2436)
Data Point: (4500, 2575)
Data Point: (5000, 2678)
Data Point: (5500, 2744)
Data Point: (6000, 2774)
Data Point: (20000, 2800)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Ash Dike Res

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 526)
Data Point: (1000, 999)
Data Point: (1500, 1417)
Data Point: (2000, 1781)
Data Point: (2500, 2092)
Data Point: (3000, 2349)
Data Point: (3500, 2552)
Data Point: (4000, 2700)
Data Point: (4500, 2795)
Data Point: (5000, 2837)
Data Point: (20000, 3500)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	34075.396
Region 2	PWR	1,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	9426.3413
Region 3	Residuum	43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23,22,21,20,19,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106	13036.297
Region 4	Blanket Drain	53,52,51,50,49,48,47,46,45,107,108,109,110,111,112,113,114,115	386.71559
Region 5	Embankment Fill - Ash Dike	96,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,107,108,109,110,111,112,113,114,115,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95	26903.486

Points

	X (ft)	Y (ft)
Point 1	550	643.3647
Point 2	550	600
Point 3	-200	600
Point 4	-200	685.0056
Point 5	25.7426	639.8508
Point 6	91.76715	636.2084
Point 7	112.72756	636.8157
Point 8	144.31997	637.4228
Point 9	185.32938	634.0833
Point 10	226.03496	638.03
Point 11	286.43432	641.4313
Point 12	289.43432	641.4313
Point 13	393.36363	637.2024
Point 14	415.19395	635.1409
Point 15	439.94649	637.2024
Point 16	457.99521	637.0306
Point 17	467.62118	637.7177
Point 18	508.09452	638.9222
Point 19	550	651.4496
Point 20	541.85333	649.8496
Point 21	519.17903	648.9358
Point 22	507.29329	647.1084
Point 23	497.05329	646.7429
Point 24	486.26473	646.1946
Point 25	448.8202	646.3468
Point 26	445.8202	646.3468
Point 27	432.09654	645.6083
Point 28	429.09654	645.6083
Point 29	392.26512	648.7703
Point 30	372.67616	654.6019
Point 31	332.30566	658.2393
Point 32	320.81182	657.9134
Point 33	289.43432	661.3487
Point 34	286.43432	661.3487
Point 35	251.23197	660

Point 36	228.7977	655.5246
Point 37	208.7887	651.8887
Point 38	177.46155	650.8788
Point 39	132.71487	648.6501
Point 40	88.65473	649.0541
Point 41	47.13084	649.4536
Point 42	8.32553	653.6954
Point 43	-200	694.96
Point 44	550	663.7246
Point 45	491.0095	658
Point 46	397.28134	660.0031
Point 47	374.91191	668.8368
Point 48	371.51592	670.0031
Point 49	362.7539	671.9827
Point 50	348.62646	673.5045
Point 51	338.09036	674.0216
Point 52	333.85513	673.6933
Point 53	297	673
Point 54	287.01309	672.4149
Point 55	283.72072	672.2682
Point 56	281.59335	672.1034
Point 57	279.83536	672.109
Point 58	258.98922	672.0388
Point 59	253.56482	671.1927
Point 60	247.40234	670.0146
Point 61	247.26941	670.0031
Point 62	246.63553	669.8069
Point 63	246.16446	669.7002
Point 64	231.4451	665.1625
Point 65	226.53674	663.8916
Point 66	209.08388	661.3512
Point 67	206.98054	660.9301
Point 68	205.71863	660.7488
Point 69	197.06118	660.0031
Point 70	192.85524	659.8323
Point 71	190.78124	659.9884
Point 72	181.39906	659.9468
Point 73	180.62914	659.9453
Point 74	163.16856	659.8467
Point 75	150.51799	659.8602
Point 76	142.43782	659.8635
Point 77	136.27384	659.8581
Point 78	133.58851	659.8636
Point 79	125.91382	659.8612
Point 80	121.0177	659.8562
Point 81	112.81162	659.8501
Point 82	100.06337	659.8179
Point 83	82.77777	659.8878
Point 84	73.65349	659.9169
Point 85	52.60684	660.0031
Point 86	32.32465	667.4898
Point 87	24.66721	670.0031

Point 88	6.2574	676.8635
Point 89	1.34452	678.2221
Point 90	0.42547	678.5441
Point 91	-3.82065	680.0031
Point 92	-8.82539	681.236
Point 93	-15.65178	683.1294
Point 94	-20.77908	684.2188
Point 95	-32.86093	687.3698
Point 96	-34.93861	688.0985
Point 97	-40.36917	690.0031
Point 98	-45.11248	692.0506
Point 99	-48.98865	693.9255
Point 100	-51.44979	694.9538
Point 101	-55.94949	696.3254
Point 102	-59.28317	697.087
Point 103	-60.04348	697.4401
Point 104	-60.64641	697.6906
Point 105	-62.85537	698.6024
Point 106	-200	730
Point 107	485.27751	660.123
Point 108	397.68249	661.995
Point 109	375.60439	670.7136
Point 110	372.06274	671.93
Point 111	363.08245	673.9589
Point 112	348.78271	675.4992
Point 113	338.06199	676.0254
Point 114	333.73698	675.6902
Point 115	297	675
Point 116	108.3899	759.37
Point 117	131.7264	770.44
Point 118	151.9611	771.04
Point 119	207.564	749.65
Point 120	258.5547	726.54
Point 121	274.704	719.62
Point 122	276.8231	718.56
Point 123	279.7673	719.5
Point 124	293.2405	720.41
Point 125	340.5962	701.24
Point 126	360.5184	693.26
Point 127	389.4693	681.17
Point 128	403.4468	674.58
Point 129	413.5669	668.6
Point 130	416.3662	667.66
Point 131	419.0419	668.73
Point 132	427.1289	670.25
Point 133	447.3202	671.17
Point 134	463.2535	668.28
Point 135	-200	750.95
Point 136	91.4571	750.95
Point 137	419.5191	668.8197
Point 138	273.1677	674.2
Point 139	326.0094	666.5

Point 140	326.0094	697.5
Point 141	353.1828	689.29
Point 142	153.2026	750.78
Point 143	272.4756	715.59
Point 144	326.0094	702.63
Point 145	381.8396	679.31
Point 146	439.6323	668.8197

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.58	(361.008, 1000.8)	159.0425	(126.026, 767.736)	(416.289, 667.686)
2	354	1.67	(361.008, 1000.8)	338.847	(118.481, 764.157)	(437.647, 670.729)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	128.87605	763.2674	-825.79496	333.7198	289.00581	-4.1609e-006
2	Optimized	136.70665	750.99165	-284.26003	1145.6681	822.57922	111
3	Optimized	146.824	737.0345	247.49488	2418.7283	1241.9678	367
4	Optimized	155.78455	726.30755	621.38035	3188.7263	1283.6701	547
5	Optimized	163.4016	718.1441	878.64947	4015.5504	1330.0496	775
6	Optimized	170.98885	710.9715	1084.9629	4403.6391	1407.1225	775
7	Optimized	180.88625	702.3966	1308.8266	5103.4408	1343.2961	1020
8	Optimized	191.7321	693.99405	1502.6997	5741.5093	1178.3946	1324
9	Optimized	202.0191	687.2581	1630.138	6344.5738	971.16516	1648
10	Optimized	211.50885	681.57275	1704.2062	6526.5203	993.38791	1648
11	Optimized	220.51075	677.0677	1739.8334	7116.0189	709.65932	2018
12	Optimized	230.6249	672.78425	1737.7395	7083.3345	705.62136	2018
13	Optimized	239.4097	669.70475	1665.909	7576.133	354.6103	2414
14	Optimized	244.65095	668.38625	1617.1771	7457.3143	258.13139	2616
15	Optimized	246.4	667.94625	1633.2178	7417.6536	255.66941	2616
16	Optimized	246.95245	667.8073	1638.085	7405.1171	254.90018	2616
17	Optimized	250.4171	666.93575	1676.1793	7326.1405	249.7257	2616
18	Optimized	256.04135	665.5209	1736.4031	7197.9915	241.3997	2616
19	Optimized	258.5363	664.8958	1756.774	7648.3601	260.4054	2616
20	Optimized	258.77195	664.8688	1756.3058	7639.4522	260.03238	2616
21	Optimized	262.9179	664.3939	1747.0486	7484.226	253.58062	2616
22	Optimized	270.7753	663.4939	1723.2775	7189.8692	241.62085	2616
23	Optimized	275.76355	662.92255	1708.4741	6994.0496	233.62002	2616
24	Optimized	278.2952	662.63255	1701.1248	7021.8809	235.17498	2616
25	Optimized	280.6803	662.35935	1694.1333	7118.6459	239.76097	2616
26	Optimized	282.657	662.13295	1688.2892	7161.6043	241.91802	2616
27	Optimized	285.3669	661.82255	1680.1664	7221.4051	244.92021	2616
28	Optimized	289.00395	661.40595	1669.2388	7301.3445	248.93649	2616
29	Optimized	292.11765	661.05545	1659.6245	7389.5365	253.25949	2616
30	Optimized	295.12025	660.728	1649.6417	7347.3124	251.83444	2616
31	Optimized	303.97375	659.76245	1620.3595	7028.899	239.05497	2616
32	Optimized	316.1786	658.80815	1580.8064	6812.6549	231.2453	2616
33	Optimized	327.12495	658.40275	1520.9361	6319.0058	403.0401	2417
34	Optimized	333.2886	658.1745	1486.4042	6040.2233	382.52294	2417
35	Optimized	335.9137	658.0773	1470.4694	5920.7633	845.55848	1940

36	Optimized	338.23765	657.99125	1456.4209	5814.35	828.00913	1940
37	Optimized	339.49055	658.05085	1442.7826	6081.2653	389.63472	2417
38	Optimized	344.68945	658.3567	1383.3025	5774.4098	834.313	1940
39	Optimized	353.9132	658.89935	1284.3001	5222.8141	1165.8185	1516
40	Optimized	359.78105	659.30195	1213.5957	5123.0628	1157.2205	1516
41	Optimized	361.63615	659.55545	1184.8712	4983.8695	1124.5212	1516
42	Optimized	367.1349	660.30695	1101.6385	4563.144	1405.3605	1131
43	Optimized	371.7893	660.94305	1033.8596	4198.203	1284.7136	1131
44	Optimized	373.4873	661.1751	1011.9093	4064.4681	1239.3294	1131
45	Optimized	375.25815	661.4171	986.89872	3922.9282	1509.1085	807
46	Optimized	378.5539	661.8675	939.57502	3656.4502	1396.464	807
47	Optimized	385.0844	662.83805	842.00501	3167.8099	1446.6725	537
48	Optimized	389.06735	663.4692	778.41928	2699.9864	1396.1002	0
49	Optimized	391.0103	663.7771	737.77608	2518.9563	1294.1032	0
50	Optimized	397.99905	664.88455	595.13482	1878.9914	921.79726	111
51	Optimized	407.07745	666.32315	289.06837	949.53763	523.08745	37
52	Optimized	412.1375	667.10015	126.97104	355.1296	197.58836	5.7978e-006
53	Optimized	414.9281	667.4938	41.628006	96.29909	47.345889	-9.0309e-007

Slices of Slip Surface: 354

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	354	125.10355	757.72905	-538.80427	721.46484	571.39556	37
2	354	136.7851	746.83505	-104.91679	1907.322	1232.1083	219
3	354	146.90245	738.24345	196.0945	2768.5327	1286.2162	547
4	354	157.5214	729.9409	463.05909	3456.5512	1496.7427	547
5	354	168.642	721.92805	692.27831	3932.052	1373.6677	775
6	354	179.76255	714.57155	871.55702	4350.6437	1475.1367	775
7	354	190.8831	707.82185	1019.0902	4717.2093	1309.1369	1020
8	354	202.0037	701.63775	1125.3977	5030.0268	1382.2415	1020
9	354	212.66305	696.19905	1196.7427	5246.4497	1125.8238	1324
10	354	222.8612	691.43865	1241.2267	5368.7105	1147.4459	1324
11	354	233.05935	687.08195	1251.1667	5445.5715	1166.05	1324
12	354	243.2575	683.1123	1237.2967	5477.8676	1178.8842	1324
13	354	253.45565	679.51535	1195.7896	5466.1348	1187.1615	1324
14	354	262.59205	676.58285	1129.9677	5431.4342	1195.8133	1324
15	354	270.6667	674.2404	1093.1196	5382.821	1192.5426	1324
16	354	275.76355	672.8481	1077.9998	5332.2238	1182.6798	1324
17	354	277.74535	672.3389	1071.5823	5382.348	1198.3985	1324
18	354	279.21745	671.9683	1073.6329	5500.2727	841.0642	1940
19	354	280.6803	671.60875	1084.3091	5584.0777	854.95871	1940
20	354	282.657	671.13315	1096.711	5674.488	384.53541	2417
21	354	285.3669	670.50335	1112.4161	5796.7144	393.48325	2417
22	354	290.1268	669.4603	1134.8064	6005.0459	409.1024	2417
23	354	295.12025	668.42155	1157.2396	6115.343	416.48301	2417
24	354	303.12285	666.98715	1186.6361	5982.9053	402.88886	2417
25	354	315.3685	665.093	1207.9322	5746.8214	381.26882	2417
26	354	327.61415	663.65415	1206.1195	5444.2781	805.25266	1940
27	354	335.8995	662.887	1191.3949	5208.0583	763.16843	1940
28	354	339.3291	662.64505	1179.4856	5098.0306	1159.9076	1516
29	354	344.68945	662.36645	1155.2923	4913.1158	1112.3333	1516
30	354	354.65055	662.059	1104.7253	4533.9997	1392.2748	1131

31	354	361.63615	661.95095	1058.7322	4241.1465	1292.0504	1131
32	354	367.1349	662.03225	1012.7857	3971.9503	1520.9999	807
33	354	371.7893	662.1202	974.70832	3733.7072	1418.1154	807
34	354	373.4873	662.1814	961.55735	3641.0457	1377.2473	807
35	354	375.25815	662.2485	945.55826	3544.1121	1335.6473	807
36	354	382.53685	662.70455	867.84774	3106.2428	1392.3027	537
37	354	391.62365	663.34145	756.60813	2414.0085	1204.1718	0
38	354	398.6124	664.0768	625.40517	1887.779	906.37283	111
39	354	408.50685	665.33315	318.48031	953.61137	503.01976	37
40	354	414.96655	666.2754	151.4063	269.54843	102.31266	7.6553e-007
41	354	417.70405	666.72825	76.169112	229.63116	132.90018	-1.9025e-006
42	354	423.0854	667.70885	-15.083424	317.03392	274.55561	-3.931e-006
43	354	432.38775	669.5958	-161.85173	164.75157	142.67706	4.1774e-006

Seepage Analysis - Surcharge Pool Condition

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 264
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 12:50:06 PM
File Name: AD 7+25 Surcharge.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 7+25\
Last Solved Date: 9/13/2010
Last Solved Time: 12:50:11 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Mass(M) Units: lbs
Mass Flux Units: lbs/sec
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Seepage Analysis - Surcharge Pool Condition

Description: Ash Dike Section Sta. 7+25 Surcharge Pool = 760
Kind: SEEP/W
Method: Steady-State
Settings
    Include Air Flow: No
Control
    Apply Runoff: Yes
Convergence
    Convergence Type: Gauss Point K
    Convergence Settings
        Maximum Number of Iterations: 500
        Tolerance: 0.01
        Maximum Change in K: 0.1
        Rate of Change in K: 1.02
        Minimum Change in K: 0.0001
    Equation Solver: Parallel Direct
    Potential Seepage Max # of Reviews: 10
Time
    Starting Time: 0 sec
    Duration: 0 sec

Ending Time: 0 sec

Materials

Embankment Fill - Ash Dike

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-6
K-Ratio: 0.08
K-Direction: 0 °

Blanket Drain

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

Residuum

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 0.1
K-Direction: 0 °

PWR

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 0.1
K-Direction: 0 °

Rock

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-7
K-Ratio: 0.1
K-Direction: 0 °

Boundary Conditions

Water Elevation = 760

Type: Head (H) 760

Potential Seepage Face

Review: true
Type: Total Flux (Q) 0

K Functions

1e-4

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-006
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-006)
Data Point: (10000, 3.28e-006)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-5

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-007
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-007)
Data Point: (10000, 3.28e-007)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-6

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-008
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-008)
Data Point: (10000, 3.28e-008)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-7

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure

Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-009
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-009)
Data Point: (10000, 3.28e-009)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

Regions

	Material	Points	Area (ft^2)
Region 1	Rock	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	34075.396
Region 2	PWR	1,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	9426.3413
Region 3	Residuum	43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23,22,21,20,19,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106	13036.297
Region 4	Blanket Drain	53,52,51,50,49,48,47,46,45,107,108,109,110,111,112,113,114,115	386.71559
Region 5	Embankment Fill - Ash Dike	96,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,107,108,109,110,111,112,113,114,115,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95	26903.486

Lines

	Start Point	End Point	Hydraulic Boundary
Line 1	1	2	
Line 2	2	3	
Line 3	3	4	Water Elevation = 760
Line 4	4	5	
Line 5	5	6	
Line 6	6	7	
Line 7	7	8	
Line 8	8	9	
Line 9	9	10	
Line 10	10	11	
Line 11	11	12	
Line 12	12	13	
Line 13	13	14	
Line 14	14	15	
Line 15	15	16	
Line 16	16	17	
Line 17	17	18	
Line 18	18	1	
Line 19	1	19	
Line 20	19	20	

Line 21	20	21	
Line 22	21	22	
Line 23	22	23	
Line 24	23	24	
Line 25	24	25	
Line 26	25	26	
Line 27	26	27	
Line 28	27	28	
Line 29	28	29	
Line 30	29	30	
Line 31	30	31	
Line 32	31	32	
Line 33	32	33	
Line 34	33	34	
Line 35	34	35	
Line 36	35	36	
Line 37	36	37	
Line 38	37	38	
Line 39	38	39	
Line 40	39	40	
Line 41	40	41	
Line 42	41	42	
Line 43	42	43	
Line 44	43	4	Water Elevation = 760
Line 45	19	44	
Line 46	44	45	Potential Seepage Face
Line 47	45	46	
Line 48	46	47	
Line 49	47	48	
Line 50	48	49	
Line 51	49	50	
Line 52	50	51	
Line 53	51	52	
Line 54	52	53	
Line 55	54	55	
Line 56	55	56	
Line 57	56	57	
Line 58	57	58	
Line 59	58	59	
Line 60	59	60	
Line 61	60	61	
Line 62	61	62	
Line 63	62	63	
Line 64	63	64	
Line 65	64	65	
Line 66	65	66	
Line 67	66	67	
Line 68	67	68	
Line 69	68	69	
Line 70	69	70	
Line 71	70	71	
Line 72	71	72	

Line 73	72	73	
Line 74	73	74	
Line 75	74	75	
Line 76	75	76	
Line 77	76	77	
Line 78	77	78	
Line 79	78	79	
Line 80	79	80	
Line 81	80	81	
Line 82	81	82	
Line 83	82	83	
Line 84	83	84	
Line 85	84	85	
Line 86	85	86	
Line 87	86	87	
Line 88	87	88	
Line 89	88	89	
Line 90	89	90	
Line 91	90	91	
Line 92	91	92	
Line 93	92	93	
Line 94	93	94	
Line 95	94	95	
Line 96	95	96	
Line 97	96	97	Water Elevation = 760
Line 98	97	98	Water Elevation = 760
Line 99	98	99	Water Elevation = 760
Line 100	99	100	Water Elevation = 760
Line 101	100	101	Water Elevation = 760
Line 102	101	102	Water Elevation = 760
Line 103	102	103	Water Elevation = 760
Line 104	103	104	Water Elevation = 760
Line 105	104	105	Water Elevation = 760
Line 106	105	106	Water Elevation = 760
Line 107	106	43	Water Elevation = 760
Line 108	45	107	Potential Seepage Face
Line 109	107	108	
Line 110	108	109	
Line 111	109	110	
Line 112	110	111	
Line 113	111	112	
Line 114	112	113	
Line 115	113	114	
Line 116	114	115	
Line 117	115	53	
Line 118	96	116	Water Elevation = 760
Line 119	116	117	Water Elevation = 760
Line 120	117	118	
Line 121	118	119	Potential Seepage Face
Line 122	119	120	Potential Seepage Face
Line 123	120	121	Potential Seepage Face
Line 124	121	122	Potential Seepage Face

Line 125	122	123	Potential Seepage Face
Line 126	123	124	Potential Seepage Face
Line 127	124	125	Potential Seepage Face
Line 128	125	126	Potential Seepage Face
Line 129	126	127	Potential Seepage Face
Line 130	127	128	Potential Seepage Face
Line 131	128	129	Potential Seepage Face
Line 132	129	130	Potential Seepage Face
Line 133	130	131	Potential Seepage Face
Line 134	131	132	Potential Seepage Face
Line 135	132	133	Potential Seepage Face
Line 136	133	134	Potential Seepage Face
Line 137	134	107	Potential Seepage Face
Line 138	145	129	
Line 139	130	146	
Line 140	146	45	
Line 141	136	142	
Line 142	54	53	
Line 143	142	143	
Line 144	145	141	

Points

	X (ft)	Y (ft)
Point 1	550	643.3647
Point 2	550	600
Point 3	-200	600
Point 4	-200	685.0056
Point 5	25.7426	639.8508
Point 6	91.76715	636.2084
Point 7	112.72756	636.8157
Point 8	144.31997	637.4228
Point 9	185.32938	634.0833
Point 10	226.03496	638.03
Point 11	286.43432	641.4313
Point 12	289.43432	641.4313
Point 13	393.36363	637.2024
Point 14	415.19395	635.1409
Point 15	439.94649	637.2024
Point 16	457.99521	637.0306
Point 17	467.62118	637.7177
Point 18	508.09452	638.9222
Point 19	550	651.4496
Point 20	541.85333	649.8496
Point 21	519.17903	648.9358
Point 22	507.29329	647.1084
Point 23	497.05329	646.7429
Point 24	486.26473	646.1946
Point 25	448.8202	646.3468
Point 26	445.8202	646.3468
Point 27	432.09654	645.6083
Point 28	429.09654	645.6083

Point 29	392.26512	648.7703
Point 30	372.67616	654.6019
Point 31	332.30566	658.2393
Point 32	320.81182	657.9134
Point 33	289.43432	661.3487
Point 34	286.43432	661.3487
Point 35	251.23197	660
Point 36	228.7977	655.5246
Point 37	208.7887	651.8887
Point 38	177.46155	650.8788
Point 39	132.71487	648.6501
Point 40	88.65473	649.0541
Point 41	47.13084	649.4536
Point 42	8.32553	653.6954
Point 43	-200	694.96
Point 44	550	663.7246
Point 45	491.0095	658
Point 46	397.28134	660.0031
Point 47	374.91191	668.8368
Point 48	371.51592	670.0031
Point 49	362.7539	671.9827
Point 50	348.62646	673.5045
Point 51	338.09036	674.0216
Point 52	333.85513	673.6933
Point 53	297	673
Point 54	287.01309	672.4149
Point 55	283.72072	672.2682
Point 56	281.59335	672.1034
Point 57	279.83536	672.109
Point 58	258.98922	672.0388
Point 59	253.56482	671.1927
Point 60	247.40234	670.0146
Point 61	247.26941	670.0031
Point 62	246.63553	669.8069
Point 63	246.16446	669.7002
Point 64	231.4451	665.1625
Point 65	226.53674	663.8916
Point 66	209.08388	661.3512
Point 67	206.98054	660.9301
Point 68	205.71863	660.7488
Point 69	197.06118	660.0031
Point 70	192.85524	659.8323
Point 71	190.78124	659.9884
Point 72	181.39906	659.9468
Point 73	180.62914	659.9453
Point 74	163.16856	659.8467
Point 75	150.51799	659.8602
Point 76	142.43782	659.8635
Point 77	136.27384	659.8581
Point 78	133.58851	659.8636
Point 79	125.91382	659.8612
Point 80	121.0177	659.8562

Point 81	112.81162	659.8501
Point 82	100.06337	659.8179
Point 83	82.77777	659.8878
Point 84	73.65349	659.9169
Point 85	52.60684	660.0031
Point 86	32.32465	667.4898
Point 87	24.66721	670.0031
Point 88	6.2574	676.8635
Point 89	1.34452	678.2221
Point 90	0.42547	678.5441
Point 91	-3.82065	680.0031
Point 92	-8.82539	681.236
Point 93	-15.65178	683.1294
Point 94	-20.77908	684.2188
Point 95	-32.86093	687.3698
Point 96	-34.93861	688.0985
Point 97	-40.36917	690.0031
Point 98	-45.11248	692.0506
Point 99	-48.98865	693.9255
Point 100	-51.44979	694.9538
Point 101	-55.94949	696.3254
Point 102	-59.28317	697.087
Point 103	-60.04348	697.4401
Point 104	-60.64641	697.6906
Point 105	-62.85537	698.6024
Point 106	-200	730
Point 107	485.27751	660.123
Point 108	397.68249	661.995
Point 109	375.60439	670.7136
Point 110	372.06274	671.93
Point 111	363.08245	673.9589
Point 112	348.78271	675.4992
Point 113	338.06199	676.0254
Point 114	333.73698	675.6902
Point 115	297	675
Point 116	108.3899	759.37
Point 117	131.7264	770.44
Point 118	151.9611	771.04
Point 119	207.564	749.65
Point 120	258.5547	726.54
Point 121	274.704	719.62
Point 122	276.8231	718.56
Point 123	279.7673	719.5
Point 124	293.2405	720.41
Point 125	340.5962	701.24
Point 126	360.5184	693.26
Point 127	389.4693	681.17
Point 128	403.4468	674.58
Point 129	413.5669	668.6
Point 130	416.3662	667.66
Point 131	419.0419	668.73
Point 132	427.1289	670.25

Point 133	447.3202	671.17
Point 134	463.2535	668.28
Point 135	-200	750.95
Point 136	91.4571	750.95
Point 137	419.5191	668.8197
Point 138	273.1677	674.2
Point 139	326.0094	666.5
Point 140	326.0094	697.5
Point 141	353.1828	689.29
Point 142	153.2026	750.78
Point 143	272.4756	715.59
Point 144	326.0094	702.63
Point 145	381.8396	679.31
Point 146	439.6323	668.8197

Surcharge Pool Condition Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 265
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 12:50:40 PM
File Name: AD 7+25 Surcharge.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 7+25\
Last Solved Date: 9/13/2010
Last Solved Time: 12:53:31 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Surcharge Pool Condition Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 7+25 Surcharge Pool = 760
Kind: SLOPE/W
Parent: Seepage Analysis - Surcharge Pool Condition
Method: Spencer
Settings
    PWP Conditions Source: Parent Analysis
Slip Surface
    Direction of movement: Left to Right
    Use Passive Mode: No
    Slip Surface Option: Auto-Search
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: Yes
    Tension Crack
        Tension Crack Option: (none)
FOS Distribution
    FOS Calculation Option: Constant
Advanced
    Number of Slices: 30
    Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 3 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Shear/Normal Fn.
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Strength Function: Ash Dike Fill
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Shear/Normal Fn.
Unit Weight: 124 pcf
Strength Function: Ash Dike Res
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Rock

Model: Bedrock (Impenetrable)

Slip Surface Limits

Left Coordinate: (-200, 730) ft
Right Coordinate: (550, 663.7246) ft

Shear/Normal Strength Functions

Ash Dike Fill

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress

Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 433)
Data Point: (1000, 829)
Data Point: (1500, 1188)
Data Point: (2000, 1511)
Data Point: (2500, 1797)
Data Point: (3000, 2047)
Data Point: (3500, 2259)
Data Point: (4000, 2436)
Data Point: (4500, 2575)
Data Point: (5000, 2678)
Data Point: (5500, 2744)
Data Point: (6000, 2774)
Data Point: (20000, 2800)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Ash Dike Res

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 526)
Data Point: (1000, 999)
Data Point: (1500, 1417)
Data Point: (2000, 1781)
Data Point: (2500, 2092)
Data Point: (3000, 2349)
Data Point: (3500, 2552)
Data Point: (4000, 2700)
Data Point: (4500, 2795)
Data Point: (5000, 2837)
Data Point: (20000, 3500)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	34075.396
Region 2	PWR	1,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	9426.3413
Region 3	Residuum	43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23,22,21,20,19,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106	13036.297
Region 4	Blanket Drain	53,52,51,50,49,48,47,46,45,107,108,109,110,111,112,113,114,115	386.71559
Region 5	Embankment Fill - Ash Dike	96,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,107,108,109,110,111,112,113,114,115,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95	26903.486

Points

	X (ft)	Y (ft)
Point 1	550	643.3647
Point 2	550	600
Point 3	-200	600
Point 4	-200	685.0056
Point 5	25.7426	639.8508
Point 6	91.76715	636.2084
Point 7	112.72756	636.8157
Point 8	144.31997	637.4228
Point 9	185.32938	634.0833
Point 10	226.03496	638.03
Point 11	286.43432	641.4313
Point 12	289.43432	641.4313
Point 13	393.36363	637.2024
Point 14	415.19395	635.1409
Point 15	439.94649	637.2024
Point 16	457.99521	637.0306
Point 17	467.62118	637.7177
Point 18	508.09452	638.9222
Point 19	550	651.4496
Point 20	541.85333	649.8496
Point 21	519.17903	648.9358
Point 22	507.29329	647.1084
Point 23	497.05329	646.7429
Point 24	486.26473	646.1946
Point 25	448.8202	646.3468
Point 26	445.8202	646.3468
Point 27	432.09654	645.6083
Point 28	429.09654	645.6083
Point 29	392.26512	648.7703
Point 30	372.67616	654.6019
Point 31	332.30566	658.2393
Point 32	320.81182	657.9134
Point 33	289.43432	661.3487
Point 34	286.43432	661.3487
Point 35	251.23197	660

Point 36	228.7977	655.5246
Point 37	208.7887	651.8887
Point 38	177.46155	650.8788
Point 39	132.71487	648.6501
Point 40	88.65473	649.0541
Point 41	47.13084	649.4536
Point 42	8.32553	653.6954
Point 43	-200	694.96
Point 44	550	663.7246
Point 45	491.0095	658
Point 46	397.28134	660.0031
Point 47	374.91191	668.8368
Point 48	371.51592	670.0031
Point 49	362.7539	671.9827
Point 50	348.62646	673.5045
Point 51	338.09036	674.0216
Point 52	333.85513	673.6933
Point 53	297	673
Point 54	287.01309	672.4149
Point 55	283.72072	672.2682
Point 56	281.59335	672.1034
Point 57	279.83536	672.109
Point 58	258.98922	672.0388
Point 59	253.56482	671.1927
Point 60	247.40234	670.0146
Point 61	247.26941	670.0031
Point 62	246.63553	669.8069
Point 63	246.16446	669.7002
Point 64	231.4451	665.1625
Point 65	226.53674	663.8916
Point 66	209.08388	661.3512
Point 67	206.98054	660.9301
Point 68	205.71863	660.7488
Point 69	197.06118	660.0031
Point 70	192.85524	659.8323
Point 71	190.78124	659.9884
Point 72	181.39906	659.9468
Point 73	180.62914	659.9453
Point 74	163.16856	659.8467
Point 75	150.51799	659.8602
Point 76	142.43782	659.8635
Point 77	136.27384	659.8581
Point 78	133.58851	659.8636
Point 79	125.91382	659.8612
Point 80	121.0177	659.8562
Point 81	112.81162	659.8501
Point 82	100.06337	659.8179
Point 83	82.77777	659.8878
Point 84	73.65349	659.9169
Point 85	52.60684	660.0031
Point 86	32.32465	667.4898
Point 87	24.66721	670.0031

Point 88	6.2574	676.8635
Point 89	1.34452	678.2221
Point 90	0.42547	678.5441
Point 91	-3.82065	680.0031
Point 92	-8.82539	681.236
Point 93	-15.65178	683.1294
Point 94	-20.77908	684.2188
Point 95	-32.86093	687.3698
Point 96	-34.93861	688.0985
Point 97	-40.36917	690.0031
Point 98	-45.11248	692.0506
Point 99	-48.98865	693.9255
Point 100	-51.44979	694.9538
Point 101	-55.94949	696.3254
Point 102	-59.28317	697.087
Point 103	-60.04348	697.4401
Point 104	-60.64641	697.6906
Point 105	-62.85537	698.6024
Point 106	-200	730
Point 107	485.27751	660.123
Point 108	397.68249	661.995
Point 109	375.60439	670.7136
Point 110	372.06274	671.93
Point 111	363.08245	673.9589
Point 112	348.78271	675.4992
Point 113	338.06199	676.0254
Point 114	333.73698	675.6902
Point 115	297	675
Point 116	108.3899	759.37
Point 117	131.7264	770.44
Point 118	151.9611	771.04
Point 119	207.564	749.65
Point 120	258.5547	726.54
Point 121	274.704	719.62
Point 122	276.8231	718.56
Point 123	279.7673	719.5
Point 124	293.2405	720.41
Point 125	340.5962	701.24
Point 126	360.5184	693.26
Point 127	389.4693	681.17
Point 128	403.4468	674.58
Point 129	413.5669	668.6
Point 130	416.3662	667.66
Point 131	419.0419	668.73
Point 132	427.1289	670.25
Point 133	447.3202	671.17
Point 134	463.2535	668.28
Point 135	-200	750.95
Point 136	91.4571	750.95
Point 137	419.5191	668.8197
Point 138	273.1677	674.2
Point 139	326.0094	666.5

Point 140	326.0094	697.5
Point 141	353.1828	689.29
Point 142	153.2026	750.78
Point 143	272.4756	715.59
Point 144	326.0094	702.63
Point 145	381.8396	679.31
Point 146	439.6323	668.8197

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.51	(361.008, 1000.8)	160.5524	(125.366, 767.423)	(424.446, 669.746)
2	354	1.61	(361.008, 1000.8)	338.847	(118.481, 764.157)	(437.647, 670.729)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	128.5464	762.1265	-250.44979	369.61679	320.09307	-4.6121e-006
2	Optimized	135.6838	750.23845	234.75073	1199.3775	763.97825	37
3	Optimized	145.80115	735.6402	738.25686	2498.5709	1137.1428	219
4	Optimized	153.67745	725.40245	1061.7967	3247.1172	1250.0258	367
5	Optimized	162.32735	715.72065	1337.5582	4071.3803	1366.908	547
6	Optimized	175.7308	702.918	1657.9567	5212.8392	1258.431	1020
7	Optimized	186.05485	694.9252	1827.4095	5940.2582	1143.3773	1324
8	Optimized	193.76315	689.6432	1923.4031	6170.5572	1180.7144	1324
9	Optimized	202.59065	684.33675	1996.5034	6797.3803	988.97187	1648
10	Optimized	214.53415	677.9357	2044.5583	6936.5894	1007.7495	1648
11	Optimized	226.30415	672.65425	2043.963	7658.5648	336.87312	2414
12	Optimized	235.9039	669.5626	1960.1777	7516.7744	333.39285	2414
13	Optimized	243.08375	667.2503	1924.9682	7409.5538	242.41617	2616
14	Optimized	245.8141	666.41715	1959.8783	7864.6075	260.98632	2616
15	Optimized	246.4	666.3057	1961.7195	7846.7111	260.11393	2616
16	Optimized	246.95245	666.20065	1963.2971	7829.9414	259.30299	2616
17	Optimized	250.4171	665.5418	1980.262	7724.5822	253.89632	2616
18	Optimized	256.05975	664.4687	2009.1296	7552.7916	245.02732	2616
19	Optimized	258.77195	663.9529	2015.7677	7470.8139	241.11054	2616
20	Optimized	260.8029	663.56665	2019.6699	7414.6194	238.45429	2616
21	Optimized	268.6603	662.81925	1975.8745	7584.5315	247.90007	2616
22	Optimized	275.76355	662.34625	1923.8221	7263.8906	236.02858	2616
23	Optimized	278.2952	662.17765	1906.0087	7277.2045	237.40439	2616
24	Optimized	280.6803	662.0188	1889.1926	7361.3705	241.86776	2616
25	Optimized	282.657	661.88715	1875.2562	7393.7119	243.91321	2616
26	Optimized	285.3669	661.7067	1856.0083	7438.6407	246.74979	2616
27	Optimized	287.1122	661.5905	1843.5838	7467.4454	248.57211	2616
28	Optimized	290.2259	661.26535	1829.3739	7379.019	245.29177	2616
29	Optimized	295.12025	660.74815	1807.5183	7375.0831	246.08381	2616
30	Optimized	302.0647	660.0143	1776.6909	7120.999	236.21597	2616
31	Optimized	312.1941	658.9439	1748.0235	6758.7296	221.47091	2616
32	Optimized	324.9485	658.309	1678.7977	6553.039	409.43856	2417
33	Optimized	333.1876	658.2022	1615.3132	6152.5862	381.13305	2417
34	Optimized	335.8995	658.16705	1593.0649	6019.3653	840.9997	1940
35	Optimized	339.3291	658.1226	1565.09	5850.2468	814.18235	1940

36	Optimized	343.6351	658.0668	1530.2746	5638.8927	780.63989	1940
37	Optimized	347.65025	658.00875	1498.4591	5420.4053	1160.9144	1516
38	Optimized	354.57245	657.87665	1448.0276	5082.0953	1075.701	1516
39	Optimized	361.63615	657.74185	1388.4746	4731.4132	1357.2227	1131
40	Optimized	362.91815	657.71735	1377.8347	4664.8031	1334.4989	1131
41	Optimized	364.9064	657.6794	1361.4086	4560.96	1299.0079	1131
42	Optimized	369.12315	657.76905	1318.5232	4540.4576	1308.0954	1131
43	Optimized	371.7893	657.9077	1287.8247	4370.4879	1251.5517	1131
44	Optimized	373.4873	657.996	1270.7232	4261.4478	1537.2216	807
45	Optimized	375.25815	658.0881	1251.6731	4145.4198	1487.3754	807
46	Optimized	380.89185	658.3811	1191.0282	3776.9721	1329.1658	807
47	Optimized	387.8243	658.8632	1110.6464	3501.2094	1486.9527	537
48	Optimized	393.32675	659.5559	1031.8115	3019.1331	1446.7904	325
49	Optimized	397.43335	660.07285	971.70477	2522.9363	1127.0357	0
50	Optimized	400.56465	660.46705	912.38847	2240.5223	964.94572	0
51	Optimized	406.3646	661.1972	802.27501	1660.7247	623.70024	0
52	Optimized	409.44515	661.6523	739.18659	1899.2362	842.82536	0
53	Optimized	411.5874	662.8081	590.43137	1485.3928	708.80378	37
54	Optimized	414.96655	664.63125	348.88217	700.81396	304.77763	-4.2574e-006
55	Optimized	417.70405	666.1082	153.20259	486.10526	288.29816	-4.0519e-006
56	Optimized	421.74415	668.2879	-46.221494	308.165	266.87501	-3.7756e-006

Slices of Slip Surface: 354

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	354	125.10355	757.72905	-27.792405	715.01787	566.2896	37
2	354	136.7851	746.83505	364.0005	1948.5182	1023.5804	219
3	354	146.90245	738.24345	627.56369	2803.7684	1244.8114	367
4	354	157.5214	729.9409	855.04312	3476.6817	1310.8164	547
5	354	168.642	721.92805	1049.243	3941.8227	1446.2866	547
6	354	179.76255	714.57155	1198.4669	4354.6702	1338.2338	775
7	354	190.8831	707.82185	1319.5682	4716.1206	1440.1421	775
8	354	202.0037	701.63775	1404.9804	5026.7712	1282.1166	1020
9	354	212.66305	696.19905	1459.8058	5242.1299	1338.9455	1020
10	354	222.8612	691.43865	1489.7764	5364.1442	1371.529	1020
11	354	233.05935	687.08195	1483.9673	5441.2133	1400.868	1020
12	354	243.2575	683.1123	1455.4809	5474.4656	1117.283	1324
13	354	253.45565	679.51535	1398.9623	5464.0891	1130.1106	1324
14	354	262.59205	676.58285	1319.4333	5430.7232	1142.9439	1324
15	354	270.6667	674.2404	1273.104	5383.4178	1142.6726	1324
16	354	275.76355	672.8481	1252.1477	5333.594	1134.6474	1324
17	354	277.74535	672.3389	1243.479	5384.45	1151.1954	1324
18	354	279.21745	671.9683	1244.2175	5503.8026	809.32371	1940
19	354	280.6803	671.60875	1253.7042	5587.8019	823.48114	1940
20	354	282.657	671.13315	1264.5492	5679.0612	838.75991	1940
21	354	285.3669	670.50335	1278.0661	5802.0436	380.01623	2417
22	354	290.1268	669.4603	1296.5133	6011.484	396.05975	2417
23	354	295.12025	668.42155	1315.0414	6122.9096	403.86318	2417
24	354	303.12285	666.98715	1338.9484	5992.6411	390.91236	2417
25	354	315.3685	665.093	1351.3175	5758.7971	837.42376	1940
26	354	327.61415	663.65415	1341.1802	5458.6618	782.32397	1940
27	354	335.8995	662.887	1320.749	5222.8153	1155.0299	1516

28	354	339.3291	662.64505	1306.4048	5113.3885	1126.885	1516
29	354	344.68945	662.36645	1278.4252	4929.2211	1080.6527	1516
30	354	354.65055	662.059	1221.5278	4549.3348	1351.0793	1131
31	354	361.63615	661.95095	1170.8322	4257.1608	1253.0399	1131
32	354	367.1349	662.03225	1121.2589	3985.7577	1472.342	807
33	354	371.7893	662.1202	1080.2655	3747.5987	1370.9996	807
34	354	373.4873	662.1814	1066.2887	3654.7246	1330.4467	807
35	354	375.25815	662.2485	1049.224	3557.3859	1289.1862	807
36	354	382.53685	662.70455	967.25039	3116.0319	1336.5623	537
37	354	391.62365	663.34145	849.73375	2411.6971	1134.8328	0
38	354	398.6124	664.0768	697.73611	1887.3679	854.14468	111
39	354	408.50685	665.33315	354.52361	952.91673	473.92354	37
40	354	414.96655	666.2754	168.94124	265.43626	83.565979	-1.5855e-006
41	354	417.70405	666.72825	85.343894	229.02687	124.43138	-1.7797e-006
42	354	423.0854	667.70885	-5.536059	322.89322	279.62984	-4.0006e-006
43	354	432.38775	669.5958	-140.80933	168.07894	145.55861	-2.0811e-006

Pseudostatic Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 259
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 5:55:49 PM
File Name: AD 7+25 Pseudostatic.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 7+25\
Last Solved Date: 9/13/2010
Last Solved Time: 5:56:01 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Pseudostatic Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 7+25 Seismic Coefficient "k" = 0.06 g
Kind: SLOPE/W
Parent: Seepage Analysis - Static Condition
Method: Spencer
Settings
    PWP Conditions Source: Parent Analysis
Slip Surface
    Direction of movement: Left to Right
    Use Passive Mode: No
    Slip Surface Option: Auto-Search
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: Yes
    Tension Crack
        Tension Crack Option: (none)
FOS Distribution
    FOS Calculation Option: Constant
Advanced
    Number of Slices: 30
    Optimization Tolerance: 0.01
    Minimum Slip Surface Depth: 3 ft
    Optimization Maximum Iterations: 2000

Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Mohr-Coulomb
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Cohesion: 1300 psf
Phi: 12.5 °
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Mohr-Coulomb
Unit Weight: 124 pcf
Cohesion: 1400 psf
Phi: 11.3 °
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Rock

Model: Bedrock (Impenetrable)

Slip Surface Limits

Left Coordinate: (-200, 730) ft
Right Coordinate: (550, 663.7246) ft

Seismic Loads

Horz Seismic Load: 0.06
Ignore seismic load in strength: No

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	34075.396
Region 2	PWR	1,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	9426.3413
Region 3	Residuum	43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23,22,21,20,19,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106	13036.297
Region 4	Blanket Drain	53,52,51,50,49,48,47,46,45,107,108,109,110,111,112,113,114,115	386.71559
Region 5	Embankment Fill - Ash Dike	96,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,107,108,109,110,111,112,113,114,115,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95	26903.486

Points

	X (ft)	Y (ft)
Point 1	550	643.3647
Point 2	550	600
Point 3	-200	600
Point 4	-200	685.0056
Point 5	25.7426	639.8508
Point 6	91.76715	636.2084
Point 7	112.72756	636.8157
Point 8	144.31997	637.4228
Point 9	185.32938	634.0833
Point 10	226.03496	638.03
Point 11	286.43432	641.4313
Point 12	289.43432	641.4313
Point 13	393.36363	637.2024
Point 14	415.19395	635.1409
Point 15	439.94649	637.2024
Point 16	457.99521	637.0306
Point 17	467.62118	637.7177
Point 18	508.09452	638.9222
Point 19	550	651.4496
Point 20	541.85333	649.8496
Point 21	519.17903	648.9358
Point 22	507.29329	647.1084
Point 23	497.05329	646.7429
Point 24	486.26473	646.1946
Point 25	448.8202	646.3468
Point 26	445.8202	646.3468
Point 27	432.09654	645.6083
Point 28	429.09654	645.6083
Point 29	392.26512	648.7703
Point 30	372.67616	654.6019
Point 31	332.30566	658.2393
Point 32	320.81182	657.9134
Point 33	289.43432	661.3487
Point 34	286.43432	661.3487
Point 35	251.23197	660

Point 36	228.7977	655.5246
Point 37	208.7887	651.8887
Point 38	177.46155	650.8788
Point 39	132.71487	648.6501
Point 40	88.65473	649.0541
Point 41	47.13084	649.4536
Point 42	8.32553	653.6954
Point 43	-200	694.96
Point 44	550	663.7246
Point 45	491.0095	658
Point 46	397.28134	660.0031
Point 47	374.91191	668.8368
Point 48	371.51592	670.0031
Point 49	362.7539	671.9827
Point 50	348.62646	673.5045
Point 51	338.09036	674.0216
Point 52	333.85513	673.6933
Point 53	297	673
Point 54	287.01309	672.4149
Point 55	283.72072	672.2682
Point 56	281.59335	672.1034
Point 57	279.83536	672.109
Point 58	258.98922	672.0388
Point 59	253.56482	671.1927
Point 60	247.40234	670.0146
Point 61	247.26941	670.0031
Point 62	246.63553	669.8069
Point 63	246.16446	669.7002
Point 64	231.4451	665.1625
Point 65	226.53674	663.8916
Point 66	209.08388	661.3512
Point 67	206.98054	660.9301
Point 68	205.71863	660.7488
Point 69	197.06118	660.0031
Point 70	192.85524	659.8323
Point 71	190.78124	659.9884
Point 72	181.39906	659.9468
Point 73	180.62914	659.9453
Point 74	163.16856	659.8467
Point 75	150.51799	659.8602
Point 76	142.43782	659.8635
Point 77	136.27384	659.8581
Point 78	133.58851	659.8636
Point 79	125.91382	659.8612
Point 80	121.0177	659.8562
Point 81	112.81162	659.8501
Point 82	100.06337	659.8179
Point 83	82.77777	659.8878
Point 84	73.65349	659.9169
Point 85	52.60684	660.0031
Point 86	32.32465	667.4898
Point 87	24.66721	670.0031

Point 88	6.2574	676.8635
Point 89	1.34452	678.2221
Point 90	0.42547	678.5441
Point 91	-3.82065	680.0031
Point 92	-8.82539	681.236
Point 93	-15.65178	683.1294
Point 94	-20.77908	684.2188
Point 95	-32.86093	687.3698
Point 96	-34.93861	688.0985
Point 97	-40.36917	690.0031
Point 98	-45.11248	692.0506
Point 99	-48.98865	693.9255
Point 100	-51.44979	694.9538
Point 101	-55.94949	696.3254
Point 102	-59.28317	697.087
Point 103	-60.04348	697.4401
Point 104	-60.64641	697.6906
Point 105	-62.85537	698.6024
Point 106	-200	730
Point 107	485.27751	660.123
Point 108	397.68249	661.995
Point 109	375.60439	670.7136
Point 110	372.06274	671.93
Point 111	363.08245	673.9589
Point 112	348.78271	675.4992
Point 113	338.06199	676.0254
Point 114	333.73698	675.6902
Point 115	297	675
Point 116	108.3899	759.37
Point 117	131.7264	770.44
Point 118	151.9611	771.04
Point 119	207.564	749.65
Point 120	258.5547	726.54
Point 121	274.704	719.62
Point 122	276.8231	718.56
Point 123	279.7673	719.5
Point 124	293.2405	720.41
Point 125	340.5962	701.24
Point 126	360.5184	693.26
Point 127	389.4693	681.17
Point 128	403.4468	674.58
Point 129	413.5669	668.6
Point 130	416.3662	667.66
Point 131	419.0419	668.73
Point 132	427.1289	670.25
Point 133	447.3202	671.17
Point 134	463.2535	668.28
Point 135	-200	750.95
Point 136	91.4571	750.95
Point 137	419.5191	668.8197
Point 138	273.1677	674.2
Point 139	326.0094	666.5

Point 140	326.0094	697.5
Point 141	353.1828	689.29
Point 142	153.2026	750.78
Point 143	272.4756	715.59
Point 144	326.0094	702.63
Point 145	381.8396	679.31
Point 146	439.6323	668.8197

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.25	(349.815, 984.274)	157.9741	(116.738, 763.33)	(416.352, 667.665)
2	344	1.36	(349.815, 984.274)	319.323	(118.481, 764.157)	(410.042, 670.683)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	120.4854	758.99125	-596.32631	-94.98625	-21.057945	1300
2	Optimized	127.9794	750.31335	-232.73419	886.71858	196.58078	1300
3	Optimized	133.5739	743.83505	18.596087	1555.5406	340.7324	1300
4	Optimized	139.5563	737.42385	255.42132	2282.2325	449.33323	1300
5	Optimized	147.82615	728.88015	555.77749	3043.9298	551.6101	1300
6	Optimized	152.2521	724.3077	705.47768	3440.4451	606.32768	1300
7	Optimized	157.09725	719.4711	856.60167	3772.2522	646.38417	1300
8	Optimized	166.48955	711.2783	1094.4581	4705.634	800.57843	1300
9	Optimized	176.16585	703.9647	1275.9197	5047.781	836.20153	1300
10	Optimized	185.854	697.1314	1432.9045	5612.4319	926.57893	1300
11	Optimized	194.919	691.4859	1541.4862	6025.5121	994.0846	1300
12	Optimized	203.349	686.54785	1622.4501	6195.4236	1013.8038	1300
13	Optimized	208.4724	683.5467	1662.2996	6292.0413	1026.389	1300
14	Optimized	213.8383	680.9803	1677.8352	6725.1171	1118.9554	1300
15	Optimized	222.7533	676.9117	1698.8566	6728.4846	1115.0417	1300
16	Optimized	234.5262	672.17235	1674.8467	6970.3007	1173.9739	1300
17	Optimized	242.8051	669.21445	1588.9835	7290.8724	1264.0783	1300
18	Optimized	244.96655	668.6472	1583.1049	7244.5601	1131.2704	1400
19	Optimized	246.4	668.271	1597.5247	7214.4555	1122.3735	1400
20	Optimized	246.95245	668.126	1602.8187	7202.7656	1118.9798	1400
21	Optimized	250.4171	667.21675	1644.4407	7129.4946	1096.0219	1400
22	Optimized	256.05975	665.7359	1709.9527	7010.2751	1059.1089	1400
23	Optimized	258.77195	665.0241	1734.7291	6953.3856	1042.7905	1400
24	Optimized	259.07915	664.9435	1737.4384	6947.9252	1041.158	1400
25	Optimized	263.0528	664.4501	1731.4489	7373.5158	1127.3962	1400
26	Optimized	270.82025	663.51055	1711.8939	7088.6262	1074.3771	1400
27	Optimized	275.76355	662.91265	1699.5652	6898.4224	1038.8342	1400
28	Optimized	278.2952	662.6064	1693.4167	6928.3037	1046.0336	1400
29	Optimized	280.6803	662.3179	1687.5435	7026.9007	1066.9088	1400
30	Optimized	282.657	662.0788	1682.6444	7072.2678	1076.953	1400
31	Optimized	285.3669	661.751	1675.7489	7134.0093	1090.668	1400
32	Optimized	287.32265	661.51445	1670.7485	7178.6543	1100.5882	1400
33	Optimized	290.43635	661.28875	1653.1413	7462.1037	1160.7452	1400
34	Optimized	295.12025	660.9743	1625.706	7432.1324	1160.2385	1400
35	Optimized	301.3245	660.55775	1590.2504	7170.7201	1115.0879	1400

36	Optimized	309.9735	659.9771	1550.3356	6814.0241	1051.7888	1400
37	Optimized	318.62245	659.39645	1519.3035	6456.982	986.64554	1400
38	Optimized	328.34195	658.6171	1491.6543	5983.8771	897.6347	1400
39	Optimized	335.8995	657.93205	1472.0657	5696.8629	844.19778	1400
40	Optimized	339.3291	657.62115	1461.9985	5566.6924	820.19878	1400
41	Optimized	344.68945	657.1353	1446.2162	5364.6739	782.9851	1400
42	Optimized	349.0546	656.73965	1433.4349	5200.8355	752.80091	1400
43	Optimized	354.92245	656.88145	1377.5266	5305.5851	784.90355	1400
44	Optimized	361.63615	657.08115	1308.4348	4934.073	724.47401	1400
45	Optimized	367.1349	657.24475	1253.152	4618.8091	672.52465	1400
46	Optimized	371.7951	657.3834	1207.4216	4351.5155	628.25196	1400
47	Optimized	373.4931	657.66915	1181.1628	4779.3655	718.99184	1400
48	Optimized	382.1906	659.3698	1031.0745	4039.1504	601.07287	1400
49	Optimized	391.41285	661.17305	871.99409	3239.8379	473.14188	1400
50	Optimized	395.17735	661.90915	795.90136	2713.9064	1393.5122	0
51	Optimized	397.6601	662.3946	738.77231	2646.5544	422.94511	1300
52	Optimized	400.88435	663.25455	612.13078	2548.4651	429.27499	1300
53	Optimized	408.50685	665.42775	310.48039	1636.3579	293.93998	1300
54	Optimized	414.95965	667.2675	55.117295	878.56243	182.55339	1300

Slices of Slip Surface: 344

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	344	125.10355	757.5915	-559.65128	374.49667	83.023914	1300
2	344	136.7851	746.4942	-116.38821	1704.3769	377.85126	1300
3	344	146.90245	737.79755	189.87757	2615.6145	537.77293	1300
4	344	156.5947	730.11045	439.46396	3287.9478	631.49366	1300
5	344	165.86185	723.32155	637.1971	3705.1573	680.15041	1300
6	344	175.12895	717.0265	799.00644	4079.9368	727.36474	1300
7	344	184.3961	711.19105	935.5093	4414.0422	771.17219	1300
8	344	193.6633	705.7862	1045.0354	4708.448	812.15901	1300
9	344	202.93045	700.7873	1126.641	4964.3487	850.79932	1300
10	344	212.66305	695.96085	1187.5256	5155.7438	879.73278	1300
11	344	222.8612	691.32545	1228.7453	5277.8375	897.66214	1300
12	344	233.05935	687.11225	1235.6428	5353.2657	912.85502	1300
13	344	243.2575	683.3035	1218.6611	5382.6664	923.13775	1300
14	344	253.45565	679.88405	1174.7296	5366.493	929.29158	1300
15	344	262.59205	677.1234	1109.1492	5326.4801	934.95974	1300
16	344	270.6667	674.94385	1069.9385	5271.5261	931.46955	1300
17	344	275.76355	673.6582	1051.9686	5216.4645	923.2465	1300
18	344	278.2952	673.0673	1040.8657	5304.297	945.17996	1300
19	344	281.05445	672.4452	1028.3038	5468.8857	984.45332	1300
20	344	283.03115	672.0139	1025.4101	5555.9062	905.28244	1400
21	344	285.3669	671.5272	1035.3563	5656.3226	923.36018	1400
22	344	290.1268	670.5955	1051.8448	5856.1498	959.99486	1400
23	344	295.12025	669.6762	1065.9104	5957.7142	977.47886	1400
24	344	301.5921	668.6478	1085.2648	5841.3574	950.36108	1400
25	344	310.77635	667.3805	1094.5925	5656.4572	911.55052	1400
26	344	319.9606	666.38355	1089.4714	5432.6139	867.84551	1400
27	344	329.14485	665.65435	1069.3155	5169.3091	819.25956	1400
28	344	335.8995	665.2621	1045.7314	4952.9662	780.74255	1400
29	344	339.3291	665.12615	1029.1937	4833.6138	760.19814	1400

30	344	344.68945	665.0188	997.6959	4633.4899	726.50334	1400
31	344	354.65055	665.042	932.68831	4225.4265	657.95402	1400
32	344	361.63615	665.1723	880.94364	3914.8283	606.22997	1400
33	344	367.1349	665.4517	829.70368	3632.2755	560.00912	1400
34	344	371.7893	665.70855	788.82448	3386.6709	519.10093	1400
35	344	373.4873	665.8333	772.96999	3291.7727	503.30645	1400
36	344	375.25815	665.9669	754.78412	3192.0773	487.01923	1400
37	344	378.25625	666.23175	719.05306	3017.1345	459.20199	1400
38	344	383.0602	666.6942	650.51246	2602.096	1417.9085	0
39	344	387.3408	667.17135	583.03386	2449.8946	413.87307	1300
40	344	396.45805	668.4554	415.46112	1779.7287	302.45084	1300
41	344	406.7446	670.08515	84.535875	914.32836	183.96056	1300

Rapid Drawdown Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 270
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 5:51:33 PM
File Name: AD 7+25 RDD.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 7+25\
Last Solved Date: 9/16/2010
Last Solved Time: 3:02:00 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Rapid Drawdown Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 7+25 Pool Drawdown from 750.95 to 745.63
Kind: SLOPE/W
Parent: Seepage Analysis - Static Condition
Method: Spencer
Settings
- Apply Phreatic Correction: No
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: Yes

Slip Surface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: Yes
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced

Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 3 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Mohr-Coulomb
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Cohesion: 0 psf
Phi: 38 °
Phi-B: 0 °
Drawdown Total Cohesion: 1300 psf
Drawdown Total Phi: 12.5 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °
Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Residuum

Model: Mohr-Coulomb
Unit Weight: 124 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °
Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °
Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Rock

Model: Bedrock (Impenetrable)
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (7.99993, 709.4501) ft
Left-Zone Right Coordinate: (79.99993, 745.2528) ft
Left-Zone Increment: 4
Right Projection: Range
Right-Zone Left Coordinate: (87.03167, 748.7494) ft
Right-Zone Right Coordinate: (145, 770.8336) ft
Right-Zone Increment: 4
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (-200, 730) ft
Right Coordinate: (550, 663.7246) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-200	750.95
	150	750.95

Piezometric Line 2

Coordinates

	X (ft)	Y (ft)

	-200	745.63
	150	745.63

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	34075.396
Region 2	PWR	1,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	9426.3413
Region 3	Residuum	43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23,22,21,20,19,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106	13036.297
Region 4	Blanket Drain	53,52,51,50,49,48,47,46,45,107,108,109,110,111,112,113,114,115	386.71559
Region 5	Embankment Fill - Ash Dike	96,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,107,108,109,110,111,112,113,114,115,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95	26903.486

Points

	X (ft)	Y (ft)
Point 1	550	643.3647
Point 2	550	600
Point 3	-200	600
Point 4	-200	685.0056
Point 5	25.7426	639.8508
Point 6	91.76715	636.2084
Point 7	112.72756	636.8157
Point 8	144.31997	637.4228
Point 9	185.32938	634.0833
Point 10	226.03496	638.03
Point 11	286.43432	641.4313
Point 12	289.43432	641.4313
Point 13	393.36363	637.2024
Point 14	415.19395	635.1409
Point 15	439.94649	637.2024
Point 16	457.99521	637.0306
Point 17	467.62118	637.7177
Point 18	508.09452	638.9222
Point 19	550	651.4496
Point 20	541.85333	649.8496
Point 21	519.17903	648.9358
Point 22	507.29329	647.1084
Point 23	497.05329	646.7429
Point 24	486.26473	646.1946
Point 25	448.8202	646.3468
Point 26	445.8202	646.3468
Point 27	432.09654	645.6083
Point 28	429.09654	645.6083

Point 29	392.26512	648.7703
Point 30	372.67616	654.6019
Point 31	332.30566	658.2393
Point 32	320.81182	657.9134
Point 33	289.43432	661.3487
Point 34	286.43432	661.3487
Point 35	251.23197	660
Point 36	228.7977	655.5246
Point 37	208.7887	651.8887
Point 38	177.46155	650.8788
Point 39	132.71487	648.6501
Point 40	88.65473	649.0541
Point 41	47.13084	649.4536
Point 42	8.32553	653.6954
Point 43	-200	694.96
Point 44	550	663.7246
Point 45	491.0095	658
Point 46	397.28134	660.0031
Point 47	374.91191	668.8368
Point 48	371.51592	670.0031
Point 49	362.7539	671.9827
Point 50	348.62646	673.5045
Point 51	338.09036	674.0216
Point 52	333.85513	673.6933
Point 53	297	673
Point 54	287.01309	672.4149
Point 55	283.72072	672.2682
Point 56	281.59335	672.1034
Point 57	279.83536	672.109
Point 58	258.98922	672.0388
Point 59	253.56482	671.1927
Point 60	247.40234	670.0146
Point 61	247.26941	670.0031
Point 62	246.63553	669.8069
Point 63	246.16446	669.7002
Point 64	231.4451	665.1625
Point 65	226.53674	663.8916
Point 66	209.08388	661.3512
Point 67	206.98054	660.9301
Point 68	205.71863	660.7488
Point 69	197.06118	660.0031
Point 70	192.85524	659.8323
Point 71	190.78124	659.9884
Point 72	181.39906	659.9468
Point 73	180.62914	659.9453
Point 74	163.16856	659.8467
Point 75	150.51799	659.8602
Point 76	142.43782	659.8635
Point 77	136.27384	659.8581
Point 78	133.58851	659.8636

Point 79	125.91382	659.8612
Point 80	121.0177	659.8562
Point 81	112.81162	659.8501
Point 82	100.06337	659.8179
Point 83	82.77777	659.8878
Point 84	73.65349	659.9169
Point 85	52.60684	660.0031
Point 86	32.32465	667.4898
Point 87	24.66721	670.0031
Point 88	6.2574	676.8635
Point 89	1.34452	678.2221
Point 90	0.42547	678.5441
Point 91	-3.82065	680.0031
Point 92	-8.82539	681.236
Point 93	-15.65178	683.1294
Point 94	-20.77908	684.2188
Point 95	-32.86093	687.3698
Point 96	-34.93861	688.0985
Point 97	-40.36917	690.0031
Point 98	-45.11248	692.0506
Point 99	-48.98865	693.9255
Point 100	-51.44979	694.9538
Point 101	-55.94949	696.3254
Point 102	-59.28317	697.087
Point 103	-60.04348	697.4401
Point 104	-60.64641	697.6906
Point 105	-62.85537	698.6024
Point 106	-200	730
Point 107	485.27751	660.123
Point 108	397.68249	661.995
Point 109	375.60439	670.7136
Point 110	372.06274	671.93
Point 111	363.08245	673.9589
Point 112	348.78271	675.4992
Point 113	338.06199	676.0254
Point 114	333.73698	675.6902
Point 115	297	675
Point 116	108.3899	759.37
Point 117	131.7264	770.44
Point 118	151.9611	771.04
Point 119	207.564	749.65
Point 120	258.5547	726.54
Point 121	274.704	719.62
Point 122	276.8231	718.56
Point 123	279.7673	719.5
Point 124	293.2405	720.41
Point 125	340.5962	701.24
Point 126	360.5184	693.26
Point 127	389.4693	681.17
Point 128	403.4468	674.58

Point 129	413.5669	668.6
Point 130	416.3662	667.66
Point 131	419.0419	668.73
Point 132	427.1289	670.25
Point 133	447.3202	671.17
Point 134	463.2535	668.28
Point 135	-200	750.95
Point 136	91.4571	750.95
Point 137	419.5191	668.8197
Point 138	273.1677	674.2
Point 139	326.0094	666.5
Point 140	326.0094	697.5
Point 141	353.1828	689.29
Point 142	153.2026	750.78
Point 143	272.4756	715.59
Point 144	326.0094	702.63
Point 145	381.8396	679.31
Point 146	439.6323	668.8197

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.47	(53.843, 801.774)	25.27965	(101.653, 756.02)	(61.8751, 736.24)
2	82	1.50	(53.843, 801.774)	65.978	(101.126, 755.758)	(61.9999, 736.302)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	62.56741	736.41645	574.92307	615.89753	32.012755	0
2	Optimized	63.95209	736.76935	552.90674	609.26324	44.030523	0
3	Optimized	65.428275	737.1645	528.24471	595.79904	52.779223	0
4	Optimized	66.995965	737.60195	500.9465	583.78733	64.722352	0
5	Optimized	68.32749	737.98025	477.34329	570.64698	72.896836	0
6	Optimized	69.422855	738.29935	457.42915	560.68115	80.669303	0
7	Optimized	70.66911	738.6687	434.38531	547.02785	88.005993	0
8	Optimized	72.06625	739.08825	408.20579	532.87212	97.400011	0
9	Optimized	73.32204	739.4646	384.71954	520.46751	106.05794	0
10	Optimized	74.43648	739.7978	363.93179	509.35148	113.61431	0
11	Optimized	75.672245	740.16735	340.87147	496.98303	121.96772	0
12	Optimized	77.02933	740.57325	315.54119	483.42837	131.16784	0
13	Optimized	78.47052	741.00345	288.69734	469.34366	141.13637	0
14	Optimized	79.99582	741.4579	260.34156	454.30184	151.53838	0
15	Optimized	81.1709	741.808	238.4922	455.42054	169.48299	0
16	Optimized	82.153765	742.16815	216.02268	443.56193	177.77315	0
17	Optimized	83.294635	742.64265	186.4098	449.99599	205.9361	0
18	Optimized	84.43508	743.22	150.38376	409.02061	202.06926	0
19	Optimized	85.575095	743.90025	107.93673	391.84595	221.8142	0
20	Optimized	86.71511	744.5805	65.4897	374.67882	241.56502	0
21	Optimized	87.772475	745.2753	22.132894	328.26892	239.17968	0
22	Optimized	88.84124	746.05315	-26.404901	303.09836	236.80639	0

23	Optimized	89.931265	746.8646	-77.039202	275.06075	214.90101	0
24	Optimized	90.94849	747.6412	-125.49715	252.67427	197.41077	0
25	Optimized	92.188375	748.5878	-184.56453	225.38383	176.08915	0
26	Optimized	93.499555	749.59705	-247.54874	194.365	151.85458	0
27	Optimized	94.65937	750.499	-303.82931	167.67784	131.00429	0
28	Optimized	95.25516	750.96235	-332.7414	153.9687	120.29353	0
29	Optimized	96.159445	751.67375	-377.1305	131.84927	103.01194	0
30	Optimized	97.553755	752.7818	-446.27651	96.876287	75.688051	0
31	Optimized	98.56557	753.59985	-497.32389	71.448664	55.821814	0
32	Optimized	99.71679	754.51165	-554.21565	44.736984	34.952362	0
33	Optimized	101.00745	755.51715	-616.95646	14.908049	11.647445	0

Slices of Slip Surface: 82

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	82	62.669875	736.39255	576.41359	643.11971	52.116527	0
2	82	64.00977	736.5875	564.25334	650.92881	67.7183	0
3	82	65.349665	736.81065	550.32886	654.80066	81.622315	0
4	82	66.68956	737.0623	534.62524	654.80465	93.894445	0
5	82	68.029455	737.3428	517.11823	651.03339	104.62599	0
6	82	69.36935	737.6525	497.79706	643.54489	113.87069	0
7	82	70.70925	737.99185	476.61961	632.39025	121.70136	0
8	82	72.049145	738.36135	453.56497	617.62969	128.18141	0
9	82	73.38904	738.7615	428.59159	599.2983	133.3707	0
10	82	74.728935	739.1929	401.67244	577.42626	137.31393	0
11	82	76.06883	739.6562	372.76242	552.04985	140.07469	0
12	82	77.408725	740.1521	341.81975	523.18254	141.69614	0
13	82	78.74862	740.6814	308.79308	490.83732	142.22855	0
14	82	80.08852	741.245	273.62545	455.0313	141.72978	0
15	82	81.403445	741.83205	236.99043	434.40379	154.23623	0
16	82	82.693395	742.4422	198.91785	428.20462	179.13846	0
17	82	83.98334	743.08705	158.68353	417.60021	202.28788	0
18	82	85.273285	743.76775	116.20608	402.58736	223.74558	0
19	82	86.563235	744.4856	71.40953	383.12613	243.5397	0
20	82	87.853185	745.242	24.212346	359.18291	261.70769	0
21	82	89.237895	746.1003	-29.345681	333.29968	260.40225	0
22	82	90.717365	747.0692	-89.805861	305.9105	239.00347	0
23	82	92.200095	748.09875	-154.05067	274.29189	214.30031	0
24	82	93.686085	749.1927	-222.31257	238.47861	186.31991	0
25	82	95.172075	750.35285	-294.70374	198.58827	155.15416	0
26	82	96.5664	751.50355	-366.50688	157.66768	123.18349	0
27	82	97.86906	752.6407	-437.46945	116.12225	90.724641	0
28	82	99.17172	753.84025	-512.31881	71.589208	55.931619	0
29	82	100.47437	755.107	-591.35771	24.120226	18.844786	0

Seepage Analysis - Static Condition

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 259
Last Edited By: Cedric Ruhl
Date: 9/16/2010
Time: 2:56:51 PM
File Name: AD 7+25 WSEL = 74563.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 7+25\
Last Solved Date: 9/16/2010
Last Solved Time: 2:56:56 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Mass(M) Units: lbs
Mass Flux Units: lbs/sec
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Seepage Analysis - Static Condition

Description: Ash Dike Section Sta. 7+25 Water Surface Elevation = 745.63
Kind: SEEP/W
Method: Steady-State
Settings
    Include Air Flow: No
Control
    Apply Runoff: Yes
Convergence
    Convergence Type: Gauss Point K
    Convergence Settings
        Maximum Number of Iterations: 500
        Tolerance: 0.01
        Maximum Change in K: 0.1
        Rate of Change in K: 1.02
        Minimum Change in K: 0.0001
    Equation Solver: Parallel Direct
    Potential Seepage Max # of Reviews: 10

Time
Starting Time: 0 sec
Duration: 0 sec
Ending Time: 0 sec

Materials

Embankment Fill - Ash Dike

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-6
K-Ratio: 0.08
K-Direction: 0 °

Blanket Drain

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

Residuum

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 0.1
K-Direction: 0 °

PWR

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 0.1
K-Direction: 0 °

Rock

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-7
K-Ratio: 0.1
K-Direction: 0 °

Boundary Conditions

Water Elevation = 745.63

Type: Head (H) 745.63

Potential Seepage Face

Review: true
Type: Total Flux (Q) 0

K Functions

1e-4

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-006
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-006)
Data Point: (10000, 3.28e-006)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-5

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-007
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-007)
Data Point: (10000, 3.28e-007)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-6

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-008
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-008)
Data Point: (10000, 3.28e-008)
Estimation Properties

Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

1e-7

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-009
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-009)
Data Point: (10000, 3.28e-009)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	34075.396
Region 2	PWR	1,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41, 42,43,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	9426.3413
Region 3	Residuum	43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23,22,21,20, 19,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66, 67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91, 92,93,94,95,96,97,98,99,100,101,102,103,104,105,106	13036.297
Region 4	Blanket Drain	53,52,51,50,49,48,47,46,45,107,108,109,110,111,112,113,114,115	386.71559
Region 5	Embankment Fill - Ash Dike	96,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132, 133,134,107,108,109,110,111,112,113,114,115,53,54,55,56,57,58,59,60,61,62, 63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87, 88,89,90,91,92,93,94,95	26903.486

Lines

	Start Point	End Point	Hydraulic Boundary
Line 1	1	2	
Line 2	2	3	
Line 3	3	4	Water Elevation = 745.63
Line 4	4	5	
Line 5	5	6	
Line 6	6	7	
Line 7	7	8	

Line 8	8	9	
Line 9	9	10	
Line 10	10	11	
Line 11	11	12	
Line 12	12	13	
Line 13	13	14	
Line 14	14	15	
Line 15	15	16	
Line 16	16	17	
Line 17	17	18	
Line 18	18	1	
Line 19	1	19	
Line 20	19	20	
Line 21	20	21	
Line 22	21	22	
Line 23	22	23	
Line 24	23	24	
Line 25	24	25	
Line 26	25	26	
Line 27	26	27	
Line 28	27	28	
Line 29	28	29	
Line 30	29	30	
Line 31	30	31	
Line 32	31	32	
Line 33	32	33	
Line 34	33	34	
Line 35	34	35	
Line 36	35	36	
Line 37	36	37	
Line 38	37	38	
Line 39	38	39	
Line 40	39	40	
Line 41	40	41	
Line 42	41	42	
Line 43	42	43	
Line 44	43	4	Water Elevation = 745.63
Line 45	19	44	
Line 46	44	45	Potential Seepage Face
Line 47	45	46	
Line 48	46	47	
Line 49	47	48	
Line 50	48	49	
Line 51	49	50	
Line 52	50	51	
Line 53	51	52	
Line 54	52	53	
Line 55	54	55	
Line 56	55	56	

Line 57	56	57	
Line 58	57	58	
Line 59	58	59	
Line 60	59	60	
Line 61	60	61	
Line 62	61	62	
Line 63	62	63	
Line 64	63	64	
Line 65	64	65	
Line 66	65	66	
Line 67	66	67	
Line 68	67	68	
Line 69	68	69	
Line 70	69	70	
Line 71	70	71	
Line 72	71	72	
Line 73	72	73	
Line 74	73	74	
Line 75	74	75	
Line 76	75	76	
Line 77	76	77	
Line 78	77	78	
Line 79	78	79	
Line 80	79	80	
Line 81	80	81	
Line 82	81	82	
Line 83	82	83	
Line 84	83	84	
Line 85	84	85	
Line 86	85	86	
Line 87	86	87	
Line 88	87	88	
Line 89	88	89	
Line 90	89	90	
Line 91	90	91	
Line 92	91	92	
Line 93	92	93	
Line 94	93	94	
Line 95	94	95	
Line 96	95	96	
Line 97	96	97	Water Elevation = 745.63
Line 98	97	98	Water Elevation = 745.63
Line 99	98	99	Water Elevation = 745.63
Line 100	99	100	Water Elevation = 745.63
Line 101	100	101	Water Elevation = 745.63
Line 102	101	102	Water Elevation = 745.63
Line 103	102	103	Water Elevation = 745.63
Line 104	103	104	Water Elevation = 745.63
Line 105	104	105	Water Elevation = 745.63

Line 106	105	106	Water Elevation = 745.63
Line 107	106	43	Water Elevation = 745.63
Line 108	45	107	Potential Seepage Face
Line 109	107	108	
Line 110	108	109	
Line 111	109	110	
Line 112	110	111	
Line 113	111	112	
Line 114	112	113	
Line 115	113	114	
Line 116	114	115	
Line 117	115	53	
Line 118	96	116	Water Elevation = 745.63
Line 119	116	117	Water Elevation = 745.63
Line 120	117	118	
Line 121	118	119	Potential Seepage Face
Line 122	119	120	Potential Seepage Face
Line 123	120	121	Potential Seepage Face
Line 124	121	122	Potential Seepage Face
Line 125	122	123	Potential Seepage Face
Line 126	123	124	Potential Seepage Face
Line 127	124	125	Potential Seepage Face
Line 128	125	126	Potential Seepage Face
Line 129	126	127	Potential Seepage Face
Line 130	127	128	Potential Seepage Face
Line 131	128	129	Potential Seepage Face
Line 132	129	130	Potential Seepage Face
Line 133	130	131	Potential Seepage Face
Line 134	131	132	Potential Seepage Face
Line 135	132	133	Potential Seepage Face
Line 136	133	134	Potential Seepage Face
Line 137	134	107	Potential Seepage Face
Line 138	145	129	
Line 139	130	146	
Line 140	146	45	
Line 141	136	142	
Line 142	54	53	
Line 143	142	143	
Line 144	145	141	

Points

	X (ft)	Y (ft)
Point 1	550	643.3647
Point 2	550	600
Point 3	-200	600
Point 4	-200	685.0056
Point 5	25.7426	639.8508
Point 6	91.76715	636.2084

Point 7	112.72756	636.8157
Point 8	144.31997	637.4228
Point 9	185.32938	634.0833
Point 10	226.03496	638.03
Point 11	286.43432	641.4313
Point 12	289.43432	641.4313
Point 13	393.36363	637.2024
Point 14	415.19395	635.1409
Point 15	439.94649	637.2024
Point 16	457.99521	637.0306
Point 17	467.62118	637.7177
Point 18	508.09452	638.9222
Point 19	550	651.4496
Point 20	541.85333	649.8496
Point 21	519.17903	648.9358
Point 22	507.29329	647.1084
Point 23	497.05329	646.7429
Point 24	486.26473	646.1946
Point 25	448.8202	646.3468
Point 26	445.8202	646.3468
Point 27	432.09654	645.6083
Point 28	429.09654	645.6083
Point 29	392.26512	648.7703
Point 30	372.67616	654.6019
Point 31	332.30566	658.2393
Point 32	320.81182	657.9134
Point 33	289.43432	661.3487
Point 34	286.43432	661.3487
Point 35	251.23197	660
Point 36	228.7977	655.5246
Point 37	208.7887	651.8887
Point 38	177.46155	650.8788
Point 39	132.71487	648.6501
Point 40	88.65473	649.0541
Point 41	47.13084	649.4536
Point 42	8.32553	653.6954
Point 43	-200	694.96
Point 44	550	663.7246
Point 45	491.0095	658
Point 46	397.28134	660.0031
Point 47	374.91191	668.8368
Point 48	371.51592	670.0031
Point 49	362.7539	671.9827
Point 50	348.62646	673.5045
Point 51	338.09036	674.0216
Point 52	333.85513	673.6933
Point 53	297	673
Point 54	287.01309	672.4149
Point 55	283.72072	672.2682

Point 56	281.59335	672.1034
Point 57	279.83536	672.109
Point 58	258.98922	672.0388
Point 59	253.56482	671.1927
Point 60	247.40234	670.0146
Point 61	247.26941	670.0031
Point 62	246.63553	669.8069
Point 63	246.16446	669.7002
Point 64	231.4451	665.1625
Point 65	226.53674	663.8916
Point 66	209.08388	661.3512
Point 67	206.98054	660.9301
Point 68	205.71863	660.7488
Point 69	197.06118	660.0031
Point 70	192.85524	659.8323
Point 71	190.78124	659.9884
Point 72	181.39906	659.9468
Point 73	180.62914	659.9453
Point 74	163.16856	659.8467
Point 75	150.51799	659.8602
Point 76	142.43782	659.8635
Point 77	136.27384	659.8581
Point 78	133.58851	659.8636
Point 79	125.91382	659.8612
Point 80	121.0177	659.8562
Point 81	112.81162	659.8501
Point 82	100.06337	659.8179
Point 83	82.77777	659.8878
Point 84	73.65349	659.9169
Point 85	52.60684	660.0031
Point 86	32.32465	667.4898
Point 87	24.66721	670.0031
Point 88	6.2574	676.8635
Point 89	1.34452	678.2221
Point 90	0.42547	678.5441
Point 91	-3.82065	680.0031
Point 92	-8.82539	681.236
Point 93	-15.65178	683.1294
Point 94	-20.77908	684.2188
Point 95	-32.86093	687.3698
Point 96	-34.93861	688.0985
Point 97	-40.36917	690.0031
Point 98	-45.11248	692.0506
Point 99	-48.98865	693.9255
Point 100	-51.44979	694.9538
Point 101	-55.94949	696.3254
Point 102	-59.28317	697.087
Point 103	-60.04348	697.4401
Point 104	-60.64641	697.6906

Point 105	-62.85537	698.6024
Point 106	-200	730
Point 107	485.27751	660.123
Point 108	397.68249	661.995
Point 109	375.60439	670.7136
Point 110	372.06274	671.93
Point 111	363.08245	673.9589
Point 112	348.78271	675.4992
Point 113	338.06199	676.0254
Point 114	333.73698	675.6902
Point 115	297	675
Point 116	108.3899	759.37
Point 117	131.7264	770.44
Point 118	151.9611	771.04
Point 119	207.564	749.65
Point 120	258.5547	726.54
Point 121	274.704	719.62
Point 122	276.8231	718.56
Point 123	279.7673	719.5
Point 124	293.2405	720.41
Point 125	340.5962	701.24
Point 126	360.5184	693.26
Point 127	389.4693	681.17
Point 128	403.4468	674.58
Point 129	413.5669	668.6
Point 130	416.3662	667.66
Point 131	419.0419	668.73
Point 132	427.1289	670.25
Point 133	447.3202	671.17
Point 134	463.2535	668.28
Point 135	-200	750.95
Point 136	91.4571	750.95
Point 137	419.5191	668.8197
Point 138	273.1677	674.2
Point 139	326.0094	666.5
Point 140	326.0094	697.5
Point 141	353.1828	689.29
Point 142	153.2026	750.78
Point 143	272.4756	715.59
Point 144	326.0094	702.63
Point 145	381.8396	679.31
Point 146	439.6323	668.8197

Static Slope Stability Analysis - Lower

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 260
Last Edited By: Cedric Ruhl
Date: 9/16/2010
Time: 2:57:07 PM
File Name: AD 7+25 WSEL = 74563.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 7+25\
Last Solved Date: 9/16/2010
Last Solved Time: 2:58:12 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Static Slope Stability Analysis - Lower

Description: Ash Dike Section Sta. 7+25 Water Surface Elevation = 745.63
Kind: SLOPE/W
Parent: Seepage Analysis - Static Condition
Method: Spencer
Settings
    PWP Conditions Source: Parent Analysis
Slip Surface
    Direction of movement: Left to Right
    Use Passive Mode: No
    Slip Surface Option: Entry and Exit
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: Yes
    Tension Crack
        Tension Crack Option: (none)
FOS Distribution
    FOS Calculation Option: Constant
Advanced
    Number of Slices: 30
    Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 3 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Shear/Normal Fn.
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Strength Function: Ash Dike Fill
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Shear/Normal Fn.
Unit Weight: 124 pcf
Strength Function: Ash Dike Res
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Rock

Model: Bedrock (Impenetrable)

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (239.72408, 735.0744) ft
Left-Zone Right Coordinate: (322, 708.7679) ft
Left-Zone Increment: 4
Right Projection: Range
Right-Zone Left Coordinate: (379.47396, 685.3441) ft
Right-Zone Right Coordinate: (541, 662.8512) ft

Right-Zone Increment: 4
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (-200, 730) ft
Right Coordinate: (550, 663.7246) ft

Shear/Normal Strength Functions

Ash Dike Fill

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
- Curve Fit to Data: 100 %
- Segment Curvature: 0 %

Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
- Data Point: (0, 0)
- Data Point: (500, 433)
- Data Point: (1000, 829)
- Data Point: (1500, 1188)
- Data Point: (2000, 1511)
- Data Point: (2500, 1797)
- Data Point: (3000, 2047)
- Data Point: (3500, 2259)
- Data Point: (4000, 2436)
- Data Point: (4500, 2575)
- Data Point: (5000, 2678)
- Data Point: (5500, 2744)
- Data Point: (6000, 2774)
- Data Point: (20000, 2800)

Estimation Properties
- Intact Rock Param.: 10
- Geological Strength: 100
- Disturbance Factor: 0
- SigmaC: 600000 psf
- Sigma3: 300000 psf
- Num. Points: 20

Ash Dike Res

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
- Curve Fit to Data: 100 %
- Segment Curvature: 0 %

Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
- Data Point: (0, 0)
- Data Point: (500, 526)
- Data Point: (1000, 999)
- Data Point: (1500, 1417)

Data Point: (2000, 1781)
Data Point: (2500, 2092)
Data Point: (3000, 2349)
Data Point: (3500, 2552)
Data Point: (4000, 2700)
Data Point: (4500, 2795)
Data Point: (5000, 2837)
Data Point: (20000, 3500)

Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	34075.396
Region 2	PWR	1,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42, 43,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	9426.3413
Region 3	Residuum	43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23,22,21,20,19, 44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68, 69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93, 94,95,96,97,98,99,100,101,102,103,104,105,106	13036.297
Region 4	Blanket Drain	53,52,51,50,49,48,47,46,45,107,108,109,110,111,112,113,114,115	386.71559
Region 5	Embankment Fill - Ash Dike	96,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132, 133,134,107,108,109,110,111,112,113,114,115,53,54,55,56,57,58,59,60,61,62, 63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88, 89,90,91,92,93,94,95	26903.486

Points

	X (ft)	Y (ft)
Point 1	550	643.3647
Point 2	550	600
Point 3	-200	600
Point 4	-200	685.0056
Point 5	25.7426	639.8508
Point 6	91.76715	636.2084
Point 7	112.72756	636.8157
Point 8	144.31997	637.4228
Point 9	185.32938	634.0833
Point 10	226.03496	638.03
Point 11	286.43432	641.4313
Point 12	289.43432	641.4313
Point 13	393.36363	637.2024
Point 14	415.19395	635.1409
Point 15	439.94649	637.2024

Point 16	457.99521	637.0306
Point 17	467.62118	637.7177
Point 18	508.09452	638.9222
Point 19	550	651.4496
Point 20	541.85333	649.8496
Point 21	519.17903	648.9358
Point 22	507.29329	647.1084
Point 23	497.05329	646.7429
Point 24	486.26473	646.1946
Point 25	448.8202	646.3468
Point 26	445.8202	646.3468
Point 27	432.09654	645.6083
Point 28	429.09654	645.6083
Point 29	392.26512	648.7703
Point 30	372.67616	654.6019
Point 31	332.30566	658.2393
Point 32	320.81182	657.9134
Point 33	289.43432	661.3487
Point 34	286.43432	661.3487
Point 35	251.23197	660
Point 36	228.7977	655.5246
Point 37	208.7887	651.8887
Point 38	177.46155	650.8788
Point 39	132.71487	648.6501
Point 40	88.65473	649.0541
Point 41	47.13084	649.4536
Point 42	8.32553	653.6954
Point 43	-200	694.96
Point 44	550	663.7246
Point 45	491.0095	658
Point 46	397.28134	660.0031
Point 47	374.91191	668.8368
Point 48	371.51592	670.0031
Point 49	362.7539	671.9827
Point 50	348.62646	673.5045
Point 51	338.09036	674.0216
Point 52	333.85513	673.6933
Point 53	297	673
Point 54	287.01309	672.4149
Point 55	283.72072	672.2682
Point 56	281.59335	672.1034
Point 57	279.83536	672.109
Point 58	258.98922	672.0388
Point 59	253.56482	671.1927
Point 60	247.40234	670.0146
Point 61	247.26941	670.0031
Point 62	246.63553	669.8069
Point 63	246.16446	669.7002
Point 64	231.4451	665.1625
Point 65	226.53674	663.8916

Point 66	209.08388	661.3512
Point 67	206.98054	660.9301
Point 68	205.71863	660.7488
Point 69	197.06118	660.0031
Point 70	192.85524	659.8323
Point 71	190.78124	659.9884
Point 72	181.39906	659.9468
Point 73	180.62914	659.9453
Point 74	163.16856	659.8467
Point 75	150.51799	659.8602
Point 76	142.43782	659.8635
Point 77	136.27384	659.8581
Point 78	133.58851	659.8636
Point 79	125.91382	659.8612
Point 80	121.0177	659.8562
Point 81	112.81162	659.8501
Point 82	100.06337	659.8179
Point 83	82.77777	659.8878
Point 84	73.65349	659.9169
Point 85	52.60684	660.0031
Point 86	32.32465	667.4898
Point 87	24.66721	670.0031
Point 88	6.2574	676.8635
Point 89	1.34452	678.2221
Point 90	0.42547	678.5441
Point 91	-3.82065	680.0031
Point 92	-8.82539	681.236
Point 93	-15.65178	683.1294
Point 94	-20.77908	684.2188
Point 95	-32.86093	687.3698
Point 96	-34.93861	688.0985
Point 97	-40.36917	690.0031
Point 98	-45.11248	692.0506
Point 99	-48.98865	693.9255
Point 100	-51.44979	694.9538
Point 101	-55.94949	696.3254
Point 102	-59.28317	697.087
Point 103	-60.04348	697.4401
Point 104	-60.64641	697.6906
Point 105	-62.85537	698.6024
Point 106	-200	730
Point 107	485.27751	660.123
Point 108	397.68249	661.995
Point 109	375.60439	670.7136
Point 110	372.06274	671.93
Point 111	363.08245	673.9589
Point 112	348.78271	675.4992
Point 113	338.06199	676.0254
Point 114	333.73698	675.6902
Point 115	297	675

Point 116	108.3899	759.37
Point 117	131.7264	770.44
Point 118	151.9611	771.04
Point 119	207.564	749.65
Point 120	258.5547	726.54
Point 121	274.704	719.62
Point 122	276.8231	718.56
Point 123	279.7673	719.5
Point 124	293.2405	720.41
Point 125	340.5962	701.24
Point 126	360.5184	693.26
Point 127	389.4693	681.17
Point 128	403.4468	674.58
Point 129	413.5669	668.6
Point 130	416.3662	667.66
Point 131	419.0419	668.73
Point 132	427.1289	670.25
Point 133	447.3202	671.17
Point 134	463.2535	668.28
Point 135	-200	750.95
Point 136	91.4571	750.95
Point 137	419.5191	668.8197
Point 138	273.1677	674.2
Point 139	326.0094	666.5
Point 140	326.0094	697.5
Point 141	353.1828	689.29
Point 142	153.2026	750.78
Point 143	272.4756	715.59
Point 144	326.0094	702.63
Point 145	381.8396	679.31
Point 146	439.6323	668.8197

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.63	(423.863, 815.361)	54.69621	(321.999, 708.769)	(417.792, 668.23)
2	107	1.80	(423.863, 815.361)	147.439	(322, 708.768)	(414.745, 668.204)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	323.36815	708.2096	-356.7831	0.47340098	0.40997157	-9.5169e-010
2	Optimized	326.10725	707.0918	-342.75516	1.4202368	1.229944	3.3559e-009
3	Optimized	329.0575	705.81165	-328.2588	10.079419	8.7289111	5.999e-008
4	Optimized	332.21895	704.36915	-310.76241	26.593654	23.030459	-4.3957e-007
5	Optimized	335.4988	702.72835	-288.56317	54.739009	47.404713	7.3596e-007
6	Optimized	338.89705	700.8893	-261.75138	98.846472	85.602364	-1.6339e-006
7	Optimized	341.83325	699.3003	-243.27327	137.45839	119.0408	8.9484e-007
8	Optimized	344.42965	697.8079	-224.41105	172.4075	149.3072	4.3909e-006

9	Optimized	347.14835	696.1621	-202.28429	223.02656	193.14398	-2.7762e-006
10	Optimized	350.11955	694.21045	-174.22156	274.04354	237.32537	6.98e-006
11	Optimized	353.3432	691.95295	-140.22339	356.42177	308.66601	-4.437e-006
12	Optimized	356.56685	689.69545	-105.03351	438.77458	379.98465	-5.4623e-006
13	Optimized	359.34855	687.64285	-70.006021	489.98512	424.33366	-6.1036e-006
14	Optimized	361.6554	685.8211	-37.341596	561.40087	444.62592	37
15	Optimized	363.7457	684.30335	-9.781539	671.93391	532.16738	37
16	Optimized	366.1489	682.73805	18.664468	722.49927	557.43269	37
17	Optimized	369.04875	680.8472	59.947335	786.25091	575.22781	37
18	Optimized	372.11285	678.97815	104.09298	886.60648	619.74571	37
19	Optimized	375.34115	677.13085	150.63465	936.02222	622.02196	37
20	Optimized	378.87925	675.26375	211.15534	1028.7797	647.55329	37
21	Optimized	382.7272	673.3769	264.34668	1058.0867	628.63708	37
22	Optimized	385.8557	671.93285	304.88134	1126.5496	650.75602	37
23	Optimized	388.26475	670.93155	331.44476	1126.0513	629.32331	37
24	Optimized	390.6015	669.96035	357.4742	1119.1688	603.25729	37
25	Optimized	393.7147	668.90385	380.37032	1166.9837	622.99278	37
26	Optimized	397.67675	667.7319	399.82932	1085.5657	543.09881	37
27	Optimized	401.5523	666.85215	360.5137	1087.6701	575.90321	37
28	Optimized	405.7656	666.1989	301.46828	884.58823	461.82729	37
29	Optimized	409.45505	665.9783	236.38994	810.33565	454.56136	37
30	Optimized	412.1963	666.25605	169.92478	498.24373	284.3286	-4.0593e-006
31	Optimized	413.66785	666.40515	141.09649	331.57601	164.95781	-2.3544e-006
32	Optimized	415.0675	667.0012	72.84223	275.24649	175.28479	4.9021e-006
33	Optimized	417.0792	667.90865	-18.998063	12.137154	10.510938	6.9272e-008

Slices of Slip Surface: 107

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	107	323.5497	707.32895	-332.31028	61.054772	52.874248	8.2135e-007
2	107	326.64905	704.5307	-274.91586	182.34581	157.91391	-2.2704e-006
3	107	329.7484	701.8861	-223.3443	298.03909	258.10583	-3.7102e-006
4	107	332.8478	699.38465	-176.02073	407.88665	353.23529	-5.0767e-006
5	107	335.94715	697.01725	-140.99901	511.75596	405.30747	37
6	107	339.0465	694.776	-108.79668	610.03835	483.14649	37
7	107	342.2564	692.58255	-77.96273	705.18359	558.50092	37
8	107	345.57675	690.4387	-48.541596	796.70894	630.98841	37
9	107	348.8971	688.41785	-21.945076	880.2096	697.1204	37
10	107	352.2175	686.51425	1.8946258	955.57789	755.31108	37
11	107	355.53785	684.7228	29.04931	1023.411	787.52817	37
12	107	358.8582	683.03895	55.32247	1082.0941	737.21261	111
13	107	362.1268	681.4817	80.33743	1127.9366	752.16659	111
14	107	365.34355	680.04445	104.14901	1160.8159	758.67715	111
15	107	368.5603	678.698	132.53541	1184.1793	755.07068	111
16	107	371.7771	677.4397	160.04307	1197.7856	745.08958	111
17	107	374.99385	676.2672	185.72056	1201.3969	729.2463	111
18	107	378.2106	675.17835	216.61216	1194.4839	774.46821	37
19	107	381.4274	674.17115	239.24952	1177.1343	742.79879	37
20	107	384.64415	673.24385	254.47654	1149.2934	708.68923	37
21	107	387.8609	672.395	264.99489	1110.5765	669.69527	37

22	107	390.86705	671.669	270.38363	1055.5187	621.822	37
23	107	393.66255	671.0555	271.09677	984.92156	565.34469	37
24	107	396.45805	670.49855	267.53506	904.96418	504.8398	37
25	107	399.25355	669.99745	244.34985	817.13299	453.6406	37
26	107	402.04905	669.5517	205.82238	721.1814	408.16107	37
27	107	405.1335	669.12655	159.76246	575.66708	360.17895	-5.1702e-006
28	107	408.50685	668.73385	105.5452	375.78678	234.03282	-3.3586e-006
29	107	411.8802	668.41965	47.149338	157.32007	95.409324	7.1591e-007
30	107	414.15595	668.24325	9.3866173	20.934816	10.000894	6.8603e-008

ASH DIKE SECTION STA. 10+00

Seepage Analysis – Static Condition

Seepage Analysis Flow Net – Static Condition

Static Slope Stability Analysis – Global

Static Slope Stability Analysis – Upper

Static Slope Stability Analysis – Lower

Seepage Analysis - Pool from 100-year Slope Storm Event

Pool from 100-year Slope Storm Event Stability Analysis – Global

Pool from 100-year Slope Storm Event Stability Analysis – Upper

Pool from 100-year Storm Event Slope Stability Analysis – Lower

Seepage Analysis - Surcharge Pool = 760

Surcharge Pool = 760 Slope Stability Analysis – Global

Surcharge Pool = 760 Slope Stability Analysis – Upper

Surcharge Pool = 760 Slope Stability Analysis – Lower

Pseudostatic Slope Stability Analysis – Global

Pseudostatic Slope Stability Analysis – Upper

Pseudostatic Slope Stability Analysis – Lower

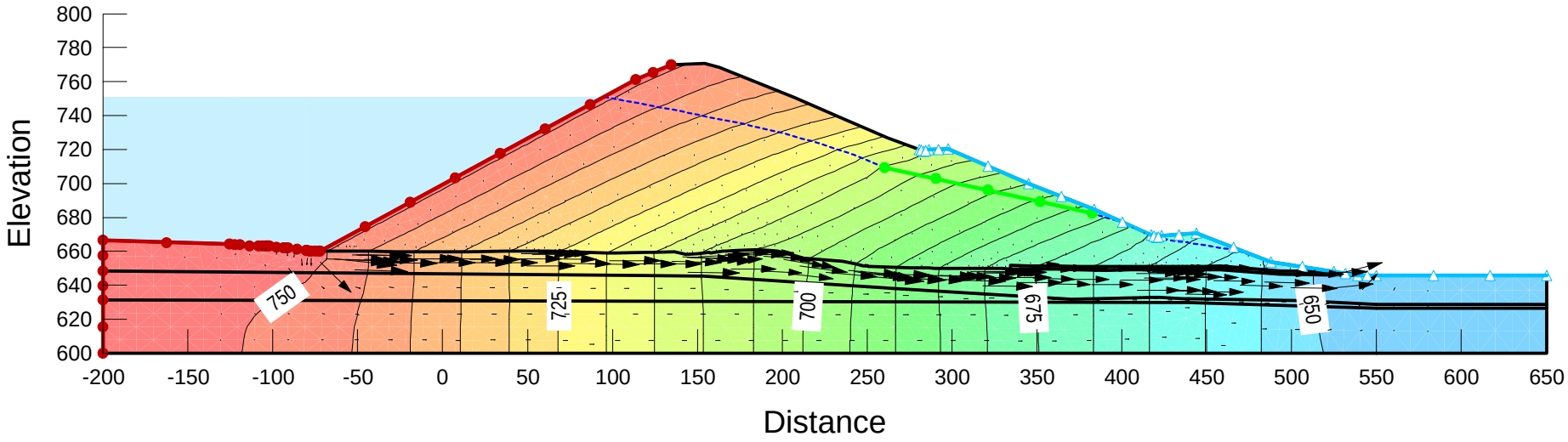
Rapid Drawdown Stability Analysis

Seepage Analysis - Water Surface Elevation = 745.63

Water Surface Elevation = 745.63 Slope Stability Analysis – Lower

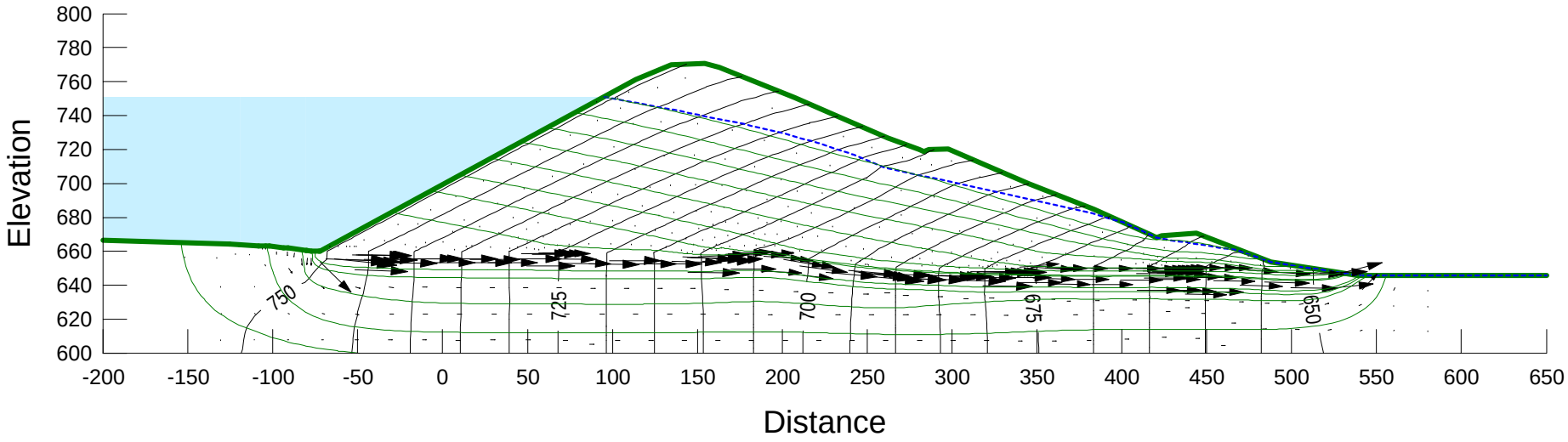
Name: Seepage Analysis - Static Condition
Description: Ash Dike Section Sta. 10+00

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 1e-6 K-Ratio: 0.1 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0
Name: Rock Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0



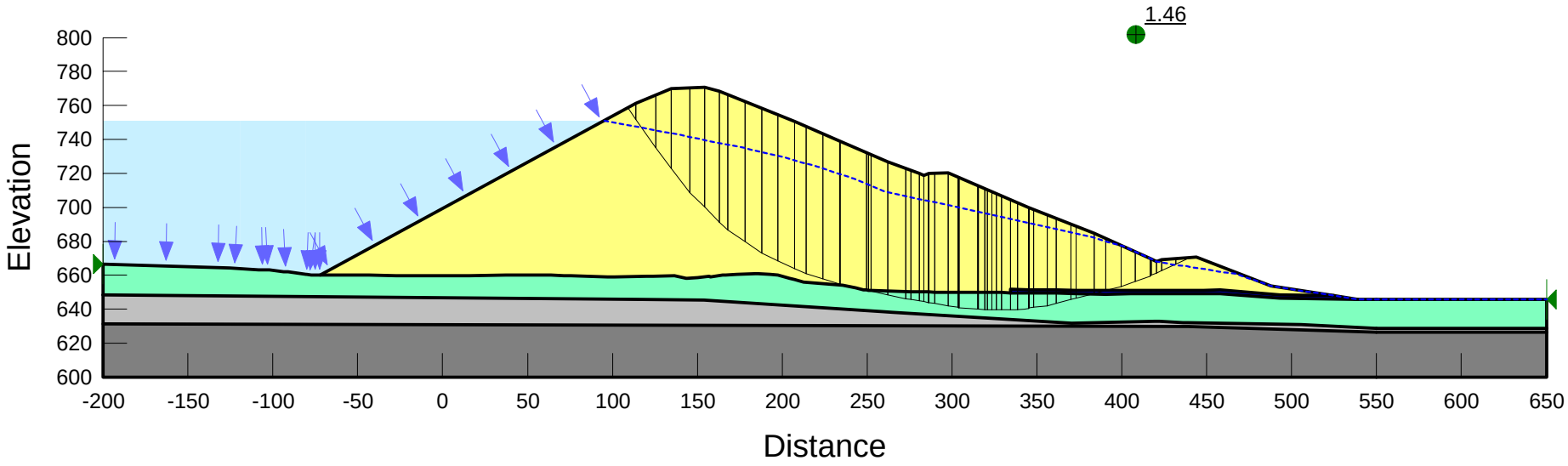
Name: Seepage Analysis - Static Condition
Description: Ash Dike Section Sta. 10+00

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 1e-6 K-Ratio: 0.1 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0
Name: Rock Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0



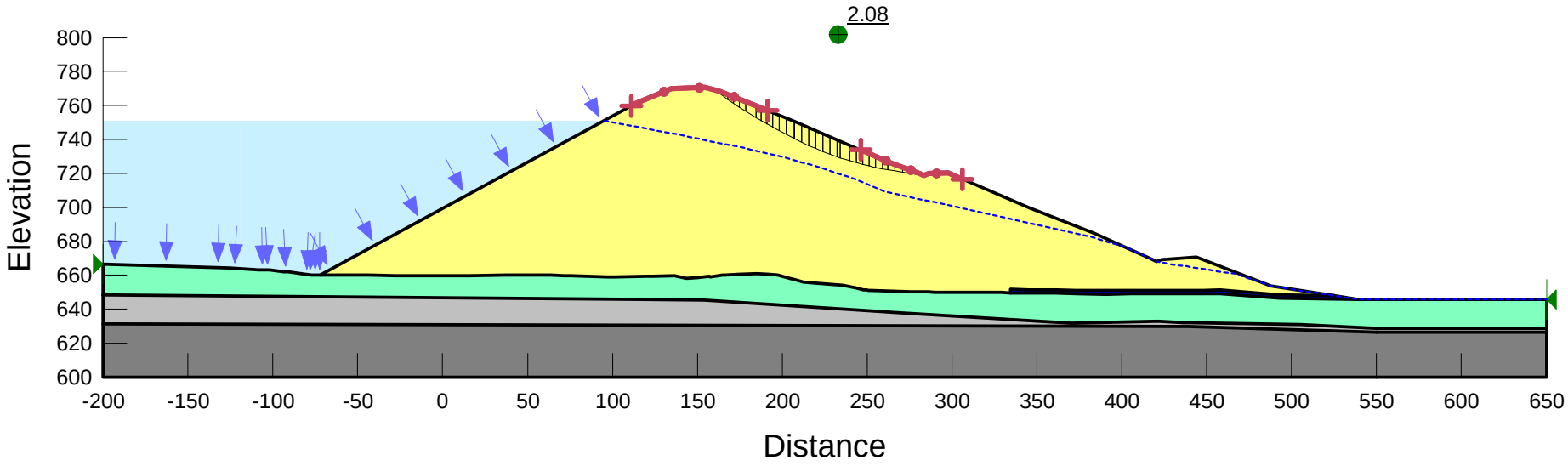
Name: Static Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 10+00

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



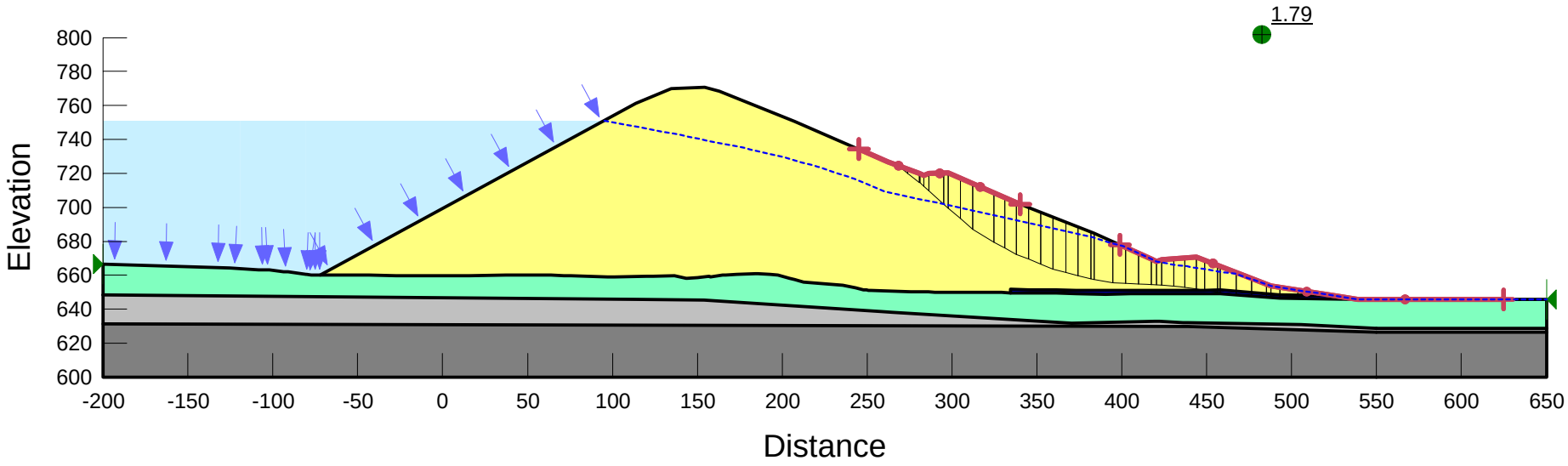
Name: Static Slope Stability Analysis - Upper
Description: Ash Dike Section Sta. 10+00

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



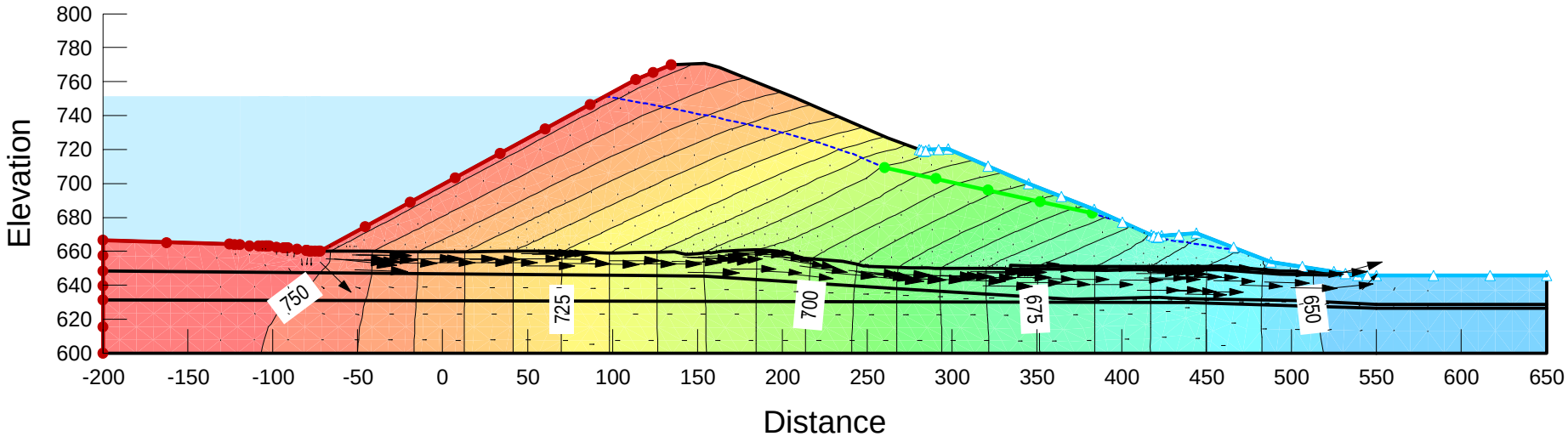
Name: Static Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 10+00

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



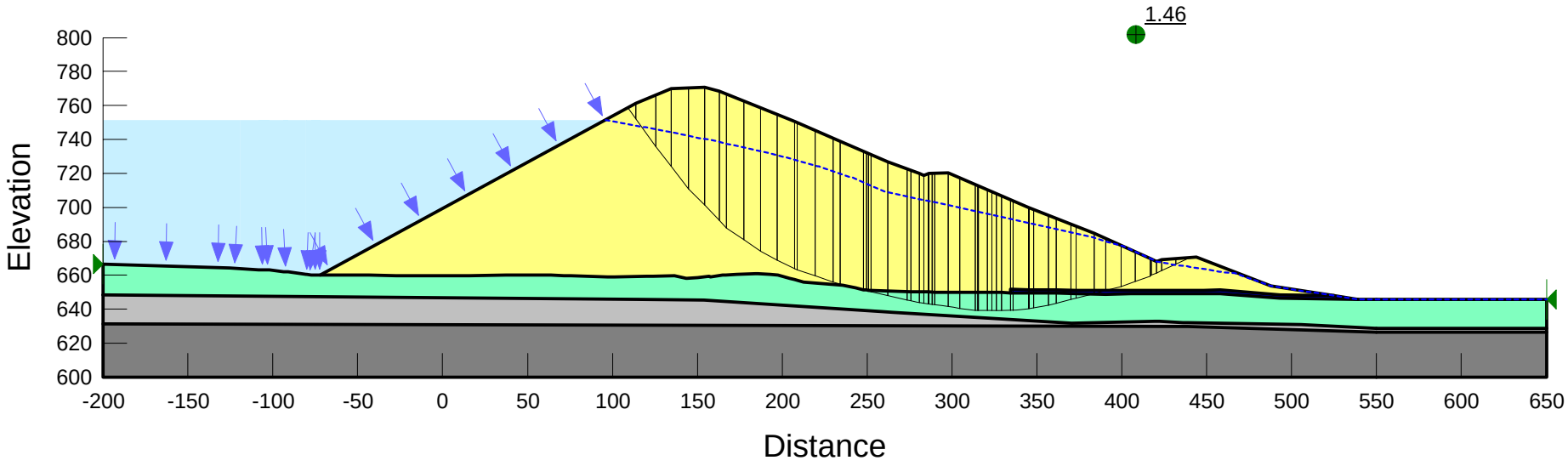
Name: Seepage Analysis - Pool from 100-yr Storm Event Condition
Description: Ash Dike Section Sta. 10+00
Pool from 100-yr Storm Event = 751.4

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 1e-6 K-Ratio: 0.1 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0
Name: Rock Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0



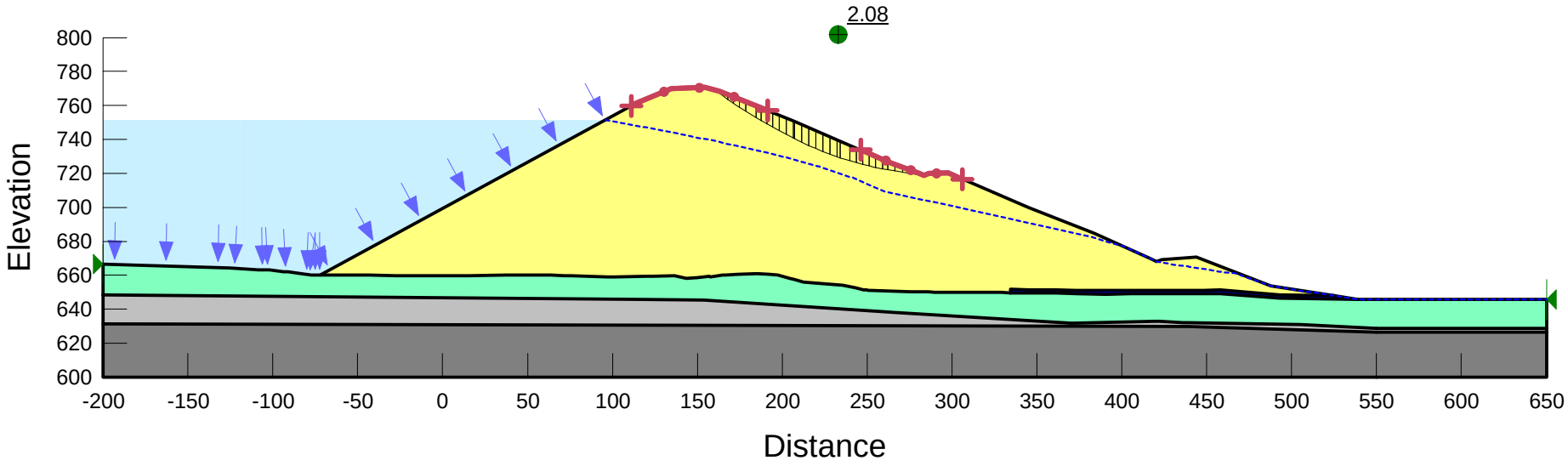
Name: Pool from 100-yr Storm Event Condition Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 10+00
Pool from 100-yr Storm Event = 751.4

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



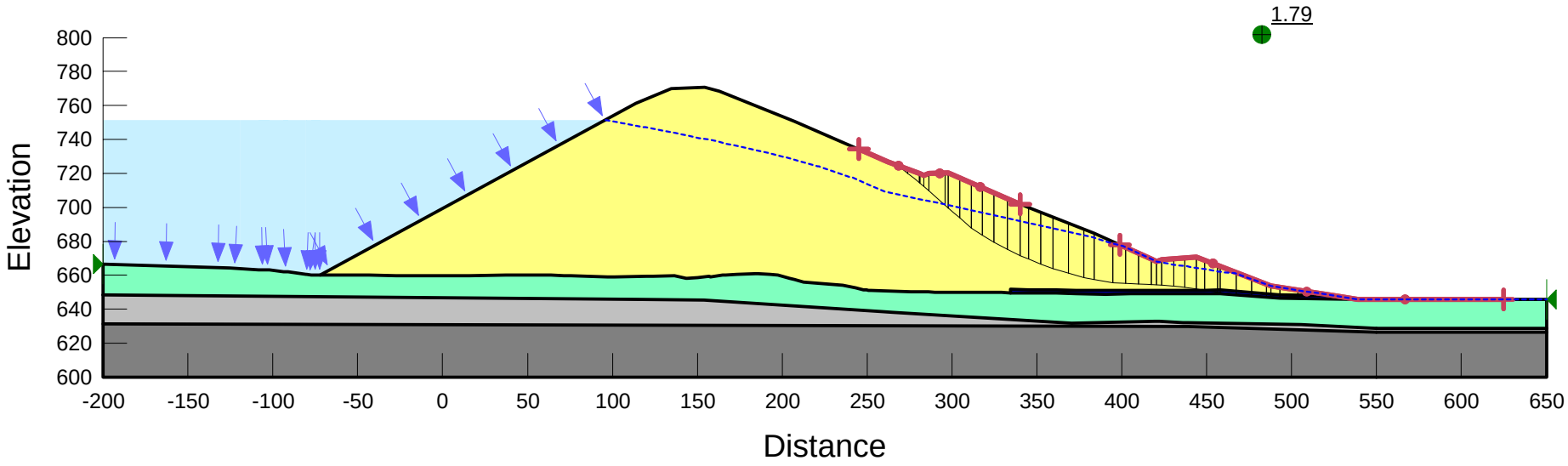
Name: Pool from 100-yr Storm Event Condition Slope Stability Analysis - Upper
Description: Ash Dike Section Sta. 10+00
Pool from 100-yr Storm Event = 751.4

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



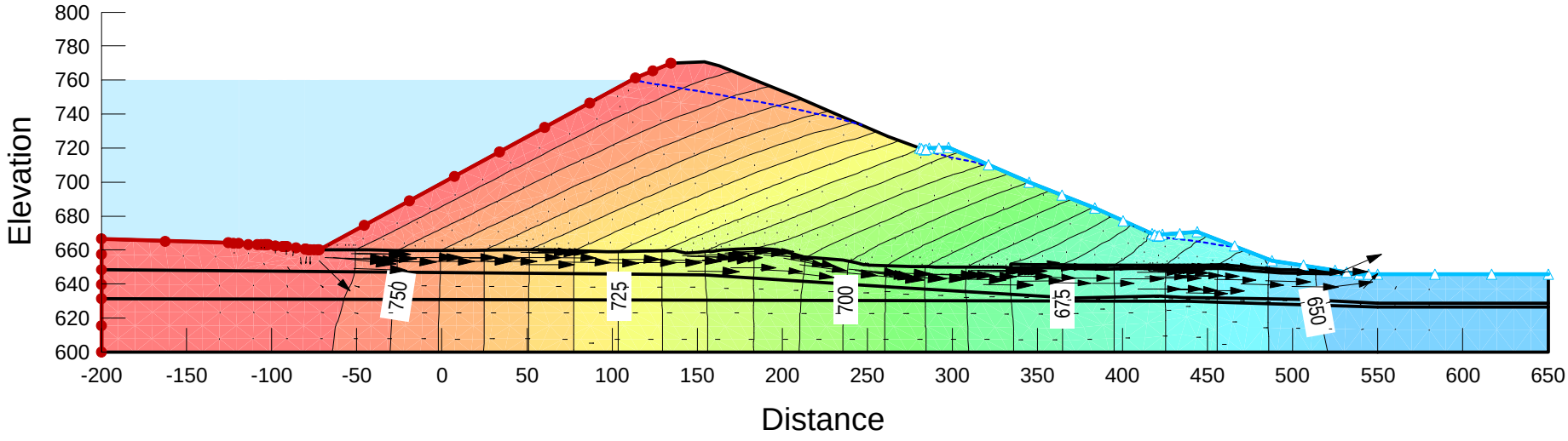
Name: Pool from 100-yr Storm Event Condition Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 10+00
Pool from 100-yr Storm Event = 751.4

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



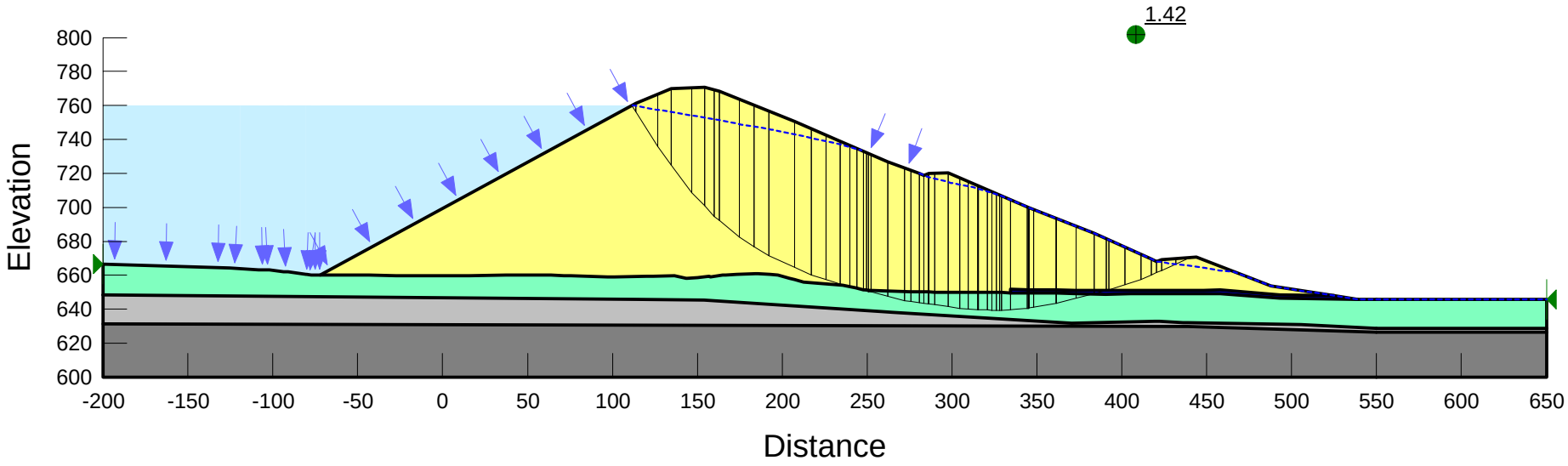
Name: Seepage Analysis - Surcharge Pool Condition
Description: Ash Dike Section Sta. 10+00
Surcharge Pool = 760

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 1e-6 K-Ratio: 0.1 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0
Name: Rock Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0



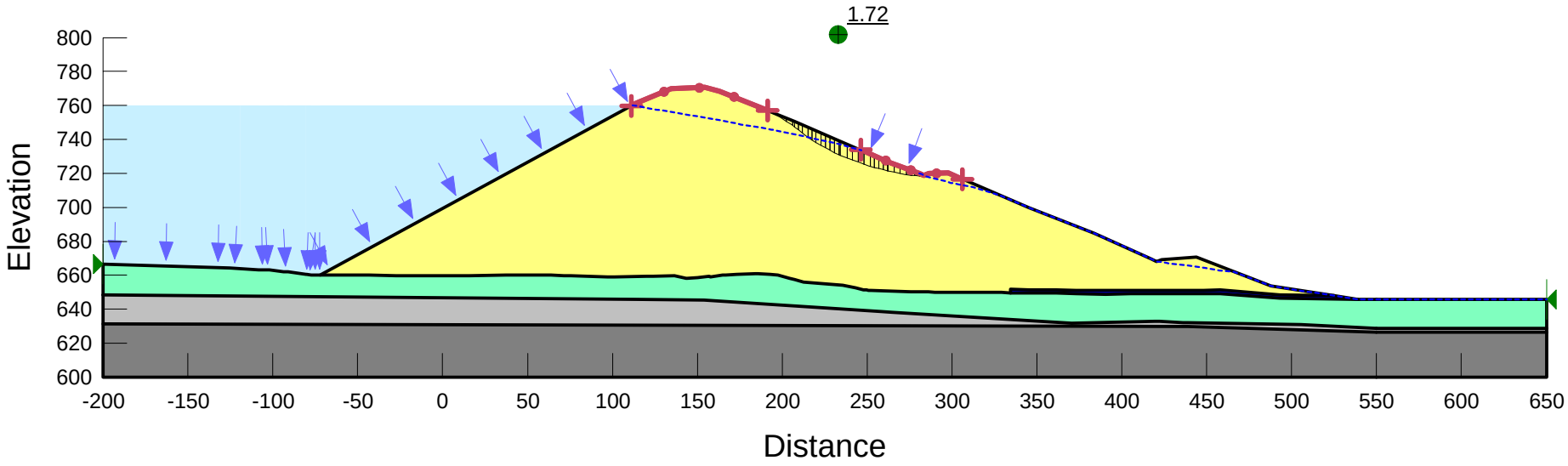
Name: Surcharge Pool Condition Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 10+00
Surcharge Pool = 760

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



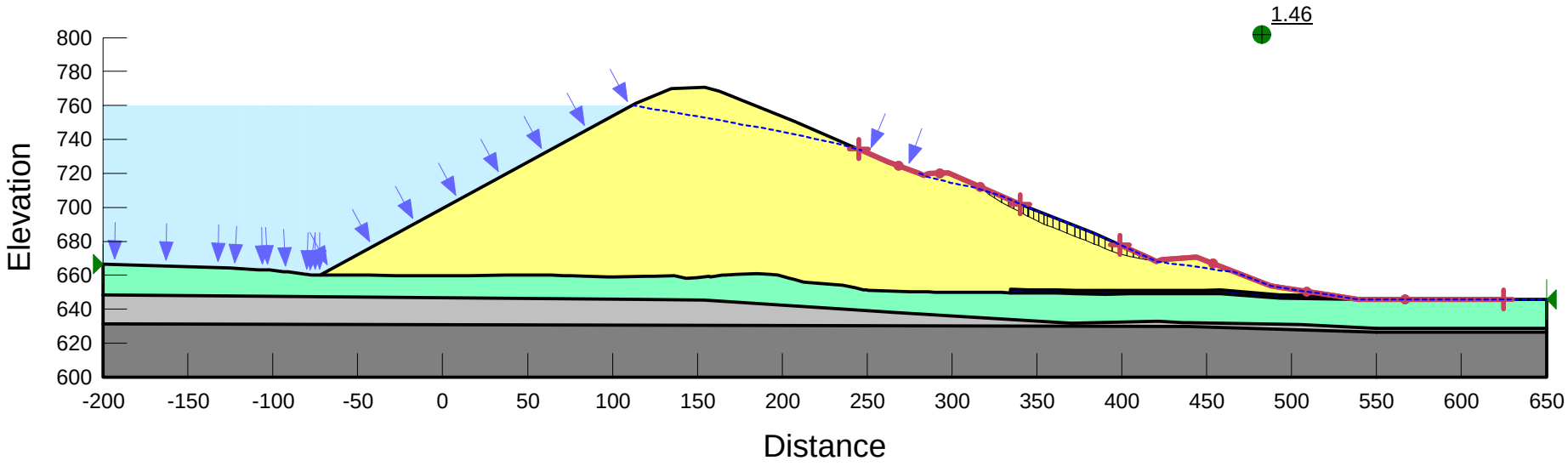
Name: Surcharge Pool Condition Slope Stability Analysis - Upper
Description: Ash Dike Section Sta. 10+00
Surcharge Pool = 760

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



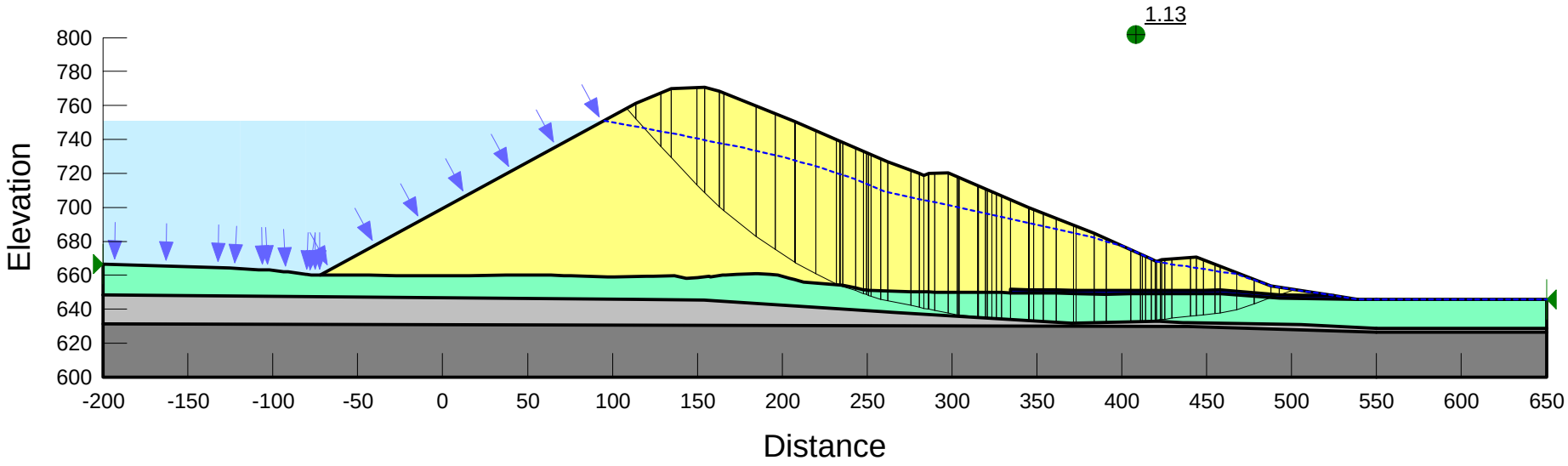
Name: Surcharge Pool Condition Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 10+00
Surcharge Pool = 760

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



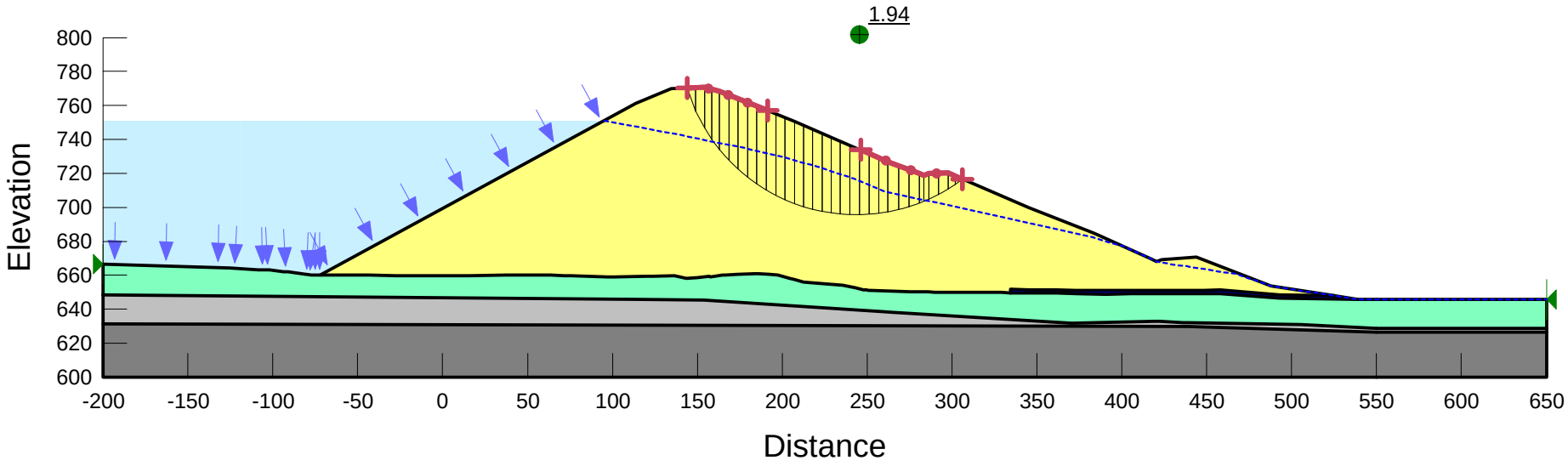
Name: Pseudostatic Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 10+00
Seismic Coefficient "k" = 0.06 g

Name: Embankment Fill - Ash Dike Model: Mohr-Coulomb Unit Weight: 123 Unit Wt. Above Water Table: 121 Cohesion: 1300 Phi: 12.5 Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Mohr-Coulomb Unit Weight: 124 Cohesion: 1400 Phi: 11.3 Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



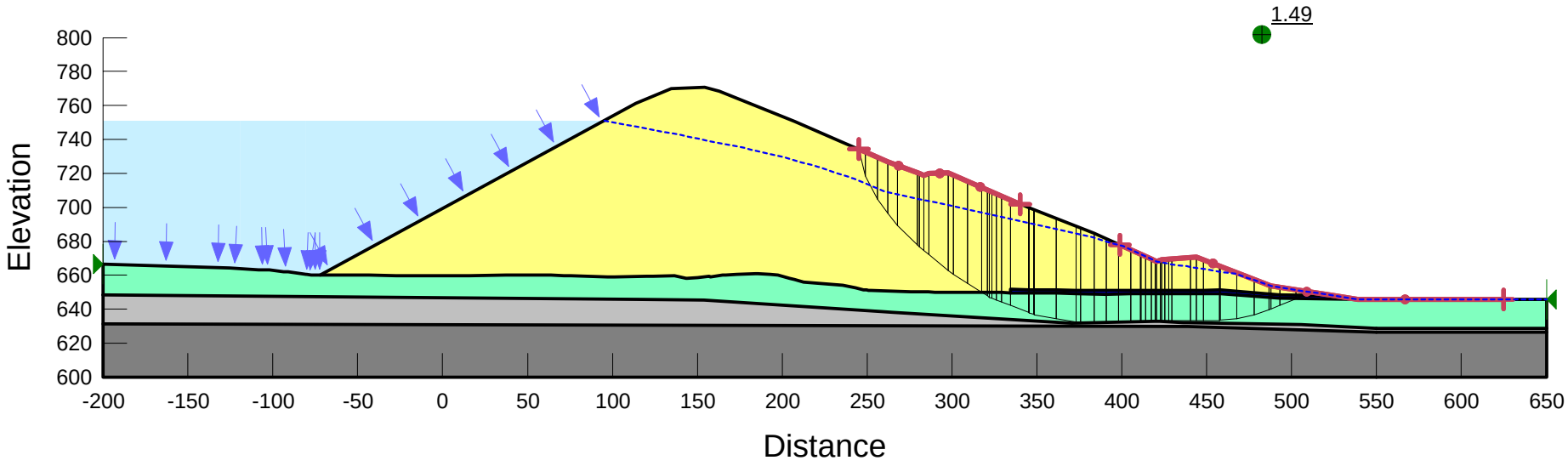
Name: Pseudostatic Slope Stability Analysis - Upper
Description: Ash Dike Section Sta. 10+00
Seismic Coefficient "k" = 0.06 g

Name: Embankment Fill - Ash Dike Model: Mohr-Coulomb Unit Weight: 123 Unit Wt. Above Water Table: 121 Cohesion: 1300 Phi: 12.5 Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Mohr-Coulomb Unit Weight: 124 Cohesion: 1400 Phi: 11.3 Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



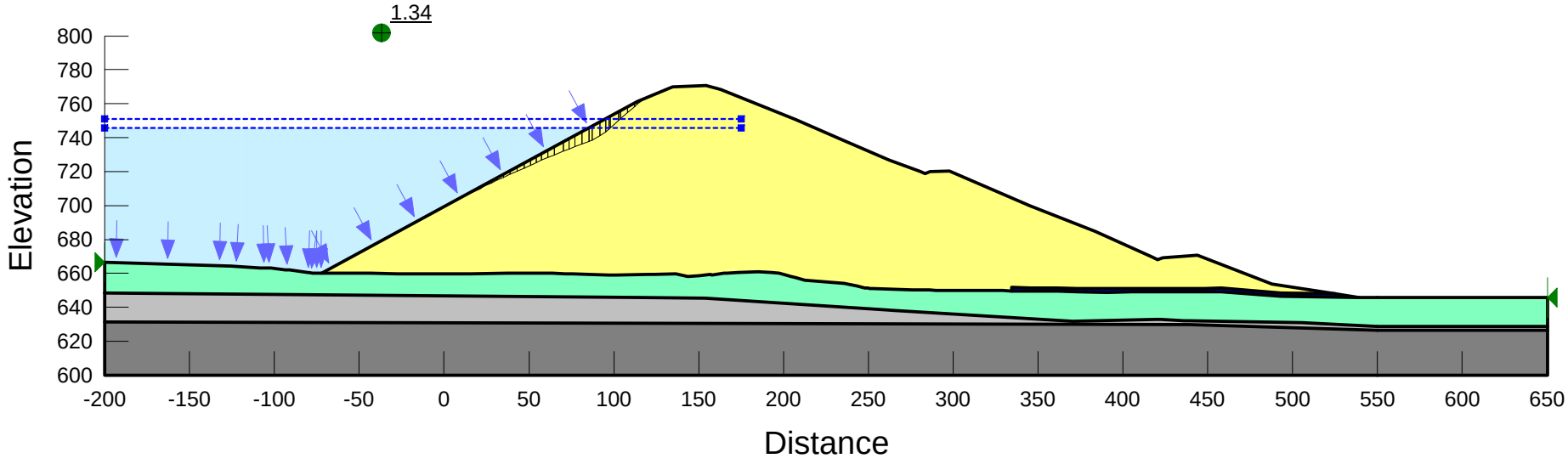
Name: Pseudostatic Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 10+00
Seismic Coefficient "k" = 0.06 g

Name: Embankment Fill - Ash Dike Model: Mohr-Coulomb Unit Weight: 123 Unit Wt. Above Water Table: 121 Cohesion: 1300 Phi: 12.5 Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Mohr-Coulomb Unit Weight: 124 Cohesion: 1400 Phi: 11.3 Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



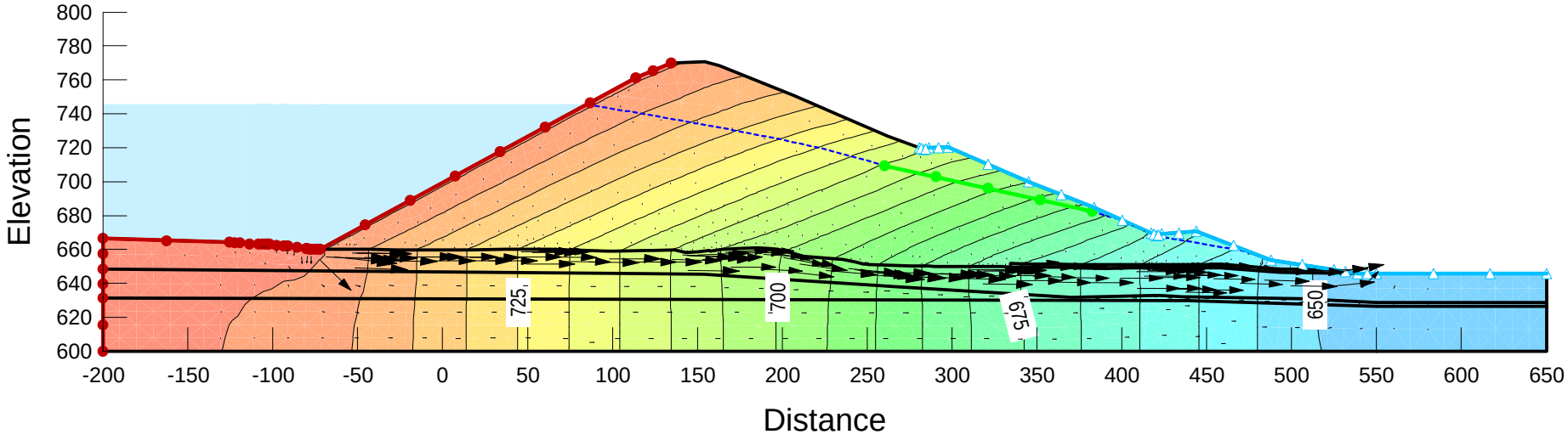
Name: Rapid Drawdown Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 10+00
Pool Drawdown from 750.95 to 745.63

Name: Embankment Fill - Ash Dike Model: Mohr-Coulomb Unit Weight: 123 pcf Unit Wt. Above Water Table: 121 pcf Cohesion: 0 psf Phi: 38 ° Phi-B: 0 °
Drawdown Total Cohesion: 1300 psf Drawdown Total Phi: 12.5 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 36 ° Phi-B: 0 ° Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Residuum Model: Mohr-Coulomb Unit Weight: 124 pcf Cohesion: 0 psf Phi: 36 ° Phi-B: 0 ° Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 pcf Cohesion: 1000 psf Phi: 38 ° Phi-B: 0 ° Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Rock Model: Bedrock (Impenetrable) Piezometric Line: 1 Piezometric Line After Drawdown: 2



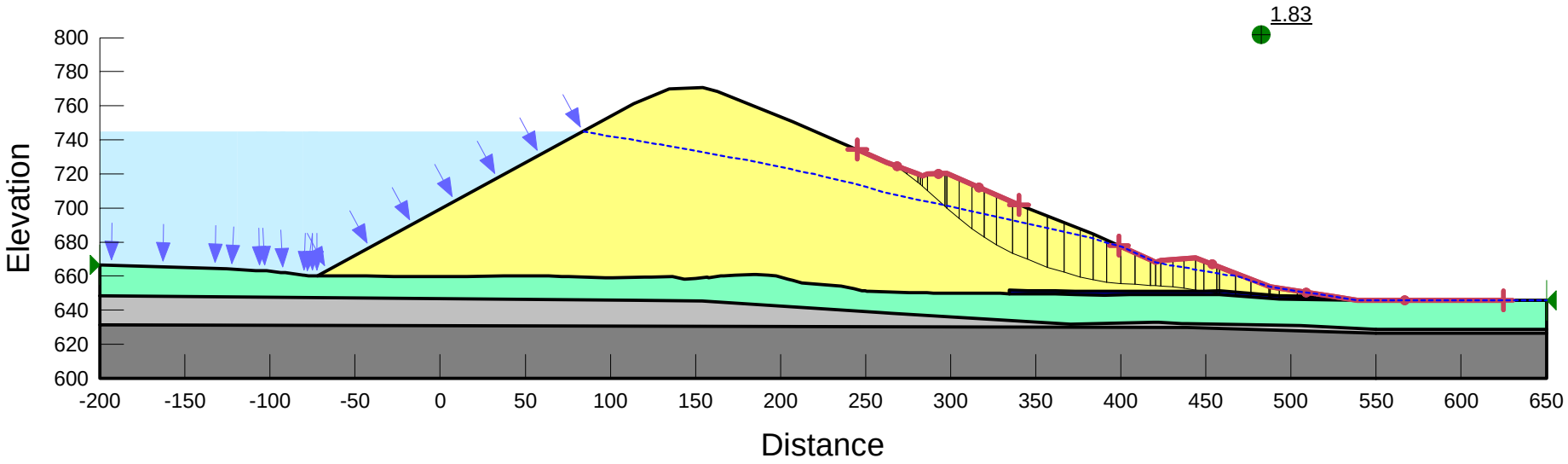
Name: Seepage Analysis - Static Condition
Description: Ash Dike Section Sta. 10+00
Water Surface Elevation = 745.63

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 1e-6 K-Ratio: 0.1 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0
Name: Rock Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0



Name: Static Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 10+00
Water Surface Elevation = 745

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0
Name: Rock Model: Bedrock (Impenetrable)



Seepage Analysis - Static Condition

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 156
Last Edited By: Cedric Ruhl
Date: 9/12/2010
Time: 9:00:57 PM
File Name: AD 10+00 Static.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 10+00\
Last Solved Date: 9/13/2010
Last Solved Time: 1:58:37 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Mass(M) Units: lbs
Mass Flux Units: lbs/sec
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Seepage Analysis - Static Condition

Description: Ash Dike Section Sta. 10+00
Kind: SEEP/W
Method: Steady-State
Settings
    Include Air Flow: No
Control
    Apply Runoff: Yes
Convergence
    Convergence Type: Gauss Point K
    Convergence Settings
        Maximum Number of Iterations: 500
        Tolerance: 0.01
        Maximum Change in K: 0.1
        Rate of Change in K: 1.02
        Minimum Change in K: 0.0001
    Equation Solver: Parallel Direct
    Potential Seepage Max # of Reviews: 10
Time
    Starting Time: 0 sec
    Duration: 0 sec

Ending Time: 0 sec

Materials

Embankment Fill - Ash Dike

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-6
K-Ratio: 0.1
K-Direction: 0 °

Blanket Drain

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

Residuum

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

PWR

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

Rock

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

Boundary Conditions

Water Elevation

Type: Head (H) 750.95

Potential Seepage Face

Review: true
Type: Total Flux (Q) 0

Zero Pressure

Type: Pressure Head 0

K Functions

1e-4

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-006
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-006)
Data Point: (10000, 3.28e-006)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-5

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-007
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-007)
Data Point: (10000, 3.28e-007)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-6

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-008
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-008)
Data Point: (10000, 3.28e-008)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6	22678.912
Region 2	PWR	7,8,9,10,11,12,13,14,15,16,17,18,1,6,5,4	7884.8849
Region 3	Residuum	7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35, 36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63, 64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91, 92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113	11257.694
Region 4	Blanket Drain	20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,114,115,116,117,118,119, 120,121,122,123,124,125,126,127,128,129,130,131,132	395.05906
Region 5	Embankment Fill - Ash Dike	101,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150, 132,131,130,129,128,127,126,125,124,123,122,121,120,119,118,117,116,115,114, 38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64, 65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91, 92,93,94,95,96,97,98,99,100	32814.463
Region 6	Residuum	19,18,157,158	1719.61
Region 7	PWR	18,1,156,157	227.13
Region 8	Rock	156,155,2,1	2629.16

Lines

	Start Point	End Point	Hydraulic Boundary
Line 1	1	2	
Line 2	2	3	
Line 3	3	4	Water Elevation
Line 4	4	5	
Line 5	5	6	
Line 6	6	1	
Line 7	7	8	
Line 8	8	9	
Line 9	9	10	
Line 10	10	11	
Line 11	11	12	
Line 12	12	13	
Line 13	13	14	
Line 14	14	15	
Line 15	15	16	
Line 16	16	17	
Line 17	17	18	
Line 18	18	1	
Line 19	4	7	Water Elevation
Line 20	18	19	
Line 21	19	20	Potential Seepage Face
Line 22	20	21	
Line 23	21	22	
Line 24	22	23	
Line 25	23	24	
Line 26	24	25	
Line 27	25	26	
Line 28	26	27	
Line 29	27	28	
Line 30	28	29	

Line 31	29	30	
Line 32	30	31	
Line 33	31	32	
Line 34	32	33	
Line 35	33	34	
Line 36	34	35	
Line 37	35	36	
Line 38	36	37	
Line 39	37	38	
Line 40	38	39	
Line 41	39	40	
Line 42	40	41	
Line 43	41	42	
Line 44	42	43	
Line 45	43	44	
Line 46	44	45	
Line 47	45	46	
Line 48	46	47	
Line 49	47	48	
Line 50	48	49	
Line 51	49	50	
Line 52	50	51	
Line 53	51	52	
Line 54	52	53	
Line 55	53	54	
Line 56	54	55	
Line 57	55	56	
Line 58	56	57	
Line 59	57	58	
Line 60	58	59	
Line 61	59	60	
Line 62	60	61	
Line 63	61	62	
Line 64	62	63	
Line 65	63	64	
Line 66	64	65	
Line 67	65	66	
Line 68	66	67	
Line 69	67	68	
Line 70	68	69	
Line 71	69	70	
Line 72	70	71	
Line 73	71	72	
Line 74	72	73	
Line 75	73	74	
Line 76	74	75	
Line 77	75	76	
Line 78	76	77	
Line 79	77	78	
Line 80	78	79	
Line 81	79	80	
Line 82	80	81	

Line 83	81	82	
Line 84	82	83	
Line 85	83	84	
Line 86	84	85	
Line 87	85	86	
Line 88	86	87	
Line 89	87	88	
Line 90	88	89	
Line 91	89	90	
Line 92	90	91	
Line 93	91	92	
Line 94	92	93	
Line 95	93	94	
Line 96	94	95	
Line 97	95	96	
Line 98	96	97	
Line 99	97	98	
Line 100	98	99	
Line 101	99	100	
Line 102	100	101	
Line 103	101	102	
Line 104	102	103	Water Elevation
Line 105	103	104	Water Elevation
Line 106	104	105	Water Elevation
Line 107	105	106	Water Elevation
Line 108	106	107	Water Elevation
Line 109	107	108	Water Elevation
Line 110	108	109	Water Elevation
Line 111	109	110	Water Elevation
Line 112	110	111	Water Elevation
Line 113	111	112	Water Elevation
Line 114	112	113	Water Elevation
Line 115	113	7	Water Elevation
Line 116	38	114	
Line 117	114	115	
Line 118	115	116	
Line 119	116	117	
Line 120	117	118	
Line 121	118	119	
Line 122	119	120	
Line 123	120	121	
Line 124	121	122	
Line 125	122	123	
Line 126	123	124	
Line 127	124	125	
Line 128	125	126	
Line 129	126	127	
Line 130	127	128	
Line 131	128	129	
Line 132	129	130	
Line 133	130	131	
Line 134	131	132	

Line 135	132	20	Potential Seepage Face
Line 136	101	133	Water Elevation
Line 137	133	134	Water Elevation
Line 138	134	135	
Line 139	135	136	
Line 140	136	137	
Line 141	137	138	
Line 142	138	139	
Line 143	139	140	
Line 144	140	141	Potential Seepage Face
Line 145	141	142	Potential Seepage Face
Line 146	142	143	Potential Seepage Face
Line 147	143	144	Potential Seepage Face
Line 148	144	145	Potential Seepage Face
Line 149	145	146	Potential Seepage Face
Line 150	146	147	Potential Seepage Face
Line 151	147	148	Potential Seepage Face
Line 152	148	149	Potential Seepage Face
Line 153	149	150	Potential Seepage Face
Line 154	150	132	Potential Seepage Face
Line 155	152	153	
Line 156	154	150	
Line 157	18	157	
Line 158	157	158	
Line 159	158	19	Potential Seepage Face
Line 160	1	156	
Line 161	156	157	
Line 162	156	155	
Line 163	155	2	
Line 164	153	159	
Line 165	159	160	Zero Pressure
Line 166	160	147	
Line 167	147	154	

Points

	X (ft)	Y (ft)
Point 1	550	626.2916
Point 2	550	600
Point 3	-200	600
Point 4	-200	631.2263
Point 5	435.77054	629.9876
Point 6	438.77054	629.9876
Point 7	-200	648.4542
Point 8	115.92382	645.6152
Point 9	153.92041	645.3586
Point 10	259.22799	638.5324
Point 11	264.65748	638.2309
Point 12	370.34779	631.7877
Point 13	419.11319	632.9682
Point 14	422.11319	632.9682
Point 15	435.77054	632.1976

Point 16	438.77054	632.1976
Point 17	505.53902	630.9464
Point 18	550	628.5629
Point 19	550	645.759
Point 20	538.93239	645.759
Point 21	493.15087	646.4361
Point 22	457.9644	649.3258
Point 23	447.9316	649.1229
Point 24	440.39668	649.1239
Point 25	429.54704	649.1174
Point 26	425.1771	649.1104
Point 27	422.72062	649.0876
Point 28	419.51694	649.089
Point 29	417.40666	649.072
Point 30	414.03007	649.0786
Point 31	411.0988	649.0585
Point 32	405.22983	649.0813
Point 33	390.67981	648.9569
Point 34	372.93156	649.1925
Point 35	361.48377	649.3536
Point 36	347.97674	649.5625
Point 37	345.4121	649.595
Point 38	334.44	649.713
Point 39	329.03159	649.7712
Point 40	326.05577	649.8079
Point 41	323.36622	649.844
Point 42	320.67423	649.8778
Point 43	315.64527	649.9205
Point 44	315.05016	649.9228
Point 45	304.48331	649.9634
Point 46	304.18245	649.9655
Point 47	303.91306	649.9678
Point 48	289.7402	650.0008
Point 49	286.04752	650.1426
Point 50	275.87032	650.1308
Point 51	275.68718	650.1467
Point 52	252.33972	651.0708
Point 53	250.94149	651.1413
Point 54	249.61047	651.3034
Point 55	247.81262	651.5924
Point 56	243.06874	652.4655
Point 57	235.69178	653.9221
Point 58	212.39077	655.8256
Point 59	207.17314	657.5836
Point 60	204.28213	658.0709
Point 61	197.46189	660.0008
Point 62	192.80663	660.6529
Point 63	185.53317	660.9307
Point 64	184.03956	660.9749
Point 65	173.13572	660.4524
Point 66	166.60252	660.1628
Point 67	164.93059	660.0008

Point 68	157.55079	659.1082
Point 69	156.96739	659.2087
Point 70	150.09613	658.5439
Point 71	144.22778	658.0809
Point 72	143.43809	658.218
Point 73	136.29536	659.5715
Point 74	124.16845	659.2793
Point 75	120.06523	659.2642
Point 76	101.1411	659.0708
Point 77	96.93915	658.9887
Point 78	75.53524	659.6735
Point 79	71.54497	659.7824
Point 80	63.91382	660.0008
Point 81	56.69252	660.2908
Point 82	56.25338	660.3097
Point 83	51.5101	660.1655
Point 84	47.91942	660.0008
Point 85	43.57514	659.9731
Point 86	37.25178	659.9476
Point 87	15.88238	659.809
Point 88	15.38216	659.8061
Point 89	15.26928	659.805
Point 90	-4.33215	659.8763
Point 91	-13.95702	659.8807
Point 92	-16.84171	659.8919
Point 93	-27.54675	659.8822
Point 94	-43.26967	659.9473
Point 95	-48.10755	659.9678
Point 96	-49.16786	659.9719
Point 97	-51.29902	659.9759
Point 98	-56.91536	659.9813
Point 99	-57.36383	659.9822
Point 100	-71.72542	659.9943
Point 101	-72.27759	659.9953
Point 102	-72.71754	659.9959
Point 103	-77.51457	660.0008
Point 104	-80.12556	660.3701
Point 105	-80.43329	660.3826
Point 106	-91.20495	662.1665
Point 107	-93.86835	661.9907
Point 108	-102.02052	663.332
Point 109	-104.44391	663.1704
Point 110	-108.27329	663.0626
Point 111	-119.27774	663.9084
Point 112	-125.59455	664.34
Point 113	-200	666.4545
Point 114	334.44	651.7132
Point 115	345.43553	651.5948
Point 116	348.00486	651.5623
Point 117	361.51331	651.3534
Point 118	372.9581	651.1923
Point 119	390.68453	650.957

Point 120	405.22518	651.0814
Point 121	411.09583	651.0585
Point 122	414.02518	651.0786
Point 123	417.40055	651.072
Point 124	419.5093	651.089
Point 125	422.71179	651.0876
Point 126	425.16623	651.1104
Point 127	429.54584	651.1174
Point 128	440.39696	651.1239
Point 129	447.91152	651.1229
Point 130	458.02619	651.3274
Point 131	493.24762	648.4349
Point 132	524.74647	647.969
Point 133	113.86	761.07
Point 134	134.63	769.93
Point 135	154.09	770.57
Point 136	163.11	768.22
Point 137	207.12	750.72
Point 138	234.33	738.92
Point 139	262.34	726.92
Point 140	280.84	719.98
Point 141	283.41	718.87
Point 142	286.3	719.93
Point 143	297.84	720.24
Point 144	344.96	699.81
Point 145	383.68	684.74
Point 146	417.44	669.6
Point 147	420.54	668.04
Point 148	423.33	669.22
Point 149	443.74	670.61
Point 150	487.96	653.7
Point 151	-200	750.95
Point 152	95.2232	750.95
Point 153	163.0634	744.33
Point 154	434.9039	663.1
Point 155	650	600
Point 156	650	626.2916
Point 157	650	628.5629
Point 158	650	645.759
Point 159	260.0928	709.5
Point 160	382.6296	682.42

Static Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 157
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 1:58:51 PM
File Name: AD 10+00 Static.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 10+00\
Last Solved Date: 9/13/2010
Last Solved Time: 2:00:44 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Static Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 10+00
Kind: SLOPE/W
Parent: Seepage Analysis - Static Condition
Method: Spencer
Settings
PWP Conditions Source: Parent Analysis
Slip Surface
Direction of movement: Left to Right
Use Passive Mode: No
Slip Surface Option: Auto-Search
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: Yes
Tension Crack
Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 3 ft
Optimization Maximum Iterations: 2000

Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Shear/Normal Fn.
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Strength Function: Ash Dike Fill
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Shear/Normal Fn.
Unit Weight: 124 pcf
Strength Function: Ash Dike Res
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Rock

Model: Bedrock (Impenetrable)

Slip Surface Limits

Left Coordinate: (-200, 666.4545) ft
Right Coordinate: (650, 645.759) ft

Shear/Normal Strength Functions

Ash Dike Fill

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 0 %

Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 433)
Data Point: (1000, 829)
Data Point: (1500, 1188)
Data Point: (2000, 1511)
Data Point: (2500, 1797)
Data Point: (3000, 2047)
Data Point: (3500, 2259)
Data Point: (4000, 2436)
Data Point: (4500, 2575)
Data Point: (5000, 2678)
Data Point: (5500, 2744)
Data Point: (6000, 2774)
Data Point: (20000, 2800)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Ash Dike Res

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 526)
Data Point: (1000, 999)
Data Point: (1500, 1417)
Data Point: (2000, 1781)
Data Point: (2500, 2092)
Data Point: (3000, 2349)
Data Point: (3500, 2552)
Data Point: (4000, 2700)
Data Point: (4500, 2795)
Data Point: (5000, 2837)
Data Point: (20000, 3500)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)

Region 1	Rock	1,2,3,4,5,6	22678.912
Region 2	PWR	7,8,9,10,11,12,13,14,15,16,17,18,1,6,5,4	7884.8849
Region 3	Residuum	7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113	11257.694
Region 4	Blanket Drain	20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132	395.05906
Region 5	Embankment Fill - Ash Dike	101,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,132,131,130,129,128,127,126,125,124,123,122,121,120,119,118,117,116,115,114,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100	32814.463
Region 6	Residuum	19,18,157,158	1719.61
Region 7	PWR	18,1,156,157	227.13
Region 8	Rock	156,155,2,1	2629.16

Points

	X (ft)	Y (ft)
Point 1	550	626.2916
Point 2	550	600
Point 3	-200	600
Point 4	-200	631.2263
Point 5	435.77054	629.9876
Point 6	438.77054	629.9876
Point 7	-200	648.4542
Point 8	115.92382	645.6152
Point 9	153.92041	645.3586
Point 10	259.22799	638.5324
Point 11	264.65748	638.2309
Point 12	370.34779	631.7877
Point 13	419.11319	632.9682
Point 14	422.11319	632.9682
Point 15	435.77054	632.1976
Point 16	438.77054	632.1976
Point 17	505.53902	630.9464
Point 18	550	628.5629
Point 19	550	645.759
Point 20	538.93239	645.759
Point 21	493.15087	646.4361
Point 22	457.9644	649.3258
Point 23	447.9316	649.1229
Point 24	440.39668	649.1239
Point 25	429.54704	649.1174
Point 26	425.1771	649.1104
Point 27	422.72062	649.0876
Point 28	419.51694	649.089
Point 29	417.40666	649.072
Point 30	414.03007	649.0786
Point 31	411.0988	649.0585
Point 32	405.22983	649.0813
Point 33	390.67981	648.9569

Point 34	372.93156	649.1925
Point 35	361.48377	649.3536
Point 36	347.97674	649.5625
Point 37	345.4121	649.595
Point 38	334.44	649.713
Point 39	329.03159	649.7712
Point 40	326.05577	649.8079
Point 41	323.36622	649.844
Point 42	320.67423	649.8778
Point 43	315.64527	649.9205
Point 44	315.05016	649.9228
Point 45	304.48331	649.9634
Point 46	304.18245	649.9655
Point 47	303.91306	649.9678
Point 48	289.7402	650.0008
Point 49	286.04752	650.1426
Point 50	275.87032	650.1308
Point 51	275.68718	650.1467
Point 52	252.33972	651.0708
Point 53	250.94149	651.1413
Point 54	249.61047	651.3034
Point 55	247.81262	651.5924
Point 56	243.06874	652.4655
Point 57	235.69178	653.9221
Point 58	212.39077	655.8256
Point 59	207.17314	657.5836
Point 60	204.28213	658.0709
Point 61	197.46189	660.0008
Point 62	192.80663	660.6529
Point 63	185.53317	660.9307
Point 64	184.03956	660.9749
Point 65	173.13572	660.4524
Point 66	166.60252	660.1628
Point 67	164.93059	660.0008
Point 68	157.55079	659.1082
Point 69	156.96739	659.2087
Point 70	150.09613	658.5439
Point 71	144.22778	658.0809
Point 72	143.43809	658.218
Point 73	136.29536	659.5715
Point 74	124.16845	659.2793
Point 75	120.06523	659.2642
Point 76	101.1411	659.0708
Point 77	96.93915	658.9887
Point 78	75.53524	659.6735
Point 79	71.54497	659.7824
Point 80	63.91382	660.0008
Point 81	56.69252	660.2908
Point 82	56.25338	660.3097
Point 83	51.5101	660.1655
Point 84	47.91942	660.0008
Point 85	43.57514	659.9731

Point 86	37.25178	659.9476
Point 87	15.88238	659.809
Point 88	15.38216	659.8061
Point 89	15.26928	659.805
Point 90	-4.33215	659.8763
Point 91	-13.95702	659.8807
Point 92	-16.84171	659.8919
Point 93	-27.54675	659.8822
Point 94	-43.26967	659.9473
Point 95	-48.10755	659.9678
Point 96	-49.16786	659.9719
Point 97	-51.29902	659.9759
Point 98	-56.91536	659.9813
Point 99	-57.36383	659.9822
Point 100	-71.72542	659.9943
Point 101	-72.27759	659.9953
Point 102	-72.71754	659.9959
Point 103	-77.51457	660.0008
Point 104	-80.12556	660.3701
Point 105	-80.43329	660.3826
Point 106	-91.20495	662.1665
Point 107	-93.86835	661.9907
Point 108	-102.02052	663.332
Point 109	-104.44391	663.1704
Point 110	-108.27329	663.0626
Point 111	-119.27774	663.9084
Point 112	-125.59455	664.34
Point 113	-200	666.4545
Point 114	334.44	651.7132
Point 115	345.43553	651.5948
Point 116	348.00486	651.5623
Point 117	361.51331	651.3534
Point 118	372.9581	651.1923
Point 119	390.68453	650.957
Point 120	405.22518	651.0814
Point 121	411.09583	651.0585
Point 122	414.02518	651.0786
Point 123	417.40055	651.072
Point 124	419.5093	651.089
Point 125	422.71179	651.0876
Point 126	425.16623	651.1104
Point 127	429.54584	651.1174
Point 128	440.39696	651.1239
Point 129	447.91152	651.1229
Point 130	458.02619	651.3274
Point 131	493.24762	648.4349
Point 132	524.74647	647.969
Point 133	113.86	761.07
Point 134	134.63	769.93
Point 135	154.09	770.57
Point 136	163.11	768.22
Point 137	207.12	750.72

Point 138	234.33	738.92
Point 139	262.34	726.92
Point 140	280.84	719.98
Point 141	283.41	718.87
Point 142	286.3	719.93
Point 143	297.84	720.24
Point 144	344.96	699.81
Point 145	383.68	684.74
Point 146	417.44	669.6
Point 147	420.54	668.04
Point 148	423.33	669.22
Point 149	443.74	670.61
Point 150	487.96	653.7
Point 151	-200	750.95
Point 152	95.2232	750.95
Point 153	163.0634	744.33
Point 154	434.9039	663.1
Point 155	650	600
Point 156	650	626.2916
Point 157	650	628.5629
Point 158	650	645.759
Point 159	260.0928	709.5
Point 160	382.6296	682.42

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.46	(321.169, 921.429)	169.5923	(109.309, 758.599)	(439.982, 670.354)
2	335	1.50	(321.169, 921.429)	276.505	(101.037, 754.107)	(436.478, 670.115)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	111.58435	755.26	-339.8782	271.74169	235.33193	6.9296e-006
2	Optimized	119.64515	743.43395	125.80386	1262.3223	816.00979	111
3	Optimized	130.03015	728.9311	650.66632	2790.4093	1223.955	367
4	Optimized	140.07135	715.7998	1084.5692	4000.1965	1457.8104	547
5	Optimized	149.80135	704.44105	1437.403	5568.0199	1148.3169	1324
6	Optimized	158.6	695.73635	1689.2741	6284.9289	946.69648	1648
7	Optimized	165.48665	688.92325	1885.4834	6732.9719	998.57378	1648
8	Optimized	172.90545	683.21735	2033.1332	7940.4145	354.43374	2414
9	Optimized	182.9898	676.50805	2193.3829	8227.1469	11.205949	2762.9
10	Optimized	192.804	670.88985	2313.4816	9069.7036	12.546524	2762.9
11	Optimized	202.348	666.3627	2403.4156	9150.9282	12.53035	2762.9
12	Optimized	210.69505	662.4033	2498.7057	9207.7066	12.458832	2762.9
13	Optimized	219.1113	659.2117	2573.5983	9773.7728	13.372214	2762.9
14	Optimized	228.7937	656.2201	2615.3388	9635.0328	13.037025	2762.9
15	Optimized	233.98245	654.64905	2635.0813	9916.5675	13.521956	2762.9
16	Optimized	241.97025	652.91915	2642.7737	9718.1208	13.139149	2762.9
17	Optimized	250.276	651.12035	2643.9245	9512.6065	303.5926	2616
18	Optimized	251.6406	650.8248	2642.4445	9478.9413	302.17003	2616
19	Optimized	257.33985	649.5905	2646.1769	9338.6317	295.80343	2616

20	Optimized	267.56625	647.37575	2653.0675	9118.9261	285.78799	2616
21	Optimized	274.23985	645.9982	2653.7771	9170.2749	288.02622	2616
22	Optimized	278.2636	645.3152	2645.734	9072.7552	284.07139	2616
23	Optimized	282.125	644.65975	2638.3306	8970.5159	279.87969	2616
24	Optimized	284.72875	644.21775	2633.5129	9015.239	282.06937	2616
25	Optimized	286.17375	643.9725	2630.8956	9107.2917	286.25374	2616
26	Optimized	288.0201	643.6591	2628.0668	9155.7052	288.51862	2616
27	Optimized	293.7901	642.67965	2620.6047	9291.1575	294.83537	2616
28	Optimized	300.55655	641.5311	2612.1501	9301.7584	295.67762	2616
29	Optimized	303.5931	641.0408	2606.8565	9519.9357	305.55493	2616
30	Optimized	304.0478	640.9993	2604.0044	9500.9321	304.84105	2616
31	Optimized	309.61635	640.4909	2571.727	9270.6797	296.09064	2616
32	Optimized	315.34775	639.96765	2540.5599	9034.3663	287.02327	2616
33	Optimized	317.44775	639.77595	2529.2887	8947.7338	283.69233	2616
34	Optimized	319.9622	639.61735	2511.3581	9237.478	297.29141	2616
35	Optimized	322.0202	639.6346	2487.5143	9124.5262	293.35288	2616
36	Optimized	324.711	639.6572	2456.3465	8977.0211	288.21083	2616
37	Optimized	327.5437	639.68095	2423.3474	8821.7949	282.80845	2616
38	Optimized	331.7358	639.71605	2376.2157	8592.242	274.74552	2616
39	Optimized	336.4649	639.7557	2327.0646	8327.0123	265.19494	2616
40	Optimized	341.7249	640.20135	2247.5233	8478.8118	275.4201	2616
41	Optimized	345.18605	640.65995	2185.1484	8229.1163	267.14061	2616
42	Optimized	346.7085	640.8617	2157.7788	8127.1811	263.84484	2616
43	Optimized	351.9986	641.56265	2064.9851	7773.4191	252.31017	2616
44	Optimized	358.7528	642.7866	1926.4939	7743.3885	257.10407	2616
45	Optimized	365.80995	644.5628	1750.5297	7144.7611	238.42256	2616
46	Optimized	371.53235	646.01655	1607.1967	6692.9771	224.78916	2616
47	Optimized	378.31905	647.78905	1433.554	6102.9369	392.23035	2417
48	Optimized	387.06995	650.0746	1209.0766	5422.3213	3061.1014	0
49	Optimized	395.0762	652.16565	1025.5551	4374.2318	1419.8427	775
50	Optimized	403.88295	654.9068	816.66465	3663.1937	1423.2613	547
51	Optimized	412.26385	657.97775	593.95117	2521.5616	1245.2144	219
52	Optimized	416.94715	659.7403	468.37598	2033.0844	1010.7838	219
53	Optimized	418.99	660.6816	404.62949	1645.9406	891.24994	111
54	Optimized	421.935	662.03855	302.65752	1366.4739	763.81042	111
55	Optimized	427.49305	664.5995	122.66204	1101.1768	774.97748	37
56	Optimized	435.8192	668.4359	-143.34388	412.54589	357.27025	-5.1126e-006

Slices of Slip Surface: 335

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	335	107.44865	746.28365	106.21917	787.25172	539.37345	37
2	335	119.0525	732.8937	580.80352	2375.0769	1159.0802	219
3	335	129.4375	722.3269	927.2181	3777.3317	1425.0536	547
4	335	139.495	713.0844	1198.8725	4993.0943	1343.1573	1020
5	335	149.225	704.97755	1422.2174	5976.9667	938.27003	1648
6	335	158.6	697.8338	1606.7797	6769.4752	681.47853	2018
7	335	168.61125	690.9139	1774.3169	7327.8302	333.20785	2414
8	335	179.61375	683.99335	1932.9464	7802.6708	352.18034	2414
9	335	190.61625	677.7661	2065.8919	8200.4381	11.393122	2762.9
10	335	201.61875	672.17995	2178.2991	8524.3849	11.784887	2762.9
11	335	213.9225	666.67755	2284.8704	8769.4637	12.0421	2762.9

12	335	227.5275	661.36445	2396.7364	8921.1125	12.115978	2762.9
13	335	238.99835	657.46185	2458.7412	8979.0124	12.109493	2762.9
14	335	248.335	654.7337	2492.307	8972.9044	12.035811	2762.9
15	335	257.67165	652.35715	2496.6843	8921.5994	11.931276	2762.9
16	335	264.03115	650.8983	2485.6439	8876.1838	11.868555	2762.9
17	335	270.70475	649.61605	2474.9413	8831.9015	280.97473	2616
18	335	278.2636	648.2863	2461.2711	8763.6052	278.56028	2616
19	335	282.125	647.69835	2449.9502	8708.3573	276.61873	2616
20	335	284.72875	647.33975	2439.9713	8780.3037	280.23979	2616
21	335	286.17375	647.1483	2434.0069	8887.4728	285.24023	2616
22	335	288.0201	646.92445	2425.5503	8952.1709	288.47364	2616
23	335	293.7901	646.3137	2395.0188	9128.7132	297.62621	2616
24	335	301.16165	645.6697	2348.0758	9154.0426	300.82061	2616
25	335	309.76675	645.2106	2277.5474	8880.421	291.84398	2616
26	335	315.34775	644.9862	2228.8418	8691.2564	285.63577	2616
27	335	318.15975	644.95255	2199.3304	8585.3619	282.25967	2616
28	335	322.0202	644.92935	2157.6128	8436.0976	277.50615	2616
29	335	324.711	644.9507	2126.2777	8326.7312	274.0572	2616
30	335	327.5437	645.00225	2091.5061	8207.6563	270.33104	2616
31	335	331.7358	645.14	2035.8941	8022.1877	264.59143	2616
32	335	339.7	645.59675	1930.0607	7635.4528	252.17572	2616
33	335	345.18605	645.96985	1854.9846	7364.0123	243.4965	2616
34	335	346.7085	646.10985	1831.9891	7291.7799	241.32025	2616
35	335	354.74435	647.0548	1698.3751	6881.7957	229.10481	2616
36	335	365.6463	648.55795	1503.2715	6285.6427	401.72142	2417
37	335	371.38345	649.5272	1390.0026	6130.1878	3443.9461	0
38	335	376.1373	650.46295	1287.4001	5792.7996	3273.3643	0
39	335	381.49825	651.5957	1177.4086	5188.4704	1115.0804	1324
40	335	389.30665	653.5145	1023.8925	4527.7254	1240.3594	1020
41	335	400.56	656.63245	776.295	3425.8749	1324.787	547
42	335	411.81335	660.27235	495.87387	2114.4402	1045.5754	219
43	335	418.99	662.8116	293.1588	1115.5742	651.34776	37
44	335	421.935	663.9438	204.26977	902.22487	552.776	37
45	335	429.90395	667.30255	-47.957122	554.9371	439.50666	37

Seepage Analysis - Pool from 100-yr Storm Event Condition

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 162
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 2:11:24 PM
File Name: AD 10+00 100 Year.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 10+00\
Last Solved Date: 9/13/2010
Last Solved Time: 2:11:48 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Mass(M) Units: lbs
Mass Flux Units: lbs/sec
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Seepage Analysis - Pool from 100-yr Storm Event Condition

Description: Ash Dike Section Sta. 10+00 Pool from 100-yr Storm Event = 751.4
Kind: SEEP/W
Method: Steady-State
Settings
    Include Air Flow: No
Control
    Apply Runoff: Yes
Convergence
    Convergence Type: Gauss Point K
    Convergence Settings
        Maximum Number of Iterations: 500
        Tolerance: 0.01
        Maximum Change in K: 0.1
        Rate of Change in K: 1.02
        Minimum Change in K: 0.0001
    Equation Solver: Parallel Direct
    Potential Seepage Max # of Reviews: 10
Time

Starting Time: 0 sec
Duration: 0 sec
Ending Time: 0 sec

Materials

Embankment Fill - Ash Dike

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-6
K-Ratio: 0.1
K-Direction: 0 °

Blanket Drain

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

Residuum

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

PWR

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

Rock

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

Boundary Conditions

Water Elevation = 751.4

Type: Head (H) 751.4

Potential Seepage Face

Review: true
Type: Total Flux (Q) 0

Zero Pressure

Type: Pressure Head 0

K Functions

1e-4

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-006
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-006)
Data Point: (10000, 3.28e-006)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-5

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-007
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-007)
Data Point: (10000, 3.28e-007)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-6

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-008
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-008)
Data Point: (10000, 3.28e-008)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20

Residual Water Content: 0 ft^3/ft^3

Regions

	Material	Points	Area (ft^2)
Region 1	Rock	1,2,3,4,5,6	22678.912
Region 2	PWR	7,8,9,10,11,12,13,14,15,16,17,18,1,6,5,4	7884.8849
Region 3	Residuum	7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113	11257.694
Region 4	Blanket Drain	20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132	395.05906
Region 5	Embankment Fill - Ash Dike	101,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,132,131,130,129,128,127,126,125,124,123,122,121,120,119,118,117,116,115,114,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100	32814.463
Region 6	Residuum	19,18,157,158	1719.61
Region 7	PWR	18,1,156,157	227.13
Region 8	Rock	156,155,2,1	2629.16

Lines

	Start Point	End Point	Hydraulic Boundary
Line 1	1	2	
Line 2	2	3	
Line 3	3	4	Water Elevation = 751.4
Line 4	4	5	
Line 5	5	6	
Line 6	6	1	
Line 7	7	8	
Line 8	8	9	
Line 9	9	10	
Line 10	10	11	
Line 11	11	12	
Line 12	12	13	
Line 13	13	14	
Line 14	14	15	
Line 15	15	16	
Line 16	16	17	
Line 17	17	18	
Line 18	18	1	
Line 19	4	7	Water Elevation = 751.4
Line 20	18	19	
Line 21	19	20	Potential Seepage Face
Line 22	20	21	
Line 23	21	22	
Line 24	22	23	
Line 25	23	24	
Line 26	24	25	
Line 27	25	26	

Line 28	26	27	
Line 29	27	28	
Line 30	28	29	
Line 31	29	30	
Line 32	30	31	
Line 33	31	32	
Line 34	32	33	
Line 35	33	34	
Line 36	34	35	
Line 37	35	36	
Line 38	36	37	
Line 39	37	38	
Line 40	38	39	
Line 41	39	40	
Line 42	40	41	
Line 43	41	42	
Line 44	42	43	
Line 45	43	44	
Line 46	44	45	
Line 47	45	46	
Line 48	46	47	
Line 49	47	48	
Line 50	48	49	
Line 51	49	50	
Line 52	50	51	
Line 53	51	52	
Line 54	52	53	
Line 55	53	54	
Line 56	54	55	
Line 57	55	56	
Line 58	56	57	
Line 59	57	58	
Line 60	58	59	
Line 61	59	60	
Line 62	60	61	
Line 63	61	62	
Line 64	62	63	
Line 65	63	64	
Line 66	64	65	
Line 67	65	66	
Line 68	66	67	
Line 69	67	68	
Line 70	68	69	
Line 71	69	70	
Line 72	70	71	
Line 73	71	72	
Line 74	72	73	
Line 75	73	74	
Line 76	74	75	
Line 77	75	76	
Line 78	76	77	
Line 79	77	78	

Line 80	78	79	
Line 81	79	80	
Line 82	80	81	
Line 83	81	82	
Line 84	82	83	
Line 85	83	84	
Line 86	84	85	
Line 87	85	86	
Line 88	86	87	
Line 89	87	88	
Line 90	88	89	
Line 91	89	90	
Line 92	90	91	
Line 93	91	92	
Line 94	92	93	
Line 95	93	94	
Line 96	94	95	
Line 97	95	96	
Line 98	96	97	
Line 99	97	98	
Line 100	98	99	
Line 101	99	100	
Line 102	100	101	
Line 103	101	102	
Line 104	102	103	Water Elevation = 751.4
Line 105	103	104	Water Elevation = 751.4
Line 106	104	105	Water Elevation = 751.4
Line 107	105	106	Water Elevation = 751.4
Line 108	106	107	Water Elevation = 751.4
Line 109	107	108	Water Elevation = 751.4
Line 110	108	109	Water Elevation = 751.4
Line 111	109	110	Water Elevation = 751.4
Line 112	110	111	Water Elevation = 751.4
Line 113	111	112	Water Elevation = 751.4
Line 114	112	113	Water Elevation = 751.4
Line 115	113	7	Water Elevation = 751.4
Line 116	38	114	
Line 117	114	115	
Line 118	115	116	
Line 119	116	117	
Line 120	117	118	
Line 121	118	119	
Line 122	119	120	
Line 123	120	121	
Line 124	121	122	
Line 125	122	123	
Line 126	123	124	
Line 127	124	125	
Line 128	125	126	
Line 129	126	127	
Line 130	127	128	
Line 131	128	129	

Line 132	129	130	
Line 133	130	131	
Line 134	131	132	
Line 135	132	20	Potential Seepage Face
Line 136	101	133	Water Elevation = 751.4
Line 137	133	134	Water Elevation = 751.4
Line 138	134	135	
Line 139	135	136	
Line 140	136	137	
Line 141	137	138	
Line 142	138	139	
Line 143	139	140	
Line 144	140	141	Potential Seepage Face
Line 145	141	142	Potential Seepage Face
Line 146	142	143	Potential Seepage Face
Line 147	143	144	Potential Seepage Face
Line 148	144	145	Potential Seepage Face
Line 149	145	146	Potential Seepage Face
Line 150	146	147	Potential Seepage Face
Line 151	147	148	Potential Seepage Face
Line 152	148	149	Potential Seepage Face
Line 153	149	150	Potential Seepage Face
Line 154	150	132	Potential Seepage Face
Line 155	152	153	
Line 156	154	150	
Line 157	18	157	
Line 158	157	158	
Line 159	158	19	Potential Seepage Face
Line 160	1	156	
Line 161	156	157	
Line 162	156	155	
Line 163	155	2	
Line 164	153	159	
Line 165	159	160	Zero Pressure
Line 166	160	147	
Line 167	147	154	

Points

	X (ft)	Y (ft)
Point 1	550	626.2916
Point 2	550	600
Point 3	-200	600
Point 4	-200	631.2263
Point 5	435.77054	629.9876
Point 6	438.77054	629.9876
Point 7	-200	648.4542
Point 8	115.92382	645.6152
Point 9	153.92041	645.3586
Point 10	259.22799	638.5324
Point 11	264.65748	638.2309
Point 12	370.34779	631.7877

Point 13	419.11319	632.9682
Point 14	422.11319	632.9682
Point 15	435.77054	632.1976
Point 16	438.77054	632.1976
Point 17	505.53902	630.9464
Point 18	550	628.5629
Point 19	550	645.759
Point 20	538.93239	645.759
Point 21	493.15087	646.4361
Point 22	457.9644	649.3258
Point 23	447.9316	649.1229
Point 24	440.39668	649.1239
Point 25	429.54704	649.1174
Point 26	425.1771	649.1104
Point 27	422.72062	649.0876
Point 28	419.51694	649.089
Point 29	417.40666	649.072
Point 30	414.03007	649.0786
Point 31	411.0988	649.0585
Point 32	405.22983	649.0813
Point 33	390.67981	648.9569
Point 34	372.93156	649.1925
Point 35	361.48377	649.3536
Point 36	347.97674	649.5625
Point 37	345.4121	649.595
Point 38	334.44	649.713
Point 39	329.03159	649.7712
Point 40	326.05577	649.8079
Point 41	323.36622	649.844
Point 42	320.67423	649.8778
Point 43	315.64527	649.9205
Point 44	315.05016	649.9228
Point 45	304.48331	649.9634
Point 46	304.18245	649.9655
Point 47	303.91306	649.9678
Point 48	289.7402	650.0008
Point 49	286.04752	650.1426
Point 50	275.87032	650.1308
Point 51	275.68718	650.1467
Point 52	252.33972	651.0708
Point 53	250.94149	651.1413
Point 54	249.61047	651.3034
Point 55	247.81262	651.5924
Point 56	243.06874	652.4655
Point 57	235.69178	653.9221
Point 58	212.39077	655.8256
Point 59	207.17314	657.5836
Point 60	204.28213	658.0709
Point 61	197.46189	660.0008
Point 62	192.80663	660.6529
Point 63	185.53317	660.9307
Point 64	184.03956	660.9749

Point 65	173.13572	660.4524
Point 66	166.60252	660.1628
Point 67	164.93059	660.0008
Point 68	157.55079	659.1082
Point 69	156.96739	659.2087
Point 70	150.09613	658.5439
Point 71	144.22778	658.0809
Point 72	143.43809	658.218
Point 73	136.29536	659.5715
Point 74	124.16845	659.2793
Point 75	120.06523	659.2642
Point 76	101.1411	659.0708
Point 77	96.93915	658.9887
Point 78	75.53524	659.6735
Point 79	71.54497	659.7824
Point 80	63.91382	660.0008
Point 81	56.69252	660.2908
Point 82	56.25338	660.3097
Point 83	51.5101	660.1655
Point 84	47.91942	660.0008
Point 85	43.57514	659.9731
Point 86	37.25178	659.9476
Point 87	15.88238	659.809
Point 88	15.38216	659.8061
Point 89	15.26928	659.805
Point 90	-4.33215	659.8763
Point 91	-13.95702	659.8807
Point 92	-16.84171	659.8919
Point 93	-27.54675	659.8822
Point 94	-43.26967	659.9473
Point 95	-48.10755	659.9678
Point 96	-49.16786	659.9719
Point 97	-51.29902	659.9759
Point 98	-56.91536	659.9813
Point 99	-57.36383	659.9822
Point 100	-71.72542	659.9943
Point 101	-72.27759	659.9953
Point 102	-72.71754	659.9959
Point 103	-77.51457	660.0008
Point 104	-80.12556	660.3701
Point 105	-80.43329	660.3826
Point 106	-91.20495	662.1665
Point 107	-93.86835	661.9907
Point 108	-102.02052	663.332
Point 109	-104.44391	663.1704
Point 110	-108.27329	663.0626
Point 111	-119.27774	663.9084
Point 112	-125.59455	664.34
Point 113	-200	666.4545
Point 114	334.44	651.7132
Point 115	345.43553	651.5948
Point 116	348.00486	651.5623

Point 117	361.51331	651.3534
Point 118	372.9581	651.1923
Point 119	390.68453	650.957
Point 120	405.22518	651.0814
Point 121	411.09583	651.0585
Point 122	414.02518	651.0786
Point 123	417.40055	651.072
Point 124	419.5093	651.089
Point 125	422.71179	651.0876
Point 126	425.16623	651.1104
Point 127	429.54584	651.1174
Point 128	440.39696	651.1239
Point 129	447.91152	651.1229
Point 130	458.02619	651.3274
Point 131	493.24762	648.4349
Point 132	524.74647	647.969
Point 133	113.86	761.07
Point 134	134.63	769.93
Point 135	154.09	770.57
Point 136	163.11	768.22
Point 137	207.12	750.72
Point 138	234.33	738.92
Point 139	262.34	726.92
Point 140	280.84	719.98
Point 141	283.41	718.87
Point 142	286.3	719.93
Point 143	297.84	720.24
Point 144	344.96	699.81
Point 145	383.68	684.74
Point 146	417.44	669.6
Point 147	420.54	668.04
Point 148	423.33	669.22
Point 149	443.74	670.61
Point 150	487.96	653.7
Point 151	-200	750.95
Point 152	95.2232	750.95
Point 153	163.0634	744.33
Point 154	434.9039	663.1
Point 155	650	600
Point 156	650	626.2916
Point 157	650	628.5629
Point 158	650	645.759
Point 159	260.0928	709.5
Point 160	382.6296	682.42

Pool from 100-yr Storm Event Condition Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 162
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 2:11:24 PM
File Name: AD 10+00 100 Year.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 10+00\
Last Solved Date: 9/13/2010
Last Solved Time: 2:13:32 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Pool from 100-yr Storm Event Condition Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 10+00 Pool from 100-yr Storm Event = 751.4
Kind: SLOPE/W
Parent: Seepage Analysis - Pool from 100-yr Storm Event Condition
Method: Spencer
Settings
    PWP Conditions Source: Parent Analysis
Slip Surface
    Direction of movement: Left to Right
    Use Passive Mode: No
    Slip Surface Option: Auto-Search
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: Yes
    Tension Crack
        Tension Crack Option: (none)
FOS Distribution
    FOS Calculation Option: Constant
Advanced
    Number of Slices: 30
    Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 3 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Shear/Normal Fn.
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Strength Function: Ash Dike Fill
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Shear/Normal Fn.
Unit Weight: 124 pcf
Strength Function: Ash Dike Res
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Rock

Model: Bedrock (Impenetrable)

Slip Surface Limits

Left Coordinate: (-200, 666.4545) ft
Right Coordinate: (650, 645.759) ft

Shear/Normal Strength Functions

Ash Dike Fill

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress

Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 433)
Data Point: (1000, 829)
Data Point: (1500, 1188)
Data Point: (2000, 1511)
Data Point: (2500, 1797)
Data Point: (3000, 2047)
Data Point: (3500, 2259)
Data Point: (4000, 2436)
Data Point: (4500, 2575)
Data Point: (5000, 2678)
Data Point: (5500, 2744)
Data Point: (6000, 2774)
Data Point: (20000, 2800)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Ash Dike Res

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 526)
Data Point: (1000, 999)
Data Point: (1500, 1417)
Data Point: (2000, 1781)
Data Point: (2500, 2092)
Data Point: (3000, 2349)
Data Point: (3500, 2552)
Data Point: (4000, 2700)
Data Point: (4500, 2795)
Data Point: (5000, 2837)
Data Point: (20000, 3500)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6	22678.912
Region 2	PWR	7,8,9,10,11,12,13,14,15,16,17,18,1,6,5,4	7884.8849
Region 3	Residuum	7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113	11257.694
Region 4	Blanket Drain	20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132	395.05906
Region 5	Embankment Fill - Ash Dike	101,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,132,131,130,129,128,127,126,125,124,123,122,121,120,119,118,117,116,115,114,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100	32814.463
Region 6	Residuum	19,18,157,158	1719.61
Region 7	PWR	18,1,156,157	227.13
Region 8	Rock	156,155,2,1	2629.16

Points

	X (ft)	Y (ft)
Point 1	550	626.2916
Point 2	550	600
Point 3	-200	600
Point 4	-200	631.2263
Point 5	435.77054	629.9876
Point 6	438.77054	629.9876
Point 7	-200	648.4542
Point 8	115.92382	645.6152
Point 9	153.92041	645.3586
Point 10	259.22799	638.5324
Point 11	264.65748	638.2309
Point 12	370.34779	631.7877
Point 13	419.11319	632.9682
Point 14	422.11319	632.9682
Point 15	435.77054	632.1976
Point 16	438.77054	632.1976
Point 17	505.53902	630.9464
Point 18	550	628.5629
Point 19	550	645.759
Point 20	538.93239	645.759
Point 21	493.15087	646.4361
Point 22	457.9644	649.3258
Point 23	447.9316	649.1229
Point 24	440.39668	649.1239
Point 25	429.54704	649.1174
Point 26	425.1771	649.1104
Point 27	422.72062	649.0876
Point 28	419.51694	649.089
Point 29	417.40666	649.072
Point 30	414.03007	649.0786

Point 31	411.0988	649.0585
Point 32	405.22983	649.0813
Point 33	390.67981	648.9569
Point 34	372.93156	649.1925
Point 35	361.48377	649.3536
Point 36	347.97674	649.5625
Point 37	345.4121	649.595
Point 38	334.44	649.713
Point 39	329.03159	649.7712
Point 40	326.05577	649.8079
Point 41	323.36622	649.844
Point 42	320.67423	649.8778
Point 43	315.64527	649.9205
Point 44	315.05016	649.9228
Point 45	304.48331	649.9634
Point 46	304.18245	649.9655
Point 47	303.91306	649.9678
Point 48	289.7402	650.0008
Point 49	286.04752	650.1426
Point 50	275.87032	650.1308
Point 51	275.68718	650.1467
Point 52	252.33972	651.0708
Point 53	250.94149	651.1413
Point 54	249.61047	651.3034
Point 55	247.81262	651.5924
Point 56	243.06874	652.4655
Point 57	235.69178	653.9221
Point 58	212.39077	655.8256
Point 59	207.17314	657.5836
Point 60	204.28213	658.0709
Point 61	197.46189	660.0008
Point 62	192.80663	660.6529
Point 63	185.53317	660.9307
Point 64	184.03956	660.9749
Point 65	173.13572	660.4524
Point 66	166.60252	660.1628
Point 67	164.93059	660.0008
Point 68	157.55079	659.1082
Point 69	156.96739	659.2087
Point 70	150.09613	658.5439
Point 71	144.22778	658.0809
Point 72	143.43809	658.218
Point 73	136.29536	659.5715
Point 74	124.16845	659.2793
Point 75	120.06523	659.2642
Point 76	101.1411	659.0708
Point 77	96.93915	658.9887
Point 78	75.53524	659.6735
Point 79	71.54497	659.7824
Point 80	63.91382	660.0008
Point 81	56.69252	660.2908
Point 82	56.25338	660.3097

Point 83	51.5101	660.1655
Point 84	47.91942	660.0008
Point 85	43.57514	659.9731
Point 86	37.25178	659.9476
Point 87	15.88238	659.809
Point 88	15.38216	659.8061
Point 89	15.26928	659.805
Point 90	-4.33215	659.8763
Point 91	-13.95702	659.8807
Point 92	-16.84171	659.8919
Point 93	-27.54675	659.8822
Point 94	-43.26967	659.9473
Point 95	-48.10755	659.9678
Point 96	-49.16786	659.9719
Point 97	-51.29902	659.9759
Point 98	-56.91536	659.9813
Point 99	-57.36383	659.9822
Point 100	-71.72542	659.9943
Point 101	-72.27759	659.9953
Point 102	-72.71754	659.9959
Point 103	-77.51457	660.0008
Point 104	-80.12556	660.3701
Point 105	-80.43329	660.3826
Point 106	-91.20495	662.1665
Point 107	-93.86835	661.9907
Point 108	-102.02052	663.332
Point 109	-104.44391	663.1704
Point 110	-108.27329	663.0626
Point 111	-119.27774	663.9084
Point 112	-125.59455	664.34
Point 113	-200	666.4545
Point 114	334.44	651.7132
Point 115	345.43553	651.5948
Point 116	348.00486	651.5623
Point 117	361.51331	651.3534
Point 118	372.9581	651.1923
Point 119	390.68453	650.957
Point 120	405.22518	651.0814
Point 121	411.09583	651.0585
Point 122	414.02518	651.0786
Point 123	417.40055	651.072
Point 124	419.5093	651.089
Point 125	422.71179	651.0876
Point 126	425.16623	651.1104
Point 127	429.54584	651.1174
Point 128	440.39696	651.1239
Point 129	447.91152	651.1229
Point 130	458.02619	651.3274
Point 131	493.24762	648.4349
Point 132	524.74647	647.969
Point 133	113.86	761.07
Point 134	134.63	769.93

Point 135	154.09	770.57
Point 136	163.11	768.22
Point 137	207.12	750.72
Point 138	234.33	738.92
Point 139	262.34	726.92
Point 140	280.84	719.98
Point 141	283.41	718.87
Point 142	286.3	719.93
Point 143	297.84	720.24
Point 144	344.96	699.81
Point 145	383.68	684.74
Point 146	417.44	669.6
Point 147	420.54	668.04
Point 148	423.33	669.22
Point 149	443.74	670.61
Point 150	487.96	653.7
Point 151	-200	750.95
Point 152	95.2232	750.95
Point 153	163.0634	744.33
Point 154	434.9039	663.1
Point 155	650	600
Point 156	650	626.2916
Point 157	650	628.5629
Point 158	650	645.759
Point 159	260.0928	709.5
Point 160	382.6296	682.42

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.46	(321.169, 921.429)	169.308	(109.302, 758.595)	(439.982, 670.354)
2	335	1.49	(321.169, 921.429)	276.505	(101.037, 754.107)	(436.478, 670.115)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	111.58085	755.4358	-320.61185	269.61533	233.49048	-3.3599e-006
2	Optimized	119.72585	744.1463	120.04239	1254.7846	814.7345	111
3	Optimized	130.11085	730.09995	623.34398	2698.455	1186.9848	367
4	Optimized	139.7543	717.47605	1040.5314	3860.3969	1409.9296	547
5	Optimized	149.4843	706.06355	1394.2937	5345.6913	1398.7976	1020
6	Optimized	158.6	696.75245	1665.4684	6108.8115	1235.2552	1324
7	Optimized	165.2174	689.9932	1861.2878	6556.6658	967.2393	1648
8	Optimized	172.29505	684.3738	2008.6239	7738.0373	343.76175	2414
9	Optimized	182.2355	677.44015	2178.5121	8051.3278	352.36582	2414
10	Optimized	192.18425	671.48915	2310.1539	8938.9396	12.30987	2762.9
11	Optimized	202.1414	666.52085	2412.42	9050.282	12.327884	2762.9
12	Optimized	207.95315	663.621	2478.8813	9111.7494	12.317451	2762.9
13	Optimized	214.07235	661.4009	2533.2376	9647.232	13.21216	2762.9
14	Optimized	224.64445	657.79205	2597.8688	9535.3359	12.883102	2762.9
15	Optimized	232.13025	655.44395	2630.4728	9796.1444	13.306885	2762.9
16	Optimized	241.0713	653.2342	2648.2742	9605.9342	12.921815	2762.9

17	Optimized	248.71155	651.3459	2664.388	9443.585	299.6374	2616
18	Optimized	250.276	650.95925	2665.7321	9410.9118	298.13385	2616
19	Optimized	251.6406	650.622	2666.9425	9382.0667	296.80541	2616
20	Optimized	257.33985	649.2134	2681.0547	9262.9284	290.9158	2616
21	Optimized	267.9887	646.58155	2707.7494	9075.0979	281.43389	2616
22	Optimized	274.6623	645.01715	2719.88	9291.2464	290.45138	2616
23	Optimized	278.2636	644.42565	2711.2934	9201.3155	286.856	2616
24	Optimized	282.125	643.79145	2702.3519	9096.7907	282.63126	2616
25	Optimized	284.72875	643.3638	2696.5124	9139.274	284.76711	2616
26	Optimized	286.17375	643.12645	2693.3174	9230.7247	288.95041	2616
27	Optimized	287.28875	642.9433	2691.1314	9261.3523	290.40075	2616
28	Optimized	289.00885	642.6823	2686.8206	9415.8986	297.42216	2616
29	Optimized	293.7901	642.03755	2670.0974	9509.1098	302.28121	2616
30	Optimized	301.16165	641.0435	2644.4639	9469.7676	301.67529	2616
31	Optimized	309.0811	639.9756	2618.4313	9187.8962	290.36734	2616
32	Optimized	314.36455	639.3522	2598.273	9518.2741	305.86088	2616
33	Optimized	315.34775	639.3473	2587.7247	9466.0314	304.018	2616
34	Optimized	318.15975	639.33325	2557.3556	9317.1179	298.7784	2616
35	Optimized	322.0202	639.314	2515.6546	9112.8493	291.59298	2616
36	Optimized	324.711	639.3006	2486.5936	8970.1638	286.57083	2616
37	Optimized	327.5437	639.28645	2455.864	8820.3163	281.30588	2616
38	Optimized	331.7358	639.2655	2412.1393	8598.1691	273.41968	2616
39	Optimized	335.2856	639.2478	2378.0903	8404.529	266.36583	2616
40	Optimized	340.5456	639.89715	2285.4835	8653.084	281.44502	2616
41	Optimized	345.18605	640.5842	2197.0208	8306.9309	270.05523	2616
42	Optimized	346.7085	640.8096	2168.0856	8201.7625	266.68576	2616
43	Optimized	352.47015	641.6626	2061.2824	7803.0544	253.78369	2616
44	Optimized	359.22435	642.90075	1921.5853	7712.5211	255.95671	2616
45	Optimized	365.81	644.561	1757.005	7153.1577	238.50748	2616
46	Optimized	371.5324	646.01655	1613.2967	6699.5332	224.80932	2616
47	Optimized	378.31905	647.7891	1439.417	6109.2426	392.26754	2417
48	Optimized	387.0698	650.07465	1214.5743	5428.8708	3061.8657	0
49	Optimized	395.07595	652.1657	1030.5118	4378.9625	1419.7469	775
50	Optimized	403.88275	654.90685	820.73958	3668.4453	1423.8497	547
51	Optimized	412.2637	657.97775	597.08586	2525.2491	1245.5715	219
52	Optimized	416.9471	659.7403	471.04694	2036.8303	1011.4782	219
53	Optimized	418.99	660.6816	407.06143	1648.8713	891.60807	111
54	Optimized	421.935	662.03855	304.56522	1369.1112	764.33422	111
55	Optimized	427.49305	664.5995	123.88385	1103.7956	776.08389	37
56	Optimized	435.8192	668.4359	-142.22045	414.10607	358.62138	-5.1316e-006

Slices of Slip Surface: 335

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	335	107.44865	746.28365	132.7443	794.61707	524.19902	37
2	335	119.0525	732.8937	604.48861	2379.4777	1146.6227	219
3	335	129.4375	722.3269	948.51193	3779.4819	1415.4818	547
4	335	139.495	713.0844	1218.1604	4993.5591	1336.4939	1020
5	335	149.225	704.97755	1439.6803	5976.162	934.50694	1648
6	335	158.6	697.8338	1623.0098	6768.2199	679.17044	2018
7	335	168.61125	690.9139	1789.3239	7326.2386	332.21193	2414
8	335	179.61375	683.99335	1947.1547	7801.1095	351.23418	2414

9	335	190.61625	677.7661	2079.4311	8198.8358	11.365001	2762.9
10	335	201.61875	672.17995	2191.411	8522.7459	11.757494	2762.9
11	335	213.9225	666.67755	2297.674	8768.7863	12.018195	2762.9
12	335	227.5275	661.36445	2409.1845	8920.4209	12.091577	2762.9
13	335	238.99835	657.46185	2470.9107	8978.3988	12.085752	2762.9
14	335	248.335	654.7337	2504.0856	8972.4911	12.012039	2762.9
15	335	257.67165	652.35715	2508.0466	8921.4951	11.909982	2762.9
16	335	264.03115	650.8983	2496.81	8876.1838	11.847818	2762.9
17	335	270.70475	649.61605	2485.7945	8832.0989	280.50374	2616
18	335	278.2636	648.2863	2471.6239	8763.9887	278.11964	2616
19	335	282.125	647.69835	2460.1196	8708.7425	276.18627	2616
20	335	284.72875	647.33975	2450.0062	8780.6796	279.81286	2616
21	335	286.17375	647.1483	2443.9863	8887.8656	284.81652	2616
22	335	288.0201	646.92445	2435.4488	8952.7481	288.06164	2616
23	335	293.7901	646.3137	2404.6013	9129.4503	297.23524	2616
24	335	301.16165	645.6697	2357.384	9154.7933	300.44237	2616
25	335	309.76675	645.2106	2286.3411	8881.3665	291.4971	2616
26	335	315.34775	644.9862	2237.2417	8692.4324	285.31647	2616
27	335	318.15975	644.95255	2207.6815	8586.5549	281.94328	2616
28	335	322.0202	644.92935	2165.8223	8437.5835	277.20897	2616
29	335	324.711	644.9507	2134.3081	8328.2183	273.76799	2616
30	335	327.5437	645.00225	2099.401	8209.0001	270.04148	2616
31	335	331.7358	645.14	2043.6541	8023.6658	264.31378	2616
32	335	339.7	645.59675	1937.4584	7637.0651	251.92	2616
33	335	345.18605	645.96985	1862.1461	7365.7752	243.25789	2616
34	335	346.7085	646.10985	1839.0939	7293.7001	241.09109	2616
35	335	354.74435	647.0548	1705.1501	6883.7103	228.88999	2616
36	335	365.6463	648.55795	1509.6734	6287.6581	401.35295	2417
37	335	371.38345	649.5272	1396.1228	6131.7491	3440.6339	0
38	335	376.1373	650.46295	1293.3342	5794.495	3270.2847	0
39	335	381.49825	651.5957	1183.0446	5190.2596	1114.011	1324
40	335	389.30665	653.5145	1028.8014	4529.2755	1484.205	775
41	335	400.56	656.63245	780.16792	3427.2368	1323.5315	547
42	335	411.81335	660.27235	498.54347	2115.1957	1044.339	219
43	335	418.99	662.8116	294.92084	1115.7251	650.07172	37
44	335	421.935	663.9438	205.61154	902.42514	551.87193	37
45	335	429.90395	667.30255	-47.031306	555.42658	439.89432	37

Seepage Analysis - Surcharge Pool Condition

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 163
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 2:21:41 PM
File Name: AD 10+00 Surcharge.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 10+00\
Last Solved Date: 9/13/2010
Last Solved Time: 2:21:46 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Mass(M) Units: lbs
Mass Flux Units: lbs/sec
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Seepage Analysis - Surcharge Pool Condition

Description: Ash Dike Section Sta. 10+00 Surcharge Pool = 760
Kind: SEEP/W
Method: Steady-State
Settings
    Include Air Flow: No
Control
    Apply Runoff: Yes
Convergence
    Convergence Type: Gauss Point K
    Convergence Settings
        Maximum Number of Iterations: 500
        Tolerance: 0.01
        Maximum Change in K: 0.1
        Rate of Change in K: 1.02
        Minimum Change in K: 0.0001
    Equation Solver: Parallel Direct
    Potential Seepage Max # of Reviews: 10
Time
    Starting Time: 0 sec
    Duration: 0 sec

Ending Time: 0 sec

Materials

Embankment Fill - Ash Dike

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-6
K-Ratio: 0.1
K-Direction: 0 °

Blanket Drain

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

Residuum

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

PWR

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

Rock

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

Boundary Conditions

Water Elevation = 760

Type: Head (H) 760

Potential Seepage Face

Review: true
Type: Total Flux (Q) 0

K Functions

1e-4

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-006
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-006)
Data Point: (10000, 3.28e-006)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-5

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-007
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-007)
Data Point: (10000, 3.28e-007)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-6

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-008
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-008)
Data Point: (10000, 3.28e-008)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6	22678.912
Region 2	PWR	7,8,9,10,11,12,13,14,15,16,17,18,1,6,5,4	7884.8849
Region 3	Residuum	7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35, 36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63, 64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91, 92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113	11257.694
Region 4	Blanket Drain	20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,114,115,116,117,118,119, 120,121,122,123,124,125,126,127,128,129,130,131,132	395.05906
Region 5	Embankment Fill - Ash Dike	101,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150, 132,131,130,129,128,127,126,125,124,123,122,121,120,119,118,117,116,115,114, 38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64, 65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91, 92,93,94,95,96,97,98,99,100	32814.463
Region 6	Residuum	19,18,157,158	1719.61
Region 7	PWR	18,1,156,157	227.13
Region 8	Rock	156,155,2,1	2629.16

Lines

	Start Point	End Point	Hydraulic Boundary
Line 1	1	2	
Line 2	2	3	
Line 3	3	4	Water Elevation = 760
Line 4	4	5	
Line 5	5	6	
Line 6	6	1	
Line 7	7	8	
Line 8	8	9	
Line 9	9	10	
Line 10	10	11	
Line 11	11	12	
Line 12	12	13	
Line 13	13	14	
Line 14	14	15	
Line 15	15	16	
Line 16	16	17	
Line 17	17	18	
Line 18	18	1	
Line 19	4	7	Water Elevation = 760
Line 20	18	19	
Line 21	19	20	Potential Seepage Face
Line 22	20	21	
Line 23	21	22	
Line 24	22	23	
Line 25	23	24	
Line 26	24	25	
Line 27	25	26	
Line 28	26	27	
Line 29	27	28	
Line 30	28	29	
Line 31	29	30	

Line 32	30	31	
Line 33	31	32	
Line 34	32	33	
Line 35	33	34	
Line 36	34	35	
Line 37	35	36	
Line 38	36	37	
Line 39	37	38	
Line 40	38	39	
Line 41	39	40	
Line 42	40	41	
Line 43	41	42	
Line 44	42	43	
Line 45	43	44	
Line 46	44	45	
Line 47	45	46	
Line 48	46	47	
Line 49	47	48	
Line 50	48	49	
Line 51	49	50	
Line 52	50	51	
Line 53	51	52	
Line 54	52	53	
Line 55	53	54	
Line 56	54	55	
Line 57	55	56	
Line 58	56	57	
Line 59	57	58	
Line 60	58	59	
Line 61	59	60	
Line 62	60	61	
Line 63	61	62	
Line 64	62	63	
Line 65	63	64	
Line 66	64	65	
Line 67	65	66	
Line 68	66	67	
Line 69	67	68	
Line 70	68	69	
Line 71	69	70	
Line 72	70	71	
Line 73	71	72	
Line 74	72	73	
Line 75	73	74	
Line 76	74	75	
Line 77	75	76	
Line 78	76	77	
Line 79	77	78	
Line 80	78	79	
Line 81	79	80	
Line 82	80	81	
Line 83	81	82	

Line 84	82	83	
Line 85	83	84	
Line 86	84	85	
Line 87	85	86	
Line 88	86	87	
Line 89	87	88	
Line 90	88	89	
Line 91	89	90	
Line 92	90	91	
Line 93	91	92	
Line 94	92	93	
Line 95	93	94	
Line 96	94	95	
Line 97	95	96	
Line 98	96	97	
Line 99	97	98	
Line 100	98	99	
Line 101	99	100	
Line 102	100	101	
Line 103	101	102	
Line 104	102	103	Water Elevation = 760
Line 105	103	104	Water Elevation = 760
Line 106	104	105	Water Elevation = 760
Line 107	105	106	Water Elevation = 760
Line 108	106	107	Water Elevation = 760
Line 109	107	108	Water Elevation = 760
Line 110	108	109	Water Elevation = 760
Line 111	109	110	Water Elevation = 760
Line 112	110	111	Water Elevation = 760
Line 113	111	112	Water Elevation = 760
Line 114	112	113	Water Elevation = 760
Line 115	113	7	Water Elevation = 760
Line 116	38	114	
Line 117	114	115	
Line 118	115	116	
Line 119	116	117	
Line 120	117	118	
Line 121	118	119	
Line 122	119	120	
Line 123	120	121	
Line 124	121	122	
Line 125	122	123	
Line 126	123	124	
Line 127	124	125	
Line 128	125	126	
Line 129	126	127	
Line 130	127	128	
Line 131	128	129	
Line 132	129	130	
Line 133	130	131	
Line 134	131	132	
Line 135	132	20	Potential Seepage Face

Line 136	101	133	Water Elevation = 760
Line 137	133	134	Water Elevation = 760
Line 138	134	135	
Line 139	135	136	
Line 140	136	137	
Line 141	137	138	
Line 142	138	139	
Line 143	139	140	
Line 144	140	141	Potential Seepage Face
Line 145	141	142	Potential Seepage Face
Line 146	142	143	Potential Seepage Face
Line 147	143	144	Potential Seepage Face
Line 148	144	145	Potential Seepage Face
Line 149	145	146	Potential Seepage Face
Line 150	146	147	Potential Seepage Face
Line 151	147	148	Potential Seepage Face
Line 152	148	149	Potential Seepage Face
Line 153	149	150	Potential Seepage Face
Line 154	150	132	Potential Seepage Face
Line 155	152	153	
Line 156	154	150	
Line 157	18	157	
Line 158	157	158	
Line 159	158	19	Potential Seepage Face
Line 160	1	156	
Line 161	156	157	
Line 162	156	155	
Line 163	155	2	
Line 164	153	159	
Line 165	159	160	
Line 166	160	147	
Line 167	147	154	

Points

	X (ft)	Y (ft)
Point 1	550	626.2916
Point 2	550	600
Point 3	-200	600
Point 4	-200	631.2263
Point 5	435.77054	629.9876
Point 6	438.77054	629.9876
Point 7	-200	648.4542
Point 8	115.92382	645.6152
Point 9	153.92041	645.3586
Point 10	259.22799	638.5324
Point 11	264.65748	638.2309
Point 12	370.34779	631.7877
Point 13	419.11319	632.9682
Point 14	422.11319	632.9682
Point 15	435.77054	632.1976
Point 16	438.77054	632.1976

Point 17	505.53902	630.9464
Point 18	550	628.5629
Point 19	550	645.759
Point 20	538.93239	645.759
Point 21	493.15087	646.4361
Point 22	457.9644	649.3258
Point 23	447.9316	649.1229
Point 24	440.39668	649.1239
Point 25	429.54704	649.1174
Point 26	425.1771	649.1104
Point 27	422.72062	649.0876
Point 28	419.51694	649.089
Point 29	417.40666	649.072
Point 30	414.03007	649.0786
Point 31	411.0988	649.0585
Point 32	405.22983	649.0813
Point 33	390.67981	648.9569
Point 34	372.93156	649.1925
Point 35	361.48377	649.3536
Point 36	347.97674	649.5625
Point 37	345.4121	649.595
Point 38	334.44	649.713
Point 39	329.03159	649.7712
Point 40	326.05577	649.8079
Point 41	323.36622	649.844
Point 42	320.67423	649.8778
Point 43	315.64527	649.9205
Point 44	315.05016	649.9228
Point 45	304.48331	649.9634
Point 46	304.18245	649.9655
Point 47	303.91306	649.9678
Point 48	289.7402	650.0008
Point 49	286.04752	650.1426
Point 50	275.87032	650.1308
Point 51	275.68718	650.1467
Point 52	252.33972	651.0708
Point 53	250.94149	651.1413
Point 54	249.61047	651.3034
Point 55	247.81262	651.5924
Point 56	243.06874	652.4655
Point 57	235.69178	653.9221
Point 58	212.39077	655.8256
Point 59	207.17314	657.5836
Point 60	204.28213	658.0709
Point 61	197.46189	660.0008
Point 62	192.80663	660.6529
Point 63	185.53317	660.9307
Point 64	184.03956	660.9749
Point 65	173.13572	660.4524
Point 66	166.60252	660.1628
Point 67	164.93059	660.0008
Point 68	157.55079	659.1082

Point 69	156.96739	659.2087
Point 70	150.09613	658.5439
Point 71	144.22778	658.0809
Point 72	143.43809	658.218
Point 73	136.29536	659.5715
Point 74	124.16845	659.2793
Point 75	120.06523	659.2642
Point 76	101.1411	659.0708
Point 77	96.93915	658.9887
Point 78	75.53524	659.6735
Point 79	71.54497	659.7824
Point 80	63.91382	660.0008
Point 81	56.69252	660.2908
Point 82	56.25338	660.3097
Point 83	51.5101	660.1655
Point 84	47.91942	660.0008
Point 85	43.57514	659.9731
Point 86	37.25178	659.9476
Point 87	15.88238	659.809
Point 88	15.38216	659.8061
Point 89	15.26928	659.805
Point 90	-4.33215	659.8763
Point 91	-13.95702	659.8807
Point 92	-16.84171	659.8919
Point 93	-27.54675	659.8822
Point 94	-43.26967	659.9473
Point 95	-48.10755	659.9678
Point 96	-49.16786	659.9719
Point 97	-51.29902	659.9759
Point 98	-56.91536	659.9813
Point 99	-57.36383	659.9822
Point 100	-71.72542	659.9943
Point 101	-72.27759	659.9953
Point 102	-72.71754	659.9959
Point 103	-77.51457	660.0008
Point 104	-80.12556	660.3701
Point 105	-80.43329	660.3826
Point 106	-91.20495	662.1665
Point 107	-93.86835	661.9907
Point 108	-102.02052	663.332
Point 109	-104.44391	663.1704
Point 110	-108.27329	663.0626
Point 111	-119.27774	663.9084
Point 112	-125.59455	664.34
Point 113	-200	666.4545
Point 114	334.44	651.7132
Point 115	345.43553	651.5948
Point 116	348.00486	651.5623
Point 117	361.51331	651.3534
Point 118	372.9581	651.1923
Point 119	390.68453	650.957
Point 120	405.22518	651.0814

Point 121	411.09583	651.0585
Point 122	414.02518	651.0786
Point 123	417.40055	651.072
Point 124	419.5093	651.089
Point 125	422.71179	651.0876
Point 126	425.16623	651.1104
Point 127	429.54584	651.1174
Point 128	440.39696	651.1239
Point 129	447.91152	651.1229
Point 130	458.02619	651.3274
Point 131	493.24762	648.4349
Point 132	524.74647	647.969
Point 133	113.86	761.07
Point 134	134.63	769.93
Point 135	154.09	770.57
Point 136	163.11	768.22
Point 137	207.12	750.72
Point 138	234.33	738.92
Point 139	262.34	726.92
Point 140	280.84	719.98
Point 141	283.41	718.87
Point 142	286.3	719.93
Point 143	297.84	720.24
Point 144	344.96	699.81
Point 145	383.68	684.74
Point 146	417.44	669.6
Point 147	420.54	668.04
Point 148	423.33	669.22
Point 149	443.74	670.61
Point 150	487.96	653.7
Point 151	-200	750.95
Point 152	95.2232	750.95
Point 153	163.0634	744.33
Point 154	434.9039	663.1
Point 155	650	600
Point 156	650	626.2916
Point 157	650	628.5629
Point 158	650	645.759
Point 159	260.0928	709.5
Point 160	382.6296	682.42

Surcharge Pool Condition Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 164
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 2:22:15 PM
File Name: AD 10+00 Surcharge.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 10+00\
Last Solved Date: 9/13/2010
Last Solved Time: 2:23:41 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Surcharge Pool Condition Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 10+00 Surcharge Pool = 760
Kind: SLOPE/W
Parent: Seepage Analysis - Surcharge Pool Condition
Method: Spencer
Settings
    PWP Conditions Source: Parent Analysis
Slip Surface
    Direction of movement: Left to Right
    Use Passive Mode: No
    Slip Surface Option: Auto-Search
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: Yes
    Tension Crack
        Tension Crack Option: (none)
FOS Distribution
    FOS Calculation Option: Constant
Advanced
    Number of Slices: 30
    Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 3 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Shear/Normal Fn.
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Strength Function: Ash Dike Fill
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Shear/Normal Fn.
Unit Weight: 124 pcf
Strength Function: Ash Dike Res
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Rock

Model: Bedrock (Impenetrable)

Slip Surface Limits

Left Coordinate: (-200, 666.4545) ft
Right Coordinate: (650, 645.759) ft

Shear/Normal Strength Functions

Ash Dike Fill

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress

Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 433)
Data Point: (1000, 829)
Data Point: (1500, 1188)
Data Point: (2000, 1511)
Data Point: (2500, 1797)
Data Point: (3000, 2047)
Data Point: (3500, 2259)
Data Point: (4000, 2436)
Data Point: (4500, 2575)
Data Point: (5000, 2678)
Data Point: (5500, 2744)
Data Point: (6000, 2774)
Data Point: (20000, 2800)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Ash Dike Res

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 526)
Data Point: (1000, 999)
Data Point: (1500, 1417)
Data Point: (2000, 1781)
Data Point: (2500, 2092)
Data Point: (3000, 2349)
Data Point: (3500, 2552)
Data Point: (4000, 2700)
Data Point: (4500, 2795)
Data Point: (5000, 2837)
Data Point: (20000, 3500)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6	22678.912
Region 2	PWR	7,8,9,10,11,12,13,14,15,16,17,18,1,6,5,4	7884.8849
Region 3	Residuum	7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113	11257.694
Region 4	Blanket Drain	20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132	395.05906
Region 5	Embankment Fill - Ash Dike	101,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,132,131,130,129,128,127,126,125,124,123,122,121,120,119,118,117,116,115,114,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100	32814.463
Region 6	Residuum	19,18,157,158	1719.61
Region 7	PWR	18,1,156,157	227.13
Region 8	Rock	156,155,2,1	2629.16

Points

	X (ft)	Y (ft)
Point 1	550	626.2916
Point 2	550	600
Point 3	-200	600
Point 4	-200	631.2263
Point 5	435.77054	629.9876
Point 6	438.77054	629.9876
Point 7	-200	648.4542
Point 8	115.92382	645.6152
Point 9	153.92041	645.3586
Point 10	259.22799	638.5324
Point 11	264.65748	638.2309
Point 12	370.34779	631.7877
Point 13	419.11319	632.9682
Point 14	422.11319	632.9682
Point 15	435.77054	632.1976
Point 16	438.77054	632.1976
Point 17	505.53902	630.9464
Point 18	550	628.5629
Point 19	550	645.759
Point 20	538.93239	645.759
Point 21	493.15087	646.4361
Point 22	457.9644	649.3258
Point 23	447.9316	649.1229
Point 24	440.39668	649.1239
Point 25	429.54704	649.1174
Point 26	425.1771	649.1104
Point 27	422.72062	649.0876
Point 28	419.51694	649.089
Point 29	417.40666	649.072
Point 30	414.03007	649.0786

Point 31	411.0988	649.0585
Point 32	405.22983	649.0813
Point 33	390.67981	648.9569
Point 34	372.93156	649.1925
Point 35	361.48377	649.3536
Point 36	347.97674	649.5625
Point 37	345.4121	649.595
Point 38	334.44	649.713
Point 39	329.03159	649.7712
Point 40	326.05577	649.8079
Point 41	323.36622	649.844
Point 42	320.67423	649.8778
Point 43	315.64527	649.9205
Point 44	315.05016	649.9228
Point 45	304.48331	649.9634
Point 46	304.18245	649.9655
Point 47	303.91306	649.9678
Point 48	289.7402	650.0008
Point 49	286.04752	650.1426
Point 50	275.87032	650.1308
Point 51	275.68718	650.1467
Point 52	252.33972	651.0708
Point 53	250.94149	651.1413
Point 54	249.61047	651.3034
Point 55	247.81262	651.5924
Point 56	243.06874	652.4655
Point 57	235.69178	653.9221
Point 58	212.39077	655.8256
Point 59	207.17314	657.5836
Point 60	204.28213	658.0709
Point 61	197.46189	660.0008
Point 62	192.80663	660.6529
Point 63	185.53317	660.9307
Point 64	184.03956	660.9749
Point 65	173.13572	660.4524
Point 66	166.60252	660.1628
Point 67	164.93059	660.0008
Point 68	157.55079	659.1082
Point 69	156.96739	659.2087
Point 70	150.09613	658.5439
Point 71	144.22778	658.0809
Point 72	143.43809	658.218
Point 73	136.29536	659.5715
Point 74	124.16845	659.2793
Point 75	120.06523	659.2642
Point 76	101.1411	659.0708
Point 77	96.93915	658.9887
Point 78	75.53524	659.6735
Point 79	71.54497	659.7824
Point 80	63.91382	660.0008
Point 81	56.69252	660.2908
Point 82	56.25338	660.3097

Point 83	51.5101	660.1655
Point 84	47.91942	660.0008
Point 85	43.57514	659.9731
Point 86	37.25178	659.9476
Point 87	15.88238	659.809
Point 88	15.38216	659.8061
Point 89	15.26928	659.805
Point 90	-4.33215	659.8763
Point 91	-13.95702	659.8807
Point 92	-16.84171	659.8919
Point 93	-27.54675	659.8822
Point 94	-43.26967	659.9473
Point 95	-48.10755	659.9678
Point 96	-49.16786	659.9719
Point 97	-51.29902	659.9759
Point 98	-56.91536	659.9813
Point 99	-57.36383	659.9822
Point 100	-71.72542	659.9943
Point 101	-72.27759	659.9953
Point 102	-72.71754	659.9959
Point 103	-77.51457	660.0008
Point 104	-80.12556	660.3701
Point 105	-80.43329	660.3826
Point 106	-91.20495	662.1665
Point 107	-93.86835	661.9907
Point 108	-102.02052	663.332
Point 109	-104.44391	663.1704
Point 110	-108.27329	663.0626
Point 111	-119.27774	663.9084
Point 112	-125.59455	664.34
Point 113	-200	666.4545
Point 114	334.44	651.7132
Point 115	345.43553	651.5948
Point 116	348.00486	651.5623
Point 117	361.51331	651.3534
Point 118	372.9581	651.1923
Point 119	390.68453	650.957
Point 120	405.22518	651.0814
Point 121	411.09583	651.0585
Point 122	414.02518	651.0786
Point 123	417.40055	651.072
Point 124	419.5093	651.089
Point 125	422.71179	651.0876
Point 126	425.16623	651.1104
Point 127	429.54584	651.1174
Point 128	440.39696	651.1239
Point 129	447.91152	651.1229
Point 130	458.02619	651.3274
Point 131	493.24762	648.4349
Point 132	524.74647	647.969
Point 133	113.86	761.07
Point 134	134.63	769.93

Point 135	154.09	770.57
Point 136	163.11	768.22
Point 137	207.12	750.72
Point 138	234.33	738.92
Point 139	262.34	726.92
Point 140	280.84	719.98
Point 141	283.41	718.87
Point 142	286.3	719.93
Point 143	297.84	720.24
Point 144	344.96	699.81
Point 145	383.68	684.74
Point 146	417.44	669.6
Point 147	420.54	668.04
Point 148	423.33	669.22
Point 149	443.74	670.61
Point 150	487.96	653.7
Point 151	-200	750.95
Point 152	95.2232	750.95
Point 153	163.0634	744.33
Point 154	434.9039	663.1
Point 155	650	600
Point 156	650	626.2916
Point 157	650	628.5629
Point 158	650	645.759
Point 159	260.0928	709.5
Point 160	382.6296	682.42

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.42	(321.169, 921.429)	169.5583	(111.525, 759.802)	(440.25, 670.372)
2	335	1.45	(321.169, 921.429)	276.505	(101.037, 754.107)	(436.478, 670.115)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	112.69265	757.95305	88.094174	171.92185	72.59589	3.649e-006
2	Optimized	120.2311	746.0118	566.32301	1211.281	510.80266	37
3	Optimized	130.6161	730.4535	1120.8924	2749.4046	1052.0004	219
4	Optimized	140.66445	716.7694	1557.8419	3927.7074	1355.5875	367
5	Optimized	150.39445	704.7543	1912.0019	5474.8062	1261.2353	1020
6	Optimized	157.1047	697.8595	2093.7168	6031.1769	1393.8637	1020
7	Optimized	161.6147	693.47705	2205.8561	6736.0579	933.2133	1648
8	Optimized	168.83575	687.2724	2351.3415	7082.3059	974.57003	1648
9	Optimized	178.965	679.66275	2512.461	8202.9736	341.42773	2414
10	Optimized	187.77205	674.283	2607.227	8402.7767	347.7299	2414
11	Optimized	199.6478	668.16275	2695.517	9095.7354	11.88653	2762.9
12	Optimized	212.1688	662.4146	2797.3507	9161.2988	11.819169	2762.9
13	Optimized	221.4957	658.8263	2861.5658	9733.9845	12.763504	2762.9
14	Optimized	230.0519	656.28525	2878.7076	9599.6508	12.48101	2762.9
15	Optimized	237.09225	654.19435	2891.706	9490.6606	12.255625	2762.9
16	Optimized	241.88985	652.84095	2907.0914	9548.2732	12.334049	2762.9

17	Optimized	245.8689	651.7988	2915.2691	9469.7097	289.70327	2616
18	Optimized	248.71155	651.0543	2921.7822	9424.8607	287.43309	2616
19	Optimized	250.276	650.6446	2922.7139	9398.8501	286.24225	2616
20	Optimized	251.6406	650.2872	2923.7092	9376.0162	285.18901	2616
21	Optimized	257.33985	648.7945	2936.7637	9280.9045	280.40812	2616
22	Optimized	267.2428	646.20085	2959.7614	9122.7658	272.40197	2616
23	Optimized	273.9164	644.6799	2962.0765	9513.6838	289.57804	2616
24	Optimized	278.2636	644.09835	2938.7992	9378.6511	284.63851	2616
25	Optimized	282.125	643.5818	2918.3993	9252.9814	279.98563	2616
26	Optimized	284.72875	643.2335	2904.9066	9286.682	282.07155	2616
27	Optimized	286.17375	643.0402	2897.4703	9373.0948	286.21964	2616
28	Optimized	288.0201	642.7932	2888.6329	9414.1313	288.42404	2616
29	Optimized	293.7901	642.0213	2862.1062	9525.6288	294.52464	2616
30	Optimized	301.16165	641.03515	2828.6507	9485.4315	294.22666	2616
31	Optimized	306.935	640.26285	2802.8769	9279.2487	286.25267	2616
32	Optimized	312.21845	639.83325	2765.0744	9465.836	296.17059	2616
33	Optimized	315.34775	639.72095	2734.3721	9313.4565	290.79251	2616
34	Optimized	318.15975	639.62	2706.7689	9176.5051	285.95937	2616
35	Optimized	322.0202	639.4814	2668.8332	8988.3002	279.31755	2616
36	Optimized	324.711	639.38485	2642.421	8857.1172	274.68672	2616
37	Optimized	327.09185	639.2994	2618.9507	8741.4105	270.60992	2616
38	Optimized	328.57975	639.2961	2600.9927	9128.4683	288.51143	2616
39	Optimized	331.7358	639.53295	2549.9588	8925.5934	281.80013	2616
40	Optimized	339.44135	640.1112	2431.117	8424.2701	264.89462	2616
41	Optimized	344.70135	640.5318	2348.7936	8499.1445	271.84269	2616
42	Optimized	345.18605	640.61665	2338.2593	8462.137	270.67259	2616
43	Optimized	346.7085	640.8831	2305.5785	8350.4896	267.1823	2616
44	Optimized	354.6349	642.27055	2139.1928	7769.4958	248.85681	2616
45	Optimized	361.37435	643.4589	1997.4053	7591.9998	247.27851	2616
46	Optimized	367.2077	644.9397	1846.4316	7093.8769	231.93468	2616
47	Optimized	378.3058	647.75695	1558.7929	6139.8549	384.81135	2417
48	Optimized	387.2998	650.0401	1324.6984	5418.4051	2974.2521	0
49	Optimized	391.6353	651.1407	1214.7048	4768.0889	1257.9005	1020
50	Optimized	397.0813	652.8248	1080.1672	4359.9586	1390.6353	775
51	Optimized	406.54185	655.8296	832.55081	3210.4802	1360.2	367
52	Optimized	414.35605	658.7198	607.05218	2450.0016	1190.5244	219
53	Optimized	418.99	660.80515	452.60542	1613.5063	833.51615	111
54	Optimized	421.935	662.13045	339.79564	1343.9512	795.28485	37
55	Optimized	427.55995	664.6617	143.91399	1092.9098	751.59868	37
56	Optimized	436.01985	668.46875	-124.84547	417.4271	361.49744	-5.1692e-006

Slices of Slip Surface: 335

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	335	107.44865	746.28365	664.71015	1016.3189	304.4979	-4.3806e-006
2	335	119.0525	732.8937	1124.4833	2477.1474	971.20042	111
3	335	129.4375	722.3269	1457.0669	3832.6124	1358.8364	367
4	335	139.495	713.0844	1710.8933	5010.9105	1399.211	775
5	335	149.225	704.97755	1916.006	5968.2755	1126.5362	1324
6	335	158.6	697.8338	2078.8872	6743.5609	960.91424	1648
7	335	168.61125	690.9139	2223.5427	7294.0265	669.30653	2018
8	335	179.61375	683.99335	2351.9336	7765.3547	714.57443	2018

9	335	190.61625	677.7661	2454.3632	8164.3869	342.59838	2414
10	335	201.61875	672.17995	2535.5989	8489.9661	357.25887	2414
11	335	213.9225	666.67755	2610.8546	8741.6887	11.386228	2762.9
12	335	227.5275	661.36445	2695.2133	8901.0573	11.524454	2762.9
13	335	238.99835	657.46185	2734.8549	8965.309	11.570155	2762.9
14	335	248.335	654.7337	2753.3989	8973.6276	11.552252	2762.9
15	335	257.67165	652.35715	2742.4854	8950.37	11.529327	2762.9
16	335	264.03115	650.8983	2720.4792	8915.5255	11.505483	2762.9
17	335	270.70475	649.61605	2701.2814	8860.712	272.24401	2616
18	335	278.2636	648.2863	2678.8706	8779.3261	269.63734	2616
19	335	282.125	647.69835	2663.3544	8719.9135	267.69714	2616
20	335	284.72875	647.33975	2650.4776	8793.458	271.51692	2616
21	335	286.17375	647.1483	2642.9437	8901.2238	276.61311	2616
22	335	288.0201	646.92445	2632.4652	8967.1773	279.99137	2616
23	335	293.7901	646.3137	2595.7605	9146.7726	289.55173	2616
24	335	301.16165	645.6697	2541.1465	9176.2623	293.26908	2616
25	335	309.76675	645.2106	2461.7407	8907.6528	284.90636	2616
26	335	315.34775	644.9862	2407.2566	8721.8323	279.10135	2616
27	335	318.15975	644.95255	2375.1019	8617.3746	275.90559	2616
28	335	322.0202	644.92935	2329.4551	8470.2729	271.42133	2616
29	335	324.711	644.9507	2295.3999	8362.4219	268.15959	2616
30	335	327.5437	645.00225	2257.8026	8244.947	264.62904	2616
31	335	331.7358	645.14	2198.1153	8061.7268	259.16894	2616
32	335	339.7	645.59675	2085.3191	7679.0807	247.2417	2616
33	335	345.18605	645.96985	2005.5525	7410.5071	238.89652	2616
34	335	346.7085	646.10985	1981.2657	7339.0169	236.81015	2616
35	335	354.74435	647.0548	1840.9435	6932.6814	225.05248	2616
36	335	365.6463	648.55795	1636.8824	6340.4149	395.09893	2417
37	335	371.38345	649.5272	1518.8702	6182.3344	3388.2051	0
38	335	376.1373	650.46295	1412.3407	5844.126	3219.8805	0
39	335	381.49825	651.5957	1297.084	5235.8843	1394.3381	1020
40	335	389.30665	653.5145	1132.405	4572.4222	1458.5712	775
41	335	400.56	656.63245	866.42765	3463.4975	1298.532	547
42	335	411.81335	660.27235	558.55069	2137.6103	1020.0545	219
43	335	418.99	662.8116	333.39901	1122.906	625.28449	37
44	335	421.935	663.9438	234.06913	911.13664	536.23317	37
45	335	429.90395	667.30255	-29.865952	577.36226	457.26724	37

Pseudostatic Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 167
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 6:07:11 PM
File Name: AD 10+00 Pseudostatic.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 10+00\
Last Solved Date: 9/13/2010
Last Solved Time: 6:07:25 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Pseudostatic Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 10+00 Seismic Coefficient "k" = 0.06 g
Kind: SLOPE/W
Parent: Seepage Analysis - Static Condition
Method: Spencer
Settings
PWP Conditions Source: Parent Analysis
Slip Surface
Direction of movement: Left to Right
Use Passive Mode: No
Slip Surface Option: Auto-Search
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: Yes
Tension Crack
Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 3 ft
Optimization Maximum Iterations: 2000

Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Mohr-Coulomb
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Cohesion: 1300 psf
Phi: 12.5 °
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Mohr-Coulomb
Unit Weight: 124 pcf
Cohesion: 1400 psf
Phi: 11.3 °
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Rock

Model: Bedrock (Impenetrable)

Slip Surface Limits

Left Coordinate: (-200, 666.4545) ft
Right Coordinate: (650, 645.759) ft

Seismic Loads

Horz Seismic Load: 0.06
Ignore seismic load in strength: No

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6	22678.912
Region 2	PWR	7,8,9,10,11,12,13,14,15,16,17,18,1,6,5,4	7884.8849
Region 3	Residuum	7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113	11257.694
Region 4	Blanket Drain	20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132	395.05906
Region 5	Embankment Fill - Ash Dike	101,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,132,131,130,129,128,127,126,125,124,123,122,121,120,119,118,117,116,115,114,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100	32814.463
Region 6	Residuum	19,18,157,158	1719.61
Region 7	PWR	18,1,156,157	227.13
Region 8	Rock	156,155,2,1	2629.16

Points

	X (ft)	Y (ft)
Point 1	550	626.2916
Point 2	550	600
Point 3	-200	600
Point 4	-200	631.2263
Point 5	435.77054	629.9876
Point 6	438.77054	629.9876
Point 7	-200	648.4542
Point 8	115.92382	645.6152
Point 9	153.92041	645.3586
Point 10	259.22799	638.5324
Point 11	264.65748	638.2309
Point 12	370.34779	631.7877
Point 13	419.11319	632.9682
Point 14	422.11319	632.9682
Point 15	435.77054	632.1976
Point 16	438.77054	632.1976
Point 17	505.53902	630.9464
Point 18	550	628.5629
Point 19	550	645.759
Point 20	538.93239	645.759
Point 21	493.15087	646.4361
Point 22	457.9644	649.3258
Point 23	447.9316	649.1229
Point 24	440.39668	649.1239
Point 25	429.54704	649.1174
Point 26	425.1771	649.1104
Point 27	422.72062	649.0876
Point 28	419.51694	649.089
Point 29	417.40666	649.072

Point 30	414.03007	649.0786
Point 31	411.0988	649.0585
Point 32	405.22983	649.0813
Point 33	390.67981	648.9569
Point 34	372.93156	649.1925
Point 35	361.48377	649.3536
Point 36	347.97674	649.5625
Point 37	345.4121	649.595
Point 38	334.44	649.713
Point 39	329.03159	649.7712
Point 40	326.05577	649.8079
Point 41	323.36622	649.844
Point 42	320.67423	649.8778
Point 43	315.64527	649.9205
Point 44	315.05016	649.9228
Point 45	304.48331	649.9634
Point 46	304.18245	649.9655
Point 47	303.91306	649.9678
Point 48	289.7402	650.0008
Point 49	286.04752	650.1426
Point 50	275.87032	650.1308
Point 51	275.68718	650.1467
Point 52	252.33972	651.0708
Point 53	250.94149	651.1413
Point 54	249.61047	651.3034
Point 55	247.81262	651.5924
Point 56	243.06874	652.4655
Point 57	235.69178	653.9221
Point 58	212.39077	655.8256
Point 59	207.17314	657.5836
Point 60	204.28213	658.0709
Point 61	197.46189	660.0008
Point 62	192.80663	660.6529
Point 63	185.53317	660.9307
Point 64	184.03956	660.9749
Point 65	173.13572	660.4524
Point 66	166.60252	660.1628
Point 67	164.93059	660.0008
Point 68	157.55079	659.1082
Point 69	156.96739	659.2087
Point 70	150.09613	658.5439
Point 71	144.22778	658.0809
Point 72	143.43809	658.218
Point 73	136.29536	659.5715
Point 74	124.16845	659.2793
Point 75	120.06523	659.2642
Point 76	101.1411	659.0708
Point 77	96.93915	658.9887
Point 78	75.53524	659.6735
Point 79	71.54497	659.7824
Point 80	63.91382	660.0008
Point 81	56.69252	660.2908

Point 82	56.25338	660.3097
Point 83	51.5101	660.1655
Point 84	47.91942	660.0008
Point 85	43.57514	659.9731
Point 86	37.25178	659.9476
Point 87	15.88238	659.809
Point 88	15.38216	659.8061
Point 89	15.26928	659.805
Point 90	-4.33215	659.8763
Point 91	-13.95702	659.8807
Point 92	-16.84171	659.8919
Point 93	-27.54675	659.8822
Point 94	-43.26967	659.9473
Point 95	-48.10755	659.9678
Point 96	-49.16786	659.9719
Point 97	-51.29902	659.9759
Point 98	-56.91536	659.9813
Point 99	-57.36383	659.9822
Point 100	-71.72542	659.9943
Point 101	-72.27759	659.9953
Point 102	-72.71754	659.9959
Point 103	-77.51457	660.0008
Point 104	-80.12556	660.3701
Point 105	-80.43329	660.3826
Point 106	-91.20495	662.1665
Point 107	-93.86835	661.9907
Point 108	-102.02052	663.332
Point 109	-104.44391	663.1704
Point 110	-108.27329	663.0626
Point 111	-119.27774	663.9084
Point 112	-125.59455	664.34
Point 113	-200	666.4545
Point 114	334.44	651.7132
Point 115	345.43553	651.5948
Point 116	348.00486	651.5623
Point 117	361.51331	651.3534
Point 118	372.9581	651.1923
Point 119	390.68453	650.957
Point 120	405.22518	651.0814
Point 121	411.09583	651.0585
Point 122	414.02518	651.0786
Point 123	417.40055	651.072
Point 124	419.5093	651.089
Point 125	422.71179	651.0876
Point 126	425.16623	651.1104
Point 127	429.54584	651.1174
Point 128	440.39696	651.1239
Point 129	447.91152	651.1229
Point 130	458.02619	651.3274
Point 131	493.24762	648.4349
Point 132	524.74647	647.969
Point 133	113.86	761.07

Point 134	134.63	769.93
Point 135	154.09	770.57
Point 136	163.11	768.22
Point 137	207.12	750.72
Point 138	234.33	738.92
Point 139	262.34	726.92
Point 140	280.84	719.98
Point 141	283.41	718.87
Point 142	286.3	719.93
Point 143	297.84	720.24
Point 144	344.96	699.81
Point 145	383.68	684.74
Point 146	417.44	669.6
Point 147	420.54	668.04
Point 148	423.33	669.22
Point 149	443.74	670.61
Point 150	487.96	653.7
Point 151	-200	750.95
Point 152	95.2232	750.95
Point 153	163.0634	744.33
Point 154	434.9039	663.1
Point 155	650	600
Point 156	650	626.2916
Point 157	650	628.5629
Point 158	650	645.759
Point 159	260.0928	709.5
Point 160	382.6296	682.42

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.13	(391.103, 1046.89)	196.5793	(108.478, 758.147)	(501.574, 651.579)
2	354	1.17	(391.103, 1046.89)	412.142	(101.037, 754.107)	(505.551, 650.959)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	111.1688	755.1634	-331.85038	-288.93344	-64.055001	1300
2	Optimized	121.15445	744.09185	85.61915	1015.1264	206.06679	1300
3	Optimized	131.53945	732.6403	481.96524	2403.7514	426.04974	1300
4	Optimized	142.10175	721.1438	851.87761	3532.1953	594.21213	1300
5	Optimized	151.83175	710.8923	1162.9202	4771.8739	800.08577	1300
6	Optimized	158.6	704.54165	1342.9596	5248.3032	865.79384	1300
7	Optimized	164.4305	699.07085	1497.6781	5592.8226	907.87169	1300
8	Optimized	175.09625	690.25645	1732.8454	6363.2982	1026.5467	1300
9	Optimized	190.1111	678.9081	2025.8241	7334.7562	1176.9619	1300
10	Optimized	201.45035	671.36205	2212.0856	7639.1474	1203.1506	1300
11	Optimized	207.44805	667.3707	2316.9587	7798.8626	1215.3088	1300
12	Optimized	213.8433	664.02715	2398.5336	8407.5785	1332.1732	1300
13	Optimized	225.97765	657.77665	2572.678	8515.2741	1317.4418	1300
14	Optimized	232.8667	654.36855	2658.5305	9272.298	1466.237	1300
15	Optimized	234.0093	653.97535	2666.3227	9263.8717	1318.3204	1400

16	Optimized	235.0109	653.6307	2676.174	9254.5723	1314.4937	1400
17	Optimized	239.38025	652.12715	2717.9336	9215.6459	1298.371	1400
18	Optimized	245.44065	650.0417	2772.6296	9161.2387	1276.5701	1400
19	Optimized	248.71155	648.91615	2799.3724	9131.5555	1265.295	1400
20	Optimized	250.276	648.3778	2811.8344	9117.5046	1259.9972	1400
21	Optimized	251.6406	647.9082	2823.0202	9105.2952	1255.3224	1400
22	Optimized	255.26055	646.6625	2853.4069	9073.5039	1242.898	1400
23	Optimized	260.2607	645.24295	2877.554	9653.3187	1353.9314	1400
24	Optimized	269.0136	643.4983	2874.1181	9463.0757	1316.6037	1400
25	Optimized	278.2636	641.65455	2872.7582	9275.465	1279.3871	1400
26	Optimized	282.125	640.88485	2872.4057	9188.8897	1262.158	1400
27	Optimized	284.72875	640.36585	2872.3093	9241.4528	1272.6805	1400
28	Optimized	286.17375	640.07785	2872.3615	9336.6899	1291.7003	1400
29	Optimized	288.0201	639.70985	2873.2503	9390.5881	1302.2926	1400
30	Optimized	293.7901	638.55975	2876.451	9543.129	1332.1337	1400
31	Optimized	300.4753	637.2272	2880.1773	9579.0688	1338.5706	1400
32	Optimized	303.51185	636.65805	2879.5859	9937.8171	1410.3738	1400
33	Optimized	304.0478	636.59945	2876.8481	9916.8064	1406.7225	1400
34	Optimized	309.61635	635.99075	2850.9647	9699.573	1368.487	1400
35	Optimized	315.34775	635.3643	2826.8387	9476.583	1328.75	1400
36	Optimized	317.6812	635.10925	2817.0541	9385.4603	1312.4971	1400
37	Optimized	320.19565	634.85745	2805.0571	9524.3876	1342.6547	1400
38	Optimized	322.0202	634.74595	2791.9416	9440.8182	1328.5766	1400
39	Optimized	324.711	634.58155	2772.579	9318.0092	1307.906	1400
40	Optimized	327.5437	634.40845	2752.1902	9188.7256	1286.1467	1400
41	Optimized	331.7358	634.15225	2725.478	8996.9565	1253.1651	1400
42	Optimized	339.7	633.66555	2675.808	8626.6867	1189.1029	1400
43	Optimized	345.18605	633.3303	2641.611	8376.9867	1146.0412	1400
44	Optimized	346.7085	633.2373	2632.048	8315.7626	1135.7182	1400
45	Optimized	350.9372	632.9789	2607.2408	8145.4363	1106.6407	1400
46	Optimized	357.6914	632.5888	2569.8005	7896.5883	1064.3972	1400
47	Optimized	366.4909	632.10325	2519.572	7534.745	1002.1305	1400
48	Optimized	372.2133	631.84675	2483.2353	7633.3931	1029.1031	1400
49	Optimized	378.31905	631.99545	2417.9773	7312.2998	977.98213	1400
50	Optimized	387.18225	632.2113	2323.2358	6819.4206	898.42638	1400
51	Optimized	397.95485	632.4737	2206.8125	6170.8661	792.09606	1400
52	Optimized	408.1605	632.72225	2093.3552	5556.6804	692.04067	1400
53	Optimized	411.52395	632.80415	2056.0087	5354.2622	659.05609	1400
54	Optimized	412.9911	632.92185	2034.5884	5535.126	699.47643	1400
55	Optimized	415.73505	633.2051	1990.6069	5335.9782	668.47114	1400
56	Optimized	418.47465	633.4879	1946.6461	5129.5585	636.00866	1400
57	Optimized	420.02465	633.6479	1921.2934	5005.805	616.34624	1400
58	Optimized	421.6259	633.8132	1894.9495	5012.0687	622.86189	1400
59	Optimized	423.0209	633.9572	1872.2596	5073.0899	639.589	1400
60	Optimized	424.25355	634.08445	1852.535	5083.3237	645.57529	1400
61	Optimized	427.36205	634.40535	1802.9387	5071.9744	653.21778	1400
62	Optimized	434.97185	635.19085	1681.6276	5044.3327	671.93479	1400
63	Optimized	442.06835	635.9234	1569.9092	5018.3185	689.06016	1400
64	Optimized	445.8358	636.3123	1510.653	4878.41	672.94424	1400
65	Optimized	451.41735	636.88845	1422.8672	4522.4471	619.35718	1400
66	Optimized	456.46465	637.5355	1335.6956	4449.1696	622.13349	1400
67	Optimized	462.8325	638.7067	1203.3096	3958.3064	550.50269	1400

68	Optimized	472.7191	641.3854	943.30255	3599.3975	530.74015	1400
69	Optimized	482.8797	644.97485	622.13425	2500.8422	375.40288	1400
70	Optimized	490.3711	647.62135	382.97155	1052.81	486.66614	0
71	Optimized	497.17815	650.0261	153.26473	1234.6117	239.72886	1300

Slices of Slip Surface: 354

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	354	107.44865	748.02215	29.525113	301.20751	60.230538	1300
2	354	119.0525	737.37325	389.50462	1844.0246	322.45931	1300
3	354	129.4375	728.5414	672.40456	3146.8147	548.56351	1300
4	354	144.36	716.99605	995.22735	4617.9208	803.13179	1300
5	354	158.6	706.6368	1260.6273	5696.805	983.47693	1300
6	354	170.445	698.9039	1441.915	6200.6891	1054.9948	1300
7	354	185.115	690.01905	1638.1742	6688.9553	1119.7312	1300
8	354	199.785	681.9401	1808.1862	7099.3192	1173.016	1300
9	354	213.9225	674.85525	1951.2127	7399.2524	1207.8013	1300
10	354	227.5275	668.67355	2074.7655	7593.666	1223.5108	1300
11	354	241.3325	662.9996	2191.1663	7728.2847	1227.5496	1300
12	354	255.3375	657.82415	2277.2595	7801.429	1224.6789	1300
13	354	270.94295	652.75785	2322.6414	7850.3601	1225.4657	1300
14	354	280.19295	649.9543	2334.0031	7878.9908	1107.9979	1400
15	354	282.125	649.42115	2343.1355	7871.3683	1104.6499	1400
16	354	284.72875	648.7165	2354.5981	7972.1028	1122.4882	1400
17	354	286.17375	648.33095	2360.6642	8092.0534	1145.2446	1400
18	354	288.0201	647.85335	2367.9659	8177.5694	1160.8733	1400
19	354	293.7901	646.4249	2388.0962	8424.0796	1206.1085	1400
20	354	301.16165	644.698	2408.4099	8556.1351	1228.4367	1400
21	354	309.76675	642.8915	2421.3113	8434.9287	1201.6393	1400
22	354	315.34775	641.77215	2428.5411	8348.1824	1182.861	1400
23	354	318.15975	641.2643	2428.7487	8297.2788	1172.648	1400
24	354	322.0202	640.58325	2428.4193	8224.86	1158.2431	1400
25	354	324.711	640.1349	2426.5525	8170.5834	1147.7706	1400
26	354	327.5437	639.6832	2423.1942	8110.959	1136.5275	1400
27	354	331.7358	639.05735	2417.5675	8016.2315	1118.7235	1400
28	354	339.7	638.00245	2404.8365	7811.7101	1080.4	1400
29	354	345.18605	637.31585	2393.3237	7668.835	1054.1512	1400
30	354	346.7085	637.15005	2388.5574	7633.6288	1048.0687	1400
31	354	354.74435	636.41265	2359.3523	7429.2327	1013.0621	1400
32	354	367.2077	635.4832	2302.853	7077.8263	954.1338	1400
33	354	378.3058	634.98375	2231.8045	6715.8718	896.00505	1400
34	354	387.18225	634.7835	2162.7881	6368.8757	840.45923	1400
35	354	397.95485	634.8711	2056.9827	5847.9673	757.51347	1400
36	354	408.1605	635.1136	1943.9436	5323.124	675.22689	1400
37	354	412.56295	635.3117	1889.4054	5080.957	637.73495	1400
38	354	415.73505	635.49025	1847.843	4900.708	610.02263	1400
39	354	418.47465	635.6612	1810.906	4734.5096	584.19364	1400
40	354	420.02465	635.76635	1789.1172	4631.9999	568.06401	1400
41	354	421.6259	635.8832	1766.1177	4657.0553	577.66633	1400
42	354	423.0209	635.98785	1745.9254	4733.8028	597.03681	1400
43	354	424.25355	636.0864	1727.9117	4757.5851	605.38849	1400
44	354	427.36205	636.3539	1681.6919	4778.9456	618.89235	1400

45	354	434.97185	637.12765	1561.2685	4816.8745	650.53426	1400
46	354	442.06835	637.91675	1445.8414	4845.0958	679.23806	1400
47	354	445.8358	638.4059	1380.3544	4723.273	667.98105	1400
48	354	452.9789	639.4532	1248.7353	4278.608	605.42831	1400
49	354	465.50965	641.59355	998.55228	3439.896	487.8286	1400
50	354	480.47655	644.63005	667.62937	2340.551	334.28272	1400
51	354	488.8332	646.50585	467.47891	1713.724	249.02435	1400
52	354	491.477	647.1636	400.22842	983.49431	423.76747	0
53	354	494.7527	647.9993	314.86273	770.50971	331.04691	0
54	354	500.90465	649.6749	137.76895	1046.7495	201.51613	1300

Rapid Drawdown Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 168
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 6:03:29 PM
File Name: AD 10+00 RDD.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 10+00\
Last Solved Date: 9/13/2010
Last Solved Time: 6:03:48 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Rapid Drawdown Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 10+00 Pool Drawdown from 750.95 to 745.63
Kind: SLOPE/W
Parent: Seepage Analysis - Static Condition
Method: Spencer
Settings
- Apply Phreatic Correction: No
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: Yes

Slip Surface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Auto-Search
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: Yes
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced
- Number of Slices: 30
- Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 3 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Mohr-Coulomb
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Cohesion: 0 psf
Phi: 38 °
Phi-B: 0 °
Drawdown Total Cohesion: 1300 psf
Drawdown Total Phi: 12.5 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °
Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Residuum

Model: Mohr-Coulomb
Unit Weight: 124 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °
Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °

Phi-B: 0 °
Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Rock

Model: Bedrock (Impenetrable)
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Slip Surface Limits

Left Coordinate: (-200, 666.4545) ft
Right Coordinate: (650, 645.759) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-200	750.95
	175	750.95

Piezometric Line 2

Coordinates

	X (ft)	Y (ft)
	-200	745.63
	175	745.63

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6	22678.912
Region 2	PWR	7,8,9,10,11,12,13,14,15,16,17,18,1,6,5,4	7884.8849
Region 3	Residuum	7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113	11257.694
Region 4	Blanket Drain	20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132	395.05906
Region 5	Embankment Fill - Ash Dike	101,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,132,131,130,129,128,127,126,125,124,123,122,121,120,119,118,117,116,115,114,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100	32814.463

Region 6	Residuum	19,18,157,158	1719.61
Region 7	PWR	18,1,156,157	227.13
Region 8	Rock	156,155,2,1	2629.16

Points

	X (ft)	Y (ft)
Point 1	550	626.2916
Point 2	550	600
Point 3	-200	600
Point 4	-200	631.2263
Point 5	435.77054	629.9876
Point 6	438.77054	629.9876
Point 7	-200	648.4542
Point 8	115.92382	645.6152
Point 9	153.92041	645.3586
Point 10	259.22799	638.5324
Point 11	264.65748	638.2309
Point 12	370.34779	631.7877
Point 13	419.11319	632.9682
Point 14	422.11319	632.9682
Point 15	435.77054	632.1976
Point 16	438.77054	632.1976
Point 17	505.53902	630.9464
Point 18	550	628.5629
Point 19	550	645.759
Point 20	538.93239	645.759
Point 21	493.15087	646.4361
Point 22	457.9644	649.3258
Point 23	447.9316	649.1229
Point 24	440.39668	649.1239
Point 25	429.54704	649.1174
Point 26	425.1771	649.1104
Point 27	422.72062	649.0876
Point 28	419.51694	649.089
Point 29	417.40666	649.072
Point 30	414.03007	649.0786
Point 31	411.0988	649.0585
Point 32	405.22983	649.0813
Point 33	390.67981	648.9569
Point 34	372.93156	649.1925
Point 35	361.48377	649.3536
Point 36	347.97674	649.5625
Point 37	345.4121	649.595
Point 38	334.44	649.713
Point 39	329.03159	649.7712
Point 40	326.05577	649.8079
Point 41	323.36622	649.844
Point 42	320.67423	649.8778
Point 43	315.64527	649.9205
Point 44	315.05016	649.9228
Point 45	304.48331	649.9634

Point 46	304.18245	649.9655
Point 47	303.91306	649.9678
Point 48	289.7402	650.0008
Point 49	286.04752	650.1426
Point 50	275.87032	650.1308
Point 51	275.68718	650.1467
Point 52	252.33972	651.0708
Point 53	250.94149	651.1413
Point 54	249.61047	651.3034
Point 55	247.81262	651.5924
Point 56	243.06874	652.4655
Point 57	235.69178	653.9221
Point 58	212.39077	655.8256
Point 59	207.17314	657.5836
Point 60	204.28213	658.0709
Point 61	197.46189	660.0008
Point 62	192.80663	660.6529
Point 63	185.53317	660.9307
Point 64	184.03956	660.9749
Point 65	173.13572	660.4524
Point 66	166.60252	660.1628
Point 67	164.93059	660.0008
Point 68	157.55079	659.1082
Point 69	156.96739	659.2087
Point 70	150.09613	658.5439
Point 71	144.22778	658.0809
Point 72	143.43809	658.218
Point 73	136.29536	659.5715
Point 74	124.16845	659.2793
Point 75	120.06523	659.2642
Point 76	101.1411	659.0708
Point 77	96.93915	658.9887
Point 78	75.53524	659.6735
Point 79	71.54497	659.7824
Point 80	63.91382	660.0008
Point 81	56.69252	660.2908
Point 82	56.25338	660.3097
Point 83	51.5101	660.1655
Point 84	47.91942	660.0008
Point 85	43.57514	659.9731
Point 86	37.25178	659.9476
Point 87	15.88238	659.809
Point 88	15.38216	659.8061
Point 89	15.26928	659.805
Point 90	-4.33215	659.8763
Point 91	-13.95702	659.8807
Point 92	-16.84171	659.8919
Point 93	-27.54675	659.8822
Point 94	-43.26967	659.9473
Point 95	-48.10755	659.9678
Point 96	-49.16786	659.9719
Point 97	-51.29902	659.9759

Point 98	-56.91536	659.9813
Point 99	-57.36383	659.9822
Point 100	-71.72542	659.9943
Point 101	-72.27759	659.9953
Point 102	-72.71754	659.9959
Point 103	-77.51457	660.0008
Point 104	-80.12556	660.3701
Point 105	-80.43329	660.3826
Point 106	-91.20495	662.1665
Point 107	-93.86835	661.9907
Point 108	-102.02052	663.332
Point 109	-104.44391	663.1704
Point 110	-108.27329	663.0626
Point 111	-119.27774	663.9084
Point 112	-125.59455	664.34
Point 113	-200	666.4545
Point 114	334.44	651.7132
Point 115	345.43553	651.5948
Point 116	348.00486	651.5623
Point 117	361.51331	651.3534
Point 118	372.9581	651.1923
Point 119	390.68453	650.957
Point 120	405.22518	651.0814
Point 121	411.09583	651.0585
Point 122	414.02518	651.0786
Point 123	417.40055	651.072
Point 124	419.5093	651.089
Point 125	422.71179	651.0876
Point 126	425.16623	651.1104
Point 127	429.54584	651.1174
Point 128	440.39696	651.1239
Point 129	447.91152	651.1229
Point 130	458.02619	651.3274
Point 131	493.24762	648.4349
Point 132	524.74647	647.969
Point 133	113.86	761.07
Point 134	134.63	769.93
Point 135	154.09	770.57
Point 136	163.11	768.22
Point 137	207.12	750.72
Point 138	234.33	738.92
Point 139	262.34	726.92
Point 140	280.84	719.98
Point 141	283.41	718.87
Point 142	286.3	719.93
Point 143	297.84	720.24
Point 144	344.96	699.81
Point 145	383.68	684.74
Point 146	417.44	669.6
Point 147	420.54	668.04
Point 148	423.33	669.22
Point 149	443.74	670.61

Point 150	487.96	653.7
Point 151	-200	750.95
Point 152	95.2232	750.95
Point 153	163.0634	744.33
Point 154	434.9039	663.1
Point 155	650	600
Point 156	650	626.2916
Point 157	650	628.5629
Point 158	650	645.759
Point 159	260.0928	709.5
Point 160	382.6296	682.42

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.34	(-95.329, 1032.82)	74.18861	(118.286, 762.958)	(4.86015, 701.882)
2	942	1.40	(-95.329, 1032.82)	344.404	(119.077, 763.295)	(11.1199, 705.281)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	6.996554	702.951	2663.0657	2679.3907	12.754477	0
2	Optimized	11.269371	705.0892	2529.745	2553.3953	18.47764	0
3	Optimized	15.542185	707.2274	2396.4242	2427.1906	24.037284	0
4	Optimized	19.30014	709.08635	2280.3291	2322.1878	32.703604	0
5	Optimized	22.54324	710.66605	2181.7533	2230.9858	38.464636	0
6	Optimized	25.97338	712.3046	2079.5172	2142.661	49.333377	0
7	Optimized	29.590555	714.002	1973.5767	2047.7075	57.917345	0
8	Optimized	33.20773	715.6994	1867.6612	1952.779	66.501313	0
9	Optimized	36.98973	717.46645	1757.3944	1855.3209	76.508601	0
10	Optimized	40.936555	719.30315	1642.7907	1753.3515	86.379521	0
11	Optimized	44.936515	721.12275	1529.2533	1659.556	101.80363	0
12	Optimized	48.989605	722.92525	1416.7827	1563.7903	114.85493	0
13	Optimized	52.629025	724.52005	1317.2479	1483.9366	130.23148	0
14	Optimized	55.85477	725.90715	1230.6997	1412.8525	142.31343	0
15	Optimized	59.34593	727.3875	1138.3251	1340.9117	158.278	0
16	Optimized	63.102505	728.96105	1040.1377	1262.6614	173.85451	0
17	Optimized	67.52821	730.82835	923.61472	1167.6774	190.68267	0
18	Optimized	71.803805	732.5851	814.00437	1090.7098	216.18599	0
19	Optimized	75.26015	733.93755	729.61864	1029.1988	234.05764	0
20	Optimized	79.097725	735.41395	637.48262	966.95059	257.40859	0
21	Optimized	83.316535	737.01425	537.61832	897.53759	281.19975	0
22	Optimized	86.36437	738.17035	465.48365	875.13258	320.05282	0
23	Optimized	89.642335	739.8038	363.55772	821.84077	358.04996	0
24	Optimized	93.60252	742.2674	209.82484	706.41203	387.97644	0
25	Optimized	96.102555	744.0971	95.651037	637.07711	423.00841	0
26	Optimized	97.47784	745.18535	27.746249	547.53819	406.10597	0
27	Optimized	100.47287	747.87085	-139.82905	457.40756	357.36595	0
28	Optimized	103.43885	750.53085	-305.81247	376.26688	293.97191	0
29	Optimized	105.94495	752.78075	-446.20303	307.72245	240.41913	0
30	Optimized	110.02345	756.44225	-674.68686	196.1717	153.26613	0
31	Optimized	112.96135	758.94955	-831.15791	134.87258	105.37401	0

32	Optimized	116.07275	761.29195	-977.31548	59.648413	46.602448	0

Slices of Slip Surface: 942

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	942	12.88911	705.8666	2481.2431	2542.8717	48.14956	0
2	942	16.427495	707.05915	2406.833	2500.1283	72.890318	0
3	942	19.96588	708.29465	2329.7166	2452.245	95.729647	0
4	942	23.50426	709.57355	2249.9241	2399.2382	116.65697	0
5	942	27.04264	710.89645	2167.3822	2341.0761	135.70451	0
6	942	30.58102	712.2639	2082.0493	2277.7856	152.92597	0
7	942	34.1194	713.6764	1993.9147	2209.347	168.3142	0
8	942	37.657785	715.1346	1902.9202	2135.7212	181.88408	0
9	942	41.19617	716.6391	1809.0389	2056.9278	193.67203	0
10	942	44.73455	718.1906	1712.2235	1972.9414	203.69519	0
11	942	48.27293	719.7898	1612.433	1883.6935	211.93192	0
12	942	51.81131	721.4374	1509.607	1789.2264	218.46256	0
13	942	55.34969	723.1342	1403.7439	1689.4635	223.22861	0
14	942	58.888075	724.881	1294.7471	1584.4144	226.31293	0
15	942	62.42646	726.67865	1182.5549	1473.9982	227.70047	0
16	942	65.96484	728.5281	1067.1641	1358.2203	227.39796	0
17	942	69.50322	730.43025	948.45626	1237.023	225.45304	0
18	942	73.0416	732.3861	826.42387	1110.3877	221.85683	0
19	942	76.57998	734.39675	700.9466	978.23473	216.64123	0
20	942	80.118365	736.4633	571.99111	840.52538	209.80196	0
21	942	83.65675	738.5869	439.48901	697.18961	201.33777	0
22	942	86.98224	740.63415	311.73706	597.253	223.06949	0
23	942	90.09484	742.59955	189.10067	540.36112	274.43474	0
24	942	93.20744	744.61195	63.528534	477.86879	323.71809	0
25	942	94.993455	745.7823	-9.5042625	442.45107	345.68066	0
26	942	97.05903	747.1711	-96.163425	416.95666	325.76224	0
27	942	100.73075	749.6788	-252.6397	368.80514	288.14216	0
28	942	104.44885	752.2904	-415.60333	314.63987	245.82361	0
29	942	108.2133	755.00985	-585.29457	254.31192	198.69025	0
30	942	111.97775	757.80775	-759.89805	188.46524	147.24518	0
31	942	116.4685	761.26105	-975.37249	76.636842	59.875263	0

Seepage Analysis - Static Condition

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 168
Last Edited By: Cedric Ruhl
Date: 9/16/2010
Time: 3:29:29 PM
File Name: AD 10+00 WSEL = 74563.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 10+00\
Last Solved Date: 9/16/2010
Last Solved Time: 3:29:35 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Mass(M) Units: lbs
Mass Flux Units: lbs/sec
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Seepage Analysis - Static Condition

Description: Ash Dike Section Sta. 10+00 Water Surface Elevation = 745.63
Kind: SEEP/W
Method: Steady-State
Settings
    Include Air Flow: No
Control
    Apply Runoff: Yes
Convergence
    Convergence Type: Gauss Point K
    Convergence Settings
        Maximum Number of Iterations: 500
        Tolerance: 0.01
        Maximum Change in K: 0.1
        Rate of Change in K: 1.02
        Minimum Change in K: 0.0001

Equation Solver: Parallel Direct
Potential Seepage Max # of Reviews: 10

Time
Starting Time: 0 sec
Duration: 0 sec
Ending Time: 0 sec

Materials

Embankment Fill - Ash Dike

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-6
K-Ratio: 0.1
K-Direction: 0 °

Blanket Drain

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

Residuum

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

PWR

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

Rock

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

Boundary Conditions

Water Elevation = 745.63

Type: Head (H) 745.63

Potential Seepage Face

Review: true
Type: Total Flux (Q) 0

Zero Pressure

Type: Pressure Head 0

K Functions

1e-4

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-006
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-006)
Data Point: (10000, 3.28e-006)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-5

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-007
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-007)
Data Point: (10000, 3.28e-007)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-6

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-008
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-008)
Data Point: (10000, 3.28e-008)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

Regions

	Material	Points	Area (ft^2)
Region 1	Rock	1,2,3,4,5,6	22678.912
Region 2	PWR	7,8,9,10,11,12,13,14,15,16,17,18,1,6,5,4	7884.8849
Region 3	Residuum	7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30, 31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53, 54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76, 77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99, 100,101,102,103,104,105,106,107,108,109,110,111,112,113	11257.694
Region 4	Blanket Drain	20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,114,115,116, 117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132	395.05906
Region 5	Embankment Fill - Ash Dike	101,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148, 149,150,132,131,130,129,128,127,126,125,124,123,122,121,120,119,118, 117,116,115,114,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55, 56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79, 80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100	32814.463
Region 6	Residuum	19,18,157,158	1719.61
Region 7	PWR	18,1,156,157	227.13
Region 8	Rock	156,155,2,1	2629.16

Lines

	Start Point	End Point	Hydraulic Boundary
Line 1	1	2	
Line 2	2	3	
Line 3	3	4	Water Elevation = 745.63
Line 4	4	5	
Line 5	5	6	
Line 6	6	1	
Line 7	7	8	
Line 8	8	9	

Line 9	9	10	
Line 10	10	11	
Line 11	11	12	
Line 12	12	13	
Line 13	13	14	
Line 14	14	15	
Line 15	15	16	
Line 16	16	17	
Line 17	17	18	
Line 18	18	1	
Line 19	4	7	Water Elevation = 745.63
Line 20	18	19	
Line 21	19	20	Potential Seepage Face
Line 22	20	21	
Line 23	21	22	
Line 24	22	23	
Line 25	23	24	
Line 26	24	25	
Line 27	25	26	
Line 28	26	27	
Line 29	27	28	
Line 30	28	29	
Line 31	29	30	
Line 32	30	31	
Line 33	31	32	
Line 34	32	33	
Line 35	33	34	
Line 36	34	35	
Line 37	35	36	
Line 38	36	37	
Line 39	37	38	
Line 40	38	39	
Line 41	39	40	
Line 42	40	41	
Line 43	41	42	
Line 44	42	43	
Line 45	43	44	
Line 46	44	45	
Line 47	45	46	
Line 48	46	47	
Line 49	47	48	
Line 50	48	49	
Line 51	49	50	
Line 52	50	51	
Line 53	51	52	
Line 54	52	53	
Line 55	53	54	

Line 56	54	55	
Line 57	55	56	
Line 58	56	57	
Line 59	57	58	
Line 60	58	59	
Line 61	59	60	
Line 62	60	61	
Line 63	61	62	
Line 64	62	63	
Line 65	63	64	
Line 66	64	65	
Line 67	65	66	
Line 68	66	67	
Line 69	67	68	
Line 70	68	69	
Line 71	69	70	
Line 72	70	71	
Line 73	71	72	
Line 74	72	73	
Line 75	73	74	
Line 76	74	75	
Line 77	75	76	
Line 78	76	77	
Line 79	77	78	
Line 80	78	79	
Line 81	79	80	
Line 82	80	81	
Line 83	81	82	
Line 84	82	83	
Line 85	83	84	
Line 86	84	85	
Line 87	85	86	
Line 88	86	87	
Line 89	87	88	
Line 90	88	89	
Line 91	89	90	
Line 92	90	91	
Line 93	91	92	
Line 94	92	93	
Line 95	93	94	
Line 96	94	95	
Line 97	95	96	
Line 98	96	97	
Line 99	97	98	
Line 100	98	99	
Line 101	99	100	
Line 102	100	101	

Line 103	101	102	
Line 104	102	103	Water Elevation = 745.63
Line 105	103	104	Water Elevation = 745.63
Line 106	104	105	Water Elevation = 745.63
Line 107	105	106	Water Elevation = 745.63
Line 108	106	107	Water Elevation = 745.63
Line 109	107	108	Water Elevation = 745.63
Line 110	108	109	Water Elevation = 745.63
Line 111	109	110	Water Elevation = 745.63
Line 112	110	111	Water Elevation = 745.63
Line 113	111	112	Water Elevation = 745.63
Line 114	112	113	Water Elevation = 745.63
Line 115	113	7	Water Elevation = 745.63
Line 116	38	114	
Line 117	114	115	
Line 118	115	116	
Line 119	116	117	
Line 120	117	118	
Line 121	118	119	
Line 122	119	120	
Line 123	120	121	
Line 124	121	122	
Line 125	122	123	
Line 126	123	124	
Line 127	124	125	
Line 128	125	126	
Line 129	126	127	
Line 130	127	128	
Line 131	128	129	
Line 132	129	130	
Line 133	130	131	
Line 134	131	132	
Line 135	132	20	Potential Seepage Face
Line 136	101	133	Water Elevation = 745.63
Line 137	133	134	Water Elevation = 745.63
Line 138	134	135	
Line 139	135	136	
Line 140	136	137	
Line 141	137	138	
Line 142	138	139	
Line 143	139	140	
Line 144	140	141	Potential Seepage Face
Line 145	141	142	Potential Seepage Face
Line 146	142	143	Potential Seepage Face
Line 147	143	144	Potential Seepage Face
Line 148	144	145	Potential Seepage Face
Line 149	145	146	Potential Seepage Face

Line 150	146	147	Potential Seepage Face
Line 151	147	148	Potential Seepage Face
Line 152	148	149	Potential Seepage Face
Line 153	149	150	Potential Seepage Face
Line 154	150	132	Potential Seepage Face
Line 155	152	153	
Line 156	154	150	
Line 157	18	157	
Line 158	157	158	
Line 159	158	19	Potential Seepage Face
Line 160	1	156	
Line 161	156	157	
Line 162	156	155	
Line 163	155	2	
Line 164	153	159	
Line 165	159	160	Zero Pressure
Line 166	160	147	
Line 167	147	154	

Points

	X (ft)	Y (ft)
Point 1	550	626.2916
Point 2	550	600
Point 3	-200	600
Point 4	-200	631.2263
Point 5	435.77054	629.9876
Point 6	438.77054	629.9876
Point 7	-200	648.4542
Point 8	115.92382	645.6152
Point 9	153.92041	645.3586
Point 10	259.22799	638.5324
Point 11	264.65748	638.2309
Point 12	370.34779	631.7877
Point 13	419.11319	632.9682
Point 14	422.11319	632.9682
Point 15	435.77054	632.1976
Point 16	438.77054	632.1976
Point 17	505.53902	630.9464
Point 18	550	628.5629
Point 19	550	645.759
Point 20	538.93239	645.759
Point 21	493.15087	646.4361
Point 22	457.9644	649.3258
Point 23	447.9316	649.1229
Point 24	440.39668	649.1239
Point 25	429.54704	649.1174

Point 26	425.1771	649.1104
Point 27	422.72062	649.0876
Point 28	419.51694	649.089
Point 29	417.40666	649.072
Point 30	414.03007	649.0786
Point 31	411.0988	649.0585
Point 32	405.22983	649.0813
Point 33	390.67981	648.9569
Point 34	372.93156	649.1925
Point 35	361.48377	649.3536
Point 36	347.97674	649.5625
Point 37	345.4121	649.595
Point 38	334.44	649.713
Point 39	329.03159	649.7712
Point 40	326.05577	649.8079
Point 41	323.36622	649.844
Point 42	320.67423	649.8778
Point 43	315.64527	649.9205
Point 44	315.05016	649.9228
Point 45	304.48331	649.9634
Point 46	304.18245	649.9655
Point 47	303.91306	649.9678
Point 48	289.7402	650.0008
Point 49	286.04752	650.1426
Point 50	275.87032	650.1308
Point 51	275.68718	650.1467
Point 52	252.33972	651.0708
Point 53	250.94149	651.1413
Point 54	249.61047	651.3034
Point 55	247.81262	651.5924
Point 56	243.06874	652.4655
Point 57	235.69178	653.9221
Point 58	212.39077	655.8256
Point 59	207.17314	657.5836
Point 60	204.28213	658.0709
Point 61	197.46189	660.0008
Point 62	192.80663	660.6529
Point 63	185.53317	660.9307
Point 64	184.03956	660.9749
Point 65	173.13572	660.4524
Point 66	166.60252	660.1628
Point 67	164.93059	660.0008
Point 68	157.55079	659.1082
Point 69	156.96739	659.2087
Point 70	150.09613	658.5439
Point 71	144.22778	658.0809
Point 72	143.43809	658.218

Point 73	136.29536	659.5715
Point 74	124.16845	659.2793
Point 75	120.06523	659.2642
Point 76	101.1411	659.0708
Point 77	96.93915	658.9887
Point 78	75.53524	659.6735
Point 79	71.54497	659.7824
Point 80	63.91382	660.0008
Point 81	56.69252	660.2908
Point 82	56.25338	660.3097
Point 83	51.5101	660.1655
Point 84	47.91942	660.0008
Point 85	43.57514	659.9731
Point 86	37.25178	659.9476
Point 87	15.88238	659.809
Point 88	15.38216	659.8061
Point 89	15.26928	659.805
Point 90	-4.33215	659.8763
Point 91	-13.95702	659.8807
Point 92	-16.84171	659.8919
Point 93	-27.54675	659.8822
Point 94	-43.26967	659.9473
Point 95	-48.10755	659.9678
Point 96	-49.16786	659.9719
Point 97	-51.29902	659.9759
Point 98	-56.91536	659.9813
Point 99	-57.36383	659.9822
Point 100	-71.72542	659.9943
Point 101	-72.27759	659.9953
Point 102	-72.71754	659.9959
Point 103	-77.51457	660.0008
Point 104	-80.12556	660.3701
Point 105	-80.43329	660.3826
Point 106	-91.20495	662.1665
Point 107	-93.86835	661.9907
Point 108	-102.02052	663.332
Point 109	-104.44391	663.1704
Point 110	-108.27329	663.0626
Point 111	-119.27774	663.9084
Point 112	-125.59455	664.34
Point 113	-200	666.4545
Point 114	334.44	651.7132
Point 115	345.43553	651.5948
Point 116	348.00486	651.5623
Point 117	361.51331	651.3534
Point 118	372.9581	651.1923
Point 119	390.68453	650.957

Point 120	405.22518	651.0814
Point 121	411.09583	651.0585
Point 122	414.02518	651.0786
Point 123	417.40055	651.072
Point 124	419.5093	651.089
Point 125	422.71179	651.0876
Point 126	425.16623	651.1104
Point 127	429.54584	651.1174
Point 128	440.39696	651.1239
Point 129	447.91152	651.1229
Point 130	458.02619	651.3274
Point 131	493.24762	648.4349
Point 132	524.74647	647.969
Point 133	113.86	761.07
Point 134	134.63	769.93
Point 135	154.09	770.57
Point 136	163.11	768.22
Point 137	207.12	750.72
Point 138	234.33	738.92
Point 139	262.34	726.92
Point 140	280.84	719.98
Point 141	283.41	718.87
Point 142	286.3	719.93
Point 143	297.84	720.24
Point 144	344.96	699.81
Point 145	383.68	684.74
Point 146	417.44	669.6
Point 147	420.54	668.04
Point 148	423.33	669.22
Point 149	443.74	670.61
Point 150	487.96	653.7
Point 151	-200	750.95
Point 152	95.2232	750.95
Point 153	163.0634	744.33
Point 154	434.9039	663.1
Point 155	650	600
Point 156	650	626.2916
Point 157	650	628.5629
Point 158	650	645.759
Point 159	260.0928	709.5
Point 160	382.6296	682.42

Static Slope Stability Analysis - Lower

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 169
Last Edited By: Cedric Ruhl
Date: 9/16/2010
Time: 3:29:46 PM
File Name: AD 10+00 WSEL = 74563.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 10+00\
Last Solved Date: 9/16/2010
Last Solved Time: 3:30:36 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Static Slope Stability Analysis - Lower

Description: Ash Dike Section Sta. 10+00 Water Surface Elevation = 745.63
Kind: SLOPE/W
Parent: Seepage Analysis - Static Condition
Method: Spencer
Settings
    PWP Conditions Source: Parent Analysis
Slip Surface
    Direction of movement: Left to Right
    Use Passive Mode: No
    Slip Surface Option: Entry and Exit
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: Yes
    Tension Crack
        Tension Crack Option: (none)
FOS Distribution
    FOS Calculation Option: Constant
Advanced
    Number of Slices: 30

Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 3 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Shear/Normal Fn.
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Strength Function: Ash Dike Fill
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Shear/Normal Fn.
Unit Weight: 124 pcf
Strength Function: Ash Dike Res
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Rock

Model: Bedrock (Impenetrable)

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (245.09497, 734.3081) ft
Left-Zone Right Coordinate: (340.00003, 701.9605) ft
Left-Zone Increment: 4
Right Projection: Range

Right-Zone Left Coordinate: (398.66817, 678.0184) ft
Right-Zone Right Coordinate: (625, 645.759) ft
Right-Zone Increment: 4
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (-200, 666.4545) ft
Right Coordinate: (650, 645.759) ft

Shear/Normal Strength Functions

Ash Dike Fill

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
- Curve Fit to Data: 100 %
- Segment Curvature: 0 %

Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
- Data Point: (0, 0)
- Data Point: (500, 433)
- Data Point: (1000, 829)
- Data Point: (1500, 1188)
- Data Point: (2000, 1511)
- Data Point: (2500, 1797)
- Data Point: (3000, 2047)
- Data Point: (3500, 2259)
- Data Point: (4000, 2436)
- Data Point: (4500, 2575)
- Data Point: (5000, 2678)
- Data Point: (5500, 2744)
- Data Point: (6000, 2774)
- Data Point: (20000, 2800)

Estimation Properties
- Intact Rock Param.: 10
- Geological Strength: 100
- Disturbance Factor: 0
- SigmaC: 600000 psf
- Sigma3: 300000 psf
- Num. Points: 20

Ash Dike Res

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
- Curve Fit to Data: 100 %
- Segment Curvature: 0 %

Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
- Data Point: (0, 0)

Data Point: (500, 526)
Data Point: (1000, 999)
Data Point: (1500, 1417)
Data Point: (2000, 1781)
Data Point: (2500, 2092)
Data Point: (3000, 2349)
Data Point: (3500, 2552)
Data Point: (4000, 2700)
Data Point: (4500, 2795)
Data Point: (5000, 2837)
Data Point: (20000, 3500)

Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	Rock	1,2,3,4,5,6	22678.912
Region 2	PWR	7,8,9,10,11,12,13,14,15,16,17,18,1,6,5,4	7884.8849
Region 3	Residuum	7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31, 32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55, 56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79, 80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102, 103,104,105,106,107,108,109,110,111,112,113	11257.694
Region 4	Blanket Drain	20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,114,115,116,117, 118,119,120,121,122,123,124,125,126,127,128,129,130,131,132	395.05906
Region 5	Embankment Fill - Ash Dike	101,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149, 150,132,131,130,129,128,127,126,125,124,123,122,121,120,119,118,117,116, 115,114,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59, 60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84, 85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100	32814.463
Region 6	Residuum	19,18,157,158	1719.61
Region 7	PWR	18,1,156,157	227.13
Region 8	Rock	156,155,2,1	2629.16

Points

	X (ft)	Y (ft)
Point 1	550	626.2916
Point 2	550	600
Point 3	-200	600
Point 4	-200	631.2263
Point 5	435.77054	629.9876
Point 6	438.77054	629.9876

Point 7	-200	648.4542
Point 8	115.92382	645.6152
Point 9	153.92041	645.3586
Point 10	259.22799	638.5324
Point 11	264.65748	638.2309
Point 12	370.34779	631.7877
Point 13	419.11319	632.9682
Point 14	422.11319	632.9682
Point 15	435.77054	632.1976
Point 16	438.77054	632.1976
Point 17	505.53902	630.9464
Point 18	550	628.5629
Point 19	550	645.759
Point 20	538.93239	645.759
Point 21	493.15087	646.4361
Point 22	457.9644	649.3258
Point 23	447.9316	649.1229
Point 24	440.39668	649.1239
Point 25	429.54704	649.1174
Point 26	425.1771	649.1104
Point 27	422.72062	649.0876
Point 28	419.51694	649.089
Point 29	417.40666	649.072
Point 30	414.03007	649.0786
Point 31	411.0988	649.0585
Point 32	405.22983	649.0813
Point 33	390.67981	648.9569
Point 34	372.93156	649.1925
Point 35	361.48377	649.3536
Point 36	347.97674	649.5625
Point 37	345.4121	649.595
Point 38	334.44	649.713
Point 39	329.03159	649.7712
Point 40	326.05577	649.8079
Point 41	323.36622	649.844
Point 42	320.67423	649.8778
Point 43	315.64527	649.9205
Point 44	315.05016	649.9228
Point 45	304.48331	649.9634
Point 46	304.18245	649.9655
Point 47	303.91306	649.9678
Point 48	289.7402	650.0008
Point 49	286.04752	650.1426
Point 50	275.87032	650.1308
Point 51	275.68718	650.1467
Point 52	252.33972	651.0708
Point 53	250.94149	651.1413
Point 54	249.61047	651.3034
Point 55	247.81262	651.5924

Point 56	243.06874	652.4655
Point 57	235.69178	653.9221
Point 58	212.39077	655.8256
Point 59	207.17314	657.5836
Point 60	204.28213	658.0709
Point 61	197.46189	660.0008
Point 62	192.80663	660.6529
Point 63	185.53317	660.9307
Point 64	184.03956	660.9749
Point 65	173.13572	660.4524
Point 66	166.60252	660.1628
Point 67	164.93059	660.0008
Point 68	157.55079	659.1082
Point 69	156.96739	659.2087
Point 70	150.09613	658.5439
Point 71	144.22778	658.0809
Point 72	143.43809	658.218
Point 73	136.29536	659.5715
Point 74	124.16845	659.2793
Point 75	120.06523	659.2642
Point 76	101.1411	659.0708
Point 77	96.93915	658.9887
Point 78	75.53524	659.6735
Point 79	71.54497	659.7824
Point 80	63.91382	660.0008
Point 81	56.69252	660.2908
Point 82	56.25338	660.3097
Point 83	51.5101	660.1655
Point 84	47.91942	660.0008
Point 85	43.57514	659.9731
Point 86	37.25178	659.9476
Point 87	15.88238	659.809
Point 88	15.38216	659.8061
Point 89	15.26928	659.805
Point 90	-4.33215	659.8763
Point 91	-13.95702	659.8807
Point 92	-16.84171	659.8919
Point 93	-27.54675	659.8822
Point 94	-43.26967	659.9473
Point 95	-48.10755	659.9678
Point 96	-49.16786	659.9719
Point 97	-51.29902	659.9759
Point 98	-56.91536	659.9813
Point 99	-57.36383	659.9822
Point 100	-71.72542	659.9943
Point 101	-72.27759	659.9953
Point 102	-72.71754	659.9959
Point 103	-77.51457	660.0008
Point 104	-80.12556	660.3701

Point 105	-80.43329	660.3826
Point 106	-91.20495	662.1665
Point 107	-93.86835	661.9907
Point 108	-102.02052	663.332
Point 109	-104.44391	663.1704
Point 110	-108.27329	663.0626
Point 111	-119.27774	663.9084
Point 112	-125.59455	664.34
Point 113	-200	666.4545
Point 114	334.44	651.7132
Point 115	345.43553	651.5948
Point 116	348.00486	651.5623
Point 117	361.51331	651.3534
Point 118	372.9581	651.1923
Point 119	390.68453	650.957
Point 120	405.22518	651.0814
Point 121	411.09583	651.0585
Point 122	414.02518	651.0786
Point 123	417.40055	651.072
Point 124	419.5093	651.089
Point 125	422.71179	651.0876
Point 126	425.16623	651.1104
Point 127	429.54584	651.1174
Point 128	440.39696	651.1239
Point 129	447.91152	651.1229
Point 130	458.02619	651.3274
Point 131	493.24762	648.4349
Point 132	524.74647	647.969
Point 133	113.86	761.07
Point 134	134.63	769.93
Point 135	154.09	770.57
Point 136	163.11	768.22
Point 137	207.12	750.72
Point 138	234.33	738.92
Point 139	262.34	726.92
Point 140	280.84	719.98
Point 141	283.41	718.87
Point 142	286.3	719.93
Point 143	297.84	720.24
Point 144	344.96	699.81
Point 145	383.68	684.74
Point 146	417.44	669.6
Point 147	420.54	668.04
Point 148	423.33	669.22
Point 149	443.74	670.61
Point 150	487.96	653.7
Point 151	-200	750.95
Point 152	95.2232	750.95
Point 153	163.0634	744.33

Point 154	434.9039	663.1
Point 155	650	600
Point 156	650	626.2916
Point 157	650	628.5629
Point 158	650	645.759
Point 159	260.0928	709.5
Point 160	382.6296	682.42

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.82	(477.149, 1007.18)	129.3343	(267.407, 725.019)	(528.599, 647.369)
2	12	1.89	(477.149, 1007.18)	358.205	(245.095, 734.308)	(509.096, 650.407)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	273.56985	720.3032	-479.76759	204.01865	176.68287	5.2011e-006
2	Optimized	280.2864	715.10555	-365.91931	408.47963	353.74881	-5.0915e-006
3	Optimized	282.125	713.506	-327.96443	475.74217	411.99907	-5.93e-006
4	Optimized	284.855	711.13095	-265.12686	667.15066	528.37908	37
5	Optimized	291.46885	705.37695	-106.12747	1194.3172	857.50878	111
6	Optimized	297.23885	700.36705	36.648347	1642.6497	1037.4586	219
7	Optimized	301.2589	696.93605	137.14713	1822.881	1088.9649	219
8	Optimized	308.0967	691.10015	306.28672	2089.1882	1151.7341	219
9	Optimized	315.3883	685.70405	452.05197	2536.8111	1192.5036	367
10	Optimized	323.13365	680.74775	573.89546	2698.3048	1215.184	367
11	Optimized	332.16295	675.63435	686.22863	3002.0722	1324.6863	367
12	Optimized	341.1398	671.49215	754.43203	3215.6259	1407.8282	367
13	Optimized	350.70495	667.719	800.61466	3204.1427	1374.8427	367
14	Optimized	361.3722	663.9479	834.9418	3316.24	1419.3281	367
15	Optimized	371.21685	660.93805	849.5127	3223.8605	1358.1514	367
16	Optimized	379.9096	658.68265	851.06593	3286.6367	1393.1715	367
17	Optimized	387.72035	657.12805	836.51112	3080.7524	1283.7291	367
18	Optimized	395.8996	656.00765	802.32294	2988.836	1250.708	367
19	Optimized	404.1774	655.37515	745.76958	2594.1068	1194.0048	219
20	Optimized	412.87815	654.79785	687.40819	2192.3309	972.16298	219
21	Optimized	418.99	654.4481	646.94173	1866.3019	875.48943	111
22	Optimized	421.935	654.2796	627.25348	1865.4431	889.00875	111
23	Optimized	426.96385	653.99185	593.5912	2018.9327	1023.3821	111
24	Optimized	433.8833	653.30725	560.86392	2056.3454	1073.742	111
25	Optimized	440.45445	652.354	543.98123	2231.4977	1090.1165	219
26	Optimized	446.2774	651.5093	529.63263	2244.5862	1107.8405	219
27	Optimized	452.608	650.5909	524.46747	2047.9082	1106.8445	0
28	Optimized	457.2137	649.9499	524.80996	1944.2842	1031.3084	0
29	Optimized	462.593	649.34955	514.7244	1757.4947	902.92546	0
30	Optimized	471.74555	648.3281	497.17264	1440.0138	685.01418	0
31	Optimized	482.00515	647.36515	461.74605	1081.7383	450.45071	0

32	Optimized	487.8195	646.91655	434.21936	898.39715	337.24491	0
33	Optimized	490.6038	646.967	404.57696	830.57782	309.50774	0
34	Optimized	497.9025	647.0992	324.90675	663.85023	246.25685	0
35	Optimized	507.21225	647.2678	222.01013	450.58218	166.06732	0
36	Optimized	518.3068	647.35855	104.30659	208.89269	75.986253	0
37	Optimized	526.67275	647.3669	19.359427	38.538711	13.934566	0

Slices of Slip Surface: 12

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	12	249.40625	730.75615	-603.64412	140.84343	121.97229	9.1666e-007
2	12	258.02875	723.8698	-449.34677	415.30243	359.65745	-5.1677e-006
3	12	266.965	717.18335	-309.16492	698.69573	553.36257	37
4	12	276.215	710.69685	-168.86326	989.07029	783.33738	37
5	12	282.125	706.7283	-77.805201	1160.2078	833.01852	111
6	12	284.855	704.97475	-35.315212	1329.5826	954.62808	111
7	12	292.07	700.5724	73.980186	1845.1832	1144.177	219
8	12	302.552	694.45875	223.53703	2316.1612	1197.0025	367
9	12	311.976	689.37905	339.09843	2470.6214	1219.253	367
10	12	321.4	684.65465	438.67	2589.2309	1230.1429	367
11	12	330.824	680.27015	521.67858	2672.2673	1230.1589	367
12	12	340.248	676.21205	588.62348	2719.8464	1219.0814	367
13	12	349.8	672.4218	637.90159	2754.6233	1210.7866	367
14	12	359.48	668.89705	674.75666	2777.0839	1202.5528	367
15	12	369.16	665.683	693.07477	2763.3751	1184.2331	367
16	12	378.84	662.771	705.24168	2713.2245	1148.5868	367
17	12	387.9	660.30375	709.56792	2604.7401	1224.2597	219
18	12	396.34	658.2407	707.25413	2440.3915	1119.587	219
19	12	404.78	656.3928	696.91174	2244.9057	999.98647	219
20	12	413.22	654.7567	686.10203	2016.3836	955.12995	111
21	12	418.99	653.73615	677.94787	1832.8688	829.22261	111
22	12	421.935	653.2635	671.55426	1877.3984	865.78503	111
23	12	427.0044	652.52635	657.28718	2092.1951	1030.2507	111
24	12	434.3532	651.56465	633.22427	2305.6551	1080.3713	219
25	12	439.2123	650.9963	617.08862	2433.0179	1319.3499	0
26	12	442.0685	650.7056	609.67115	2507.6894	1378.9909	0
27	12	445.82575	650.358	597.84189	2480.6797	1367.9617	0
28	12	452.96885	649.8327	568.62436	2221.4879	1200.8757	0
29	12	462.59575	649.3047	517.47625	1839.5706	960.55774	0
30	12	471.7349	649.0498	452.76953	1433.7775	712.74399	0
31	12	480.87405	649.02825	369.927	983.79138	445.99857	0
32	12	486.7018	649.10935	309.94341	686.26041	325.89555	-4.678e-006
33	12	493.244	649.3806	227.03211	476.29761	215.86725	6.3384e-006
34	12	503.812	650.01275	79.826184	169.04146	77.261623	3.8664e-006

ASH DIKE SECTION STA. 12+00

Seepage Analysis – Static Condition

Seepage Analysis Flow Net – Static Condition

Static Slope Stability Analysis – Global

Static Slope Stability Analysis – Upper

Static Slope Stability Analysis – Lower

Seepage Analysis - Pool from 100-year Slope Storm Event

Pool from 100-year Slope Storm Event Stability Analysis – Global

Pool from 100-year Slope Storm Event Stability Analysis – Upper

Pool from 100-year Storm Event Slope Stability Analysis – Lower

Seepage Analysis - Surcharge Pool = 760

Surcharge Pool = 760 Slope Stability Analysis – Global

Surcharge Pool = 760 Slope Stability Analysis – Upper

Surcharge Pool = 760 Slope Stability Analysis – Lower

Pseudostatic Slope Stability Analysis – Global

Pseudostatic Slope Stability Analysis – Upper

Pseudostatic Slope Stability Analysis – Lower

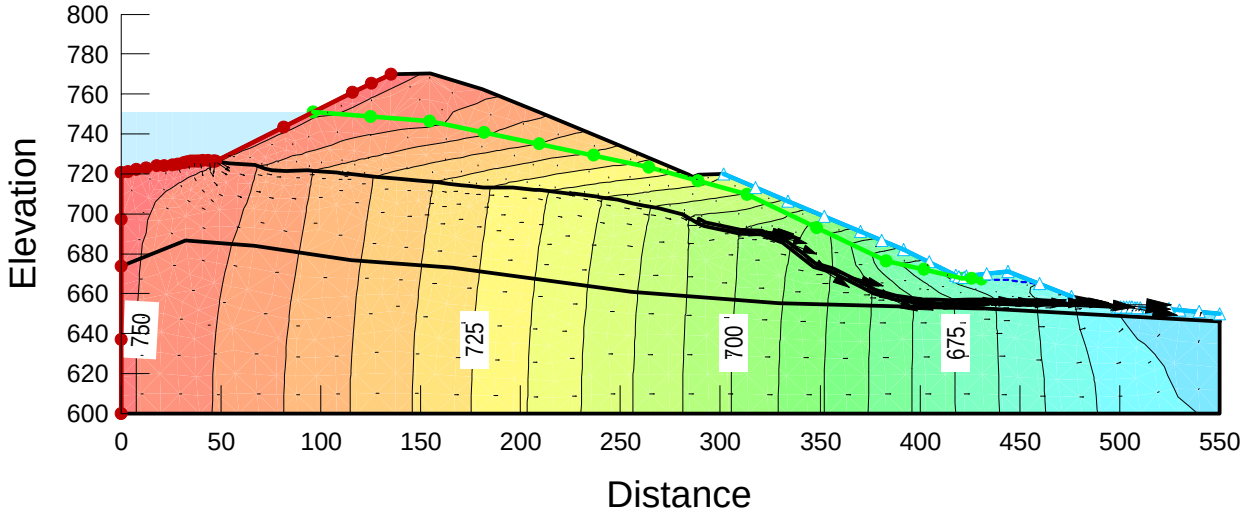
Rapid Drawdown Stability Analysis

Seepage Analysis - Water Surface Elevation = 745.63

Water Surface Elevation = 745.63 Slope Stability Analysis – Lower

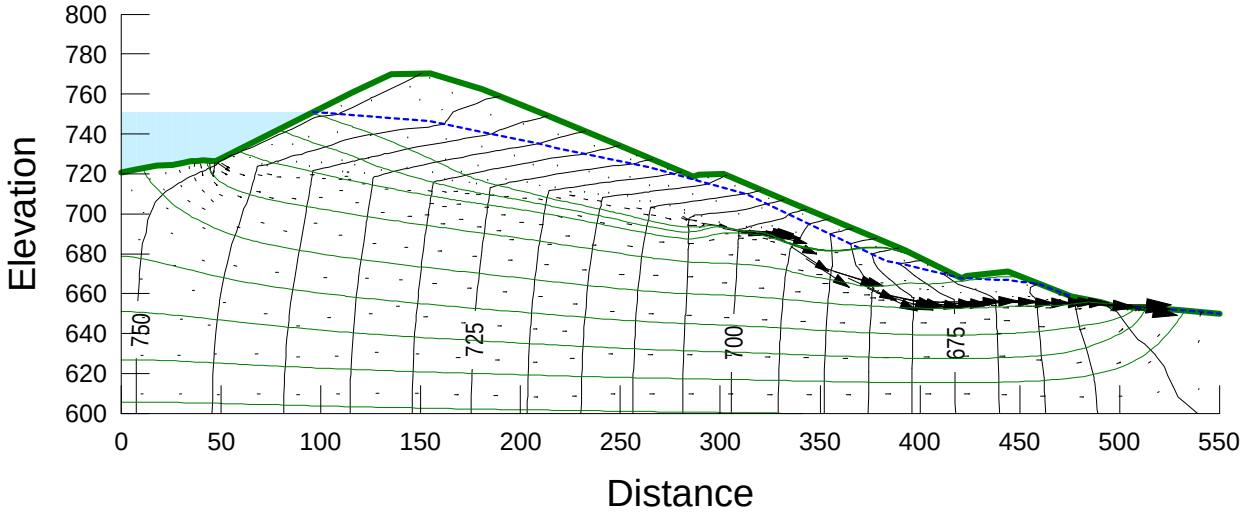
Name: Seepage Analysis - Static Condition
Description: Ash Dike Section Sta. 12+00

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 3e-6 K-Ratio: 0.1 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0



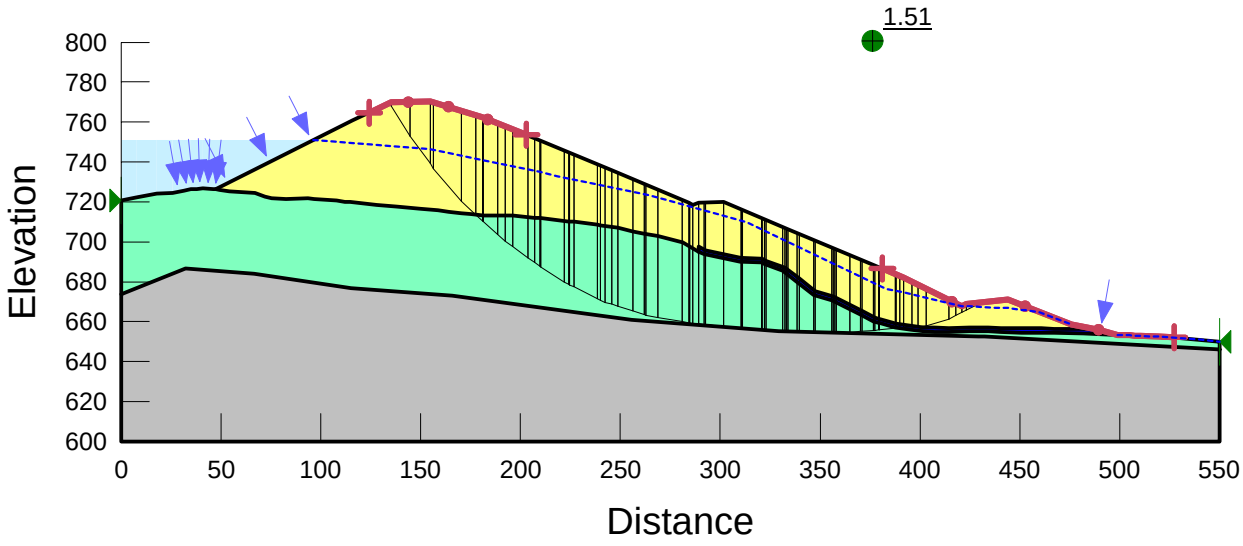
Name: Seepage Analysis - Static Condition
Description: Ash Dike Section Sta. 12+00

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 3e-6 K-Ratio: 0.1 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0



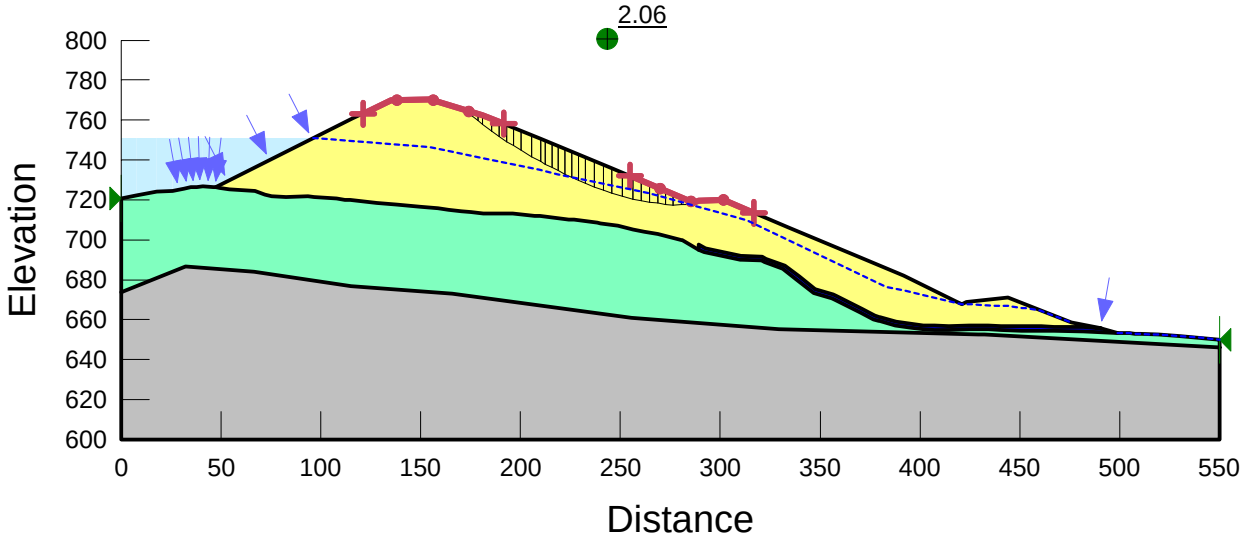
Name: Static Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 12+00

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0



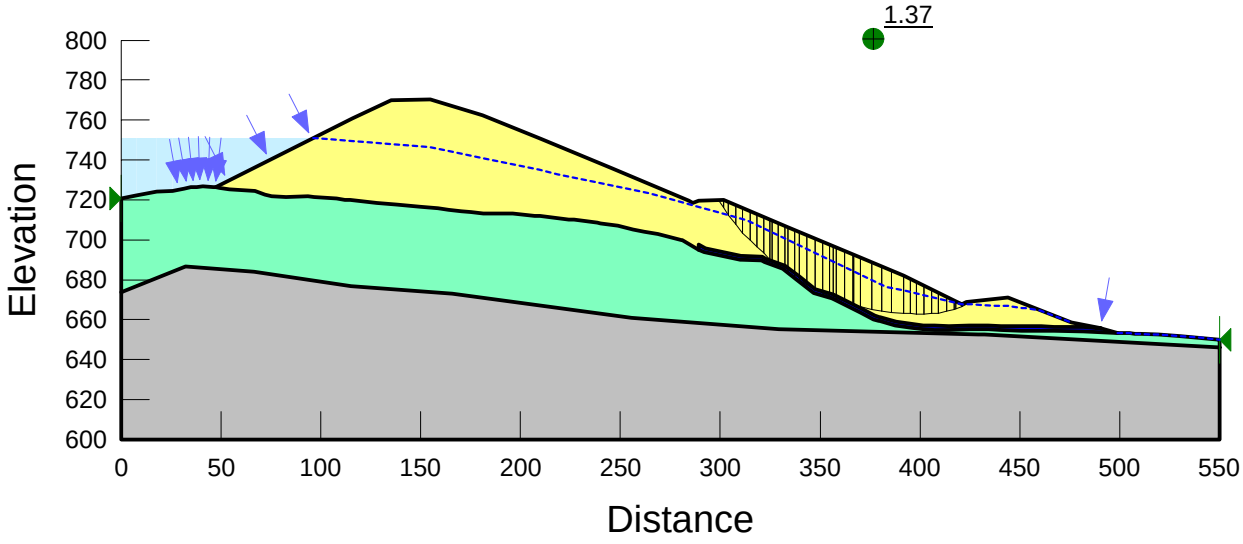
Name: Static Slope Stability Analysis - Upper
Description: Ash Dike Section Sta. 12+00

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0



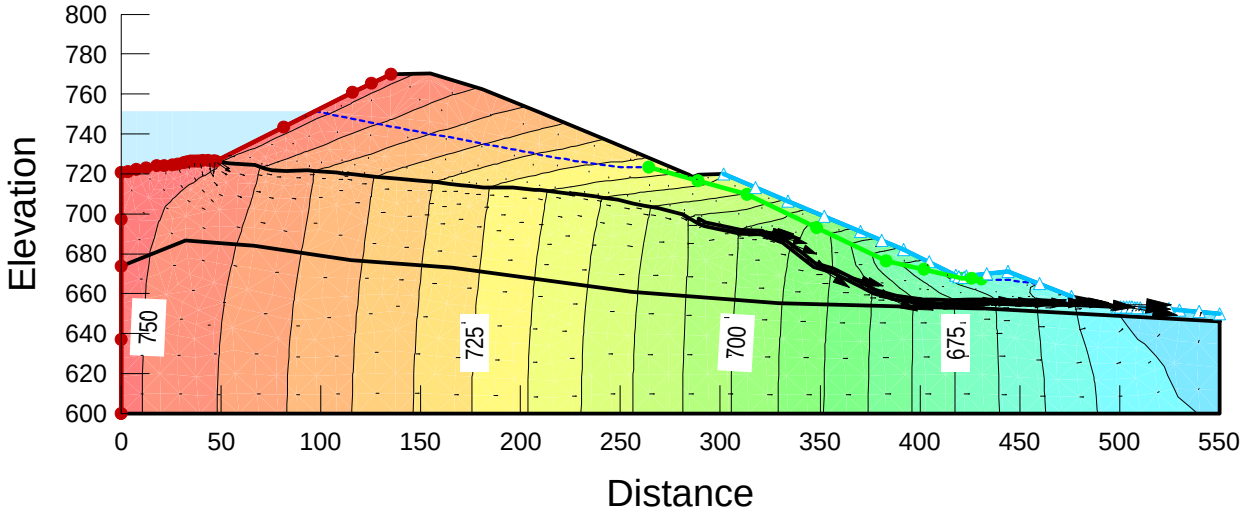
Name: Static Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 12+00

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0



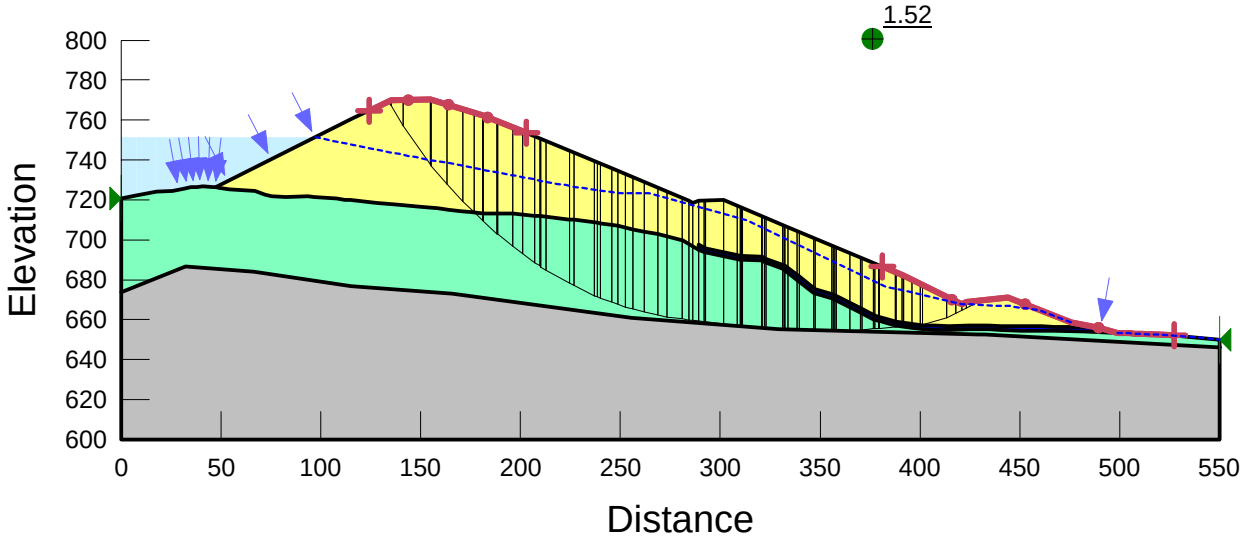
Name: Seepage Analysis - Pool from 100-yr Storm Event Condition
Description: Ash Dike Section Sta. 12+00
Pool from 100-yr Storm Event = 751.4

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 3e-6 K-Ratio: 0.1 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0



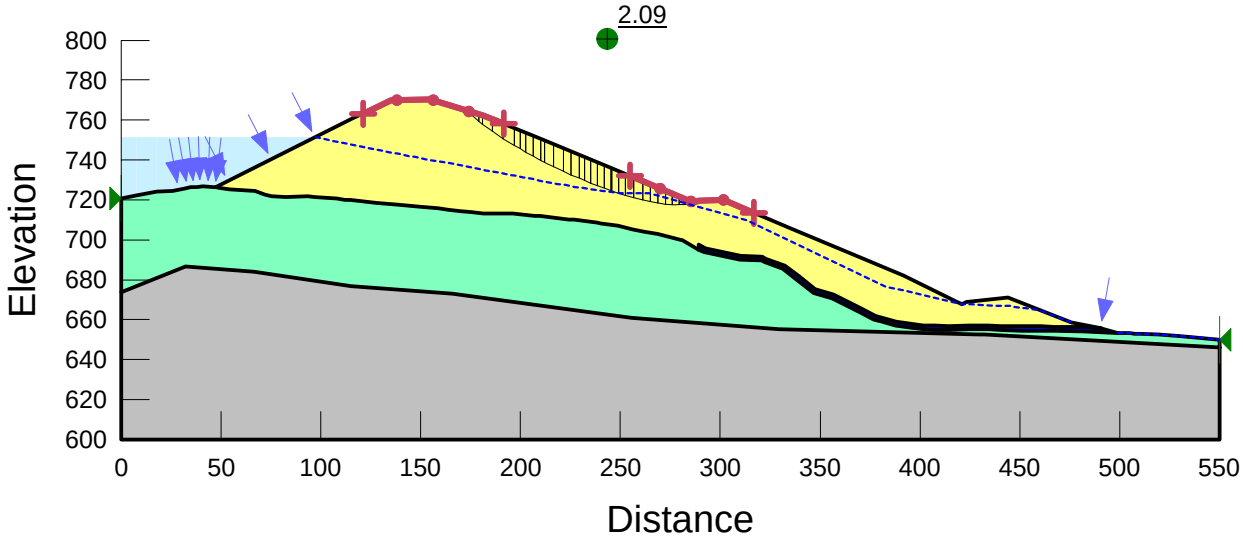
Name: Pool from 100-yr Storm Event Condition Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 12+00
Pool from 100-yr Storm Event = 751.4

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0



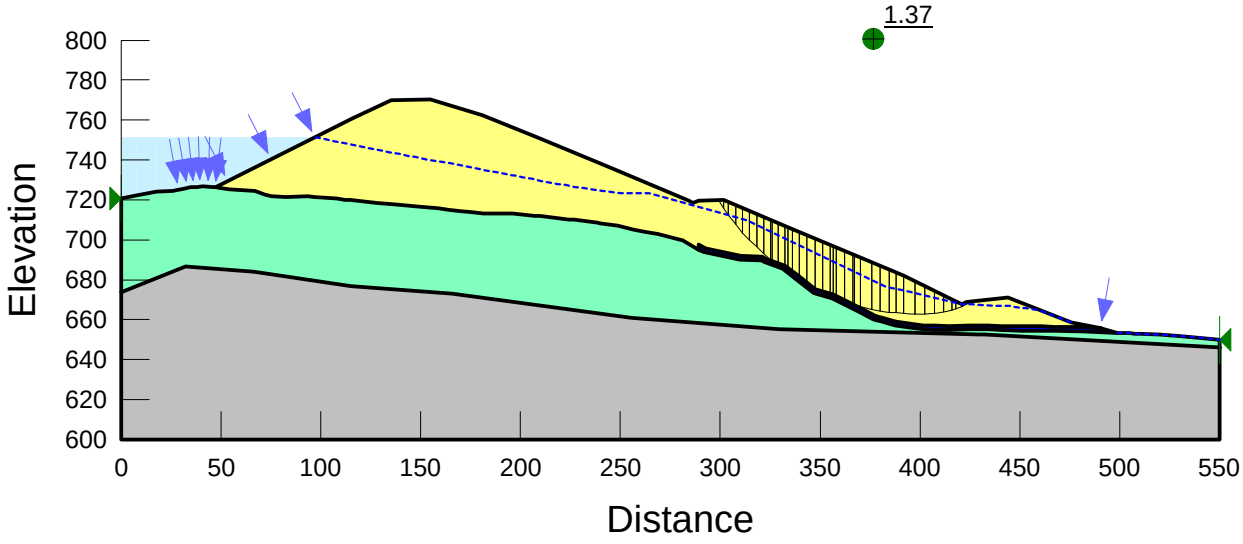
Name: Pool from 100-yr Storm Event Condition Slope Stability Analysis - Upper
Description: Ash Dike Section Sta. 12+00
Pool from 100-yr Storm Event = 751.4

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0



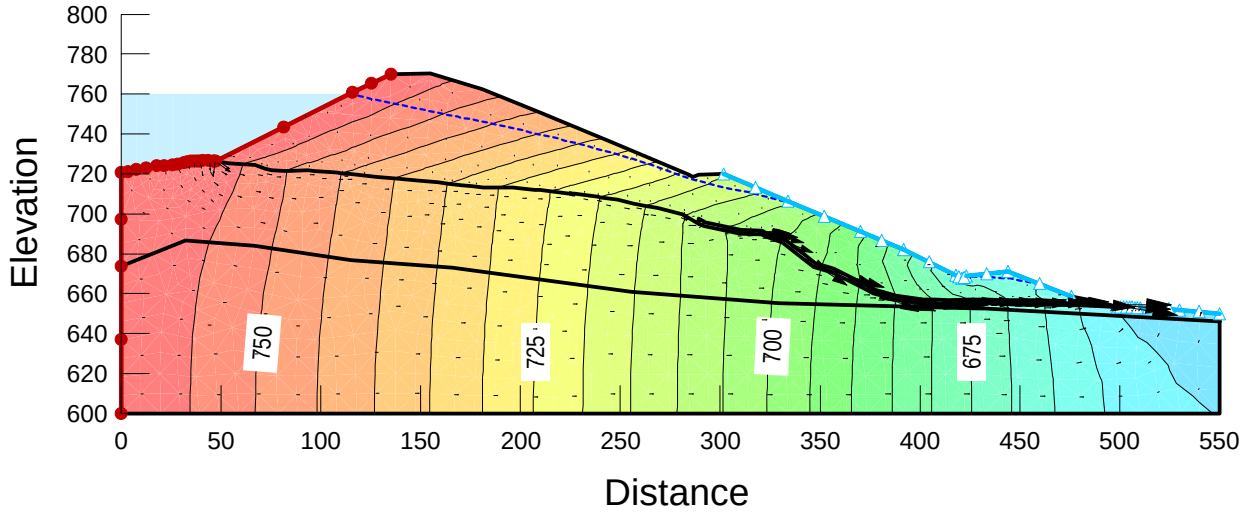
Name: Pool from 100-yr Storm Event Condition Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 12+00
Pool from 100-yr Storm Event = 751.4

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0



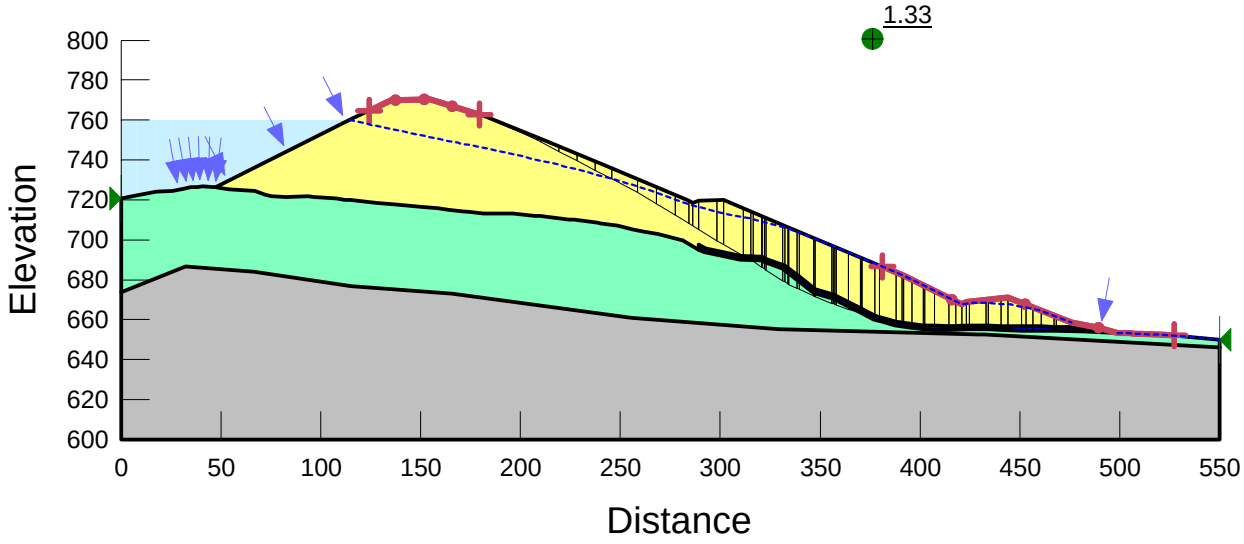
Name: Seepage Analysis - Surcharge Pool Condition
Description: Ash Dike Section Sta. 12+00
Surcharge Pool = 760

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 3e-6 K-Ratio: 0.1 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0



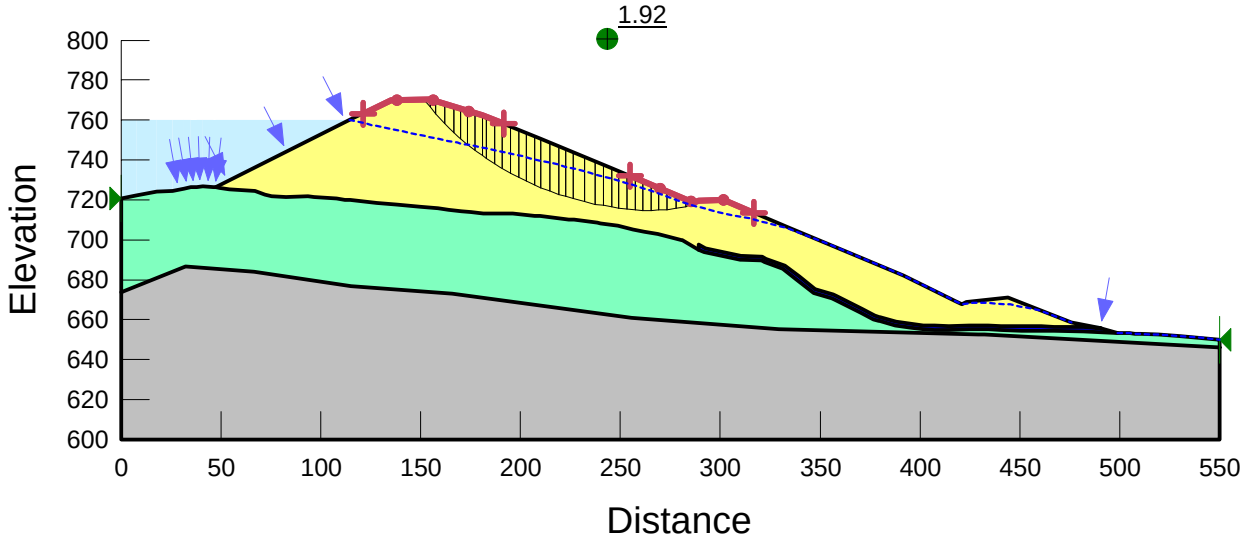
Name: Surcharge Pool Condition Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 12+00
Surcharge Pool = 760

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0



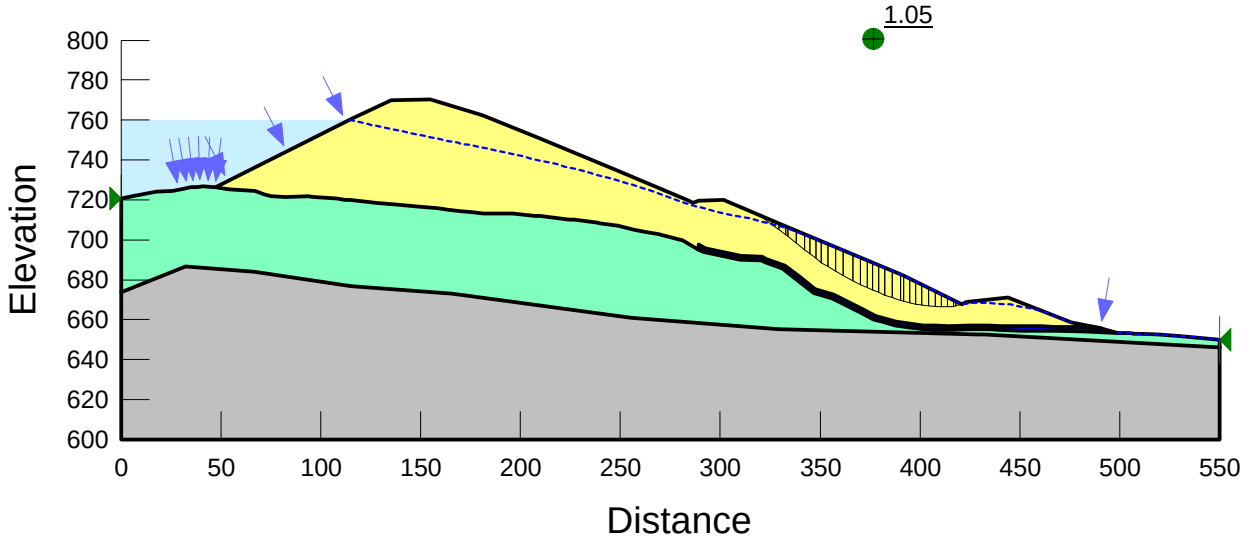
Name: Surcharge Pool Condition Slope Stability Analysis - Upper
Description: Ash Dike Section Sta. 12+00
Surcharge Pool = 760

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0



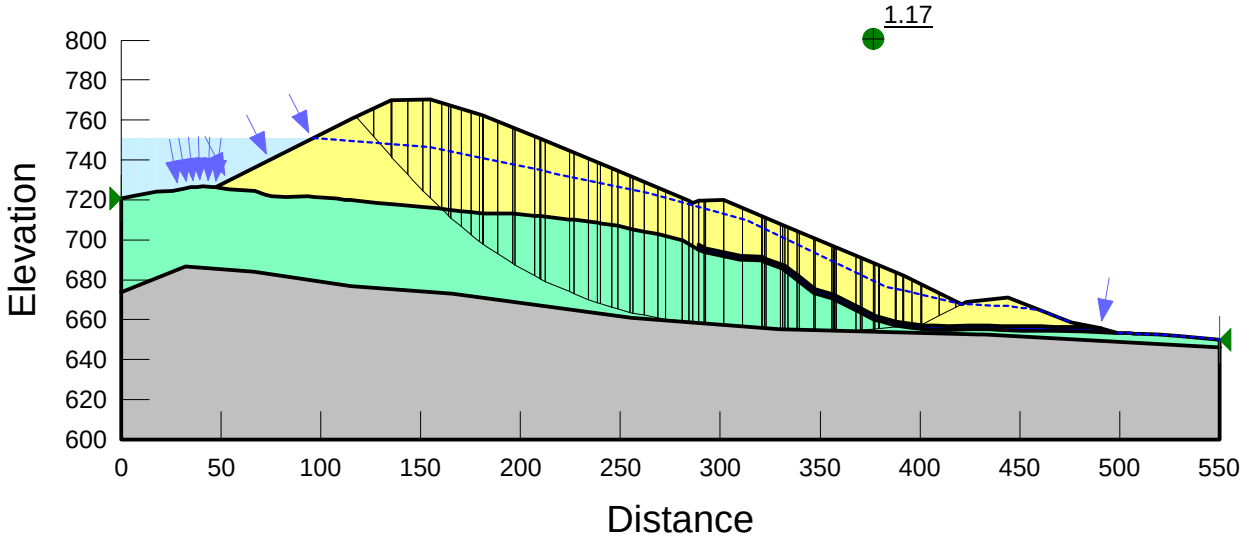
Name: Surcharge Pool Condition Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 12+00
Surcharge Pool = 760

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0



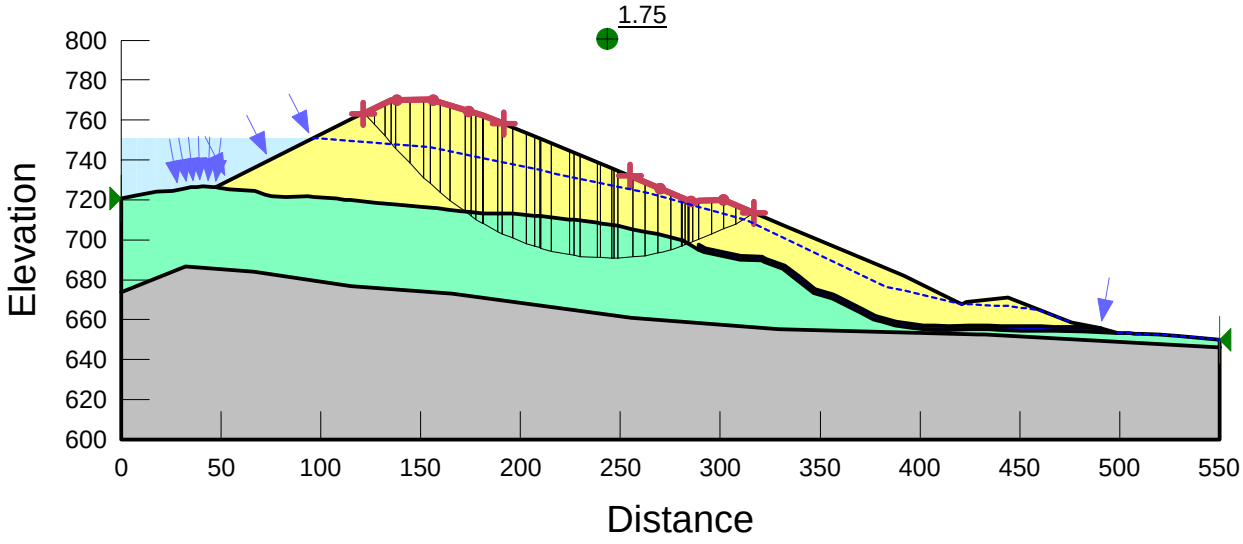
Name: Pseudostatic Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 12+00
Seismic Coefficient "k" = 0.06 g

Name: Embankment Fill - Ash Dike Model: Mohr-Coulomb Unit Weight: 123 Unit Wt. Above Water Table: 121 Cohesion: 1300 Phi: 12.5 Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Mohr-Coulomb Unit Weight: 124 Cohesion: 1400 Phi: 11.3 Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0



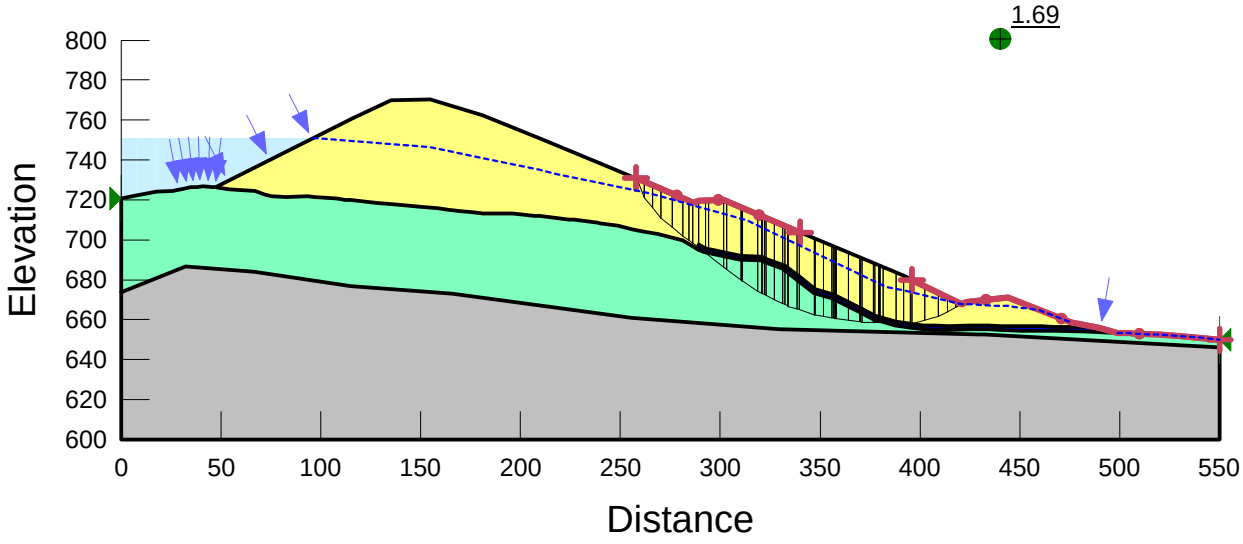
Name: Pseudostatic Slope Stability Analysis - Upper
Description: Ash Dike Section Sta. 12+00
Seismic Coefficient "k" = 0.06 g

Name: Embankment Fill - Ash Dike Model: Mohr-Coulomb Unit Weight: 123 Unit Wt. Above Water Table: 121 Cohesion: 1300 Phi: 12.5 Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Mohr-Coulomb Unit Weight: 124 Cohesion: 1400 Phi: 11.3 Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0



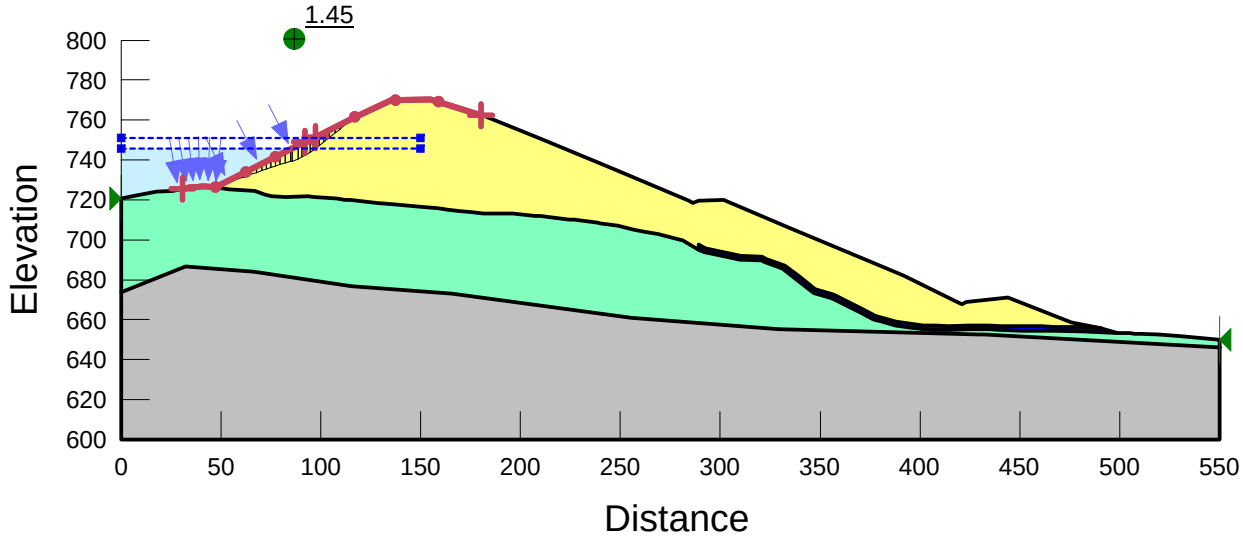
Name: Pseudostatic Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 12+00
Seismic Coefficient "k" = 0.06 g

Name: Embankment Fill - Ash Dike Model: Mohr-Coulomb Unit Weight: 123 Unit Wt. Above Water Table: 121 Cohesion: 1300 Phi: 12.5 Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Mohr-Coulomb Unit Weight: 124 Cohesion: 1400 Phi: 11.3 Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0



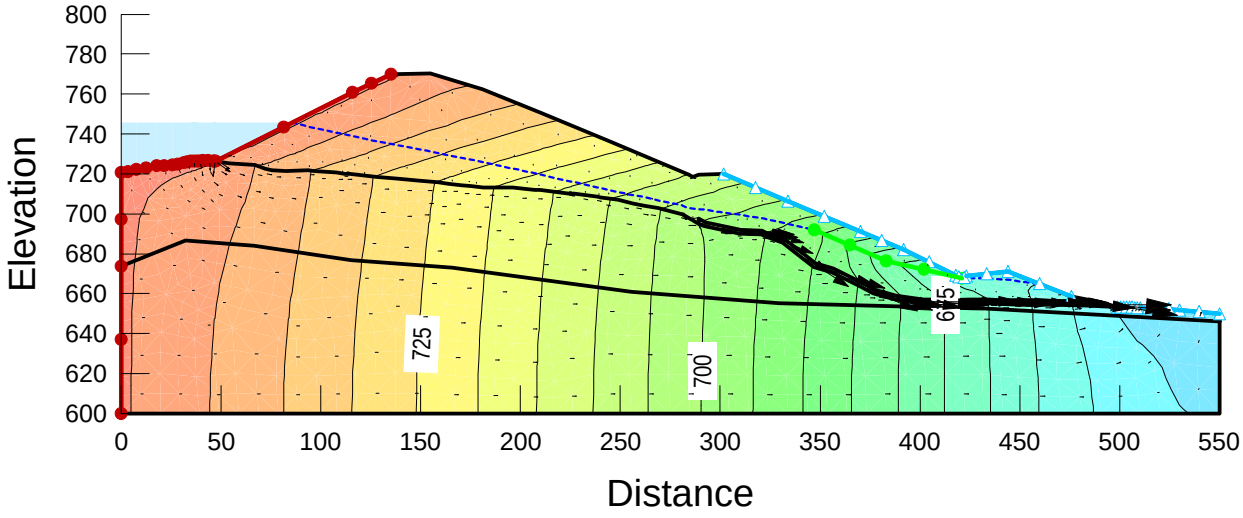
Name: Rapid Drawdown Slope Stability Analysis - Global
Description: Ash Dike Section Sta. 12+00
Pool Drawdown from 750.95 to 745.63

Name: Embankment Fill - Ash Dike Model: Mohr-Coulomb Unit Weight: 123 pcf Unit Wt. Above Water Table: 121 pcf Cohesion: 0 psf Phi: 38 ° Phi-B: 0 °
Drawdown Total Cohesion: 1300 psf Drawdown Total Phi: 12.5 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 36 ° Phi-B: 0 ° Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Residuum Model: Mohr-Coulomb Unit Weight: 124 pcf Cohesion: 0 psf Phi: 36 ° Phi-B: 0 ° Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 pcf Cohesion: 1000 psf Phi: 38 ° Phi-B: 0 ° Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2



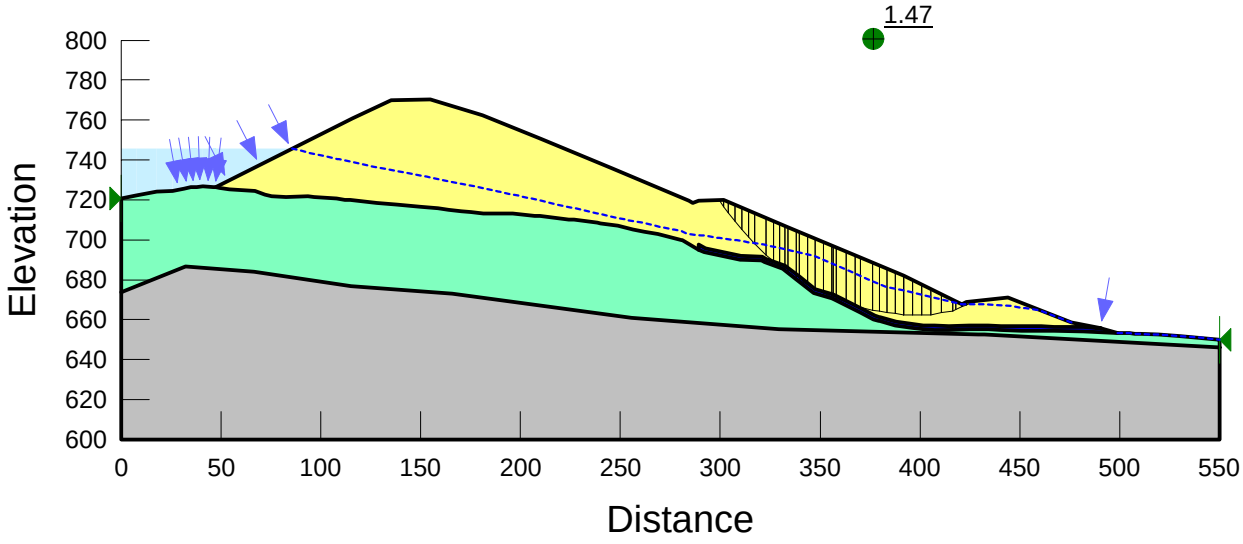
Name: Seepage Analysis - Static Condition
Description: Ash Dike Section Sta. 12+00
Water Surface Elevation = 745.63

Name: Embankment Fill - Ash Dike Model: Saturated / Unsaturated K-Function: 3e-6 K-Ratio: 0.1 K-Direction: 0
Name: Blanket Drain Model: Saturated / Unsaturated K-Function: 1e-4 K-Ratio: 1 K-Direction: 0
Name: Residuum Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0
Name: PWR Model: Saturated / Unsaturated K-Function: 1e-5 K-Ratio: 1 K-Direction: 0



Name: Static Slope Stability Analysis - Lower
Description: Ash Dike Section Sta. 12+00
Water Surface Elevation = 745.63

Name: Embankment Fill - Ash Dike Model: Shear/Normal Fn. Unit Weight: 123 Unit Wt. Above Water Table: 121 Strength Function: Ash Dike Fill Phi-B: 0
Name: Blanket Drain Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 0 Phi: 36 Phi-B: 0
Name: Residuum Model: Shear/Normal Fn. Unit Weight: 124 Strength Function: Ash Dike Res Phi-B: 0
Name: PWR Model: Mohr-Coulomb Unit Weight: 140 Cohesion: 1000 Phi: 38 Phi-B: 0



Seepage Analysis - Static Condition

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 165
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 6:55:56 PM
File Name: AD 12+00 Static.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 12+00\
Last Solved Date: 9/13/2010
Last Solved Time: 6:56:06 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Mass(M) Units: lbs
Mass Flux Units: lbs/sec
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Seepage Analysis - Static Condition

Description: Ash Dike Section Sta. 12+00
Kind: SEEP/W
Method: Steady-State
Settings
  Include Air Flow: No
Control
  Apply Runoff: Yes
Convergence
  Convergence Type: Gauss Point K
  Convergence Settings
    Maximum Number of Iterations: 500
    Tolerance: 0.01
    Maximum Change in K: 0.1
    Rate of Change in K: 1.02
    Minimum Change in K: 0.0001
  Equation Solver: Parallel Direct
  Potential Seepage Max # of Reviews: 10
Time
  Starting Time: 0 sec
  Duration: 0 sec

Ending Time: 0 sec

Materials

Embankment Fill - Ash Dike

Model: Saturated / Unsaturated
Hydraulic
K-Function: 3e-6
K-Ratio: 0.1
K-Direction: 0 °

Blanket Drain

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

Residuum

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

PWR

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

Boundary Conditions

Water Elevation

Type: Head (H) 750.95

Potential Seepage Face

Review: true
Type: Total Flux (Q) 0

Zero Pressure

Type: Pressure Head 0

K Functions

1e-4

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %

Segment Curvature: 100 %
K-Saturation: 3.28e-006
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-006)
Data Point: (10000, 3.28e-006)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

1e-5

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-007
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-007)
Data Point: (10000, 3.28e-007)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

3e-6

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 9.84e-008
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 9.84e-008)
Data Point: (10000, 9.84e-008)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

Regions

	Material	Points	Area (ft²)
Region 1	PWR	1,2,3,4,5,6,7,8,9,10,11,12	34875.27

Region 2	Residuum	13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,1,2,3,4,5,6,7,8,9,10	15102.129
Region 3	Embankment Fill - Ash Dike	22,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,59,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23	11779.951
Region 4	Blanket Drain	96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88	429.94757

Lines

	Start Point	End Point	Hydraulic Boundary
Line 1	1	2	
Line 2	2	3	
Line 3	3	4	
Line 4	4	5	
Line 5	5	6	
Line 6	6	7	
Line 7	7	8	
Line 8	8	9	
Line 9	9	10	
Line 10	10	11	Water Elevation
Line 11	11	12	
Line 12	12	1	
Line 13	13	14	Water Elevation
Line 14	14	15	Water Elevation
Line 15	15	16	Water Elevation
Line 16	16	17	Water Elevation
Line 17	17	18	Water Elevation
Line 18	18	19	Water Elevation
Line 19	19	20	Water Elevation
Line 20	20	21	Water Elevation
Line 21	21	22	Water Elevation
Line 22	22	23	
Line 23	23	24	
Line 24	24	25	
Line 25	25	26	
Line 26	26	27	
Line 27	27	28	
Line 28	28	29	
Line 29	29	30	
Line 30	30	31	
Line 31	31	32	
Line 32	32	33	
Line 33	33	34	
Line 34	34	35	
Line 35	35	36	
Line 36	36	37	
Line 37	37	38	

Line 38	38	39	
Line 39	39	40	
Line 40	40	41	
Line 41	41	42	
Line 42	42	43	
Line 43	43	44	
Line 44	44	45	
Line 45	45	46	
Line 46	46	47	
Line 47	47	48	
Line 48	48	49	
Line 49	49	50	
Line 50	50	51	
Line 51	51	52	
Line 52	52	53	
Line 53	53	54	
Line 54	54	55	
Line 55	55	56	
Line 56	56	57	
Line 57	57	58	
Line 58	58	59	
Line 59	59	60	
Line 60	60	61	
Line 61	61	62	
Line 62	62	63	
Line 63	63	64	
Line 64	64	65	
Line 65	65	66	
Line 66	66	67	
Line 67	67	68	
Line 68	68	69	
Line 69	69	70	
Line 70	70	71	
Line 71	71	72	
Line 72	72	73	
Line 73	73	74	
Line 74	74	75	
Line 75	75	76	
Line 76	76	77	
Line 77	77	78	
Line 78	78	79	
Line 79	79	80	
Line 80	80	81	
Line 81	81	82	
Line 82	82	83	
Line 83	83	84	
Line 84	84	85	
Line 85	85	86	
Line 86	86	87	
Line 87	87	88	
Line 88	88	89	Potential Seepage Face
Line 89	89	90	Potential Seepage Face

Line 90	90	91	Potential Seepage Face
Line 91	91	92	Potential Seepage Face
Line 92	92	93	Potential Seepage Face
Line 93	93	94	Potential Seepage Face
Line 94	94	95	Potential Seepage Face
Line 95	95	1	
Line 96	10	13	Water Elevation
Line 97	22	126	Water Elevation
Line 98	126	127	Water Elevation
Line 99	127	128	
Line 100	128	129	
Line 101	129	130	
Line 102	130	131	
Line 103	131	132	
Line 104	132	133	
Line 105	133	134	
Line 106	134	135	
Line 107	135	136	Potential Seepage Face
Line 108	136	137	Potential Seepage Face
Line 109	137	138	Potential Seepage Face
Line 110	138	139	Potential Seepage Face
Line 111	139	140	Potential Seepage Face
Line 112	140	141	Potential Seepage Face
Line 113	141	142	Potential Seepage Face
Line 114	142	143	Potential Seepage Face
Line 115	143	144	
Line 116	144	96	
Line 117	96	97	
Line 118	97	98	
Line 119	98	99	
Line 120	99	100	
Line 121	100	101	
Line 122	101	102	
Line 123	102	103	
Line 124	103	104	
Line 125	104	105	
Line 126	105	106	
Line 127	106	107	
Line 128	107	108	
Line 129	108	109	
Line 130	109	110	
Line 131	110	111	
Line 132	111	112	
Line 133	112	113	
Line 134	113	114	
Line 135	114	115	
Line 136	115	116	
Line 137	116	117	
Line 138	117	118	
Line 139	118	119	
Line 140	119	120	
Line 141	120	121	

Line 142	121	122	
Line 143	122	123	
Line 144	123	124	
Line 145	124	125	
Line 146	125	59	
Line 147	88	96	
Line 148	147	148	Zero Pressure
Line 149	148	149	Zero Pressure
Line 150	149	150	Zero Pressure
Line 151	140	151	Zero Pressure
Line 152	156	88	
Line 153	151	156	
Line 154	150	140	Zero Pressure
Line 155	146	147	Zero Pressure

Points

	X (ft)	Y (ft)
Point 1	550	646.2121
Point 2	432.28284	652.71
Point 3	429.28284	652.71
Point 4	329.50979	655.3527
Point 5	255.39889	660.9638
Point 6	165.93156	672.8646
Point 7	115.00223	676.7478
Point 8	66.50809	683.9278
Point 9	32.02336	686.4408
Point 10	0	673.6772
Point 11	0	600
Point 12	550	600
Point 13	0	720.8323
Point 14	7.46834	722.0398
Point 15	17.77472	724.1848
Point 16	25.57517	724.516
Point 17	31.28542	725.5687
Point 18	34.87149	726.2089
Point 19	37.67175	726.5403
Point 20	40.93893	726.7039
Point 21	46.19081	726.4746
Point 22	47.16212	726.3444
Point 23	49.38769	726.046
Point 24	53.99285	725.1701
Point 25	66.88823	724.3223
Point 26	71.8387	722.4442
Point 27	75.30131	721.797
Point 28	82.45112	721.6417
Point 29	93.64932	721.9043
Point 30	96.52628	721.4946
Point 31	107.86425	720.7568
Point 32	112.04926	720.0827
Point 33	113.76575	720.0026
Point 34	114.78083	719.8752

Point 35	127.86646	718.305
Point 36	137.96649	717.6227
Point 37	149.75519	716.6597
Point 38	158.52901	715.7262
Point 39	163.94611	715.1232
Point 40	170.23801	714.2245
Point 41	175.22762	713.9809
Point 42	181.50178	713.2469
Point 43	188.5807	713.1223
Point 44	195.93295	713.0265
Point 45	207.0338	712.0464
Point 46	209.6519	712.0968
Point 47	224.14526	710.2482
Point 48	224.47398	710.2521
Point 49	226.65718	710.0026
Point 50	238.40625	708.4686
Point 51	240.00628	708.2563
Point 52	248.88633	707.0993
Point 53	256.27544	705.3133
Point 54	261.98263	704.1692
Point 55	268.69369	702.8011
Point 56	280.42697	700.0026
Point 57	280.55013	699.942
Point 58	280.81912	699.8237
Point 59	289.34	695.145
Point 60	291.93842	693.7183
Point 61	309.94718	690.0026
Point 62	310.6437	689.9203
Point 63	310.80713	689.8745
Point 64	320.52166	689.5469
Point 65	322.11323	688.7431
Point 66	331.40237	685.3953
Point 67	338.36902	680.0026
Point 68	346.67675	673.3234
Point 69	355.97678	670.6425
Point 70	357.3582	670.0026
Point 71	370.11699	663.5631
Point 72	376.6901	660.0026
Point 73	379.31551	659.301
Point 74	379.67289	659.2879
Point 75	387.50838	657.1924
Point 76	395.6543	655.9514
Point 77	401.62265	655.2704
Point 78	407.40479	654.9811
Point 79	414.69105	654.8719
Point 80	424.58073	655.1187
Point 81	434.12333	655.052
Point 82	440.76845	654.709
Point 83	450.8547	654.5724
Point 84	456.596	654.5475
Point 85	460.58523	654.5506
Point 86	467.1647	654.377

Point 87	481.83285	654.1694
Point 88	499.00652	653.4161
Point 89	501.90915	653.2851
Point 90	505.18877	653.174
Point 91	507.81999	653.0849
Point 92	510.26762	652.8252
Point 93	519.53725	652.4508
Point 94	530.07024	651.847
Point 95	550	650.0076
Point 96	491.0719	655.7661
Point 97	481.89084	656.1688
Point 98	467.20522	656.3767
Point 99	460.61083	656.5506
Point 100	456.59956	656.5475
Point 101	450.87258	656.5723
Point 102	440.83357	656.7083
Point 103	434.1819	657.0516
Point 104	424.56277	657.1189
Point 105	414.68108	656.8723
Point 106	407.46977	656.9803
Point 107	401.78616	657.2648
Point 108	395.91836	657.9343
Point 109	387.91859	659.153
Point 110	379.97164	661.2783
Point 111	379.61406	661.2914
Point 112	377.43481	661.8737
Point 113	371.04405	665.3355
Point 114	358.22938	671.8032
Point 115	356.67823	672.5218
Point 116	347.61678	675.1339
Point 117	339.60782	681.5728
Point 118	332.3772	687.1699
Point 119	322.90598	690.5834
Point 120	321.02968	691.5309
Point 121	311.11503	691.8653
Point 122	311.03314	691.8882
Point 123	310.26713	691.9787
Point 124	292.63726	695.6162
Point 125	289.34	697.4267
Point 126	115.99	760.87
Point 127	134.99	769.85
Point 128	154.66	770.34
Point 129	181.08	762.2
Point 130	210.24	750.56
Point 131	245.68	735.99
Point 132	284.25	719.57
Point 133	286.27	718.57
Point 134	289.34	719.52
Point 135	301.7	719.94
Point 136	333.76	706.14
Point 137	370.37	691.24
Point 138	391.78	681.97

Point 139	418.04	669.19
Point 140	420.85	667.78
Point 141	423.38	668.84
Point 142	444.04	671.12
Point 143	475.91	658.55
Point 144	489.58	656.04
Point 145	0	750.95
Point 146	96.2142	750.95
Point 147	154.2851	746.62
Point 148	264.3657	723.23
Point 149	313.5525	709.86
Point 150	382.9612	676.57
Point 151	430.7828	667.36
Point 152	154.28	767.29
Point 153	154.3	767.29
Point 154	264.4	702.5
Point 155	264.4	724.2
Point 156	462.7289	658.58

Static Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 166
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 6:56:19 PM
File Name: AD 12+00 Static.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 12+00\
Last Solved Date: 9/13/2010
Last Solved Time: 6:57:33 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Static Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 12+00
Kind: SLOPE/W
Parent: Seepage Analysis - Static Condition
Method: Spencer
Settings
    PWP Conditions Source: Parent Analysis
Slip Surface
    Direction of movement: Left to Right
    Use Passive Mode: No
    Slip Surface Option: Entry and Exit
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: Yes
    Tension Crack
        Tension Crack Option: (none)
FOS Distribution
    FOS Calculation Option: Constant
Advanced
    Number of Slices: 30
    Optimization Tolerance: 0.01
    Minimum Slip Surface Depth: 0.1 ft
    Optimization Maximum Iterations: 2000

Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Shear/Normal Fn.
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Strength Function: Ash Dike Fill
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Shear/Normal Fn.
Unit Weight: 124 pcf
Strength Function: Ash Dike Res
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (124.15807, 764.7305) ft
Left-Zone Right Coordinate: (203.00007, 753.45) ft
Left-Zone Increment: 4
Right Projection: Range
Right-Zone Left Coordinate: (381.33093, 686.4942) ft
Right-Zone Right Coordinate: (527.40123, 652) ft
Right-Zone Increment: 4
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 720.8323) ft
Right Coordinate: (550, 650.0076) ft

Seismic Loads

Horz Seismic Load: 0

Shear/Normal Strength Functions

Ash Dike Fill

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 433)
Data Point: (1000, 829)
Data Point: (1500, 1188)
Data Point: (2000, 1511)
Data Point: (2500, 1797)
Data Point: (3000, 2047)
Data Point: (3500, 2259)
Data Point: (4000, 2436)
Data Point: (4500, 2575)
Data Point: (5000, 2678)
Data Point: (5500, 2744)
Data Point: (6000, 2774)
Data Point: (20000, 2800)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Ash Dike Res

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 526)
Data Point: (1000, 999)
Data Point: (1500, 1417)
Data Point: (2000, 1781)
Data Point: (2500, 2092)
Data Point: (3000, 2349)
Data Point: (3500, 2552)
Data Point: (4000, 2700)

Data Point: (4500, 2795)
Data Point: (5000, 2837)
Data Point: (20000, 3500)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	PWR	1,2,3,4,5,6,7,8,9,10,11,12	34875.27
Region 2	Residuum	13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,1,2,3,4,5,6,7,8,9,10	15102.129
Region 3	Embankment Fill - Ash Dike	22,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,59,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23	11779.951
Region 4	Blanket Drain	96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88	429.94757

Points

	X (ft)	Y (ft)
Point 1	550	646.2121
Point 2	432.28284	652.71
Point 3	429.28284	652.71
Point 4	329.50979	655.3527
Point 5	255.39889	660.9638
Point 6	165.93156	672.8646
Point 7	115.00223	676.7478
Point 8	66.50809	683.9278
Point 9	32.02336	686.4408
Point 10	0	673.6772
Point 11	0	600
Point 12	550	600
Point 13	0	720.8323
Point 14	7.46834	722.0398
Point 15	17.77472	724.1848
Point 16	25.57517	724.516
Point 17	31.28542	725.5687
Point 18	34.87149	726.2089
Point 19	37.67175	726.5403
Point 20	40.93893	726.7039
Point 21	46.19081	726.4746
Point 22	47.16212	726.3444

Point 23	49.38769	726.046
Point 24	53.99285	725.1701
Point 25	66.88823	724.3223
Point 26	71.8387	722.4442
Point 27	75.30131	721.797
Point 28	82.45112	721.6417
Point 29	93.64932	721.9043
Point 30	96.52628	721.4946
Point 31	107.86425	720.7568
Point 32	112.04926	720.0827
Point 33	113.76575	720.0026
Point 34	114.78083	719.8752
Point 35	127.86646	718.305
Point 36	137.96649	717.6227
Point 37	149.75519	716.6597
Point 38	158.52901	715.7262
Point 39	163.94611	715.1232
Point 40	170.23801	714.2245
Point 41	175.22762	713.9809
Point 42	181.50178	713.2469
Point 43	188.5807	713.1223
Point 44	195.93295	713.0265
Point 45	207.0338	712.0464
Point 46	209.6519	712.0968
Point 47	224.14526	710.2482
Point 48	224.47398	710.2521
Point 49	226.65718	710.0026
Point 50	238.40625	708.4686
Point 51	240.00628	708.2563
Point 52	248.88633	707.0993
Point 53	256.27544	705.3133
Point 54	261.98263	704.1692
Point 55	268.69369	702.8011
Point 56	280.42697	700.0026
Point 57	280.55013	699.942
Point 58	280.81912	699.8237
Point 59	289.34	695.145
Point 60	291.93842	693.7183
Point 61	309.94718	690.0026
Point 62	310.6437	689.9203
Point 63	310.80713	689.8745
Point 64	320.52166	689.5469
Point 65	322.11323	688.7431
Point 66	331.40237	685.3953
Point 67	338.36902	680.0026
Point 68	346.67675	673.3234
Point 69	355.97678	670.6425
Point 70	357.3582	670.0026
Point 71	370.11699	663.5631
Point 72	376.6901	660.0026
Point 73	379.31551	659.301
Point 74	379.67289	659.2879

Point 75	387.50838	657.1924
Point 76	395.6543	655.9514
Point 77	401.62265	655.2704
Point 78	407.40479	654.9811
Point 79	414.69105	654.8719
Point 80	424.58073	655.1187
Point 81	434.12333	655.052
Point 82	440.76845	654.709
Point 83	450.8547	654.5724
Point 84	456.596	654.5475
Point 85	460.58523	654.5506
Point 86	467.1647	654.377
Point 87	481.83285	654.1694
Point 88	499.00652	653.4161
Point 89	501.90915	653.2851
Point 90	505.18877	653.174
Point 91	507.81999	653.0849
Point 92	510.26762	652.8252
Point 93	519.53725	652.4508
Point 94	530.07024	651.847
Point 95	550	650.0076
Point 96	491.0719	655.7661
Point 97	481.89084	656.1688
Point 98	467.20522	656.3767
Point 99	460.61083	656.5506
Point 100	456.59956	656.5475
Point 101	450.87258	656.5723
Point 102	440.83357	656.7083
Point 103	434.1819	657.0516
Point 104	424.56277	657.1189
Point 105	414.68108	656.8723
Point 106	407.46977	656.9803
Point 107	401.78616	657.2648
Point 108	395.91836	657.9343
Point 109	387.91859	659.153
Point 110	379.97164	661.2783
Point 111	379.61406	661.2914
Point 112	377.43481	661.8737
Point 113	371.04405	665.3355
Point 114	358.22938	671.8032
Point 115	356.67823	672.5218
Point 116	347.61678	675.1339
Point 117	339.60782	681.5728
Point 118	332.3772	687.1699
Point 119	322.90598	690.5834
Point 120	321.02968	691.5309
Point 121	311.11503	691.8653
Point 122	311.03314	691.8882
Point 123	310.26713	691.9787
Point 124	292.63726	695.6162
Point 125	289.34	697.4267
Point 126	115.99	760.87

Point 127	134.99	769.85
Point 128	154.66	770.34
Point 129	181.08	762.2
Point 130	210.24	750.56
Point 131	245.68	735.99
Point 132	284.25	719.57
Point 133	286.27	718.57
Point 134	289.34	719.52
Point 135	301.7	719.94
Point 136	333.76	706.14
Point 137	370.37	691.24
Point 138	391.78	681.97
Point 139	418.04	669.19
Point 140	420.85	667.78
Point 141	423.38	668.84
Point 142	444.04	671.12
Point 143	475.91	658.55
Point 144	489.58	656.04
Point 145	0	750.95
Point 146	96.2142	750.95
Point 147	154.2851	746.62
Point 148	264.3657	723.23
Point 149	313.5525	709.86
Point 150	382.9612	676.57
Point 151	430.7828	667.36
Point 152	154.28	767.29
Point 153	154.3	767.29
Point 154	264.4	702.5
Point 155	264.4	724.2
Point 156	462.7289	658.58

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.51	(342.735, 891.346)	162.7135	(133.994, 769.38)	(430.733, 669.651)
2	33	1.60	(342.735, 891.346)	233.046	(143.733, 770.068)	(416.081, 670.144)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	134.49225	768.61105	-1110.3447	57.040876	49.39816	7.6849e-007
2	Optimized	139.80645	760.40685	-687.57711	544.69449	431.39457	37
3	Optimized	149.64145	746.0744	26.914633	1518.341	1070.8305	111
4	Optimized	155.56555	737.9333	238.53994	2098.429	1201.4671	219
5	Optimized	163.3782	728.55265	456.82825	2831.1902	1358.1594	367
6	Optimized	173.97645	717.05595	718.92161	3915.9908	1355.561	775
7	Optimized	179.3738	712.1421	860.70511	4127.5707	1326.3373	1131
8	Optimized	181.2909	710.3967	945.92178	4236.1798	1335.8345	1131
9	Optimized	185.04125	706.9823	1113.6288	4422.8643	1343.5394	1131
10	Optimized	190.46945	702.04035	1356.1358	4692.3213	1354.4809	1131
11	Optimized	194.1456	698.9754	1502.9057	5213.3691	1098.3145	1516
12	Optimized	199.7229	694.7772	1697.4359	5415.1619	1100.4643	1516

13	Optimized	205.2733	690.7529	1881.2819	5831.7021	1169.3428	1516
14	Optimized	208.34285	688.71035	1970.8303	5917.7694	1168.3124	1516
15	Optimized	209.94595	687.6436	2017.4	5962.7327	1167.8369	1516
16	Optimized	215.97815	683.6296	2192.7632	6124.7496	1163.8864	1516
17	Optimized	222.9308	679.21565	2382.3015	6826.6942	844.43726	1940
18	Optimized	224.30965	678.53935	2407.0419	6839.1027	842.0942	1940
19	Optimized	225.5656	677.9233	2429.5769	6850.4699	839.97231	1940
20	Optimized	232.53175	674.50665	2554.8346	6913.7112	828.18915	1940
21	Optimized	239.2063	671.233	2675.0148	6974.2739	816.8618	1940
22	Optimized	241.10645	670.301	2709.1188	6991.3007	813.6171	1940
23	Optimized	243.9433	669.2108	2740.2227	7592.9913	407.63484	2417
24	Optimized	247.28315	668.15195	2763.3059	7555.5593	402.55153	2417
25	Optimized	252.58085	666.47235	2800.203	7491.375	394.06065	2417
26	Optimized	259.129	664.3963	2844.9238	7411.8676	383.62541	2417
27	Optimized	262.42335	663.35185	2866.595	7372.063	378.46142	2417
28	Optimized	265.7789	662.69545	2863.9696	7813.59	415.77043	2417
29	Optimized	274.7564	661.10415	2847.143	7550.8853	395.11656	2417
30	Optimized	282.53455	659.7254	2832.2258	7322.4309	853.14164	1940
31	Optimized	284.50705	659.37575	2828.5847	7261.3814	842.234	1940
32	Optimized	285.51705	659.25625	2822.8919	7521.8081	394.71116	2417
33	Optimized	287.805	659.0315	2807.4296	7560.3471	399.24729	2417
34	Optimized	290.6392	658.75305	2788.2413	7649.0016	408.30614	2417
35	Optimized	292.28785	658.59105	2777.112	7675.2592	411.44666	2417
36	Optimized	297.16865	658.11155	2744.2332	7753.4745	221.40617	2616
37	Optimized	305.98075	657.24585	2684.8435	7653.7278	417.38861	2417
38	Optimized	310.4526	656.8123	2654.3902	7594.3023	414.95493	2417
39	Optimized	310.7254	656.79375	2651.9494	7582.0565	414.13131	2417
40	Optimized	310.9201	656.7805	2650.304	7573.3063	413.53449	2417
41	Optimized	315.7774	656.45005	2607.4462	7359.3745	399.1642	2417
42	Optimized	320.7757	656.11	2563.461	7138.3346	384.29152	2417
43	Optimized	321.57145	656.05585	2556.4083	7102.5869	381.88113	2417
44	Optimized	322.5096	655.992	2548.1303	7060.9399	379.07812	2417
45	Optimized	327.1542	655.676	2507.1539	6852.3705	825.59376	1940
46	Optimized	331.8898	655.35385	2464.0678	6638.5319	793.15066	1940
47	Optimized	332.7745	655.29365	2455.7204	6597.7632	786.9906	1940
48	Optimized	333.4659	655.26	2448.3358	6738.0226	815.04306	1940
49	Optimized	336.0645	655.2017	2416.609	6609.9386	796.73512	1940
50	Optimized	338.9884	655.1361	2381.06	6466.7278	776.27931	1940
51	Optimized	343.1423	655.04295	2330.3183	6261.7492	1163.7219	1516
52	Optimized	347.1468	654.95315	2281.5872	6063.6001	1119.4935	1516
53	Optimized	351.7968	654.84885	2223.3641	5835.7329	1069.2781	1516
54	Optimized	356.3275	654.7472	2165.2546	5611.6752	1399.2361	1131
55	Optimized	357.0182	654.7317	2156.3176	5576.9318	1388.7588	1131
56	Optimized	357.7938	654.7143	2146.4332	5537.9906	1376.9618	1131
57	Optimized	361.54455	654.63015	2098.3245	5349.8529	1320.1105	1131
58	Optimized	367.61485	654.80255	2001.4883	5391.3476	1376.2724	1131
59	Optimized	370.70705	655.07945	1940.0143	5178.5924	1314.8527	1131
60	Optimized	373.8671	655.36245	1876.4622	4950.9177	1248.2194	1131
61	Optimized	377.06245	655.64865	1811.9799	4717.9956	1493.6815	807
62	Optimized	378.37515	655.7662	1785.5374	4622.0608	1457.9627	807
63	Optimized	379.4648	655.86375	1763.5669	4542.1972	1428.206	807
64	Optimized	379.6435	655.87975	1759.9124	4529.383	1423.4979	807

65	Optimized	383.59065	656.23325	1680.3426	4239.4362	1315.3648	807
66	Optimized	387.7135	656.60245	1596.7641	3931.5122	1452.2353	537
67	Optimized	388.9708	656.71505	1570.807	3837.4944	1409.9009	537
68	Optimized	390.9015	656.88795	1531.2916	3595.2927	1499.5846	0
69	Optimized	393.8492	657.15195	1471.3152	3355.2976	1368.7933	0
70	Optimized	397.3842	657.46855	1398.4819	3058.8033	1206.2941	0
71	Optimized	400.94925	657.7878	1312.0777	2791.9728	1062.551	111
72	Optimized	408.7147	659.6591	1008.8911	2346.5791	960.44768	111
73	Optimized	416.21045	662.27205	621.62784	1642.6578	733.09013	111
74	Optimized	419.445	663.91565	403.39813	942.74285	427.15759	37
75	Optimized	422.115	665.2724	233.87741	666.51468	374.66965	-5.2778e-006
76	Optimized	427.05635	667.7833	-18.056271	449.12732	388.95025	-5.5174e-006

Slices of Slip Surface: 33

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	33	149.1963	761.8989	-805.53337	485.21773	420.20503	-6.0523e-006
2	33	159.06335	748.08465	-134.06494	1364.9525	980.02334	111
3	33	167.87	737.43645	177.12792	2071.6689	1223.8519	219
4	33	176.67665	727.9583	386.05715	2751.9195	1353.2976	367
5	33	186.86125	718.2762	581.10078	3432.1853	1425.5391	547
6	33	194.28775	711.7098	727.86836	3815.7451	1253.6684	1131
7	33	201.4834	706.11755	989.87915	4215.6717	1309.6618	1131
8	33	208.34285	700.96085	1228.082	4584.5565	1362.7183	1131
9	33	209.94595	699.83295	1278.8741	4663.5356	1374.1621	1131
10	33	213.7163	697.31755	1389.4433	4830.5343	1397.0723	1131
11	33	220.8333	692.77105	1584.0582	5127.297	1048.8152	1516
12	33	225.5656	689.90115	1703.4883	5309.9391	1067.5263	1516
13	33	232.53175	686.1118	1851.1922	5532.4305	1089.6637	1516
14	33	239.2063	682.5607	1986.7464	5737.6108	1110.2734	1516
15	33	242.84315	680.818	2049.0462	5828.3486	1118.6912	1516
16	33	247.28315	678.7522	2119.3104	5929.6989	1127.8928	1516
17	33	252.58085	676.4822	2189.89	6022.6966	1134.5287	1516
18	33	259.129	673.83515	2269.1172	6118.9623	1139.5721	1516
19	33	265.33815	671.5567	2326.6352	6182.5755	1141.3764	1516
20	33	274.7564	668.5255	2390.0464	6227.2623	1135.8338	1516
21	33	282.53455	666.21715	2430.8566	6237.7813	1126.8675	1516
22	33	285.26	665.5014	2439.5685	6221.0196	1119.3272	1516
23	33	287.805	664.8721	2445.3871	6330.1497	1149.9079	1516
24	33	290.6392	664.2018	2450.0316	6506.2846	770.69049	1940
25	33	292.28785	663.82635	2451.9008	6583.1531	784.9404	1940
26	33	297.16865	662.84525	2450.6624	6797.6204	825.92462	1940
27	33	306.4075	661.1986	2435.3747	6925.495	853.12554	1940
28	33	315.81835	659.9086	2394.3953	6750.7692	827.71363	1940
29	33	320.7757	659.33755	2365.7118	6642.2962	812.55359	1940
30	33	321.57145	659.2641	2359.9186	6621.7789	809.75598	1940
31	33	322.5096	659.18015	2352.9932	6597.9066	806.53607	1940
32	33	327.1542	658.8609	2312.738	6465.661	789.05784	1940
33	33	331.8898	658.5535	2268.9098	6325.3212	770.72059	1940
34	33	333.0686	658.5021	2256.084	6285.9513	765.67718	1940
35	33	336.0645	658.4074	2221.254	6188.3676	1174.2842	1516
36	33	338.9884	658.33145	2186.3498	6091.3185	1155.889	1516

37	33	343.1423	658.3277	2130.3049	5938.0889	1127.1218	1516
38	33	347.1468	658.3428	2075.2001	5786.7567	1098.6381	1516
39	33	351.7968	658.5144	1999.0844	5590.6234	1063.1123	1516
40	33	356.3275	658.69755	1923.4431	5391.7605	1408.1261	1131
41	33	357.0182	658.7389	1911.1904	5358.6726	1399.6671	1131
42	33	357.7938	658.788	1897.1263	5321.1633	1390.1484	1131
43	33	364.2997	659.38055	1768.314	4977.7864	1303.0358	1131
44	33	370.70705	659.98565	1639.4223	4624.8763	1534.5126	807
45	33	373.29535	660.3242	1579.9263	4453.5265	1477.0201	807
46	33	376.4907	660.7602	1508.1876	4152.4024	1921.1345	0
47	33	378.52445	661.06775	1462.4018	4002.9691	1845.8301	0
48	33	385.69705	662.3785	1204.6129	3444.9942	1281.5211	367
49	33	395.8301	664.4677	811.30092	2549.6724	1122.9682	219
50	33	403.93035	666.5179	474.55928	1662.5477	852.9648	111
51	33	412.0306	668.8819	87.983145	644.21493	440.53204	37

Seepage Analysis - Pool from 100-yr Storm Event Condition

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 171
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 7:06:50 PM
File Name: AD 12+00 100 Year.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 12+00\
Last Solved Date: 9/13/2010
Last Solved Time: 7:06:54 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Mass(M) Units: lbs
Mass Flux Units: lbs/sec
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Seepage Analysis - Pool from 100-yr Storm Event Condition

Description: Ash Dike Section Sta. 12+00 Pool from 100-yr Storm Event = 751.4
Kind: SEEP/W
Method: Steady-State
Settings
  Include Air Flow: No
Control
  Apply Runoff: Yes
Convergence
  Convergence Type: Gauss Point K
  Convergence Settings
    Maximum Number of Iterations: 500
    Tolerance: 0.01
    Maximum Change in K: 0.1
    Rate of Change in K: 1.02
    Minimum Change in K: 0.0001
  Equation Solver: Parallel Direct
  Potential Seepage Max # of Reviews: 10
Time
  Starting Time: 0 sec

Duration: 0 sec
Ending Time: 0 sec

Materials

Embankment Fill - Ash Dike

Model: Saturated / Unsaturated
Hydraulic
K-Function: 3e-6
K-Ratio: 0.1
K-Direction: 0 °

Blanket Drain

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

Residuum

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

PWR

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

Boundary Conditions

Water Elevation = 751.4

Type: Head (H) 751.4

Potential Seepage Face

Review: true
Type: Total Flux (Q) 0

Zero Pressure

Type: Pressure Head 0

K Functions

1e-4

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %

Segment Curvature: 100 %
K-Saturation: 3.28e-006
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-006)
Data Point: (10000, 3.28e-006)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

1e-5

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-007
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-007)
Data Point: (10000, 3.28e-007)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

3e-6

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 9.84e-008
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 9.84e-008)
Data Point: (10000, 9.84e-008)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

Regions

	Material	Points	Area (ft²)
Region 1	PWR	1,2,3,4,5,6,7,8,9,10,11,12	34875.27

Region 2	Residuum	13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39, 40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66, 67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93, 94,95,1,2,3,4,5,6,7,8,9,10	15102.129
Region 3	Embankment Fill - Ash Dike	22,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144, 96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116, 117,118,119,120,121,122,123,124,125,59,58,57,56,55,54,53,52,51,50,49,48,47,46,45, 44,43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23	11779.951
Region 4	Blanket Drain	96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116, 117,118,119,120,121,122,123,124,125,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74, 75,76,77,78,79,80,81,82,83,84,85,86,87,88	429.94757

Lines

	Start Point	End Point	Hydraulic Boundary
Line 1	1	2	
Line 2	2	3	
Line 3	3	4	
Line 4	4	5	
Line 5	5	6	
Line 6	6	7	
Line 7	7	8	
Line 8	8	9	
Line 9	9	10	
Line 10	10	11	Water Elevation = 751.4
Line 11	11	12	
Line 12	12	1	
Line 13	13	14	Water Elevation = 751.4
Line 14	14	15	Water Elevation = 751.4
Line 15	15	16	Water Elevation = 751.4
Line 16	16	17	Water Elevation = 751.4
Line 17	17	18	Water Elevation = 751.4
Line 18	18	19	Water Elevation = 751.4
Line 19	19	20	Water Elevation = 751.4
Line 20	20	21	Water Elevation = 751.4
Line 21	21	22	Water Elevation = 751.4
Line 22	22	23	
Line 23	23	24	
Line 24	24	25	
Line 25	25	26	
Line 26	26	27	
Line 27	27	28	
Line 28	28	29	
Line 29	29	30	
Line 30	30	31	
Line 31	31	32	
Line 32	32	33	
Line 33	33	34	
Line 34	34	35	
Line 35	35	36	
Line 36	36	37	
Line 37	37	38	
Line 38	38	39	

Line 39	39	40	
Line 40	40	41	
Line 41	41	42	
Line 42	42	43	
Line 43	43	44	
Line 44	44	45	
Line 45	45	46	
Line 46	46	47	
Line 47	47	48	
Line 48	48	49	
Line 49	49	50	
Line 50	50	51	
Line 51	51	52	
Line 52	52	53	
Line 53	53	54	
Line 54	54	55	
Line 55	55	56	
Line 56	56	57	
Line 57	57	58	
Line 58	58	59	
Line 59	59	60	
Line 60	60	61	
Line 61	61	62	
Line 62	62	63	
Line 63	63	64	
Line 64	64	65	
Line 65	65	66	
Line 66	66	67	
Line 67	67	68	
Line 68	68	69	
Line 69	69	70	
Line 70	70	71	
Line 71	71	72	
Line 72	72	73	
Line 73	73	74	
Line 74	74	75	
Line 75	75	76	
Line 76	76	77	
Line 77	77	78	
Line 78	78	79	
Line 79	79	80	
Line 80	80	81	
Line 81	81	82	
Line 82	82	83	
Line 83	83	84	
Line 84	84	85	
Line 85	85	86	
Line 86	86	87	
Line 87	87	88	
Line 88	88	89	Potential Seepage Face
Line 89	89	90	Potential Seepage Face
Line 90	90	91	Potential Seepage Face
Line 91	91	92	Potential Seepage Face

Line 92	92	93	Potential Seepage Face
Line 93	93	94	Potential Seepage Face
Line 94	94	95	Potential Seepage Face
Line 95	95	1	
Line 96	10	13	Water Elevation = 751.4
Line 97	22	126	Water Elevation = 751.4
Line 98	126	127	Water Elevation = 751.4
Line 99	127	128	
Line 100	128	129	
Line 101	129	130	
Line 102	130	131	
Line 103	131	132	
Line 104	132	133	
Line 105	133	134	
Line 106	134	135	
Line 107	135	136	Potential Seepage Face
Line 108	136	137	Potential Seepage Face
Line 109	137	138	Potential Seepage Face
Line 110	138	139	Potential Seepage Face
Line 111	139	140	Potential Seepage Face
Line 112	140	141	Potential Seepage Face
Line 113	141	142	Potential Seepage Face
Line 114	142	143	Potential Seepage Face
Line 115	143	144	
Line 116	144	96	
Line 117	96	97	
Line 118	97	98	
Line 119	98	99	
Line 120	99	100	
Line 121	100	101	
Line 122	101	102	
Line 123	102	103	
Line 124	103	104	
Line 125	104	105	
Line 126	105	106	
Line 127	106	107	
Line 128	107	108	
Line 129	108	109	
Line 130	109	110	
Line 131	110	111	
Line 132	111	112	
Line 133	112	113	
Line 134	113	114	
Line 135	114	115	
Line 136	115	116	
Line 137	116	117	
Line 138	117	118	
Line 139	118	119	
Line 140	119	120	
Line 141	120	121	
Line 142	121	122	
Line 143	122	123	
Line 144	123	124	

Line 145	124	125	
Line 146	125	59	
Line 147	88	96	
Line 148	147	148	
Line 149	148	149	Zero Pressure
Line 150	149	150	Zero Pressure
Line 151	140	151	Zero Pressure
Line 152	156	88	
Line 153	151	156	
Line 154	150	140	Zero Pressure
Line 155	146	147	

Points

	X (ft)	Y (ft)
Point 1	550	646.2121
Point 2	432.28284	652.71
Point 3	429.28284	652.71
Point 4	329.50979	655.3527
Point 5	255.39889	660.9638
Point 6	165.93156	672.8646
Point 7	115.00223	676.7478
Point 8	66.50809	683.9278
Point 9	32.02336	686.4408
Point 10	0	673.6772
Point 11	0	600
Point 12	550	600
Point 13	0	720.8323
Point 14	7.46834	722.0398
Point 15	17.77472	724.1848
Point 16	25.57517	724.516
Point 17	31.28542	725.5687
Point 18	34.87149	726.2089
Point 19	37.67175	726.5403
Point 20	40.93893	726.7039
Point 21	46.19081	726.4746
Point 22	47.16212	726.3444
Point 23	49.38769	726.046
Point 24	53.99285	725.1701
Point 25	66.88823	724.3223
Point 26	71.8387	722.4442
Point 27	75.30131	721.797
Point 28	82.45112	721.6417
Point 29	93.64932	721.9043
Point 30	96.52628	721.4946
Point 31	107.86425	720.7568
Point 32	112.04926	720.0827
Point 33	113.76575	720.0026
Point 34	114.78083	719.8752
Point 35	127.86646	718.305
Point 36	137.96649	717.6227
Point 37	149.75519	716.6597
Point 38	158.52901	715.7262

Point 39	163.94611	715.1232
Point 40	170.23801	714.2245
Point 41	175.22762	713.9809
Point 42	181.50178	713.2469
Point 43	188.5807	713.1223
Point 44	195.93295	713.0265
Point 45	207.0338	712.0464
Point 46	209.6519	712.0968
Point 47	224.14526	710.2482
Point 48	224.47398	710.2521
Point 49	226.65718	710.0026
Point 50	238.40625	708.4686
Point 51	240.00628	708.2563
Point 52	248.88633	707.0993
Point 53	256.27544	705.3133
Point 54	261.98263	704.1692
Point 55	268.69369	702.8011
Point 56	280.42697	700.0026
Point 57	280.55013	699.942
Point 58	280.81912	699.8237
Point 59	289.34	695.145
Point 60	291.93842	693.7183
Point 61	309.94718	690.0026
Point 62	310.6437	689.9203
Point 63	310.80713	689.8745
Point 64	320.52166	689.5469
Point 65	322.11323	688.7431
Point 66	331.40237	685.3953
Point 67	338.36902	680.0026
Point 68	346.67675	673.3234
Point 69	355.97678	670.6425
Point 70	357.3582	670.0026
Point 71	370.11699	663.5631
Point 72	376.6901	660.0026
Point 73	379.31551	659.301
Point 74	379.67289	659.2879
Point 75	387.50838	657.1924
Point 76	395.6543	655.9514
Point 77	401.62265	655.2704
Point 78	407.40479	654.9811
Point 79	414.69105	654.8719
Point 80	424.58073	655.1187
Point 81	434.12333	655.052
Point 82	440.76845	654.709
Point 83	450.8547	654.5724
Point 84	456.596	654.5475
Point 85	460.58523	654.5506
Point 86	467.1647	654.377
Point 87	481.83285	654.1694
Point 88	499.00652	653.4161
Point 89	501.90915	653.2851
Point 90	505.18877	653.174
Point 91	507.81999	653.0849

Point 92	510.26762	652.8252
Point 93	519.53725	652.4508
Point 94	530.07024	651.847
Point 95	550	650.0076
Point 96	491.0719	655.7661
Point 97	481.89084	656.1688
Point 98	467.20522	656.3767
Point 99	460.61083	656.5506
Point 100	456.59956	656.5475
Point 101	450.87258	656.5723
Point 102	440.83357	656.7083
Point 103	434.1819	657.0516
Point 104	424.56277	657.1189
Point 105	414.68108	656.8723
Point 106	407.46977	656.9803
Point 107	401.78616	657.2648
Point 108	395.91836	657.9343
Point 109	387.91859	659.153
Point 110	379.97164	661.2783
Point 111	379.61406	661.2914
Point 112	377.43481	661.8737
Point 113	371.04405	665.3355
Point 114	358.22938	671.8032
Point 115	356.67823	672.5218
Point 116	347.61678	675.1339
Point 117	339.60782	681.5728
Point 118	332.3772	687.1699
Point 119	322.90598	690.5834
Point 120	321.02968	691.5309
Point 121	311.11503	691.8653
Point 122	311.03314	691.8882
Point 123	310.26713	691.9787
Point 124	292.63726	695.6162
Point 125	289.34	697.4267
Point 126	115.99	760.87
Point 127	134.99	769.85
Point 128	154.66	770.34
Point 129	181.08	762.2
Point 130	210.24	750.56
Point 131	245.68	735.99
Point 132	284.25	719.57
Point 133	286.27	718.57
Point 134	289.34	719.52
Point 135	301.7	719.94
Point 136	333.76	706.14
Point 137	370.37	691.24
Point 138	391.78	681.97
Point 139	418.04	669.19
Point 140	420.85	667.78
Point 141	423.38	668.84
Point 142	444.04	671.12
Point 143	475.91	658.55
Point 144	489.58	656.04

Point 145	0	750.95
Point 146	96.2142	750.95
Point 147	154.2851	746.62
Point 148	264.3657	723.23
Point 149	313.5525	709.86
Point 150	382.9612	676.57
Point 151	430.7828	667.36
Point 152	154.28	767.29
Point 153	154.3	767.29
Point 154	264.4	702.5
Point 155	264.4	724.2
Point 156	462.7289	658.58

Pool from 100-yr Storm Event Condition Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 171
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 7:06:50 PM
File Name: AD 12+00 100 Year.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 12+00\
Last Solved Date: 9/13/2010
Last Solved Time: 7:07:49 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Pool from 100-yr Storm Event Condition Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 12+00 Pool from 100-yr Storm Event = 751.4
Kind: SLOPE/W
Parent: Seepage Analysis - Pool from 100-yr Storm Event Condition
Method: Spencer
Settings
    PWP Conditions Source: Parent Analysis
Slip Surface
    Direction of movement: Left to Right
    Use Passive Mode: No
    Slip Surface Option: Entry and Exit
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: Yes
    Tension Crack
        Tension Crack Option: (none)
FOS Distribution
    FOS Calculation Option: Constant
Advanced
    Number of Slices: 30

Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Shear/Normal Fn.
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Strength Function: Ash Dike Fill
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Shear/Normal Fn.
Unit Weight: 124 pcf
Strength Function: Ash Dike Res
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (124.15807, 764.7305) ft
Left-Zone Right Coordinate: (203.00007, 753.45) ft
Left-Zone Increment: 4
Right Projection: Range
Right-Zone Left Coordinate: (381.33093, 686.4942) ft
Right-Zone Right Coordinate: (527.40123, 652) ft
Right-Zone Increment: 4
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 720.8323) ft
Right Coordinate: (550, 650.0076) ft

Seismic Loads

Horz Seismic Load: 0

Shear/Normal Strength Functions

Ash Dike Fill

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
- Curve Fit to Data: 100 %
- Segment Curvature: 0 %

Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
- Data Point: (0, 0)
- Data Point: (500, 433)
- Data Point: (1000, 829)
- Data Point: (1500, 1188)
- Data Point: (2000, 1511)
- Data Point: (2500, 1797)
- Data Point: (3000, 2047)
- Data Point: (3500, 2259)
- Data Point: (4000, 2436)
- Data Point: (4500, 2575)
- Data Point: (5000, 2678)
- Data Point: (5500, 2744)
- Data Point: (6000, 2774)
- Data Point: (20000, 2800)

Estimation Properties
- Intact Rock Param.: 10
- Geological Strength: 100
- Disturbance Factor: 0
- SigmaC: 600000 psf
- Sigma3: 300000 psf
- Num. Points: 20

Ash Dike Res

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
- Curve Fit to Data: 100 %
- Segment Curvature: 0 %

Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
- Data Point: (0, 0)
- Data Point: (500, 526)
- Data Point: (1000, 999)
- Data Point: (1500, 1417)

Data Point: (2000, 1781)
Data Point: (2500, 2092)
Data Point: (3000, 2349)
Data Point: (3500, 2552)
Data Point: (4000, 2700)
Data Point: (4500, 2795)
Data Point: (5000, 2837)
Data Point: (20000, 3500)

Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	PWR	1,2,3,4,5,6,7,8,9,10,11,12	34875.27
Region 2	Residuum	13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,1,2,3,4,5,6,7,8,9,10	15102.129
Region 3	Embankment Fill - Ash Dike	22,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,59,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23	11779.951
Region 4	Blanket Drain	96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88	429.94757

Points

	X (ft)	Y (ft)
Point 1	550	646.2121
Point 2	432.28284	652.71
Point 3	429.28284	652.71
Point 4	329.50979	655.3527
Point 5	255.39889	660.9638
Point 6	165.93156	672.8646
Point 7	115.00223	676.7478
Point 8	66.50809	683.9278
Point 9	32.02336	686.4408
Point 10	0	673.6772
Point 11	0	600
Point 12	550	600
Point 13	0	720.8323
Point 14	7.46834	722.0398
Point 15	17.77472	724.1848
Point 16	25.57517	724.516

Point 17	31.28542	725.5687
Point 18	34.87149	726.2089
Point 19	37.67175	726.5403
Point 20	40.93893	726.7039
Point 21	46.19081	726.4746
Point 22	47.16212	726.3444
Point 23	49.38769	726.046
Point 24	53.99285	725.1701
Point 25	66.88823	724.3223
Point 26	71.8387	722.4442
Point 27	75.30131	721.797
Point 28	82.45112	721.6417
Point 29	93.64932	721.9043
Point 30	96.52628	721.4946
Point 31	107.86425	720.7568
Point 32	112.04926	720.0827
Point 33	113.76575	720.0026
Point 34	114.78083	719.8752
Point 35	127.86646	718.305
Point 36	137.96649	717.6227
Point 37	149.75519	716.6597
Point 38	158.52901	715.7262
Point 39	163.94611	715.1232
Point 40	170.23801	714.2245
Point 41	175.22762	713.9809
Point 42	181.50178	713.2469
Point 43	188.5807	713.1223
Point 44	195.93295	713.0265
Point 45	207.0338	712.0464
Point 46	209.6519	712.0968
Point 47	224.14526	710.2482
Point 48	224.47398	710.2521
Point 49	226.65718	710.0026
Point 50	238.40625	708.4686
Point 51	240.00628	708.2563
Point 52	248.88633	707.0993
Point 53	256.27544	705.3133
Point 54	261.98263	704.1692
Point 55	268.69369	702.8011
Point 56	280.42697	700.0026
Point 57	280.55013	699.942
Point 58	280.81912	699.8237
Point 59	289.34	695.145
Point 60	291.93842	693.7183
Point 61	309.94718	690.0026
Point 62	310.6437	689.9203
Point 63	310.80713	689.8745
Point 64	320.52166	689.5469
Point 65	322.11323	688.7431
Point 66	331.40237	685.3953
Point 67	338.36902	680.0026

Point 68	346.67675	673.3234
Point 69	355.97678	670.6425
Point 70	357.3582	670.0026
Point 71	370.11699	663.5631
Point 72	376.6901	660.0026
Point 73	379.31551	659.301
Point 74	379.67289	659.2879
Point 75	387.50838	657.1924
Point 76	395.6543	655.9514
Point 77	401.62265	655.2704
Point 78	407.40479	654.9811
Point 79	414.69105	654.8719
Point 80	424.58073	655.1187
Point 81	434.12333	655.052
Point 82	440.76845	654.709
Point 83	450.8547	654.5724
Point 84	456.596	654.5475
Point 85	460.58523	654.5506
Point 86	467.1647	654.377
Point 87	481.83285	654.1694
Point 88	499.00652	653.4161
Point 89	501.90915	653.2851
Point 90	505.18877	653.174
Point 91	507.81999	653.0849
Point 92	510.26762	652.8252
Point 93	519.53725	652.4508
Point 94	530.07024	651.847
Point 95	550	650.0076
Point 96	491.0719	655.7661
Point 97	481.89084	656.1688
Point 98	467.20522	656.3767
Point 99	460.61083	656.5506
Point 100	456.59956	656.5475
Point 101	450.87258	656.5723
Point 102	440.83357	656.7083
Point 103	434.1819	657.0516
Point 104	424.56277	657.1189
Point 105	414.68108	656.8723
Point 106	407.46977	656.9803
Point 107	401.78616	657.2648
Point 108	395.91836	657.9343
Point 109	387.91859	659.153
Point 110	379.97164	661.2783
Point 111	379.61406	661.2914
Point 112	377.43481	661.8737
Point 113	371.04405	665.3355
Point 114	358.22938	671.8032
Point 115	356.67823	672.5218
Point 116	347.61678	675.1339
Point 117	339.60782	681.5728
Point 118	332.3772	687.1699

Point 119	322.90598	690.5834
Point 120	321.02968	691.5309
Point 121	311.11503	691.8653
Point 122	311.03314	691.8882
Point 123	310.26713	691.9787
Point 124	292.63726	695.6162
Point 125	289.34	697.4267
Point 126	115.99	760.87
Point 127	134.99	769.85
Point 128	154.66	770.34
Point 129	181.08	762.2
Point 130	210.24	750.56
Point 131	245.68	735.99
Point 132	284.25	719.57
Point 133	286.27	718.57
Point 134	289.34	719.52
Point 135	301.7	719.94
Point 136	333.76	706.14
Point 137	370.37	691.24
Point 138	391.78	681.97
Point 139	418.04	669.19
Point 140	420.85	667.78
Point 141	423.38	668.84
Point 142	444.04	671.12
Point 143	475.91	658.55
Point 144	489.58	656.04
Point 145	0	750.95
Point 146	96.2142	750.95
Point 147	154.2851	746.62
Point 148	264.3657	723.23
Point 149	313.5525	709.86
Point 150	382.9612	676.57
Point 151	430.7828	667.36
Point 152	154.28	767.29
Point 153	154.3	767.29
Point 154	264.4	702.5
Point 155	264.4	724.2
Point 156	462.7289	658.58

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.52	(342.735, 891.346)	162.7179	(133.772, 769.274)	(430.873, 669.667)
2	33	1.61	(342.735, 891.346)	233.046	(143.733, 770.068)	(416.081, 670.144)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	134.38085	768.2588	-1074.6309	70.675064	61.205549	3.0765e-006
2	Optimized	138.085	762.0844	-824.8091	425.31141	368.32536	-3.7639e-005
3	Optimized	147.92	747.3311	-238.72261	1399.5172	1004.8405	111

4	Optimized	154.9227	737.36285	99.635991	2074.6877	1275.8609	219
5	Optimized	159.15625	732.52735	255.87362	2659.3612	1374.8196	367
6	Optimized	167.09795	723.6043	516.93755	3199.99	1341.5232	547
7	Optimized	173.9056	716.47325	716.92464	3916.4258	1356.5921	775
8	Optimized	178.9112	711.7628	884.1096	4118.5918	1313.1898	1131
9	Optimized	181.2909	709.5234	994.59623	4259.7187	1325.6296	1131
10	Optimized	184.82405	706.19855	1159.3682	4444.6831	1333.8277	1131
11	Optimized	188.3635	702.9015	1322.3533	4969.141	1079.4662	1516
12	Optimized	192.25685	699.84165	1466.66	5122.0279	1082.006	1516
13	Optimized	198.44345	694.97945	1695.5857	5364.5525	1086.0313	1516
14	Optimized	203.99385	690.85195	1886.2083	5757.9274	1146.0469	1516
15	Optimized	208.34285	687.7698	2024.9174	5897.621	1146.3384	1516
16	Optimized	209.94595	686.6337	2075.8438	5949.3743	1146.5831	1516
17	Optimized	211.5152	685.52155	2125.6387	5998.213	1146.3001	1516
18	Optimized	218.6322	681.5386	2287.1512	6649.4489	828.83916	1940
19	Optimized	225.5656	677.88405	2429.7443	6738.8896	818.74017	1940
20	Optimized	231.7679	674.61485	2555.2126	6819.2086	810.16177	1940
21	Optimized	237.64245	671.64655	2666.4942	7454.7745	402.21779	2417
22	Optimized	239.2063	671.08465	2682.1929	7446.2879	400.18621	2417
23	Optimized	242.84315	669.7779	2717.605	7425.975	395.50529	2417
24	Optimized	247.28315	668.1826	2759.748	7398.8542	389.6871	2417
25	Optimized	250.785	666.9244	2793.2539	7373.8333	384.77082	2417
26	Optimized	254.47955	665.80855	2815.7479	7759.8159	415.30403	2417
27	Optimized	259.129	664.6859	2825.6522	7661.2815	406.19513	2417
28	Optimized	265.33815	663.18665	2838.0933	7529.4785	394.07856	2417
29	Optimized	271.09815	661.7958	2849.9323	7407.3176	382.82249	2417
30	Optimized	277.16085	660.7715	2835.3696	7686.7186	407.51559	2417
31	Optimized	282.53455	660.11975	2806.5512	7489.5378	393.37307	2417
32	Optimized	285.26	659.7892	2791.9656	7380.5671	385.44467	2417
33	Optimized	287.805	659.48055	2778.3697	7413.7501	389.37413	2417
34	Optimized	290.6392	659.1368	2763.2121	7509.5675	398.69607	2417
35	Optimized	292.28785	658.93685	2754.4136	7540.0473	401.99548	2417
36	Optimized	297.16865	658.3449	2728.6215	7631.0483	411.80615	2417
37	Optimized	305.2043	657.3703	2685.9929	7585.1715	411.5333	2417
38	Optimized	309.3279	656.9015	2662.2103	7628.8079	417.19652	2417
39	Optimized	310.10715	656.8464	2655.5934	7594.7141	414.88845	2417
40	Optimized	310.4554	656.82175	2652.6393	7579.3858	413.84901	2417
41	Optimized	310.7254	656.80265	2650.4181	7567.8275	413.06469	2417
42	Optimized	310.9201	656.7889	2648.7512	7559.0964	412.4713	2417
43	Optimized	315.7774	656.4453	2606.7505	7346.6505	398.15382	2417
44	Optimized	320.7757	656.09175	2563.5724	7127.5796	383.37874	2417
45	Optimized	321.57145	656.0355	2556.6694	7091.9681	380.96722	2417
46	Optimized	322.5096	655.96915	2548.5366	7050.6911	378.18309	2417
47	Optimized	327.1542	655.6406	2508.4478	6843.6974	823.7	1940
48	Optimized	331.7036	655.3188	2467.7718	6640.2817	792.77936	1940
49	Optimized	332.191	655.2926	2462.8006	6785.4915	821.31385	1940
50	Optimized	333.0686	655.26945	2452.2855	6740.0622	814.68012	1940
51	Optimized	336.0645	655.1904	2416.5932	6593.0353	793.52648	1940
52	Optimized	338.9884	655.11325	2381.5576	6451.501	773.29166	1940
53	Optimized	343.1423	655.0037	2331.9322	6248.7016	1159.3821	1516
54	Optimized	347.1468	654.8981	2284.1325	6053.0203	1115.6084	1516

55	Optimized	351.7968	654.7754	2227.0961	5827.9967	1065.8834	1516
56	Optimized	356.3275	654.65585	2170.0342	5606.4324	1395.167	1131
57	Optimized	357.0182	654.63765	2161.4025	5571.9844	1384.6857	1131
58	Optimized	357.7938	654.6172	2151.6195	5533.5554	1373.0555	1131
59	Optimized	361.54675	654.5182	2104.4089	5347.733	1316.7795	1131
60	Optimized	367.61705	654.6685	2009.08	5393.0128	1373.8662	1131
61	Optimized	370.70705	654.9354	1948.239	5182.1	1312.9375	1131
62	Optimized	373.8671	655.20835	1885.2769	4956.3514	1246.8467	1131
63	Optimized	377.06245	655.48435	1821.4466	4725.3261	1492.5836	807
64	Optimized	378.37515	655.5977	1795.2516	4630.2329	1457.1702	807
65	Optimized	379.4648	655.6918	1773.5339	4551.1337	1427.6762	807
66	Optimized	379.6435	655.70725	1769.8848	4538.2618	1422.9357	807
67	Optimized	383.59065	656.0482	1691.1085	4251.0398	1315.7955	807
68	Optimized	387.7135	656.4043	1608.4285	3945.9626	1453.9682	537
69	Optimized	389.4013	656.55005	1573.9452	3820.7153	1397.5121	537
70	Optimized	391.332	656.7168	1534.6112	3580.5741	1486.4791	0
71	Optimized	393.8492	656.93425	1483.9057	3375.0079	1373.9662	0
72	Optimized	397.96685	657.28995	1399.9195	3032.4659	1186.1144	0
73	Optimized	400.64655	657.5214	1341.1575	2840.4603	1076.4856	111
74	Optimized	407.36675	659.18925	1074.918	2458.8492	993.64987	111
75	Optimized	415.74785	661.9692	659.48337	1745.7073	779.89879	111
76	Optimized	419.445	663.85085	409.67359	951.79255	429.35477	37
77	Optimized	422.115	665.2097	239.82148	677.11232	378.69971	-3.7847e-005
78	Optimized	427.1263	667.7602	-16.686909	456.69248	395.50179	-5.6073e-006

Slices of Slip Surface: 33

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	33	149.1963	761.8989	-892.48193	486.03176	420.90999	-6.0621e-006
2	33	159.06335	748.08465	-356.68942	1367.0476	981.5276	111
3	33	167.87	737.43645	7.3083834	2041.4349	1163.5413	367
4	33	176.67665	727.9583	289.16856	2739.4162	1401.5668	367
5	33	186.86125	718.2762	543.17817	3430.9643	1443.8898	547
6	33	194.28775	711.7098	721.87112	3818.7905	1257.3397	1131
7	33	201.4834	706.11755	984.65003	4218.8235	1313.0644	1131
8	33	208.34285	700.96085	1223.6198	4587.677	1365.7968	1131
9	33	209.94595	699.83295	1274.5283	4666.6097	1377.1745	1131
10	33	213.7163	697.31755	1385.3712	4833.6483	1399.9898	1131
11	33	220.8333	692.77105	1580.5469	5130.3401	1050.7554	1516
12	33	225.5656	689.90115	1700.3208	5313.1067	1069.4015	1516
13	33	232.53175	686.1118	1848.4177	5535.0551	1091.2619	1516
14	33	239.2063	682.5607	1984.2827	5740.4105	1111.8314	1516
15	33	242.84315	680.818	2046.8169	5830.5779	1120.0109	1516
16	33	247.28315	678.7522	2117.1196	5931.6905	1129.1308	1516
17	33	252.58085	676.4822	2187.8933	6024.4437	1135.6369	1516
18	33	259.129	673.83515	2267.3182	6120.2707	1140.492	1516
19	33	265.33815	671.5567	2324.9486	6183.5593	1142.1668	1516
20	33	274.7564	668.5255	2388.5476	6227.6567	1136.3942	1516
21	33	282.53455	666.21715	2429.505	6237.4997	1127.1842	1516
22	33	285.26	665.5014	2438.2732	6220.5399	1119.5686	1516
23	33	287.805	664.8721	2444.0893	6329.8332	1150.1984	1516

24	33	290.6392	664.2018	2448.7562	6505.9095	770.86154	1940
25	33	292.28785	663.82635	2450.6435	6582.4546	785.04658	1940
26	33	297.16865	662.84525	2449.4721	6796.6465	825.96574	1940
27	33	306.4075	661.1986	2434.2206	6923.9213	853.04581	1940
28	33	315.81835	659.9086	2393.4449	6748.446	827.45281	1940
29	33	320.7757	659.33755	2364.7319	6639.7487	812.25572	1940
30	33	321.57145	659.2641	2358.9076	6619.1135	809.44166	1940
31	33	322.5096	659.18015	2351.9879	6595.1419	806.20179	1940
32	33	327.1542	658.8609	2311.7985	6462.6077	788.65622	1940
33	33	331.8898	658.5535	2267.9875	6321.9397	770.25332	1940
34	33	333.0686	658.5021	2255.217	6282.4108	765.16922	1940
35	33	336.0645	658.4074	2220.3865	6184.6807	1173.4496	1516
36	33	338.9884	658.33145	2185.462	6087.3636	1154.9811	1516
37	33	343.1423	658.3277	2129.4562	5933.9864	1126.1587	1516
38	33	347.1468	658.3428	2074.4556	5782.396	1097.5677	1516
39	33	351.7968	658.5144	1998.2477	5585.8423	1061.9448	1516
40	33	356.3275	658.69755	1922.7315	5386.637	1406.3349	1131
41	33	357.0182	658.7389	1910.4565	5353.535	1397.8792	1131
42	33	357.7938	658.788	1896.3245	5316.0086	1388.3812	1131
43	33	364.2997	659.38055	1767.5759	4972.3734	1301.1379	1131
44	33	370.70705	659.98565	1638.6858	4618.9849	1531.863	807
45	33	373.29535	660.3242	1579.2878	4447.8019	1474.4059	807
46	33	376.4907	660.7602	1507.5588	4146.8477	1917.5557	0
47	33	378.52445	661.06775	1461.767	3997.4372	1842.2722	0
48	33	385.69705	662.3785	1204.1282	3439.8239	1278.8409	367
49	33	395.8301	664.4677	810.98839	2544.8642	1120.064	219
50	33	403.93035	666.5179	474.39251	1658.6168	850.26216	111
51	33	412.0306	668.8819	87.951321	642.09332	438.87694	37

Seepage Analysis - Surcharge Pool Condition

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 174
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 7:15:15 PM
File Name: AD 12+00 Surcharge.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 12+00\
Last Solved Date: 9/13/2010
Last Solved Time: 7:15:20 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Mass(M) Units: lbs
Mass Flux Units: lbs/sec
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Seepage Analysis - Surcharge Pool Condition

Description: Ash Dike Section Sta. 12+00 Surcharge Pool = 760
Kind: SEEP/W
Method: Steady-State
Settings
    Include Air Flow: No
Control
    Apply Runoff: Yes
Convergence
    Convergence Type: Gauss Point K
    Convergence Settings
        Maximum Number of Iterations: 500
        Tolerance: 0.01
        Maximum Change in K: 0.1
        Rate of Change in K: 1.02
        Minimum Change in K: 0.0001
    Equation Solver: Parallel Direct
    Potential Seepage Max # of Reviews: 10
Time
    Starting Time: 0 sec
    Duration: 0 sec

Ending Time: 0 sec

Materials

Embankment Fill - Ash Dike

Model: Saturated / Unsaturated
Hydraulic
K-Function: 3e-6
K-Ratio: 0.1
K-Direction: 0 °

Blanket Drain

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

Residuum

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

PWR

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

Boundary Conditions

Water Elevation = 760

Type: Head (H) 760

Potential Seepage Face

Review: true
Type: Total Flux (Q) 0

K Functions

1e-4

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-006
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)

Data Point: (0.01, 3.28e-006)
Data Point: (10000, 3.28e-006)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

1e-5

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-007
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-007)
Data Point: (10000, 3.28e-007)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

3e-6

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 9.84e-008
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 9.84e-008)
Data Point: (10000, 9.84e-008)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft³/ft³

Regions

	Material	Points	Area (ft²)
Region 1	PWR	1,2,3,4,5,6,7,8,9,10,11,12	34875.27
Region 2	Residuum	13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,1,2,3,4,5,6,7,8,9,10	15102.129

Region 3	Embankment Fill - Ash Dike	22,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143, 144,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114, 115,116,117,118,119,120,121,122,123,124,125,59,58,57,56,55,54,53,52,51,50,49, 48,47,46,45,44,43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23	11779.951
Region 4	Blanket Drain	96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116, 117,118,119,120,121,122,123,124,125,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73, 74,75,76,77,78,79,80,81,82,83,84,85,86,87,88	429.94757

Lines

	Start Point	End Point	Hydraulic Boundary
Line 1	1	2	
Line 2	2	3	
Line 3	3	4	
Line 4	4	5	
Line 5	5	6	
Line 6	6	7	
Line 7	7	8	
Line 8	8	9	
Line 9	9	10	
Line 10	10	11	Water Elevation = 760
Line 11	11	12	
Line 12	12	1	
Line 13	13	14	Water Elevation = 760
Line 14	14	15	Water Elevation = 760
Line 15	15	16	Water Elevation = 760
Line 16	16	17	Water Elevation = 760
Line 17	17	18	Water Elevation = 760
Line 18	18	19	Water Elevation = 760
Line 19	19	20	Water Elevation = 760
Line 20	20	21	Water Elevation = 760
Line 21	21	22	Water Elevation = 760
Line 22	22	23	
Line 23	23	24	
Line 24	24	25	
Line 25	25	26	
Line 26	26	27	
Line 27	27	28	
Line 28	28	29	
Line 29	29	30	
Line 30	30	31	
Line 31	31	32	
Line 32	32	33	
Line 33	33	34	
Line 34	34	35	
Line 35	35	36	
Line 36	36	37	
Line 37	37	38	
Line 38	38	39	
Line 39	39	40	
Line 40	40	41	
Line 41	41	42	

Line 42	42	43	
Line 43	43	44	
Line 44	44	45	
Line 45	45	46	
Line 46	46	47	
Line 47	47	48	
Line 48	48	49	
Line 49	49	50	
Line 50	50	51	
Line 51	51	52	
Line 52	52	53	
Line 53	53	54	
Line 54	54	55	
Line 55	55	56	
Line 56	56	57	
Line 57	57	58	
Line 58	58	59	
Line 59	59	60	
Line 60	60	61	
Line 61	61	62	
Line 62	62	63	
Line 63	63	64	
Line 64	64	65	
Line 65	65	66	
Line 66	66	67	
Line 67	67	68	
Line 68	68	69	
Line 69	69	70	
Line 70	70	71	
Line 71	71	72	
Line 72	72	73	
Line 73	73	74	
Line 74	74	75	
Line 75	75	76	
Line 76	76	77	
Line 77	77	78	
Line 78	78	79	
Line 79	79	80	
Line 80	80	81	
Line 81	81	82	
Line 82	82	83	
Line 83	83	84	
Line 84	84	85	
Line 85	85	86	
Line 86	86	87	
Line 87	87	88	
Line 88	88	89	Potential Seepage Face
Line 89	89	90	Potential Seepage Face
Line 90	90	91	Potential Seepage Face
Line 91	91	92	Potential Seepage Face
Line 92	92	93	Potential Seepage Face
Line 93	93	94	Potential Seepage Face

Line 94	94	95	Potential Seepage Face
Line 95	95	1	
Line 96	10	13	Water Elevation = 760
Line 97	22	126	Water Elevation = 760
Line 98	126	127	Water Elevation = 760
Line 99	127	128	
Line 100	128	129	
Line 101	129	130	
Line 102	130	131	
Line 103	131	132	
Line 104	132	133	
Line 105	133	134	
Line 106	134	135	
Line 107	135	136	Potential Seepage Face
Line 108	136	137	Potential Seepage Face
Line 109	137	138	Potential Seepage Face
Line 110	138	139	Potential Seepage Face
Line 111	139	140	Potential Seepage Face
Line 112	140	141	Potential Seepage Face
Line 113	141	142	Potential Seepage Face
Line 114	142	143	Potential Seepage Face
Line 115	143	144	
Line 116	144	96	
Line 117	96	97	
Line 118	97	98	
Line 119	98	99	
Line 120	99	100	
Line 121	100	101	
Line 122	101	102	
Line 123	102	103	
Line 124	103	104	
Line 125	104	105	
Line 126	105	106	
Line 127	106	107	
Line 128	107	108	
Line 129	108	109	
Line 130	109	110	
Line 131	110	111	
Line 132	111	112	
Line 133	112	113	
Line 134	113	114	
Line 135	114	115	
Line 136	115	116	
Line 137	116	117	
Line 138	117	118	
Line 139	118	119	
Line 140	119	120	
Line 141	120	121	
Line 142	121	122	
Line 143	122	123	
Line 144	123	124	
Line 145	124	125	

Line 146	125	59	
Line 147	88	96	
Line 148	147	148	
Line 149	148	149	
Line 150	149	150	
Line 151	140	151	
Line 152	156	88	
Line 153	151	156	
Line 154	150	140	
Line 155	146	147	

Points

	X (ft)	Y (ft)
Point 1	550	646.2121
Point 2	432.28284	652.71
Point 3	429.28284	652.71
Point 4	329.50979	655.3527
Point 5	255.39889	660.9638
Point 6	165.93156	672.8646
Point 7	115.00223	676.7478
Point 8	66.50809	683.9278
Point 9	32.02336	686.4408
Point 10	0	673.6772
Point 11	0	600
Point 12	550	600
Point 13	0	720.8323
Point 14	7.46834	722.0398
Point 15	17.77472	724.1848
Point 16	25.57517	724.516
Point 17	31.28542	725.5687
Point 18	34.87149	726.2089
Point 19	37.67175	726.5403
Point 20	40.93893	726.7039
Point 21	46.19081	726.4746
Point 22	47.16212	726.3444
Point 23	49.38769	726.046
Point 24	53.99285	725.1701
Point 25	66.88823	724.3223
Point 26	71.8387	722.4442
Point 27	75.30131	721.797
Point 28	82.45112	721.6417
Point 29	93.64932	721.9043
Point 30	96.52628	721.4946
Point 31	107.86425	720.7568
Point 32	112.04926	720.0827
Point 33	113.76575	720.0026
Point 34	114.78083	719.8752
Point 35	127.86646	718.305
Point 36	137.96649	717.6227
Point 37	149.75519	716.6597
Point 38	158.52901	715.7262

Point 39	163.94611	715.1232
Point 40	170.23801	714.2245
Point 41	175.22762	713.9809
Point 42	181.50178	713.2469
Point 43	188.5807	713.1223
Point 44	195.93295	713.0265
Point 45	207.0338	712.0464
Point 46	209.6519	712.0968
Point 47	224.14526	710.2482
Point 48	224.47398	710.2521
Point 49	226.65718	710.0026
Point 50	238.40625	708.4686
Point 51	240.00628	708.2563
Point 52	248.88633	707.0993
Point 53	256.27544	705.3133
Point 54	261.98263	704.1692
Point 55	268.69369	702.8011
Point 56	280.42697	700.0026
Point 57	280.55013	699.942
Point 58	280.81912	699.8237
Point 59	289.34	695.145
Point 60	291.93842	693.7183
Point 61	309.94718	690.0026
Point 62	310.6437	689.9203
Point 63	310.80713	689.8745
Point 64	320.52166	689.5469
Point 65	322.11323	688.7431
Point 66	331.40237	685.3953
Point 67	338.36902	680.0026
Point 68	346.67675	673.3234
Point 69	355.97678	670.6425
Point 70	357.3582	670.0026
Point 71	370.11699	663.5631
Point 72	376.6901	660.0026
Point 73	379.31551	659.301
Point 74	379.67289	659.2879
Point 75	387.50838	657.1924
Point 76	395.6543	655.9514
Point 77	401.62265	655.2704
Point 78	407.40479	654.9811
Point 79	414.69105	654.8719
Point 80	424.58073	655.1187
Point 81	434.12333	655.052
Point 82	440.76845	654.709
Point 83	450.8547	654.5724
Point 84	456.596	654.5475
Point 85	460.58523	654.5506
Point 86	467.1647	654.377
Point 87	481.83285	654.1694
Point 88	499.00652	653.4161
Point 89	501.90915	653.2851
Point 90	505.18877	653.174

Point 91	507.81999	653.0849
Point 92	510.26762	652.8252
Point 93	519.53725	652.4508
Point 94	530.07024	651.847
Point 95	550	650.0076
Point 96	491.0719	655.7661
Point 97	481.89084	656.1688
Point 98	467.20522	656.3767
Point 99	460.61083	656.5506
Point 100	456.59956	656.5475
Point 101	450.87258	656.5723
Point 102	440.83357	656.7083
Point 103	434.1819	657.0516
Point 104	424.56277	657.1189
Point 105	414.68108	656.8723
Point 106	407.46977	656.9803
Point 107	401.78616	657.2648
Point 108	395.91836	657.9343
Point 109	387.91859	659.153
Point 110	379.97164	661.2783
Point 111	379.61406	661.2914
Point 112	377.43481	661.8737
Point 113	371.04405	665.3355
Point 114	358.22938	671.8032
Point 115	356.67823	672.5218
Point 116	347.61678	675.1339
Point 117	339.60782	681.5728
Point 118	332.3772	687.1699
Point 119	322.90598	690.5834
Point 120	321.02968	691.5309
Point 121	311.11503	691.8653
Point 122	311.03314	691.8882
Point 123	310.26713	691.9787
Point 124	292.63726	695.6162
Point 125	289.34	697.4267
Point 126	115.99	760.87
Point 127	134.99	769.85
Point 128	154.66	770.34
Point 129	181.08	762.2
Point 130	210.24	750.56
Point 131	245.68	735.99
Point 132	284.25	719.57
Point 133	286.27	718.57
Point 134	289.34	719.52
Point 135	301.7	719.94
Point 136	333.76	706.14
Point 137	370.37	691.24
Point 138	391.78	681.97
Point 139	418.04	669.19
Point 140	420.85	667.78
Point 141	423.38	668.84
Point 142	444.04	671.12

Point 143	475.91	658.55
Point 144	489.58	656.04
Point 145	0	750.95
Point 146	96.2142	750.95
Point 147	154.2851	746.62
Point 148	264.3657	723.23
Point 149	313.5525	709.86
Point 150	382.9612	676.57
Point 151	430.7828	667.36
Point 152	154.28	767.29
Point 153	154.3	767.29
Point 154	264.4	702.5
Point 155	264.4	724.2
Point 156	462.7289	658.58

Surcharge Pool Condition Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 176
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 7:17:08 PM
File Name: AD 12+00 Surcharge.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 12+00\
Last Solved Date: 9/13/2010
Last Solved Time: 7:17:24 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Surcharge Pool Condition Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 12+00 Surcharge Pool = 760
Kind: SLOPE/W
Parent: Seepage Analysis - Surcharge Pool Condition
Method: Spencer
Settings
    PWP Conditions Source: Parent Analysis
Slip Surface
    Direction of movement: Left to Right
    Use Passive Mode: No
    Slip Surface Option: Entry and Exit
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: Yes
    Tension Crack
        Tension Crack Option: (none)
FOS Distribution
    FOS Calculation Option: Constant
Advanced
    Number of Slices: 30
    Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Shear/Normal Fn.
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Strength Function: Ash Dike Fill
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Shear/Normal Fn.
Unit Weight: 124 pcf
Strength Function: Ash Dike Res
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (124.15807, 764.7305) ft
Left-Zone Right Coordinate: (179.37579, 762.7251) ft
Left-Zone Increment: 4
Right Projection: Range
Right-Zone Left Coordinate: (381.33093, 686.4942) ft
Right-Zone Right Coordinate: (527.40123, 652) ft
Right-Zone Increment: 4
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 720.8323) ft
Right Coordinate: (550, 650.0076) ft

Seismic Loads

Horz Seismic Load: 0

Shear/Normal Strength Functions

Ash Dike Fill

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
- Curve Fit to Data: 100 %
- Segment Curvature: 0 %

Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
- Data Point: (0, 0)
- Data Point: (500, 433)
- Data Point: (1000, 829)
- Data Point: (1500, 1188)
- Data Point: (2000, 1511)
- Data Point: (2500, 1797)
- Data Point: (3000, 2047)
- Data Point: (3500, 2259)
- Data Point: (4000, 2436)
- Data Point: (4500, 2575)
- Data Point: (5000, 2678)
- Data Point: (5500, 2744)
- Data Point: (6000, 2774)
- Data Point: (20000, 2800)

Estimation Properties
- Intact Rock Param.: 10
- Geological Strength: 100
- Disturbance Factor: 0
- SigmaC: 600000 psf
- Sigma3: 300000 psf
- Num. Points: 20

Ash Dike Res

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
- Curve Fit to Data: 100 %
- Segment Curvature: 0 %

Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
- Data Point: (0, 0)
- Data Point: (500, 526)
- Data Point: (1000, 999)
- Data Point: (1500, 1417)
- Data Point: (2000, 1781)
- Data Point: (2500, 2092)
- Data Point: (3000, 2349)

Data Point: (3500, 2552)
Data Point: (4000, 2700)
Data Point: (4500, 2795)
Data Point: (5000, 2837)
Data Point: (20000, 3500)

Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	PWR	1,2,3,4,5,6,7,8,9,10,11,12	34875.27
Region 2	Residuum	13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,1,2,3,4,5,6,7,8,9,10	15102.129
Region 3	Embankment Fill - Ash Dike	22,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,59,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23	11779.951
Region 4	Blanket Drain	96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88	429.94757

Points

	X (ft)	Y (ft)
Point 1	550	646.2121
Point 2	432.28284	652.71
Point 3	429.28284	652.71
Point 4	329.50979	655.3527
Point 5	255.39889	660.9638
Point 6	165.93156	672.8646
Point 7	115.00223	676.7478
Point 8	66.50809	683.9278
Point 9	32.02336	686.4408
Point 10	0	673.6772
Point 11	0	600
Point 12	550	600
Point 13	0	720.8323
Point 14	7.46834	722.0398
Point 15	17.77472	724.1848
Point 16	25.57517	724.516
Point 17	31.28542	725.5687
Point 18	34.87149	726.2089
Point 19	37.67175	726.5403
Point 20	40.93893	726.7039

Point 21	46.19081	726.4746
Point 22	47.16212	726.3444
Point 23	49.38769	726.046
Point 24	53.99285	725.1701
Point 25	66.88823	724.3223
Point 26	71.8387	722.4442
Point 27	75.30131	721.797
Point 28	82.45112	721.6417
Point 29	93.64932	721.9043
Point 30	96.52628	721.4946
Point 31	107.86425	720.7568
Point 32	112.04926	720.0827
Point 33	113.76575	720.0026
Point 34	114.78083	719.8752
Point 35	127.86646	718.305
Point 36	137.96649	717.6227
Point 37	149.75519	716.6597
Point 38	158.52901	715.7262
Point 39	163.94611	715.1232
Point 40	170.23801	714.2245
Point 41	175.22762	713.9809
Point 42	181.50178	713.2469
Point 43	188.5807	713.1223
Point 44	195.93295	713.0265
Point 45	207.0338	712.0464
Point 46	209.6519	712.0968
Point 47	224.14526	710.2482
Point 48	224.47398	710.2521
Point 49	226.65718	710.0026
Point 50	238.40625	708.4686
Point 51	240.00628	708.2563
Point 52	248.88633	707.0993
Point 53	256.27544	705.3133
Point 54	261.98263	704.1692
Point 55	268.69369	702.8011
Point 56	280.42697	700.0026
Point 57	280.55013	699.942
Point 58	280.81912	699.8237
Point 59	289.34	695.145
Point 60	291.93842	693.7183
Point 61	309.94718	690.0026
Point 62	310.6437	689.9203
Point 63	310.80713	689.8745
Point 64	320.52166	689.5469
Point 65	322.11323	688.7431
Point 66	331.40237	685.3953
Point 67	338.36902	680.0026
Point 68	346.67675	673.3234
Point 69	355.97678	670.6425
Point 70	357.3582	670.0026
Point 71	370.11699	663.5631
Point 72	376.6901	660.0026

Point 73	379.31551	659.301
Point 74	379.67289	659.2879
Point 75	387.50838	657.1924
Point 76	395.6543	655.9514
Point 77	401.62265	655.2704
Point 78	407.40479	654.9811
Point 79	414.69105	654.8719
Point 80	424.58073	655.1187
Point 81	434.12333	655.052
Point 82	440.76845	654.709
Point 83	450.8547	654.5724
Point 84	456.596	654.5475
Point 85	460.58523	654.5506
Point 86	467.1647	654.377
Point 87	481.83285	654.1694
Point 88	499.00652	653.4161
Point 89	501.90915	653.2851
Point 90	505.18877	653.174
Point 91	507.81999	653.0849
Point 92	510.26762	652.8252
Point 93	519.53725	652.4508
Point 94	530.07024	651.847
Point 95	550	650.0076
Point 96	491.0719	655.7661
Point 97	481.89084	656.1688
Point 98	467.20522	656.3767
Point 99	460.61083	656.5506
Point 100	456.59956	656.5475
Point 101	450.87258	656.5723
Point 102	440.83357	656.7083
Point 103	434.1819	657.0516
Point 104	424.56277	657.1189
Point 105	414.68108	656.8723
Point 106	407.46977	656.9803
Point 107	401.78616	657.2648
Point 108	395.91836	657.9343
Point 109	387.91859	659.153
Point 110	379.97164	661.2783
Point 111	379.61406	661.2914
Point 112	377.43481	661.8737
Point 113	371.04405	665.3355
Point 114	358.22938	671.8032
Point 115	356.67823	672.5218
Point 116	347.61678	675.1339
Point 117	339.60782	681.5728
Point 118	332.3772	687.1699
Point 119	322.90598	690.5834
Point 120	321.02968	691.5309
Point 121	311.11503	691.8653
Point 122	311.03314	691.8882
Point 123	310.26713	691.9787
Point 124	292.63726	695.6162

Point 125	289.34	697.4267
Point 126	115.99	760.87
Point 127	134.99	769.85
Point 128	154.66	770.34
Point 129	181.08	762.2
Point 130	210.24	750.56
Point 131	245.68	735.99
Point 132	284.25	719.57
Point 133	286.27	718.57
Point 134	289.34	719.52
Point 135	301.7	719.94
Point 136	333.76	706.14
Point 137	370.37	691.24
Point 138	391.78	681.97
Point 139	418.04	669.19
Point 140	420.85	667.78
Point 141	423.38	668.84
Point 142	444.04	671.12
Point 143	475.91	658.55
Point 144	489.58	656.04
Point 145	0	750.95
Point 146	96.2142	750.95
Point 147	154.2851	746.62
Point 148	264.3657	723.23
Point 149	313.5525	709.86
Point 150	382.9612	676.57
Point 151	430.7828	667.36
Point 152	154.28	767.29
Point 153	154.3	767.29
Point 154	264.4	702.5
Point 155	264.4	724.2
Point 156	462.7289	658.58

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.33	(465.042, 1089.2)	166.7784	(179.376, 762.725)	(497.328, 653.913)
2	117	1.48	(465.042, 1089.2)	433.808	(179.376, 762.725)	(489.398, 656.073)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	180.228	762.35185	-631.02725	11.088534	9.6028186	6.5977e-008
2	Optimized	185.67345	759.9669	-567.881	40.034339	34.670272	5.3811e-007
3	Optimized	194.86035	755.94335	-463.46787	75.746381	65.597377	3.2879e-006
4	Optimized	204.0473	751.9198	-379.0061	111.46241	96.527937	-1.387e-006
5	Optimized	209.4404	749.48755	-328.48699	130.85685	113.32378	8.5166e-007
6	Optimized	214.75275	746.6941	-272.5939	189.06133	163.72964	4.8137e-006
7	Optimized	223.77825	741.94815	-181.48083	286.4212	248.04458	-3.5644e-006
8	Optimized	232.80375	737.20225	-99.203508	383.78107	332.35953	-4.7759e-006
9	Optimized	241.49825	732.6055	-27.12359	477.90641	413.87333	-5.9474e-006
10	Optimized	252.0858	726.9752	48.684056	595.60318	433.15647	37

11	Optimized	263.20325	720.7825	134.56794	718.07323	462.13248	37
12	Optimized	272.6266	715.2101	218.15681	872.03349	517.86618	37
13	Optimized	280.79415	710.2909	300.79089	1001.3969	554.87551	37
14	Optimized	285.26	707.5345	354.99499	1079.881	574.10514	37
15	Optimized	287.805	705.9637	386.42605	1223.1143	662.65175	37
16	Optimized	293.8083	702.2584	454.34419	1623.8277	839.67842	111
17	Optimized	299.9883	698.512	545.65273	2038.1474	1071.5975	111
18	Optimized	306.6109	694.68755	654.67982	2217.2691	1009.4149	219
19	Optimized	313.3619	690.78895	778.4793	2339.1322	1133.8807	0
20	Optimized	315.7473	689.4114	837.16993	2320.4607	1240.0476	163
21	Optimized	318.40715	687.7573	908.08755	2310.8709	1172.7425	163
22	Optimized	320.7757	686.2572	971.74999	2364.2286	1164.1276	163
23	Optimized	321.57145	685.7532	992.9151	2381.6708	1161.0153	163
24	Optimized	322.5096	685.15905	1017.5414	2402.6778	1157.9895	163
25	Optimized	327.1542	682.21745	1138.1026	2506.1921	1143.7382	163
26	Optimized	331.8898	679.2182	1258.259	2610.6339	1130.6005	163
27	Optimized	333.0686	678.4716	1287.8741	2635.8652	1126.9357	163
28	Optimized	334.06075	677.8432	1312.6434	2658.1502	1124.8588	163
29	Optimized	336.36525	676.7228	1349.0772	2908.3408	1135.1598	325
30	Optimized	338.9884	675.5055	1384.642	2925.5413	1121.7904	325
31	Optimized	343.0997	673.5976	1440.1614	2952.6686	1101.1206	325
32	Optimized	346.6342	671.96005	1487.2962	3075.8529	1156.4854	325
33	Optimized	347.1468	671.7548	1492.3206	3076.4855	1153.2882	325
34	Optimized	351.7968	669.8929	1537.4367	3077.0943	1120.8864	325
35	Optimized	356.3275	668.0788	1578.8988	3076.8013	1252.2632	163
36	Optimized	357.0182	667.80225	1584.9503	3076.5156	1246.9653	163
37	Optimized	357.7938	667.4917	1591.7177	3076.3404	1241.1612	163
38	Optimized	361.15055	666.14765	1620.9438	3075.6778	1216.1738	163
39	Optimized	367.22085	664.18725	1645.4106	3278.1937	1188.6828	325
40	Optimized	370.42085	663.38375	1643.8029	3219.2055	1146.9091	325
41	Optimized	370.7579	663.29915	1643.7666	3207.9942	1136.4779	0
42	Optimized	374.23945	662.4249	1643.3076	3137.1269	1085.3233	0
43	Optimized	378.52445	661.3489	1639.013	3049.2665	1024.6091	0
44	Optimized	383.76635	660.0327	1629.9302	2938.5693	950.78197	0
45	Optimized	389.43135	658.61025	1620.8029	2818.5088	870.18431	0
46	Optimized	391.36205	658.1708	1614.9814	2926.3174	952.74138	0
47	Optimized	393.8492	657.81615	1594.9157	2822.0996	891.60131	0
48	Optimized	398.8523	657.10275	1553.5781	2606.309	764.85374	0
49	Optimized	402.12585	656.63595	1526.037	2465.0918	682.26328	0
50	Optimized	404.96765	656.58135	1480.1944	2474.6841	722.53907	0
51	Optimized	411.07545	656.5663	1378.6219	2067.3019	500.3553	0
52	Optimized	416.36055	656.55325	1292.4949	1713.9089	306.17517	0
53	Optimized	419.445	656.54565	1241.633	1504.408	190.91718	0
54	Optimized	422.115	656.53905	1197.6642	1487.4261	210.52436	0
55	Optimized	423.9714	656.53445	1167.0869	1578.6617	299.02661	0
56	Optimized	428.8184	656.5225	1087.7151	1670.8502	423.67241	0
57	Optimized	433.62795	656.4626	1012.0326	1685.3124	489.16648	0
58	Optimized	437.50775	656.11665	969.90743	1792.1372	597.38492	0
59	Optimized	442.4368	655.67715	916.26643	1927.6511	734.81398	0
60	Optimized	447.4563	655.2296	861.24908	1836.2351	708.36882	0
61	Optimized	451.9148	654.83205	812.26764	1659.4669	615.52629	0
62	Optimized	454.7783	654.69925	772.72639	1594.6368	597.15283	0

63	Optimized	458.6052	654.6155	713.51824	1402.2373	500.38369	0
64	Optimized	463.908	654.4994	631.5523	1135.8754	366.41218	0
65	Optimized	467.77385	654.41475	570.80592	941.95152	269.65306	0
66	Optimized	472.12625	654.33845	493.47323	724.11043	167.56773	0
67	Optimized	478.9004	654.22415	372.77084	486.41764	82.569228	0
68	Optimized	485.7354	654.1088	240.99331	383.96646	103.87608	0
69	Optimized	490.32595	654.03135	147.48893	290.48088	103.88973	0
70	Optimized	494.2	653.966	68.583383	130.57101	45.036648	0

Slices of Slip Surface: 117

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	117	180.2279	761.9834	-616.1004	37.498473	32.474178	5.0406e-007
2	117	185.94	757.15655	-459.75934	246.65039	213.60253	6.2799e-006
3	117	195.66	749.22055	-224.73287	585.28117	463.53896	37
4	117	205.38	741.73775	-34.848121	906.26872	717.75906	37
5	117	216.14665	733.9672	139.1661	1253.5625	800.1264	111
6	117	227.96	725.9732	290.16553	1593.6633	935.89946	111
7	117	239.77335	718.52815	414.97153	1888.4044	1057.9113	111
8	117	251.0798	711.8765	519.86652	2124.4274	1036.5281	219
9	117	261.8794	705.952	624.96625	2305.0391	1085.3079	219
10	117	267.98645	702.72885	685.37886	2357.7612	1217.5114	325
11	117	274.7564	699.40855	784.25037	2440.5735	1205.8201	325
12	117	282.53455	695.65335	873.72259	2526.4526	1203.2043	325
13	117	285.26	694.39785	892.0148	2541.5146	1200.8527	325
14	117	287.805	693.2508	908.21034	2667.0429	1280.448	325
15	117	290.6392	691.99325	952.1608	2858.4557	1387.8021	325
16	117	292.28785	691.2711	977.19267	2947.9328	1434.7189	325
17	117	297.16865	689.21755	1050.3028	3208.8008	1342.606	537
18	117	306.4075	685.466	1185.5781	3464.1064	1417.266	537
19	117	315.81835	681.89315	1294.8602	3469.2311	1352.4791	537
20	117	320.7757	680.08045	1344.5266	3462.5361	1317.4218	537
21	117	321.57145	679.80105	1351.6409	3459.5353	1311.1301	537
22	117	322.5096	679.4733	1359.8641	3456.2517	1303.9728	537
23	117	327.1542	677.91115	1396.4688	3432.4744	1266.4146	537
24	117	331.8898	676.3297	1431.6496	3405.3421	1436.8683	325
25	117	333.0686	675.9517	1439.1666	3395.8986	1424.5208	325
26	117	336.0645	675.01325	1455.0303	3376.1991	1398.6304	325
27	117	338.9884	674.1075	1468.0279	3357.1697	1375.3144	325
28	117	343.1423	672.8845	1482.2691	3322.0043	1339.346	325
29	117	347.1468	671.71685	1494.5831	3287.0796	1304.9557	325
30	117	351.7968	670.45365	1503.7542	3236.5991	1261.5288	325
31	117	356.3275	669.2324	1509.8575	3184.3639	1219.0578	325
32	117	357.0182	669.0542	1509.6448	3175.111	1212.4764	325
33	117	357.7938	668.85565	1509.638	3164.6453	1204.8622	325
34	117	359.83575	668.34295	1509.0243	3135.9369	1184.409	325
35	117	365.60305	666.96145	1507.9091	3052.6621	1122.3287	0
36	117	370.067	665.91355	1506.3612	2980.9038	1058.708	111
37	117	375.7225	664.7193	1470.5519	2853.1651	992.70357	111
38	117	386.4275	662.6066	1400.334	2586.1578	851.41058	111
39	117	396.15665	660.91625	1309.634	2279.988	768.51425	37
40	117	404.91	659.5997	1245.6628	1938.188	548.47553	37

41	117	413.66335	658.465	1155.4797	1564.6507	354.34752	-5.0893e-006
42	117	419.445	657.7944	1125.0147	1296.3734	148.39891	4.3644e-006
43	117	422.115	657.5201	1114.0702	1312.6165	171.94382	5.0551e-006
44	117	424.93595	657.24985	1099.8631	1443.0944	297.24286	-4.2691e-006
45	117	430.3369	656.7968	1045.5471	1584.3744	391.48094	0
46	117	437.50775	656.27665	959.99916	1773.7142	591.19855	0
47	117	442.4368	655.98145	897.37984	1899.9985	728.4451	0
48	117	447.4563	655.7592	828.27328	1790.8216	699.33231	0
49	117	453.7361	655.54595	737.24115	1507.7172	559.78358	0
50	117	458.6052	655.4415	662.13627	1276.9611	446.69636	0
51	117	463.908	655.4031	574.95641	1012.7512	318.07657	0
52	117	471.5576	655.4599	434.63168	611.26183	128.32931	0
53	117	478.9004	655.62085	289.20967	310.04894	15.140618	0
54	117	484.4429	655.83065	161.79245	187.00744	18.319764	0
55	117	488.1966	656.00915	84.444657	96.889264	10.777196	7.3562e-008

Pseudostatic Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 173
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 7:27:22 PM
File Name: AD 12+00 Pseudostatic.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 12+00\
Last Solved Date: 9/13/2010
Last Solved Time: 7:27:34 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Pseudostatic Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 12+00 Seismic Coefficient "k" = 0.06 g
Kind: SLOPE/W
Parent: Seepage Analysis - Static Condition
Method: Spencer
Settings
PWP Conditions Source: Parent Analysis
Slip Surface
Direction of movement: Left to Right
Use Passive Mode: No
Slip Surface Option: Auto-Search
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: Yes
Tension Crack
Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000

Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Mohr-Coulomb
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Cohesion: 1300 psf
Phi: 12.5 °
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Mohr-Coulomb
Unit Weight: 124 pcf
Cohesion: 1400 psf
Phi: 11.3 °
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Slip Surface Limits

Left Coordinate: (0, 720.8323) ft
Right Coordinate: (550, 650.0076) ft

Seismic Loads

Horz Seismic Load: 0.06
Ignore seismic load in strength: No

Regions

	Material	Points	Area (ft²)

Region 1	PWR	1,2,3,4,5,6,7,8,9,10,11,12	34875.27
Region 2	Residuum	13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39, 40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66, 67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93, 94,95,1,2,3,4,5,6,7,8,9,10	15102.129
Region 3	Embankment Fill - Ash Dike	22,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143, 144,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114, 115,116,117,118,119,120,121,122,123,124,125,59,58,57,56,55,54,53,52,51,50,49, 48,47,46,45,44,43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23	11779.951
Region 4	Blanket Drain	96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116, 117,118,119,120,121,122,123,124,125,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73, 74,75,76,77,78,79,80,81,82,83,84,85,86,87,88	429.94757

Points

	X (ft)	Y (ft)
Point 1	550	646.2121
Point 2	432.28284	652.71
Point 3	429.28284	652.71
Point 4	329.50979	655.3527
Point 5	255.39889	660.9638
Point 6	165.93156	672.8646
Point 7	115.00223	676.7478
Point 8	66.50809	683.9278
Point 9	32.02336	686.4408
Point 10	0	673.6772
Point 11	0	600
Point 12	550	600
Point 13	0	720.8323
Point 14	7.46834	722.0398
Point 15	17.77472	724.1848
Point 16	25.57517	724.516
Point 17	31.28542	725.5687
Point 18	34.87149	726.2089
Point 19	37.67175	726.5403
Point 20	40.93893	726.7039
Point 21	46.19081	726.4746
Point 22	47.16212	726.3444
Point 23	49.38769	726.046
Point 24	53.99285	725.1701
Point 25	66.88823	724.3223
Point 26	71.8387	722.4442
Point 27	75.30131	721.797
Point 28	82.45112	721.6417
Point 29	93.64932	721.9043
Point 30	96.52628	721.4946
Point 31	107.86425	720.7568
Point 32	112.04926	720.0827
Point 33	113.76575	720.0026
Point 34	114.78083	719.8752
Point 35	127.86646	718.305
Point 36	137.96649	717.6227

Point 37	149.75519	716.6597
Point 38	158.52901	715.7262
Point 39	163.94611	715.1232
Point 40	170.23801	714.2245
Point 41	175.22762	713.9809
Point 42	181.50178	713.2469
Point 43	188.5807	713.1223
Point 44	195.93295	713.0265
Point 45	207.0338	712.0464
Point 46	209.6519	712.0968
Point 47	224.14526	710.2482
Point 48	224.47398	710.2521
Point 49	226.65718	710.0026
Point 50	238.40625	708.4686
Point 51	240.00628	708.2563
Point 52	248.88633	707.0993
Point 53	256.27544	705.3133
Point 54	261.98263	704.1692
Point 55	268.69369	702.8011
Point 56	280.42697	700.0026
Point 57	280.55013	699.942
Point 58	280.81912	699.8237
Point 59	289.34	695.145
Point 60	291.93842	693.7183
Point 61	309.94718	690.0026
Point 62	310.6437	689.9203
Point 63	310.80713	689.8745
Point 64	320.52166	689.5469
Point 65	322.11323	688.7431
Point 66	331.40237	685.3953
Point 67	338.36902	680.0026
Point 68	346.67675	673.3234
Point 69	355.97678	670.6425
Point 70	357.3582	670.0026
Point 71	370.11699	663.5631
Point 72	376.6901	660.0026
Point 73	379.31551	659.301
Point 74	379.67289	659.2879
Point 75	387.50838	657.1924
Point 76	395.6543	655.9514
Point 77	401.62265	655.2704
Point 78	407.40479	654.9811
Point 79	414.69105	654.8719
Point 80	424.58073	655.1187
Point 81	434.12333	655.052
Point 82	440.76845	654.709
Point 83	450.8547	654.5724
Point 84	456.596	654.5475
Point 85	460.58523	654.5506
Point 86	467.1647	654.377
Point 87	481.83285	654.1694
Point 88	499.00652	653.4161

Point 89	501.90915	653.2851
Point 90	505.18877	653.174
Point 91	507.81999	653.0849
Point 92	510.26762	652.8252
Point 93	519.53725	652.4508
Point 94	530.07024	651.847
Point 95	550	650.0076
Point 96	491.0719	655.7661
Point 97	481.89084	656.1688
Point 98	467.20522	656.3767
Point 99	460.61083	656.5506
Point 100	456.59956	656.5475
Point 101	450.87258	656.5723
Point 102	440.83357	656.7083
Point 103	434.1819	657.0516
Point 104	424.56277	657.1189
Point 105	414.68108	656.8723
Point 106	407.46977	656.9803
Point 107	401.78616	657.2648
Point 108	395.91836	657.9343
Point 109	387.91859	659.153
Point 110	379.97164	661.2783
Point 111	379.61406	661.2914
Point 112	377.43481	661.8737
Point 113	371.04405	665.3355
Point 114	358.22938	671.8032
Point 115	356.67823	672.5218
Point 116	347.61678	675.1339
Point 117	339.60782	681.5728
Point 118	332.3772	687.1699
Point 119	322.90598	690.5834
Point 120	321.02968	691.5309
Point 121	311.11503	691.8653
Point 122	311.03314	691.8882
Point 123	310.26713	691.9787
Point 124	292.63726	695.6162
Point 125	289.34	697.4267
Point 126	115.99	760.87
Point 127	134.99	769.85
Point 128	154.66	770.34
Point 129	181.08	762.2
Point 130	210.24	750.56
Point 131	245.68	735.99
Point 132	284.25	719.57
Point 133	286.27	718.57
Point 134	289.34	719.52
Point 135	301.7	719.94
Point 136	333.76	706.14
Point 137	370.37	691.24
Point 138	391.78	681.97
Point 139	418.04	669.19
Point 140	420.85	667.78

Point 141	423.38	668.84
Point 142	444.04	671.12
Point 143	475.91	658.55
Point 144	489.58	656.04
Point 145	0	750.95
Point 146	96.2142	750.95
Point 147	154.2851	746.62
Point 148	264.3657	723.23
Point 149	313.5525	709.86
Point 150	382.9612	676.57
Point 151	430.7828	667.36
Point 152	154.28	767.29
Point 153	154.3	767.29
Point 154	264.4	702.5
Point 155	264.4	724.2
Point 156	462.7289	658.58

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.17	(346.674, 989.198)	159.3453	(117.735, 761.695)	(420.856, 667.783)
2	144	1.23	(346.674, 989.198)	329.431	(111.428, 758.582)	(420.24, 668.086)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	122.04845	756.71455	-417.05243	-71.924014	-15.94517	1300
2	Optimized	130.67615	746.7545	56.79338	1060.8443	222.59273	1300
3	Optimized	135.31625	741.39785	224.24105	1673.2535	321.23832	1300
4	Optimized	139.5073	736.90885	352.53508	2182.9001	405.78215	1300
5	Optimized	147.2369	728.68415	559.44013	2899.6653	518.81542	1300
6	Optimized	152.88085	722.83185	695.04456	3569.555	637.26362	1300
7	Optimized	157.50715	718.30745	798.31318	3893.2583	686.13281	1300
8	Optimized	162.1502	713.7667	948.95028	4160.341	641.69919	1400
9	Optimized	164.48375	711.4846	1062.3465	4305.5021	648.04643	1400
10	Optimized	167.6297	708.7881	1191.7288	4803.1621	721.63559	1400
11	Optimized	172.7328	704.5412	1394.9111	5061.4246	732.64169	1400
12	Optimized	177.2554	700.77745	1575.2825	5290.3003	742.33381	1400
13	Optimized	180.1816	698.49575	1682.7483	5892.6365	841.21866	1400
14	Optimized	181.2909	697.76215	1715.4742	5930.5054	842.24634	1400
15	Optimized	185.04125	695.2819	1826.2168	6032.2066	840.4397	1400
16	Optimized	192.25685	690.5099	2038.5404	6228.1613	837.16887	1400
17	Optimized	196.5482	687.67185	2163.991	6344.6022	835.36855	1400
18	Optimized	202.0986	684.6157	2288.9186	6829.3541	907.26853	1400
19	Optimized	208.34285	681.2637	2422.966	6922.8082	899.15719	1400
20	Optimized	209.94595	680.40315	2457.3028	6947.0267	897.13536	1400
21	Optimized	211.3002	679.67615	2486.2005	6965.8324	895.11878	1400
22	Optimized	218.4172	676.55645	2595.6685	7396.9364	959.38798	1400
23	Optimized	225.5656	673.5462	2695.9176	7408.1485	941.59664	1400
24	Optimized	230.3696	671.5232	2762.1789	7415.6678	929.85883	1400
25	Optimized	236.24415	669.2865	2828.8118	7816.7675	996.6919	1400
26	Optimized	239.2063	668.3639	2849.9107	7784.7434	986.07689	1400

27	Optimized	242.84315	667.23115	2874.186	7745.3256	973.34973	1400
28	Optimized	247.28315	665.84825	2903.6534	7694.7769	957.36094	1400
29	Optimized	251.748	664.4576	2933.4906	7638.9196	940.23749	1400
30	Optimized	255.44255	663.41435	2951.7116	8108.2151	1030.3711	1400
31	Optimized	259.129	662.74185	2946.0232	8003.6129	1010.6062	1400
32	Optimized	265.33815	661.60915	2936.3145	7827.2402	977.30339	1400
33	Optimized	270.71505	660.62825	2927.9078	7674.3209	948.42692	1400
34	Optimized	276.77775	659.8726	2897.0332	7826.0415	984.91305	1400
35	Optimized	282.53455	659.32145	2857.1909	7595.0939	946.72643	1400
36	Optimized	285.26	659.06055	2838.3589	7476.7055	926.83312	1400
37	Optimized	287.805	658.8169	2820.7184	7502.8283	935.57787	1400
38	Optimized	290.6392	658.54555	2801.134	7591.4646	957.20251	1400
39	Optimized	292.28785	658.38775	2789.7462	7617.5668	964.69375	1400
40	Optimized	297.1204	657.9251	2756.463	7694.7374	986.76459	1400
41	Optimized	301.65175	657.4923	2725.1106	7858.6314	1025.7787	1400
42	Optimized	306.4075	657.13585	2686.1383	7654.7686	992.8303	1400
43	Optimized	315.81835	656.4305	2608.1807	7246.784	926.88439	1400
44	Optimized	320.7757	656.059	2566.5195	7031.7726	892.24562	1400
45	Optimized	321.57145	655.9994	2559.8455	6996.6657	886.56416	1400
46	Optimized	322.5096	655.92905	2552.0354	6955.8311	879.96521	1400
47	Optimized	326.4508	655.63365	2518.8857	6784.1687	852.28766	1400
48	Optimized	330.699	655.3489	2480.4963	6786.1911	860.36272	1400
49	Optimized	331.8898	655.31655	2466.2904	6725.3609	851.04627	1400
50	Optimized	333.0686	655.28455	2452.3064	6664.7389	841.72707	1400
51	Optimized	336.0645	655.2032	2416.5428	6519.1568	819.78316	1400
52	Optimized	338.9884	655.1238	2381.7497	6379.0642	798.74226	1400
53	Optimized	343.1423	655.011	2332.308	6179.9869	768.84212	1400
54	Optimized	347.1468	654.90225	2284.6169	5988.9842	740.20564	1400
55	Optimized	351.7968	654.776	2227.7675	5769.4048	707.68897	1400
56	Optimized	356.3275	654.653	2170.9866	5554.4424	676.08117	1400
57	Optimized	356.80835	654.63995	2164.9917	5531.4463	672.68402	1400
58	Optimized	357.14835	654.6351	2160.4539	5589.5991	685.21082	1400
59	Optimized	357.7938	654.6311	2151.5231	5556.7238	680.42625	1400
60	Optimized	363.0842	654.5982	2078.4139	5288.776	641.49366	1400
61	Optimized	369.028	654.66175	1990.1219	5298.1478	661.00879	1400
62	Optimized	370.2435	654.7664	1966.0093	5219.2219	650.05602	1400
63	Optimized	370.70705	654.8063	1956.8586	5187.9887	645.64348	1400
64	Optimized	373.8671	655.07835	1893.7923	4972.3519	615.1569	1400
65	Optimized	377.06245	655.35345	1830.0525	4754.8721	584.43663	1400
66	Optimized	378.37515	655.46645	1803.9294	4665.943	571.88675	1400
67	Optimized	379.4648	655.56025	1782.1864	4591.9566	561.44749	1400
68	Optimized	379.6435	655.57565	1778.5642	4580.0314	559.78839	1400
69	Optimized	383.59065	655.9155	1699.9228	4311.6673	521.87807	1400
70	Optimized	387.7135	656.27045	1617.2347	4031.7929	482.47633	1400
71	Optimized	389.6838	656.4401	1577.0193	3898.4528	463.8682	1400
72	Optimized	391.6145	656.60635	1537.5757	3666.0544	1546.4303	0
73	Optimized	393.8492	656.7987	1492.6322	3474.2778	1439.7498	0
74	Optimized	398.3097	657.1827	1401.7221	3088.7132	1225.6708	0
75	Optimized	400.82585	657.39935	1349.3245	3065.1953	380.39939	1300
76	Optimized	405.223	659.63635	1071.7009	3835.1241	612.63618	1300
77	Optimized	413.76765	664.08885	499.62891	2458.9132	434.36287	1300
78	Optimized	419.445	667.04725	100.18245	1545.1842	320.34918	1300

79	Optimized	420.853	667.78095	-0.072648742	1369.3315	303.57349	1300

Slices of Slip Surface: 144

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	144	113.70895	756.2998	-361.48957	-219.70495	-48.707414	1300
2	144	120.74	749.5401	-22.719022	688.44104	152.6237	1300
3	144	130.24	740.9213	261.27196	1931.7684	370.34015	1300
4	144	139.9075	732.8147	481.34441	2984.7675	554.99554	1300
5	144	149.7425	725.1809	646.90675	3832.963	706.33167	1300
6	144	159.27315	718.3214	785.55321	4482.2668	819.54168	1300
7	144	167.06215	713.06415	938.38824	4863.0479	784.2244	1400
8	144	172.7328	709.4472	1096.9176	5129.4672	805.78292	1400
9	144	178.1538	706.1538	1238.37	5368.8587	825.3531	1400
10	144	181.2909	704.28915	1318.1111	5502.0574	836.03496	1400
11	144	185.04125	702.17355	1406.5428	5618.5397	841.64003	1400
12	144	192.25685	698.22945	1568.6992	5830.1497	851.52184	1400
13	144	201.4834	693.5527	1752.695	6062.064	861.09689	1400
14	144	208.34285	690.22125	1879.2244	6219.2478	867.22226	1400
15	144	209.94595	689.48145	1906.0817	6251.8119	868.36258	1400
16	144	217.357	686.30875	2014.7315	6365.5101	869.37135	1400
17	144	225.5656	682.83865	2131.583	6485.7782	870.05406	1400
18	144	232.53175	680.23685	2206.4283	6549.0267	867.73678	1400
19	144	239.2063	677.7905	2275.4543	6603.3372	864.79633	1400
20	144	242.84315	676.5722	2306.4464	6619.9311	861.91929	1400
21	144	247.28315	675.1227	2339.1882	6632.6757	857.92344	1400
22	144	252.58085	673.5142	2370.7089	6627.3239	850.55561	1400
23	144	259.129	671.62635	2403.6858	6607.8555	840.076	1400
24	144	265.33815	669.9847	2422.7903	6570.8024	828.85461	1400
25	144	274.7564	667.7732	2436.3312	6478.8286	807.77068	1400
26	144	282.53455	666.0762	2439.578	6383.6941	788.11215	1400
27	144	285.26	665.54405	2436.9615	6333.522	778.60963	1400
28	144	287.805	665.0736	2432.9015	6413.9605	795.4941	1400
29	144	290.6392	664.5705	2427.1421	6559.3516	825.69693	1400
30	144	292.28785	664.28775	2423.2157	6618.7518	838.35085	1400
31	144	297.16865	663.54045	2407.4773	6785.6409	874.84342	1400
32	144	306.4075	662.2718	2369.1322	6827.6209	890.89396	1400
33	144	315.81835	661.24945	2312.0872	6578.838	852.58095	1400
34	144	320.7757	660.7869	2276.8963	6435.4749	830.966	1400
35	144	321.57145	660.7255	2270.433	6410.0877	827.18463	1400
36	144	322.5096	660.65495	2262.6993	6380.495	822.81678	1400
37	144	327.1542	660.3736	2220.3301	6224.0442	800.02102	1400
38	144	331.8898	660.0995	2174.6992	6059.9719	776.35409	1400
39	144	333.0686	660.04905	2161.8071	6015.7618	770.09613	1400
40	144	336.0645	659.9462	2127.5045	5907.735	755.36458	1400
41	144	338.9884	659.85745	2093.3924	5802.0219	741.05729	1400
42	144	343.1423	659.8051	2040.3614	5641.1239	719.50335	1400
43	144	347.1468	659.7679	1988.0195	5483.6489	698.49568	1400
44	144	351.7968	659.8336	1918.3087	5287.1597	673.16285	1400
45	144	356.3275	659.9089	1849.3729	5090.9767	647.73635	1400
46	144	357.0182	659.9299	1838.2918	5059.3447	643.62988	1400
47	144	357.7938	659.9553	1825.6769	5023.7663	639.04132	1400

48	144	364.2997	660.2953	1712.2826	4706.1039	598.22454	1400
49	144	370.70705	660.64525	1599.0213	4384.5469	556.60294	1400
50	144	372.9669	660.82385	1554.2383	4255.35	539.73539	1400
51	144	376.16225	661.0922	1493.4882	4051.8753	1858.777	0
52	144	378.35165	661.29515	1451.8517	3905.0236	1782.3337	0
53	144	385.52425	662.1268	1231.01	3481.8297	498.99471	1300
54	144	396.15665	663.5349	887.79939	2744.4707	411.61412	1300
55	144	404.91	664.98605	594.72026	2041.6206	320.77009	1300
56	144	413.66335	666.6813	258.74251	1290.1332	228.65381	1300
57	144	419.13975	667.83835	31.982614	795.26328	169.21525	1300

Rapid Drawdown Slope Stability Analysis - Global

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 176
Last Edited By: Cedric Ruhl
Date: 9/13/2010
Time: 7:36:31 PM
File Name: AD 12+00 RDD.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 12+00\
Last Solved Date: 9/13/2010
Last Solved Time: 7:36:41 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Rapid Drawdown Slope Stability Analysis - Global

Description: Ash Dike Section Sta. 12+00 Pool Drawdown from 750.95 to 745.63
Kind: SLOPE/W
Parent: Seepage Analysis - Static Condition
Method: Spencer
Settings
- Apply Phreatic Correction: No
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: Yes

Slip Surface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: Yes
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced
- Number of Slices: 30
- Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 3 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Mohr-Coulomb
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Cohesion: 0 psf
Phi: 38 °
Phi-B: 0 °
Drawdown Total Cohesion: 1300 psf
Drawdown Total Phi: 12.5 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °
Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Residuum

Model: Mohr-Coulomb
Unit Weight: 124 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °
Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °

Phi-B: 0 °
Drawdown Total Cohesion: 0 psf
Drawdown Total Phi: 0 °
Pore Water Pressure
Piezometric Line: 1
Piezometric Line After Drawdown: 2

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (30.76421, 725.4726) ft
Left-Zone Right Coordinate: (92.14539, 748.909) ft
Left-Zone Increment: 4
Right Projection: Range
Right-Zone Left Coordinate: (97.40189, 751.5458) ft
Right-Zone Right Coordinate: (180.18811, 762.4748) ft
Right-Zone Increment: 4
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 720.8323) ft
Right Coordinate: (550, 650.0076) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	750.95
	150	750.95

Piezometric Line 2

Coordinates

	X (ft)	Y (ft)
	0	745.63
	150	745.63

Seismic Loads

Horz Seismic Load: 0

Regions

	Material	Points	Area (ft²)
Region 1	PWR	1,2,3,4,5,6,7,8,9,10,11,12	34875.27

Region 2	Residuum	13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39, 40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66, 67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93, 94,95,1,2,3,4,5,6,7,8,9,10	15102.129
Region 3	Embankment Fill - Ash Dike	22,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144, 96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116, 117,118,119,120,121,122,123,124,125,59,58,57,56,55,54,53,52,51,50,49,48,47,46,45, 44,43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23	11779.951
Region 4	Blanket Drain	96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116, 117,118,119,120,121,122,123,124,125,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73, 74,75,76,77,78,79,80,81,82,83,84,85,86,87,88	429.94757

Points

	X (ft)	Y (ft)
Point 1	550	646.2121
Point 2	432.28284	652.71
Point 3	429.28284	652.71
Point 4	329.50979	655.3527
Point 5	255.39889	660.9638
Point 6	165.93156	672.8646
Point 7	115.00223	676.7478
Point 8	66.50809	683.9278
Point 9	32.02336	686.4408
Point 10	0	673.6772
Point 11	0	600
Point 12	550	600
Point 13	0	720.8323
Point 14	7.46834	722.0398
Point 15	17.77472	724.1848
Point 16	25.57517	724.516
Point 17	31.28542	725.5687
Point 18	34.87149	726.2089
Point 19	37.67175	726.5403
Point 20	40.93893	726.7039
Point 21	46.19081	726.4746
Point 22	47.16212	726.3444
Point 23	49.38769	726.046
Point 24	53.99285	725.1701
Point 25	66.88823	724.3223
Point 26	71.8387	722.4442
Point 27	75.30131	721.797
Point 28	82.45112	721.6417
Point 29	93.64932	721.9043
Point 30	96.52628	721.4946
Point 31	107.86425	720.7568
Point 32	112.04926	720.0827
Point 33	113.76575	720.0026
Point 34	114.78083	719.8752
Point 35	127.86646	718.305
Point 36	137.96649	717.6227
Point 37	149.75519	716.6597

Point 38	158.52901	715.7262
Point 39	163.94611	715.1232
Point 40	170.23801	714.2245
Point 41	175.22762	713.9809
Point 42	181.50178	713.2469
Point 43	188.5807	713.1223
Point 44	195.93295	713.0265
Point 45	207.0338	712.0464
Point 46	209.6519	712.0968
Point 47	224.14526	710.2482
Point 48	224.47398	710.2521
Point 49	226.65718	710.0026
Point 50	238.40625	708.4686
Point 51	240.00628	708.2563
Point 52	248.88633	707.0993
Point 53	256.27544	705.3133
Point 54	261.98263	704.1692
Point 55	268.69369	702.8011
Point 56	280.42697	700.0026
Point 57	280.55013	699.942
Point 58	280.81912	699.8237
Point 59	289.34	695.145
Point 60	291.93842	693.7183
Point 61	309.94718	690.0026
Point 62	310.6437	689.9203
Point 63	310.80713	689.8745
Point 64	320.52166	689.5469
Point 65	322.11323	688.7431
Point 66	331.40237	685.3953
Point 67	338.36902	680.0026
Point 68	346.67675	673.3234
Point 69	355.97678	670.6425
Point 70	357.3582	670.0026
Point 71	370.11699	663.5631
Point 72	376.6901	660.0026
Point 73	379.31551	659.301
Point 74	379.67289	659.2879
Point 75	387.50838	657.1924
Point 76	395.6543	655.9514
Point 77	401.62265	655.2704
Point 78	407.40479	654.9811
Point 79	414.69105	654.8719
Point 80	424.58073	655.1187
Point 81	434.12333	655.052
Point 82	440.76845	654.709
Point 83	450.8547	654.5724
Point 84	456.596	654.5475
Point 85	460.58523	654.5506
Point 86	467.1647	654.377
Point 87	481.83285	654.1694
Point 88	499.00652	653.4161
Point 89	501.90915	653.2851

Point 90	505.18877	653.174
Point 91	507.81999	653.0849
Point 92	510.26762	652.8252
Point 93	519.53725	652.4508
Point 94	530.07024	651.847
Point 95	550	650.0076
Point 96	491.0719	655.7661
Point 97	481.89084	656.1688
Point 98	467.20522	656.3767
Point 99	460.61083	656.5506
Point 100	456.59956	656.5475
Point 101	450.87258	656.5723
Point 102	440.83357	656.7083
Point 103	434.1819	657.0516
Point 104	424.56277	657.1189
Point 105	414.68108	656.8723
Point 106	407.46977	656.9803
Point 107	401.78616	657.2648
Point 108	395.91836	657.9343
Point 109	387.91859	659.153
Point 110	379.97164	661.2783
Point 111	379.61406	661.2914
Point 112	377.43481	661.8737
Point 113	371.04405	665.3355
Point 114	358.22938	671.8032
Point 115	356.67823	672.5218
Point 116	347.61678	675.1339
Point 117	339.60782	681.5728
Point 118	332.3772	687.1699
Point 119	322.90598	690.5834
Point 120	321.02968	691.5309
Point 121	311.11503	691.8653
Point 122	311.03314	691.8882
Point 123	310.26713	691.9787
Point 124	292.63726	695.6162
Point 125	289.34	697.4267
Point 126	115.99	760.87
Point 127	134.99	769.85
Point 128	154.66	770.34
Point 129	181.08	762.2
Point 130	210.24	750.56
Point 131	245.68	735.99
Point 132	284.25	719.57
Point 133	286.27	718.57
Point 134	289.34	719.52
Point 135	301.7	719.94
Point 136	333.76	706.14
Point 137	370.37	691.24
Point 138	391.78	681.97
Point 139	418.04	669.19
Point 140	420.85	667.78
Point 141	423.38	668.84

Point 142	444.04	671.12
Point 143	475.91	658.55
Point 144	489.58	656.04
Point 145	0	750.95
Point 146	96.2142	750.95
Point 147	154.2851	746.62
Point 148	264.3657	723.23
Point 149	313.5525	709.86
Point 150	382.9612	676.57
Point 151	430.7828	667.36
Point 152	154.28	767.29
Point 153	154.3	767.29
Point 154	264.4	702.5
Point 155	264.4	724.2
Point 156	462.7289	658.58

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.45	(26.618, 857.179)	43.3311	(115.48, 760.614)	(47.1753, 726.351)
2	7	1.49	(26.618, 857.179)	131.772	(117.124, 761.406)	(49.1698, 727.351)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	48.341975	726.79095	1175.537	1208.2587	25.565035	0
2	Optimized	50.67534	727.67085	1120.6398	1165.552	35.089263	0
3	Optimized	52.808675	728.4685	1070.8596	1128.8777	45.328656	0
4	Optimized	54.741985	729.1839	1026.2304	1095.0176	53.742504	0
5	Optimized	56.97642	729.99755	975.45045	1059.6946	65.818722	0
6	Optimized	59.511975	730.90945	918.55783	1018.1663	77.822665	0
7	Optimized	61.810805	731.72215	867.85004	985.26209	91.73234	0
8	Optimized	63.872915	732.43565	823.30496	954.60297	102.58125	0
9	Optimized	66.3137	733.27075	771.22506	920.98957	117.00885	0
10	Optimized	69.133165	734.2274	711.50735	881.18895	132.5698	0
11	Optimized	71.66001	735.06595	659.20154	851.78636	150.46375	0
12	Optimized	73.89423	735.7865	614.21822	824.52375	164.30868	0
13	Optimized	76.17312	736.52085	568.40597	796.87444	178.49914	0
14	Optimized	78.49668	737.269	521.70451	768.64873	192.93398	0
15	Optimized	80.97834	738.03225	474.10982	749.86238	215.44151	0
16	Optimized	83.6181	738.81055	425.52882	726.06241	234.80258	0
17	Optimized	85.27328	739.3085	394.45538	701.65117	240.00765	0
18	Optimized	87.008945	739.87175	359.31202	721.61265	283.06027	0
19	Optimized	89.48215	740.86815	297.14153	686.2168	303.97892	0
20	Optimized	91.627825	741.95205	229.50574	675.15147	348.1766	0
21	Optimized	93.579035	743.08755	158.64713	600.45089	345.17493	0
22	Optimized	95.335785	744.27465	84.570615	558.71033	370.43855	0
23	Optimized	96.43797	745.01945	38.096701	532.55046	386.30961	0
24	Optimized	96.951535	745.40035	14.329527	487.10383	369.37177	0
25	Optimized	98.303635	746.47195	-52.539889	451.59075	352.82136	0
26	Optimized	100.42834	748.1559	-157.61598	401.05744	313.34041	0
27	Optimized	102.72225	749.97395	-271.064	346.52996	270.73888	0

28	Optimized	105.5888	752.2458	-412.82531	278.39645	217.50714	0
29	Optimized	108.2773	754.39615	-546.99836	210.89293	164.76762	0
30	Optimized	110.38425	756.10525	-653.67042	158.09137	123.51452	0
31	Optimized	112.4483	757.8734	-763.99617	94.383769	73.740682	0
32	Optimized	114.46945	759.7006	-877.99367	31.461623	24.580514	0

Slices of Slip Surface: 7

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	7	50.308485	727.5596	1127.5722	1210.0291	64.422332	0
2	7	52.58591	727.9966	1100.3099	1213.7416	88.622625	0
3	7	54.863335	728.4754	1070.4556	1211.945	110.54361	0
4	7	57.14076	728.99645	1037.9304	1204.6896	130.28652	0
5	7	59.418185	729.5603	1002.746	1191.9915	147.85479	0
6	7	61.69561	730.16745	964.87805	1173.9201	163.32159	0
7	7	63.973035	730.81855	924.22446	1150.5119	176.7951	0
8	7	66.25046	731.5143	880.81966	1121.816	188.28698	0
9	7	68.527885	732.25545	834.57874	1087.8497	197.87699	0
10	7	70.80531	733.0428	785.42933	1048.6042	205.61475	0
11	7	73.082735	733.87725	733.39105	1004.1241	211.51981	0
12	7	75.36016	734.75975	678.29177	954.3896	215.71127	0
13	7	77.637585	735.6913	620.17707	899.39642	218.15007	0
14	7	79.915015	736.67315	558.90554	839.16146	218.95992	0
15	7	82.19244	737.7065	494.43418	773.64079	218.14011	0
16	7	84.469865	738.79265	426.66054	702.81624	215.75647	0
17	7	86.669135	739.8921	358.04854	657.20426	233.72606	0
18	7	88.79025	741.00265	288.74559	636.10074	271.38359	0
19	7	90.91137	742.16305	216.33969	608.84248	306.65678	0
20	7	93.03249	743.3748	140.72274	575.39152	339.60047	0
21	7	95.153605	744.6396	61.800103	535.69753	370.24925	0
22	7	96.4896	745.45775	10.749099	508.15852	388.61883	0
23	7	98.06873	746.4714	-52.502886	481.07505	375.85702	0
24	7	100.67611	748.1987	-160.28869	436.04361	340.6746	0
25	7	103.2835	750.0173	-273.76785	384.38168	300.31188	0
26	7	105.72745	751.80605	-385.37889	330.24761	258.01771	0
27	7	108.008	753.55775	-494.69972	274.31248	214.3164	0
28	7	110.2886	755.39075	-609.08049	213.41359	166.73697	0
29	7	112.56915	757.30945	-728.78003	147.58394	115.30521	0
30	7	114.8497	759.31885	-854.18703	76.869994	60.057421	0
31	7	116.55695	760.8764	-951.39635	20.231916	15.806905	0

Seepage Analysis - Static Condition

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 178
Last Edited By: Cedric Ruhl
Date: 9/16/2010
Time: 3:36:42 PM
File Name: AD 12+00 WSEL = 745.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 12+00\
Last Solved Date: 9/16/2010
Last Solved Time: 3:36:47 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Mass(M) Units: lbs
Mass Flux Units: lbs/sec
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Seepage Analysis - Static Condition

Description: Ash Dike Section Sta. 12+00 Water Surface Elevation = 745.63
Kind: SEEP/W
Method: Steady-State
Settings
    Include Air Flow: No
Control
    Apply Runoff: Yes
Convergence
    Convergence Type: Gauss Point K
    Convergence Settings
        Maximum Number of Iterations: 500
        Tolerance: 0.01
        Maximum Change in K: 0.1

Rate of Change in K: 1.02
Minimum Change in K: 0.0001
Equation Solver: Parallel Direct
Potential Seepage Max # of Reviews: 10
Time
Starting Time: 0 sec
Duration: 0 sec
Ending Time: 0 sec

Materials

Embankment Fill - Ash Dike

Model: Saturated / Unsaturated
Hydraulic
K-Function: 3e-6
K-Ratio: 0.1
K-Direction: 0 °

Blanket Drain

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-4
K-Ratio: 1
K-Direction: 0 °

Residuum

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

PWR

Model: Saturated / Unsaturated
Hydraulic
K-Function: 1e-5
K-Ratio: 1
K-Direction: 0 °

Boundary Conditions

Water Elevation = 745.63

Type: Head (H) 745.63

Potential Seepage Face

Review: true
Type: Total Flux (Q) 0

Zero Pressure

Type: Pressure Head 0

K Functions

1e-4

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-006
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-006)
Data Point: (10000, 3.28e-006)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

1e-5

Model: Data Point Function
Function: X-Conductivity vs. Pore-Water Pressure
Curve Fit to Data: 100 %
Segment Curvature: 100 %
K-Saturation: 3.28e-007
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
Data Point: (0.01, 3.28e-007)
Data Point: (10000, 3.28e-007)
Estimation Properties
Hydraulic K Sat: 0 ft/sec
Hyd. K-Function Estimation Method: Van Genuchten Function
Maximum: 1000
Minimum: 0.01
Num. Points: 20
Residual Water Content: 0 ft^3/ft^3

3e-6

Model: Data Point Function

Function: X-Conductivity vs. Pore-Water Pressure
- Curve Fit to Data: 100 %
- Segment Curvature: 100 %

K-Saturation: 9.84e-008
Data Points: Matric Suction (psf), X-Conductivity (ft/sec)
- Data Point: (0.01, 9.84e-008)
- Data Point: (10000, 9.84e-008)

Estimation Properties
- Hydraulic K Sat: 0 ft/sec
- Hyd. K-Function Estimation Method: Van Genuchten Function
- Maximum: 1000
- Minimum: 0.01
- Num. Points: 20
- Residual Water Content: 0 ft^3/ft^3

Regions

	Material	Points	Area (ft^2)
Region 1	PWR	1,2,3,4,5,6,7,8,9,10,11,12	34875.27
Region 2	Residuum	13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,1,2,3,4,5,6,7,8,9,10	15102.129
Region 3	Embankment Fill - Ash Dike	22,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,59,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,43,42,41,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24,23	11779.951
Region 4	Blanket Drain	96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88	429.94757

Lines

	Start Point	End Point	Hydraulic Boundary
Line 1	1	2	
Line 2	2	3	
Line 3	3	4	
Line 4	4	5	
Line 5	5	6	
Line 6	6	7	
Line 7	7	8	
Line 8	8	9	
Line 9	9	10	

Line 10	10	11	Water Elevation = 745.63
Line 11	11	12	
Line 12	12	1	
Line 13	13	14	Water Elevation = 745.63
Line 14	14	15	Water Elevation = 745.63
Line 15	15	16	Water Elevation = 745.63
Line 16	16	17	Water Elevation = 745.63
Line 17	17	18	Water Elevation = 745.63
Line 18	18	19	Water Elevation = 745.63
Line 19	19	20	Water Elevation = 745.63
Line 20	20	21	Water Elevation = 745.63
Line 21	21	22	Water Elevation = 745.63
Line 22	22	23	
Line 23	23	24	
Line 24	24	25	
Line 25	25	26	
Line 26	26	27	
Line 27	27	28	
Line 28	28	29	
Line 29	29	30	
Line 30	30	31	
Line 31	31	32	
Line 32	32	33	
Line 33	33	34	
Line 34	34	35	
Line 35	35	36	
Line 36	36	37	
Line 37	37	38	
Line 38	38	39	
Line 39	39	40	
Line 40	40	41	
Line 41	41	42	
Line 42	42	43	
Line 43	43	44	
Line 44	44	45	
Line 45	45	46	
Line 46	46	47	
Line 47	47	48	
Line 48	48	49	
Line 49	49	50	
Line 50	50	51	
Line 51	51	52	
Line 52	52	53	
Line 53	53	54	
Line 54	54	55	

Line 55	55	56	
Line 56	56	57	
Line 57	57	58	
Line 58	58	59	
Line 59	59	60	
Line 60	60	61	
Line 61	61	62	
Line 62	62	63	
Line 63	63	64	
Line 64	64	65	
Line 65	65	66	
Line 66	66	67	
Line 67	67	68	
Line 68	68	69	
Line 69	69	70	
Line 70	70	71	
Line 71	71	72	
Line 72	72	73	
Line 73	73	74	
Line 74	74	75	
Line 75	75	76	
Line 76	76	77	
Line 77	77	78	
Line 78	78	79	
Line 79	79	80	
Line 80	80	81	
Line 81	81	82	
Line 82	82	83	
Line 83	83	84	
Line 84	84	85	
Line 85	85	86	
Line 86	86	87	
Line 87	87	88	
Line 88	88	89	Potential Seepage Face
Line 89	89	90	Potential Seepage Face
Line 90	90	91	Potential Seepage Face
Line 91	91	92	Potential Seepage Face
Line 92	92	93	Potential Seepage Face
Line 93	93	94	Potential Seepage Face
Line 94	94	95	Potential Seepage Face
Line 95	95	1	
Line 96	10	13	Water Elevation = 745.63
Line 97	22	126	Water Elevation = 745.63
Line 98	126	127	Water Elevation = 745.63
Line 99	127	128	

Line 100	128	129	
Line 101	129	130	
Line 102	130	131	
Line 103	131	132	
Line 104	132	133	
Line 105	133	134	
Line 106	134	135	
Line 107	135	136	Potential Seepage Face
Line 108	136	137	Potential Seepage Face
Line 109	137	138	Potential Seepage Face
Line 110	138	139	Potential Seepage Face
Line 111	139	140	Potential Seepage Face
Line 112	140	141	Potential Seepage Face
Line 113	141	142	Potential Seepage Face
Line 114	142	143	Potential Seepage Face
Line 115	143	144	
Line 116	144	96	
Line 117	96	97	
Line 118	97	98	
Line 119	98	99	
Line 120	99	100	
Line 121	100	101	
Line 122	101	102	
Line 123	102	103	
Line 124	103	104	
Line 125	104	105	
Line 126	105	106	
Line 127	106	107	
Line 128	107	108	
Line 129	108	109	
Line 130	109	110	
Line 131	110	111	
Line 132	111	112	
Line 133	112	113	
Line 134	113	114	
Line 135	114	115	
Line 136	115	116	
Line 137	116	117	
Line 138	117	118	
Line 139	118	119	
Line 140	119	120	
Line 141	120	121	
Line 142	121	122	
Line 143	122	123	
Line 144	123	124	

Line 145	124	125	
Line 146	125	59	
Line 147	88	96	
Line 148	147	148	
Line 149	148	149	
Line 150	149	150	Zero Pressure
Line 151	140	151	
Line 152	156	88	
Line 153	151	156	
Line 154	150	140	Zero Pressure
Line 155	146	147	

Points

	X (ft)	Y (ft)
Point 1	550	646.2121
Point 2	432.28284	652.71
Point 3	429.28284	652.71
Point 4	329.50979	655.3527
Point 5	255.39889	660.9638
Point 6	165.93156	672.8646
Point 7	115.00223	676.7478
Point 8	66.50809	683.9278
Point 9	32.02336	686.4408
Point 10	0	673.6772
Point 11	0	600
Point 12	550	600
Point 13	0	720.8323
Point 14	7.46834	722.0398
Point 15	17.77472	724.1848
Point 16	25.57517	724.516
Point 17	31.28542	725.5687
Point 18	34.87149	726.2089
Point 19	37.67175	726.5403
Point 20	40.93893	726.7039
Point 21	46.19081	726.4746
Point 22	47.16212	726.3444
Point 23	49.38769	726.046
Point 24	53.99285	725.1701
Point 25	66.88823	724.3223
Point 26	71.8387	722.4442
Point 27	75.30131	721.797
Point 28	82.45112	721.6417
Point 29	93.64932	721.9043
Point 30	96.52628	721.4946

Point 31	107.86425	720.7568
Point 32	112.04926	720.0827
Point 33	113.76575	720.0026
Point 34	114.78083	719.8752
Point 35	127.86646	718.305
Point 36	137.96649	717.6227
Point 37	149.75519	716.6597
Point 38	158.52901	715.7262
Point 39	163.94611	715.1232
Point 40	170.23801	714.2245
Point 41	175.22762	713.9809
Point 42	181.50178	713.2469
Point 43	188.5807	713.1223
Point 44	195.93295	713.0265
Point 45	207.0338	712.0464
Point 46	209.6519	712.0968
Point 47	224.14526	710.2482
Point 48	224.47398	710.2521
Point 49	226.65718	710.0026
Point 50	238.40625	708.4686
Point 51	240.00628	708.2563
Point 52	248.88633	707.0993
Point 53	256.27544	705.3133
Point 54	261.98263	704.1692
Point 55	268.69369	702.8011
Point 56	280.42697	700.0026
Point 57	280.55013	699.942
Point 58	280.81912	699.8237
Point 59	289.34	695.145
Point 60	291.93842	693.7183
Point 61	309.94718	690.0026
Point 62	310.6437	689.9203
Point 63	310.80713	689.8745
Point 64	320.52166	689.5469
Point 65	322.11323	688.7431
Point 66	331.40237	685.3953
Point 67	338.36902	680.0026
Point 68	346.67675	673.3234
Point 69	355.97678	670.6425
Point 70	357.3582	670.0026
Point 71	370.11699	663.5631
Point 72	376.6901	660.0026
Point 73	379.31551	659.301
Point 74	379.67289	659.2879
Point 75	387.50838	657.1924

Point 76	395.6543	655.9514
Point 77	401.62265	655.2704
Point 78	407.40479	654.9811
Point 79	414.69105	654.8719
Point 80	424.58073	655.1187
Point 81	434.12333	655.052
Point 82	440.76845	654.709
Point 83	450.8547	654.5724
Point 84	456.596	654.5475
Point 85	460.58523	654.5506
Point 86	467.1647	654.377
Point 87	481.83285	654.1694
Point 88	499.00652	653.4161
Point 89	501.90915	653.2851
Point 90	505.18877	653.174
Point 91	507.81999	653.0849
Point 92	510.26762	652.8252
Point 93	519.53725	652.4508
Point 94	530.07024	651.847
Point 95	550	650.0076
Point 96	491.0719	655.7661
Point 97	481.89084	656.1688
Point 98	467.20522	656.3767
Point 99	460.61083	656.5506
Point 100	456.59956	656.5475
Point 101	450.87258	656.5723
Point 102	440.83357	656.7083
Point 103	434.1819	657.0516
Point 104	424.56277	657.1189
Point 105	414.68108	656.8723
Point 106	407.46977	656.9803
Point 107	401.78616	657.2648
Point 108	395.91836	657.9343
Point 109	387.91859	659.153
Point 110	379.97164	661.2783
Point 111	379.61406	661.2914
Point 112	377.43481	661.8737
Point 113	371.04405	665.3355
Point 114	358.22938	671.8032
Point 115	356.67823	672.5218
Point 116	347.61678	675.1339
Point 117	339.60782	681.5728
Point 118	332.3772	687.1699
Point 119	322.90598	690.5834
Point 120	321.02968	691.5309

Point 121	311.11503	691.8653
Point 122	311.03314	691.8882
Point 123	310.26713	691.9787
Point 124	292.63726	695.6162
Point 125	289.34	697.4267
Point 126	115.99	760.87
Point 127	134.99	769.85
Point 128	154.66	770.34
Point 129	181.08	762.2
Point 130	210.24	750.56
Point 131	245.68	735.99
Point 132	284.25	719.57
Point 133	286.27	718.57
Point 134	289.34	719.52
Point 135	301.7	719.94
Point 136	333.76	706.14
Point 137	370.37	691.24
Point 138	391.78	681.97
Point 139	418.04	669.19
Point 140	420.85	667.78
Point 141	423.38	668.84
Point 142	444.04	671.12
Point 143	475.91	658.55
Point 144	489.58	656.04
Point 145	0	750.95
Point 146	96.2142	750.95
Point 147	154.2851	746.62
Point 148	264.3657	723.23
Point 149	347.00016	691.8087
Point 150	382.9612	676.57
Point 151	430.7828	667.36
Point 152	154.28	767.29
Point 153	154.3	767.29
Point 154	264.4	702.5
Point 155	264.4	724.2
Point 156	462.7289	658.58

Static Slope Stability Analysis - Lower

Report generated using GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd.

File Information

Created By: Cedric Ruhl
Revision Number: 179
Last Edited By: Cedric Ruhl
Date: 9/16/2010
Time: 3:37:29 PM
File Name: AD 12+00 WSEL = 745.gsz
Directory: S:\1356\PROJECTS\2009\1356-09-029 Belews Creek Slope Stability\Task 3 - Slope Stability\Calculations\Slope Stability Calculation\GeoStudios\Current Models\AD 12+00\
Last Solved Date: 9/16/2010
Last Solved Time: 3:37:47 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Static Slope Stability Analysis - Lower

Description: Ash Dike Section Sta. 12+00 Water Surface Elevation = 745.63
Kind: SLOPE/W
Parent: Seepage Analysis - Static Condition
Method: Spencer
Settings
    PWP Conditions Source: Parent Analysis
Slip Surface
    Direction of movement: Left to Right
    Use Passive Mode: No
    Slip Surface Option: Auto-Search
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: Yes
    Tension Crack
        Tension Crack Option: (none)
FOS Distribution
    FOS Calculation Option: Constant
Advanced
    Number of Slices: 30

Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 3 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Embankment Fill - Ash Dike

Model: Shear/Normal Fn.
Unit Weight: 123 pcf
Unit Wt. Above Water Table: 121 pcf
Strength Function: Ash Dike Fill
Phi-B: 0 °

Blanket Drain

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 36 °
Phi-B: 0 °

Residuum

Model: Shear/Normal Fn.
Unit Weight: 124 pcf
Strength Function: Ash Dike Res
Phi-B: 0 °

PWR

Model: Mohr-Coulomb
Unit Weight: 140 pcf
Cohesion: 1000 psf
Phi: 38 °
Phi-B: 0 °

Slip Surface Limits

Left Coordinate: (0, 720.8323) ft
Right Coordinate: (550, 650.0076) ft

Seismic Loads

Horz Seismic Load: 0

Shear/Normal Strength Functions

Ash Dike Fill

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 433)
Data Point: (1000, 829)
Data Point: (1500, 1188)
Data Point: (2000, 1511)
Data Point: (2500, 1797)
Data Point: (3000, 2047)
Data Point: (3500, 2259)
Data Point: (4000, 2436)
Data Point: (4500, 2575)
Data Point: (5000, 2678)
Data Point: (5500, 2744)
Data Point: (6000, 2774)
Data Point: (20000, 2800)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Ash Dike Res

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 0 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (500, 526)
Data Point: (1000, 999)
Data Point: (1500, 1417)
Data Point: (2000, 1781)
Data Point: (2500, 2092)
Data Point: (3000, 2349)
Data Point: (3500, 2552)
Data Point: (4000, 2700)
Data Point: (4500, 2795)
Data Point: (5000, 2837)
Data Point: (20000, 3500)

Estimation Properties
- Intact Rock Param.: 10
- Geological Strength: 100
- Disturbance Factor: 0
- SigmaC: 600000 psf
- Sigma3: 300000 psf
- Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	PWR	1,2,3,4,5,6,7,8,9,10,11,12	34875.27
Region 2	Residuum	13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34, 35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56, 57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78, 79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,1,2,3,4,5,6,7,8,9,10	15102.129
Region 3	Embankment Fill - Ash Dike	22,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141, 142,143,144,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110, 111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,59,58,57, 56,55,54,53,52,51,50,49,48,47,46,45,44,43,42,41,40,39,38,37,36,35,34,33, 32,31,30,29,28,27,26,25,24,23	11779.951
Region 4	Blanket Drain	96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114, 115,116,117,118,119,120,121,122,123,124,125,59,60,61,62,63,64,65,66,67,68, 69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88	429.94757

Points

	X (ft)	Y (ft)
Point 1	550	646.2121
Point 2	432.28284	652.71
Point 3	429.28284	652.71
Point 4	329.50979	655.3527
Point 5	255.39889	660.9638
Point 6	165.93156	672.8646
Point 7	115.00223	676.7478
Point 8	66.50809	683.9278
Point 9	32.02336	686.4408
Point 10	0	673.6772
Point 11	0	600
Point 12	550	600
Point 13	0	720.8323
Point 14	7.46834	722.0398
Point 15	17.77472	724.1848
Point 16	25.57517	724.516
Point 17	31.28542	725.5687
Point 18	34.87149	726.2089
Point 19	37.67175	726.5403
Point 20	40.93893	726.7039
Point 21	46.19081	726.4746

Point 22	47.16212	726.3444
Point 23	49.38769	726.046
Point 24	53.99285	725.1701
Point 25	66.88823	724.3223
Point 26	71.8387	722.4442
Point 27	75.30131	721.797
Point 28	82.45112	721.6417
Point 29	93.64932	721.9043
Point 30	96.52628	721.4946
Point 31	107.86425	720.7568
Point 32	112.04926	720.0827
Point 33	113.76575	720.0026
Point 34	114.78083	719.8752
Point 35	127.86646	718.305
Point 36	137.96649	717.6227
Point 37	149.75519	716.6597
Point 38	158.52901	715.7262
Point 39	163.94611	715.1232
Point 40	170.23801	714.2245
Point 41	175.22762	713.9809
Point 42	181.50178	713.2469
Point 43	188.5807	713.1223
Point 44	195.93295	713.0265
Point 45	207.0338	712.0464
Point 46	209.6519	712.0968
Point 47	224.14526	710.2482
Point 48	224.47398	710.2521
Point 49	226.65718	710.0026
Point 50	238.40625	708.4686
Point 51	240.00628	708.2563
Point 52	248.88633	707.0993
Point 53	256.27544	705.3133
Point 54	261.98263	704.1692
Point 55	268.69369	702.8011
Point 56	280.42697	700.0026
Point 57	280.55013	699.942
Point 58	280.81912	699.8237
Point 59	289.34	695.145
Point 60	291.93842	693.7183
Point 61	309.94718	690.0026
Point 62	310.6437	689.9203
Point 63	310.80713	689.8745
Point 64	320.52166	689.5469
Point 65	322.11323	688.7431
Point 66	331.40237	685.3953
Point 67	338.36902	680.0026
Point 68	346.67675	673.3234
Point 69	355.97678	670.6425
Point 70	357.3582	670.0026

Point 71	370.11699	663.5631
Point 72	376.6901	660.0026
Point 73	379.31551	659.301
Point 74	379.67289	659.2879
Point 75	387.50838	657.1924
Point 76	395.6543	655.9514
Point 77	401.62265	655.2704
Point 78	407.40479	654.9811
Point 79	414.69105	654.8719
Point 80	424.58073	655.1187
Point 81	434.12333	655.052
Point 82	440.76845	654.709
Point 83	450.8547	654.5724
Point 84	456.596	654.5475
Point 85	460.58523	654.5506
Point 86	467.1647	654.377
Point 87	481.83285	654.1694
Point 88	499.00652	653.4161
Point 89	501.90915	653.2851
Point 90	505.18877	653.174
Point 91	507.81999	653.0849
Point 92	510.26762	652.8252
Point 93	519.53725	652.4508
Point 94	530.07024	651.847
Point 95	550	650.0076
Point 96	491.0719	655.7661
Point 97	481.89084	656.1688
Point 98	467.20522	656.3767
Point 99	460.61083	656.5506
Point 100	456.59956	656.5475
Point 101	450.87258	656.5723
Point 102	440.83357	656.7083
Point 103	434.1819	657.0516
Point 104	424.56277	657.1189
Point 105	414.68108	656.8723
Point 106	407.46977	656.9803
Point 107	401.78616	657.2648
Point 108	395.91836	657.9343
Point 109	387.91859	659.153
Point 110	379.97164	661.2783
Point 111	379.61406	661.2914
Point 112	377.43481	661.8737
Point 113	371.04405	665.3355
Point 114	358.22938	671.8032
Point 115	356.67823	672.5218
Point 116	347.61678	675.1339
Point 117	339.60782	681.5728
Point 118	332.3772	687.1699
Point 119	322.90598	690.5834

Point 120	321.02968	691.5309
Point 121	311.11503	691.8653
Point 122	311.03314	691.8882
Point 123	310.26713	691.9787
Point 124	292.63726	695.6162
Point 125	289.34	697.4267
Point 126	115.99	760.87
Point 127	134.99	769.85
Point 128	154.66	770.34
Point 129	181.08	762.2
Point 130	210.24	750.56
Point 131	245.68	735.99
Point 132	284.25	719.57
Point 133	286.27	718.57
Point 134	289.34	719.52
Point 135	301.7	719.94
Point 136	333.76	706.14
Point 137	370.37	691.24
Point 138	391.78	681.97
Point 139	418.04	669.19
Point 140	420.85	667.78
Point 141	423.38	668.84
Point 142	444.04	671.12
Point 143	475.91	658.55
Point 144	489.58	656.04
Point 145	0	750.95
Point 146	96.2142	750.95
Point 147	154.2851	746.62
Point 148	264.3657	723.23
Point 149	347.00016	691.8087
Point 150	382.9612	676.57
Point 151	430.7828	667.36
Point 152	154.28	767.29
Point 153	154.3	767.29
Point 154	264.4	702.5
Point 155	264.4	724.2
Point 156	462.7289	658.58

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.47	(393.886, 763.049)	75.0569	(299.279, 719.858)	(427.467, 669.291)
2	946	1.52	(393.886, 763.049)	98.745	(305.961, 718.106)	(420.497, 667.957)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	300.48965	718.14555	-702.36903	101.37302	87.790391	-1.266e-006
2	Optimized	302.78325	714.901	-583.52188	264.38729	228.96292	6.7555e-006

3	Optimized	305.61525	711.2823	-452.42952	447.19498	387.27682	-5.5782e-006
4	Optimized	309.1128	707.10965	-304.77877	620.87149	491.72627	37
5	Optimized	312.47905	703.27055	-172.03665	821.97547	650.99935	37
6	Optimized	315.7139	699.7651	-50.06738	968.07696	766.7108	37
7	Optimized	320.17355	695.1987	102.98015	1232.7564	811.16895	111
8	Optimized	324.905	690.78355	258.55772	1545.0272	923.67331	111
9	Optimized	328.2701	687.93095	382.0467	1696.4951	955.00267	0
10	Optimized	331.0616	685.7636	482.46849	1923.6365	1047.0698	0
11	Optimized	333.0686	684.3659	542.97558	1976.3988	1041.4429	0
12	Optimized	335.8865	682.40345	627.60299	2056.2502	1037.973	0
13	Optimized	338.8104	680.44295	711.55522	2237.7826	1108.8691	0
14	Optimized	341.59405	678.7689	777.18268	2294.7016	1102.5421	0
15	Optimized	345.61955	676.348	870.25348	2377.0287	1094.7363	0
16	Optimized	349.6666	674.2392	943.15362	2641.8971	1234.2094	0
17	Optimized	353.68215	672.4744	997.32299	2655.8042	1204.9571	0
18	Optimized	356.18405	671.4049	1029.9182	2754.3024	1252.8385	0
19	Optimized	357.4538	670.92415	1042.2036	2750.6314	1241.2454	0
20	Optimized	360.55415	669.75035	1073.7283	2742.3497	1212.3244	0
21	Optimized	365.2674	667.9659	1121.995	2730.1029	1168.3588	0
22	Optimized	369.01295	666.70585	1143.5245	2899.7444	1134.4981	219
23	Optimized	373.25335	665.5943	1132.8161	2819.5853	1089.6337	219
24	Optimized	377.9746	664.4977	1113.3417	2849.8251	1121.7486	219
25	Optimized	381.6504	663.8161	1088.3582	2738.8173	1066.1778	219
26	Optimized	385.56125	663.23685	1053.439	2735.3182	1086.4749	219
27	Optimized	389.7071	662.7599	1013.829	2566.3827	1002.932	219
28	Optimized	391.8839	662.50945	994.5473	2476.7593	1064.2146	111
29	Optimized	394.2582	662.4858	952.66934	2538.0878	1024.1623	219
30	Optimized	398.79895	662.4624	871.64873	2232.8566	977.33477	111
31	Optimized	403.3397	662.439	798.04969	1924.5423	808.81133	111
32	Optimized	408.2677	662.9109	673.91484	1810.8407	816.30235	111
33	Optimized	413.58285	663.87815	490.51701	1222.8867	580.03211	37
34	Optimized	417.1402	664.75685	343.66172	1116.8255	612.34083	37
35	Optimized	419.445	665.7688	207.6295	616.63226	354.20184	-4.9412e-006
36	Optimized	422.115	666.94115	72.718337	349.00676	239.26946	6.8522e-006
37	Optimized	425.4235	668.3938	-32.095134	214.06688	185.38478	-2.605e-006

Slices of Slip Surface: 946

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	946	307.9185	714.6305	-600.73759	131.94841	114.26909	8.6346e-007
2	946	311.8333	708.22555	-364.71257	412.50836	357.23775	-5.1508e-006
3	946	315.7481	702.75915	-173.69282	687.4528	544.45824	37
4	946	319.6629	697.9892	-4.3406005	949.91783	752.32888	37
5	946	323.5777	693.76965	137.09265	1224.9142	781.04591	111
6	946	327.4925	690.00405	279.11513	1477.9341	860.74101	111
7	946	330.91355	687.01275	411.40646	1701.0869	937.0077	0
8	946	333.0686	685.26005	492.08319	1817.5168	962.98389	0
9	946	335.22195	683.6395	564.11666	1926.8874	990.11089	0
10	946	338.14585	681.5595	655.35972	2068.1545	1026.4555	0

11	946	342.2692	678.9265	761.77897	2241.3647	1074.982	0
12	946	346.3767	676.4997	853.63303	2388.4691	991.48664	219
13	946	349.2689	674.97335	905.63417	2482.1816	1018.4317	219
14	946	352.2058	673.54655	952.58567	2569.4973	1174.7551	0
15	946	355.1874	672.21715	994.06836	2638.5685	1194.7993	0
16	946	357.4538	671.27415	1021.9911	2684.5243	1207.9011	0
17	946	360.9955	669.98865	1055.0352	2737.2457	1222.1975	0
18	946	365.4137	668.51345	1082.473	2791.1483	1103.7848	219
19	946	368.7179	667.58035	1081.068	2810.4079	1117.134	219
20	946	372.15415	666.7422	1065.1306	2809.1477	1126.6152	219
21	946	375.7225	666.0057	1041.403	2784.6222	1126.0998	219
22	946	379.29085	665.4051	1009.6805	2741.4285	1118.6895	219
23	946	382.85915	664.9379	970.06292	2678.6246	1103.7114	219
24	946	386.4275	664.60225	922.07532	2595.4588	1080.9867	219
25	946	389.99585	664.39675	873.09086	2489.8169	1044.3866	219
26	946	393.6557	664.322	811.12874	2343.3141	989.77432	219
27	946	397.40715	664.38455	735.57129	2149.3056	1015.0483	111
28	946	401.1586	664.5901	652.0277	1921.6036	911.54381	111
29	946	404.91	664.93945	561.53077	1657.1489	786.64375	111
30	946	408.6614	665.4341	448.61014	1351.5761	715.14329	37
31	946	412.41285	666.0764	320.24327	997.20262	536.1475	37
32	946	416.1643	666.8693	176.11087	584.30085	353.49797	-5.0358e-006
33	946	419.26835	667.63055	45.776303	182.06672	118.02932	-1.6791e-006