REPORT

SAFETY FACTOR ASSESSMENT FOR STABILITY OF THE BOTTOM ASH STAGING AREA

Westar Energy – Tecumseh Energy Center

Submitted To: Westar Energy
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August 23, 2016 **1657212**

Golder Associates

EXECUTIVE SUMMARY

Golder Associates Inc. (Golder) has prepared this report for Westar Energy (Westar) to summarize the results of Golder's slope stability evaluation of the bottom ash staging area at Westar's Tecumseh Energy Center (TEC) near Tecumseh, Kansas. This report serves as the initial safety factor assessment required under 40 CFR 257.73(e)(1) for surface impoundments used in the management of coal combustion residuals (CCRs). The report presents a description of the bottom ash staging area at TEC, a summary of Golder's subsurface investigation around the bottom ash staging area, a narrative describing the basis and results of Golder's slope stability evaluation, closing remarks, and a list of cited references.

The computed minimum factors of safety resulting from Golder's slope stability evaluation are summarized and compared with the minimum required factors of safety in Table ES-1.

Table ES-1: Summary of Slope Stability Evaluation Results

Loading Condition	Computed Minimum Factor of Safety	Minimum Required Factor of Safety
Static, long-term maximum storage pool	1.51	1.50
Static, maximum surcharge pool	1.51	1.40
Seismic	1.38	1.00

In each case, the computed minimum factor of safety resulting from Golder's slope stability evaluation meets or exceeds the minimum required factor of safety specified in 40 CFR 257.73(e)(1) for surface impoundments used in the management of CCRs.

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1.0 INTRODUCTION

1.1 Background

Golder Associates Inc. (Golder) has prepared this report for Westar Energy (Westar) to summarize the results of Golder's slope stability evaluation of the bottom ash staging area at Westar's Tecumseh Energy Center (TEC) near Tecumseh, Kansas. This report serves as the initial safety factor assessment required under 40 CFR 257.73(e)(1) for surface impoundments used in the management of coal combustion residuals (CCRs). The report presents a description of the bottom ash staging area at TEC (Section 1), a summary of Golder's subsurface investigation around the bottom ash staging area (Section 2), a narrative describing the basis and results of Golder's slope stability evaluation (Section 3), closing remarks (Section 4), and a list of cited references (Section 5).

1.2 Bottom Ash Staging Area Description

Tecumseh Energy Center is a coal-fired electric generating facility located in Shawnee County, Kansas. Bottom ash generated at TEC is temporarily staged (with small quantities of other permitted non-hazardous materials) in a surface impoundment located west of the power block to facilitate dewatering. The bottom ash staging area is shown in Figure 1. After bottom ash is dewatered, it is transported to an on-site landfill for permanent storage or used beneficially off site. The bottom ash staging area was primarily constructed by excavation from existing grades, although some fill was used to establish the crest of the berm surrounding the surface impoundment. The bottom ash staging area underwent modification in 1980, when the center dike was lengthened and raised, the outlet area was modified, and the northeast portion of the surface impoundment was deepened to allow for greater storage capacity. The berm to the north of the bottom ash staging area was reshaped and revegetated in 2010 to flatten the downstream slope and protect against erosion of the downstream berm slope and toe. The reshaped downstream berm slope was specifically designed to yield a minimum static factor of safety equal to 1.5. Appendix A presents the relevant design information for the reshaping work[1].

Mixed-use land surrounds the west and south sides of the bottom ash staging area, and energy generation facility infrastructure and the Kansas River are situated to the east and north. Tecumseh Creek lies at the toe of the berm on the west and north sides of the surface impoundment and discharges into the Kansas River approximately 700 feet downstream of the bottom ash staging area.

[1] Reshaping from Sta. 0+50 to Sta. 3+00 is relevant for slope stability of the bottom ash staging area.

2.0 SUBSURFACE INVESTIGATION

Three boreholes, TEC-3, TEC-4, and TEC-5, were completed on October 27, 2009, at the locations shown in Figure 1 to support a slope stability evaluation of the bottom ash staging area. The borehole locations were designated by Golder and Westar in areas where site topography indicated a downstream berm slope height of 12 feet or more, generally around the south, west, and north sides of the bottom ash staging area. The boreholes were drilled between the center and the downstream edge of the berm crest and were advanced with a truck-mounted Central Mine Equipment Company (CME) drill rig using 6-inch-diameter hollow-stem continuous-flight augers. Relatively undisturbed soil samples were collected from each borehole using 2-inch-diameter thin-walled tube samplers (Shelby tubes). Soil strata were visually classified by a geotechnical engineer from Golder in accordance with the Unified Soil Classification System (USCS). Berm stratigraphy was fairly consistent between the boreholes and generally consisted of gravel road surfacing underlain primarily by low-plasticity clay (CL), with some high-plasticity clay (CH)[2], to the completed borehole depths. The berm crest around the bottom ash staging area is at an approximate elevation of 885 feet above mean sea level, and the borehole depths ranged from 15 to 25 feet. Groundwater was not observed in any of the three boreholes. Borehole logs with field and laboratory soil classifications are provided in Appendix B.

Two additional boreholes, P-1 and P-2, were completed on March 23, 2010, at the locations shown in Figure 1. Piezometers were installed in these boreholes to better define piezometric levels in the steepest portions of the berm on the north side of the bottom ash staging area. The boreholes were drilled 16 to 22 feet from the upstream edge of the berm crest and were advanced with a truck-mounted CME drill rig using 6-inch-diameter hollow-stem continuous-flight augers. A relatively undisturbed soil sample was collected from P-2 using a 2-inch-diameter thin-walled tube sampler (Shelby tube). Soil strata were visually classified by a geotechnical engineer from Golder in accordance with the USCS. Berm stratigraphy was fairly consistent between the boreholes and generally consisted of gravel road surfacing underlain by CL to the completed borehole depths. The borehole depth was approximately 40 feet for both P-1 and P-2. Borehole logs with field soil classifications are provided in Appendix B.

The piezometers consisted of polyvinyl chloride (PVC) pipe, with the lowest 10 feet slotted to allow measurement of piezometric levels. The annular space around the slotted PVC pipe was backfilled with granular material to create a filter pack. A bentonite seal approximately 10 feet in height was placed in the annular space above the filter pack. The remaining annular space was filled with cuttings, and a concrete pad was installed at the ground surface. A lockable well cap was installed on each piezometer. The piezometers were registered with the Kansas Department of Health and Environment. Groundwater elevations in the piezometers were recorded on August 30, 2010, approximately five months after

[2] A single soil sample classified as CH by laboratory geotechnical testing. The test results were on the borderline between CL and CH (liquid limit equal to 50), and the specimen was designated as CH in accordance with the USCS.

installation of the piezometers. At that time, the groundwater level was measured at an elevation of 859 feet above mean sea level in both P-1 and P-2. The piezometers were subsequently abandoned.

In 2016, additional subsurface investigation was conducted by others in the vicinity of the bottom ash staging area (Haley & Aldrich 2016). The findings of this work are generally consistent with those from the subsurface investigation conducted by Golder in 2009 and 2010. Based on a review of the findings, berm stratigraphy was fairly consistent between boreholes and generally consisted of CL and CH[3]. The groundwater elevation measured in a piezometer installed in the berm on the north side of the bottom ash staging area as part of the 2016 subsurface investigation was 853.6 feet above mean sea level approximately one month after piezometer installation.

[3] Classification was likely limited to field methods. Haley & Aldrich (2016) does not indicate that laboratory geotechnical testing was conducted as part of the subsurface investigation.

3.0 SLOPE STABILITY EVALUATION

3.1 Minimum Required Factors of Safety

Under 40 CFR 257.73(e)(1), the computed minimum factors of safety for slope stability of the bottom ash staging area are required to meet or exceed the following minimum factors of safety:

- 1.50 for static loading under the long-term, maximum storage pool condition
- 1.40 for static loading under the maximum surcharge pool condition
- 1.00 for seismic loading under the seismic event with a two-percent probability of being exceeded in 50 years based on seismic hazard maps published by the United States Geological Survey (USGS), as stated in 40 CFR 257.53
- 1.20 for liquefaction factor of safety, if the berms are constructed of soils that are susceptible to liquefaction

As described in Section 2.0, the berm around the bottom ash staging area consists primarily of CL soil. Based on laboratory geotechnical testing summarized in Appendix C, the liquid limit of soil samples collected at TEC ranged from 42 to 50. The plasticity index of soil samples collected at TEC ranged from 24 to 33. The moisture contents of soil samples collected at TEC were approximately half of the liquid limit. Soil materials having these characteristics are not susceptible to liquefaction (Bray et al. 2004). Therefore, the requirement to compute the liquefaction factor of safety does not apply to the bottom ash staging area at TEC.

3.2 Cross Section

Golder identified the critical cross section for slope stability through the berm surrounding the bottom ash staging area. The location of the critical cross section is shown in Figure 1. Golder selected the steepest portion of the berm as the critical cross section, since we observed subsurface conditions to be fairly consistent across the bottom ash staging area. The location of the critical cross section is through the berm north of the bottom ash staging area, which has an overall downstream slope as steep as 1.73 horizontal to 1 vertical based on survey information from the reshaping and revegetation work in 2010. Riprap placed at the toe of the downstream slope in this location as part of the reshaping and revegetation work in 2010 is represented in the cross section (refer to Appendix A). For purposes of the slope stability evaluation, we assumed that the bottom ash staging area was filled with bottom ash to an elevation of 880 feet above mean sea level (approximately 5 feet below the berm crest). We assumed the depth of the surface impoundment to be approximately 20 feet (i.e., bottom elevation of approximately 865 feet above mean sea level) based on site observations and conservatively assumed an upstream berm slope of 0.5 horizontal to 1 vertical. Tecumseh Creek on the north and west sides of the facility has a bottom elevation of approximately 846 feet above mean sea level. The base of the cross section is at an elevation of 842 feet above mean sea level, which corresponds with the top of the underlying shale layer (Haley & Aldrich 2016).

For the maximum storage pool condition, the water level in the surface impoundment was taken as the elevation of the outlet weir, which is 880 feet above mean sea level (approximately 5 feet below the berm crest). For the maximum surcharge pool condition, the water level was conservatively assumed to be at the berm crest elevation, which is approximately 885 feet above mean sea level.

3.3 Engineering Parameters

Golder collected relatively undisturbed soil samples from most of the boreholes described in Section 2.0 for laboratory geotechnical testing to determine engineering parameters for use in the slope stability evaluation. The laboratory geotechnical test results are presented in Appendix C.

Soil materials composing the berm were considered to be uniform based on the similarities in field soil classifications and laboratory geotechnical test data. Golder assigned a moist unit weight of 125 pounds per cubic foot (pcf) to the soil material based on the average value derived from density and moisture content testing of undisturbed soil samples collected at TEC. For static slope stability analyses, Golder assigned effective stress (drained) Mohr-Coulomb strength parameters to the soil material based on the results of consolidated-undrained triaxial testing (with pore pressure measurement) of TEC-4 Sample 2, an undisturbed sample collected at TEC[4]:

- Effective friction angle = 29 degrees
- Effective cohesion = 180 pounds per square foot (psf)

For the seismic slope stability analysis, Golder assigned a vertical stress ratio (ratio of undrained strength to initial vertical effective stress) of 0.38 to the soil material based on the results of consolidated-undrained triaxial testing of TEC-4 Sample 2, an undisturbed soil sample collected at TEC, with a 20-percent strength reduction applied as recommended by Makdisi and Seed (1977)[5]. A minimum undrained shear strength of 1,000 psf was applied based on the description of the soil as “stiff” or “very stiff” on the borehole logs provided in Appendix B[6] (Terzaghi and Peck 1967).

Golder assigned a moist unit weight of 130 pcf and an effective friction angle of 45 degrees to riprap based on experience with similar materials. No effective cohesion was assumed. Because excess pore

[4] Golder considers these strength parameters to be conservative for soil materials near the surface of the downstream berm slope, since these materials were placed and compacted as structural fill as part of the reshaping and revegetation work in 2010. The compactive effort would be expected to increase the strength of the materials relative to the strength of undisturbed specimens.

[5] The vertical stress ratios for the individual specimens tested were 0.59 for Specimen A, 0.48 for Specimen B, and 0.48 for Specimen C.

[6] The assumed minimum undrained shear strength is lower than the compressive strengths indicated by pocket penetrometer testing conducted on relatively undisturbed samples in the field, as shown on the borehole logs provided in Appendix B.

pressures are not expected to develop during shearing of riprap, drained conditions were assumed for static and seismic slope stability analyses.

Golder assigned a moist unit weight of 85 pcf to bottom ash within the surface impoundment based on experience with similar materials. Golder conservatively assumed that the bottom ash within the surface impoundment contributes no strength.

The engineering parameters assigned to soil materials and bottom ash are summarized in Table 1.

Table 1: Summary of Slope Stability Evaluation Engineering Parameters

Material	Moist Unit Weight	Drained Strength Parameters		Undrained Strength Parameters	
		Effective Friction Angle	Effective Cohesion	Vertical Stress Ratio	Minimum Shear Strength
Soil	125 pcf	29 degrees	180 psf	0.38	1,000 psf
Riprap	130 pcf	45 degrees	0 psf	Not applicable	
Bottom ash	85 pcf	No strength			

3.4 Groundwater

Groundwater was observed at an elevation of 859 feet above mean sea level in P-1 and P-2 approximately five months after installation of the piezometers. Golder conservatively assumed the phreatic surface to consist of two segments:

- A straight line between the modeled water level in the surface impoundment and the observed groundwater level in P-2 at a horizontal distance of 16 feet from the upstream edge of the berm crest.
- A straight line from the observed groundwater level in P-2 at a horizontal distance of 16 feet from the upstream edge of the berm crest to the observed flow depth in Tecumseh Creek at the interface of the riprap and the native soil near the berm toe.

On September 2, 2010, a test hole was excavated approximately 30 feet upslope from the berm toe near the location of the critical cross section. Groundwater was encountered at an elevation of 851 feet above mean sea level, which is in agreement with the assumed phreatic surface.

3.5 Stability Analyses

Golder performed stability analyses using Slide, a two-dimensional slope stability computer program developed by Rocscience (2016). Factors of safety were computed for circular slip surfaces using Spencer's method for force and moment equilibrium. For the seismic analysis, Golder used a seismic coefficient of 0.03, which is half of the peak ground acceleration (PGA) with a two-percent chance of exceedance in 50 years (United States Environmental Protection Agency 1995). The PGA with a two-percent chance of exceedance in 50 years at the site was taken from the seismic hazard map provided in Appendix D, as published by USGS (2014).

The slip surface with the minimum computed factor of safety for static loading under the maximum storage pool condition is shown in Figure 2. The slip surface with the minimum computed factor of safety for static loading under the maximum surcharge pool condition is shown in Figure 3. The slip surface with the minimum computed factor of safety for seismic loading is shown in Figure 4. The computed minimum factors of safety for static and seismic slope stability analyses are summarized and compared with the minimum required factors of safety in Table 2. In each case, the computed minimum factor of safety meets or exceeds the minimum required factor of safety.

Table 2: Summary of Slope Stability Evaluation Results

Loading Condition	Computed Minimum Factor of Safety	Minimum Required Factor of Safety
Static, long-term maximum storage pool	1.51	1.50
Static, maximum surcharge pool	1.51	1.40
Seismic	1.38	1.00

4.0 CLOSING

This report summarizes the results of Golder's slope stability evaluation of the bottom ash staging area at TEC. The computed minimum factors of safety resulting from Golder's slope stability evaluation meet or exceed the minimum required factors of safety specified in 40 CFR 257.73(e)(1) for surface impoundments used in the management of CCRs. This report serves as the initial safety factor assessment required under 40 CFR 257.73(e)(1) for the bottom ash staging area at TEC.

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RRJ/JEO/dls

5.0 REFERENCES

Bray, J.D., Sancio, R.B., Riemer, M.F., and Durgunoglu, H.T. (2004). *Liquefaction susceptibility of fine-grained soils.* Proceedings of the 11th International Conference on Soil Dynamics and Earthquake Engineering and the 3rd International Conference on Earthquake Geotechnical Engineering. Berkeley, CA. January 7 to 9, 2004.

Haley & Aldrich, Inc. (2016). *CCR Groundwater Monitoring Network Description for the Tecumseh Energy Center, Tecumseh, Kansas.* Draft letter report prepared for Westar Energy. File No. 41938-120. May 24, 2016.

Makdisi, F.I., and Seed, H.B. (1977). *A Simplified Procedure for Estimating Earthquake-Induced Deformations in Dams and Embankments.* Report No. UCB/EERC-77/19. August 1977.

Rocscience Inc. (2016). *SLIDE Version 7.017*. Build date: June 1, 2016.

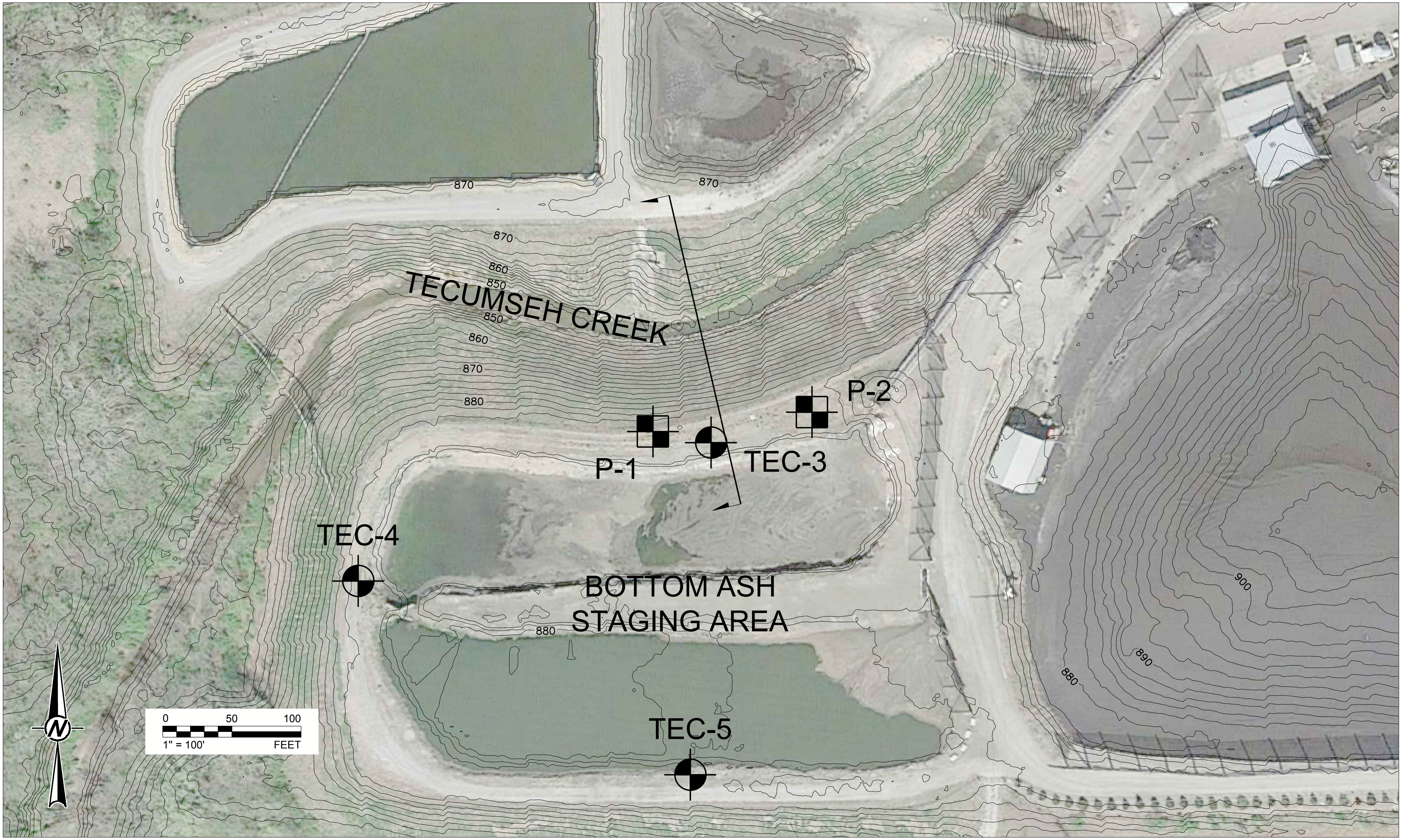
Terzaghi, K., and Peck, R.B. (1967). *Soil Mechanics in Engineering Practice.* John Wiley & Sons, Inc. New York, NY.

United States Environmental Protection Agency. (1995). *RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste* Landfill *Facilities.* Report No. EPA/600/R-95/051. April 1995.

United States Geological Survey (USGS). (2014). *Two-percent probability of exceedance in 50 years map of peak ground acceleration*. Available on the web: http://earthquake.usgs.gov/hazards/products/conterminous/2014/2014pga2pct.pdf (accessed June 29, 2016).

FIGURES

Path: \\Denver.golder.gds\projects\16JOBS\1657212 Westar TEC\Report\Draft\Figures\ | File Name: FIGURE 1.DWG



NOTES:
1. AERIAL IMAGE IS FROM GOOGLE EARTH PRO, DATED APRIL 2016.
2. TOPOGRAPHIC CONTOURS WERE EXTRACTED FROM LIDAR DATA AVAILABLE FROM THE STATE OF KANSAS, GEOGRAPHIC INFORMATION SYSTEMS, DATA ACCESS & SUPPORT CENTER, DATED 2015. TOPOGRAPHIC CONTOURS (2-FOOT CONTOUR INTERVAL) ARE CONSIDERED APPROXIMATE AND ARE SHOWN FOR REFERENCE ONLY.

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YYYY-MM-DD	2016-07-18
DESIGNED	JEO
PREPARED	JEO
REVIEWED	CCS
APPROVED	RRJ

PROJECT
TECUMSEH ENERGY CENTER
EVALUATION OF BOTTOM ASH STAGING AREA
SLOPE STABILITY

TITLE
FACILITY LAYOUT

PROJECT NO.	REV.	FIGURE
1657212	A	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
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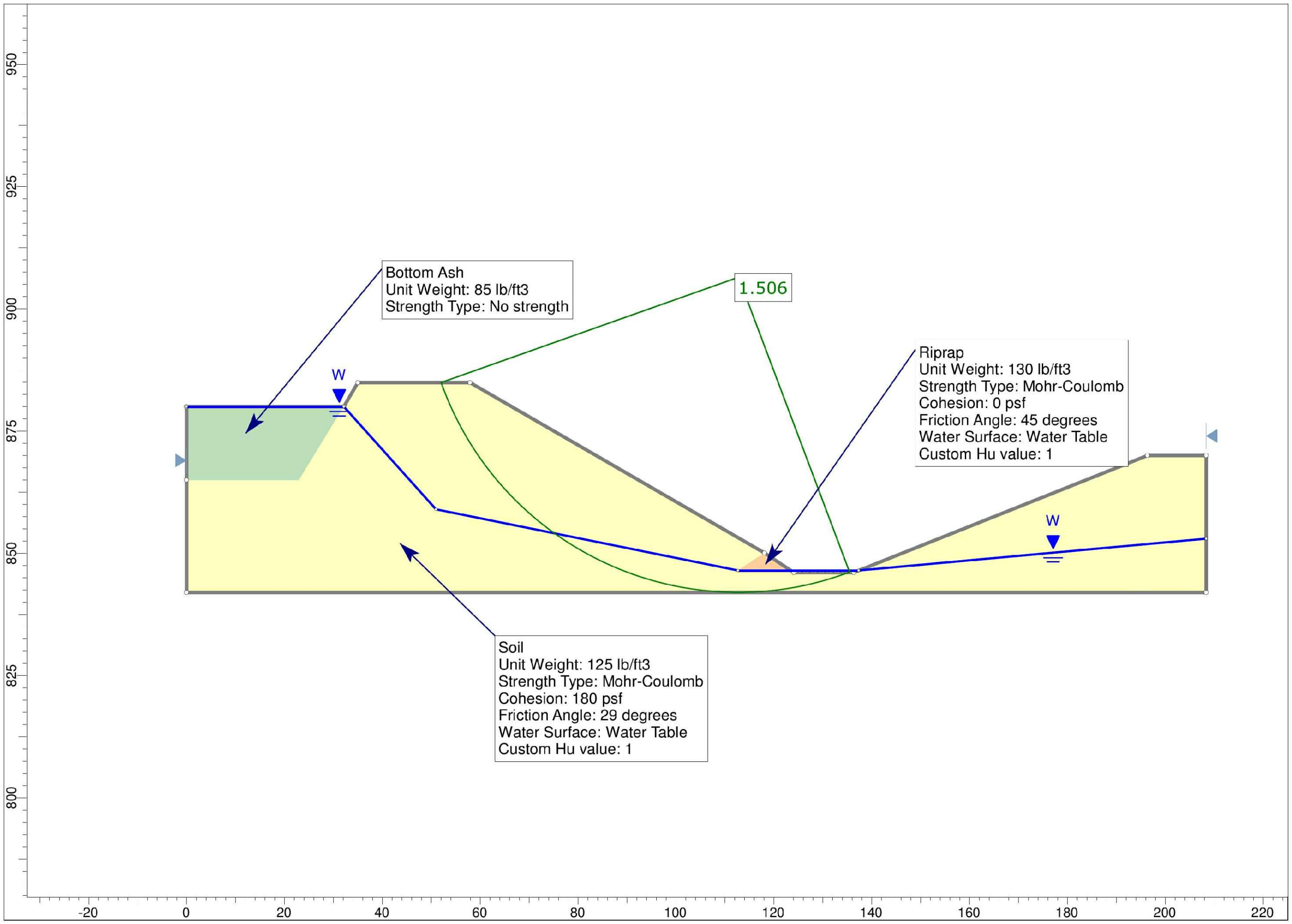
Path: \\Denver.golder.gds\projects\16JOBS\1657212 Westar TEC\Stability Analysis\ | File Name: Figures 2-4.dwg



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YYYY-MM-DD	2016-07-18
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PREPARED	JEO
REVIEWED	CCS
APPROVED	RRJ

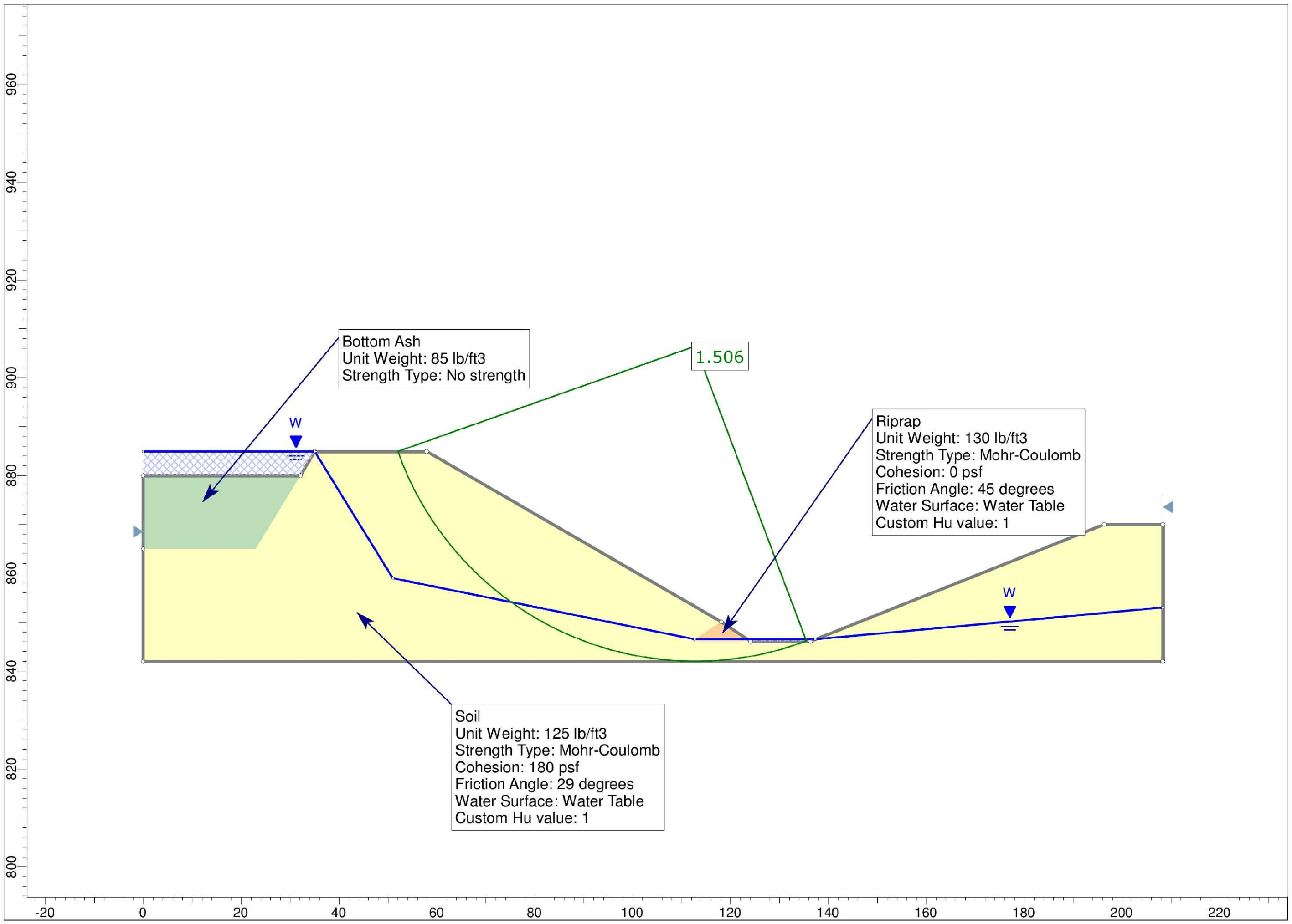
PROJECT
TECUMSEH ENERGY CENTER
EVALUATION OF BOTTOM ASH STAGING AREA
SLOPE STABILITY

TITLE
SLOPE STABILITY ANALYSIS RESULT – STATIC LOADING, MAXIMUM STORAGE POOL CONDITION

PROJECT NO.	REV.	FIGURE
1657212	A	2

1 in IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

Path: \\Denver.golder.gds\projects\16JOBS\1657212 Westar TEC\Stability Analysis\ | File Name: Figures 2-4.dwg



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YYYY-MM-DD	2016-07-18
DESIGNED	JEO
PREPARED	JEO
REVIEWED	CCS
APPROVED	RRJ

PROJECT
TECUMSEH ENERGY CENTER
EVALUATION OF BOTTOM ASH STAGING AREA
SLOPE STABILITY

TITLE
SLOPE STABILITY ANALYSIS RESULT – STATIC LOADING, MAXIMUM SURCHARGE POOL CONDITION

PROJECT NO.	REV.	FIGURE
1657212	A	3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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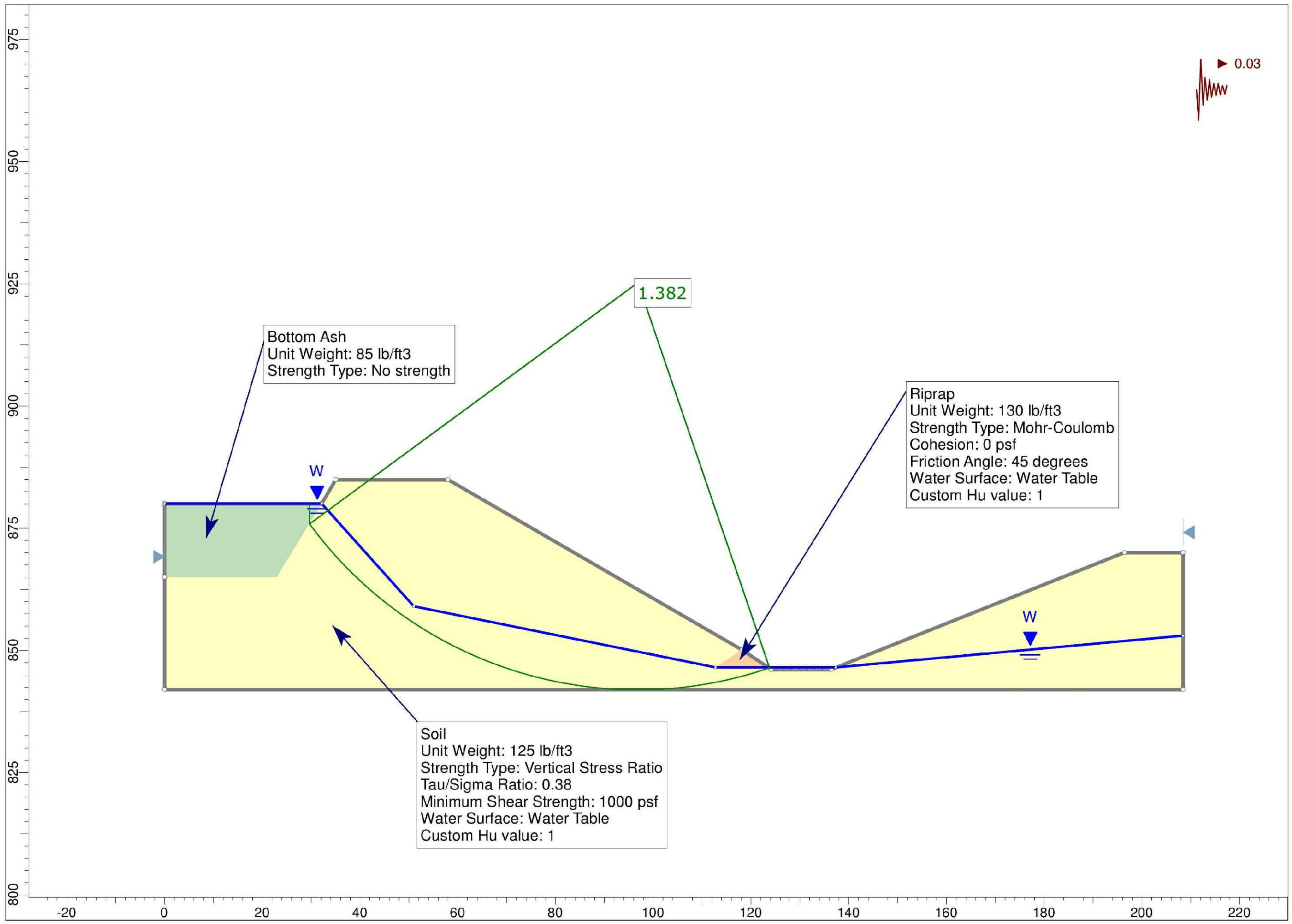

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REVIEWED	CCS
APPROVED	RRJ

PROJECT
TECUMSEH ENERGY CENTER
EVALUATION OF BOTTOM ASH STAGING AREA
SLOPE STABILITY

TITLE
SLOPE STABILITY ANALYSIS RESULT – SEISMIC LOADING

PROJECT NO.	REV.	FIGURE
1657212	A	4

APPENDIX A

BERM RESHAPING DESIGN INFORMATION

GENERAL NOTES

1. Structure locations to be field located and staked by The Watershed Institute.

2. Before any construction activity, the contractor is responsible for calling Kansas One Call at 800-344-7233 (800-DIG-SAFE).

3. Accepted Erosion Control practices will be applied to all disturbed areas.

4. Corps of Engineers 404 and applicable state permits will be obtained prior to project construction.

5. The information shown in these plans concerning type and location of underground utilities is not guaranteed to be accurate or all inclusive. Existing utilities and their locations, as shown on the plans, represent the best information obtained for the design. Location information has been obtained from the various utility companies and is either from company record drawings or company provided field locations. The plan locations shown are not guaranteed. Additional existing utilities may also be encountered. The contractor is responsible for making his own determinations as to the type and location of underground utilities as may be necessary to avoid damage thereto.

6. Contractor shall maintain construction limits within the existing and/or proposed rights-of-way and easements.

7. The engineer has not performed property or right-of-way surveys for any of the locations shown on this project. Right-of-way or property lines shown on the plans are approximate and are shown for general orientation only. Property corners or other survey markers have not been located, unless specifically called out on the plans.

8. Coordinates for this project are not associated with any known survey or coordinate system.

9. Soil moving calculations are based on available information. Contractor shall inspect the site and make an evaluation of existing conditions. Actual soil moving will be based on truck load tickets or field measurement after construction or as-built survey.

10. Incorporate all concrete rubble in stream bed and banks into LPSTP structure.

11. Slope top of bank to direct overland flow toward the ash pond and away from graded slope.

12. Remove all in-channel woody debris and bank vegetation. All woody debris and vegetation is to be hauled off-site.

13. Contractor to coordinate construction with Westar personnel.

14. Remove all metal and miscellaneous debris from stream bank. All removed metal and miscellaneous debris is to be hauled off-site.

15. Existing fence is to be replaced at locations where the proposed top of bank will encroach on the existing fence (approximately Sta. 0+75 to 3+00). New fencing, barbed wire, and barb arms shall match the existing materials, unless indicated otherwise. Round fence posts shall be spaced at 10-foot intervals. Post holes shall be at least 9 inches in diameter and at least 3 feet deep, shall be located at least 1 foot from the top of the graded slope, and shall be filled with concrete having a minimum 28-day compressive strength of 3,500 psi.

16. Existing trees and vegetation shall be completely removed between Sta. 0+00 and Sta. 3+00, unless indicated otherwise. Existing trees shall be cut as near to the ground surface as possible between Sta. 3+00 and Sta. 4+50. Materials resulting from clearing and grubbing activities shall be hauled off-site.

17. Topsoil shall be stripped and stockpiled separately. Topsoil shall be applied to the finished slope to a minimum thickness of 6 inches between Sta. 0+00 and Sta. 3+00.

18. Structural fill shall consist of earthen material classified as CL or ML under the Unified Soil Classification System, unless otherwise approved by the Engineer.

19. Structural fill shall be placed in horizontal lifts having a loose thickness no greater than 12 inches, progressing from the base of the slope to the crest of the slope. Lifts shall be keyed into competent native materials as shown in the Drawings. Structural fill shall be compacted to a minimum of 95 percent of the standard Proctor maximum dry density at a moisture content between the standard Proctor optimum moisture content and 4 percent below the standard Proctor optimum moisture content.

20. Native grass seed shall be planted following topsoil placement between Sta. 0+00 and Sta. 3+00 using a seed mix, seed application rate, and planting method approved by the Owner.

21. Geotextile and turf reinforcement mat shall be installed in accordance with manufacturer's instructions and recommendations. Refer to Construction Specifications for additional information.

LEGEND

BM	Bench Mark Location
	Existing one foot contour
	Existing five foot contour
	New improvements
	Edge of Water
	Turf Reinforcement Mat
	Bank Armoring Riprap
	Existing Fence
E	Existing Electric Cable (Approx.)

REFERENCE POINTS

BM
Sta 5+50.84
17.45' Left
N 5043.6
E 4927.6
Elev. 870.66

ISSUED FOR CONSTRUCTION

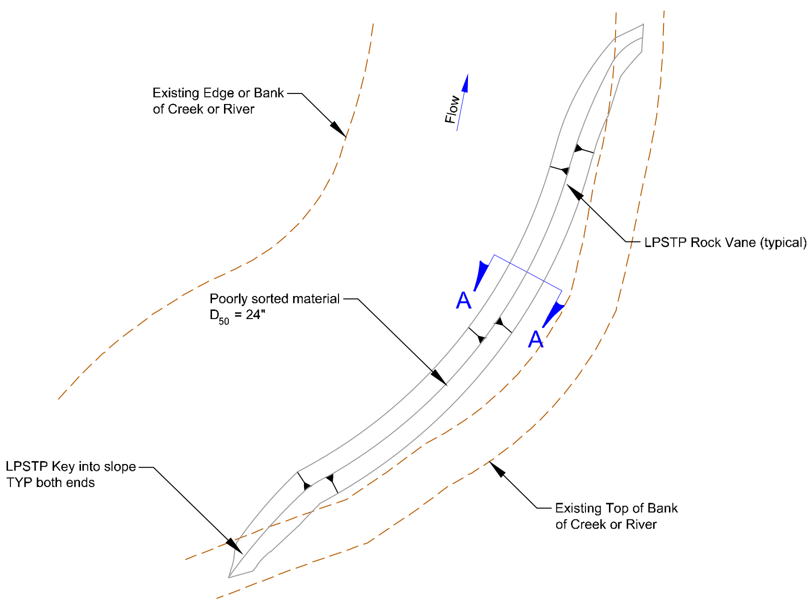
Golder Associates

THE WATERSHED INSTITUTE
1200 SW Executive Dr. Topeka, Kansas 66615 785-272-2252

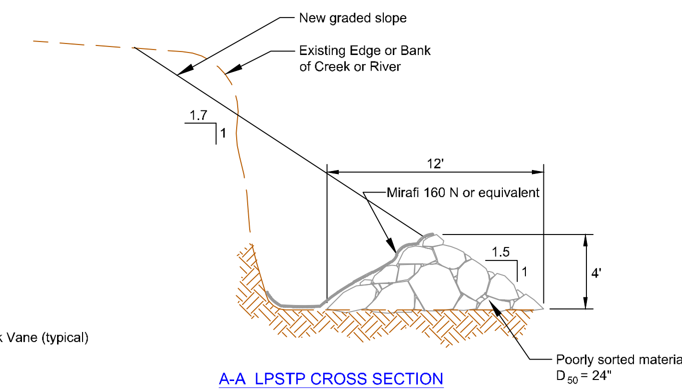
TCOM NORTH ASH POND BERM REDESIGN
BUDGET ITEM 0110644

PLAN SHEET

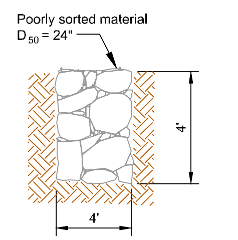
DESIGNED	BAE
DRAWN BY:	JAG
APPROVED BY:	JEO
DESIGN PROJ:	14668.077
CONST	-----
SCALE:	AS NOTED
DATE:	9/3/2010
DRAWING NO:	CO2
SHEET NO:	2 of 6



LONGITUDINAL PEAKED STONE TOE PROTECTION (LPSTP)
PLAN VIEW
Not To Scale



A-A LPSTP CROSS SECTION
Not To Scale



LPSTP ROCK KEY SECTION VIEW
Not To Scale

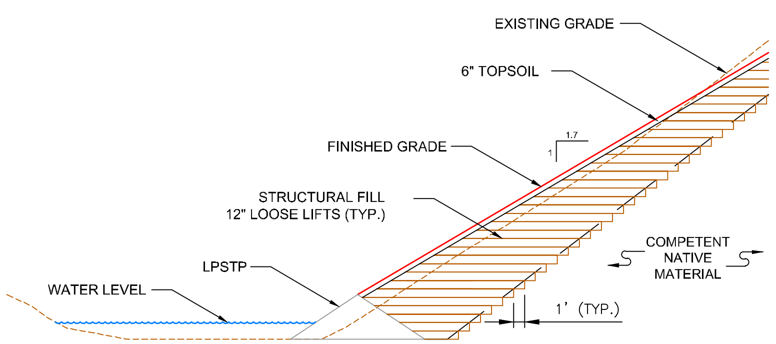
Structure Specification Sheet											
Project Name				Stream		County		State	Bank		
Tecumseh Energy Center-Ash Pond				Tecumseh Creek		Shawnee		Kansas	Length		Height
									Shaped	Total	37 Feet
Structure							Key		300 Feet	486 Feet	
Number	Type	Spacing (ft)	Angle (Degrees)	Height (ft)	Length (ft)	Key Length (ft)	Volume (yd^3)	Volume (yd^3)	Tons	Material Specifications	
1	LPSTP	-	-	4	365	35	325	21	519	Poorly Sorted Limestone Rock (D_{50} = 24")	
						Total yds3	346				

Site Information					
Structure Height (ft)	4	BkF Elev	856.0	At Station	0+75
Crest Width (ft)	-	Rosgen Classification	F6/E6		
Finished Slope Grade / H:V	1.7:1	Width/Depth Ratio	4.7		
Schumm Channel Stage	V	Entrenchment Ratio	2.3		
Radius of Curvature (ft)	220	Channel Width (ft)	36.7		
Maximum Structure Spacing (ft)	-	Tortuosity	6.0		
Regular Structure Spacing (ft)	-	Shear Stress (lbs/ft^2)	0.17		
Hydraulic Radius (ft)	4.9	Slope = (ft/ ft)	0.00056		
Mean Depth (ft)	7.8	Wetted Perimeter (ft)	49.8		
Cross Sectional Area (ft^2)	265	Manning's n	0.031		
Bank Full Discharge (cfs)	874	Mean Velocity (ft/sec)	3.3		
Q_5 Discharge (cfs)	2,610	Drainage Area (mi^2)	10.1		

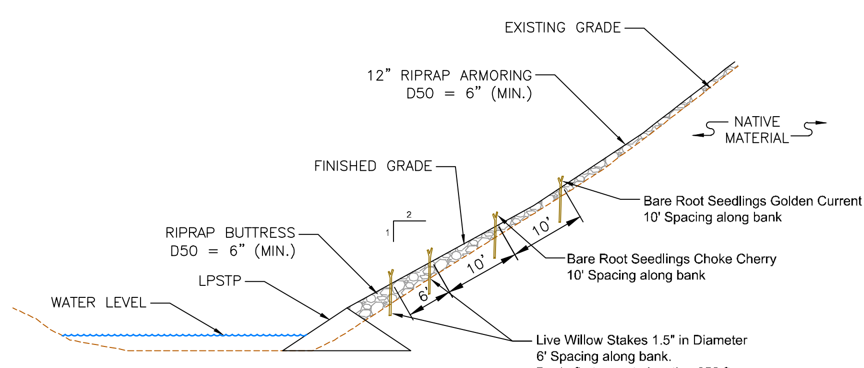
Quantities List	
Poorly Sorted Rock (cubic yards)	346
Poorly Sorted Rock (tons)	519
Bare Root Trees	80
Live Stakes	134
Native Grass Seeding (acres)	0.5
Turf Reinforcement Mat (square yards)	2,030
Geotextile Fabric (square yards)	500

Channel Bank Vegetation	
Vegetation Type	Quantity
Bare Root Seedlings / ea.	80
Live Stakes / ea.	134
Seeding/ acres	0.5

Landowner	Westar Energy -Tecumseh Energy Center
%	Paul Huber-Plant Support Engineer
Address	818 S. Kansas Ave., P.O. Box 889
City, State Zip	Topeka, KS 66601
Phone	785-575-6436
Legal	NW/4 Sec. 31 T11S R17E
Date	9/3/2010



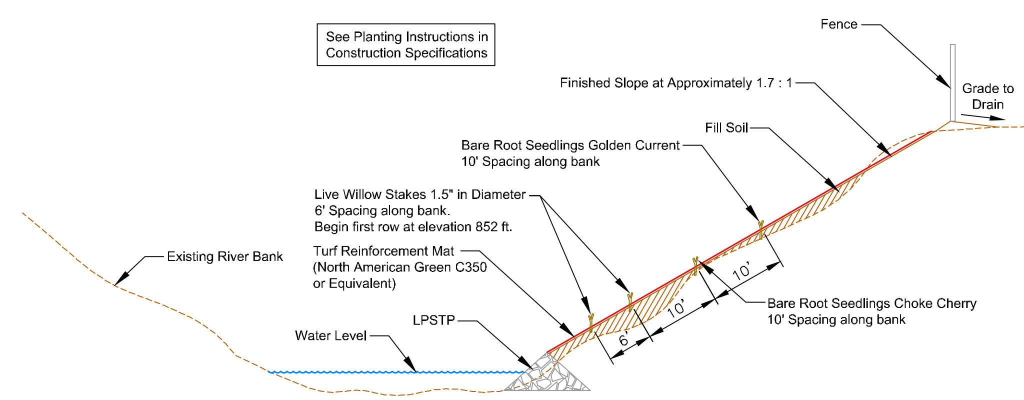
STRUCTURAL FILL DETAIL
(Sta. 0+00 to Sta. 3+00)
Not To Scale



STREAM CROSS SECTION
(Sta. 3+00 to Sta. 4+25)
Not To Scale

The Contractor shall place bank armoring riprap (D_{50}=6" min.) where native material slope and surface provide a stable foundation. In areas where existing slope or surface conditions do not allow for stable placement of bank armoring riprap, the Contractor will leave native materials undisturbed.

See Planting Instructions in Construction Specifications



STREAM CROSS SECTION
(Sta. 0+00 to Sta. 3+00)
Not To Scale

ISSUED FOR CONSTRUCTION

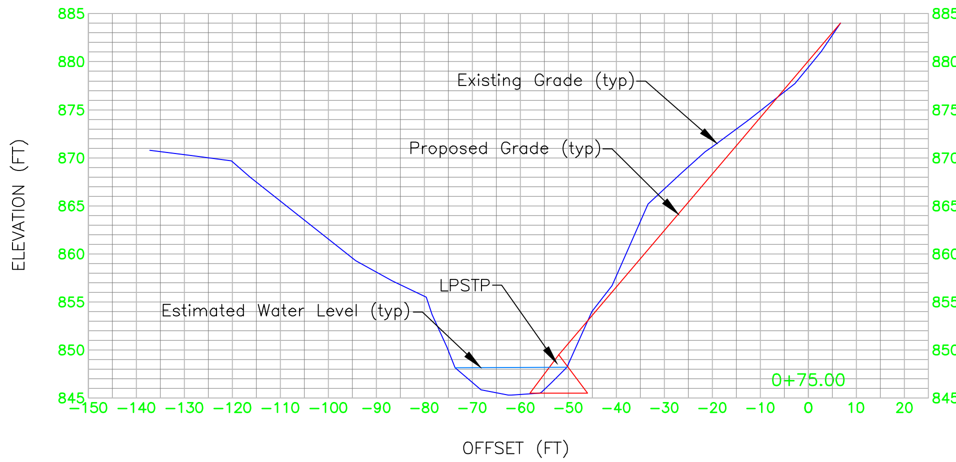
Golder Associates

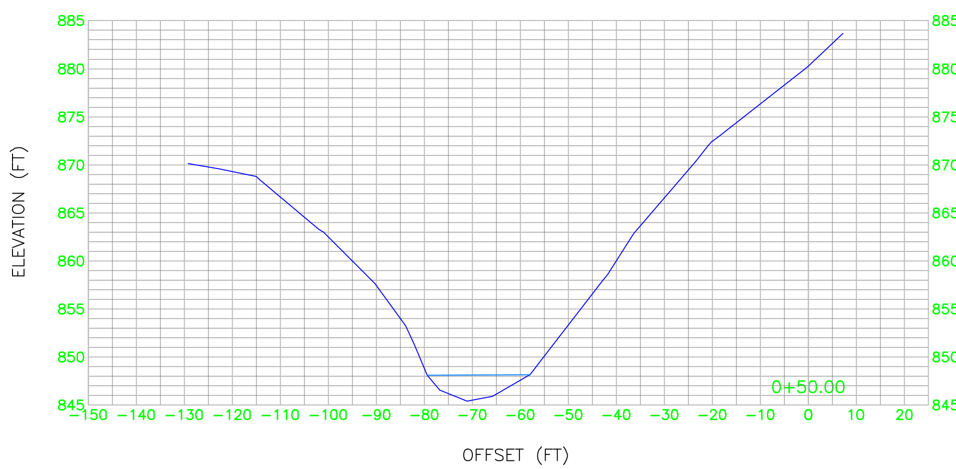
THE WATERSHED INSTITUTE
1200 SW Executive Dr. Topeka, Kansas 66615 785-272-2252

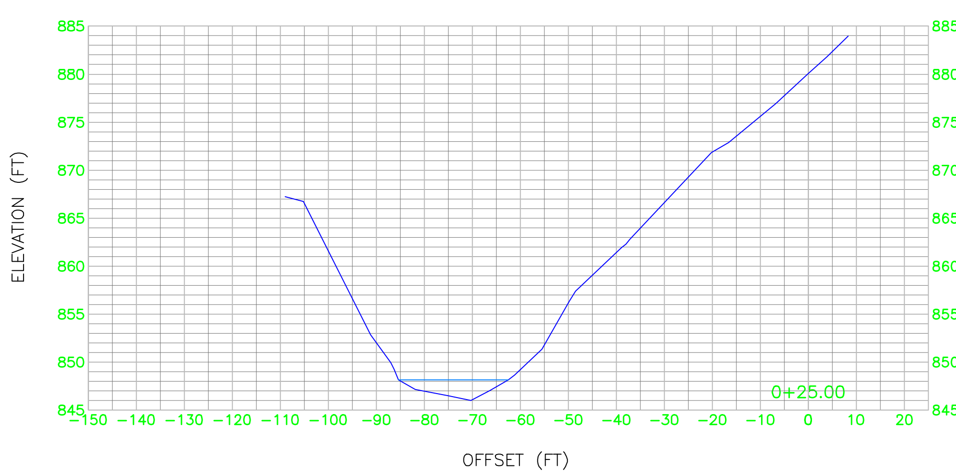
TCOM NORTH ASH POND BERM REDESIGN
BUDGET ITEM 0110644

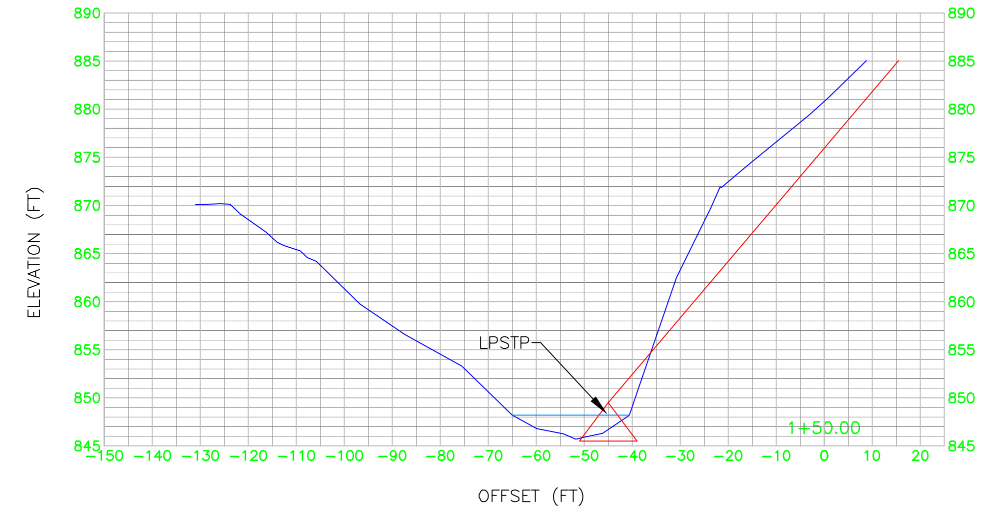
DETAIL SHEET

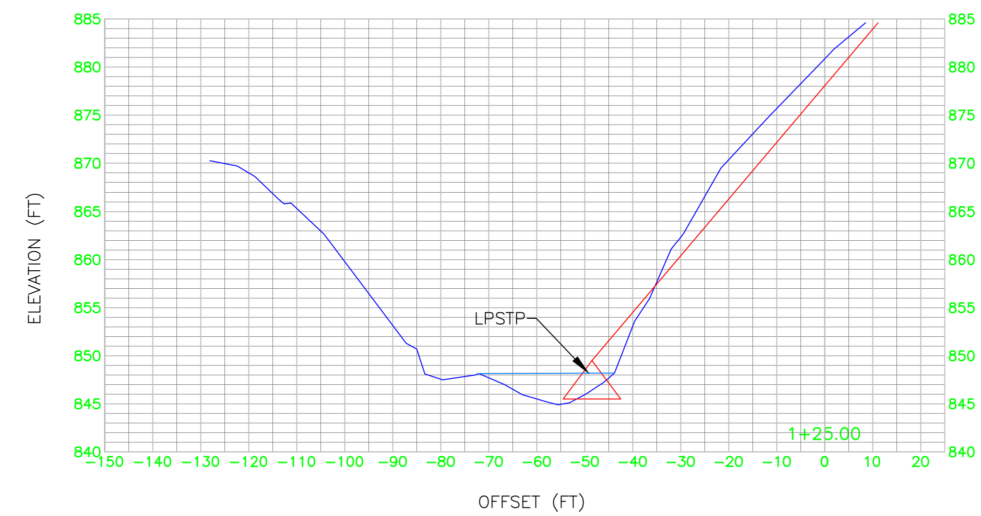
DESIGNED	BAE
DRAWN BY:	JAG
APPROVED BY:	JEO
DESIGN PROJ:	14668.077
CONST	-----
SCALE:	AS NOTED
DATE:	9/3/2010
DRAWING NO:	CO3
SHEET NO:	3 of 6

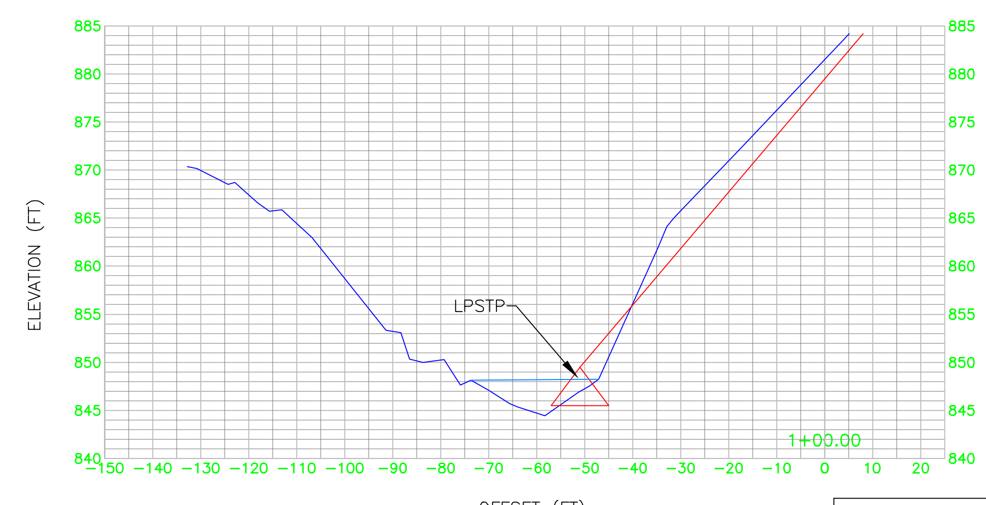












ISSUED FOR CONSTRUCTION

Golder Associates

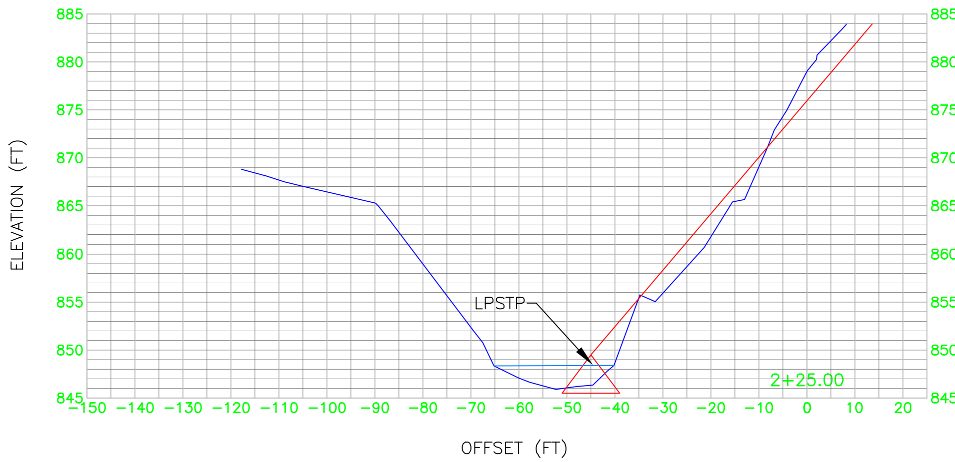
THE WATERSHED INSTITUTE

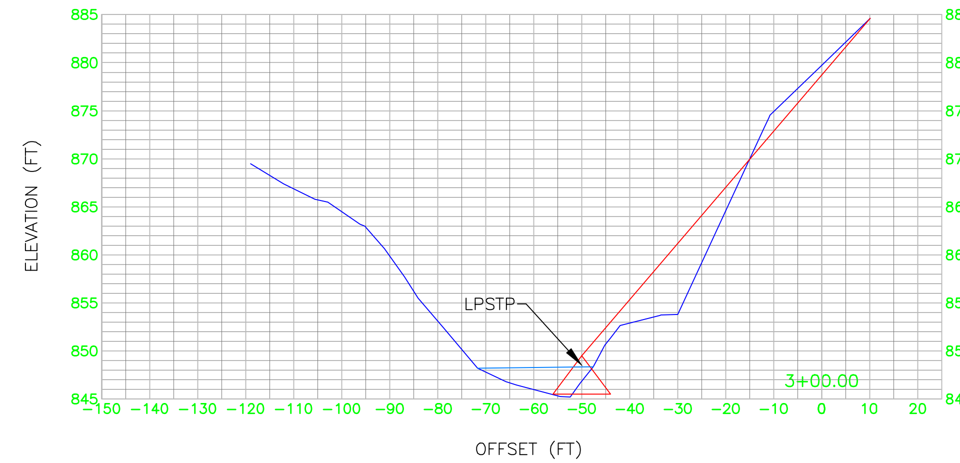
1200 SW Executive Dr. Topeka, Kansas 66615 785-272-2252

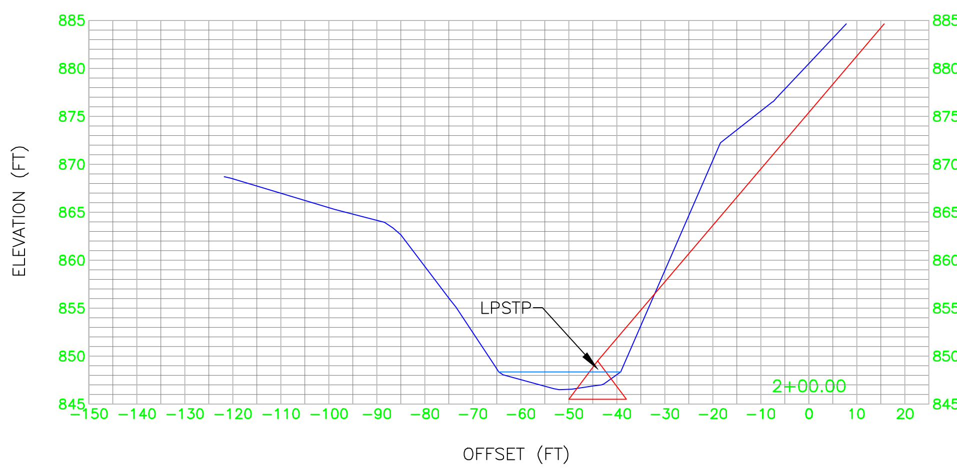
TCOM NORTH ASH POND BERM REDESIGN
BUDGET ITEM 0110644

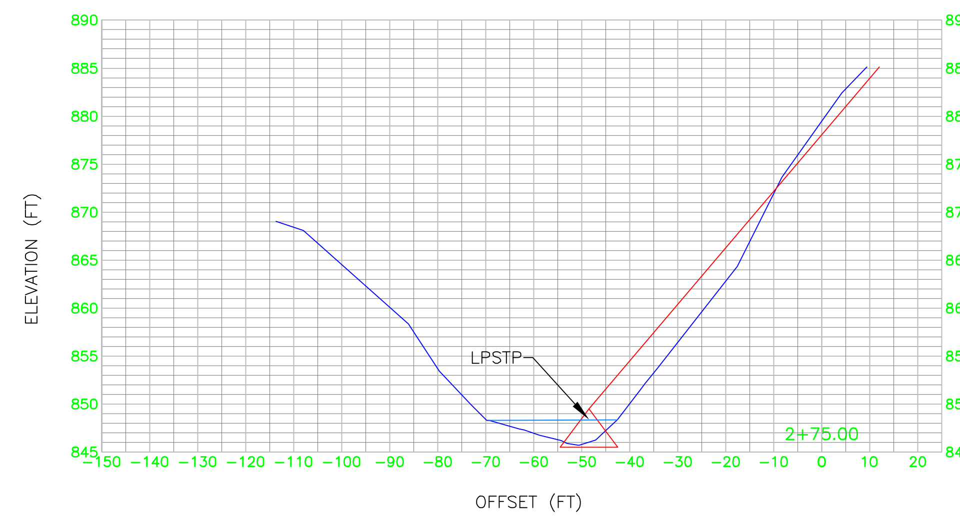
CROSS SECTION SHEET

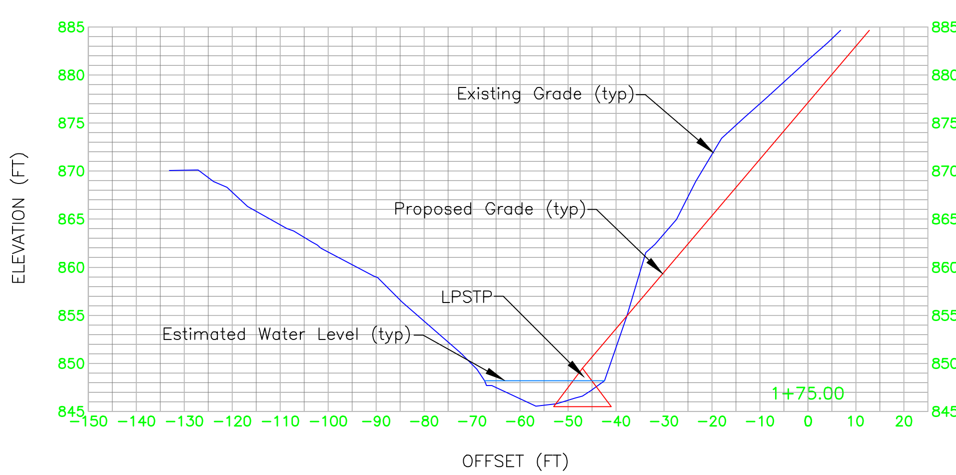
DESIGNED	BAE
DRAWN BY:	JAG
APPROVED BY:	JEO
DESIGN PROJ:	14668.077
CONST	-----
SCALE:	AS NOTED
DATE:	9/3/2010
DRAWING NO:	CO4
SHEET NO:	4 of 6

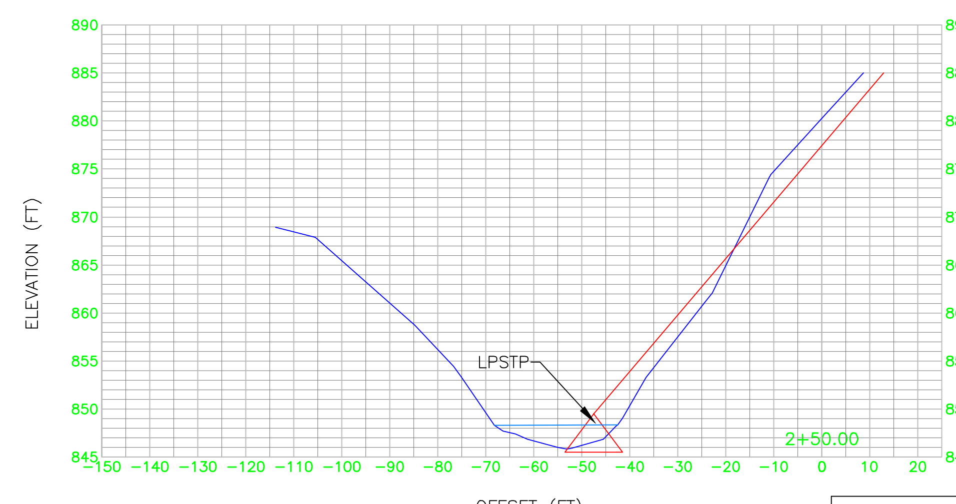












ISSUED FOR CONSTRUCTION

Golder Associates

THE WATERSHED INSTITUTE

1200 SW Executive Dr. Topeka, Kansas 66615 785-272-2252

TCOM NORTH ASH POND BERM REDESIGN
BUDGET ITEM 0110644

CROSS SECTION SHEET

DESIGNED	BAE
DRAWN BY:	JAG
APPROVED BY:	JEO
DESIGN PROJ:	14668.077
CONST	-----
SCALE:	AS NOTED
DATE:	9/3/2010
DRAWING NO:	CO5
SHEET NO:	5 of 6

APPENDIX B

BOREHOLE LOGS

BOREHOLE LOG

Golder Associates

Temp: 50ºF	Weather: Partly cloudy	Engineer: J. Obermeyer	Operator: J. Johnson	Boring	TEC-3
Equipment: Truck-mounted CME drill rig		Contractor: Terracon Consultants, Inc.		Date	10/27/09
Location Tecumseh Energy Center		Northing 271,140	Easting 2,001,850	Job No.	093-81765.1

Depth (ft)	Material	Notes
0–5	0-1' GRAVEL 1-5' Stiff to very stiff, brown to reddish-brown, SILTY CLAY, little sand, (CL)	Road surface 2" Shelby tube sample (Sample 1) from 3-5' (26" recovered) Pocket penetrometer result: 3.75 tsf (5')
5–10	5-16' Stiff, dark brown, CLAY, trace sand, (CH)	
10–15		2" Shelby tube sample (Sample 2) from 13-15' (16" recovered) Pocket penetrometer result: 2.75 tsf (15')
15–20	16-25' Stiff, brown, SILTY CLAY, little sand, (CL)	
20–25		
25–30		End of boring at 25'

Sample Descriptions and Boring Notes	Time	Depth of Hole	Depth to Waterline
• Groundwater was not encountered. • Northing and easting are approximate (±25'). Borehole location was approximately 125' west of the bottom ash discharge point and 6' from the upstream berm crest.			
	Special Notes:		
	Terracon personnel: John Johnson, Brandon Hall		

BOREHOLE LOG

Temp: 50ºF	Weather: Partly cloudy	Engineer:	J. Obermeyer	Operator:	J. Johnson	Boring	TEC-4
Equipment: Truck-mounted CME drill rig		Contractor:	Terracon Consultants, Inc.			Date	10/27/09
Location Tecumseh Energy Center		Northing	271,040	Easting	2,001,595	Job No.	093-81765.1

Depth (ft)	Material	Notes
0–5	0-1' SAND with gravel and organics, black 1-7' Stiff to very stiff, brown to reddish-brown, SILTY CLAY, little sand, (CL)	Road surface 2" Shelby tube sample (Sample 1) from 3-5' (12" recovered) Pocket penetrometer result: 3.75 tsf (5')
5–10	7-12' Stiff, reddish-brown to dark brown, SILTY CLAY, little sand, (CL)	
10–15	12-25' Stiff, brown to reddish-brown, SILTY CLAY, some sand, (CL to CH)	2" Shelby tube sample (Sample 2) from 13-15' (18" recovered) Pocket penetrometer result: 1.5 tsf (15')
15–20		
20–25		
25–30		End of boring at 25'

Sample Descriptions and Boring Notes	Time	Depth of Hole	Depth to Waterline
• Groundwater was not encountered. • Northing and easting are approximate (±25').			
	Special Notes: Terracon personnel: John Johnson, Brandon Hall		

BOREHOLE LOG

Temp: 50ºF	Weather: Partly cloudy	Engineer: J. Obermeyer	Operator: J. Johnson	Boring	TEC-5
Equipment: Truck-mounted CME drill rig		Contractor: Terracon Consultants, Inc.		Date	10/27/09
Location Tecumseh Energy Center		Northing 270,900	Easting 2,001,835	Job No.	093-81765.1

Depth (ft)	Material	Notes
0–5	0-1' Dense, black, organic SAND, some gravel, (SP) 1-5' Very stiff, red to brown, SILTY CLAY, trace sand (CL to CH)	Road surface 2" Shelby tube sample (Sample 1) from 3-5' (24" recovered) Pocket penetrometer result: 4.25 tsf (5')
5–10	5-15' Stiff, dark brown to dark gray, SILTY CLAY, little sand, (CL)	
10–15		2" Shelby tube sample (Sample 2) from 13-15' (29" recovered) Pocket penetrometer result: 1.75 tsf (15')
15–20		End of boring at 15'
20–25		
25–30		

Sample Descriptions and Boring Notes	Time	Depth of Hole	Depth to Waterline
• Groundwater was not encountered. • Northing and easting are approximate (±25'). Borehole location was approximately in the center of the berm.			

Special Notes:
Terracon personnel: John Johnson, Brandon Hall

BOREHOLE LOG

Golder Associates

Temp: 50ºF Weather: Sunny Engineer: J. Obermeyer Operator: J. Johnson Boring P-1
Equipment: Truck-mounted CME-75 drill rig Contractor: Terracon Consultants, Inc. Date 3/23/10
Location Tecumseh Energy Center Northing 271,148 Easting 2,001,808 Job No. 093-81765.1

Depth (ft)	Material	Notes
0–5	0-3' Compact, gray, SILTY SAND, trace fines, (SM) 3-6' Stiff to very stiff, brown to reddish-brown, SANDY CLAY, (CL)	Road surface Moisture content below optimum moisture content
5–10	6-11' Stiff to very stiff, brown, SANDY CLAY, (CL)	Moisture content near optimum moisture content
10–15	11-17' Hard, reddish-brown, cemented, CLAY, (CL)	Difficult drilling, dry
15–20	17-23' Stiff, brown, SILTY CLAY, (CL)	Moisture content dry of optimum moisture content
20–25 (▼)	23-36' Stiff, brown, SANDY CLAY, (CL)	Moisture content increasing from optimum moisture content to saturated with depth
25–30		
30–35		1.6" diameter liner sample from 33-35' (24" recovered)
35–40	36-40' Firm, brown, SANDY CLAY, (CL)	Saturated End of boring at 40'

<table>
<tr><th>Sample Descriptions and Boring Notes</th><th>Time</th><th>Depth of Hole</th><th>Depth to Waterline</th></tr>
<tr><td rowspan="4">• Groundwater was measured at a depth of 23.5’ approximately 2 hours after drilling was completed.
• Northing and easting are approximate (±10’). Borehole location was approximately 22’ from the upstream berm crest. Surface elevation is approximately 885’.</td><td>15:30</td><td>40’</td><td>23.5’</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Terracon personnel: John (driller), Rick (helper)</td></tr>
</table>

BOREHOLE LOG

Golder Associates

Temp: 50ºF	Weather: Sunny	Engineer:	J. Obermeyer	Operator: J. Johnson	Boring P-2
Equipment:	Truck-mounted CME-75 drill rig	Contractor:	Terracon Consultants, Inc.		Date 3/23/10
Location	Tecumseh Energy Center	Northing	271,162	Easting 2,001,923	Job No. 093-81765.1

Depth (ft)	Material	Notes
0–5	0-2.5' Compact, gray, SILTY SAND, trace fines, (SM) 2.5-5' Stiff to very stiff, brown to reddish-brown, SANDY CLAY, (CL)	Road surface
5–10	5-10' Stiff to very stiff, brown, SANDY CLAY, (CL)	Moisture content slightly below optimum moisture content
10–15	10-12.5' Stiff to very stiff, gray, SANDY CLAY, (CL) 12.5-18' Very stiff, brown, CLAY, (CL)	Moisture content slightly below optimum moisture content
15–20	18-33' Stiff, brown, CLAY, (CL)	Moisture content increasing, near optimum moisture content
20–25 ▼		
25–30		
30–35	33-39.5' Firm, brown, CLAY, (CL)	Moisture content above optimum moisture content
35–40		End of boring at 39.5'

<table>
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<tr><td rowspan="4">Groundwater was measured at a depth of 24.5’ approximately 5 hours after drilling was completed.
Northing and easting are approximate (±10’). Borehole location was approximately 16’ from the upstream berm crest. Surface elevation is approximately 885’.</td><td>15:00</td><td>39.5’</td><td>24.5’</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Terracon personnel: John (driller), Rick (helper)</td></tr>
</table>

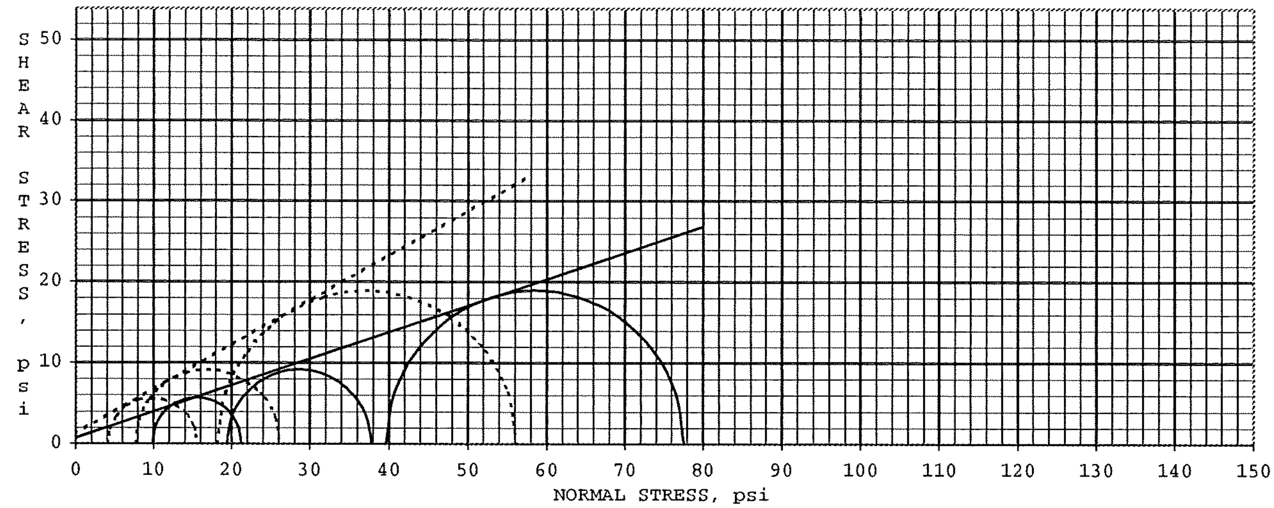
APPENDIX C

LABORATORY GEOTECHNICAL TEST RESULTS

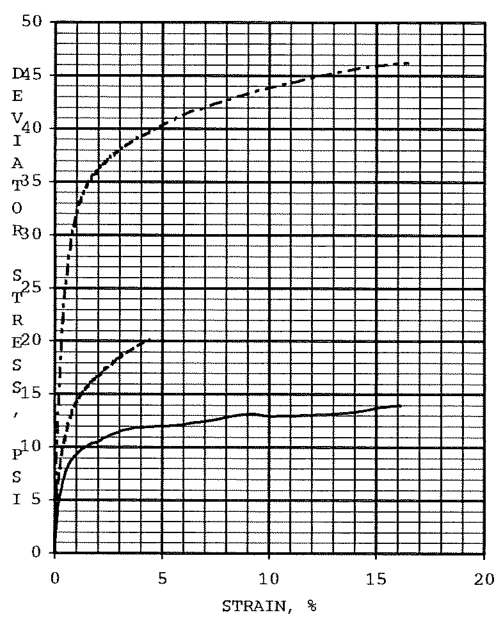
EVALUATION OF BOTTOM ASH STAGING AREA SLOPE STABILITY
WESTAR ENERGY - TECUMSEH ENERGY CENTER
SUMMARY OF LABORATORY GEOTECHNICAL TEST RESULTS

Borehole	Sample	Depth	USCS Classification	Dry Unit Weight	Moisture Content	Liquid Limit	Plasticity Limit	Plasticity Index	Effective Friction Angle	Effective Cohesion
TEC-3	2	13-15'	CH	100 pcf	24%	50	17	33		
TEC-4	2	13-15'	CL	102 pcf	23%	42	18	24	29 deg	180 psf
TEC-5	1	3-5'	CL	104 pcf	22%	48	18	30		
P-1	1	33-35'	CL			44	17	27		

Golder Associates



EFFECTIVE STRESS ---	ANGLE OF INTERNAL FRICTION, deg	28.9	COHESION, psi	1.2
TOTAL STRESS ——	ANGLE OF INTERNAL FRICTION, deg	18.1	COHESION, psi	0.7



SPECIMEN ID:		A	B	C
INITIAL	WATER CONTENT, %	22.1	24.5	22.7
	DRY DENSITY, pcf	101.9	101.2	104.5
	SATURATION, %	91	99	100
	VOID RATIO	0.65	0.67	0.61
BEFORE SHEAR	WATER CONTENT, %	23.2	22.7	21.4
	DRY DENSITY, pcf	103.6	104.5	106.8
	SATURATION (B PARAMETER)	0.98	0.96	NA
	VOID RATIO	0.63	0.61	0.58
	FINAL BACK PRESSURE, psi	100.5	100.0	99.9
MINOR PRINCIPAL STRESS, psi		9.8	19.4	39.6
EFFECTIVE STRESS PEAK AT % STRAIN		3.0	3.0	3.0
EFF. DEVIATOR STRESS AT PEAK STRAIN, psi		11.5	18.5	38.0
TOTAL STRESS PEAK AT % STRAIN		3.0	3.0	3.0
TOTAL DEVIATOR STRESS AT PEAK STRAIN, psi		11.5	18.5	38.0
ULTIMATE DEVIATOR STRESS (15% STR), psi		13.7	NA	46.0
TIME TO 50% PRIMARY CONSOLIDATION, min		2.20	12.70	NA
STRAIN RATE, % / hour		5.39	1.35	1.37
INITIAL DIAMETER, inch		1.864	1.874	1.871
INITIAL HEIGHT, inch		3.662	3.665	3.562
AREA AFTER CONSOLIDATION, inch2		2.709	2.707	2.838

CONTROLLED - STRAIN TEST

SAMPLE TYPE: 2" SHELBY TUBE

DESCRIPTION OF SPECIMENS:
LEAN CLAY, REDDISH BROWN & GRAY

LL 42	PL 18	PI 24	Gs 2.7 EST.

PROJECT NO. 14095047

PROJECT: LEC / TEC LAB

CIRCLE B & C SAMPLE WAS STAGE LOADED

BORING #: TEC-4

LABORATORY: TERRACON - LENEXA

SAMPLE #: 2

DATE: 11/18/2009

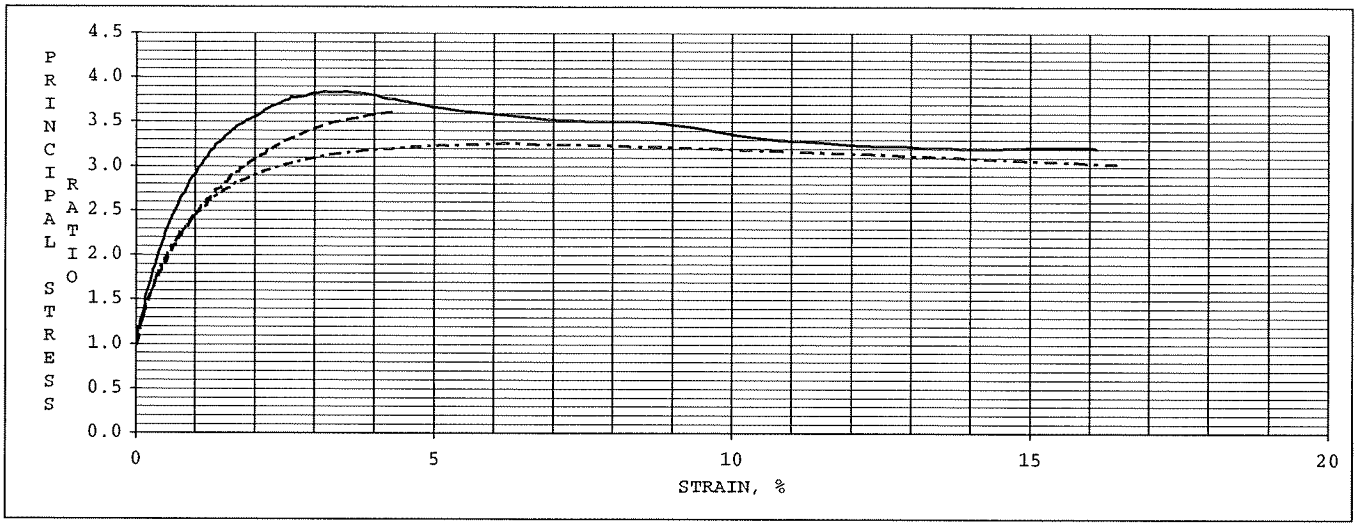
DEPTH, feet: 13.0 - 15.0 feet

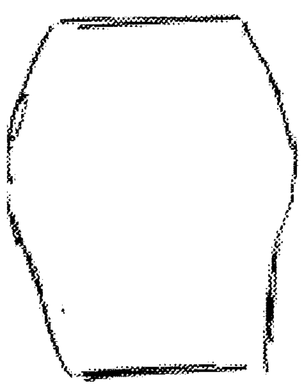
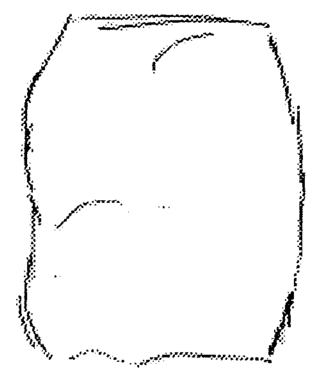
PROCEDURE: ASTM D4767, CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ON COHESIVE SOILS (TERRACON MODIFIED FOR STAGE LOADING)

Terracon

LEC / TEC LAB

14095047	TEC-4	2	13.0 - 15.0 feet



FAILURE SKETCH	FAILURE SKETCH	FAILURE SKETCH
		
SPECIMEN A	SPECIMEN B	SPECIMEN C

REMARKS:

SPECIMENS SATURATED BY THE WET METHOD.

EFFECTIVE STRESS FAILURE DATA BASED ON 3 % STRAIN.

EFFECTIVE STRESS MOHR'S CIRCLES DRAWN AT 3 % STRAIN.

TOTAL STRESS FAILURE DATA BASED ON 3 % STRAIN.

TOTAL STRESS MOHR'S CIRCLES DRAWN AT 3 % STRAIN.

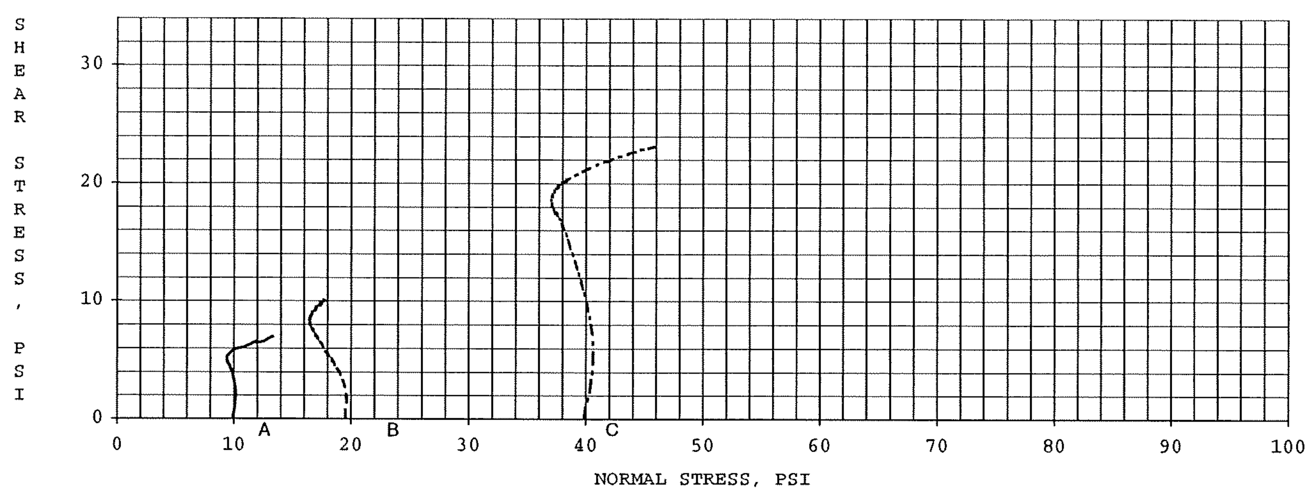
DEVIATOR STRESSES CORRECTED FOR MEMBRANE AND FILTER PAPER EFFECTS.

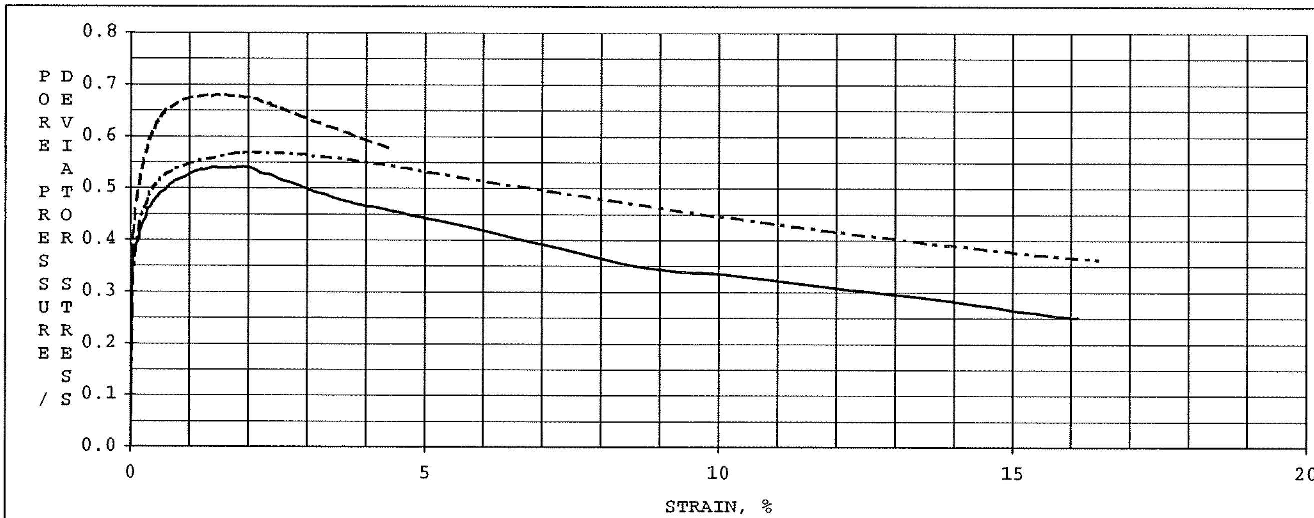
AREA AFTER CONSOLIDATION CALCULATED AS PER SECTION 10.3.2.1 METHOD A

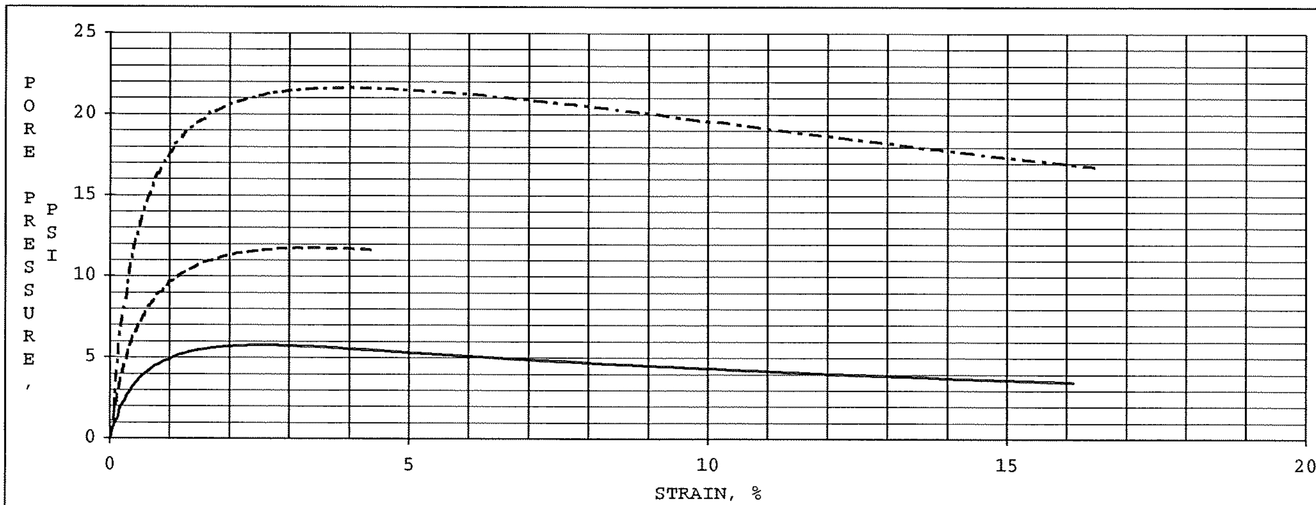
Terracon

LEC / TEC LAB

14095047 TEC-4 2 13.0 - 15.0 feet



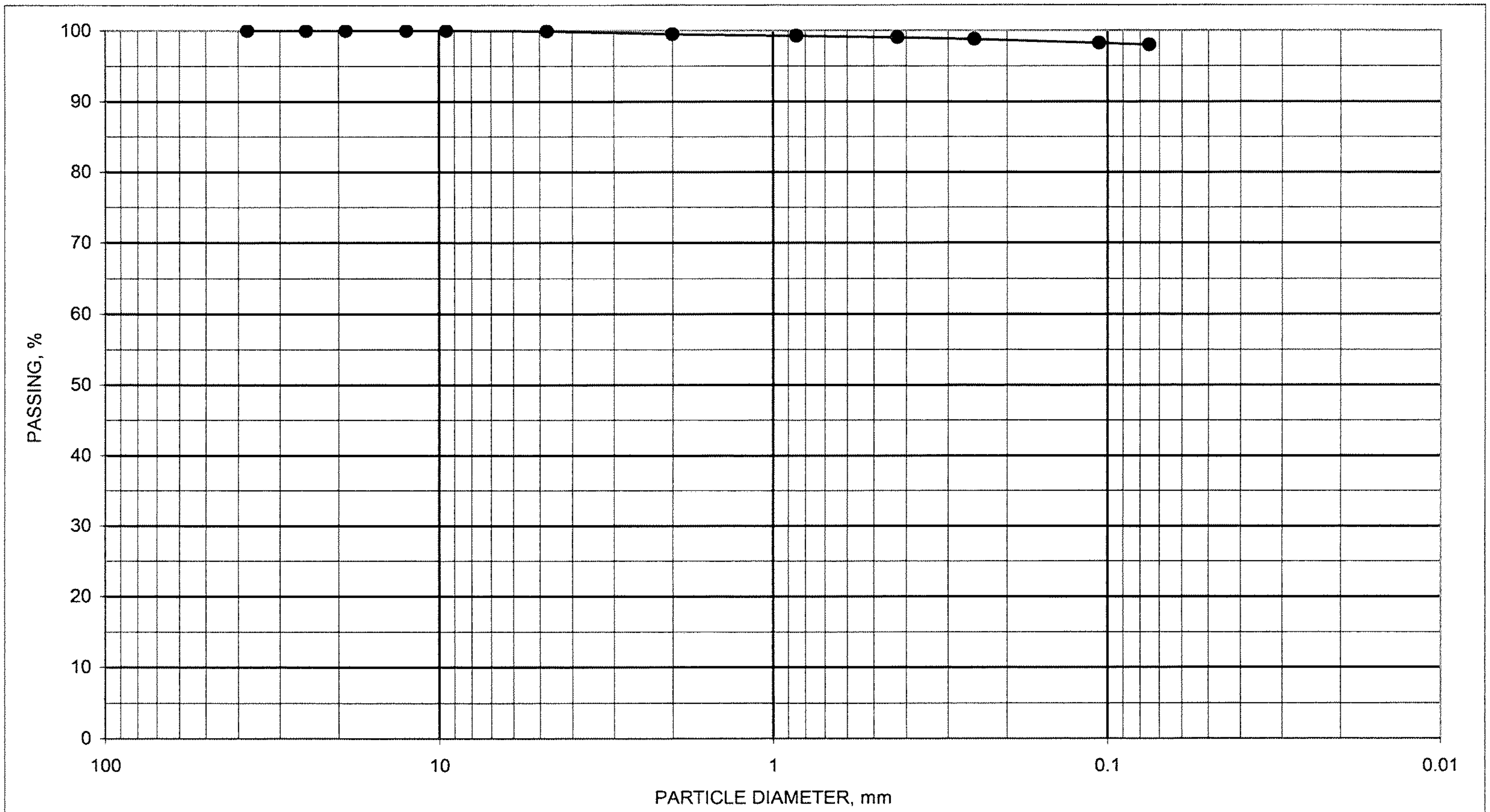




Terracon

N:\CM\LAB_DATA\00 Projects in Progress\2009 Projects in Progress\14095047\[14095047 Triaxial CU Staged B-C TEC4-2-13.0.xls]REPORT

SIEVE SIZE	DIAMETER, mm	PASS, %
1.5"	37.5	100
1"	25.0	100
3/4"	19.0	100
1/2"	12.5	100
3/8"	9.50	100
#4	4.75	100
#10	2.00	99
#20	0.850	99
#40	0.425	99
#60	0.250	99
#140	0.106	98
#200	0.075	98.0



GRAIN SIZE DISTRIBUTION CURVE

BORING ID	SAMPLE ID	DEPTH, feet	USCS DESCRIPTION	UNIFIED SYMBOL	NAT M%	ATTERBERG LIMITS LL	PL	PI
TEC -3	2	13 TO 15	FAT CLAY DARK GRAY	CH	24.1	50	17	33

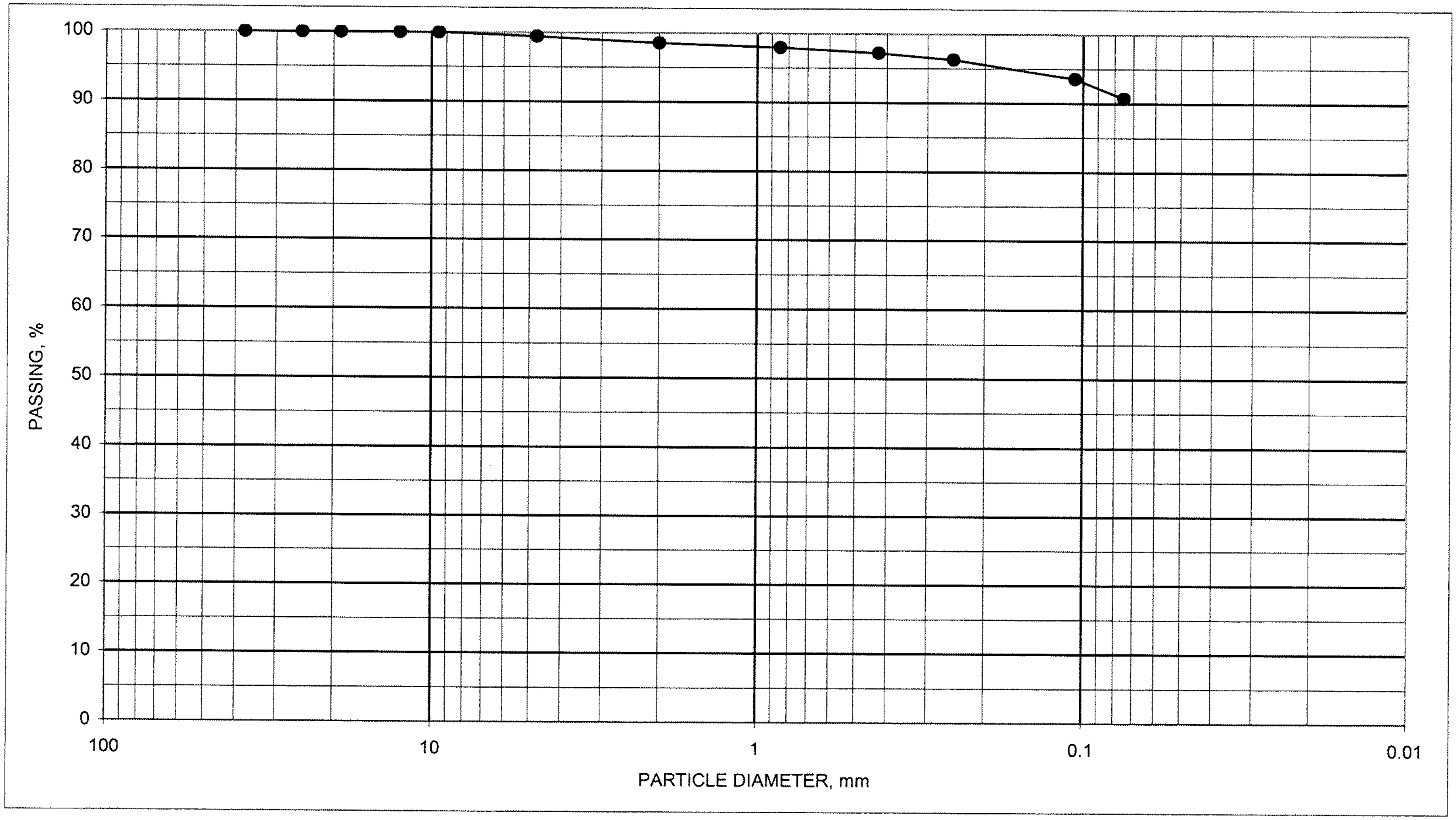
PROJECT LEC / TEC LAB

JOB NO. 14095047 DATE 11/13/2009

Terracon

N:\CM\LAB_DATA\00 Projects in Progress\2009 Projects in Progress\14095047\[14095047 GradALPlot TEC3-2-13.0.xls]ATTERBERG M%

SIEVE SIZE	DIAMETER, mm	PASS, %
1.5"	37.5	100
1"	25.0	100
3/4"	19.0	100
1/2"	12.5	100
3/8"	9.50	100
#4	4.75	99
#10	2.00	99
#20	0.850	98
#40	0.425	97
#60	0.250	96
#140	0.106	94
#200	0.075	90.7



GRAIN SIZE DISTRIBUTION CURVE

BORING ID	SAMPLE ID	DEPTH, feet	USCS DESCRIPTION	UNIFIED SYMBOL	NAT M%	ATTERBERG LIMITS LL	PL	PI
TEC-4	2	13 TO 15	LEAN CLAY REDDISH BROWN & GRAY	CL		42	18	24

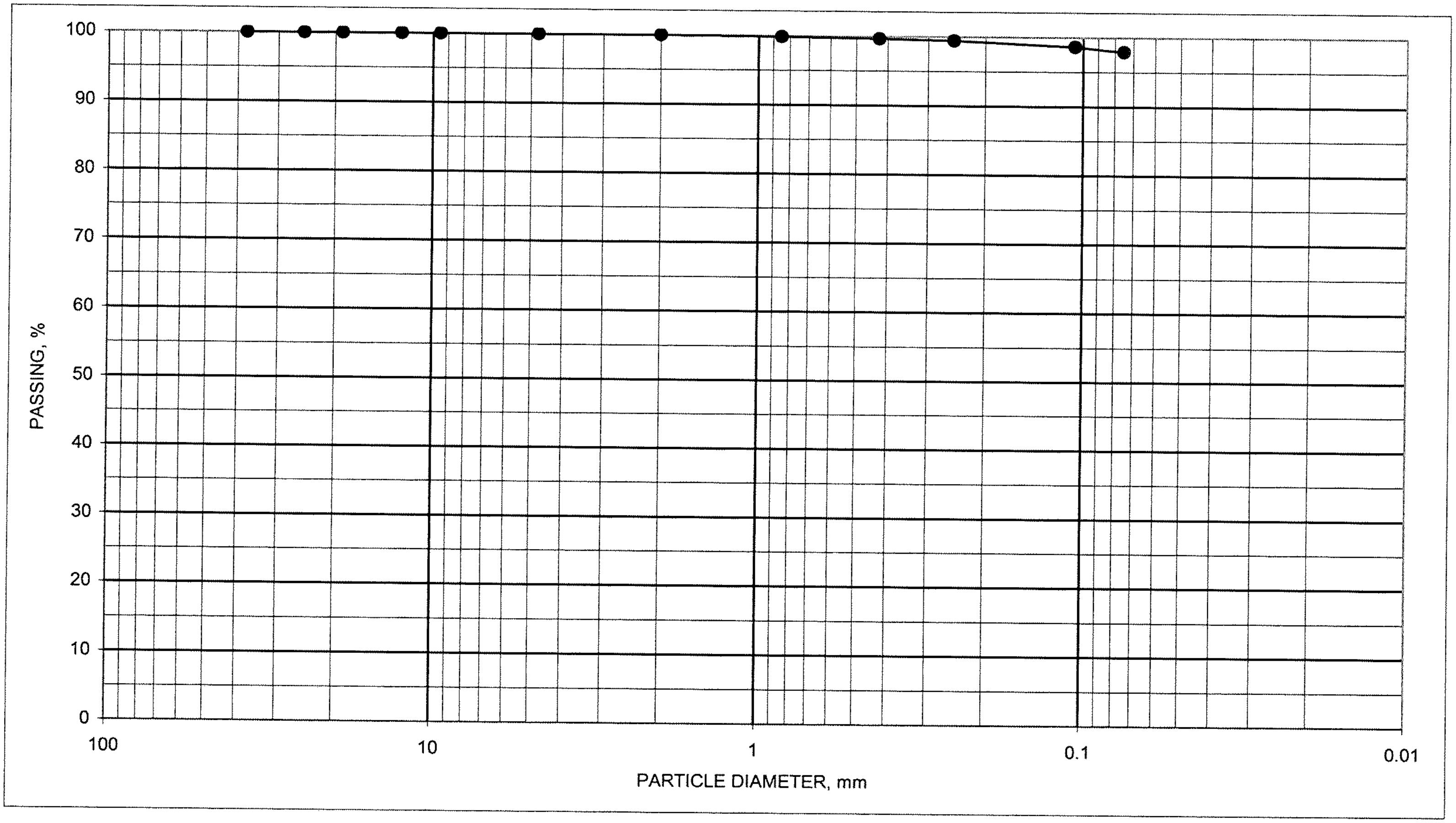
PROJECT LEC / TEC LAB

JOB NO. 14095047 DATE 11/13/2009

N:\CM\LAB_DATA\00 Projects in Progress\2009 Projects in Progress\14095047\[14095047 GradALPlot TEC4-2-13.0.xls]ATTERBERG M%

Terracon

SIEVE SIZE	DIAMETER, mm	PASS, %
1.5"	37.5	100
1"	25.0	100
3/4"	19.0	100
1/2"	12.5	100
3/8"	9.50	100
#4	4.75	100
#10	2.00	100
#20	0.850	100
#40	0.425	100
#60	0.250	99
#140	0.106	99
#200	0.075	97.9



GRAIN SIZE DISTRIBUTION CURVE

BORING ID	SAMPLE ID	DEPTH, feet	USCS DESCRIPTION	UNIFIED SYMBOL	NAT M%	ATTERBERG LIMITS LL	PL	PI
TEC -5	1	3 TO 5	LEAN CLAY DARK BROWN & REDDISH BROWN	CL	22.3	48	18	30

PROJECT LEC / TEC LAB

JOB NO. 14095047 DATE 11/13/2009

N:\CM\LAB_DATA\00 Projects in Progress\2009 Projects in Progress\14095047\[14095047 GradALPlot TEC5-1-3.0.xls]ATTERBERG M%

Terracon

ATTERBERG LIMITS

ASTM D 4318

PROJECT NAME: Westar/TEC Ash Pond Stability/CO
PROJECT NUMBER: 093-81765.1
SAMPLE ID: P-1 **SAMPLE DEPTH (ft):** 33-35
SAMPLE TYPE: Tube

SAMPLE PREPARATION
Wet or Dry: Dry Minus #40 Sieve: Yes

PLASTIC LIMIT DETERMINATION / **LIQUID LIMIT DETERMINATION**

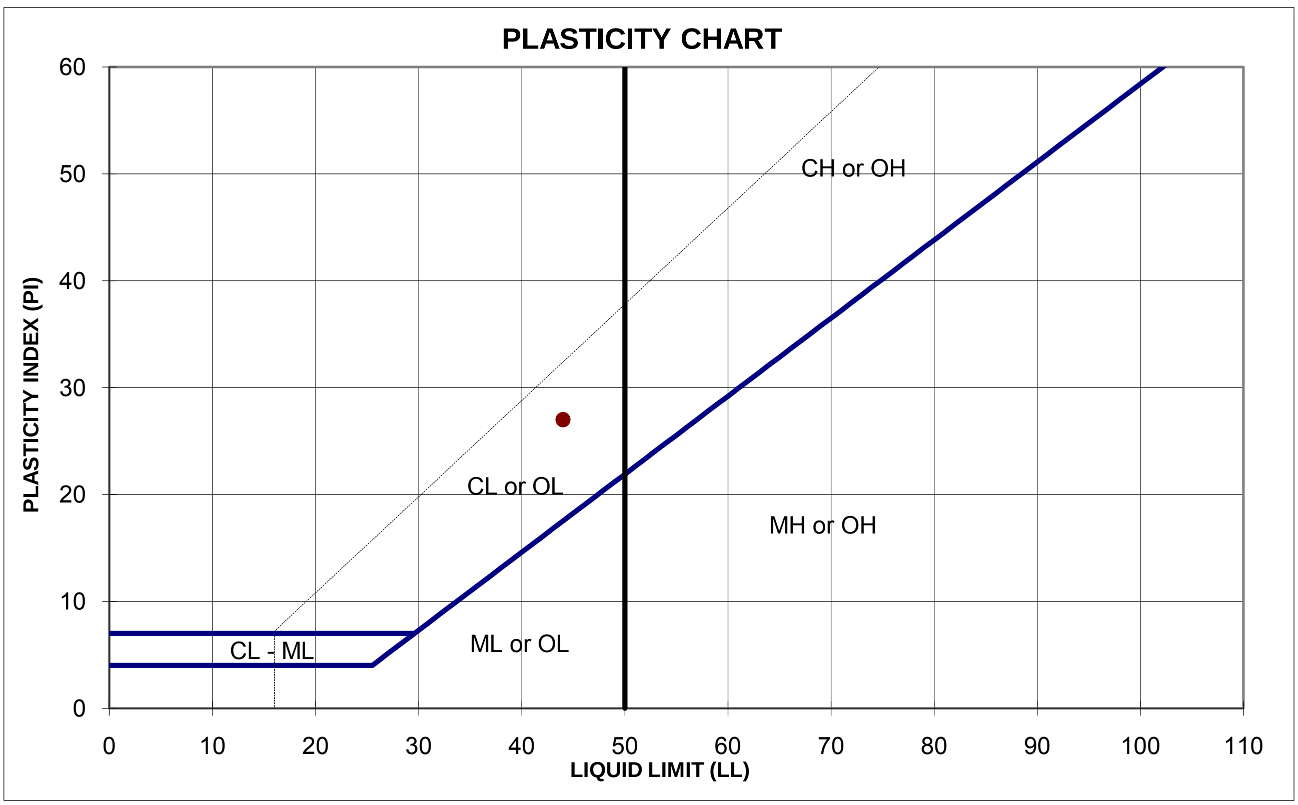
	PL 1	PL 2	LL 1	LL 2	LL 3
Number of Blows			34	18	27
Weight of Wet Soil & Tare (g)	24.38	23.64	25.25	26.69	27.60
Weight of Dry Soil & Tare (g)	23.15	22.34	21.78	22.67	24.02
Weight of Tare (g)	15.68	14.53	13.74	13.91	15.84
Weight of Water (g)	1.23	1.30	3.47	4.02	3.58
Weight of Dry Soil (g)	7.47	7.81	8.04	8.76	8.18
Water Content (%)	16.47	16.65	43.16	45.89	43.77

PLASTIC LIMIT (PL): 17

LIQUID LIMIT (LL): 44

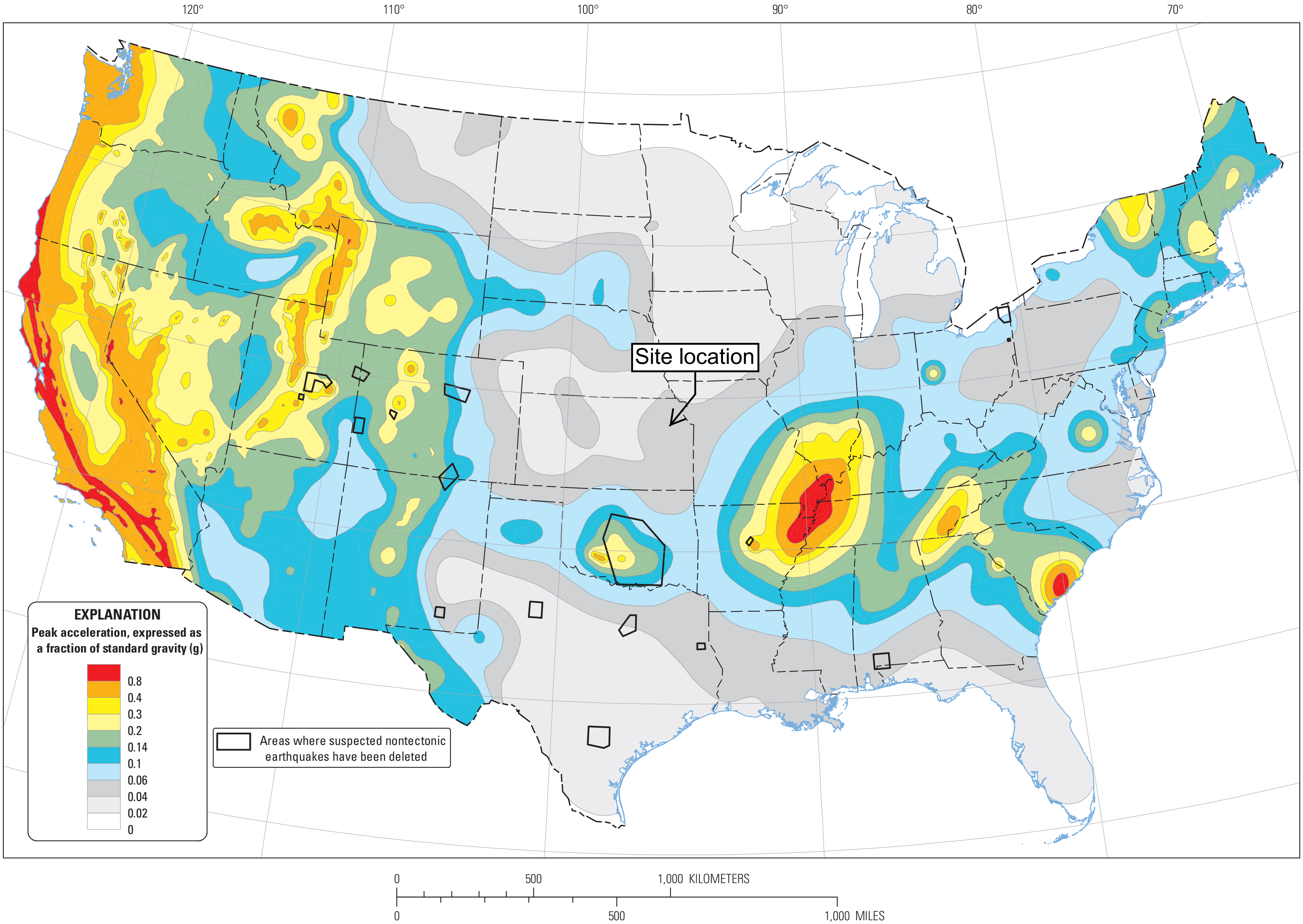
PLASTICITY INDEX (PI): 27

NOTE:



TECH	PRH
DATE	4/8/10
REVIEW	MB

APPENDIX D
SEISMIC HAZARD MAP



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

Reference: United States Geological Survey (2014). Site location callout added.

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