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REPORT ON

DETAILED INITIAL SAFETY FACTOR ASSESSMENT
SIKESTON POWER STATION
BOTTOM ASH POND
SIKESTON, MISSOURI

by Haley & Aldrich, Inc.
Cleveland, Ohio

for Sikeston Board of Municipal Utilities
Sikeston, Missouri

File No. 128065-001
October 2016

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14 October 2016
File No. 128065-001

Sikeston Power Station Board of Municipal Utilities
P.O. Box 468
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Attention: Mr. Mark, McGill
Results Engineer/Plant Chemist

Subject: Report on Detailed Initial Safety Factor Assessment
Sikeston Power Station
Bottom Ash Pond
Sikeston, Missouri

Mr. McGill:

We are pleased to submit herewith our report entitled, "Report on Detailed Initial Safety Factor Assessment, Sikeston Power Station, Bottom Ash Pond, Sikeston, Missouri." This report includes background information regarding the project from inception through completion including references to our Preliminary Seismic Screening completed 20 June 2016, the results of our field investigation program, and the results of the Detailed Initial Safety Factor Assessment.

This work was performed by Haley & Aldrich, Inc. (Haley & Aldrich) on behalf of the Sikeston Board of Municipal Utilities (Sikeston BMU) in accordance with the United States Environmental Protection Agency's Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities, 40 CFR Part 257, specifically §257.73(e). The safety factor assessment discussed herein has been referred to as an "initial" assessment to coincide with the terminology used in §257.73(e) and §257.73(f) to distinguish it from the "periodic" assessments that are required every five years following the "initial" assessment has been completed.

The scope of our work in this Detailed Initial Safety Factor Assessment consisted of the following: 1) using the results of the Preliminary Seismic Screening to identify data and information gaps needed to complete this safety factor assessment work; 2) Planning and executing a field investigation program to obtain supplemental subsurface information for seismic response evaluation and slope stability analyses; 3) Conducting a geotechnical laboratory testing program on soil samples recovered from the supplemental subsurface explorations; 4) performing advanced/detailed level engineering evaluations related to seismic response analysis, liquefaction and slope stability; and 5) preparing and submitting this report presenting the results of our assessment.

Thank you for inviting us to complete this assessment and please feel free to contact us if you wish to discuss the contents of the report.

Sincerely yours,
HALEY & ALDRICH, INC.

Derrick A. Shelton
Geotechnical Program Manager | Senior Associate

Steven F. Putrich, P.E.
Project Principal

Enclosures

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1. Introduction

1.1 GENERAL

Haley & Aldrich, Inc. (Haley & Aldrich) has been contracted by the Sikeston Board of Municipal Utilities (Sikeston BMU) to perform a Detailed Initial Safety Factor Assessment for the Bottom Ash Pond located at Sikeston Power Station in Sikeston, Missouri. This work was completed in accordance with the United States Environmental Protection Agency's (EPA's) Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities, 40 CFR Part 257, specifically §257.73(e) (EPA, 2015) and in accordance with our scope of services dated 29 June 2016.

1.2 PURPOSE OF SAFETY FACTOR ASSESSMENT

The purpose of this study was to investigate the subsurface soil and water conditions at the site and to perform a detailed initial safety factor assessment in accordance with Section §257.73(e)(1) of the Final CCR Rule. To achieve the objective discussed above, the scope of work undertaken for this investigation included the tasks listed below.

- Planning and executing a field investigation program to obtain supplemental subsurface information for the detailed liquefaction and slope stability analyses. The program consisted of:
  - performing a seismic survey;
  - installing four (4) drive-point piezometers to depths ranging from 3 ft to 15 ft below ground surface; and
  - collecting four (4) bulk samples of ponded material from the Bottom Ash Pond.
- Conducting a geotechnical laboratory testing program on bulk samples collected during the field investigation program.
- Performing an advanced site-specific seismic response analysis and Newmark displacement analysis of the impoundment embankment.
- Evaluating liquefaction susceptibility of material used to construct the impoundment embankments.
- Performing static and seismic stability analyses for rotational failure surfaces using limit equilibrium methods.

1.3 ELEVATION DATUM AND HORIZONTAL CONTROL

The elevations referenced in this report are in feet and are based on the North American Vertical Datum of 1988 (NAVD88). The horizontal control is the Missouri State Plane East coordinate system, which is based on North American Datum 83 (NAD83).

2. Description of Ponds

A summary of relevant information associated with the Bottom Ash Pond is provided below. Additional details can be found in the Dam Safety Assessment report prepared by O'Brien and Gere (O'Brien & Gere, 2010) and the Global Stability Evaluations report prepared by Geotechnology, Inc. (Geotechnology, 2011). Refer to Figure 1, "Project Locus" for the general site location.

2.1 DESCRIPTION OF BOTTOM ASH POND

The Bottom Ash Pond is a Coal Combustion Residuals (CCR) surface impoundment located east of the Sikeston Power Station in Sikeston, Missouri. The Bottom Ash Pond makes up the southern portion of the oval shaped Sikeston Power Station CCR impoundment system. The Bottom Ash Pond is bordered on the north by the Fly Ash Pond and the plant's coal stockpiling area, on the south agricultural land, on the east by agricultural land and residential properties, and on the west by the plant facilities and agricultural land.

The Bottom Ash Pond was originally designed by Burns & McDonnell, with construction completed in 1981. The Bottom Ash Pond previously received sluiced scrubber sludge until 1998 when the plant facilities underwent system upgrades and no longer generated scrubber sludge. The current primary function of the Bottom Ash Pond is to settle and store bottom ash sluiced from the Sikeston Power Station generating unit. A 30-in. diameter pipe connects the Bottom Ash Pond to the Fly Ash Pond through a splitter dike, which is generally closed to flow unless heavy rainfall temporarily raises the water level in the Bottom Ash Pond. Effluent from the Bottom Ash Pond flows into a 12-in. diameter steel pipe that extends below grade and discharges into the Process Waste Pond.

The impoundment is a combined incised/diked earthen embankment structure with an average 20-ft crest width. The embankment height as measured from the crest to the exterior toe of slope is approximately 12 ft. The interior and exterior slopes are designed at 2 horizontal to 1 vertical (2H:1V). The Bottom Ash Pond was designed with a 2-ft thick clay liner on the interior slope and bottom of the pond. The impoundment has a total surface area of approximately 54 acres. The top of the impoundment embankment is at approximately El. 322. The maximum storage and surcharge pool levels of are El. 315 and El. 322, respectively. The corresponding available freeboard is 7 ft.

3. Field Investigation Program

3.1 PREVIOUS EXPLORATIONS AND LABORATORY TESTING PERFORMED BY OTHERS

Several subsurface exploration and laboratory testing programs were previously completed at the site by others. The approximate locations of the relevant historic explorations performed by others are shown on the attached Figure 2. A brief summary of the explorations is provided below, and relevant logs and laboratory test results are included in Appendix A. Note that "relevant" explorations refers to explorations from previous investigations by others that were directly used in our safety factor assessment of the Bottom Ash Pond.

- Twenty (20) rotary wash test borings and seven (7) Dutch cone soundings were performed by Burns & McDonnell in 1977 as part of the subsurface exploration program for the power plant site. Out of these, seven (7) test borings are relevant to Bottom Ash Pond and were used in our evaluation of the subsurface conditions.

- Fourteen (14) test borings were drilled by Geotechnology, Inc. in 2011 as part of the ash ponds investigation program. In six (6) of these test borings, a piezometer was installed. Of the fourteen (14) test borings, six (6) were relevant to Bottom Ash Pond and were used in our evaluation of the subsurface conditions.

- One (1) groundwater monitoring well was installed by Layne-Western Company, Inc. in 1979 adjacent to the west side of the Bottom Ash pond.

3.2 CURRENT SUBSURFACE EXPLORATION PROGRAM

A subsurface exploration program was conducted at the project site by Haley & Aldrich on 21 July 2016 to obtain subsurface information for engineering evaluations. The program consisted of installing drive-in piezometers and performing a seismic survey.

3.2.1 Piezometers

Four (4) piezometers were installed to depths ranging from 5.0 to 14.5 ft below ground surface as summarized in Table I[1]. The location of the piezometers is shown on Figure 2.

The piezometers consisted of drive-point piezometers manufactured by Solinst Canada, Ltd. Each piezometer consisted of a stainless steel 50 mesh cylindrical filter-screen within a 6-in. long, 0.75-in. diameter stainless steel body. The individual piezometers were attached to various lengths of 0.75-in. diameter NPT black iron pipe. The piezometers were installed by Haley & Aldrich representatives using a slide hammer and each piezometer included a shield to reduce the potential for smearing and plugging of the mesh screen during installation.

At each piezometer location, bulk samples of CCR material within the upper 1.0 to 2.0 ft below ground surface were collected. The samples were transmitted to Shannon & Wilson, Inc. of St. Louis, MO for laboratory testing.

[1] Note: A table that does not appear near its citation can be found in a separate table at the end of the report.

3.2.2 Seismic Survey

Haley & Aldrich engaged the University of Memphis Center for Earthquake Research and Information (CERI) to perform a seismic survey at the site on 21 July 2016. The purpose of the seismic survey was to characterize the shear wave velocity of the subsurface soils at the site and develop a subsurface shear wave velocity profile to be used in seismic response analysis and liquefaction evaluation. The survey was performed along County Road 478 located south of the power plant. The survey was performed using multi-channel analysis of surface wavers (MASW), Refraction Microtremor (ReMi), and refraction/reflection techniques. Details of the techniques used and results of the survey are included in Appendix C along with a plan showing the location of the survey.

3.3 LABORATORY TESTING PROGRAM

A laboratory testing program was conducted on selected samples of bottom ash and scrubber sludge (CCR material) recovered at the location of each drive-in piezometer to aid in classification and for determination of engineering properties required for design. The primary purpose of the testing program was to evaluate the index properties of the CCR material. Testing included natural moisture contents and grain size distributions with hydrometer analysis. The tests were performed in general conformance with applicable ASTM test procedures. Results of the laboratory testing program are presented in Appendix B and are summarized in Table III.

4. Subsurface Conditions

4.1 GEOLOGY

The site is located within the New Madrid seismic zone. The new Madrid Seismic Zone lies at the north end of the Mississippi embayment, which is a deep, low-lying basin filled with Cretaceous to recent sediments. Sikeston Power Station is located in the Southeastern Lowlands physiographic region in southeastern Missouri (MDNR, 2002). The site lies on Sikeston Ridge and in the adjacent lowland flood plain area immediately west of it. Soils underlying the site consist of alluvial soils, deposited and reworked through stream actions of Ohio and Mississippi Rivers (Burns & McDonnell, 1977).

Bedrock is present at a depth of approximately 770 ft below ground surface. The bedrock consists of limestone, sandstone, and dolomite (Luckey, 1985). The seismic survey conducted at the site indicates that the geologic strata consist of, from top to bottom, a Holocene silt and clay stratum at the ground surface; a Quaternary sand stratum at a depth of approximately 13 ft, and a Quaternary gravel stratum at a depth of approximately 73 ft. Below the Quaternary gravel, Eocene strata exist at a depth of 191 ft below ground surface; the Paleocene Midway Group is located at a depth of 252 ft and the top of the Cretaceous formation is located at depth of 328 ft. Refer to the seismic survey included in Appendix C for additional geology information. The geologic stratigraphy at our site is graphically presented in Appendix D.

4.2 SUBSURFACE CONDITIONS

Descriptions of the near-surface soil conditions encountered during the historic subsurface exploration programs conducted at the site are provided below in order of increasing depth below ground surface. Actual soil conditions between boring locations may differ from these typical descriptions. Refer to the test boring logs for specific descriptions of soil samples obtained from the borings.

- *EMBANKMENT FILL* - Below the surface of the impoundment embankment crest, there is a stratum of fill material primarily described in historic logs as poorly-graded SAND (SP), silty SAND (SM) and clayey SAND (SC). This stratum was encountered in historic borings B-6, B-7, P-8, and P-10. This stratum was fully penetrated where encountered. The thickness of this stratum ranged from approximately 12 to 17 ft. The density of coarse-grained soils encountered in this stratum ranged from loose to dense but was generally medium dense.

- *ALLUVIAL SAND* – Below the EMBANKMENT FILL there is a stratum of natural soil (Quaternary alluvial deposits) primarily described in the historic logs as poorly-graded SAND (SP), well-graded SAND (SW) and silty SAND (SM). This stratum was encountered in all relevant historic test borings. Where encountered, this stratum was not fully penetrated in any of the borings. The density of coarse-grained soils encountered in this stratum ranged from loose to very dense but was generally medium dense.

4.3 GROUNDWATER CONDITIONS

Water levels were measured in the drive-in piezometers upon completion of installation. Measured water levels are summarized in Table I. Where encountered, measured water levels in the piezometers generally ranged from a depth of 0.5 to 8.0 ft below ground surface, which corresponds to a water level ranging between approximately El. 311.8 and El. 318.3. Water was not measured in piezometer HAP-2.

In historic borings performed by Burns & McDonnell and Geotechnology, Inc., water levels were typically measured in the boreholes when water was encountered during drilling of the test borings. Measured water levels in historic test borings are summarized in Table II. Where encountered, measured water levels in the test borings generally ranged from a depth of 3.5 to 17.0 ft below ground surface.

In addition to water levels measured in the test borings, long-term water levels were measured in observation wells near the Bottom Ash Pond as summarized in Table IV. Measured water levels in the observation wells generally ranged from a depth of 10.4 to 24.5 ft below ground surface, which corresponds to a water level ranging between approximately El. 296.8 and El. 299.0.

Water level readings have been made in the piezometers and subsurface explorations at times and under conditions discussed herein. However, it must be noted that fluctuations in the level of the water may occur due to variations in power plant sluicing activities, season, rainfall, temperature, dewatering activities, and other factors not evident at the time measurements were made and reported herein.

5. Safety Factor Assessment

As mentioned previously, the purpose of this study was to perform a detailed initial safety factor assessment in accordance with Section §257.73(e)(1) of the Final CCR Rule. As required by the Rule, the certified initial safety factor assessment is performed for a CCR unit to determine calculated factors of safety for each CCR unit relative to the minimum prescribed safety factors for the critical cross section of the embankment. The minimum required safety factors are defined as follows:

- For dikes constructed of soils that have susceptibility to liquefaction, the calculated liquefaction factor of safety must equal or exceed 1.20.
- The calculated static factor of safety under the long-term, maximum storage pool loading conditions must equal or exceed 1.50.
- The calculated static factor of safety under the maximum surcharge pool loading condition must equal or exceed 1.40.
- The calculated seismic factor of safety must equal or exceed 1.00.

Stability analyses have been performed in general conformance with the principles and methodologies described in the USACE Slope Stability Manual (U.S. Army Corps of Engineers, 2003). Conventional static and seismic stability analyses of the impoundment embankments were performed for rotational failures using limit equilibrium methods. Limit equilibrium methods compare forces, moments, and stresses which cause instability of the mass of the embankment to those which resist that instability. The principle of the limit equilibrium method is to assume that if the slope under consideration were about to fail, or at the structural limit of failure, then one must determine the resulting shear stresses along the expected failure surface. These determined shear stresses are then compared with the shear strength of the soils along the expected failure surface to determine the safety factor. The details of the analyses performed for the Bottom Ash Pond are presented in the following sections of this report.

5.1 DESIGN WATER LEVELS

In accordance with the Federal CCR Rule, the water retained in an impoundment must be modeled at the maximum storage pool level for the static drained and seismic undrained analyses. The maximum surcharge pool level must be used to model the ponded water for the static undrained analyses. A summary of the maximum storage pool and surcharge pool water levels at the Bottom Ash Pond are provided below.

Location	Maximum Storage Pool Level	Maximum Surcharge Pool Level	Available Freeboard
Bottom Ash Pond	El. 315	El. 322	7 ft

The elevation of the groundwater table within the embankment and at the toe of slope were estimated based on groundwater conditions encountered in nearby subsurface explorations and observation wells. Additionally, there is no current evidence of seepage emanating from the exterior slopes of the ponds, suggesting that the phreatic surface is contained within and/or below the embankments.

Given the prescribed impoundment pool levels and the observed static groundwater levels discussed above, a seepage analysis was performed to determine the piezometric head between the interior slope of the impoundment embankment and the exterior toe of the embankment. The computer software program, Slide 6.029, developed by RocScience, Inc., was used to perform the seepage analyses. Permeability values for each material layer were estimated from typical published values based on material description and correlations to grain size. During the course of the seepage analyses, minor adjustments were made to the permeability values and isotropic permeability ratios to best model the conditions observed in the field. Results from the seepage analysis provided pore pressure values within the model that were used in the stability analysis.

The models suggest that much of the seepage emanating from the Bottom Ash Pond is moving downward into the more permeable foundation soils and establishing a groundwater table at or near approximately El. 298 rather than moving laterally through the clay liner and embankments. The phreatic surfaces used in the slope stability models are shown on the slope stability graphical output included in Appendix D.

5.2 MATERIAL PROPERTIES

The material properties used in our analyses have been developed using the results of the referenced historic test borings and laboratory testing. In cases where subsurface explorations and/or laboratory test data did not exist for certain materials, properties were estimated based on properties used in historic analyses previously performed by others at or near the site as indicated below:

- Clay Liner – typical published values
- Bottom Ash/Scrubber Sludge – typical published values

A summary of the material properties is provided below in Table V. It should be noted that a small amount of cohesion was used for the Embankment Fill material to avoid surficial sloughing failures.

TABLE V
MATERIAL PROPERTIES

Material	Material Strength	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (degrees)
Bottom Ash/ Scrubber Sludge	Drained	90	0	30
	Undrained	90	750	0
Clay Liner	Drained	125	0	28
	Undrained	125	1000	0
Embankment Fill	Drained	120	50	35
	Undrained	120	100	35
Foundation Soils	Drained	120	0	35
	Undrained	120	0	35

A seismic survey was used to obtain in-situ measurements of shear wave velocity. The insitu measurements were performed to a depth of 770 ft below existing ground surface. The site specific shear wave velocity profile is included in Appendix D.

5.3 SITE SPECIFIC SEISMIC RESPONSE ANALYSIS

5.3.1 Seismic Response Analysis

As mentioned previously, the Sikeston Power Station is located within the New Madrid Seismic Zone and the Mississippi embayment. The natural embayment soils underlying the Bottom Ash Pond are estimated to be approximately 770-ft thick. It has been demonstrated that strong ground motions migrating up through the thick soil in the Mississippi embayment alter the spectral response at the ground surface so that it is much different than the response in the bedrock below the site.

Accordingly, a site-specific target response spectrum was created for the Sikeston Power Station to develop the 2,500-year earthquake motions for use in this study. This target spectrum was developed based on the maximum critical risk-targeted (MCE_R) spectral response acceleration. Two different design methods (probabilistic and deterministic) were used to approximate the MCE_R spectrum and the lesser of the spectral response accelerations from each method at each period was used to create the site-specific target spectrum. The seismic hazard analysis results were then used to compute a 2,500-yr return period deterministic target spectrum. A special type of target spectrum, called the conditional mean spectrum (CMS), was created for the study because it focuses the mean spectral response of all the ground motions to a particular period along the target spectrum.

A CMS target spectrum was generated for both the short period (T*=0.1s) related to the sliding mass and long period (T*=1.0 s) related to the soil column thickness. The CMS spectrum corresponding to the long period (T*=1.0 s) was determined to be the most conservative and was used to complete the seismic response analysis

Seven time-history records were used to match the CMS target spectrum for the site. The time histories represent the site-specific ground motions associated with the controlling earthquake event and consider the magnitude, distance and focal mechanism. The results of the one-dimensional ground response analysis indicate that the calculated site-specific peak ground acceleration (PGA) for a 2,500-year event ranges from 0.30g to 0.73g for top of bedrock and from 0.37g to 0.50g at the ground surface. Details of the seismic response analysis are included in Appendix D.

5.3.2 Newmark Displacement Analysis

The Newmark displacement analysis is based on the shear stress time history acting along the failure plane within the slope. The yield acceleration determined by the analysis is the minimum amount of ground acceleration necessary to initiate motion along the failure surface and is used to determine the appropriate pseudo-static coefficient for seismic stability analyses.

Shake 2000 was used to perform the Newmark displacement analysis by incorporating the results of the one-dimensional ground response analysis and estimating slope displacement for each of the seven time-histories discussed above. The critical impoundment cross-section was evaluated and the most conservative location of the failure plane was determined to be 10 to 12 ft below the top of slope. Correction factors were applied to scale the displacements to the target magnitude 8 event. Details of the analysis are included in Appendix D along with graphical presentation of the results.

5.4 LIQUEFACTION POTENTIAL EVALUATION

During strong earthquake shaking, loose, saturated cohesionless soil deposits may experience a sudden loss of strength and stiffness, sometimes resulting in loss of bearing capacity, large permanent lateral displacements, and/or seismic settlement of the ground. This phenomenon is called soil liquefaction. In accordance with the requirements of §257.73(e)(1), evaluations have been performed to assess the potential for liquefaction of the soils used to construct the impoundment embankment.

The results of the subsurface explorations performed at the site indicate that the majority of soils used to construct impoundment embankments consist of poorly-graded SAND, silty SAND, and clayey SAND. These materials are generally susceptible to liquefaction when saturated. However, groundwater is located approximately 5 to 10 ft below the embankments. Consequently, the existing embankment soils are not saturated and as a result, are not susceptible to liquefaction. In accordance with the requirements of §257.73(e)(1), a post-liquefaction stability analysis is not required since the soils used to construct the embankment are not susceptible to liquefaction in their current state.

5.5 STABILITY ANALYSIS

5.5.1 Methodology for Analyses

The computer software program Slide 6.029 was used to evaluate the static and seismic stability of the impoundment embankment. Analyses were performed to evaluate static drained (long-term) and undrained (short-term) strength conditions for circular failures using Spencer's method of slices. Spencer's method of slices was selected because it fully satisfies the requirements of force and moment equilibrium (limit equilibrium method).

Seismic stability was evaluated using pseudo-static analyses. Pseudo-static analyses model the seismic shaking as a "permanent" body force that is added to the force-body diagram of a conventional static limit-equilibrium analysis; typically, only the horizontal component of earthquake shaking is modeled because the effects of vertical forces tend to average out to near zero (Jibson, 2011). This is a traditional approach for evaluating the stability of a slope during earthquake shaking and provides a simplified safety factor analysis for one earthquake pulse. A 20 percent reduction in material strength was incorporated in the pseudo-static analyses to represent the approximate threshold between large and small strains induced by cyclic loading (Duncan, 2014). A safety factor greater than or equal to one ($FS \geq 1.0$) indicates a slope is stable and a safety factor below one ($FS < 1.0$) indicates that the slope is unstable.

5.5.2 Pseudo-static Coefficient

The pseudo-static coefficient, k_S, used in our seismic analyses was selected using the results of the Newmark displacement analysis discussed previously. According to the MSHA Impoundment Design Manual, the acceptable displacement of coal refuse impoundments is 25% of the upstream freeboard (MSHA, 2009)[2]. At the Bottom Ash Pond, that equates to 21 in. based on 7 ft of freeboard.

[2] This document is mentioned in the preamble of the Rule and is one of the reference documents that was used by the EPA to evaluate how to perform static and seismic stability analyses.

For a 21-in. acceptable displacement, the Newmark displacement curves in Appendix D show that the minimum allowable yield acceleration corresponding to the average displacement is 0.21g. A pseudostatic coefficient lower than 0.21g will result in more than 21 in. deformation and one higher than 0.25g will result in less than 21 in. deformation. For the seismic stability analyses performed for the impoundments, a pseudostatic coefficient of 0.25g was selected. This value was selected because it is slightly above the minimum value, which is conservative, and will result in displacements that are below MSHA acceptable values.

5.5.3 Results of Stability Evaluation

The critical cross section is defined as that which is anticipated to be most susceptible to failure amongst all cross sections. To identify the critical cross section at our project site, we examined the following conditions at several cross section locations at the impoundment:

a. the geometry of the upstream and downstream slopes;
b. phreatic surface levels within and below the cross sections;
c. subsurface soil conditions;
d. presence or lack of surcharge loads behind the crest of the embankments; and
e. presence or lack of reinforcing measures in front of the embankments.

Examination of the conditions noted above resulted in the identification of one critical cross section at the Bottom Ash Pond. The location of the critical cross section is shown on Figure 2. The results of our analyses are presented below in Table VI and are shown on the Slide output files included in Appendix D.

As shown below, the static safety factors are above the minimum required values for the critical cross sections. Similarly, the pseudo-static analyses for the analyzed section indicates an acceptable seismic safety factor.

TABLE VI
SUMMARY OF STATIC AND SEISMIC STABILITY EVALUATIONS

Pond	Cross Section	Condition	Earthquake Event	Soil Strength[1]	Required Safety Factor	Calculated Safety Factor
Bottom Ash Pond	A-A’	Static	-	Drained	1.5	2.1
				Undrained	1.4	2.5
		Seismic	2,500-year	Undrained[2]	1.0	1.2

1. Refer to Table V for material properties.
2. Soil strengths have been reduced by 20 percent for seismic analyses.

5.6 CONCLUSIONS

The analyses associated with the safety factor assessment have been performed in accordance with the requirement of Section §257.73 of the Final CCR Rule. A summary of our conclusions as they relate to the rule requirements are provided below.

- §257.73(e)(1)(i) - *The calculated static factor of safety under the long-term, maximum storage pool loading conditions must equal or exceed 1.50.*

As shown in Table VI, the static safety factors for the long-term (drained) maximum storage pool condition are above the minimum required value for the critical section analyzed. Accordingly, this requirement has been met.

- §257.73(e)(1)(ii) - *The calculated static factor of safety under the maximum surcharge pool loading condition must equal or exceed 1.40.*

  As shown in Table VI, the static safety factors for the maximum surcharge pool loading condition (undrained) are above the minimum required value for the critical section analyzed. Accordingly, this requirement has been met.

- §257.73(e)(1)(iii) - *The calculated seismic factor of safety must equal or exceed 1.00.*

  As shown in Table VI, the calculated seismic safety factor is above the minimum required value for the critical section analyzed. Accordingly, this requirement has been met.

- §257.73(e)(1)(iv) - *For dikes constructed of soils that have susceptibility to liquefaction, the calculated liquefaction factor of safety must equal or exceed 1.20.*

  The results of historic subsurface investigations indicate that the material used to construct the impoundment embankment are not susceptible to liquefaction because they are not saturated. Accordingly, this requirement has been met.

6. Certification

Based on our review of the information provided to us by Sikeston BMU and the results of our field investigations and analyses, it is our opinion that the calculated factors of safety for the critical cross section of the impoundment embankment meet the minimum factors of safety specified in §257.73(e)(1)(i) through (iv) of the EPA's Final CCR Rule.

Certification Statement

I certify that the Initial Safety Factor Assessment for the Bottom Ash Pond at the Sikeston Power Station meets the requirements of §257.73(e) of the EPA's Final CCR Rule.

Signed: ______________________________
Consulting Engineer

Print Name:	Steven F. Putrich
Missouri License No.:	2014035813
Title:	Project Principal
Company:	Haley & Aldrich, Inc.

Professional Engineer's Seal:

STATE OF MISSOURI
STEVEN F. PUTRICH
NUMBER
PE-2014035813
10-14-16
PROFESSIONAL ENGINEER

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TABLES

TABLE I
SUMMARY OF PIEZOMETER INSTALLATION
SIKESTON POWER PLANT BOTTOM ASH POND
SIKESTON, MISSOURI

Piezometer Designation[1]	Ground Surface El.[2] (ft)	Northing[2]	Easting[2]	Total Depth (ft)	Depth to Water (ft)	
					Depth 7/21/2016[3] (ft)	Elevation 7/21/2016[3] (ft)
HAP-1	320.6	380854.393	1078051.494	14.5	5.0	315.6
HAP-2	320.6	380296.771	1078427.273	11.0	Not measured	Not measured
HAP-3	319.7	380261.526	1079064.430	11.0	8.0	311.8
HAP-4	318.8	380411.896	1079534.587	5.0	0.5	318.3

Notes:

1. Installation of piezometers on 21 July 2016 was performed by Haley & Aldrich, Inc.
2. The elevation data are provided in feet above sea level and refer to NAVD88 Datum. Ground surface elevation data at piezometer locations was provided by Gredell Engineering Resources, Inc. and were determined using the results of the Surdex Aerial Mapping performed during Summer 2016. The coordinates are provided in units of feet, relative to the Missouri State Plane East Coordinate System (NAD83).
3. Water level readings at the piezometers have been made at times and under conditions discussed herein. However, it must be noted that fluctuations in the level of the water may occur due to variation in season, rainfall, temperature, plant operations, and other factors not evident at the time measurements were made and reported.

TABLE II
SUMMARY OF RELEVANT HISTORIC SUBSURFACE EXPLORATIONS
SIKESTON POWER PLANT BOTTOM ASH POND
SIKESTON, MISSOURI

Exploration Designation[1,2]	Performed By	Year Drilled	Ground Surface Elevation[3] (ft)	Boring Depth (ft)	Depth to Groundwater[3] (ft)
B-6	Geotechnology, Inc.	2011	322.2	45.0	Not Measured
B-7	Geotechnology, Inc.	2011	322.1	45.0	Not Measured
B-13	Geotechnology, Inc.	2011	306.2	35.0	11.5
B-14	Geotechnology, Inc.	2011	305.0	35.0	11.5
P-8	Geotechnology, Inc.	2011	322.0	25.0	See Table IV
P-10	Geotechnology, Inc.	2011	322.2	20.0	17.0
P-12	Burns & McDonnell	1977	306.0	60.0	9.0
P-13	Burns & McDonnell	1977	306.3	100.0	9.5
P-16	Burns & McDonnell	1977	307.1	60.0	11.0
P-17	Burns & McDonnell	1977	307.1	85.0	9.0
P-18	Burns & McDonnell	1977	303.8	75.0	7.0
P-19	Burns & McDonnell	1977	300.0	50.0	6.0
P-20	Burns & McDonnell	1977	299.4	95.0	3.5
TPZ-3	Gredell Engineering Resources, Inc.	2016	306.1	37.2	See Table IV
Well C	Layne-Western Company, Inc.	1979	310.0	15.3	Unknown

Notes:
1. Technical monitoring of explorations shown above was not performed by Haley & Aldrich, Inc.
2. "Relevant" explorations are defined as explorations used in our evaluation of the stability of the Bottom Ash Pond.
3. Ground surface elevations and groundwater depths shown above reflect the elevation and depth reported on the corresponding boring log. The ground surface elevation of Well C has been approximated using Google Earth. The ground surface elevation for TPZ-3 was provided by Sikeston BMU.

TABLE III
SUMMARY OF CURRENT AND HISTORIC LABORATORY TEST RESULTS
SIKESTON POWER PLANT BOTTOM ASH POND
SIKESTON, MISSOURI

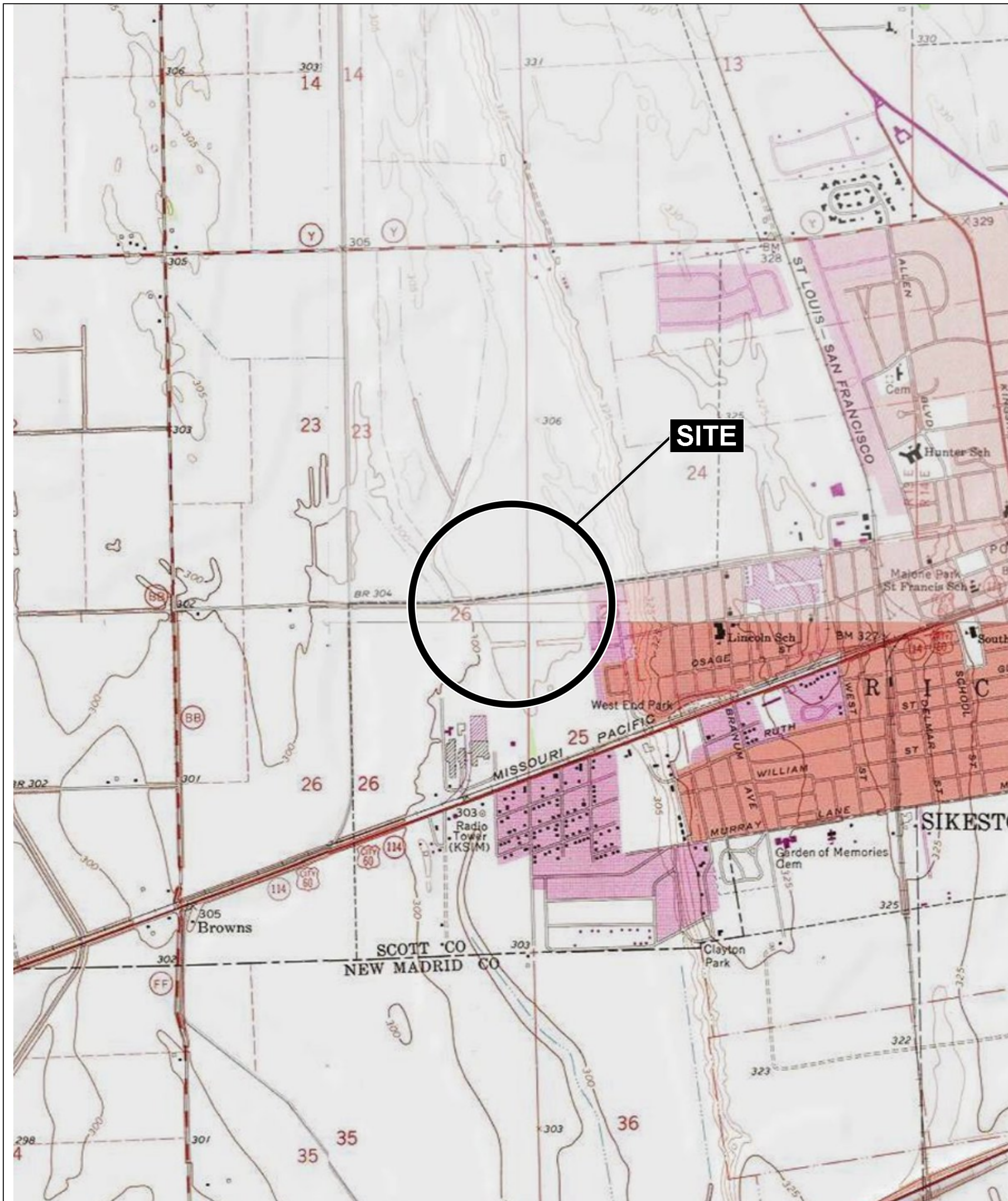
Boring Designation	Sample Number	Sample Depth (ft)	USCS Symbol	Material Type	Moisture Content (%)	LL	PL	PI	% Gravel	% Sand	% Fines	Direct Shear			
												Moisture Content (%)	Total Density	c' (tsf)	ϕ' (degrees)
↓ CURRENT TESTING BY HALEY & ALDRICH PERFORMED IN 2016 ↓															
HAP-1	P-1	1.0-2.0	ML	CCR	34.4				0.0	35.4	64.6				
HAP-2	P-2	0.0-1.0	SM	CCR	22.1				0.0	83.6	16.4				
HAP-3	P-3	1.0-2.0	SP-SM	CCR	27.5				0.0	86.0	14.0				
HAP-4	P-4	1.0-2.0	ML	CCR	54.1				0.0	47.1	52.9				
↓ HISTORIC TESTING BY GEOTECHNOLOGY, INC. IN 2011 ↓															
B-1, B-2	Composite	0.0-20.0	SM	Soil (Borrow)					1.3	81.0	17.7			0	39
B-11, B-12	Composite	0.0-15.0	SM	Soil (Borrow)					3.3	81.7	15.0			0	41
B-13, B-14	Composite	0.0-15.0	SM	Soil (Borrow)					2.0	82.0	16.0			0	42
B-6, B-7	Composite	0.0-20.0	SM	Soil (Borrow)					0.0	81.4	18.6			0	36
B-6		33.5	SP	Soil (Natural)					0.0	96.7	3.3				
B-7		13.5	SP	Soil (Natural)					0.0	96.1	3.9				
B-13		18.5	SP	Soil (Natural)					0.2	97.2	2.6				
B-14		13.5	SP	Soil (Natural)					1.8	95.7	2.5				
P-8		18.5	SM	Soil (Natural)					0.3	77.2	22.5				
↓ HISTORIC TESTING BY BURNS & MCDONNELL IN 1977 ↓															
P-13	Bag 2	5.0-8.5	SP	Soil (Natural)					0.0	96.8	3.2				
P-13	D-13	63.5-65	SP	Soil (Natural)					0.0	94.2	5.8				
P-13	D-17	83.5-85.0	SP	Soil (Natural)					26.0	71.1	2.9				
P-13	D-20	98.5-100.0	SP	Soil (Natural)					21.0	72.8	6.2				
P-16	D-5	23.5-25.0	SP	Soil (Natural)					0.0	97.0	3.0				
P-16	D-12	58.5-60.0	SP	Soil (Natural)					0.0	94.5	5.5				
P-17	Bag 2	5.0-8.5	SP	Soil (Natural)					0.0	95.5	4.5				
P-17	D-12	58.5-60.0	SP-SM	Soil (Natural)					0.0	91.7	8.3				
P-17	D-15	73.5-75.0	SP-SM	Soil (Natural)					0.0	93.6	6.4				
P-18	D-5	23.5-25.0	SP	Soil (Natural)					5.0	91.9	3.1				
P-19	Bag 1	1.5-3.5	CL	Soil (Natural)		45	21	24							
P-20	Bag 1	1.0-3.5	ML	Soil (Natural)		21	19	2							
P-20	D-3	13.5-15.0	SP-SM	Soil (Natural)					0.8	90.6	8.6				
P-20	D-12	58.5-60.0	SP-SM	Soil (Natural)					17.0	77.2	5.8				
P-20	D-18	88.5-90.0	CL	Soil (Natural)		45	22	23							

TABLE IV
SUMMARY OF GROUNDWATER LEVEL MEASUREMENTS
SIKESTON POWER PLANT BOTTOM ASH POND
SIKESTON, MISSOURI

Observation Well	Top of Casing Elevation[1] (ft)	Well Depth (ft)	Measurement Date	Depth to Water[2,3] (ft)	Groundwater Elevation (ft)	Well Installation Notes
P-8	322.0	25.0	6/1/2016	23.0	299.0	Well was installed on 8/30/2011 by Geotechnology, Inc.
			6/16/2016	24.5	297.5	
			6/24/2016	24.1	297.9	
			7/15/2016	24.2	297.8	
			9/8/2016	24.4	297.6	
TPZ-3	308.6	37.2	5/4/2016	10.4	298.1	Well was installed on 5/13/2016 by Gredell Engineering Resources, Inc.
			6/24/2016	11.0	297.6	
			7/15/2016	11.2	297.4	
			8/8/2016	11.5	297.1	
			9/8/2016	11.8	296.8	

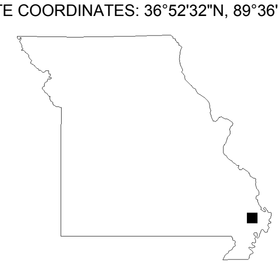
Notes:
1. Top of casing elevation of P-8 was reported by Geotechnology, Inc. and top of casing elevation of TPZ-3 was provided by Sikeston BMU.
2. Depth to water level readings were provided by Sikeston BMU.
3. Water level readings have been made in the wells at times and under conditions discussed herein. However it must be noted that fluctuations in the level of the water may occur due to variations in season, rainfall, temperature, and other factors not evident at the time measurements were made and reported.

FIGURES



MAP SOURCE: ESRI

SITE COORDINATES: 36°52'32"N, 89°36'56"W



HALEY ALDRICH

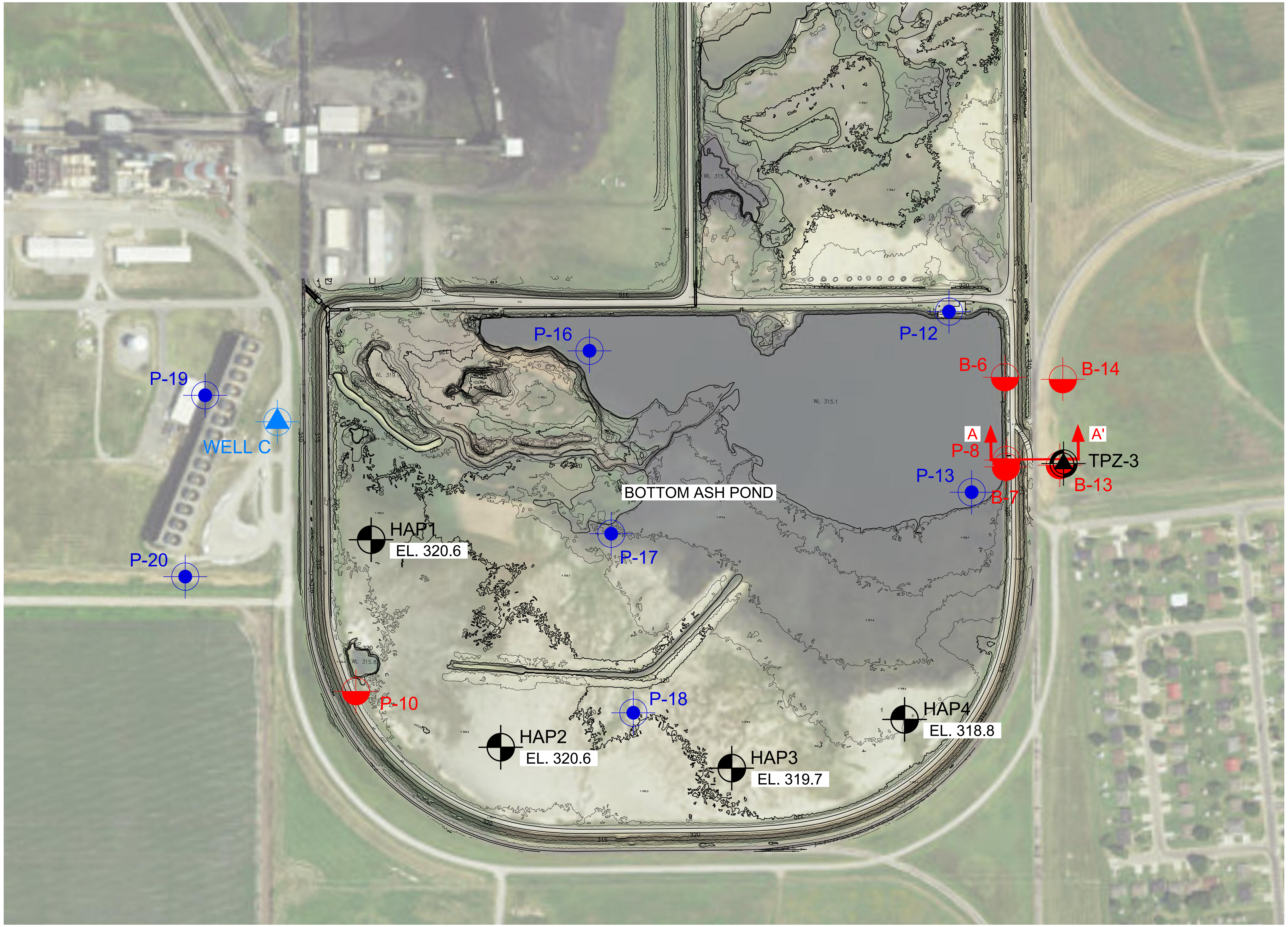
SIKESTON POWER STATION
BOTTOM ASH IMPOUNDMENT
SIKESTON, MISSOURI

PROJECT LOCUS

APPROXIMATE SCALE: 1 IN = 2000 FT
OCTOBER 2016

FIGURE 1

128065_001 LOCUS FIG 1.PDF



LEGEND

HAP4 EL. 318.8 — DESIGNATION, LOCATION AND GROUND SURFACE ELEVATION OF PIEZOMETERS INSTALLED ON 21 JULY 2016 BY HALEY & ALDRICH, INC.

TPZ-3 — DESIGNATION AND LOCATION OF MONITORING WELL INSTALLED IN 2016 BY GREDELL ENGINEERING RESOURCES, INC.

B-14 — DESIGNATION AND APPROXIMATE LOCATION OF HISTORIC BORINGS PERFORMED IN 2011 BY GEOTECHNOLOGY, INC. "P" DESIGNATION INDICATES A PIEZOMETER WAS INSTALLED IN THE COMPLETED BOREHOLE.

WELL C — DESIGNATION AND APPROXIMATE LOCATION OF MONITORING WELL INSTALLED IN 1979 BY LAYNE-WESTERN COMPANY, INC.

P-17 — DESIGNATION AND APPROXIMATE LOCATION OF BORINGS PERFORMED IN 1977 BY BURNS & MCDONNELL.

A A' — CRITICAL CROSS SECTION

NOTES:

1. BACKGROUND IMAGE FOR KEY MAP IS DATED 2 AUGUST 2014 FROM ESRI GIS.
2. ELEVATIONS INDICATED ON THIS DRAWING ARE IN FEET AND REFER TO NAVD88 DATUM.
3. THE LOCATION OF THE GEOTECHNOLOGY, INC. BORINGS WERE APPROXIMATED FROM A PLAN ENTITLED "AERIAL PHOTOGRAPH OF SITE AND BORING LOCATIONS" DATED 8 OCTOBER 2011 (LATEST REVISION) BY GEOTECHNOLOGY, INC. OF ST. LOUIS, MISSOURI.
4. THE LOCATION OF THE LAYNE-WESTERN COMPANY, INC. MONITORING WELL WAS APPROXIMATED FROM AN ELECTRONIC CAD IMAGE ENTITLED " SITE CHARACTERIZATION WORK PLAN FIGURE 1 - SITE LOCATION MAP" DATED JULY 2015 FROM GREDELL ENGINEERING RESOURCES, INC. OF JEFFERSON CITY, MISSOURI.
5. BURNS & MCDONNELL BORING LOCATIONS WERE APPROXIMATED FROM A PLAN ENTITLED "FIGURE 2" PREPARED BY BURNS & MCDONNELL OF KANSAS CITY, MISSOURI.
6. TECHNICAL MONITORING OF PIEZOMETERS INSTALLED ON 21 JULY 2016 WAS PERFORMED BY HALEY & ALDRICH, INC.
7. AS-DRILLED LOCATIONS AND ELEVATIONS OF HALEY & ALDRICH PIEZOMETERS WERE DETERMINED BY GREDELL ENGINEERING RESOURCES, INC. USING SURDEX AERIAL MAPPING INFORMATION COMPLETED IN SUMMER 2016.

N

0 300 600
SCALE IN FEET

HALEY ALDRICH

SIKESTON POWER STATION
BOTTOM ASH IMPOUNDMENT
SIKESTON, MISSOURI

SUBSURFACE EXPLORATION LOCATION PLAN

SCALE: AS SHOWN
OCTOBER 2016

FIGURE 2

POSTOLOWSKI, KEVIN Printed: 10/7/2016 10:16 AM Layout: FIG 2
G:\128065 SIKESTON\CAD\128065_001_0003 SIKESTON ELP.DWG

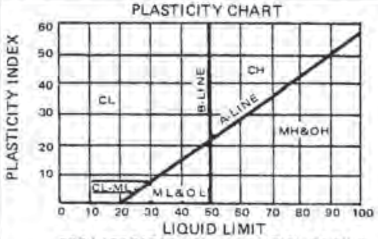
APPENDIX A

Historic Test Boring Logs and Laboratory Test Results

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			LETTER SYMBOL	DESCRIPTION
COARSE-GRAINED SOILS MORE THAN 50% LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS	GW	WELL-GRADED GRAVEL, GRAVEL-SAND MIXTURE
		LITTLE OR NO FINES	GP	POORLY-GRADED GRAVEL, GRAVEL—SAND MIXTURE
		GRAVELS WITH FINES	GM	SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURE
		APPRECIABLE FINES	GC	CLAYEY-GRAVEL, GRAVEL-SAND-CLAY MIXTURE
	SAND AND SANDY SOILS	CLEAN SANDS	SW	WELL-GRADED SAND, GRAVELLY SAND
		LITTLE OR NO FINES	SP	POORLY-GRADED SAND, GRAVELLY SAND
		SANDS WITH FINES	SM	SILTY SAND, SAND-SILT MIXTURE
		APPRECIABLE FINES	SC	CLAYEY SAND, SAND-CLAY MIXTURE
FINE-GRAINED SOILS MORE THAN 50% SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50	ML	SILT, CLAYEY SILT, SILTY OR CLAYEY VERY FINE SAND, SLIGHT PLASTICITY
			CL	CLAY, SANDY CLAY, SILTY CLAY, LOW TO MEDIUM PLASTICITY
			OL	ORGANIC SILTS OR SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT MORE THAN 50	CH	SILT, FINE SANDY OR SILTY SOIL WITH HIGH PLASTICITY
			CH	CLAY, HIGH PLASTICITY
			OH	ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS			PT	PEAT, HUMUS, SWAMP SOIL

PLASTICITY CHART



FOR LABORATORY CLASSIFICATION OF FINE GRAINED SOILS

RELATIVE PARTICLE SIZE

BOULDER	LARGER THAN 12"
COBBLE	3" TO 12"
GRAVEL COARSE	3/4" TO 3"
FINE	4.76MM TO 3/4"
SAND COARSE	2MM TO 4.76MM
MEDIUM	0.42MM to 2MM
FINE	0.074MM TO 0.42MM
SILTS AND CLAY	SMALLER THAN 0.074MM

RELATIVE PLASTICITY

NONPLASTIC	CANNOT ROLL INTO BALL
TRACE PLASTICITY	BARELY ROLL INTO BALL
MEDIUM PLASTIC	CAN BE ROLLED INTO BALL
HIGHLY PLASTIC	NO RUPTURE BY KNEADING

RELATIVE COMPOSITION

TRACE	0-10%
SOME	11-35%
AND/WITH	36-50%

RELATIVE MOISTURE

DRY	POWDERY
DAMP	BELOW PLASTIC LIMIT
MOIST	PL TO LL RANGE
WET	ABOVE LIQUID LIMIT

DENSITY	N-VALUE
VERY LOOSE	0-4
LOOSE	5-10
MEDIUM	11-30
DENSE	31-50
VERY DENSE	>50

RELATIVE CONSISTENCY		N-VALUE
VERY SOFT	< 1/4 TSF	0 - 2
SOFT	1/4-1/2 TSF	2 - 4
MEDIUM	1/2-1 TSF	4 - 8
STIFF	1-2 TSF	8 - 15
VERY STIFF	2-4 TSF	15 - 30
HARD	> 4 TSF	30 -

N-VALUE (BLOW COUNT) IS THE STANDARD PENETRATION RESISTANCE BASED ON THE TOTAL NUMBER OF BLOWS, USING A 140-LB HAMMER WITH 30-INCH FREE FALL, REQUIRED TO DRIVE A SPLIT-SPOON THE LAST TWO OF THREE 6-INCH DRIVE INCREMENTS. (EXAMPLE: 4/7/9, N = 7+9=16)

DRILLING LOG

JOB NO. 76-076-1 PROJECT PHSIKEMO HOLE NO. P-12

GROUND ELEV. 306.00 LOCATION 500' offset S. of Sta. 40+00 SHEET 1 OF 4

DRILLING TYPE	HOLE DEPTH	OVERBURDEN FOOTAGE	BEDROCK FOOTAGE	OVERBURDEN SAMPLES	NO. CORE BOXES	% CORE RECOVERY	WATER TABLE
Rotary wash	60 2						9.0

DRILLING CO. RAYMOND INT. CO. DRILLER(S) DON FERRARY

DRILLING RIG CME 750 PENETRATION TEST SPT

DRILLING DATE March 8, 77 TO March 8, 77 INSPECTOR(S) C. A. BUHR

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
1						(tan, silty sand)
2						dry
3–4	Lt. Brown, pred. fine sand, some med. sand, trace silt, tan + rust colouring, subrounded, trace lignite, med. density, damp to moist.	SP/ ~~SM~~	4/5/7	15" Recov.	D-1	damp
5						
6						moist wet
7						
8–10	Brown, fine to med. sand, trace coarse sand, trace silt, lignite part., subrounded, med. density, sat.	SP	5/5/7	10" Recov.	D-2	water @ 9'
11						
12						
13						

BURNS & McDONNELL ENGINEERING COMPANY
DRILLING LOG

PROJECT: PHSIKEMO — HOLE NO. P-12 — SHEET 2 OF 4

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
14–15	Gray-brown, prd. fine sand, w/ med. sand, trace coarse sand + fine gravel, trace silt, subrounded to occass. subangular, loose, sat., lignite part.	SP	3/3/5	11" Recov.	D-3	3/4" lignite part. in sluff mat'l.
16						
17						
18–20	Brown-gray, fine sand, some med. sand, trace coarse sand + fine gravel, trace silt, lignite part., subrounded to occass. subangular, med. density, sat.	SP	10/9/14	Full Recov.	D-4	
21						
22						
23–24	Gray, fine sand, w/ med. sand, trace silt, lignite, subrounded to subangular, dense, sat.	SP	11/17/23	10½" Recov.	D-5	
25						
26						
27						
28–30	Gray, somewhat well graded sand, some gravel, lignite part. + seam, subrounded to subangular, dense, sat.; coarser above lignite seam, (trace chert ?).	SP/SW	8/14/17	10" Recov.	D-6	

BURNS & McDONNELL ENGINEERING COMPANY
DRILLING LOG

PROJECT: PHSIKEMO — HOLE NO. P-12 — SHEET 3 OF 4

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
33–35	Similar to previous; becoming prd. finer sand toward bottom with several successive lignite seams, (trace chert)	SP/(SW)	11/12/14	10½" Recov.	D-7	
36						
37						
38–41	Top 4" brown, fine to med. sand, trace coarse sand; lignite seam; gray prd. fine sand, some med. sand, lignite part., subrounded to subangular, med. density to loose, sat.	SP	3/6/8	7½" Recov.	D-8	
42						gravel seam in drilling noted
43–46	Brown-gray, well graded sand, some fine gravel, lignite part., subrounded to subangular, med. density, sat.; slightly finer towards tip.	SW/SP	8/10/12	7" Recov.	D-9	
47						
48–50	Same as previous, consistent throughout sample.	SW/SP	8/14/15	8" Recov.	D-10	

BURNS & McDONNELL ENGINEERING COMPANY
DRILLING LOG

PROJECT PHSIKEMO HOLE No. P-12 SHEET 4 OF 4

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS		BOX OR SAMPLE NO.	REMARKS
53–55	Similar to previous; becoming slightly finner & milky toward tip, dense, red-tint.	SP/SW	13/15/21	9" Recov.		D-11	
58–60	Brown-gray well graded sand, w/ fine & coarse gravel, red-milky mat'l, trace lignite, subrounded to subangular, dense, sat.	SP/SW	11/16/22	7" Recov		D-12	
	T.D. 60±						

DRILLING LOG

JOB No. 76-076-1 PROJECT PHSIKEMO HOLE No. P-13

GROUND ELEV. 306.30 LOCATION 1000' offset S. of Sta. 40+00 SHEET 1 OF 6

DRILLING TYPE	HOLE DEPTH	OVERBURDEN FOOTAGE	BEDROCK FOOTAGE	OVERBURDEN SAMPLES	NO. CORE BOXES	% CORE RECOVERY	WATER TABLE
Rotary Wash	100±						9.5

DRILLING CO. RAYMOND INT. Co. DRILLER(S) DON FERRARY

DRILLING RIG CME 750 PENETRATION TEST SPT

DRILLING DATE MARCH 1, 77 TO March 2, 77 INSPECTOR(S) C.A. BUHR

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS		BOX OR SAMPLE NO.	REMARKS
0–2							Yellow-Lt. Brown, silty fine sand, dry, organics. (SM-SP) Bag #1
3–4	Lt.-Yellow Brown, fine sand, trace med. sand, subrounded, ~~trace~~ w/ silt, trace lignite, loose, damp.	SP (SM)	3/3/3	12" Recov		D-1	
5–7							Yellow-Lt. Brown, fine sand, w/ silt, damp. (SP-SM) Bag #2
8–10	Lt.-Brown, fine sand, trace to some med. sand, subrounded, ~~trace~~ w/ silt, lignite part., med. density, wet to sat.	SP (SM)	5/6/6	11" Recov		D-2	water 9±

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO HOLE NO.: P-13 SHEET 2 OF 6

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
14–15	Lt.- Brown, fine sand, some med. sand, slight trace coarse sand + fine gravel, subrounded, trace silt, lignite part., loose, sat.	SP	3/4/4	13" Recov	D-3	— End Tues.
16–17						Use of Fiber Tex + Mica Tex for drilling water with mud
18–21	Lt.- Brown, pred. fine sand, trace to some med. sand, trace coarse sand + fine gravel in sluff mat'l, trace silt, lignite part., subrounded, dense, sat.	SP	16/16/18	12" Recov	D-4	
23–24	Dark- Brown, same as previous, except becoming occas. subangular, med. dense.	SP	5/6/7	7" Recov.	D-5	
28–30	Dark-brown to gray-brown, fine to med. sand, trace coarse sand, trace silt, lignite part. + seams, subrounded to subangular, med. density, sat.	SP	5/12/12	9½" Recov.	D-6	coarse sand + fine gravel in sluff mat'l.

11/27/63 BURNS & McDONNELL ENGINEERING COMPANY FORM J-2-1-18

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO HOLE NO.: P-13 SHEET 3 OF 6

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
33–36	Gray, fine to med. sand, some coarse sand, trace fine gravel, trace silt – milky, lignite, subrounded to subangular, med. density, sat.	SP	6/10/12	5" Recov.	D-7	fine + coarse gravel in sluff mat'l Driller noted coal seam @≈36'2'
38–40	Gray, fine to med. sand, similar to previous, less milky, w/ fine + coarse gravel encountered @ tip.	SP	7/10/8	8" Recov.	D-8	
43–45	Gray, well graded sand, trace gravel, trace silt, lignite, subrounded to subangular, med. density, sat.	SP/SW	6/11/13	7" Recov.	D-9	
48–50	Gray, similar to previous, becoming slightly finer toward bottom, lignite seam – 3/4" part. @ tip.	SP/(SW)	8/11/13	8" Recov.	D-10	Driller noted gravel like mat'l during drilling

11/27/63 BURNS & McDONNELL ENGINEERING COMPANY FORM J-2-1-18

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO   HOLE NO. P-13   SHEET 4 OF 6

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
53–55	Top 2½" coal seam; Gray, fine to med. sand, trace coarse sand & fine gravel, milky, subrounded to subangular, dense, sat.	SP	11/15/16	7" Recov.	D-11	Coal Seam
58–60	Gray, well graded sand, pred. med to fine sand, some coarse sand, trace fine gravel, trace silt, subrounded to subangular, med. density, sat., lignite.	SW/(SP)	6/6/7	8" Recov.	D-12	
63–65	Gray, fine sand, trace med. sand, trace silt, subrounded to subangular, lignite part., very dense, sat.	SP	15/25/26	9½" Recov.	D-13	

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO   HOLE NO. P-13   SHEET 5 OF 6

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
69–72	** Interesting Sample. Brown- Gray, well graded sand, trace gravel, trace silt, lignite, milky - large 1" conclomerate ? silt-clay ~~stone~~ cemented mat'l, subrounded to subangular, med. density, sat., red tint to milkyness.	SW/SP	10/10/10	6" Recov.	D-14	
74–75	Same as previous w/ red milky tint.	SW/SP	11/13/14	6½" Recov.	D-15	
78–80	Gray- ~~Red~~-brown, fine to med. sand, trace coarse sand, red-milky tint, subrounded to subangular, lignite, dense, sat.	SP	25/21/23	8" Recov.	D-16	
83–85	Gray-brown, fine to med. sand, some coarse sand, trace gravel, red-milky tint, subrounded to subangular, lignite, med. density, sat.	SP	11/13/13	7½" Recov.	D-17	Gravel layer noted by driller

BURNS & McDONNELL ENGINEERING COMPANY
DRILLING LOG

PROJECT PHSIKEMO HOLE NO. P-13 SHEET 6 OF 6

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
87						
88	Same as previous; becoming slightly coarser ~~& more toward well graded~~					
89		SP/ ~~(SW)~~	11/14/15	7" Recov.	D-18	
90						
91						
92						
93	Similar to previous; only well graded; (trace chert)					
94		SW/ (SP)	13/14/16	7" Recov.	D-19	
95						
96						
97						
98	Red-brown, fine to med. sand, trace coarse sand & gravel, milky, subrounded to subangular, lignite, very dense, sat.					
99		SP	50/ 1½" pen.	6" Recov.	D-20	
100						
	T.D. 100'					

TF ... Course Gravel

11/27/63 BURNS & McDONNELL ENGINEERING COMPANY FORM J-2-1-1a

DRILLING LOG

JOB NO. 76-076-1 PROJECT PHSIKEMO HOLE NO. P-16

GROUND ELEV. 307.11 LOCATION 500' East S. of Sta. 50+00 SHEET 1 OF 4

DRILLING TYPE	HOLE DEPTH	OVERBURDEN FOOTAGE	BEDROCK FOOTAGE	OVERBURDEN SAMPLES	NO. CORE BOXES	% CORE RECOVERY	WATER TABLE
Rotary Wash	60'						11.0

DRILLING CO. RAYMOND INT. CO. DRILLER(S) DON FERRARY

DRILLING RIG CME 750 PENETRATION TEST SPT

DRILLING DATE MARCH 7.77 TO MARCH 7.77 INSPECTOR(S) C. A. BUHR

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
1						
2						
3	~~Yellow~~ Lt. Brown, silty fine sand, subrounded, trace lignite, loose, damp to dry.					
4		SM/ SP	2/3/4	15" Recov.	D-1	
5						
6						change
7						
8	Brown, fine sand, trace med. sand, some silt, lignite, subrounded, med. density, wet.					
9		SP/ (SM)	3/6/7	10" Recov.	D-2	
10						
11						Water @ 11'
12						
13						

122673 Burns & McDonnell Form J-2-1-1A

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO HOLE NO. P-16 SHEET 2 OF 4

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
14–15	Brown, pred. med. to fine sand, trace coarse sand, trace silt, lignite, subrounded to occass. subangular, loose, sat.	SP	2/3/4	13" Recov	D-3	
19	Brown, same as previous.	SP	4/3/5	3" Recov	D-4	fine gravel in sluff mat'l
23–27	Dark brown, pred. fine sand, some med. sand, trace silt, lignite part. + seam, subrounded to occass. subangular, med. density, sat.; becoming coarser toward bottom, trace coarse sand + fine gravel.	SP	5/10/13	9" Recov	D-5	
28–30	Brown, fine to med. sand, trace coarse sand + fine gravel, trace silt, lignite, subrounded to occass. subangular, dense, sat.	SP	12/19/23	9" Recov	D-6	

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO HOLE NO. P-16 SHEET 3 OF 4

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
						lignite seam noted @ 31'
* 33–37	Gray-brown, very fine sand; becoming yellow-brown fine to med. gravelly sand, lignite, trace chert; becoming similar to previous sample w/ lignite seams, med. density, sat.	SP	6/9/16	9½" Recov	D-7	fine + coarse gravel noted in sluff mat'l; more lignite seams noted in wash
38–40	Gray, very ~~pred.~~ fine sand, trace silt, lignite part., subrounded to subangular, med. density, sat.	SP	10/14/14	7" Recov	D-3	
43–45	Gray, pred. fine to med. sand, trace coarse sand & fine gravel, trace silt, lignite part., subrounded to subangular, med. density, sat.	SP	9/13/16	8" Recov.	D-9	
48–50	Similar to previous, milky slightly coarser & more well graded, dense, lignite seam @ tip.	SP/(SW)	15/16/17	5½" Recov	D-10	

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT PHSIKEMO HOLE NO. P-16 SHEET 4 OF 4

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
53–55	Gray, fine to med. sand, some coarse sand, trace fine gravel, very milky, lignite part., subrounded to subangular, dense, sat.	SP/(SW)	17/18/18	2½" Recov	D-11	Between 50² + 55², some caving of gravelly mat'l occurred
58–59	Gray, fine sand, trace med. sand, trace silt, lignite, subrounded to subangular, med. density, sat.	SP	11/9/10	6" Recov	D-12	
60	T.D. 60²					

11/27/63 BURNS & McDONNELL ENGINEERING COMPANY FORM J-2-1-1B

DRILLING LOG

JOB NO. 76-076-1 PROJECT PHSIKEMO HOLE NO. P-17

GROUND ELEV. 307.08 LOCATION 1000' offset S. of Sta. 50+00 SHEET 1 OF 5

DRILLING TYPE	HOLE DEPTH	OVERBURDEN FOOTAGE	BEDROCK FOOTAGE	OVERBURDEN SAMPLES	NO. CORE BOXES	% CORE RECOVERY	WATER TABLE
Rotary Wash	85²						9.0

DRILLING CO. Raymond Int. Co. DRILLER(S) DON FERRARY

DRILLING RIG CME 750 PENETRATION TEST SPT

DRILLING DATE March 2, 77 TO March 7, 77 INSPECTOR(S) C. A. BUHR

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
0–3						Lt. Yellow-brown silty fine sand, damp, organics (SM-SP) Bag #1
4–5	Lt. Rust-brown, fine sand, trace med. sand, w/silt, subrounded, trace lignite, loose, damp to dry.	SP/SM	2/4/4	13½" Recov	D-1	
5–8						Lt. Yellow-brown, fine sand, trace med. sand, w/ silt, damp to moist. (SP-SM) Bag #2
9–10	Brown, fine sand, trace med. sand, w/ silt, trace lignite, very loose, wet to sat.	SP/(SM)	2/1/1	10½" Recov	D-2	water @ 9²

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BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO HOLE NO. P-17 SHEET 2 OF 5

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
14–15	Brown, fine sand, trace med. sand, trace silt, lignite part., subrounded, med. density, sat.	SP	7/9/11	Full Recov.	D-3	
18–21	Brown, pred. fine to med. sand, some coarse sand, trace fine gravel, trace silt, lignite. part., subrounded to occass. subangular, med. density, sat.	SP	10/10/12	$9\frac{1}{2}$" Recov.	D-4	
23–26	Brown, pred. fine to med. sand, trace coarse sand, trace silt, lignite part., subrounded to subangular, dense, sat.; (fine gravel toward top of sample.)	SP	11/18/22	$9\frac{1}{2}$" Recov.	D-5	
28–30	Brown, pred. fine to med. sand, some coarse sand, trace fine & coarse gravel, trace silt – mitby, subrounded to subangular, lignite, dense, sat.	SP/SW	9/15/23	$10\frac{1}{2}$" Recov.	D-6	Drilled to 29± wed. – end drill

11/27/63 BURNS & McDONNELL ENGINEERING COMPANY FORM J-2-I-13

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO HOLE NO. P-17 SHEET 3 OF 5

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
33–36	Upper 6" pea gravel, subrounded; remaining 3" gray, pred. fine sand, trace med. sand, trace silt, lignite part., sat; becoming coarser and trace fi. gravel @ tip.	GP/SP	6/3/10	3" Recov.	D-7	Coal fragments in drilling water. Drilling water gravel from 33' to 34'
38–40	Gray, fine sand, trace coarse sand, some med. sand, trace silt, lignite part. & seams, subrounded to subangular, med. density, sat.	SP	3/11/18	6" Recov.	D-8	
44–45	Same; becoming dense, trace fine gravel.	SP	12/19/21	$7\frac{1}{2}$" Recov.	D-9	
47–50	Gray, pred. fine to med. sand, some coarse sand and fine gravel, subrounded to subangular, trace silt, lignite part. & seams, med. density, sat.; slightly coarser toward top.	SP/(SW)	3/16/23	$6\frac{1}{2}$" Recov.	D-10	

11/27/63 BURNS & McDONNELL ENGINEERING COMPANY FORM J-2-I-13

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT PHSIKEMO HOLE NO. P-17 SHEET 4 OF 5

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS		BOX OR SAMPLE NO.	REMARKS
51							
52							
* 53–55	Similar to previous; more uniformly fine to med. sand, dense, milky.	SP	13/17/16	7" Recov.		D-11	milky - silty clay & not firmly bonded as some previously found mat'l from other holes; (in sluff mat'l)
56							
57							
58–61	Gray, pred. fine sand, trace med. sand, trace silt, lignite part., subrounded to subangular, very dense, sat.; becoming very silty toward tip.	SP/SM	18/50/3" pen.	8" Recov.		D-12	fine + coarse gravel noted in sluff mat'l.
62							
63–66	Gray, pred. fine to med. sand, trace coarse sand and fine gravel, lignite subrounded to subangular, dense, sat.; lignite + ~~seam~~ ~~with~~ gravel seam present.	SP	10/18/16	9" Recov.		D-13	
67							
68							

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BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT PHSIKEMO HOLE NO. P-17 SHEET 5 OF 5

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS		BOX OR SAMPLE NO.	REMARKS
69–71	Brown-gray, well graded sand, some fine gravel, trace coarse gravel, milky, trace lignite, subrounded to subangular, dense, sat.	SW/(SP)	13/18/26	7" Recov.		D-14	
72–73	similar - finer						
74–75	Similar to previous; more uniform sand, finer, very dense.	SP/(SW)	15/50/8½" pen.	8" Recov.		D-15	
76–77	similar - finer						
78–81	Brown-gray, pred. fine to med. sand, some coarse sand, trace fine gravel, trace lignite part., subrounded to subangular, dense, sat.	SP	11/14/19	6½" Recov.		D-16	end Fri.
82							
83–85	Brown-gray, same as previous; med. density, milky.	SP	8/12/16	11" Recov.		D-17	Hole caved @ 30' casing - rate plugged. end hole
	TD 85'						

11/27/63 BURNS & McDONNELL ENGINEERING COMPANY FORM J-2-1-1a

DRILLING LOG

JOB NO. 76-076-1	PROJECT PHSIKEMO	HOLE NO. P-18
GROUND ELEV. 303.83	LOCATION 1500' S. of Sta. 50+00	SHEET 1 OF 5

DRILLING TYPE	HOLE DEPTH	OVERBURDEN FOOTAGE	BEDROCK FOOTAGE	OVERBURDEN SAMPLES	NO. CORE BOXES	% CORE RECOVERY	WATER TABLE
Rotary Wash	75±						7.0

DRILLING CO. RAYMOND INT. CO.	DRILLER(S) DON FERRAY
DRILLING RIG CME 750	PENETRATION TEST SPT
DRILLING DATE MARCH 21 77 TO MARCH 21 77	INSPECTOR(S) C.A. BUHR

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
1						
2						
3	Yellow-Brown, pred. fine sand, trace to some med. sand, some silt, trace lignite part. + seam, subrounded, med. density, moist to wet.	SP	5/7/7	15" Recov	D-1	
4						
5						
6						
7						Water @ 7±
8	Dk. brown, pred. fine to med. sand, trace coarse sand, trace to some silt, trace lignite, subrounded, loose, sat., trace of slightly silty seams.	SP/(SM)	2/3/5	11½" Recov.	D-2	
9						
10						
11						
12						
13						

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT PHSIKEMO HOLE NO. P-18 SHEET 2 OF 5

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
14	~~Dk~~ Brown, pred. med. to fine sand, trace coarse sand, trace silt, trace lignite, subrounded, med. density, sat.	SP	4/7/8	13" Recov	D-3	
15						
16						
17						
18	Brown, fine to med. sand, some coarse sand, trace fine gravel, trace silt, trace lignite, loose, sat., subrounded.	SP/(SW)	5/2/5	4" Recov.	D-4	fine gravel in wash mud
19						
20						
21						
22						
23	Brown, well graded sand, some fine gravel, trace silt, lignite part. (¼"), subrounded to occas. subangular, med. density, sat.	SW/(SP)	6/8/9	9" Recov.	D-5	
24						
25						
26						
27						
28	Gray, pred. fine to med. sand, trace coarse sand & fine gravel, lignite part. + seams, subrounded to subangular, med. density, sat.	SP/(SW)	8/7/10	9½" Recov.	D-6	
29						
30						

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO HOLE NO. P-18 SHEET 3 OF 5

Depth	Description	Log or Class	No. Blows	Core Recov. & Loss	Box or Sample No.	Remarks
33–35	Gray, pred. fine to med. sand, trace coarse sand, lignite part. + seam, subrounded to subangular, med. density, sat.	SP	7/10/10	9 1/2" Recov.	D-7	thin lignite seam
38–40	Gray, fine sand, trace med. sand + occass. coarse sand, lignite part. + pockets, subrounded to subangular, dense, sat,	SP	12/29/16	10 1/2" Recov.	D-8	
43–45	Gray, pred. fine to med. sand, trace coarse sand, milky, lignite part., subrounded to subangular, med. density, sat,	SP	6/11/13	9 1/2" Recov.	D-9	thin gravel seam
48–50	Gray, fine to med. sand, trace coarse sand, milky, lignite part. + seams, subrounded to subangular, med. density, sat.	SP	8/12/11	7" Recov.	D-10	

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO HOLE NO. P-18 SHEET 4 OF 5

Depth	Description	Log or Class	No. Blows	Core Recov. & Loss	Box or Sample No.	Remarks
53–56	Gray, pred. fine to med. sand, trace coarse sand, lignite part., subrounded to subangular, very dense, sat; alternating finer + coarser layers, becoming silty-very fine sand @ tip.	SP / SM	13/50/10" pen.	10" Recov.	D-11	
58–60	Brown-gray, fine to med. sand, trace coarse sand + fine gravel, lignite part., subrounded to subangular, dense, sat. (trace milkyness)	SP/(SW)	13/22/22	9" Recov.	D-12	
63–66	Brown-gray, fine to med. sand, trace to some coarse sand, milky, lignite part. + seam, subrounded to subangular, dense, sat.	SP/(SW)	11/15/15	10" Recov.	D-13	2" gravel seam @ 63±

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO — HOLE NO. P-18 — SHEET 5 OF 5

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
69–71	Brown-gray, med. to fine sand, trace to some coarse sand + fine gravel, slight milkyness, lignite part., subrounded to subangular, med. density, sat.	SP/SW	14/12/15	10½" Recov.	D-14	fine + coarse gravel noted in sluff until 80
73–74	Same; dense, slight red-tint.	SP/SW	8/21/19	Recov.	D-15	
76						Hole caved @ 37², plugged, end drilling
77	T.D. 75²					
79–80				Recov.	~~D-16~~	
81	~~T.D. 80²~~					
84–85				~~Recov.~~	~~D-17~~	

11/27/63 — BURNS & McDONNELL ENGINEERING COMPANY — FORM J-2-1-1A

DRILLING LOG

JOB NO. 76-076-1 — PROJECT: PHSIKEMO — HOLE NO. P-19

GROUND ELEV. 299.96 — LOCATION: 487' offset S. of Sta. 64+77 — SHEET 1 OF 3

DRILLING TYPE	HOLE DEPTH	OVERBURDEN FOOTAGE	BEDROCK FOOTAGE	OVERBURDEN SAMPLES	NO. CORE BOXES	% CORE RECOVERY	WATER TABLE
Rotary Wash	50²						6.0

DRILLING CO. RAYMOND INT. CO. — DRILLER(S) DON FERRARY

DRILLING RIG CME 750 — PENETRATION TEST SPT

DRILLING DATE MARCH 9, 77 TO MARCH 9, 77 — INSPECTOR(S) C. A. BUHR

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
2–3						Bag Sample: Rust-brown-dk. clayey silt to silty clay, low to med. plast., moist to wet.
3–5	Dk. brown, clayey silt, trace fine sand, low to no plast., occass. rust streaks, organic smell, moist to wet.	ML/CL	2/2 ft.	½" Recov.	D-1	
6						water @ 6²
8–10	Gray, well graded sand, some coarse sand + fine gravel, lignite part., subrounded to occass. subangular, med. density, sat.	SW/SP	3/6/13	9" Recov.	D-2	

122673 — Burns & McDonnell Engineers-Architects-Consultants — Form J-2-1-1A

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO HOLE NO. P - 19 SHEET 2 OF 3

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
14–17	Top 4" – brown-gray, well graded sand, trace fine gravel, subrounded & occass. subangular; becoming finner, going through color changes – brown, rust-brown, lt.-brown, lignite seam, dk. brown; typ. pred. fine sand, w/ med. sand, trace coarse sand, subrounded to subangular; lignite throughout, sat.	SW / SP	5/7/13	10½" Recov.	D-3	
18–20	Lt. Yellow-brown, fine to med. sand, trace coarse sand, lignide part., subrounded to subangular, med. density, sat.	SP	6/6/8	6" Recov.	D-4	trace chert in wash ?
21						
22						
23–25	Gray, pred. fine to med. sand, trace coarse sand & fine gravel, trace lignite, subrounded to subangular, med. density, sat.	SP/(SW)	6/8/10	4" Recov.	D-5	
26						
27						
28–30	Top 1" similar to previous, finner; becoming gray silt, trace very fine sand, no plast., lignite part. & seams, moist. med. density to dense.	ML	4/8/10	12" Recov.	D-6	— change

11/27/63 BURNS & McDONNELL ENGINEERING COMPANY FORM J-2-1-1a

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO HOLE NO. P - 19 SHEET 3 OF 3

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
33–35	Gray, very fine sand, trace silt, trace med. sand., lignite part., subrounded to subangular, sat., med. density.	SP/~~SM~~	6/8/10	1" Recov.	D-7	
36						
37						
38–40	Gray, similar to previous; becoming coarser w/ lignite part. & seams, subrounded to subangular, med. density, sat.	SP	6/10/12	6" Recov.	D-8	
41						
42						
43–46	Gray, fine to med. sand, trace coarse sand, ~~toward top~~, milky, lignite, subrounded to subangular, dense, sat.; slightly coarser toward top.	SP	10/16/23	10" Recov.	D-9	
47						
48–50	Gray, fine to med. sand, slightly milky, lignite part. subrounded to subangular, dense, sat.	SP	15/18/18	9" Recov.	D-10	excessive plugging & caving – @ [illegible] unable to pull rods, end drilling

11/27/63 T.D. 50' BURNS & McDONNELL ENGINEERING COMPANY FORM J-2-1-1a

DRILLING LOG

JOB NO. 76-076-1	PROJECT PHSIKEMO					HOLE NO. P-20	
GROUND ELEV. 299.41	LOCATION 1000' offset S. of Sta. 60+00					SHEET 1 OF 6	
DRILLING TYPE	HOLE DEPTH	OVERBURDEN FOOTAGE	BEDROCK FOOTAGE	OVERBURDEN SAMPLES	NO. CORE BOXES	% CORE RECOVERY	WATER TABLE
Rotary Wash	95.0						3.5
DRILLING CO. RAYMOND INT. CO.				DRILLER(S) DON FERRARY			
DRILLING RIG CME 750				PENETRATION TEST SPT			
DRILLING DATE MARCH 8, 77 TO MARCH 9, 77				INSPECTOR(S) C. A. BUHR			

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
1						Bag Sample: Dk. brown to black, sandy silt, trace plast., wet to sat., organic. Water @ 3±
3	Top 7" gray, silt, trace fine sand, trace clay, no plast., low dry strength; bottom 6" gray, fine to med. sand, trace coarse sand, lignite, subrounded to occass. subangular, med. density, sat.	ML / SP	2/4/10	13" Recov.	D-1	
8	Gray, fine to med. sand, trace coarse sand, trace silt, trace lignite, subrounded to subangular, dense, sat., lignite seams.	SP	7/14/21	16" Recov.	D-2	

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BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT PHSIKEMO HOLE NO. P-20 SHEET 2 OF 6

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
14	Gray, fine to med. sand, trace lignite, subrounded to subangular, very dense, sat., becoming finer towards tip.	SP	12/23/31	Full Recov.	D-3	fine gravel noted in sluff
17						gravel seam noted by driller @ 17±
18	Gray, somewhat well graded sand, trace gravel, trace lignite, chert, subrounded to subangular, med. density, sat.	SP/SW	10/11/12	6½" Recov.	D-4	
23	Gray, fine to med. sand, trace coarse sand, milky, lignite part., subrounded to subangular, med. density, sat.	SP	10/12/16	6" Recov.	D-5	
28	Dk. gray, fine to med. sand, much lignite part. + seams, subrounded to subangular, med. density, sat.	SP	6/8/14	10" Recov.	D-6	

11/27/63 BURNS & McDONNELL ENGINEERING COMPANY FORM J-2-1-1A

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO HOLE NO.: P-20 SHEET 3 OF 6

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
33–35	Gray, fine to med. sand, lignite part., subrounded to subangular, med. density, sat.	SP	8/10/15	10" Recov.	D-7	Chert in sluff
38–40	Gray, pred. fine sand, w/ med. sand, lignite part. & seams, subrounded to subangular, med. density, sat.; coarse sand + fine gravel noted above top lignite seam.	SP	7/9/9	12½" Recov.	D-8	
43–45	Gray, fine to med. sand, some coarse sand, trace fine gravel, lignite part. & seam, chert, subrounded to subangular, med. density, sat.	SP/(SW)	9/10/10	8½" Recov.	D-9	
47–49	Gray, fine to med. sand, very milky, subrounded to subangular, med. density, sat.	SP	8/12/11	8" Recov.	D-10	* silty clay - firm, in sluff mat'l & wash noted

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO HOLE NO.: P-20 SHEET 4 OF 6

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
53–55	Gray, fine sand, trace to some med. sand, lignite, subrounded to subangular, med. density to dense, sat.	SP	9/13/16	10½" Recov.	D-11	
** * 58–60	Brown-gray, well graded sand, some gravel, red-very milky-tint, chert, trace lignite, subrounded to subangular, med. density, sat.	SW/SP	10/10/12	7½" Recov.	D-12	end Turs. caving problems.
62						Lignite seam located above sample D-13
63–67	Top 2½" - gray, fine to med. sand, w/ great pred. of lignite part.; 3" fine gravel seam, subangular, very milky; 4½" brown-gray, fine to med. sand, trace coarse sand, lignite part., subrounded to subangular, med. density to dense, sat.	SP / Gravel / SP	11/11/15	10" Recov.	D-13	

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO   HOLE NO. P-20   SHEET 5 OF 6

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
68	Brown-gray, fine sand, some med. sand, trace coarse sand & fine gravel pocket, lignite part. & seam, red-tint, subrounded to subangular, very dense, sat.	SP	11/20/31	8" Recov.	D-14	
73	Brown-gray, fine sand to med. sand, trace coarse sand, red-milky tint, lignite part., subrounded to subangular, very dense, sat.	SP	16/22/26	10" Recov.	D-15	plugging & caving caused delay —
78	Brown-gray, fine to med. sand, ~~trace~~ lignite, red-milky tint, subrounded to subangular, (chert), dense to very dense, sat.	SP	10/17/23	9" Recov.	D-16	
81						gravel lenses @ 81± to 83±
83	Red-brown, very fine sand, subrounded to subangular, lignite, dense, sat.	SP	11/14/18	1½" Recov.	D-17	Coarse gravel plugged in jar — from gravel layer

BURNS & McDONNELL ENGINEERING COMPANY

DRILLING LOG

PROJECT: PHSIKEMO   HOLE NO. P-20   SHEET 6 OF 6

DEPTH	DESCRIPTION	LOG OR CLASS	NO. BLOWS	CORE RECOV. & LOSS	BOX OR SAMPLE NO.	REMARKS
88	Blue-gray, clay, very stiff to hard, mottled, high plast., high dry strength, moist. ~~trace of [illegible]~~	CH	6/9/14	9½ Recov.	D-18	
91						blue-gray water return
94	Same	CH	7/7/9	Full Recov.	D-19	caved in @ 40± end drilling.
	T.D 95±					
99				~~Recov.~~	D-20	

Surface Elevation: 322.2

Datum msl

Completion Date: 8/30/11

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GRAPHIC LOG	DRY UNIT WEIGHT (pcf) SPT BLOW COUNTS CORE RECOVERY/RQD	SAMPLES
	FILL: brown, fine sand		3-6-8	SS1
5	FILL: brown, clayey sand		3-5-14	SS2
	FILL: brown and gray, fine sand		6-12-15	SS3
10			7-12-11	SS4
	Loose to dense, brown and gray, fine to medium SAND - SP			
15			7-16-16	SS5
20			3-3-7	SS6
25			8-10-11	SS7
30			11-14-14	SS8
35			10-11-12	SS9
40			8-8-9	SS10
	Boring terminated at 45 feet.		12-17-17	SS11

SHEAR STRENGTH, tsf

Δ - UU/2 ○ - QU/2 □ - SV

0.5 1.0 1.5 2.0 2.5

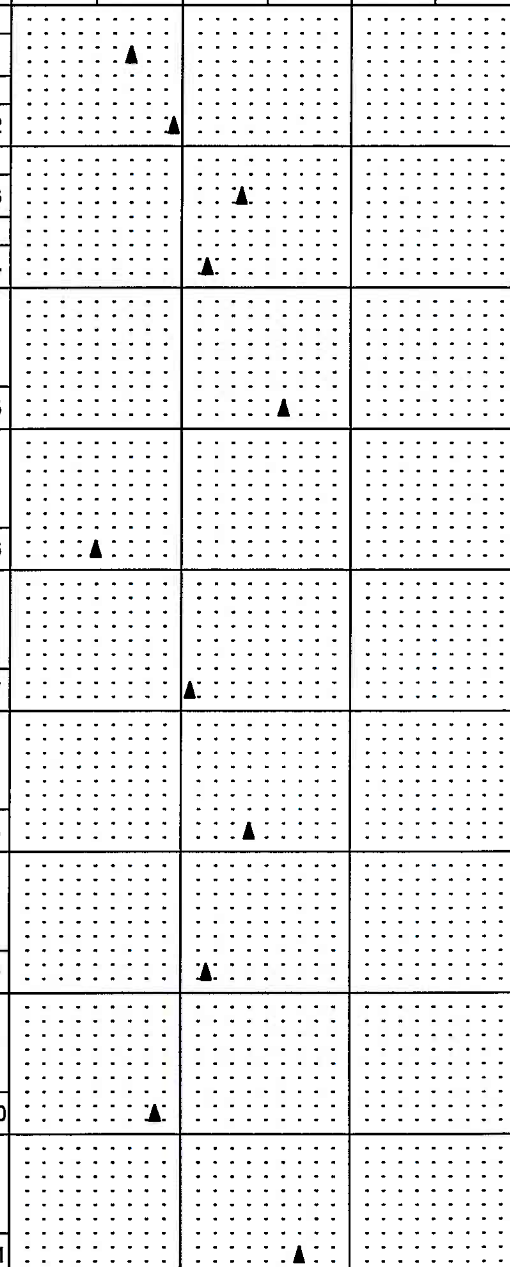
STANDARD PENETRATION RESISTANCE (ASTM D 1586)

▲ N-VALUE (BLOWS PER FOOT)

WATER CONTENT, %

PL ├──●──┤ LL

10 20 30 40 50



NOTE: STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL. GRAPHIC LOG FOR ILLUSTRATION PURPOSES ONLY.

DRILLING DATA

__ AUGER 3 3/4" HOLLOW STEM

WASHBORING FROM 20 FEET

PH DRILLER RFW LOGGER

CME 550X DRILL RIG

HAMMER TYPE Auto

REMARKS: Groundwater not encountered prior to commencement of washboring.

Drawn by: KSA	Checked by: SK	App'vd. by: MHM
Date: 9/7/11	Date: 10/3/11	Date: 10/3/11

GEOTECHNOLOGY INC
FROM THE GROUND UP

Sikeston Ash Ponds

LOG OF BORING: B-6

Project No. J019302.01

Surface Elevation: 322.1

Datum msl

Completion Date: 8/30/11

SHEAR STRENGTH, tsf

Δ - UU/2 O - QU/2 ▯ - SV

0.5 1.0 1.5 2.0 2.5

STANDARD PENETRATION RESISTANCE (ASTM D 1586)

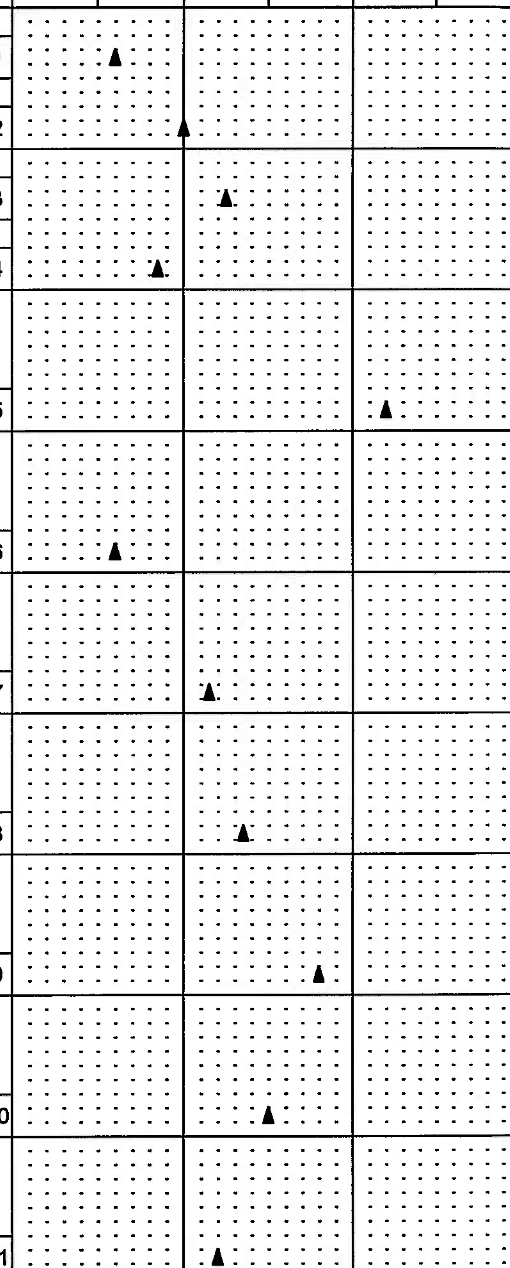
▲ N-VALUE (BLOWS PER FOOT)

WATER CONTENT, %

PL ⊢—●—⊣ LL

10 20 30 40 50

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GRAPHIC LOG	DRY UNIT WEIGHT (pcf) SPT BLOW COUNTS CORE RECOVERY/RQD	SAMPLES
	FILL: brown, fine sand		4-5-7	SS1
5			5-9-11	SS2
			7-12-13	SS3
	FILL: brown and gray, clayey SAND - SC		7-6-11	SS4
10				
	Medium dense to dense, brown, fine to coarse SAND - SP			
15			11-19-25	SS5
20			4-5-7	SS6
25			7-10-13	SS7
30			12-12-15	SS8
35			13-15-21	SS9
40			10-14-16	SS10
	Boring terminated at 45 feet.		10-10-14	SS11



NOTE: STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL. GRAPHIC LOG FOR ILLUSTRATION PURPOSES ONLY.

DRILLING DATA

___ AUGER 3 3/4" HOLLOW STEM

WASHBORING FROM 20 FEET

PH DRILLER RFW LOGGER

CME 550X DRILL RIG

HAMMER TYPE Auto

REMARKS: Groundwater not encountered prior to commencement of washboring.

Drawn by: KSA	Checked by: SRL	App'vd. by: MHM
Date: 9/7/11	Date: 10/3/11	Date: 10/3/11

GEOTECHNOLOGY INC

FROM THE GROUND UP

Sikeston Ash Ponds

LOG OF BORING: B-7

Project No. J019302.01

Surface Elevation: 322.0

Datum msl

Completion Date: 8/30/11

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GRAPHIC LOG	DRY UNIT WEIGHT (pcf) SPT BLOW COUNTS CORE RECOVERY/RQD	SAMPLES
0	FILL: brown, fine sand			
4.5			4-11-14	SS1
7	FILL: brown, silty sand			
9.5			9-12-14	SS2
14.5			18-36-26	SS3
15	Medium dense, brown, silty SAND - (SM)			
19.5			9-8-8	SS4
22	Medium dense, brown, fine to medium SAND - SP			
24.5			6-8-9	SS5
25	Boring terminated at 25 feet.			

SHEAR STRENGTH, tsf

Δ - UU/2 O - QU/2 ▯ - SV

0.5 1.0 1.5 2.0 2.5

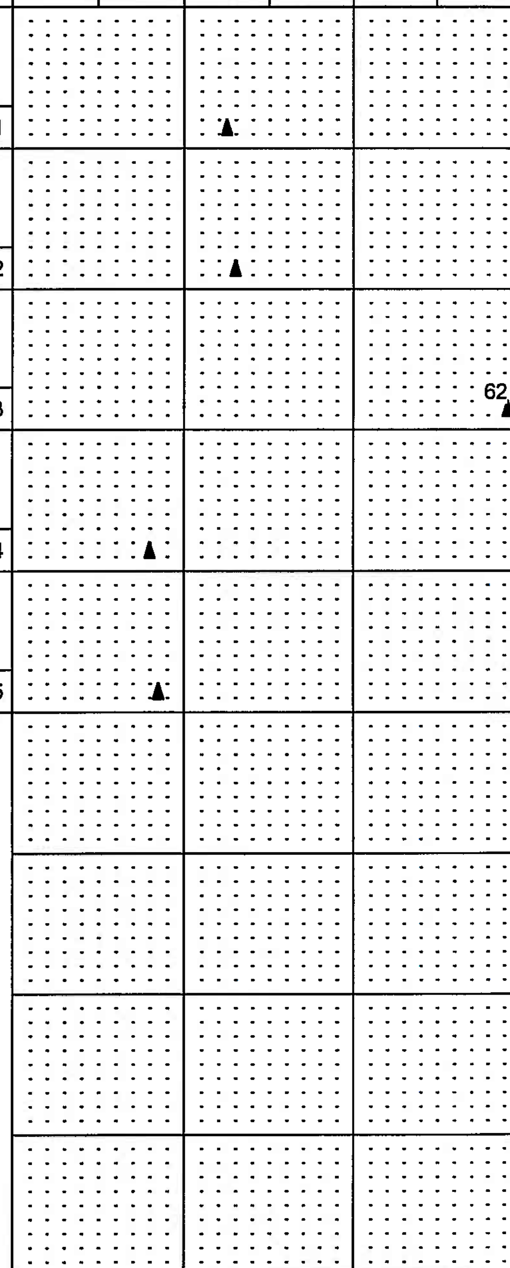
STANDARD PENETRATION RESISTANCE (ASTM D 1586)

▲ N-VALUE (BLOWS PER FOOT)

WATER CONTENT, %

PL ⊢—●—⊣ LL

10 20 30 40 50



NOTE: STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL. GRAPHIC LOG FOR ILLUSTRATION PURPOSES ONLY.

GROUNDWATER DATA

X FREE WATER NOT ENCOUNTERED DURING DRILLING

DRILLING DATA

__ AUGER 4 1/4" HOLLOW STEM

WASHBORING FROM __ FEET

PH DRILLER RFW LOGGER

CME 550X DRILL RIG

HAMMER TYPE Auto

REMARKS:

Drawn by: KSA	Checked by: SC	App'vd. by: MHM
Date: 9/7/11	Date: 10/3/11	Date: 10/3/11

GEOTECHNOLOGY INC FROM THE GROUND UP

Sikeston Ash Ponds

LOG OF BORING: P-8

Project No. J019302.01

Surface Elevation: 322.2

Datum msl

Completion Date: 8/31/11

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GRAPHIC LOG	DRY UNIT WEIGHT (pcf) SPT BLOW COUNTS CORE RECOVERY/RQD	SAMPLES
0	FILL: brown, fine sand			
4			2-3-5	SS1
9			8-22-23	SS2
14	Coal debris		12-14-17	SS3
17	Medium dense, brown and gray, fine to medium SAND -SP			
19			8-11-14	SS4
20	Boring terminated at 20 feet.			

SHEAR STRENGTH, tsf

Δ - UU/2 O - QU/2 ▯ - SV

0.5 1.0 1.5 2.0 2.5

STANDARD PENETRATION RESISTANCE

(ASTM D 1586)

▲ N-VALUE (BLOWS PER FOOT)

WATER CONTENT, %

PL ● LL

10 20 30 40 50

5 10 15 20 25 30 35 40

NOTE: STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL. GRAPHIC LOG FOR ILLUSTRATION PURPOSES ONLY.

GROUNDWATER DATA

ENCOUNTERED AT 17 FEET ⊻

DRILLING DATA

__ AUGER 4 1/4" HOLLOW STEM

WASHBORING FROM __ FEET

PH DRILLER RFW LOGGER

CME 550X DRILL RIG

HAMMER TYPE Auto

REMARKS:

Drawn by: KSA Checked by: SA App'vd. by: WHM

Date: 9/7/11 Date: 10/3/11 Date: 10/3/11

GEOTECHNOLOGY INC

FROM THE GROUND UP

Sikeston Ash Ponds

LOG OF BORING: P-10

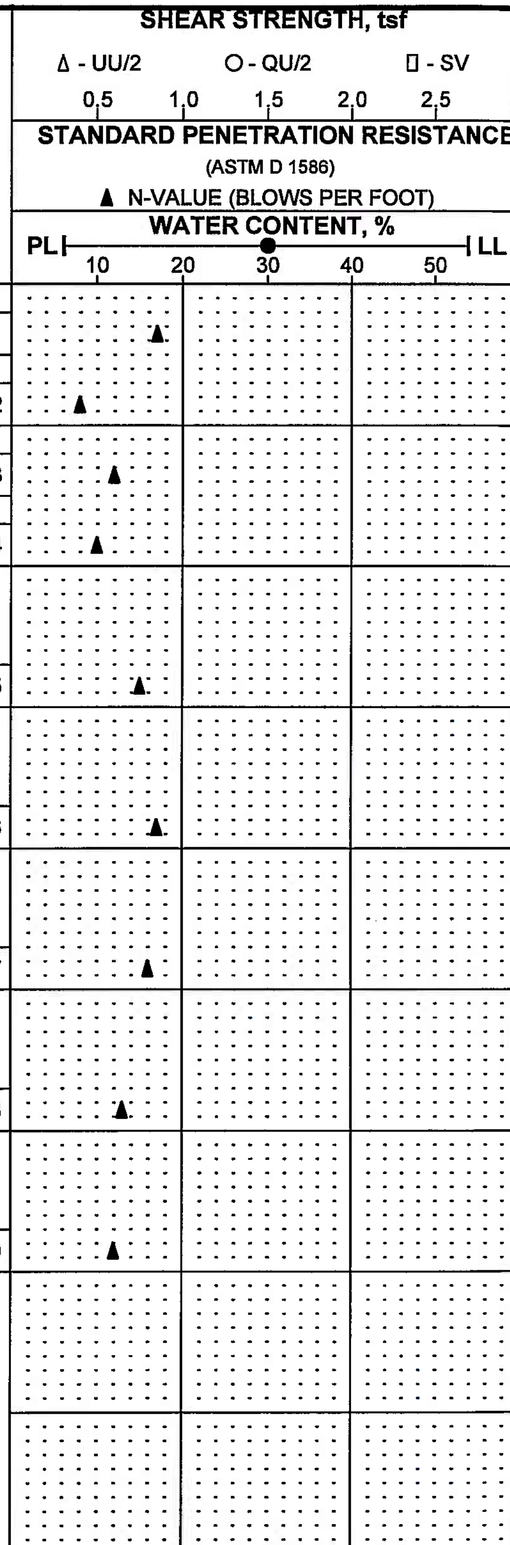
Project No. J019302.01

Surface Elevation: 306.2

Datum: msl

Completion Date: 9/1/11

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GRAPHIC LOG	DRY UNIT WEIGHT (pcf) SPT BLOW COUNTS CORE RECOVERY/RQD	SAMPLES
0	Medium dense, gray, silty SAND - SM		5-8-9	SS1
3	Loose to medium dense, brown and gray, fine to medium SAND - (SP)		3-4-4	SS2
			4-6-6	SS3
			3-4-6	SS4
			4-6-9	SS5
			8-8-9	SS6
			9-8-8	SS7
26.5	Medium dense, brown and gray, fine to coarse SAND with gravel - SP		5-6-7	SS8
			6-6-6	SS9
35	Boring terminated at 35 feet.			



NOTE: STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL. GRAPHIC LOG FOR ILLUSTRATION PURPOSES ONLY.

GROUNDWATER DATA

ENCOUNTERED AT 11.5 FEET ∇

DRILLING DATA

__ AUGER 3 3/4" HOLLOW STEM

WASHBORING FROM 15 FEET

PH DRILLER RFW LOGGER

CME 550X DRILL RIG

HAMMER TYPE Auto

REMARKS:

Drawn by: KSA	Checked by: SLC	App'vd. by: MHM
Date: 9/7/11	Date: 10/3/11	Date: 10/3/11

GEOTECHNOLOGY INC
FROM THE GROUND UP

Sikeston Ash Ponds

LOG OF BORING: B-13

Project No. J019302.01

Surface Elevation: 305.0

Datum msl

Completion Date: 9/1/11

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GRAPHIC LOG	DRY UNIT WEIGHT (pcf) SPT BLOW COUNTS CORE RECOVERY/RQD	SAMPLES
	Hard, gray SILT - ML		14-24-14	SS1
	Loose to medium dense, brown to gray, fine to medium SAND - (SP)		3-5-5	SS2
5			4-4-5	SS3
			4-6-8	SS4
10		⊻		
15			3-5-9	SS5
			9-10-12	SS6
20				
			8-6-5	SS7
25	with gravel			
			6-9-14	SS8
30				
			6-9-12	SS9
35	Boring terminated at 35 feet.			
40				

SHEAR STRENGTH, tsf

Δ - UU/2 O - QU/2 ▯ - SV

0.5 1.0 1.5 2.0 2.5

STANDARD PENETRATION RESISTANCE (ASTM D 1586)

▲ N-VALUE (BLOWS PER FOOT)

WATER CONTENT, %

PL ⊢ ● ⊣ LL

10 20 30 40 50

NOTE: STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL. GRAPHIC LOG FOR ILLUSTRATION PURPOSES ONLY.

LOG OF BORING 2002 WL J019302.01 - SIKESTON.GPJ 00 CLONE ME.GPJ 10/3/11

GROUNDWATER DATA

ENCOUNTERED AT 11.5 FEET ⊻

DRILLING DATA

___ AUGER 3 3/4" HOLLOW STEM

WASHBORING FROM 15 FEET

PH DRILLER RFW LOGGER

CME 550X DRILL RIG

HAMMER TYPE Auto

REMARKS:

Drawn by: KSA	Checked by: SK	App'vd. by: MHM
Date: 9/7/11	Date: 10/3/11	Date: 10/3/11

GEOTECHNOLOGY INC FROM THE GROUND UP

Sikeston Ash Ponds

LOG OF BORING: B-14

Project No. J019302.01

WELL INFORMATION

Layne-Western Co. Inc.

1. CONTRACT Sikeston Power Station
   Unit 1 - Contract 37 - Water Wells
2. City, State Sikeston, Missouri
3. Well No. 3 at Test Hole No. 1-78
4. Well Location (attach map)

5. Driller F. Frederick
6. DATE 1/22/80
7. Date Started 8/15/79
   Completed 9/11/79
8. Drill Crew Man Hrs
9. Working Days
   Drilling
   Other

10. MATERIAL IN WELL	LENGTH FT. IN.	DIA. IN.	GAGE NO.	WALL THICKNESS IN.	MATERIAL	TYPE	NO.
Screen	43	18			Stainless Steel	Cook ~~Shutter~~ ~~Keystone~~	0.060 Openings
Inner Casing	140	18		0.375	Carbon Steel	Welded / Screwed	
Outer Casing	33	30		0.281	Carbon Steel	Welded / Screwed	

11. GRAVEL
    Size WB50 & Lemons 3/8 x 3/4
    Tons 27 54

12. SEALING CASING
    Puddled Clay (Yes) (No)
    With .... Bags Bentonite Added
    or
    With .... Bags Cement
    Seal Material Placed in Well With neat cement grout
    Bottom of Well Screen Sealed With steel plate

13. WELL DIMENSIONS
    A. Total Depth 183'
       (From Top of Inner Casing to Bottom of Well)
    B. Height of Inner Casing
       (Above Ground Level)
    C. Distance to Top of Gravel 4'
       (From Ground Level)
    D. Diameter of Drill Hole 36"

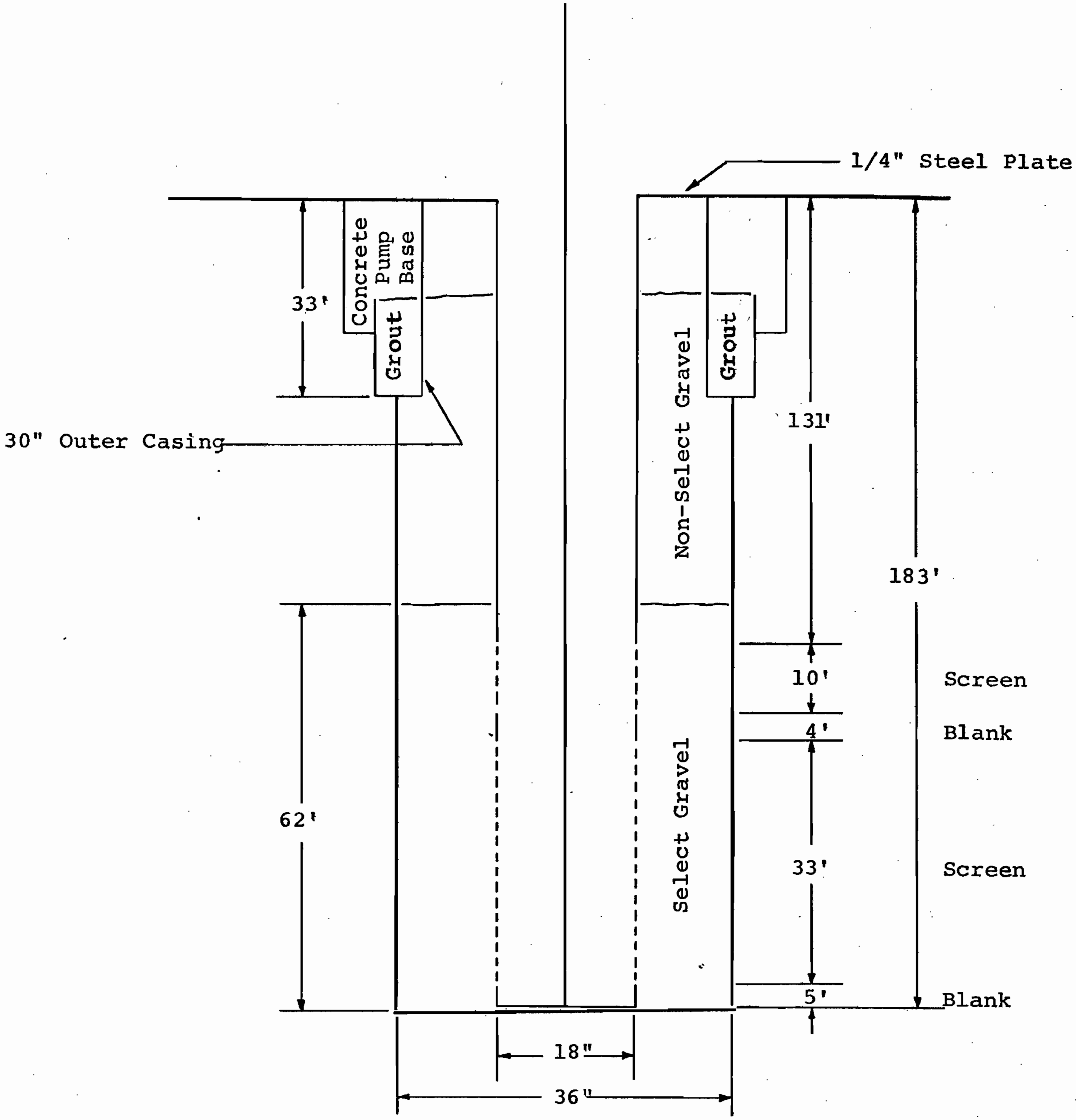
    Comments

LW-39

CONSTRUCTION OF WELL

No. 3

Sikeston Power Station - Unit 1
Contract 37



LOG OF WELL

Ft.	In.	to	Ft.	In.	Formation
0			10		Silty sand
10			16		Clay
16			35		Coarse sand
35			55		Fine sand
55			96		Medium sand
96			128		Clay
128			138		Coarse sand
138			140		Clay
140			175		Coarse sand and gravel
175			180		Clay
180			181		Fine sand

MISSOURI DEPARTMENT OF NATURAL RESOURCES DIVISION OF GEOLOGY AND LAND SURVEY
(573) 368-2165

MONITORING WELL CERTIFICATION RECORD

REF NO	DATE RECEIVED
00517353	06/22/2016
CR NO	CHECK NO. 10044
STATE WELL NO A208215 06/24/2016	REVENUE NO. 062216
ENTERED NRBASSM PH1 PH2 PH3 06/22/2016 06/22/2016 06/22/2016	APPROVED BY / ROUTE

INFORMATION SUPPLIED BY PRIMARY CONTRACTOR OR DRILLING CONTRACTOR
NOTE: THIS FORM IS NOT TO BE USED FOR NESTED WELLS

OWNER NAME SIKESTON BOARD OF MUNICIPAL UTILITIES	CONTACT NAME SIKESTON BOARD OF MUNICIPAL UTILITIES			VARIANCE GRANTED BY DNR
OWNER ADDRESS 1551 WEST WAKEFIELD STREET	CITY SIKESTON	STATE MO	ZIP 63801	NUMBER ________
SITE NAME SIKESTON POWER STATION		WELL NUMBER TPZ3		COUNTY SCOTT
SITE ADDRESS		CITY		STATIC WATER LEVEL 10.09 FT

SURFACE COMPLETION

TYPE: [X] ABOVE GROUND [ ] FLUSH MOUNT

LENGTH AND DIAMETER OF SURFACE COMPLETION: LENGTH 5.0 FT. DIAMETER 4.0 IN.

DIAMETER AND DEPTH OF THE HOLE SURFACE COMPLETION WAS PLACED: DIAMETER 12.0 IN. LENGTH 2.5 FT.

SURFACE COMPLETION GROUT: [X] CONCRETE [ ] OTHER

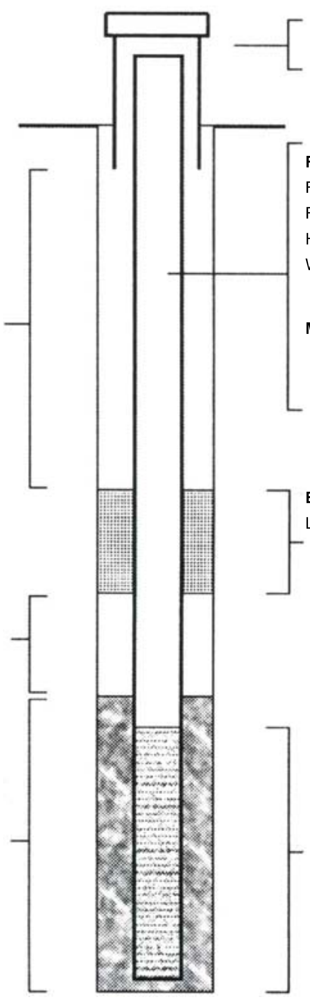
LOCATION OF WELL

LAT. 36 ° 52' 37.11"
LONG. 89 ° 36' 43.07"

SMALLEST ________ 1/4 ________ 1/4 SW 1/4 LARGEST

SEC. 24 TWN. 26 NORTH
RANGE 13 Direction E

[ ] LOCKING CAP
[ ] WEEP HOLE



SURFACE COMPLETTION: [X] STEEL [ ] ALUMINUM [ ] PLASTIC

MONITORING FOR:
[ ] RADIONUCLIDES [ ] PETROLEUM PRODUCTS ONLY
[ ] EXPLOSIVES [ ] METALS [ ] VOC
[ ] SVOCS [ ] PESTICIDES/HERBICIDESS

ELEVATION ________FT.

ANNULAR SEAL
LENGTH 16.5FT.
[ ] SLURRY [ ] CHIPS
[ ] PELLETS [ ] GRANULAR
[ ] CEMENT/SLURRY

IF CEMENT/BENTONITE MIX:
BAGS OF CEMENT USED:
%OF BENTONITE USED:
WATER USED/BAG: GAL.

RISER
RISER PIPE DIAMETER 2.0IN.
RISER PIPE LENGTH 27.1FT.
HOLE DIAMETER 8.5IN.
WEIGHT OR SDR# SCH40

MATERIAL
[ ] STEEL [X] THERMOPLASTIC (PVC)
[ ] OTHER ______

PROPOSED USE OF WELL
[ ] GAS MIGRATION WELL [ ] OBSERVATION
[ ] EXTRACTION WELL [ ] OPEN HOLE
[X] PIEZOMETERS
[ ] DIRECT PUSH

DEPTH FROM	DEPTH TO	FORMATION DESCRIPTION
0.0	2.0	LOAM
2.0	35.5	SND

TOTAL DEPTH: 35.5 FEET

BENTONITE SEAL
LENGTH: 3.1
[ ] CHIPS [ ] PELLETS [ ] GRANULAR
[ ] SLURRY
[ ] SATURATED ZONE [ ] HYDRATED

SECONDARY FILTER PACK
LENGTH: 0.0FT.

SCREEN
SCREEN DIAMETER: 2.0IN.
SCREEN LENGTH: 10.0FT.
DIAMETER OF DRILL HOLE: 8.5IN.
DEPTH TO TOP 25.5FT.

DEPTH TO TOP OF PRIMARY FILTER PACK: 22.1FT.

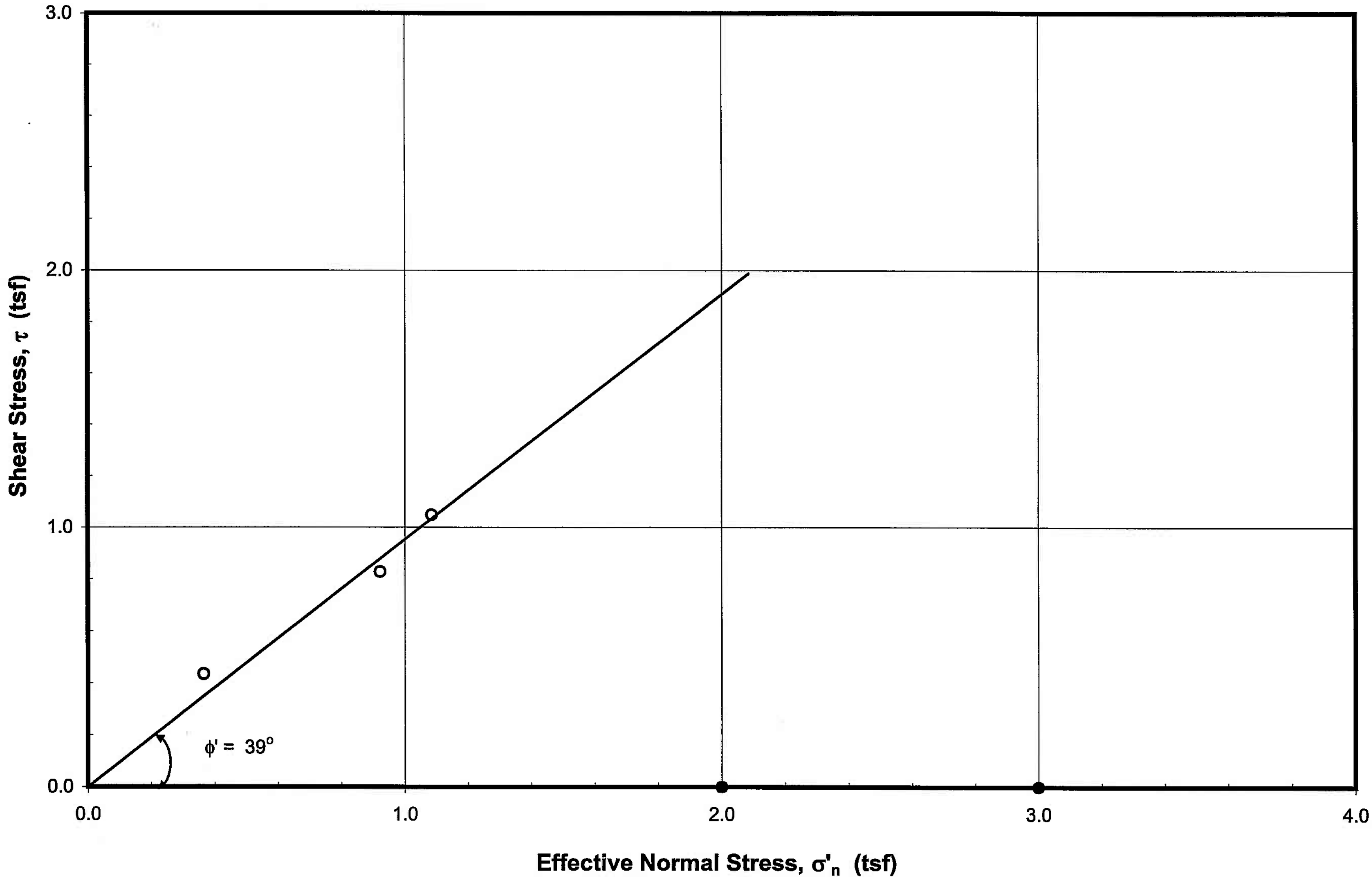
SCREEN MATERIAL
[ ] STEEL [X] THERMOPLASTIC (PVC)
[ ] OTHER

LENGTH OF PRIMARY FILTER PACK: 13.4FT.

FOR CASED WELLS, SUBMIT ADDITIONAL AS BUILT DIAGRAMS SHOWING WELL CONSTRUCTION DETAILS INCLUDING TYPE AND SIZE OF ALL CASING, HOLE DIAMETER AND GROUT USED.

SIGNATURE (PRIMARY COUNTRACTOR) x KEN EWERS	PERMIT NUMBER 006218		DATE WELL DRILLING WAS COMPLETED 05/13/2016
I HEREBY CERTIFY THAT THE MONITORING WELL HEREIN DESCRIBED WAS CONSTRUCTED IN ACCORDANCE WITH MISSOURI DEPARTMENT OF NATURAL RESOURCES REQUIREMENTS FOR THE CONSTRUCTION OF MONITORING WELLS			[ ] PUMP INSTALLED
SIGNATURE (WELL DRILLER) x FELIX DEKEN	PERMIT NUMBER 006065	SIGNATURE (APPRENTICE) x ________	APPRENTICE PERMIT NUMBER ________

GEOTECHNOLOGY INC
FROM THE GROUND UP

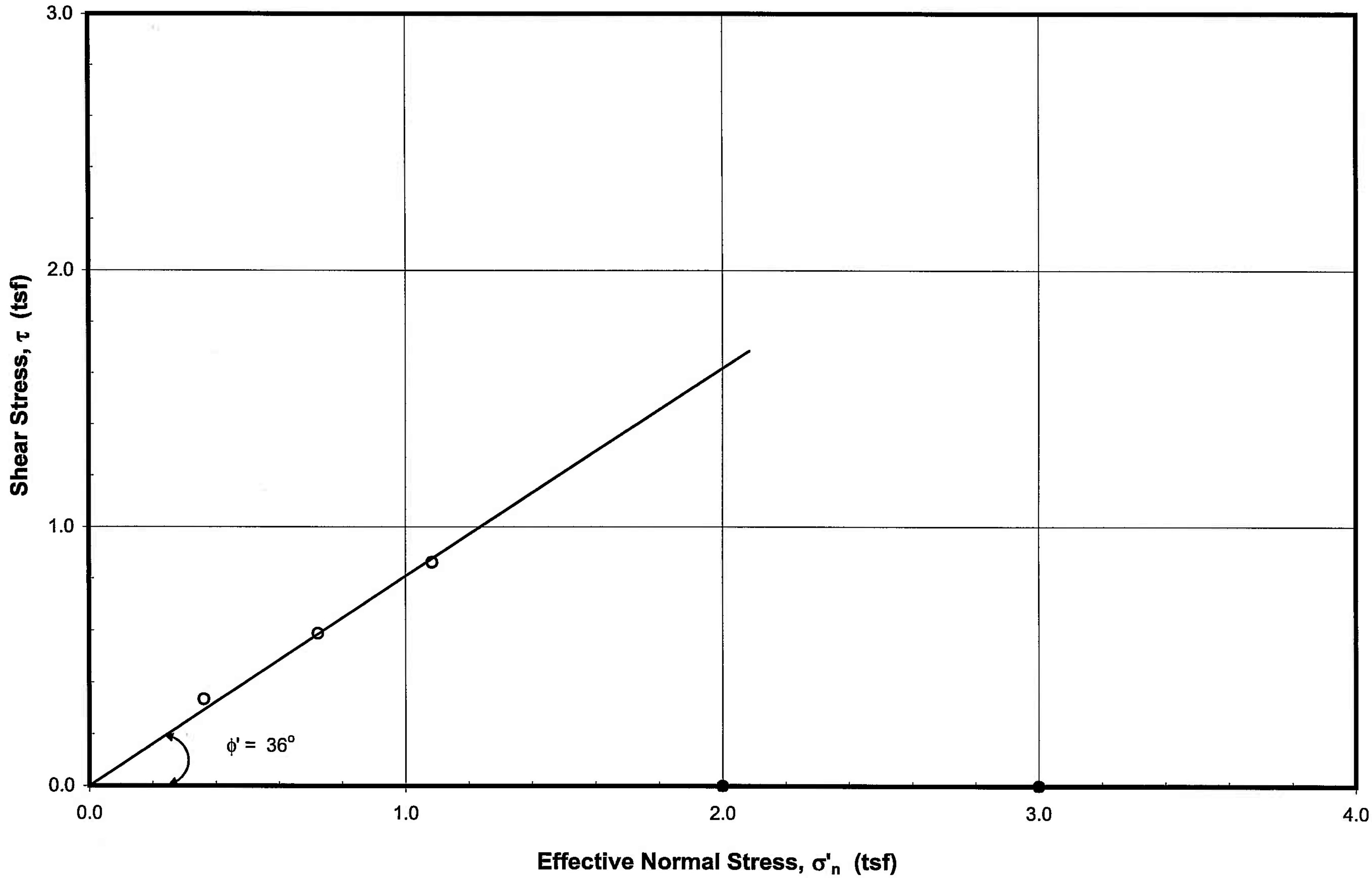


DRAINED DIRECT SHEAR TEST

ASTM D 3080

Boring: Composite B-1 & 2 (From auger cuttings 0-20 ft)

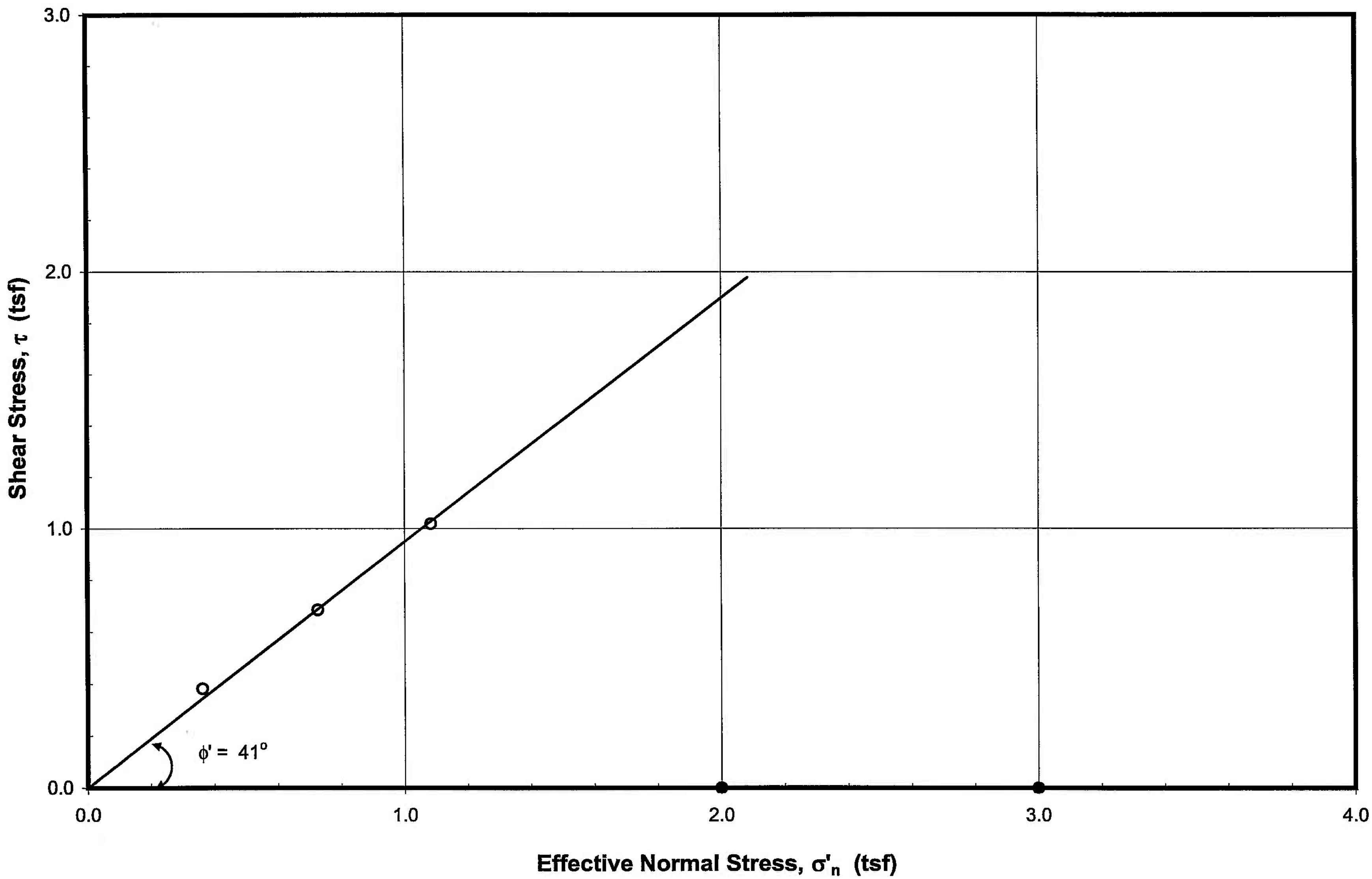
GEOTECHNOLOGY INC
FROM THE GROUND UP



DRAINED DIRECT SHEAR TEST

ASTM D 3080

Boring: Composite B-6 & 7 (From auger cuttings 0-20 ft)

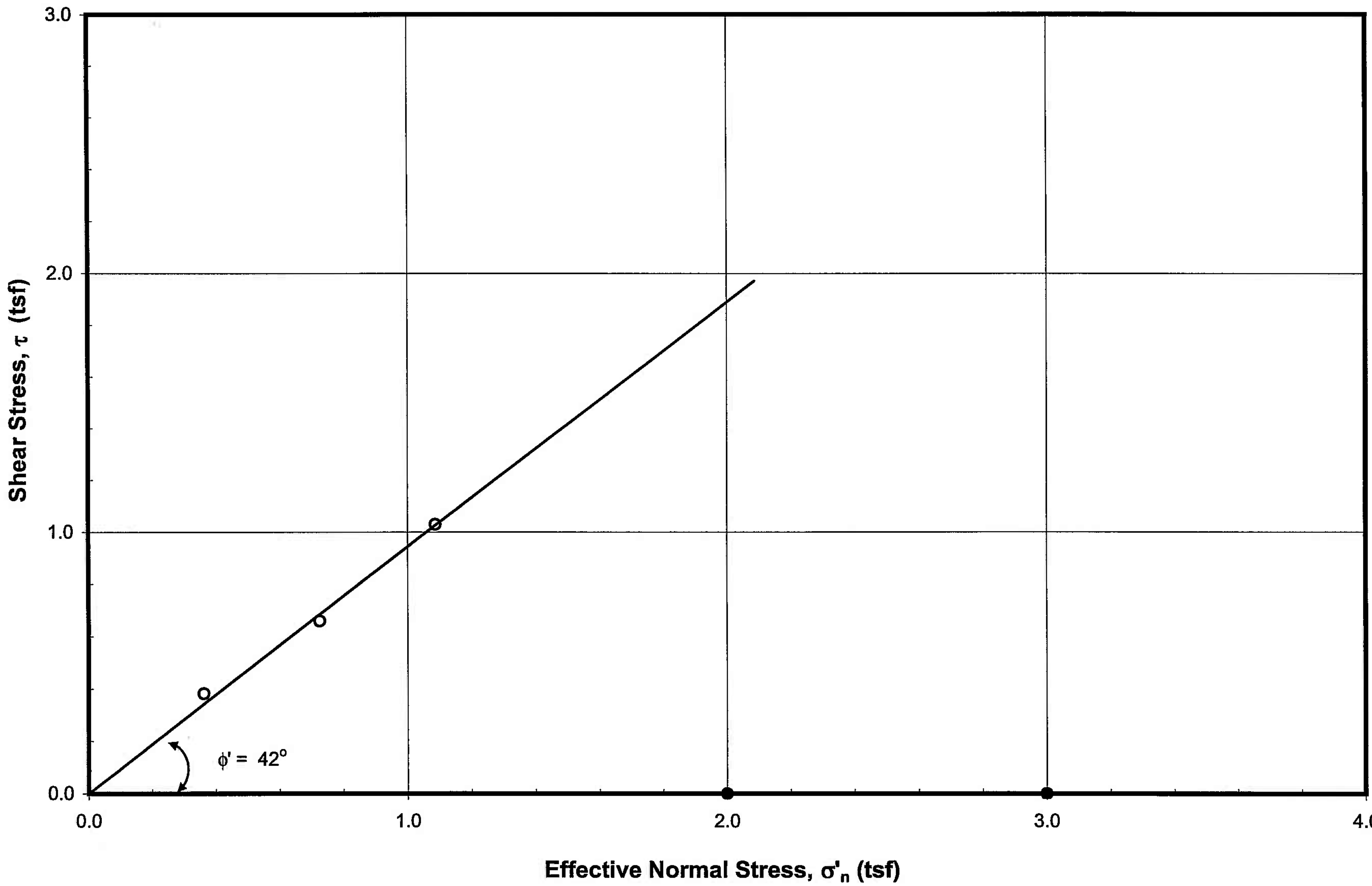


DRAINED DIRECT SHEAR TEST

ASTM D 3080

Boring: Composite B-11 & 12 (From auger cuttings 0-15 ft)

GEOTECHNOLOGY INC
FROM THE GROUND UP



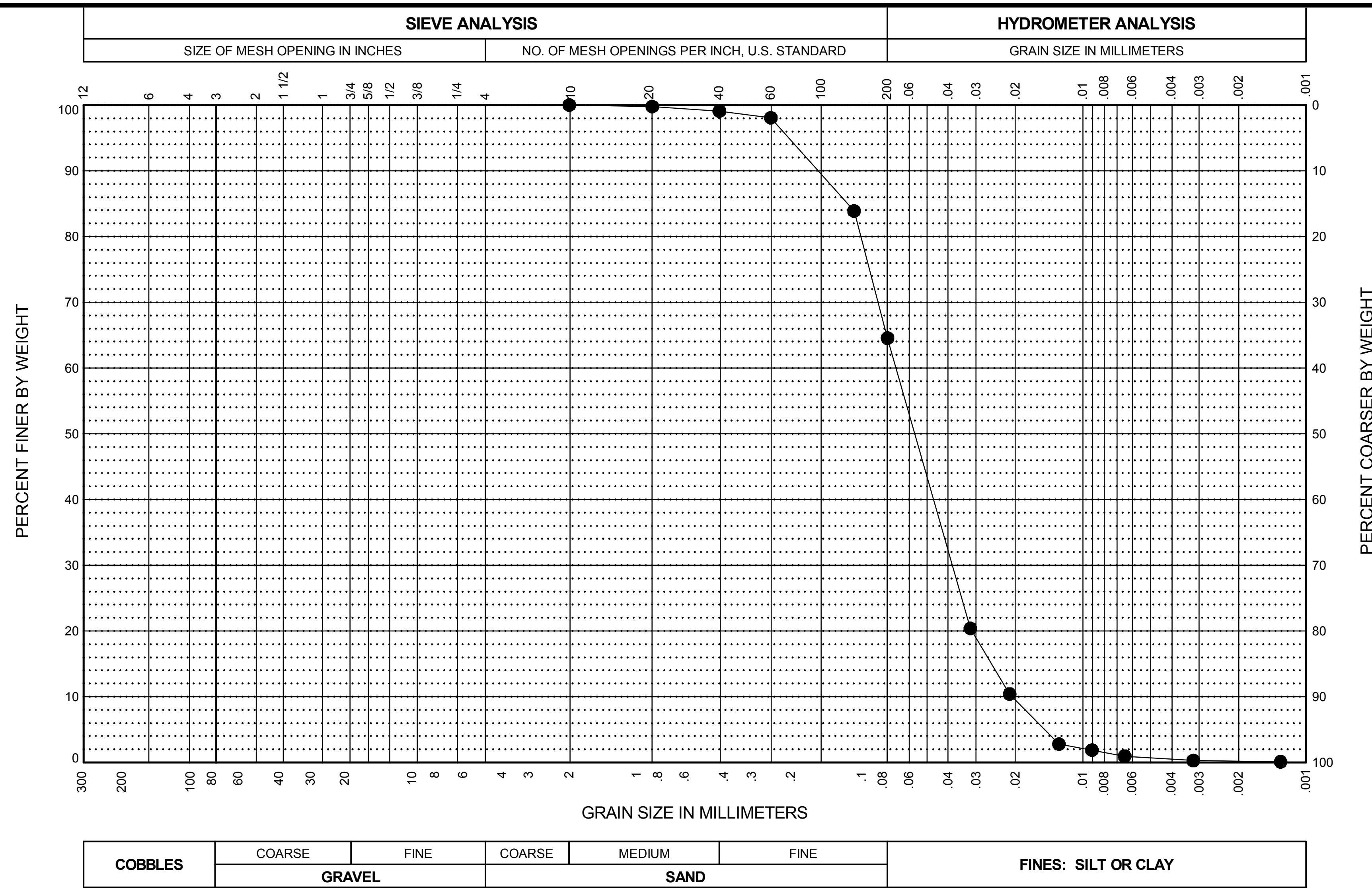
DRAINED DIRECT SHEAR TEST

ASTM D 3080

Boring: Composite B-13 & 14 (From auger cuttings 0-15 ft)

APPENDIX B

Current Laboratory Test Results



SAMPLE NO.	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● Bulk P-1	ML	Light tan, Sandy Silt.	64.6	34.4			

Sikeston Project
Sikeston, Missouri

GRAIN SIZE DISTRIBUTION

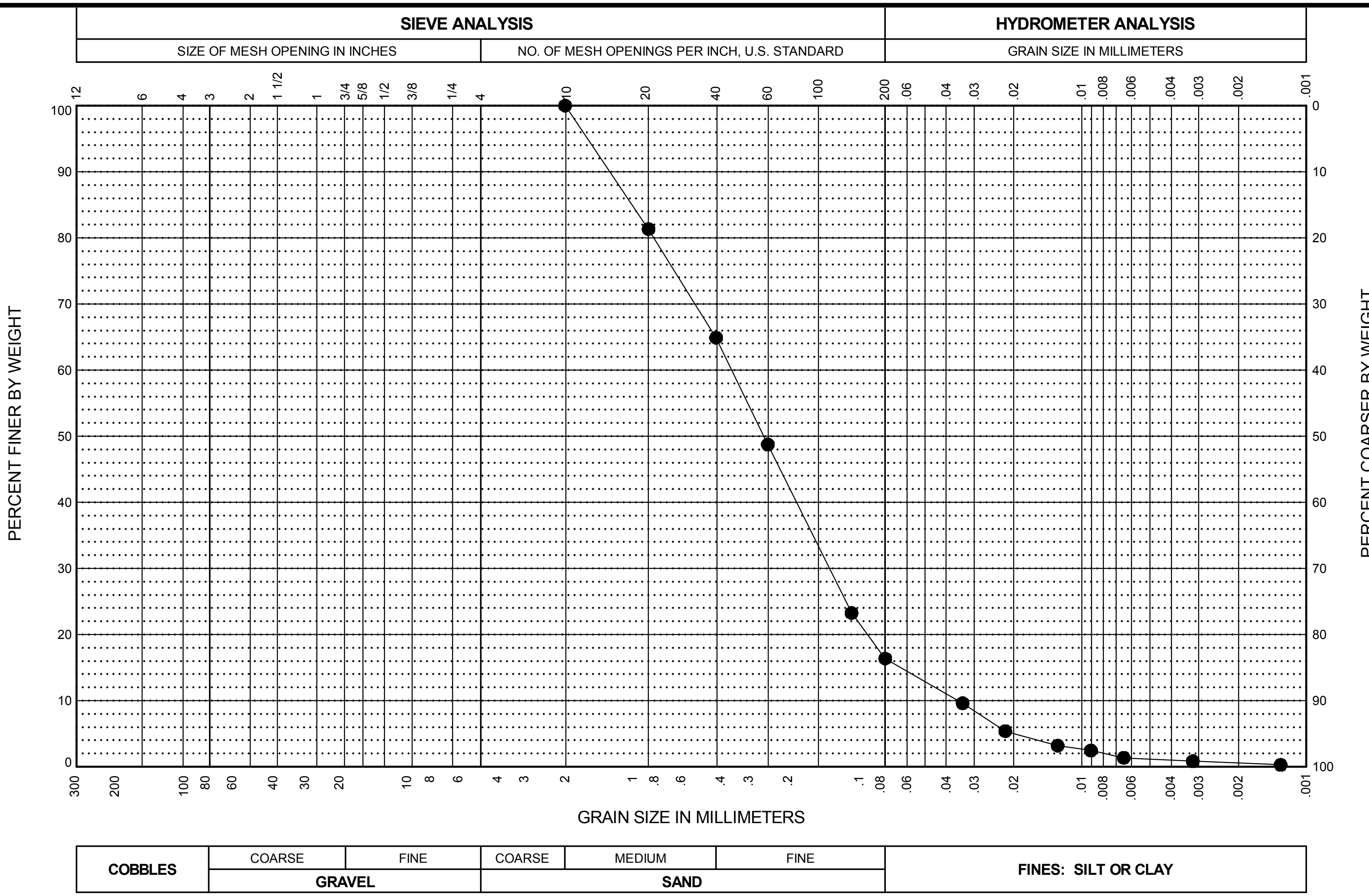
41-1-37431-005

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG.

FIG.

HAL 41-1-37431-005 LAB DATA.GPJ SHAN_WIL.GDT 8/5/16



SAMPLE NO.	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● Bulk P-2	SM	Light tan, Silty Sand.	16.4	22.1			

Sikeston Project
Sikeston, Missouri

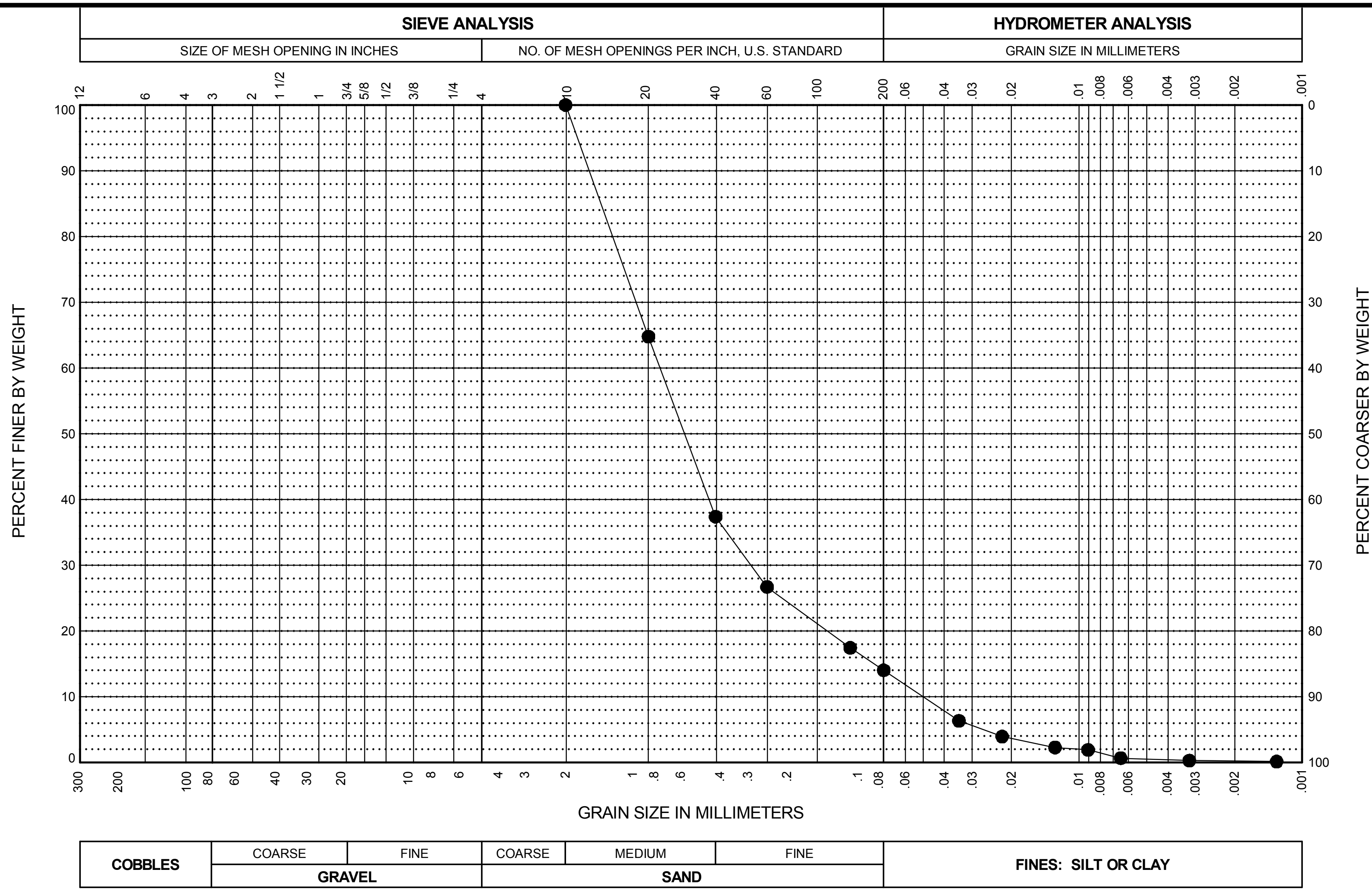
GRAIN SIZE DISTRIBUTION

41-1-37431-005

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG.

FIG.



SAMPLE NO.	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● Bulk P-3	SM	Light tan, Silty Sand.	14.0	27.5			

Sikeston Project
Sikeston, Missouri

GRAIN SIZE DISTRIBUTION

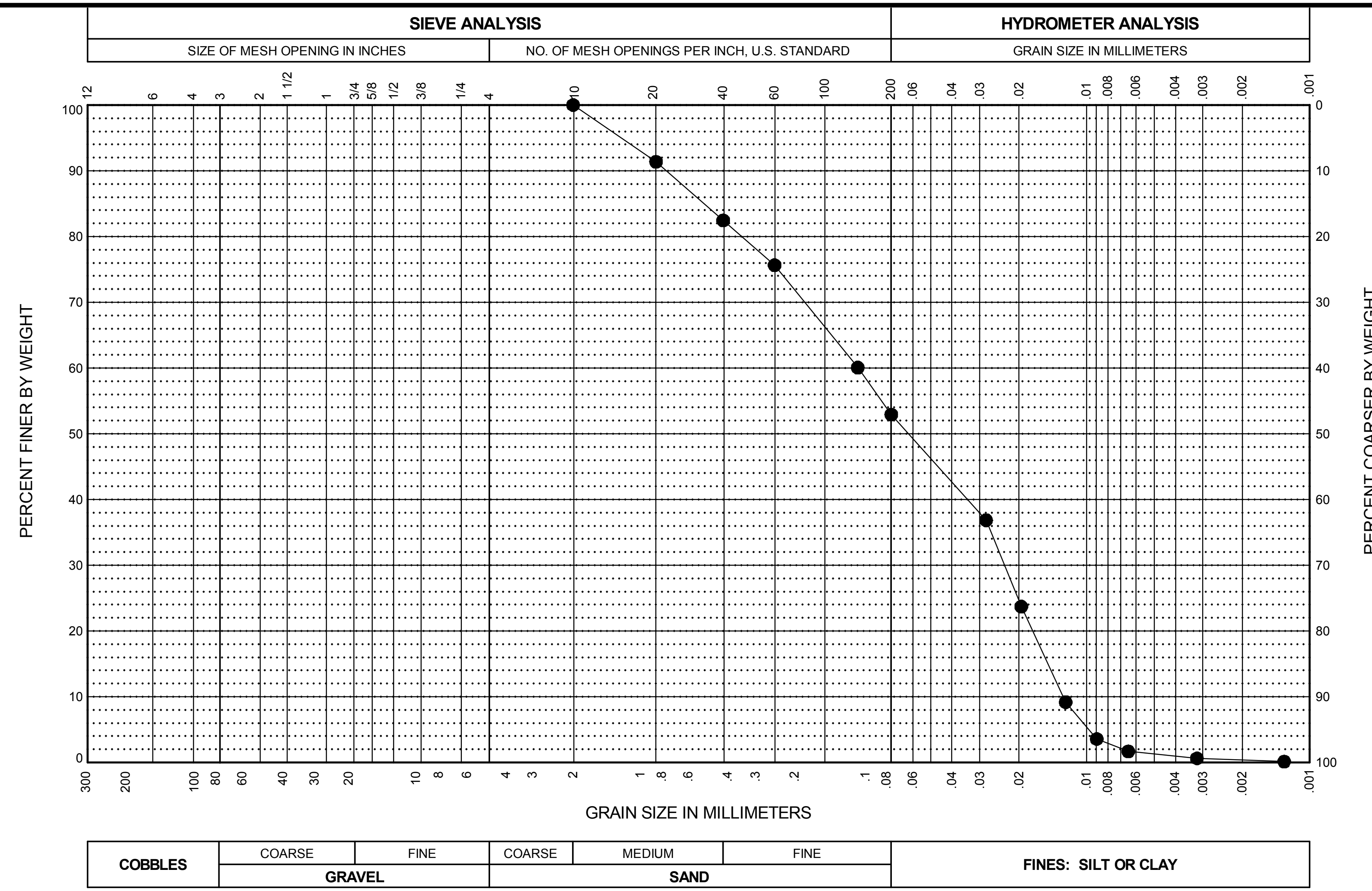
41-1-37431-005

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG.

FIG.

HAL 41-1-37431-005 LAB DATA.GPJ SHAN_WIL.GDT 8/5/16



SAMPLE NO.	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● Bulk P-4	ML	Light tan and gray, Sandy Silt.	52.9	54.1			

Sikeston Project
Sikeston, Missouri

GRAIN SIZE DISTRIBUTION

41-1-37431-005

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG.

FIG.

HAL 41-1-37431-005 LAB DATA.GPJ SHAN_WIL.GDT 8/5/16

APPENDIX C

Seismic Survey

Shear-Wave Velocity Profile Results for Sikeston Power Plant, Missouri

By

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August 15, 2016

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Shear-Wave Velocity Profile Results for Sikeston Power Plant, Missouri

EXECUTIVE SUMMARY

We conducted a seismic survey near the Sikeston Power Plant at Sikeston, MO on July 21, 2016 in order to better characterize the soil profile beneath the plant. We used multi-channel analysis of surface waves (MASW), Refraction Microtremor (ReMi), and refraction/reflection techniques to characterize the shear-wave (V_s) profile to bedrock (Paleozoic Limestones). The surface-wave techniques successfully characterized the soil profile and the refraction/reflection techniques provided constraints on the depth to the top of the Cretaceous sediments (95±10 m) and the Paleozoic bedrock (235±20 m). The V_s profile is summarized in the results section below.

INTRODUCTION

A seismic field survey was conducted near the Sikeston Power Plant on July 21, 2016. Figure 1 shows the location of the survey line along a road SW of the plant. We conducted shallow MASW and ReMi and deep refraction/reflection and ReMi surveys. Figure 2 shows us conducting the seismic surveys near the power plant. Figure 3 shows the 40 kg Propelled Energy Generator (PEG) source used in the shallow MASW survey. We also used a 450 lb weight drop source for the deeper refraction/reflection survey. The MASW survey also provided refraction/reflection information at 19 shot points along that survey.

METHODS

The seismic survey techniques employed at the Sikeston Power Plant used both active and passive source surface-wave methods and active source refraction/reflection methods. Both shallow and deep passive (ambient noise) Refraction Microtremor (ReMi) surveys (Louie, 2001; Stephenson et al., 2005; Donghong et al., 2008) were conducted using 180 m (7.5 m geophone spacing) and 400 m (20 m spacing) long survey lines. An active source Multichannel Analysis of Surface Waves (MASW) survey (Park et al., 1999) was conducted using a 144 m (2 m spacing) line and the PEG source. A deeper refraction line (415 m with variable geophone spacing) was conducted using the 450 lb. weight-drop source (Dobrin, 1960; Telford et al., 1976). Reflections were observed on both the MASW and the refraction surveys, and analyzed for depth of the reflectors (Dobrin, 1960; Telford et al., 1976).

Figure 1: Location of University of Memphis seismic survey near the Sikeston MO power plant (red line SW of plant).

Figure 2: Picture of the MASW survey being conducted next to the road with the power plant in the background.

Figure 3: Picture of the PEG source used in the MASW survey.

RESULTS

The shallow profiling and reflection results provide the best information about the V_s profile near the power plant. Surface-waves in the form of Rayleigh Waves were very efficiently generated by the PEG and weight-drop systems. Also the ambient noise consisted of Rayleigh Waves travelling along the line of geophones. The shallow MASW and ReMi results provided V_s estimates down to 125 m because of the efficient generation of surface waves, which is much deeper than the usual 30 to 60 m with these geophone spreads (lines). The results from the deep ReMi survey, although seemingly providing V_s information down to 175 m, were judged to not be reliable enough to be used. Because most of the shot energy went into surface-waves, refracted phases were weak. However, two strong reflections were noted on the deep refraction profile on the record closest to the shot and the first (shallowest) reflection also appeared on the MASW shot records.

The shallow MASW and ReMi combined results are in Table 1 and Figure 4. The strong V_s increase from 636 m/s to 1284 m/s at 100 m depth is interpreted as the top of the Cretaceous sediments based on deep borehole logs in the Mississippi embayment (see discussion below).

The uncertainty in these estimates, both in depth and velocity, is probably on the order of 10 – 20%.

Table 1: Table of V_s results from shallow MASW and ReMi.

Depth(m)	Vs(m/s)	Depth(ft)	Vs(ft/s)
-3.9	160	-12.7	526
-3.9	252	-12.7	826
-8.7	252	-28.5	826
-8.7	180	-28.5	591
-14.7	180	-48.3	591
-14.7	350	-48.3	1148
-22.3	350	-73.1	1148
-22.3	300	-73.1	983
-31.7	300	-104.0	983
-31.7	488	-104.0	1600
-43.5	488	-142.7	1600
-43.5	473	-142.7	1553
-58.2	473	-191.0	1553
-58.2	423	-191.0	1386
-76.7	423	-251.5	1386
-76.7	636	-251.5	2086
-99.7	636	-327.0	2086
-99.7	1284	-327.0	4211
-124.6	1284	-408.7	4211

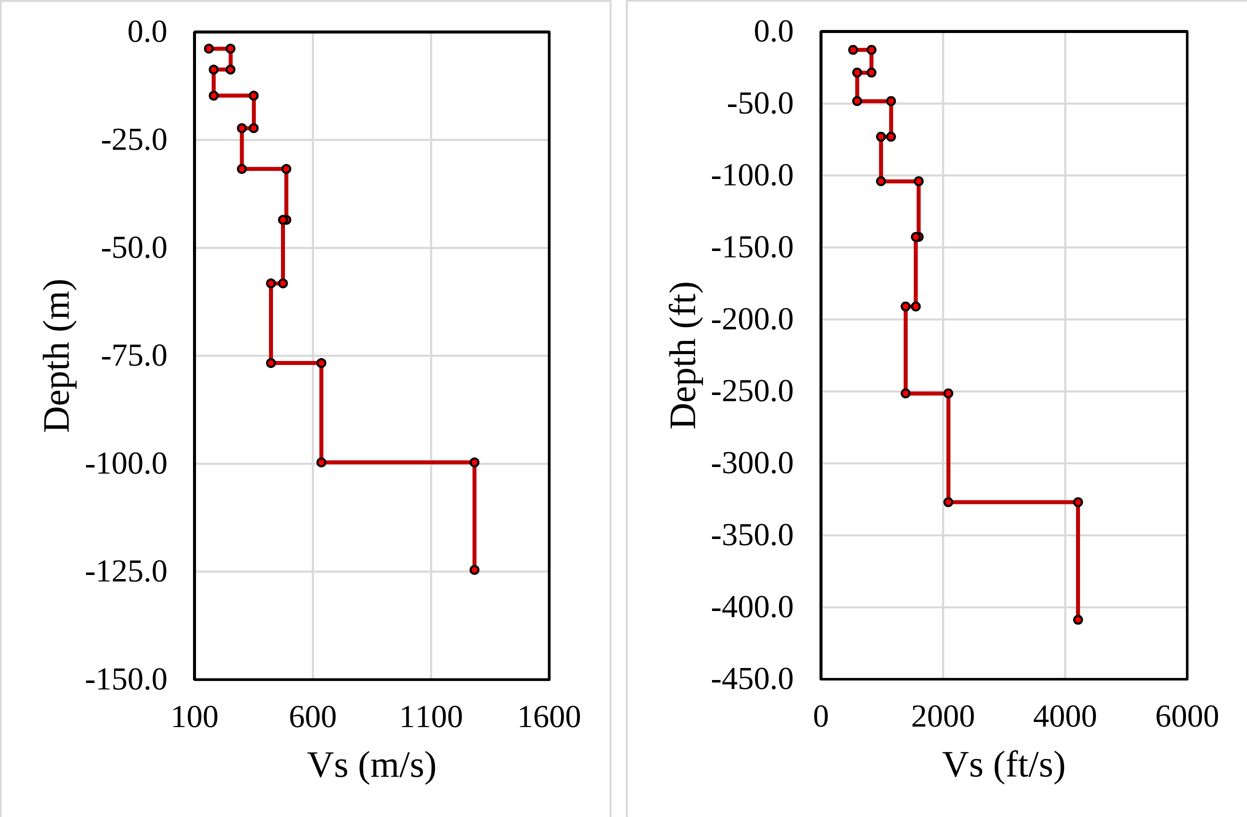

Figure 4: Graph of shallow V_s profile in meters (left) and feet (right).

The refraction results are limited because most of the shot energy went into surface (Rayleigh) waves. Above the shallow water table, the average V_p = 600 ± 100 m/s. The thickness of this shallow V_p layer is 6 ± 1 m. Below the water table, likely to the Cretaceous sediments, the average V_p = 1700 ± 100 m/s, which is near the V_p through saturated sediments.

Reflectors were noted on the near shot geophone records for both the shallow and deep surveys (Figures 5 and 6). The first reflection was clearly visible on both the shallow and deep shot records. The second reflection was only visible on the deep (450 lb weight-drop) shot record. The two-way travel time to these two reflections are 0.124 s and 0.265 s. The first reflecting layer appears to be flat laying in Figure 6.

Given the refraction V_p information above, the first reflector has an estimated depth of 95 ± 10 m. This corresponds to the top of the V_s = 1284 m/s layer at 100 m from the shallow MASW and ReMi profile. We believe this reflection is from the top of the Cretaceous sediments as it is the first strong velocity contrast in the soil profile. Assuming the Cretaceous sediments have a uniform V_p of 2,000 to 2,200 m/s based on deep boring loggings in the Mississippi embayment (Figures 7 and 8), the second reflector has an estimated depth of 235 ± 20 m. Projecting the change in V_p with depth trend for the deeper lying Cretaceous sediments to a 200 m depth in Figure 7 and using the V_p range for the Memphis Sand at 200-300 m depth in Figures 7 and 8, we arrived at the 2,000 to 2,200 m/s V_p range for the Cretaceous sediments beneath the Sikeston

Power Plant. We believe the second reflection is from the top of the Paleozoic Limestone, which from deep boring logs elsewhere has a V_p = 5,500 ± 500 m/s (Figure 7) and a V_s of 3,300 ± 200 m/s (Cramer et al., 2004).

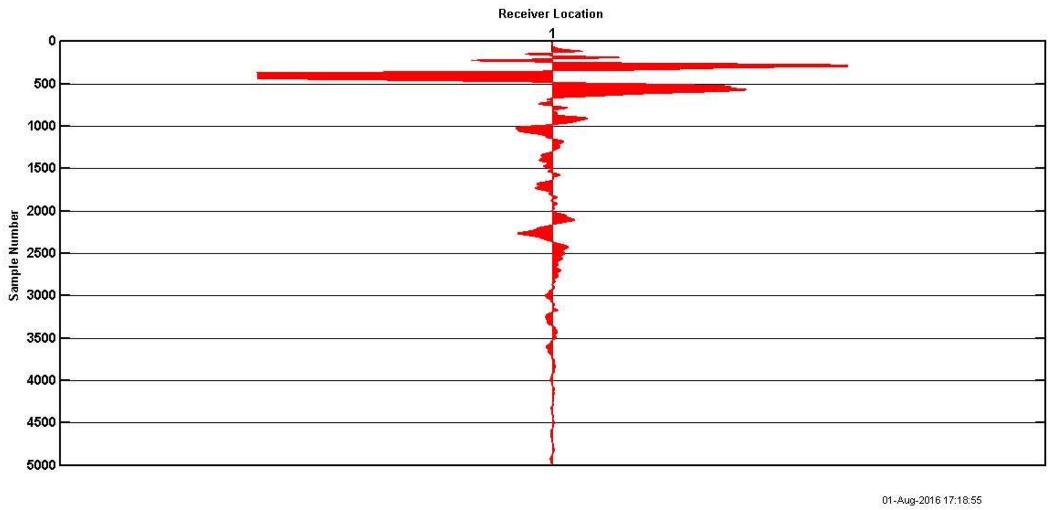

Figure 5: Single 450 lb. weight-drop shot record from the geophone nearest the shot. Two reflections are located near sample 1000 and 2200 (breaking to the left). The reflection amplitudes are greater than the shot noise on either side of them. Adjacent geophone records suggest that these reflections have normal moveout (confirming them as reflections).

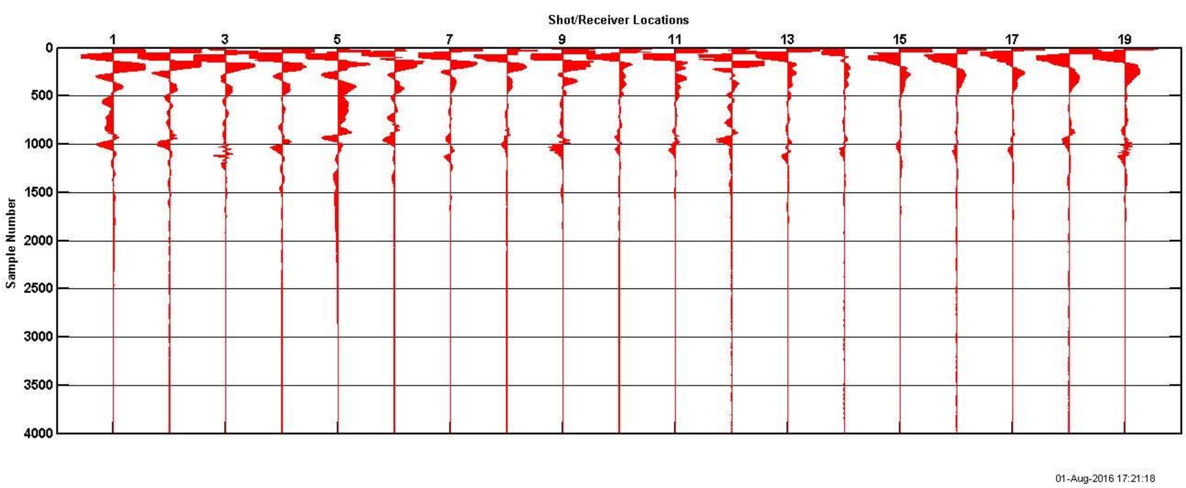

Figure 6: 19 at shot point geophone records (3 stacked records per shot point) from the MASW survey. The shot points are spaced 4 m apart along the spread. The shallow reflector in Figure 5 also appears on these records near sample 1000. There is variation in the arrival time along this profile likely from variations in the first layer (above water table) thickness and shear-wave velocity.

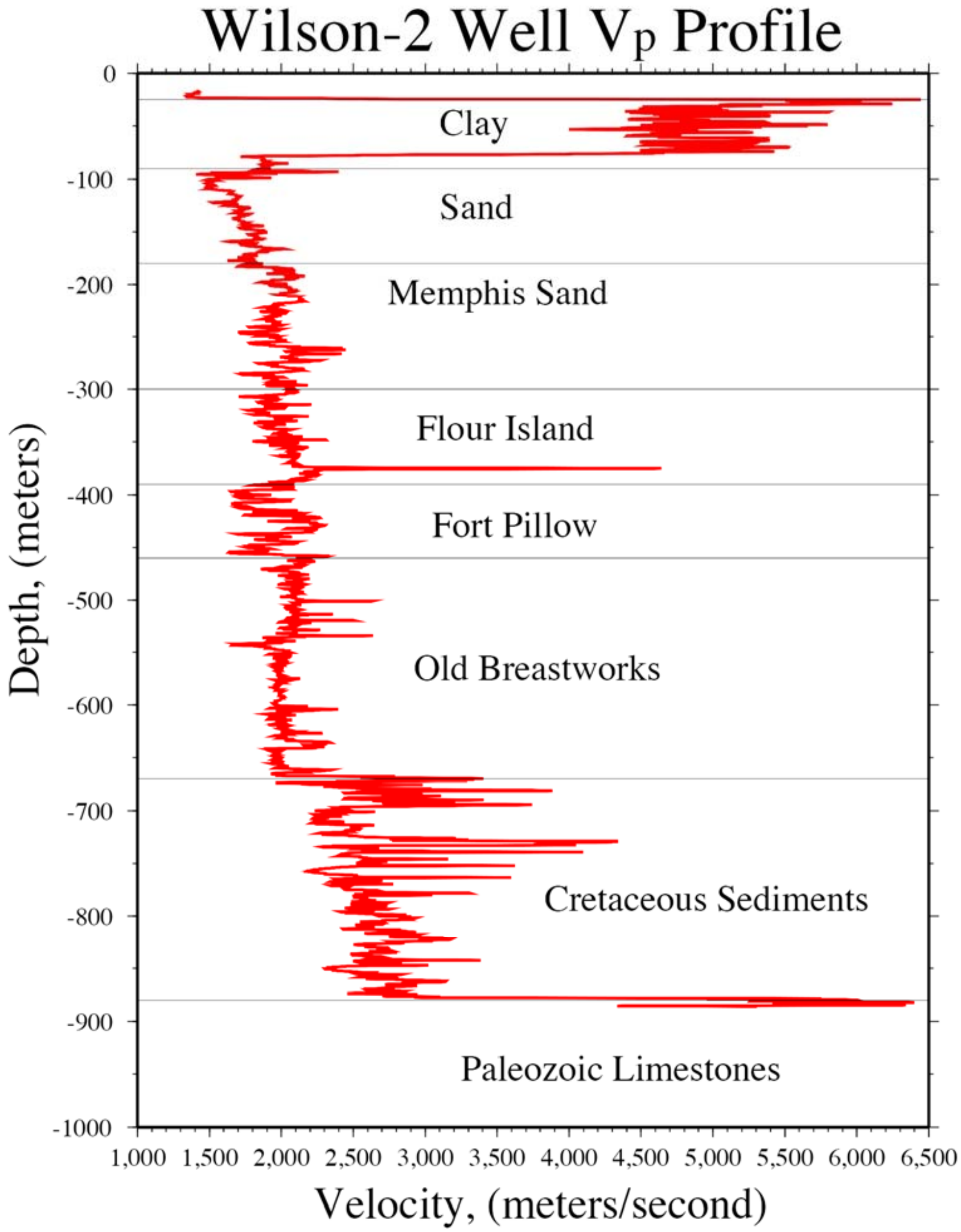

Figure 7: Wilson-2 V_P log with geology (Cramer et al., 2004, Figure 6).

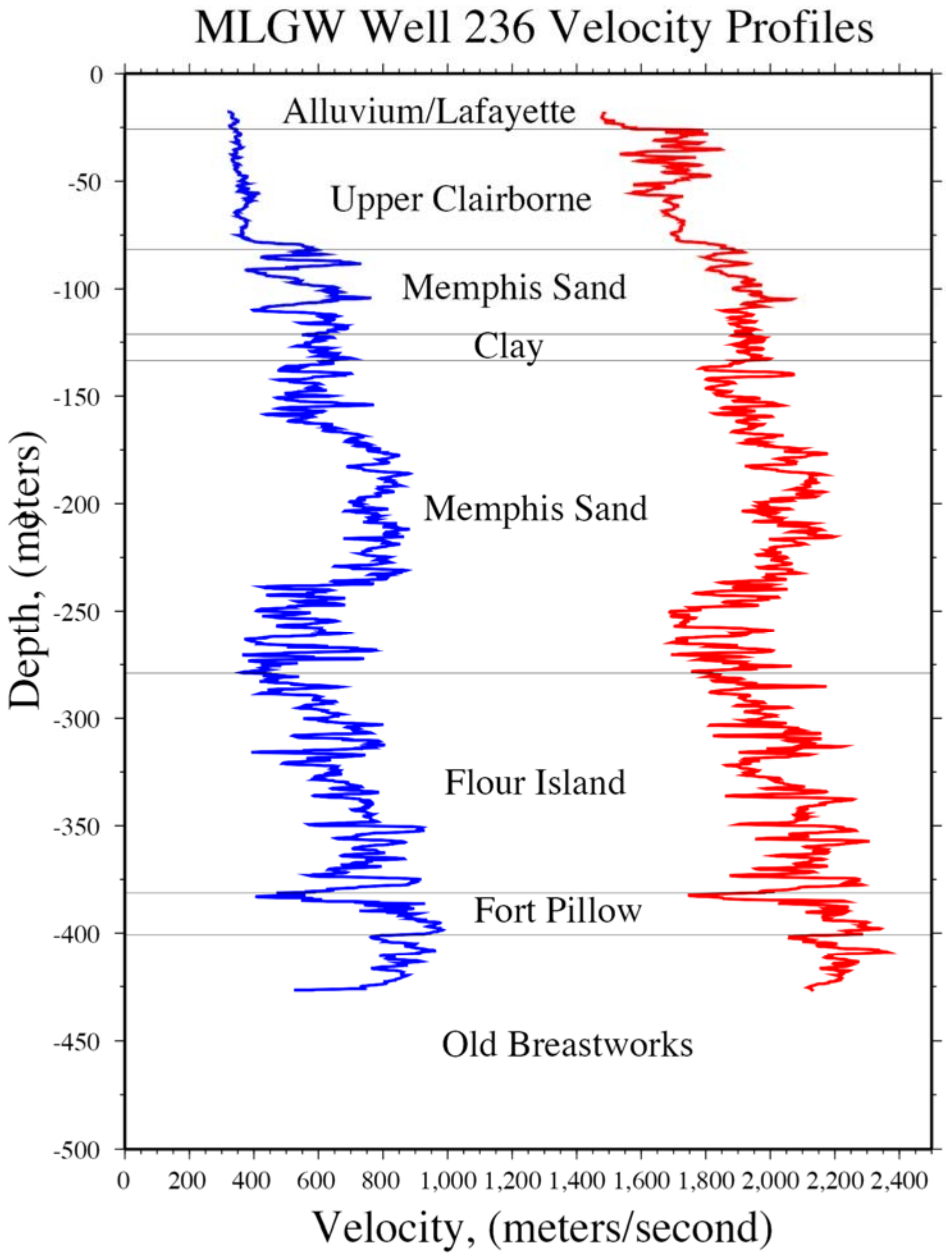

Figure 8: MLGW well 236 V_p and V_s logs with geology (Cramer et al., 2004, Figure 5).

GEOLOGY CORRELATIONS

There is borehole information about the geology in the Sikeston area. The nearest distance to boreholes providing geologic layer information vary from 1.2 to 7.4 km from the power plant. For the shallow layers (silt/clay, sand, gravel, Eocene) the nearest borehole (index SC-67) is 1.2 NE at 36.888681°N, 89.612902°W. In this borehole the Holocene silt/clay is at the surface, the top of the Quaternary sand is at 4 m, the top of the Quaternary gravel is at 19 m, and the top of the Eocene is at 60 m. These depths correlate fairly well with the V_s profile in Table 1, suggesting that at the power plant site Holocene silt/clay is at the surface, the top of the Quaternary sand is at 3.9 m, the top of the Quaternary gravel is at 22.3 m, and the top of the Eocene is at 58.2 m.

Boreholes with deeper geology are farther away from the plant and do not correlate as well in their depths-to-top with the V_s values in Table 1. The top of the Paleocene Midway Group is at 123 m depth in a borehole 3 km to the NE at 36.89N, 89.59W and the top of the Cretaceous and Paleozoic are at 135 m and 209 m in a borehole 7.4 km away to the SW at 36.8454N, 89.6925W. From Figures 7 and 8 and Cramer et al. (2004), we see that the Cretaceous layer is the first geological layer that exceeds a V_s of 1000 m/s, and the 1284 m/s at 100 m in Table 1 is similar to the mean V_s estimate of 1175 m/s for the Cretaceous in Cramer et al. (2004). Thus we judge that the top of the Cretaceous is at 100 m beneath the plant from the V_s profile in Table 1, which is much shallower than observed in the borehole 7.4 km away. This also correlates well with the first reflector seen in our seismic survey (95 ± 10 m). From this we estimate that the top of the Midway Group is at 76.7 m beneath the power plant, which is much shallower than in the borehole 3 km away. The second reflector being from the top of the Paleozoic at 235 ± 20 m corresponds fairly well with the 209m depth observed in the borehole 7.4 km away from the site.

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APPENDIX D

Analyses

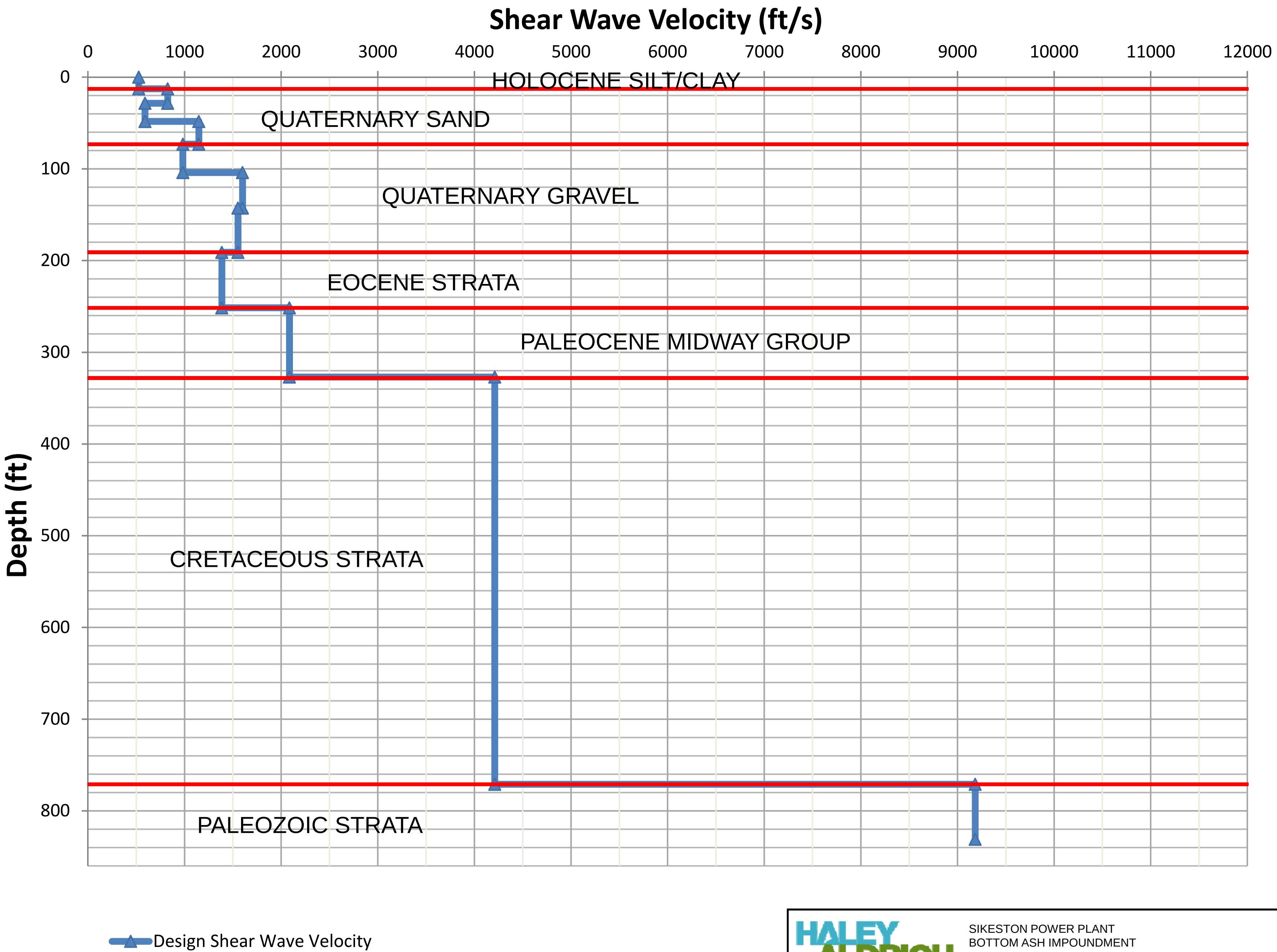
Design Soil Properties

SOIL PROPERTY CHARACTERIZATION - SIKESTON BOTTOM ASH POND

Material	Total Unit Weight, γ_T					Undrained Shear Strength, S_u									Drained Shear Strength													
	CPT	Laboratory		Historic Design[1]	Current Design	SPT		CPT		UU and CIU Trx	Historic Design[1]	Current Design			SPT		CPT		Laboratory CIU Trx						Historic Design[1]		Current Design	
	avg	Test Avg.	Tube Avg.			avg	avg - 1σ	avg	avg - 1σ	avg					avg	avg - 1σ	avg	avg - 1σ	avg		min.		max.					
	γ_T	γ_T	γ_T		γ_T	S_u	S_u	S_u	S_u	S_u		c'	φ'	S_u	φ'		φ'	φ'	c'	φ'	c'	φ'	c'	φ'	c'	φ'	c'	φ'
Clay Liner[2]	--	--	--	--	**125 pcf**	--	--	--	--	--	--	**--**	**--**	**1,000 psf**	--	--	--	--	--	--	--	--	--	--	--	--	**0 psf**	**28°**
Sluiced Bottom Ash/FGD[2]	--	--	--	--	**90 pcf**	--	--	--	--	--	--	**--**	**--**	**750 psf**	--	--	--	--	--	--	--	--	--	--	--	--	**0 psf**	**30°**
Embankment Fill	--	--	--	120 pcf	**120 pcf**	--	--	--	--	--	--	**100 psf**	**35°**	**--**	38°	36°	--	--	--	--	--	--	--	--	0 psf	35°	**50 psf**	**35°**
Foundation Sand	--	--	--	120 pcf	**120 pcf**	--	--	--	--	--	--	**0 psf**	**35°**	**--**	42°	41°	--	--	--	--	--	--	--	--	0 psf	35°	**0 psf**	**35°**

Notes:

1. Based on historic analyses performed by Geotechnology Associates.
2. Current design properties for these materials are conservatively estimated using typical published values and Haley & Aldrich's experience with similar materials.



HALEY ALDRICH

SIKESTON POWER PLANT
BOTTOM ASH IMPOUNDMENT
SIKESTON, MISSOURI

DESIGN SHEAR WAVE VELOCITY PROFILE

SCALE : AS SHOWN
SEPTEMBER 2016

FIGURE D1

128065-001_FIG D1.PPT

Seismic Response Analysis

SITE SPECIFIC SEISMIC RESPONSE ANALYSIS

Introduction

The Sikeston Power Plant is located within the New Madrid Seismic Zone (NMSZ) and the Mississippi embayment. The NMSZ is associated with strong ground motions and the Mississippi embayment is associated with thick soil. The natural embayment soils underlying the impoundments are estimated to be 770-ft thick. It has been demonstrated that the strong ground motions migrating up through the thick soil alter the spectral response at the ground surface so that it is much different than the response in the bedrock below the site. At short periods increasing soil thickness correlates with a decreasing hazard due to the nonlinear soil behavior. Similarly, at long periods, increasing soil thickness correlates with increasing hazard due to soil resonance (Cramer, 2015).

Overview of Site-Specific Seismic Analysis

A one-dimensional ground response analysis was performed to estimate the subsurface response to an earthquake event at Sikeston. Due to the complex nature of the analyses required, Dr. Professor Edward Kavazanjian, Jr. at Arizona State University and Dr. Professor Chris Cramer at the University of Memphis were retained as part of our team to assist with the site-specific seismic analyses.

It is important that the rock and soil characteristics used to develop the ground response model match the engineering and seismic characteristics of the soil and rock at the Sikeston Power Plant. Properly conditioned bedrock strong ground motions (acceleration time histories) are required to perform a site-specific seismic analysis. These rock motions should match the spectral response of characteristic ground motions with respect to the dominant seismic sources affecting Sikeston. Unfortunately, strong motion records from large magnitude events are not available for Central U.S. (Romero and Rix, 2001). Therefore, records were obtained from other sources that approximate the spectral response characteristics at the site.

A site-specific target response spectrum was created for the site to be used as a guide in selecting the proper ground motions for the study. This target spectrum was developed following well established criteria developed for building and infrastructure standards. The common design is based on the maximum critical risk-targeted (MCE_R) spectral response acceleration. Two different design methods (probabilistic and deterministic) are used to approximate the MCE_R spectrum and the lesser of the spectral response accelerations from each method at each period is used to create the site-specific target spectrum. The probabilistic target spectrum is created from the uniform hazard spectrum (UHS) by performing a probabilistic seismic hazard analysis (PSHA). [1] It is then adjusted for maximum ground motion and targeted risk. The deterministic target spectrum is calculated from 84th-percentile ground motions representing a characteristic earthquake on a known or perceived active fault within the region.

[1] The uniform hazard spectrum is calculated by research on potential sources of earthquakes (e.g., faults and locations of past earthquakes), the potential magnitudes of earthquakes from these sources and their frequencies of occurrence, and the potential ground motions generated by these earthquakes. Uncertainty and randomness in each of these components is accounted for in the computation.

The bedrock at the site is classified as NEHRP Site Class A, hard rock. The 2008 UHS, provided by USGS, for a hypothetical Site Class A rock, based on the 2,500 –year return period ground motions, was used to identify the Probabilistic Target Spectrum used for the site-specific evaluation. Ground motions scaled to this spectrum were input in Shake at the base of the soil column as outcrop motions. Shake performs the necessary deconvolution techniques on the motions to adjust to within motions used for the one dimensional analysis.

USGS Deaggregation and Deterministic Target Spectrum

Unlike the west coast, central and eastern U.S. does not have a well-defined fault system and associated seismic sources needed to properly develop a Deterministic spectral response. Therefore, it is common practice to use pseudo fault locations to develop the deterministic target. Deaggregation data obtained from a probabilistic seismic hazard analysis (PSHA) is used to provide the relevant information needed to develop the deterministic target. The NSHMP PSHA interactive deaggregation web site was used to obtain the characteristics of the most significant earthquakes deemed to contribute the most to the seismic activity at the Sikeston power plant. It should be noted that USGS has not yet released the deaggregation data for the 2014 hazard maps, therefore the 2008 deaggregation data available on the USGS website were used to determine the most significant earthquakes that are considered for the seismic hazard for Sikeston. The deaggregation data suggests that the representative design earthquake for ground motions with a return period of 2,500 years should be between magnitude 7.5 and 8.0 at a distance of approximately 18 km from the site (Figure 1). The deterministic spectrum for scenario events (i.e. for events that conformed to the CMS to be discussed later) was based upon the information on the location and magnitude obtained from the PSHA.

The deterministic target spectrum is based on ground motion prediction equations (GMPEs) that use magnitude and distance to predict the spectral response of the ground motion. According to the USGS PSHA, the largest event predicted to affect Sikeston Power Plant is a magnitude 8 earthquake that is 17.7 km from the site. The computer software program Shake 2000, developed by GeoMotions, provided the central and eastern U.S. (CEUS) GMPEs and the CMS algorithms used to create the target spectrum. Site-specific spectral responses were generated from two appropriate CEUS attenuation relationships using Shake 2000 as shown on Figure 2. These attenuation relationships were based on a magnitude 8 earthquake as a distance of 17.7 km from the source. The GMPE representing the Campbell 2003 attenuation relationship was selected to produce the deterministic target spectrum for the site because it had the largest spectral response among all GMPEs tested.

A special type of target spectrum, called the conditional mean spectrum (CMS), was created for the study because it focuses the mean spectral response of all the ground motions to a particular period along the target spectrum (Baker, 2011). According to a joint venture between NIST and NEHRP (2011):[2]

> *"The Uniform Hazard Spectrum (UHS) is constructed by enveloping the spectral amplitudes at all periods that are exceeded with a given probability, computed using probabilistic seismic hazard analysis. However, those spectral values at each period are unlikely to all occur in a single ground motion. These conditional spectra instead condition the spectrum calculation on spectral acceleration at a single period, and then compute associated spectral acceleration*

[2] Selecting and Scaling Earthquake Ground Motions for Performing Response-History Analyses; joint venture NEHRP Consultants and NIST, NIST GCR 11-917-15, 2011

values at all other periods. This conditional calculation assures that ground motions selected to match that spectrum have appropriate properties for naturally occurring ground motions that would occur at the site of interest."

The particular target period selected is related to fundamental period of the structure being analyzed. The fundamental period for the impoundment at Sikeston is related to the anticipated height of the sliding mass should failure occur and predicted to be around T* = 0.1s. However, it can be argued that at least until a slide is triggered the appropriate value to use is the resonant period of the soil layer itself as there is no impedance contrast to trigger the slide.[3] Therefore, CMS target spectrums were generated for both the short (T*=0.1s) period related to the sliding mass and long (T*=1.0 s) period related to the soil column. Separate sets of ground motions were scaled to each target spectrum and complete and separate analyses were performed. The CMS spectrum corresponding to the long period was shown to be the most conservative. The remaining portion of this report will focus on results obtained from using the long period CMS.

Conditional Mean Spectrum Groundmotions Scaled to Target Period T=1.0 s

The CMS spectrum according to Baker, 2011 is to be constructed with the ground motion scaled so that its mean spectral response at the target period, T* matches the spectral response of the uniform hazard spectrum at the same period. The target period, T*= 1.0s is chosen to approximate the fundamental frequency of the soil column. The difference between the mean response of the ground motion at the target period and the mean value of the UHS at the same period is the standard deviation. The mean values of all points on the UHS are conditioned to the standard deviation of the ground motion at T*= 1.0 s.

Shake 2000 by Geomotion, Inc. was used to provide the CMS spectrum for Campbell 2003 CEUS GMPE using a target period T* = 1.0 s . The standard deviation between the Campell GMPE and UHS spectral response at T* was estimated to be 0.66. this value was used to adjust the Campbell GMPE to provide the CMS Target used for the Shake models. Figure 3 presents the CMS target spectrum that was used for the Sikeston Power Plant.

Rock Motions for The CMS

Seven time-history records were selected to match the target response spectrum for the site. A primary focus was to match the ground motion spectra to the CMS target spectrum, as suggested by NEHRP (2011) when considering magnitude, distance, and focal mechanism. Rock motion records were selected from the Pacific Earthquake Engineering Research (PEER) Center's Strong Motion Database. The motions are summarized below in Table IV. As shown on Figure 4, the arithmetic mean spectrum of the generated records closely matches the CMS bedrock spectrum over the period range of significance.

[3] Conversation with Edward Kavazanjian

TABLE IV
EARTHQUAKE RECORDS (Long Period CMS)

Event	Return Period	PEER File Name	Earthquake Record Used			
			Earthquake	M	Mechanism	Distance (km)
Conditional Mean Response	2,500-year	RSN6_IMPVALL.I_I-ELC180.AT2	"Imperial Valley-02"	6.95	strike slip	6.09
		RSN15_KERN_TAF021.AT2	"Kern County"	7.36	Reverse	38.42
		RSN28_PARKF_C12050.AT2	"Parkfield"	6.19	strike slip	17.64
		RSN59_SFERN_CSM095.AT2	"San Fernando"	6.61	Reverse	89.37
		RSN122_FRIULI.A_A-COD000.AT2	"Friuli_ Italy-01"	6.5	Reverse	33.32
		RSN126_GAZLI_GAZ000.AT2	"Gazli_ USSR"	6.8	Reverse	3.92
		RSN143_TABAS_TAB-L1.AT2	"Tabas_ Iran"	7.35	Reverse	1.79

One-Dimensional Ground Response Analysis

As mentioned previously, a one-dimensional ground response analysis was performed to estimate the surface ground motion at the site. The soil column used as input into the model was constructed from the shear wave velocity profile at the site (from in-situ testing provided by earthquake specialists at the University of Memphis) along with other characteristics such as layer thickness, soil density and the dynamic behavior. The dynamic geotechnical properties (damping, modulus-damping curves, density, etc.) used in the ground response analysis were obtained from EPRI (1993) and are based on extensive laboratory testing and literature review. The modulus reduction and damping curves were developed for various confining pressures corresponding to depths ranging from 0 to 305 meters. These curves are shown in Figure 5.

The computer software program Shake 2000 by Geomotion was used to numerically simulate the propagation of rock motions applied to the base of the soil column up through the soil layers to the top of the soil column. Shake2000 uses an equivalent linear numerical technique to model the non-linear dynamic soil behavior in the soil column. Figure 6 shows the results of the Shake ground response analysis for the seven representative rock motions. This figure compares the spectral response of the scaled bedrock motions to the surface ground response and shows the transformation in response caused by wave propagation through the 770-ft thick soil column. Table V summarizes the surface PGA estimates at the Sikeston Power Plant.

TABLE V PREDICTED SURFACE PGA AND NEWMARK MAGNITUDE CORRECTION FACTOR				
Earthquake	Original Magnitude	CMS Scaled PGA[1]	Shake Surface PGA	Newmark Magnitude Correction Factor[2]
"Imperial Valley-02"	6.95	0.36 g	0.37 g	1.34
"Kern County"	7.36	0.55 g	0.49 g	1.19
"Parkfield"	6.19	0.70 g	0.50g	1.65
"San Fernando"	6.61	0.45 g	0.39 g	1.47
"Friuli_ Italy-01"	6.5	0.30 g	0.44 g	1.52
"Gazli_ USSR"	6.8	0.58g	0.43 g	1.40
"Tabas_ Iran"	7.35	0.73g	0.44 g	1.20

[1] CMS scaled to period range of significance at T*=1.0s
[2] Determined using the method developed by Bray and Traversarou

Newmark Displacement Analysis

The Newmark method predicts the amount of block displacement for a given value of yield acceleration. The Newmark displacement analysis is based on the shear stress time history acting along the failure plane within the slope. The yield acceleration is the minimum amount of ground acceleration necessary to initiate motion along the failure surface and is used to determine the appropriate pseudo-static coefficient for seismic stability analyses.

Shake 2000 was used to perform the Newmark displacement analysis by incorporating the results of the one-dimensional ground response analysis to estimate slope displacement. Shake 2000 incorporates several different variants of the Newmark block displacement method and the numerical approach known as YSLIP developed by Kavazanjian and Matasovic (1996) was chosen for our analysis. All seven site-specific bedrock motions were used to evaluate relationships between the Newmark permanent displacements and the associated yield acceleration. Several impoundment cross-sections were evaluated and the most conservative location of the failure plane was determined to be 10 to 12 ft below the top of slope.

After performing the Newmark displacement analysis, it was necessary to adjust the displacement predictions to correspond to the difference between the magnitudes of the ground motions used in the analysis and the magnitude of the representative earthquake event established for the New Madrid Power Plant. Correction factors were applied to scale the displacements to the target magnitude 8 event (Figure 7). The correction factors were determined using the approach developed by Bray and Travasarou (2007), which relates permanent displacement from a Newmark analysis with the magnitude of the earthquake event (Bray, 2007). Figure 8 presents the magnitude scaled permanent displacement versus yield acceleration. When seven or more ground motions are used in the analysis, it is common practice to use the average of the scaled relationships.[4]

[4] ASCE/SEI 7-10; "Minimum Design Loads for Buildings and Other Structures"

FIGURES

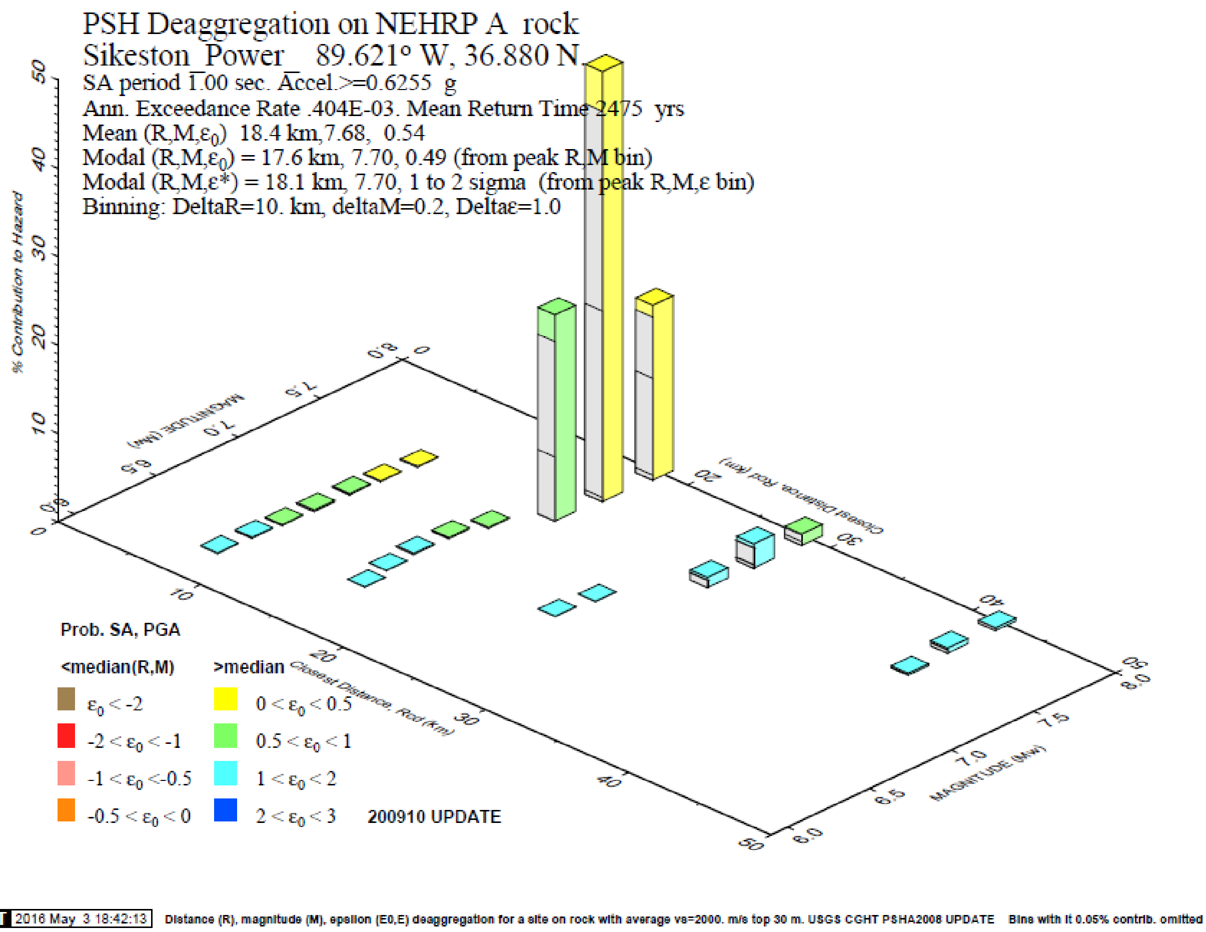


Figure 1: Deaggregation Plot for Sikeston at T = 1.0 s

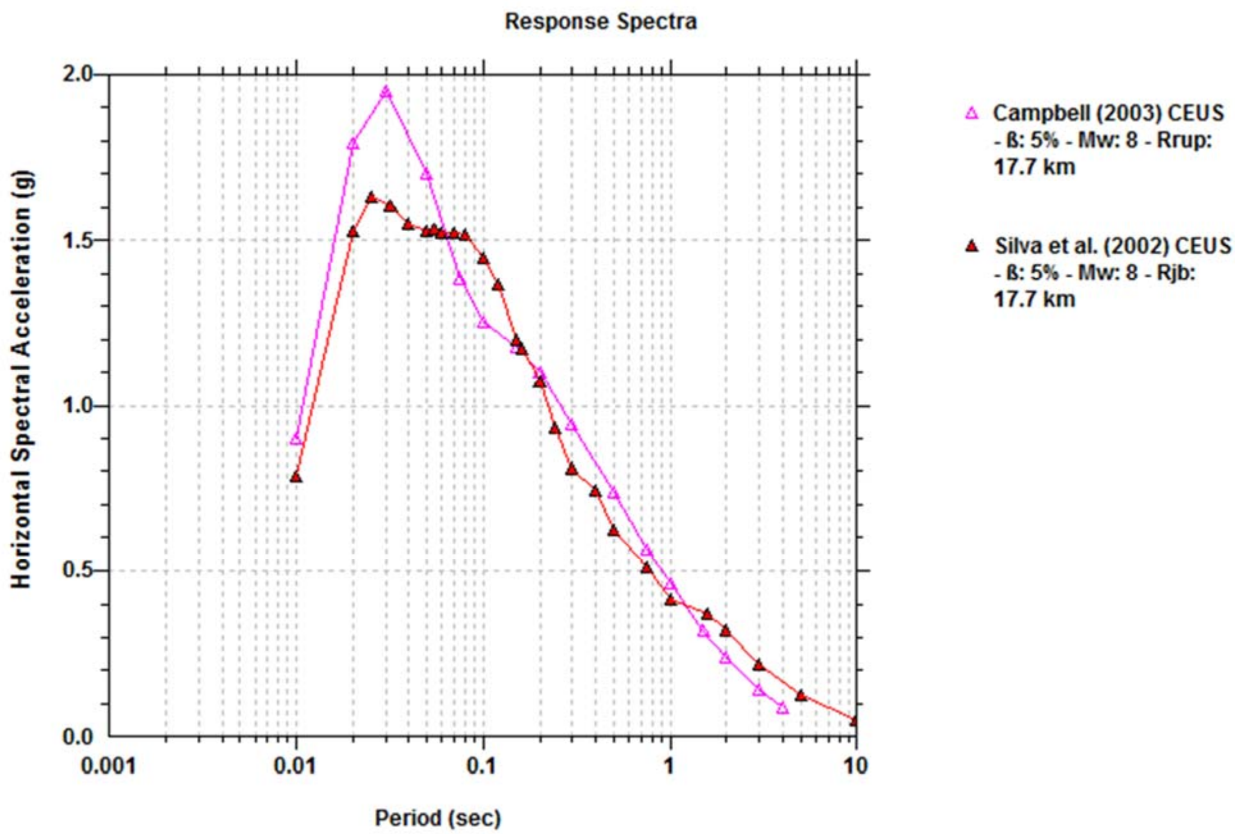


Figure 2: GMPE's -Attenuation models for Sikeston

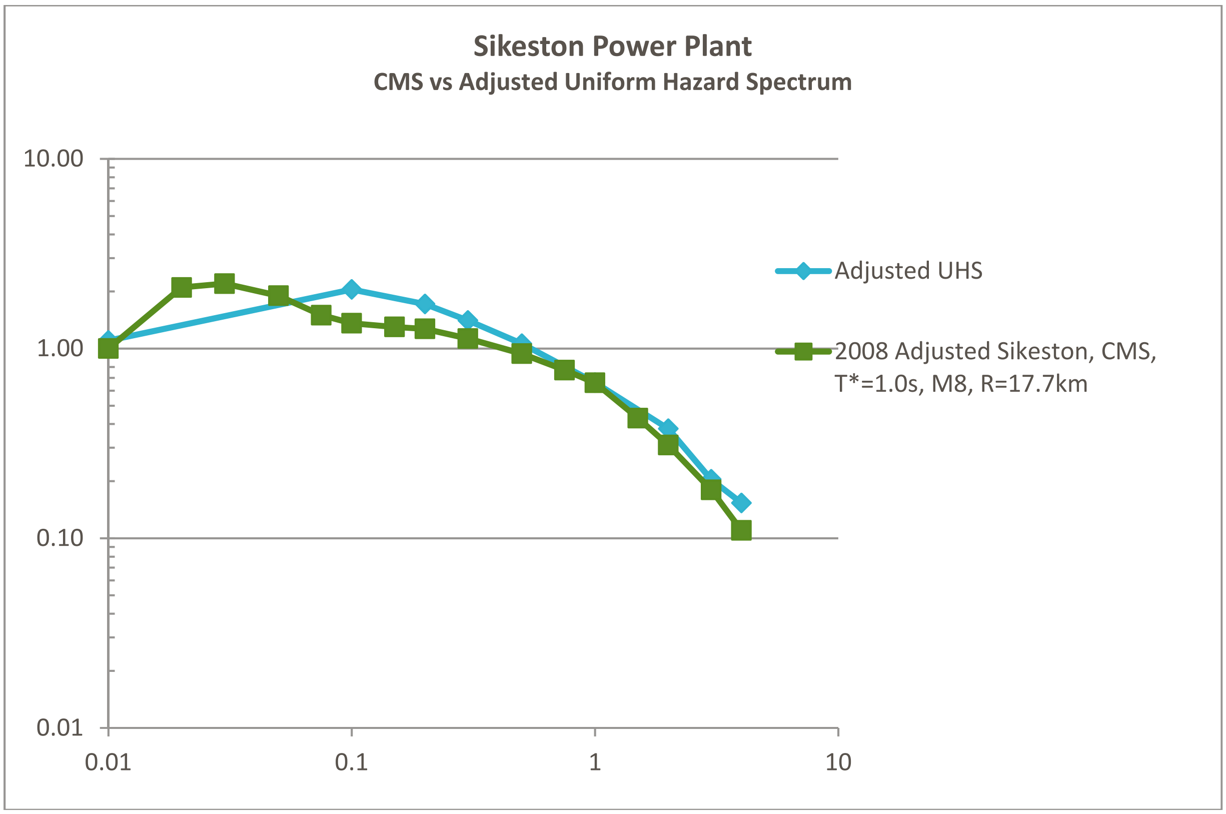


Figure 3: 2008 Uniform Hazard Spectrum and Conditional Mean Spectrum for Sikeston Power Plant

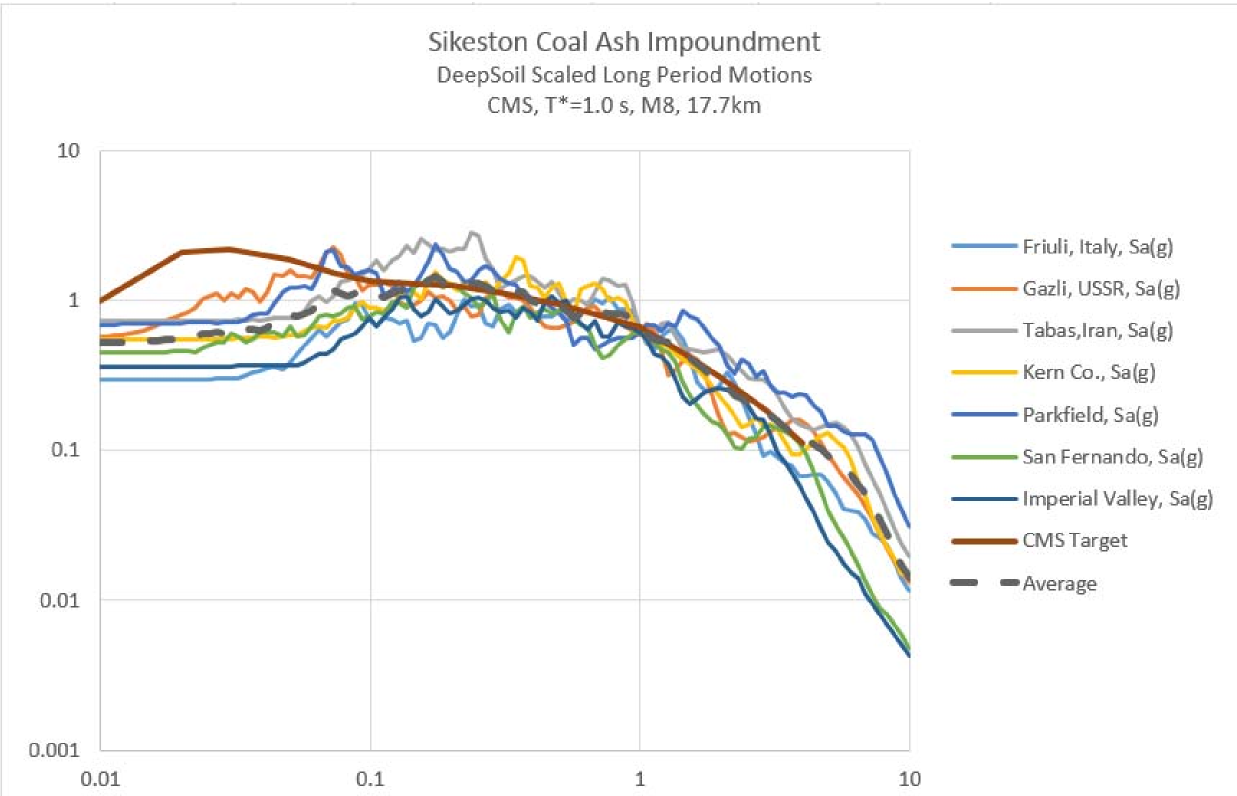


Figure 4: Ground motions scaled to CMS at target T*=1.0s

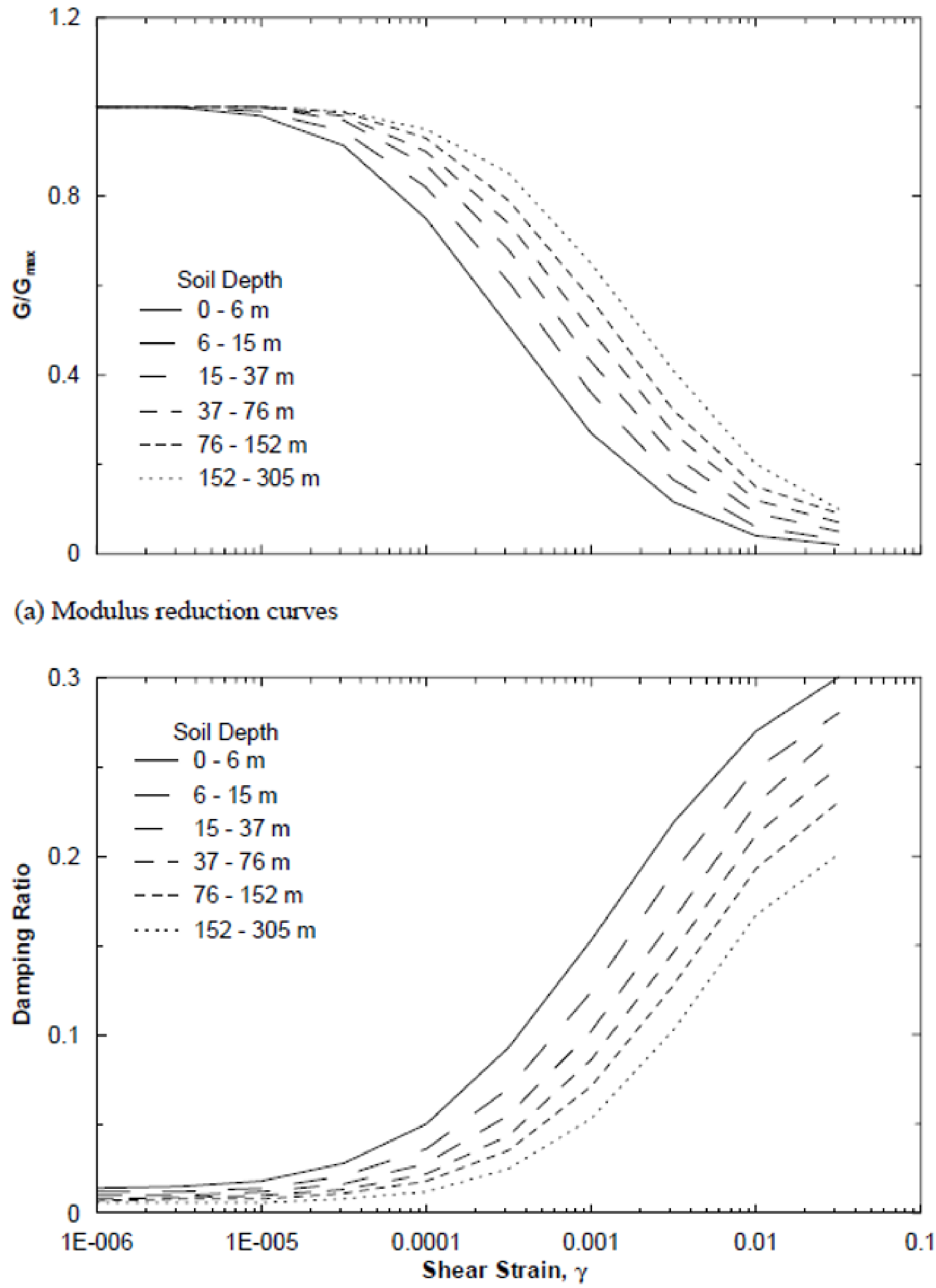


Figure 5: EPRI (1993) (a) modulus reduction and (b) damping curves

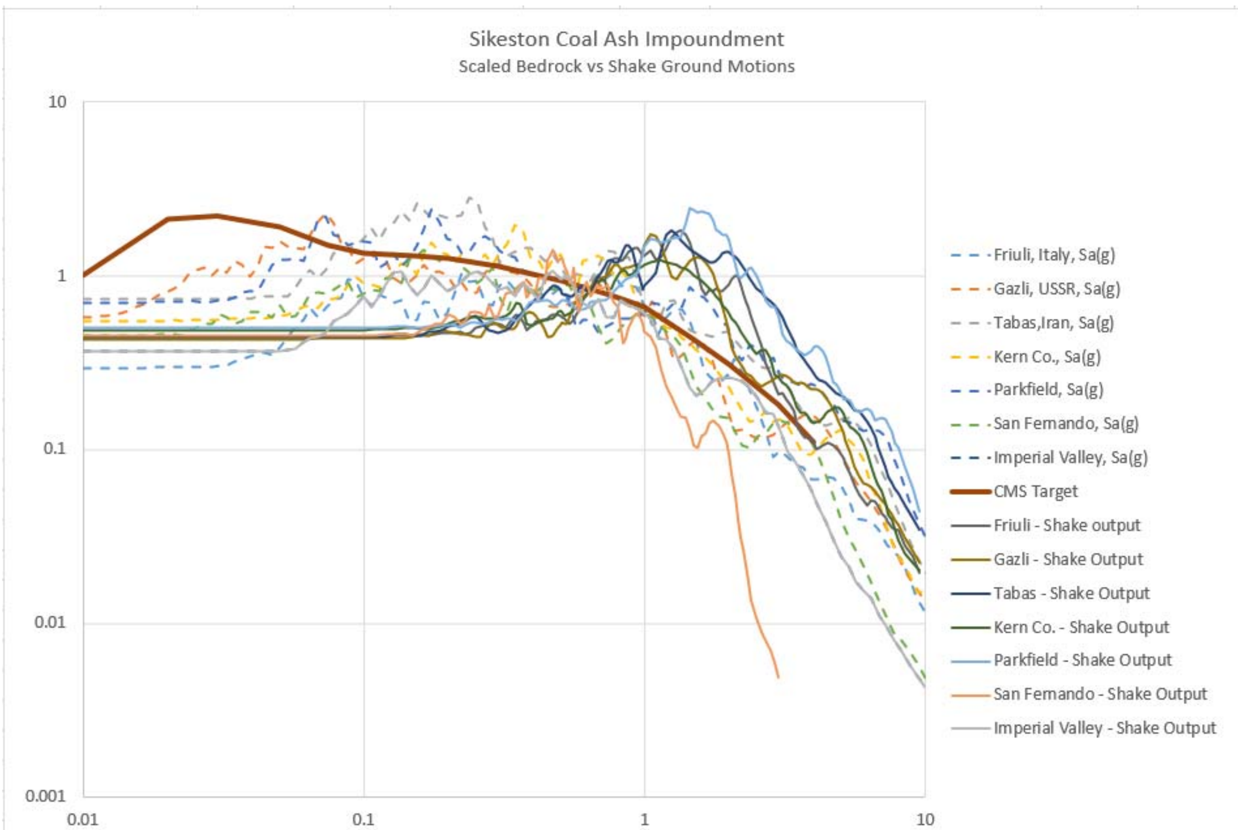


Figure 6: Comparison between input motions to Shake and output. Note that spectral response has shifted to longer periods

HALEY ALDRICH

Created by: JMK DATE: 8/16/2016
Checked by DATE:

Seismic displacement of impoundment based on Newmark method using Bray and Travasarous relationship to compensate for magnitude differences between ground motion and target earthquake

Non-zero displacment (not biased due to magnitude): Bray and Travarsarou(2007)

Fundamental period ($T_s \geq 0.05s$): $\ln(D) = -1.10 - 2.83\ln(k_y) - 0.333(\ln(k_y))^2 - 0.566\ln(k_y)\ln(S_a(1.5T_s)) + 3.04\ln(S_a(1.5T_s)) - 0.244(\ln(S_a(1.5T_s)))^2 + 1.5T_s + 0.278(M-7) \pm \varepsilon$

Assumed Rigid Sliding Block ($T_s < 0.05s$): $\ln(D) = -0.22 - 2.83\ln(k_y) - 0.333(\ln(k_y))^2 - 0.566\ln(k_y)\ln(PGA) + 3.04\ln(PGA) - 0.244(\ln(PGA))^2 + 0.278(M-7) \pm \varepsilon$

where :
- D = non-zero displacement (cm)
- k_y = yield coefficient
- T_s = initial fundamental period of sliding mass (s)
- $S_a(1.5T_s)$ = spectral acceleration of the input ground motion at a period of $1.5T_s$ (g)
- ε = normally distributed random varible with zero mean and standard deviation σ=0.67

Fundamental Period Sliding Mass = $4H/V_s$
where:
- H = height of sliding mass
- V_s = average shear wave velocity of sliding mass

Bray and Traversarou
Magnitude Correction Factor for M8 target

$$\frac{e^{0.278(8-7)}}{e^{0.278(M-7)}} = \frac{1.32}{e^{0.278(M-7)}}$$

Seismic displacement of a slope based on Newmark method using Bray and Travasarous relationship to compensate for magnitude

10 ft Sliding Mass Height

Subgrade using Preliminary Vs Profile from U of Memphis (Cramer, 8/16/2016) Long Period Motions (scaled to soil column resonance)

Sikeston Target Magnitude 8

Ground Motion	Magnitude	Distance (km)	Depth Sliding Mass (ft)	Shear wave Velocity (ft/s)	Yield Coefficient, k_y (g)	Bray and Travasarou Magnitude Correction Factor	Newmark Analysis Displacement (Inches)** Min (in)	Avg (in)	Maximum (in)	Adjusted Newmark Displacement (Inches) Min (in)	Avg (in)	Maximum (in)
Tabas, Spain	7.35	1.79	10	600	0.1	1.20	82.10	87.70	93.30	98.36	105.07	111.78
					0.15	1.20	37.00	42.20	47.50	44.33	50.56	56.91
					0.2	1.20	20.80	23.40	25.90	24.92	28.03	31.03
					0.23	1.20	14.90	16.50	18.10	17.85	19.77	21.68
					0.25	1.20	12.00	13.00	14.00	14.38	15.57	16.77
					0.28	1.20	8.50	8.70	8.90	10.18	10.42	10.66
					0.3	1.20	6.40	6.50	6.50	7.67	7.79	7.79
					0.35	1.20	1.90	2.30	2.80	2.28	2.76	3.35
					0.4	1.20	0.40	0.60	0.80	0.48	0.72	0.96
					0.5	1.20	0.00	0.00	0.00	0.00	0.00	0.00
Imperial Valley	6.95	6.09	10	600	0.07	1.34	63.30	63.60	63.80	84.76	85.16	85.43
					0.1	1.34	37.20	37.50	37.90	49.81	50.21	50.75
					0.13	1.34	21.40	23.10	25.00	28.65	30.93	33.47
					0.15	1.34	13.60	16.30	19.10	18.21	21.83	25.57
					0.18	1.34	7.70	10.00	12.20	10.31	13.39	16.34
					0.2	1.34	5.30	7.00	8.80	7.10	9.37	11.78
					0.25	1.34	2.00	2.60	3.20	2.68	3.48	4.28
					0.3	1.34	0.50	0.60	0.72	0.67	0.80	0.96
					0.4	1.34	0.00	0.00	0.00	0.00	0.00	0.00
San Fernando	6.61	89.37	10	600	0.05	1.47	66.80	67.40	68.00		99.19	
					0.1	1.47	26.30	26.80	27.40	38.71	39.44	40.32
					0.13	1.47	14.90	15.20	15.60	21.93	22.37	22.96
					0.15	1.47	9.90	10.40	11.00	14.57	15.31	16.19
					0.18	1.47	6.00	6.70	7.20	8.83	9.86	10.60
					0.2	1.47	4.40	4.90	5.40	6.48	7.21	7.95
					0.23	1.47	2.90	3.10	3.30	4.27	4.56	4.86
					0.25	1.47	2.10	2.20	2.30	3.09	3.24	3.38
					0.3	1.47	0.80	0.80	0.80	1.18	1.18	1.18
					0.4	1.47	0.00	0.00	0.00	0.00	0.00	0.00
Parkfield	6.19	17.64	10	600	0.1	1.65	136.80	139.80	142.80			
					0.15	1.65	76.50	80.20	83.80	126.53	132.65	138.60
					0.18	1.65	54.20	57.70	61.20	89.65	95.43	101.22
					0.2	1.65	43.10	46.40	49.80	71.29	76.74	82.37
					0.23	1.65	29.30	32.70	36.10	48.46	54.08	59.71
					0.25	1.65	21.90	25.40	28.80	36.22	42.01	47.63
					0.28	1.65	13.30	16.80	20.20	22.00	27.79	33.41
					0.3	1.65	9.10	12.30	15.30	15.05	20.34	25.31
					0.33	1.65	4.70	7.30	10.00	7.77	12.07	16.54
					0.35	1.65	2.80	5.00	7.10	4.63	8.27	11.74
					0.4	1.65	0.50	1.40	2.30	0.83	2.32	3.80
					0.5	1.65	0	0	0	0.00	0.00	0.00
Kern County	7.36	38.42	10	600	0.08	1.19	47.90	50.80	53.40	57.23	60.69	63.80
					0.1	1.19	30.20	34.30	38.30	36.08	40.98	45.76
					0.13	1.19	16.10	20.30	24.50	19.24	24.25	29.27
					0.15	1.19	10.50	14.70	18.90	12.54	17.56	22.58
					0.18	1.19	4.90	9.10	13.40	5.85	10.87	16.01
					0.2	1.19	2.70	7.00	11.20	3.23	8.36	13.38
					0.25	1.19	0.40	3.80	7.20	0.48	4.54	8.60
					0.3	1.19	0.00	2.10	4.20	0.00	2.51	5.02
					0.4	1.19	0.00	0.40	0.80	0.00	0.48	0.96
					0.5	1.19	0.00	0.00	0.00	0.00	0.00	0.00
Gazli, USSR	6.8	3.92	10	600	0.08	1.40	42.60	47.20	51.90	59.47	65.89	72.45
					0.1	1.40	34.30	35.80	37.20	47.88	49.98	51.93
					0.13	1.40	21.40	23.10	24.80	29.87	32.25	34.62
					0.15	1.40	14.40	17.20	19.90	20.10	24.01	27.78
					0.18	1.40	7.50	10.90	19.30	10.47	15.22	26.94
					0.2	1.40	4.70	8.00	11.40	6.56	11.17	15.91
					0.23	1.40	2.50	5.20	7.90	3.49	7.26	11.03
					0.25	1.40	1.50	3.80	6.10	2.09	5.30	8.52
					0.3	1.40	0.30	1.60	2.80	0.42	2.23	3.91
					0.4	1.40	0.00	0.00	0.20	0.00	0.00	0.28
Friuli, Italy	6.5	33.3	10	600	0.1	1.52	56.80	62.50	68.30	86.19	94.84	103.64
					0.15	1.52	26.00	28.00	30.00	39.45	42.49	45.52
					0.18	1.52	17.10	17.20	17.30	25.95	26.10	26.25
					0.2	1.52	11.00	12.30	13.60	16.69	18.66	20.64
					0.28	1.52	0.60	2.80	5.00	0.91	4.25	7.59
					0.3	1.52	0.00	1.90	3.70	0.00	2.88	5.61
					0.35	1.52	0.00	0.70	1.40	0.00	1.06	2.12
					0.4	1.52	0.00	0.10	0.30	0.00	0.15	0.46
					0.5	1.52	0.00	0.00	0.00	0.00	0.00	0.00
AVERAGE					0.1						63.42	
					0.15						43.49	
					0.2						22.79	
					0.25						11.20	
					0.3						5.39	
					0.4						0.52	
Geometric Mean					0.1						58.58	
					0.15						32.72	
					0.2						15.87	
					0.25						6.91	
					0.3						3.04	
					0.4						0.00	

Figure 7: Results of Newmark analysis with Bray and Traversarou Corrections

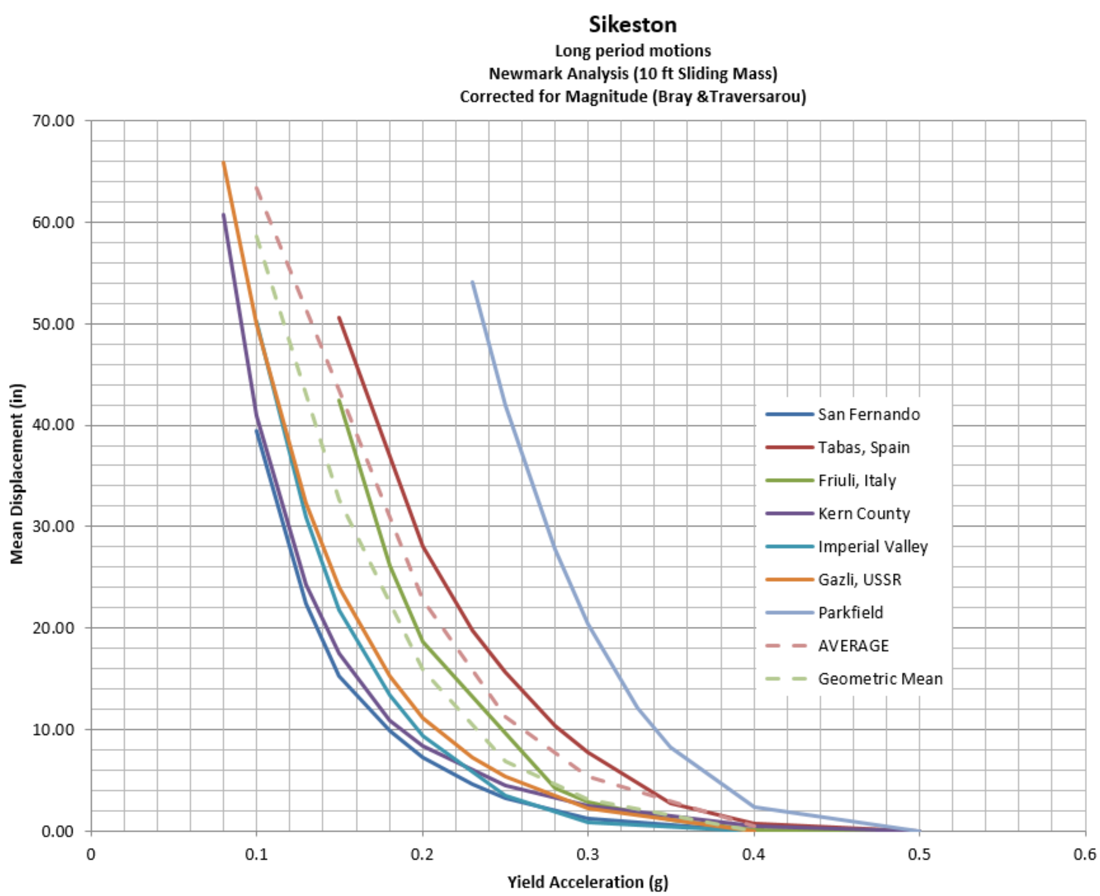
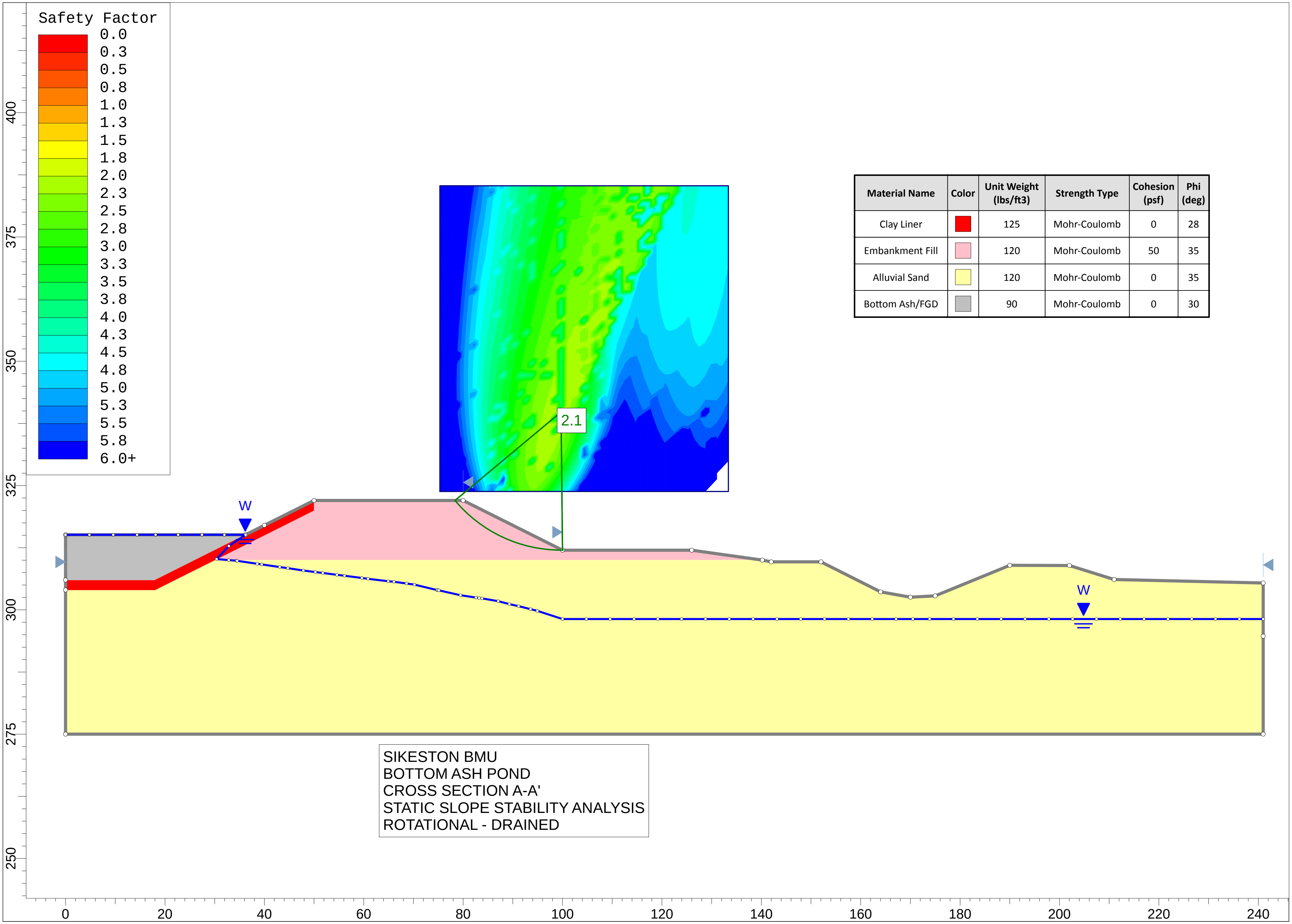


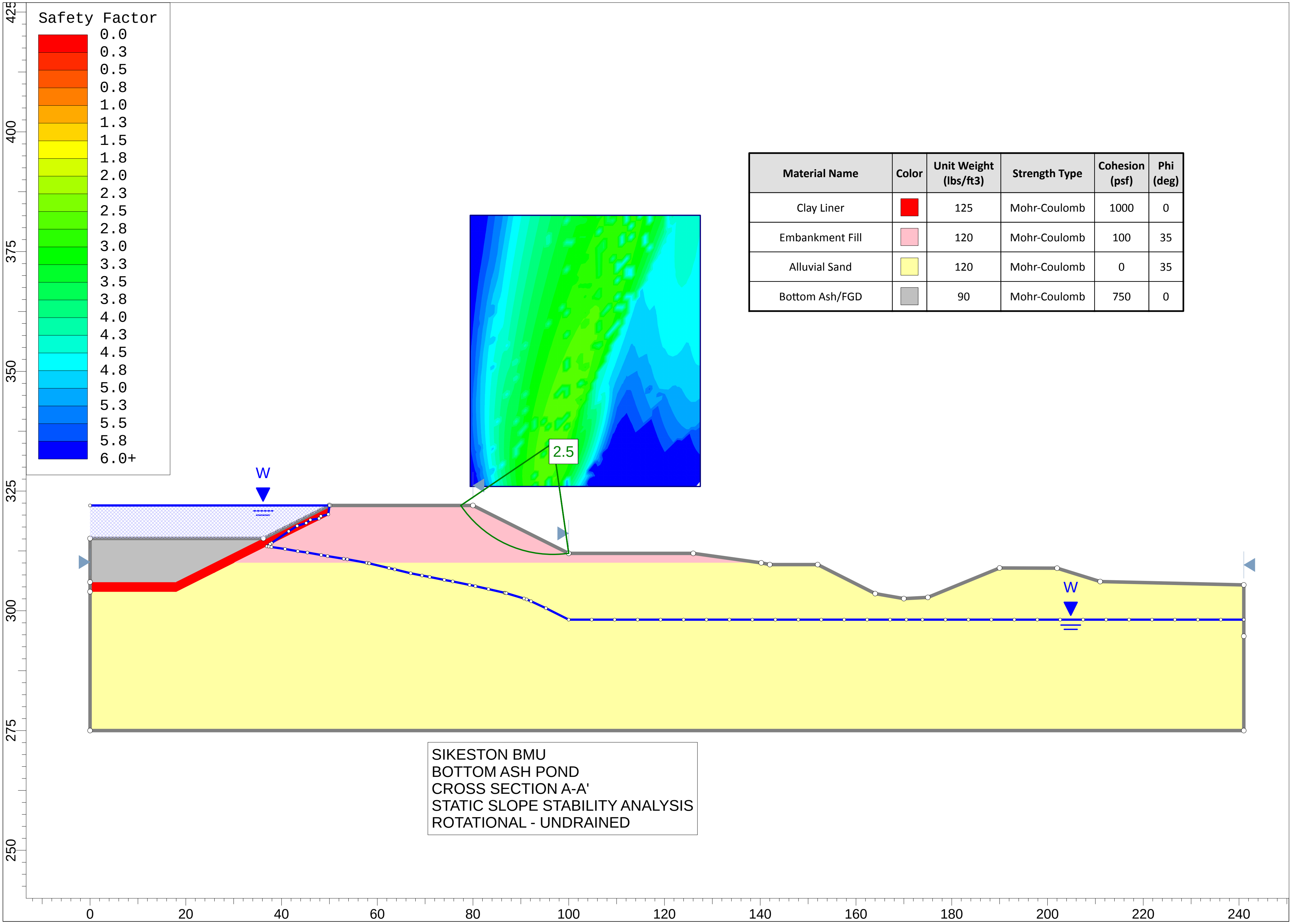
Figure 8: Newmark Block Displacement Analysis for Sikeston

Slope Stability



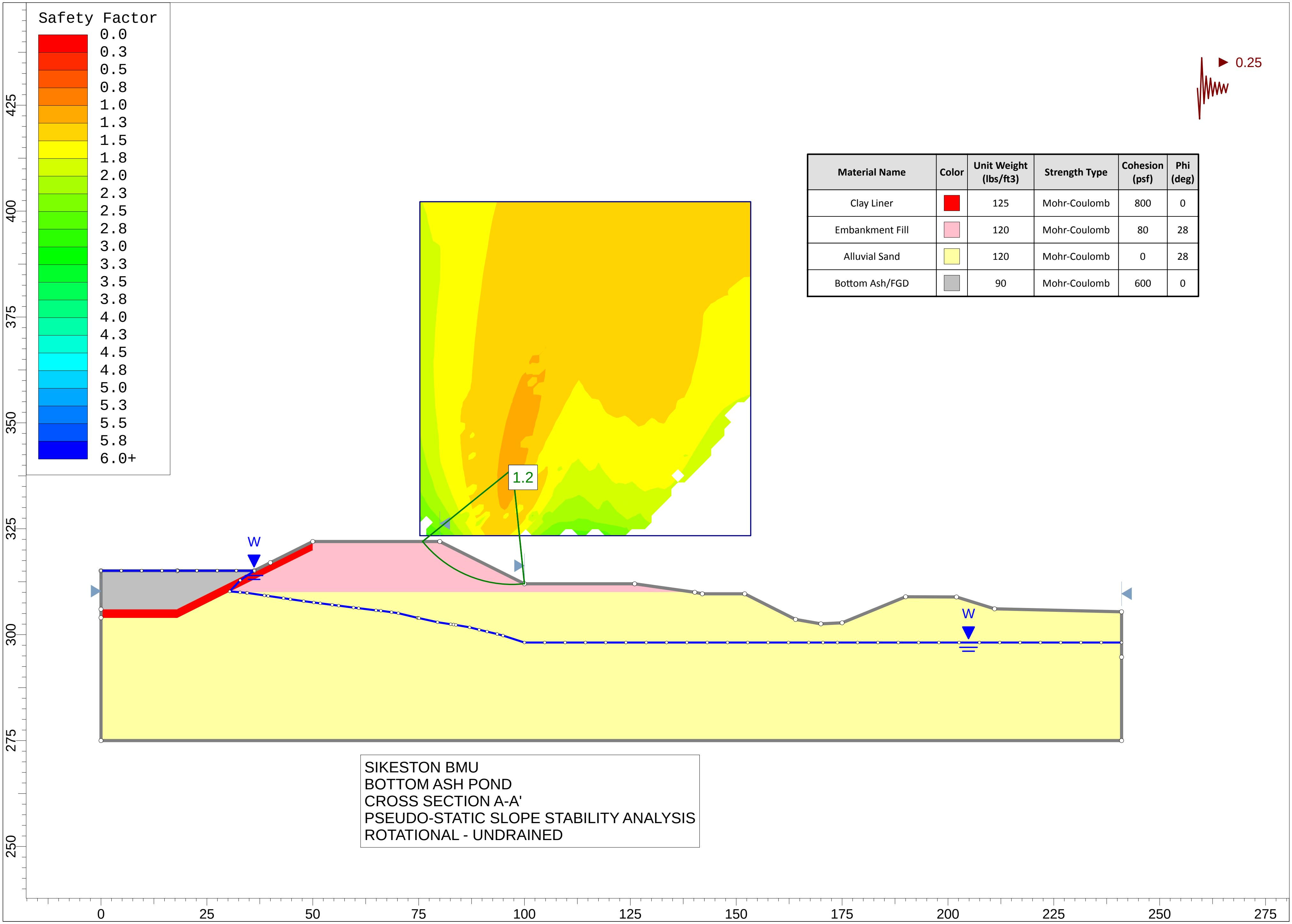
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Clay Liner		125	Mohr-Coulomb	0	28
Embankment Fill		120	Mohr-Coulomb	50	35
Alluvial Sand		120	Mohr-Coulomb	0	35
Bottom Ash/FGD		90	Mohr-Coulomb	0	30

SIKESTON BMU
BOTTOM ASH POND
CROSS SECTION A-A'
STATIC SLOPE STABILITY ANALYSIS
ROTATIONAL - DRAINED



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Clay Liner		125	Mohr-Coulomb	1000	0
Embankment Fill		120	Mohr-Coulomb	100	35
Alluvial Sand		120	Mohr-Coulomb	0	35
Bottom Ash/FGD		90	Mohr-Coulomb	750	0

SIKESTON BMU
BOTTOM ASH POND
CROSS SECTION A-A'
STATIC SLOPE STABILITY ANALYSIS
ROTATIONAL - UNDRAINED



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Clay Liner		125	Mohr-Coulomb	800	0
Embankment Fill		120	Mohr-Coulomb	80	28
Alluvial Sand		120	Mohr-Coulomb	0	28
Bottom Ash/FGD		90	Mohr-Coulomb	600	0