Stantec

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October 12, 2021
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Revision 0

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

RE: Periodic Seismic Safety Factor Assessment
Active Ash Pond 2
EPA CCR Rule
TVA Johnsonville Fossil Plant
New Johnsonville, Tennessee

1.0 PURPOSE

This letter documents certification that the Active Ash Pond 2 at the Tennessee Valley Authority (TVA) Johnsonville Fossil Plant is in compliance with the seismic safety factor requirements set forth in 40 CFR 257.73(e)(iii)&(iv) of the EPA CCR Rule. The EPA CCR Rule requires periodic safety factor assessments, certified by a professional engineer, every five years. The initial certification of seismic safety factor was placed in the operating record October 15, 2016.

2.0 INITIAL SEISMIC SAFETY FACTOR ASSESSMENT

The initial seismic safety factor assessment is attached. The assessment calculated the following seismic factors of safety for the following loading conditions:

- Seismic / Pseudo-static; and
- Liquefaction / Post-earthquake.

Geocomp compiled and reviewed available historical site, topographic, and geotechnical data for Active Ash Pond 2 as part of the initial assessment and identified Section C-C' as the most critical cross section. The critical section was analyzed for the loading conditions specified in 40 CFR 257.73(e)(1)(iii) and (iv). The result of the initial assessment was that Active Ash Pond 2 complied with 40 CFR 257.73(e)(1)(iii) and (iv).

3.0 CURRENT SEISMIC SAFETY FACTOR ASSESSMENT

Stantec reviewed the results of the initial seismic safety factor assessment as well as the changes in site conditions that have occurred in the past five years. The following items summarize changes that have occurred:

1. Coal fired power generation at Johnsonville ceased operation in December 2017. The plant is currently undergoing stages of demolition.

2. The Interim Flow Management system (IFM) was activated April 2021. All previous flows to the pond are now processed through the IFM and then discharged directly into two of the spillway structures. The spillway was modified to handle the flow from the IFM with no reduction in conveyance capacity. The pond level has been reduced by about two feet, resulting in a positive effect on stability by reducing the phreatic levels within the dike.

3. Cross-sectional geometry of the perimeter dike system has not changed.

4. Summer and winter pool levels for Kentucky Lake have remained unchanged.

5. Annual and weekly inspections conducted since 2015 were reviewed as part of this assessment. No areas of interest were identified that warrant remediation of deficient seismic stability conditions.

6. Monthly instrumentation (i.e., piezometer) monitoring conducted since 2015 has been reviewed and the phreatic condition at the critical section of Active Ash Pond 2 has reduced or remained consistent.

7. Current ground motion parameters were compared to those used in the initial seismic assessment using the USGS unified hazard tool website. The current parameters are representative of those used in the initial seismic assessment.

Based on our review there are no conditions that have changed in the past five years that would cause the results of the initial seismic stability assessment to have changed.

4.0 SUMMARY OF ASSESSMENT

Based on review of the initial seismic safety factor assessment and the items listed in Section 3.0, the result of this periodic seismic safety factor assessment is that the Active Ash Pond 2 at Johnsonville meets the requirements of §257.73(e)(1)(iii) & (iv) of the EPA CCR Rule.

5.0 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

I, Stephen H. Bickel, being a Professional Engineer in good standing in the State of Tennessee, do hereby certify, to the best of my knowledge, information, and belief:

1. That the information contained in this certification is prepared in accordance with the accepted practice of engineering;
2. That the information contained herein is accurate as of the date of my signature below; and
3. That the seismic safety factor assessment for the TVA Johnsonville Fossil Plant's Active Ash Pond 2 meets the requirements of 40 CFR 257.73(e)(1)(iii) and (iv).

SIGNATURE Stephen H. Bickel DATE 10/12/2021

STEPHEN H. BICKEL
No. 113134

ADDRESS: Stantec Consulting Services Inc.
10509 Timberwood Circle, Suite 100
Louisville, Kentucky 40223-5308

TELEPHONE: (502) 212-5075

ATTACHMENTS: Initial Seismic Safety Factor Assessment Report

References:

Stantec Consulting Services Inc. (2016). Safety Factor Assessment, Johnsonville Fossil Plant, Active Ash Pond 2, New Johnsonville, Humphreys County, Tennessee. Prepared for Tennessee Valley Authority, October 6

Geocomp (2016). Initial Seismic Safety Factor Assessment, EPA Final CCR Rule, TVA Johnsonville Fossil Plant Active Ash Pond 2, New Johnsonville, Tennessee; October 15

INITIAL SEISMIC SAFETY FACTOR ASSESSMENT

Revision 0. October 15, 2016

October 15, 2016

Tennessee Valley Authority
1101 Market Street
Chattanooga, TN 37402

RE: Initial Seismic Safety Factor Assessment
EPA Final CCR Rule
TVA Johnsonville Fossil Plant Active Ash Pond 2
New Johnsonville, Tennessee

Dear Sir/Madam:

TVA retained Geocomp Corporation (Geocomp) to prepare a seismic and liquefaction factor of safety assessment to meet the EPA's requirements under the HAZARDOUS AND SOLID WASTE MANAGEMENT SYSTEM; DISPOSAL OF COAL COMBUSTION RESIDUALS FROM ELECTRIC UTILITIES; FINAL RULE [RIN-2050-AE81; FRL-9919-44-OSWER]. This letter provides a brief project background, summary of findings, limitations, and certification.

1.0 BACKGROUND

As required by §257.73 of the EPA Final CCR Rule, within 18 months of the published date (April 17, 2015), an initial structural integrity evaluation for seismic loading is required and must include initial assessments of seismic factor of safety and liquefaction factor of safety for each existing CCR surface impoundment that meets the conditions of paragraph (b) as follows:

1. Has a height of five feet or more and a storage volume of 20 acre-feet or more; or
2. Has a height of 20 feet or more.

The seismic and liquefaction factor of safety assessments must document whether the calculated factors of safety for the critical cross section of each existing CCR surface impoundment achieve the minimum factors of safety specified in paragraphs (e)(1)(iii) and (e)(1)(iv) of §257.73 in the EPA Final CCR Rule. In accordance with paragraph (f)(2), the owner or operator of the existing CCR surface impoundment may elect to use a previously completed assessment to serve as the initial assessment required by paragraph (e) of the EPA Final CCR Rule provided that the previously completed assessment(s) was completed no earlier than 42 months prior to October of 2016, and meets the applicable requirements of paragraph (e) of the EPA Final CCR Rule.

In support of the above assessment, Geocomp completed a subsurface and laboratory investigation, seismic stability evaluation, and liquefaction assessment for Active Ash Pond 2 at the Johnsonville Fossil Plant in New Johnsonville, Tennessee. Information gathered through the subsurface and laboratory investigation, completed in October of 2016, was used to supplement data collected by Stantec in 2010, 2012, and 2013. The above information was provided in the Stantec report titled "Report of Geotechnical Exploration and Slope Stability Evaluation, Ash Disposal Areas 2 and 3 (Active Ash Disposal Area), Johnsonville Fossil Plant, New Johnsonville, Tennessee" dated April 13, 2010; letter from R.L. Roberts of Stantec to M.S. Turnbow of TVA titled " Results of Pseudo-static Slope Stability Analysis, Active CCP Disposal Facilities BRF, COF, GAF, JSF, JOF, KIF, PAF, and WCF" dated February 15, 2012; letter from S.H. Bickel and R.L. Roberts of Stantec to J. C. Kammeyer of TVA titled "Response to Recommendations USEPA CCR Impoundment Assessment DRAFT Report, Johnsonville Fossil Plant (JOF), New Johnsonville, Tennessee" dated October 3, 2012; and Stantec static slope stability analysis results using 2013 Piezometric Levels for Johnsonville Fossil Plant Active Ash Pond 2 downloaded from TVA *i*SiteCentral site on June 9, 2015. A complete listing of documents reviewed and utilized as part of this assessment is included in the Attachment.

2.0 SUMMARY OF FINDINGS

Based on a review of the available information from documents listed in the Attachment and Geocomp's stability evaluations associated with Active Ash Pond 2, Cross Section C-C' was selected as the critical cross section at Active Ash Pond 2 of the Johnsonville Fossil Plant. Table 1 below provides a summary of the factors of safety for the critical cross section.

Table 1. Summary of Factors of Safety for Critical Cross Section

Plant	Facility	Critical Cross Section	EPA Criteria	CCR Rule Reference	EPA Required FOS	Factor of Safety (FOS)
JOF	Active Ash Pond 2	C-C'	Seismic Factor of Safety (Pseudo-static stability)	§257.73(e)(1)(iii)	1.00	1.37
			Liquefaction Factor of Safety (Post-earthquake stability)	§257.73(e)(1)(iv)	1.20	1.25

Based upon the information presented in Table 1, it is Geocomp's opinion that these factors of safety meet or exceed the requirements of those specified in the EPA CCR Final Rule §257.73 paragraphs (e)(1)(iii) and (e)(1)(iv). Analyses supporting these factors of safety are presented in Geocomp's report to TVA entitled "Tennessee Valley Authority EPA Seismic Assessment Supplemental Site Exploration Johnsonville Fossil Plant Active Ash Pond 2 Final Report" dated October 2016.

3.0 LIMITATIONS

The signature of Geocomp's authorized representative on this document represents that to the best of Geocomp's knowledge, information, and belief in the exercise of its professional judgment, Geocomp's professional opinion is that the aforementioned information is accurate as of the date of such signature. Any opinion or decisions by Geocomp are made on the basis of this information, the engineering analyses, and Geocomp's experience, qualifications, and professional judgment and are not to be construed as warranties or guaranties. In addition, opinions relating to environmental, geologic, and geotechnical conditions or other estimates are based on available data and the actual conditions may vary from those encountered at the times and locations where data were obtained, despite the use of due care.

4.0 CERTIFICATION

I, W. Allen Marr, being a Registered Professional Engineer in the State of Tennessee do hereby certify to the best of my knowledge, information, and belief that the information contained in this report is true and correct and has been prepared in accordance with accepted engineering practice.

SIGNATURE W. Allen Marr DATE 10-15-16

ADDRESS: Geocomp Corporation, 125 Nagog Park, Acton, MA 01720

TELEPHONE: 978-635-0012

ATTACHMENTS: Demonstration Document for Seismic Factor of Safety and Liquefaction Factor of Safety for TVA Johnsonville Fossil Plant, Active Ash Pond 2, New Johnsonville, Tennessee.

WILLIAM ALLEN MARR
No. 00115016
W. Allen Marr

Geocomp

Attachment:

Demonstration Document for Seismic Factor of Safety and Liquefaction Factor of Safety for TVA Johnsonville Fossil Plant, Active Ash Pond 2, New Johnsonville, Tennessee.

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Appendix A: Slope Stability Analysis Results for Critical Cross Section

1.0 INTRODUCTION

1.1 OBJECTIVE

On April 17, 2015 the "Final Rule: Disposal of Coal Combustion Residuals (CCR) from Electric Utilities" (Environmental Protection Agency, 2015) was published in the Federal Register. Geocomp Corporation (Geocomp) was contracted by the Tennessee Valley Authority (TVA) to analyze the Structural Integrity Criteria for the Johnsonville Fossil Plant (JOF) CCR surface impoundments and to evaluate compliance with §257.73(e)(1) (iii) and (iv) of the Environmental Protection Agency (EPA) Final CCR Rule.

1.2 OUTLINE OF RULE REQUIREMENTS

As required by §257.73(e)(1) (iii) and (iv) of the EPA Final CCR Rule, an initial structural integrity evaluation is required by October 17, 2016 and must include an initial seismic and liquefaction factor of safety assessment for each existing CCR surface impoundment that meets the conditions of paragraph (b) as follows:

- Has a height of five feet or more and a storage volume of 20 acre-feet or more; or
- Has a height of 20 feet or more.

§257.53 requires seismic stability assessments of CCR impoundments consider a seismic event with 2% Probability of Exceedance in 50 years (i.e. probable earthquake within approximately 2,500 years) and a Horizontal Spectral Response Acceleration for 1.0-second period (5% of Critical Damping). The safety factor assessment must document whether the calculated factors of safety for each existing CCR surface impoundment perimeter dike demonstrate the minimum seismic and liquefaction factors of safety specified in paragraphs (e)(1)(iii) and (e)(1)(iv) of the EPA Final CCR Rule for the critical cross section of the embankment.

As mandated by the EPA, TVA is required to evaluate all of its active CCR impoundment facilities for seismic factors of safety and liquefaction factors of safety. The EPA established requirements for the minimum "seismic factor of safety" and the minimum "liquefaction factor of safety". Geocomp interprets what the EPA Final CCR Rule calls "seismic factor of safety" to be what geotechnical engineers call "pseudo-static factor of safety". Geocomp interprets what the EPA's final rule calls "liquefaction factor of safety" to be what geotechnical engineers call "post-earthquake" or "post-shaking" factor of safety. The EPA Final CCR Rule requirements for seismic and liquefaction factors of safety are summarized in Table 1.1.

Table 1.1: Factor of Safety Criteria

CCR Rule Criteria	CCR Rule Factor of Safety Requirements	CCR Rule Reference
Seismic Factor of Safety	≥ 1.00	§257.73(e)(1)(iii)
Liquefaction Factor of Safety	≥ 1.20	§257.73(e)(1)(iv)

1.3 DESCRIPTION OF FACILITY

The JOF facility is located in west-central Tennessee, along U.S. Highway 70 near the town of New Johnsonville, Tennessee. The facility is situated on the east bank of Kentucky Lake. The CCR surface impoundment being evaluated at JOF is Active Ash Pond 2, a 125-acre impoundment connected to the eastern shore by a causeway. The causeway divides Boat Harbor Channel and the Condenser Water Inlet Channel. Earthen dikes armored with rip rap form the northern, eastern, western, and southern perimeter of Active Ash Pond 2. TVA has determined that Active Ash Pond 2 is a CCR surface impoundment and, therefore, is subject to the EPA Final CCR Rule. Figure 1.1 shows an aerial view of the impoundment.

Figure 1.1: Johnsonville Fossil Plant

2.0 PROJECT RECONNAISSANCE

2.1 REVIEW OF EXISTING AND READILY AVAILABLE DATA

Geocomp’s review of existing and readily available data included the following documents:

- Atkinson, G., & Beresnev, I. (2002, April). Ground Motions at Memphis and St. Louis from M7.5-8.0 Earthquakes in the New Madrid Seismic Zone. Bulletin of the Seismological Society of America, 92(3), 1015-1024.
- Cramer, C., Gomberg, J., Schweig, E., Waldron, B., & Tucker, K. (n.d.). The Memphis, Shelby County, Tennessee, Seismic Hazard Maps. USGS Open-File Report 04-1294.
- Hardeman, W. D. (1966). Geologic Map of Tennessee, Department of Conservation, Tennessee Division of Geology.
- Hickman, J. (2013). Rough Creek Graben Consortium Final Report. Kentucky Geological Survey, Contract Report 55.
- Miller, R., Wilson, C., & Fullerton, D. (1964). Geologic Map and Mineral Resources. Summary of the Laguardo Quadrangle: Tennessee Division of Geology, Geologic Quadrangle Map 313 SW, scale 1:24,000.
- Smith, K. E. (2016). Physiography of Tennessee. Tennessee Archeology Net. Retrieved from http://web.archive.org/web/20071106142349/http:/www.mtsu.edu/~kesmith/TNARCHNET/physio.html#MValley
- Stantec Consulting Services, Inc. (2010). Report of Geotechnical Exploration and Slope Stability Evaluation Ash Disposal Areas 2 and 3 (Active Ash Disposal Area), Johnsonville Fossil Plant, New Johnsonville, Tennessee.
- Stantec Consulting Services, Inc. (2012, February 15). Letter from R.L. Roberts of Stantec to M.S. Turnbow of Tennessee Valley Authority. Results of Pseudo-static Slope Stability Analysis Active CCP Disposal Facilities BRF, COF, JOF, JSF, JOF, KIF, PAF, and WCF, Reference No.: ltr_002_175551015.
- Stantec Consulting Services, Inc. (2012, October 3). Letter from S.H. Bickel and R.L. Roberts of Stantec to J. C. Kammeyer of TVA titled “Response to Recommendations USEPA CCR Impoundment Assessment DRAFT Report, Johnsonville Fossil Plant (JOF), New Johnsonville, Tennessee” Reference No.: ltr_006_175551015_rev0.
- Stantec Consulting Services, Inc. (2013). Static Slope Stability Analysis Results based on 2013 Piezometric Levels, downloaded from TVA iSiteCentral system on June 9, 2015.
- Weary, D., & Doctor, D. (n.d.). Karst in the United States: A Digital Map Compilation and Database. U.S. Geological Survey Open-File Report 2014-1156(2331-1258), 23. Retrieved from http://dx.doi.org/10.3133/ofr20141156

3.0 APPROACH TO SEISMIC ASSEMENT

Geocomp’s general approach to assess the likely performance of a CCR impoundment’s seismic conditions is summarized in Figure 3.1. Please refer to Geocomp (2016) for a detailed discussion of the seismic assessment approach. This approach is applied to impoundments where prior simplified analyses show a potential problem with seismic stability.

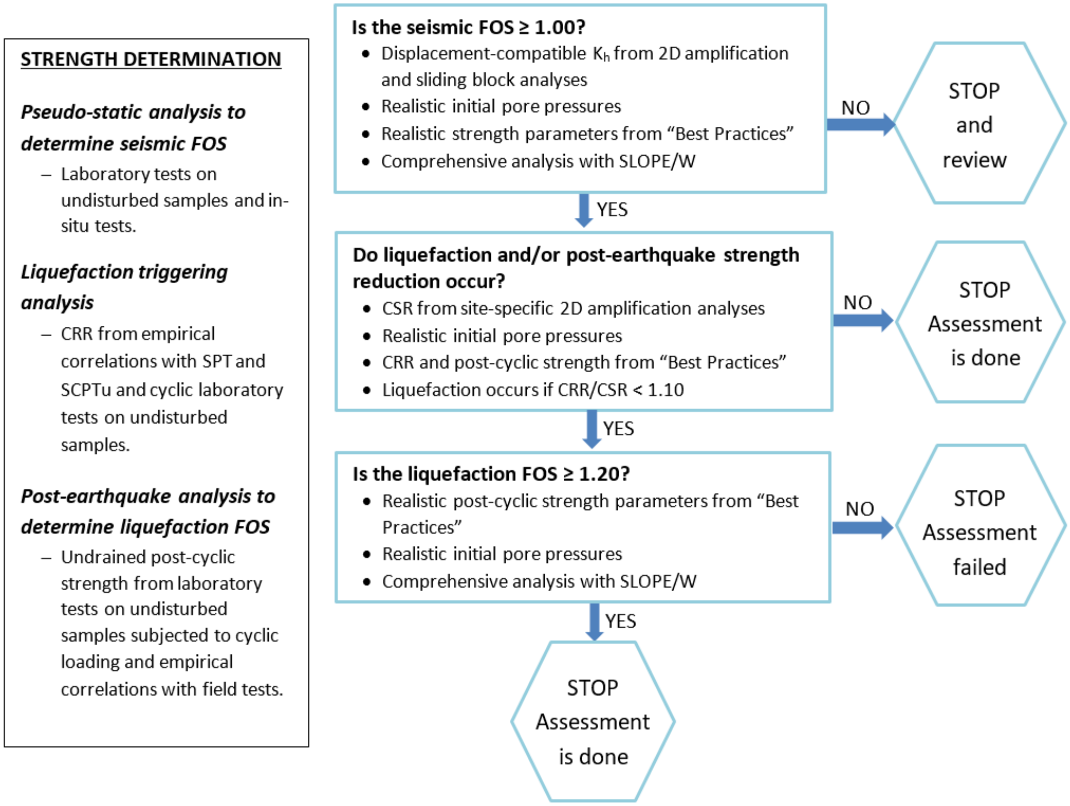

Figure 3.1: Summary of Technical Approach for Seismic Assessment

4.0 SEISMIC ASSESSMENT

4.1 SEISMICITY

The JOF facility is located at the northern end of a thick sequence of Cretaceous period deposits in an area known as the Mississippi Embayment. These thick deposits of sediments have a significant effect on earthquake ground motions. While damaging earthquakes in west central Tennessee are only moderately likely, ground motions are dominated by events originating in the New Madrid Seismic Zone. This zone is defined by a clustered pattern of earthquake hypocenters between 5 and 15 km deep. The JOF facility is located approximately 96 km from the center of this seismic zone. Figure 4.1 shows the peak and spectral accelerations at a period of 1.0-second for a 2% probability of exceedance in 50 years, equivalent to a return period of approximately 2,500 years, for JOF obtained from the USGS website (http://geohazards.usgs.gov/hazardtool/application.php last accessed 08/01/16). The seismic design criteria are summarized in Table 4.1. The 2,500-yr ground motion levels at the JOF facility are dominated by earthquakes generated in the New Madrid Fault Zone.

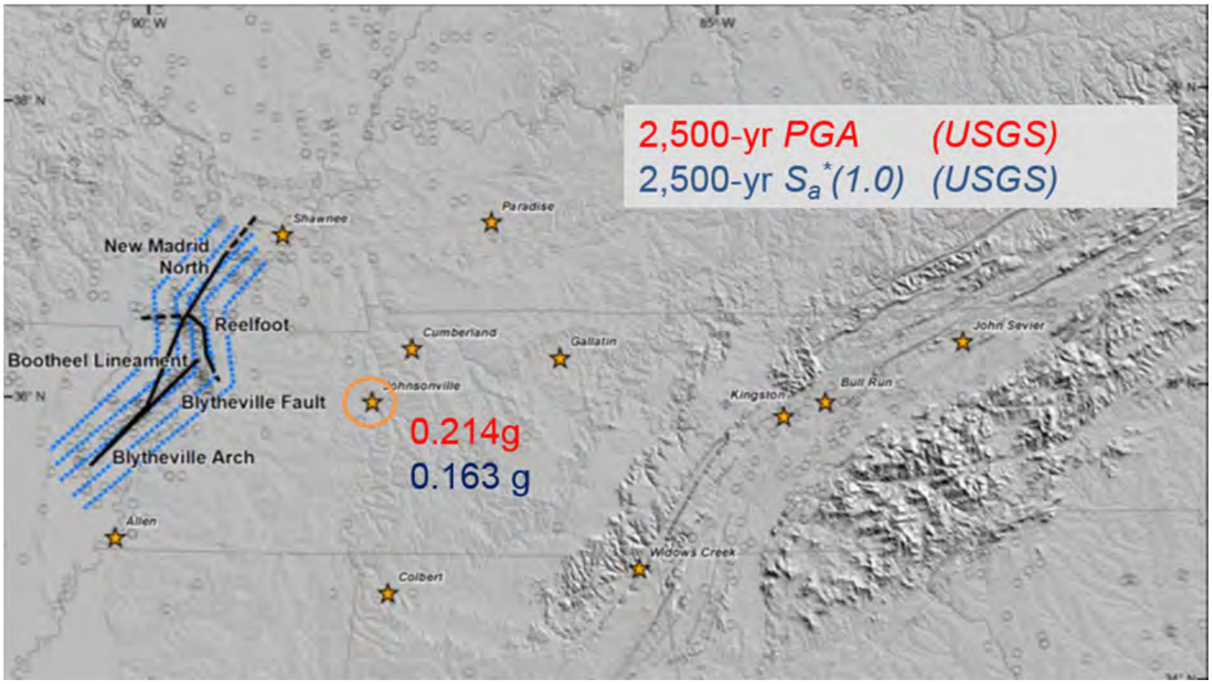

Figure 4.1: Peak Acceleration Values 2,500-yr Return Periods at JOF

Table 4.1: Johnsonville Fossil Site Summary of Seismic Design Parameters

Parameter	Value
Uniform Hazard Peak Ground Acceleration – Hard Rock (A)	0.214g
Design Peak Ground Acceleration – Hard (A)	0.24g(1)
Design Peak Ground Acceleration – Soil Class (D)	0.39g(1)
Uniform Hazard Spectral Acceleration at a period of 1.0 second	0.163g
Uniform Hazard Spectral Acceleration at a period of 0.2 second	0.381g
Mean Moment Magnitude	M7.02
Mean distance to seismic event	96.0 km
Uniform Hazard Response Spectra	See Figure 4.2

(1) Design PGA values from the 2015 NEHRP Provisions (FEMA 2015).

The site-specific seismic amplification analyses used seven ground motion time histories that have spectral contents that match the uniform hazard response spectrum (UHRS) shown in Figure 4.2. The development of these input ground motions started with the selection of recorded earthquake time histories that approximate the design criteria. These motions have response spectra with shapes similar to that of the UHRS and ground motion durations within the range expected for the deaggregated mean magnitude. The recorded motions were then modified by adding and subtracting wavelets using the software SeismoMatch (SeismoSoft 2016) until the resulting response spectra closely matched the UHRS.

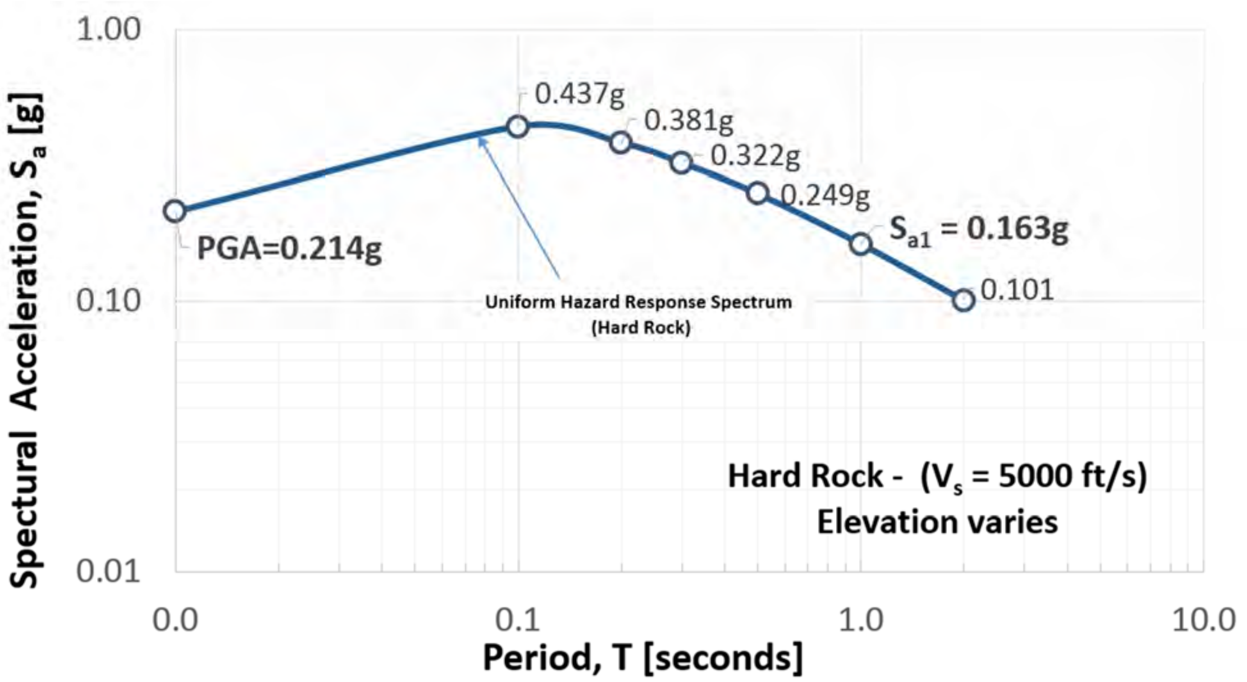

Figure 4.2: USGS Uniform Hazard Response Spectra (UHRS)

The site-specific seismic study conducted for JOF is based on the design response spectra developed by USGS as required by the EPA Final CCR Rule and presented in Figure 4.2. Table 4.2 summarizes the time history records selected for the site-specific amplification analysis.

Table 4.2: Time Histories Used in the Analysis

Motion	Earthquake	Arias Intensity [cm/sec]	Significant Duration [sec]	Spectral Acceleration at 1s Sa(1s) [g]
Motion 1	Synthetic Bootheel	198	41	0.148
Motion 2	Synthetic Reelfoot	35	21.6	0.112
Motion 3	Iwate, Japan @ Machimukai Town, UD, 2008 (ROT50)	48.8	29.5	0.159
Motion 4	Quintay Long, Chile 1985	125	39	0.130
Motion 5	Caleta de Campos, 1985	47.3	27.3	0.129
Motion 6	Chi TCU046 (ROTD50)	43.2	18.4	0.168
Motion 7	El Mayor-Cucapah, Mexico @ Sam W. Stewart 2010 (ROT50)	9.6	30.6	0.066

4.2 SELECTION OF CROSS SECTIONS FOR ASSESSMENT

Geocomp's review of existing and readily available information resulted in the selection of five cross sections as potential critical cross sections for further evaluation. Additional site subsurface explorations were planned and conducted to fill data gaps.

Stantec (2010) presented results of analyses on nine cross sections for static stability. The lowest long-term static factor of safety for global slope failure was 1.2 at Cross Section C-C’. The lowest long-term static factor of safety for drained non-global slope failure was 1.0 at Cross Section B-B’. The non-global failure modes were shallow, sloughing type failure modes on the slopes of the dikes which do not produce a risk of the release of the retained ash materials.

The most current static factors of safety made available to Geocomp were those performed by Stantec based on 2013 piezometer levels (Stantec 2013). These were downloaded from the *i*SiteCentral™ site for TVA’s facilities on June 17, 2015. The lowest static factor of safety obtained for Active Ash Pond 2 was 1.55 at Cross Section M-M’.

Stantec (2012a) presented results of pseudo-static stability analysis performed on Cross Section K-K’ under a seismic event with a 2,500-year return period. This analysis resulted in seismic factor of safety of 1.0 for this cross section. Also in 2012, Stantec (2012b) performed a liquefaction triggering assessment for Active Ash Pond 2 using a seismic event with a return period of 2,500 years (Stantec 2012). This assessment was based on SPT-N values and results from laboratory tests. Stantec performed this analysis on Cross Section K-K’ and reported that the saturated ash and alluvial sand and gravel were anticipated to undergo liquefaction for the 2,500-year earthquake. Stantec also analyzed Cross Section K-K’ for post-earthquake stability and found the liquefaction factor of safety to be 1.0. This result was dependent on residual strengths of the liquefied layer determined using SPT-N values.

Based on these results, it was determined that a more site-specific assessment be made for seismic and liquefaction factors of safety to determine if Active Ash Pond 2 meets or exceeds the EPA Final CCR Rule requirements. We concluded that this further assessment should include Cross Sections B-B’, C-C’, E-E’, H-H’, and K-K’ at Active Ash Pond 2 of the JOF facility.

4.3 FIELD INVESTIGATIONS

The field investigation for the current assessment included eight borings with standard penetration testing and undisturbed sampling and fourteen seismic cone penetration testing with pore pressure measurements (SCPTu). The generalized subsurface conditions encountered at the critical cross section at JOF are summarized in Table 4.3. A more in-depth presentation of the field investigation is found in Geocomp (2016).

Table 4.3: Generalized Subsurface Conditions at Cross Section C-C’

JOF Cross Section C-C'		
Soil Layer	**Approximate Elevation (ft)**	**General Consistency/Density**
Upper Dike	392 - 378	Stiff to very stiff lean CLAY with average PI=18
Lower Dike	378 – 370	Stiff to very stiff lean CLAY with average PI=31
Fill	370 - 350	Medium stiff to very stiff lean CLAY with average PI=23
Alluvial Clay	350 - 332	Medium stiff to very stiff lean CLAY with average PI=20
Alluvial Sand and Gravel	332 - 290	Medium dense to dense non-plastic silty SAND and GRAVEL

During the 2016 geotechnical explorations, Geocomp performed a laboratory testing program consisting of index parameters including natural moisture content, sieve and hydrometer analyses, Atterberg limits, specific gravity, and bulk density. The laboratory testing program also included constant rate of strain consolidation tests, direct simple shear tests, cyclic direct simple shear with post-cyclic monotonic strength measurement, modulus and damping versus strain using fixed-based resonant column, and shear wave measurements using bender element sensors. Geocomp (2016) provides detailed results of the laboratory testing program.

4.4 WATER CONDITIONS

4.4.1 Surface Water

For Boat Harbor Channel, a pool level of El. 357.2 feet was used for the slope stability analyses based on measurements of mean total head from automated water level gauge "JOF_TennRiver_RL" between 1/10/2013 and 7/27/2016 and an aerial survey dated April 22, 2016 provided to Geocomp by TVA.

Table 4.4 summarizes the surface water levels used in the seismic assessment of the critical cross section at JOF.

Table 4.4: Surface Water Level at Cross Section C-C'

Surface Water Levels	
Pond	**Total Head (ft)**
Boat Harbor Channel	357.2

4.4.2 Pore Water

The pore water conditions at the critical cross section, Cross Section C-C', are based on recent and historical piezometer data and results from recent SCPTu pore pressure dissipation tests. They show a decrease in total head within the fill and foundation clay layers. This indicates downward flow and pore water conditions below the phreatic surface that are less than hydrostatic. Table 4.5 summarizes the piezometric conditions used in the analyses for Cross Section C-C'.

Table 4.5: Summary of PZ Data at Cross Section C-C'

JOF Cross Section C-C' Total Head		
Soil Layer	**Total Head at Crest (ft)**	**Total Head at Toe (ft)**
Upper Dike	369.3	---
Lower Dike	369.3	---
Fill	360.8 – 369.3	361.2
Alluvial Clay and Silt	358.1 – 360.8	358.9 – 361.2
Silty Sand	358.1	358.5 – 358.9
Alluvial Sand and Silt	358.1	358.3
Clayey Gravel	358.1	358.3

4.5 MATERIAL PARAMETERS

Table 4.6 summarizes the material parameters used in the site-specific amplification analyses and for the calculation of seismic factors of safety at the critical cross section. Table 4.7 summarizes the material parameters used for the calculations of liquefaction factors of safety at the critical cross section. Please refer to Geocomp (2016) for details of the soil parameter development.

Table 4.6: Parameters used for Amplification Analyses and Calculation of Seismic Factor of Safety at Cross Section C-C'

Soil Layers	Strength Parameters			Amplification Parameters			
	Unit Weight (pcf)	Friction Angle, ϕ' (deg)	Undrained Shear Strength (psf)	V_s(1) (ft/s)	G_{max}(2) (psf)	G_o(3) (psf)	n(4)
Upper Dike	130(7)	---	2,000	606	1.31E+06	1.47E+06	0.10
Lower Dike	125	---	2,000	829	2.67E+06	2.67E+06	0.10
Fill_1-C	125	34	---	951	3.51E+06	3.01E+06	0.45
Fill_1-T	120	---	2,000	588	1.29E+06	3.01E+06	0.45
Fill_2-C	125	---	1,000	989	3.80E+06	3.01E+06	0.45
Fill_2-T	120	---	919	1,030	3.96E+06	3.01E+06	0.45
Alluvial Clay and Silt_1-C	120	---	1,466	815	2.48E+06	1.51E+06	1.20
Alluvial Clay and Silt_1-T	120	---	770(7)	551	1.13E+06	1.51E+06	1.20
Alluvial Clay and Silt_2-C	115	---	1,376	872	2.72E+06	1.99E+06	0.35
Alluvial Clay and Silt_2-T	120	---	1,298	725	1.96E+06	1.99E+06	0.35
Alluvial Clay and Silt_3-C	118	---	2,000	811	2.41E+06	1.99E+06	0.35
Silty Sand	120	30	---	1,156	4.99E+06	4.38E+06	0.50
Alluvial Sand and Gravel	125	35	---	1,007	3.94E+06	3.37E+06	0.50
Clayey Gravel	130	42	---	1,007	4.10E+06	3.00E+06	0.50
Weathered Rock	130	Strong(5)		3,000(6)	---		
Bedrock	150			5,000(6)			

(1) V_s = shear wave velocity values selected from field SCPTu tests

(2) G_{max} = Low strain shear modulus

(3) G_o = Reference low strain shear modulus at atmospheric pressure (1 atm)

(4) n = Exponent on normalized initial mean effective stress

(5) In stability analyses the critical failure surfaces are not expected to extend into bedrock depths. The strength parameters are assumed much stronger that the soil layers to contain the slip surface search to within the soil layers.

(6) Estimated value
(7) Parameters updated in the seismic slope stability analyses based on laboratory test data made available after non-linear amplification analyses were performed.

Table 4.7: Parameters used for Calculation of Liquefaction Factor of Safety at Cross Section C-C'

Soil Layers	Static Strength Parameters			Post-Earthquake Strength Parameters		
				Sand-Like Materials	Clay-Like Materials	
	Unit Weight (pcf)	Friction Angle, ϕ' (deg)	Undrained Shear Strength (psf)	Undrained Residual Shear Strength S_r/σ'_v(2)	Undrained Shear Strength (psf)	Post-Cyclic Strength Reduction(1) (%)
Upper Dike	130	---	2,000	---	2,000	0
Lower Dike	125	---	2,000	---	1,560	22
Fill_1-C	125	34	---	0.12(3)	---	---
Fill_1-T	120	---	2,000	---	1,380	31
Fill_2-C	125	---	1,000	---	690	31
Fill_2-T	120	---	919	---	634	31
Alluvial Clay and Silt_1-C	120	---	1,466	---	1,100	25
Alluvial Clay and Silt_1-T	120	---	770	---	660	14
Alluvial Clay and Silt_2-C	115	---	1,376	---	1,101	20
Alluvial Clay and Silt_2-T	120	---	1,298	---	909	30
Alluvial Clay and Silt_3-C	118	---	2,000	---	1,600	20
Silty Sand	120	30	---	0.58(3)	---	---
Alluvial Sand and Gravel	125	35	---	0.58(3)	---	---
Clayey Gravel	130	42	---	N/A(4)	---	---
Weathered Rock	130	Strong(5)		---		
Bedrock	150					

(1) Strength reductions (%) applied to clay-like materials were based on laboratory post-cyclic undrained shear strength test results and experience from similar materials at other TVA sites
(2) S_r/σ'_v represents the residual undrained strength assigned to sand-like materials based on laboratory post-cyclic undrained shear strength test results and SPT- and CPT-based correlations (Idriss and Boulanger, 2008)
(3) Residual strength determined based on SPT-based correlations (Idriss and Boulanger, 2008)
(4) N/A: Not Applicable. No liquefaction expected. Post-cyclic strength is the same as the static strength.
(5) In stability analyses the critical failure surfaces are not expected to extend into bedrock depths. The strength parameters are assumed much stronger that the soil layers to contain the slip surface search to within the soil layers.

4.6 SEISMIC ANALYSES

4.6.1 Site-Specific Amplification

Site-specific two-dimensional amplification analyses were performed to model the seismic response of the soil profile at JOF. Two-dimensional equivalent-linear amplification analyses were performed at all cross sections evaluated using the finite element program QUAD4M to help determine the most critical cross section. Two-dimensional non-linear amplification analysis was performed for the critical cross section using the finite element program OpenSees and the results were checked with the finite difference program FLAC. Dynamic models and analyses with QUAD4M and OpenSees were carried out by the University of Washington team led by Professors Kramer and Arduino. Geocomp was responsible for the checking the OpenSees results using the FLAC model.

The results of these analyses were used to determine displacement-compatible accelerations used in the pseudo-static slope stability analyses to calculate the seismic factor of safety. The results of these analyses were also used to determine cyclic shear stresses for cyclic laboratory testing to measure post-cyclic strengths for the post-earthquake slope stability analyses to calculate the liquefaction factor of safety. Geocomp (2016) provides details for the site-specific amplification analyses.

4.6.2 Seismic Factor of Safety

The seismic factor of safety of the dike cross section was evaluated under pseudo-static loading conditions using pond levels and piezometric surfaces determined by existing instrumentation and survey data provided by TVA. The pseudo-static loading conditions were determined for applied displacement-compatible accelerations. The applied displacement-compatible accelerations were selected from results of the sliding block analyses described in detail in Geocomp (2016). These use an allowable seismic displacement of 18 inches to determine the equivalent horizontal earthquake coefficient for pseudo-static stability.

4.6.3 Liquefaction Triggering

The assessment of the factor of safety against liquefaction of discrete materials and layers within the soil profiles at each cross section was performed using a combination of the stress-based approach proposed by Idriss and Boulanger (2008) and updates to the approach given in Boulanger and Idriss (2014). The stress-based approach was used to calculate the Cyclic Resistance Ratio (CRR) through the soil profile. The results of the site-specific two-dimensional amplification analysis were used to obtain the Cyclic Stress Ratio (CSR) through the soil profile. The factor of safety against liquefaction for discrete materials and layers was then calculated as CRR/CSR. If this value was less than 1.10 then the specific material or layer evaluated was considered potentially liquefiable for the maximum design earthquake and its post-cyclic undrained residual strength was evaluated for use in the post-earthquake stability analysis.

4.6.4 Liquefaction Factor of Safety

The liquefaction factor of safety was calculated to evaluate the stability of the cross sections under post-earthquake conditions. For the purposes of liquefaction hazard evaluation, soils are often described as exhibiting “sand-like” or “clay-like” behavior. Sand-like soils typically have plasticity indices less than 7, and are considered susceptible to liquefaction. Clay-like soils have higher plasticity indices and are not considered susceptible to liquefaction, although they may experience some degree of strength loss from cyclic loading. Under these conditions, the sand-like materials that could potentially liquefy are modeled with undrained residual strengths. Sand-like materials that are not expected to liquefy are modeled with static strength parameters. Clay-like materials are modeled with reduced undrained shear strengths if they are expected to exhibit post-cyclic softening; otherwise these materials are modeled with undrained strength parameters. Piezometric conditions were kept the same for all seismic and post-earthquake stability analyses.

4.7 SELECTION OF CRITICAL CROSS SECTION

According to the seismic and liquefaction factors of safety obtained from the pseudo-static and post-earthquake slope stability analyses on the five chosen cross sections, Cross Section C-C’ is the critical cross section for Active Ash Pond 2.

5.0 ANALYSIS RESULTS

The slope stability results were obtained with the two-dimensional limit equilibrium program Slope/W. The seismic and liquefaction factors of safety for the critical cross section at Active Ash Pond 2 are summarized in Table 5.1. The minimum factors of safety reported in this table correspond to slip surfaces that could potentially result in the uncontrolled release of water and CCR materials from within the impoundment during or after the maximum design earthquake. Results of these stability analyses using the limit equilibrium slope stability method are presented in Appendix A of this report. Geocomp (2016) gives details of the slope stability analyses at Active Ash Pond 2.

Table 5.1: Summary of Seismic Assessment Results at Critical Cross Section C-C'

Plant	Facility	Cross Section	EPA Criteria	EPA Final CCR Rule Required Factor of Safety	Calculated Minimum Factor of Safety
JOF	Active Ash Pond 2	C-C’	Seismic Factor of Safety	≥ 1.00	1.37
			Liquefaction Factor of Safety	≥ 1.20	1.25

6.0 CONCLUSIONS

This report documents the evaluation of seismic and liquefaction factors of safety of Johnsonville Fossil Plant’s Active Ash Pond 2. The evaluation was performed in accordance with section §257.73(e) of the EPA Final CCR Rule.

The seismic assessment at JOF resulted in a seismic factor of safety of 1.37 [§257.73(e)(1)(iii)] and a liquefaction factor of safety of 1.25 [§257.73(e)(1)(iv)] for Active Ash Pond 2. These results meet or exceed the minimum required seismic factor of safety of 1.00 and liquefaction factor of safety of 1.20.

7.0 REFERENCES

Note: These references were used for the described work and are cited in the Geocomp 2016 report. They are not all cited in this summary report.

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Appendix A

Slope Stability Analysis Results for Critical Section

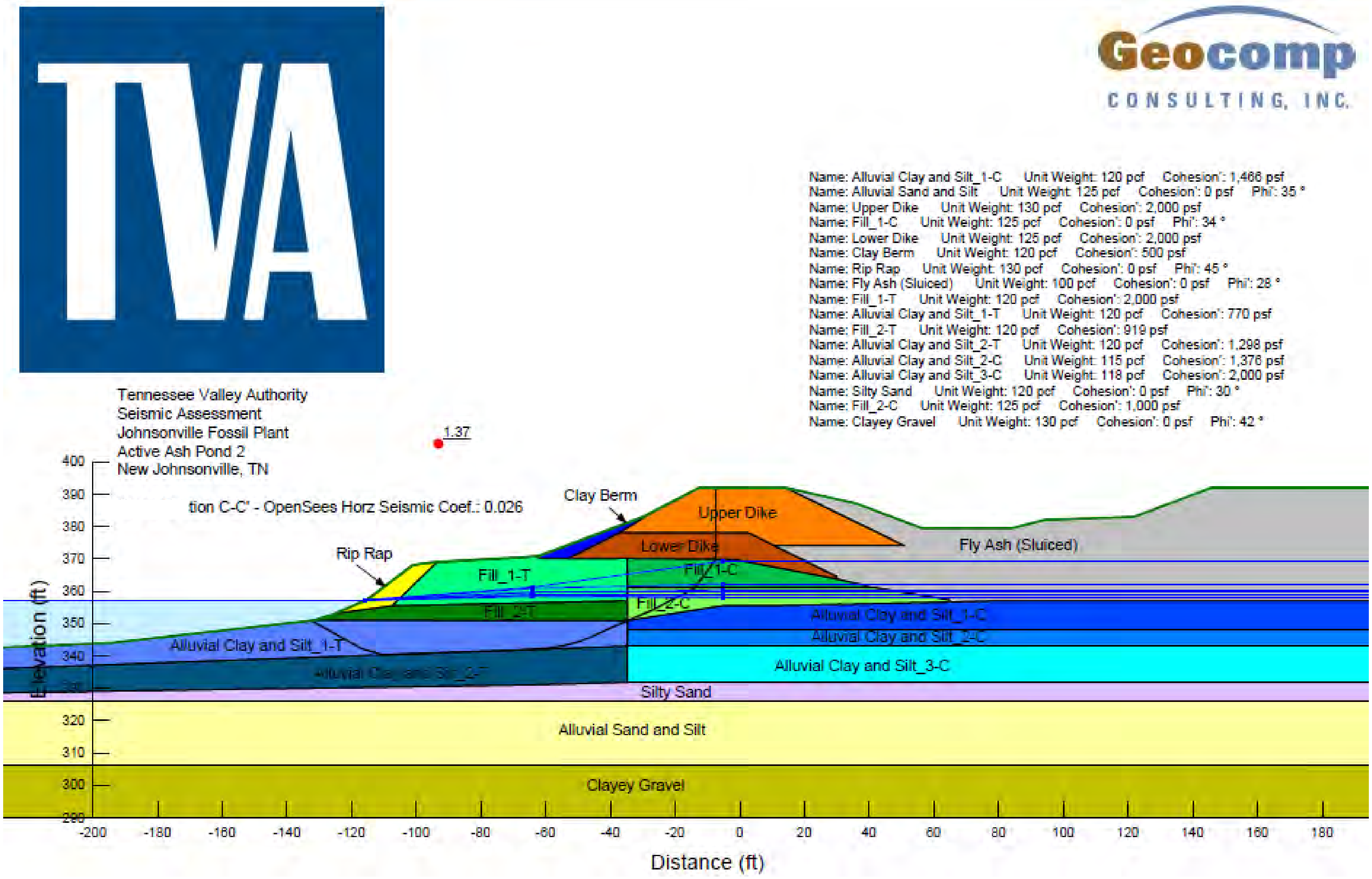
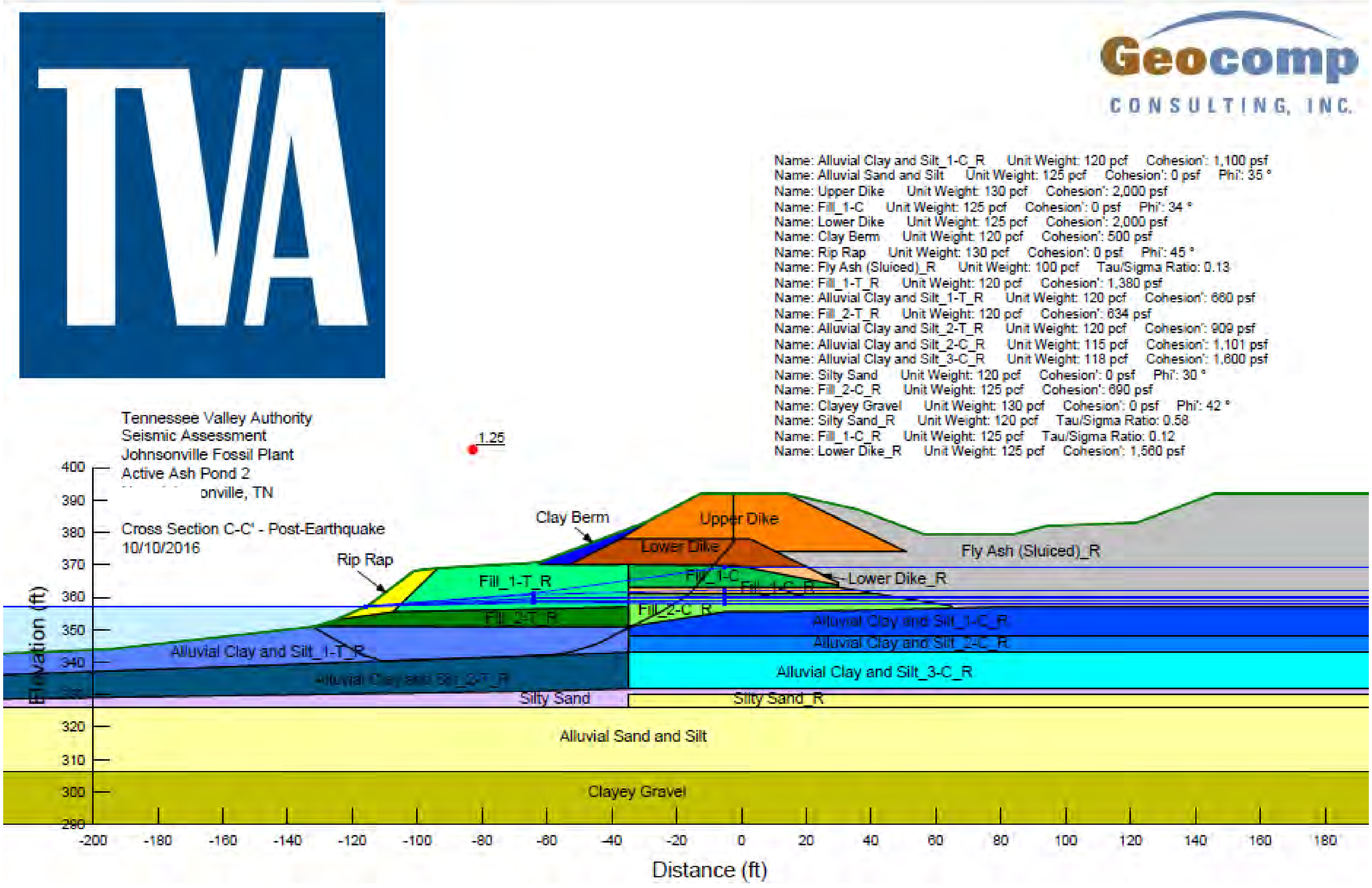


Figure A. 1: Seismic Factor of Safety by Pseudo-Static Slope Stability Analysis at Cross Section C-C'



Tennessee Valley Authority
Seismic Assessment
Johnsonville Fossil Plant
Active Ash Pond 2
onville, TN

Cross Section C-C' - Post-Earthquake
10/10/2016

Name: Alluvial Clay and Silt_1-C_R Unit Weight: 120 pcf Cohesion': 1,100 psf
Name: Alluvial Sand and Silt Unit Weight: 125 pcf Cohesion': 0 psf Phi': 35 °
Name: Upper Dike Unit Weight: 130 pcf Cohesion': 2,000 psf
Name: Fill_1-C Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 °
Name: Lower Dike Unit Weight: 125 pcf Cohesion': 2,000 psf
Name: Clay Berm Unit Weight: 120 pcf Cohesion': 500 psf
Name: Rip Rap Unit Weight: 130 pcf Cohesion': 0 psf Phi': 45 °
Name: Fly Ash (Sluiced)_R Unit Weight: 100 pcf Tau/Sigma Ratio: 0.13
Name: Fill_1-T_R Unit Weight: 120 pcf Cohesion': 1,380 psf
Name: Alluvial Clay and Silt_1-T_R Unit Weight: 120 pcf Cohesion': 660 psf
Name: Fill_2-T_R Unit Weight: 120 pcf Cohesion': 634 psf
Name: Alluvial Clay and Silt_2-T_R Unit Weight: 120 pcf Cohesion': 909 psf
Name: Alluvial Clay and Silt_2-C_R Unit Weight: 115 pcf Cohesion': 1,101 psf
Name: Alluvial Clay and Silt_3-C_R Unit Weight: 118 pcf Cohesion': 1,600 psf
Name: Silty Sand Unit Weight: 120 pcf Cohesion': 0 psf Phi': 30 °
Name: Fill_2-C_R Unit Weight: 125 pcf Cohesion': 690 psf
Name: Clayey Gravel Unit Weight: 130 pcf Cohesion': 0 psf Phi': 42 °
Name: Silty Sand_R Unit Weight: 120 pcf Tau/Sigma Ratio: 0.58
Name: Fill_1-C_R Unit Weight: 125 pcf Tau/Sigma Ratio: 0.12
Name: Lower Dike_R Unit Weight: 125 pcf Cohesion': 1,560 psf

Figure A. 2: Liquefaction Factor of Safety by Post-Earthquake Slope Stability Analysis at Cross Section C-C'