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October 7, 2016

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

Initial Static Safety Factor Assessment
Peabody Ash Pond
EPA Final CCR Rule
TVA Paradise Fossil Plant
Drakesboro, Kentucky

1.0 PURPOSE

This letter documents AECOM's certification of the initial static safety factor assessment for the TVA Paradise Fossil Plant's Peabody Ash Pond. Based on this assessment, the Peabody Ash Pond is in compliance with the static factors of safety specified in the Final CCR Rule at 40 CFR 257.73(e)(1)(i) and (ii).

2.0 INITIAL STATIC SAFETY FACTOR ASSESSMENT

The initial static safety factor assessment conducted pursuant to 40 CFR 257.73(e) addresses the following static factors of safety:

- Long-term, maximum storage pool loading condition; and
- Maximum surcharge pool loading condition.

AECOM compiled and reviewed available historical site, topographic and geotechnical data for the TVA Paradise Fossil Plant's Peabody Ash Pond as of October 07, 2016. A complete listing of documents reviewed is included in the attached references.

Based upon its review of these available documents, AECOM identified a cross section which is identified as the most critical cross section. This cross section is designated Section C-C'. It was analyzed for the loading conditions specified in 40 CFR 257.73(e)(1)(i) and (ii).

3.0 SUMMARY OF FINDINGS

The attached calculation package presents the static safety factor assessment for Section C-C' for the loading conditions specified in 40 CFR 257.73(e)(1)(i) and (ii). The calculated static factors of safety are shown in the following table. The results show that the calculated static factors of safety for Section C-C' exceed the minimum safety factors required under 40 CFR 257.73(e)(1)(i) and (ii).

Plant	Facility	Critical Cross Section	EPA Criteria	EPA Required Factor of Safety (FOS)	Calculated FOS
PAF	Peabody Ash Pond	C-C'	Long-term maximum storage pool loading condition	1.50	1.56
			Maximum surcharge pool loading condition	1.40	1.50

4.0 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

I, Nicholas S. Golden, P.E., being a Professional Engineer in good standing in the Commonwealth of Kentucky, 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 initial static safety factor assessment for the TVA Paradise Fossil Plant's Peabody Ash Pond presented in the table above meets the requirements of the static factors of safety specified in 40 CFR 257.73(e)(1)(i) and (ii).

SIGNATURE ______________________ DATE 10/7/16

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TELEPHONE: (330) 836 9111

ATTACHMENTS: Initial Safety Factor Assessment 40 CFR 257.73(e) for Coal Combustion Residuals (CCR); Existing Surface Impoundment-Peabody Ash Pond; TVA Paradise Fossil Plant

STATE OF KENTUCKY
NICHOLAS
GOLDEN
30816
LICENSED
PROFESSIONAL ENGINEER

COAL COMBUSTION PRODUCT DISPOSAL PROGRAM

TENNESSEE VALLEY AUTHORITY - PEABODY ASH POND
TVA PARADISE FOSSIL PLANT
DRAKESBORO, KENTUCKY

INITIAL SAFETY FACTOR ASSESSMENT
40 CFR §257.73(e)
FOR COAL COMBUSTION RESIDUALS (CCR)
EXISTING SURFACE IMPOUNDMENT

Prepared for

TVA

Tennessee Valley Authority
1101 Market Street
Chattanooga, TN 37402-2801

October 7, 2016 – Rev0

Prepared by

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STATE OF KENTUCKY
NICHOLAS
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LICENSED
PROFESSIONAL ENGINEER

10/7/16

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1.0 Introduction

1.1 Objective

On April 17, 2015 the “Final Rule: Disposal of Coal Combustion Residuals (CCR) from Electric Utilities” (CCR Rule) was published in the Federal Register by the Environmental Protection Agency (EPA). AECOM has been contracted by TVA to perform an initial safety factor assessment for the Paradise Fossil Plant (PAF) CCR surface impoundments and evaluate compliance with §257.73 of the CCR Rule.

1.2 Outline of CCR Rule Requirements

As required by §257.73 of the EPA Final CCR Rule, an initial safety factor assessment is required by October 17, 2016 and must include an initial safety factor assessment 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 safety factor assessment must document whether the calculated factors of safety for each existing CCR surface impoundment perimeter dike demonstrate the minimum static safety factors specified in paragraphs (e)(1)(i) and (e)(1)(ii) of the CCR Rule for the critical cross section of the embankment.

In addition, 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 CCR Rule provided that the previous 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. Note that only the static slope stability analyses load cases are covered in this assessment.

1.3 Description of Structure

PAF is a coal-fired, electric-generating plant. The plant is located in western Kentucky along the banks of the Green River, in Muhlenberg County. TVA has determined that the Peabody Ash Pond is a CCR surface impoundment and, therefore, is subject to the CCR rule. A plan view showing the Peabody Ash Pond is shown in **Figure 1**.

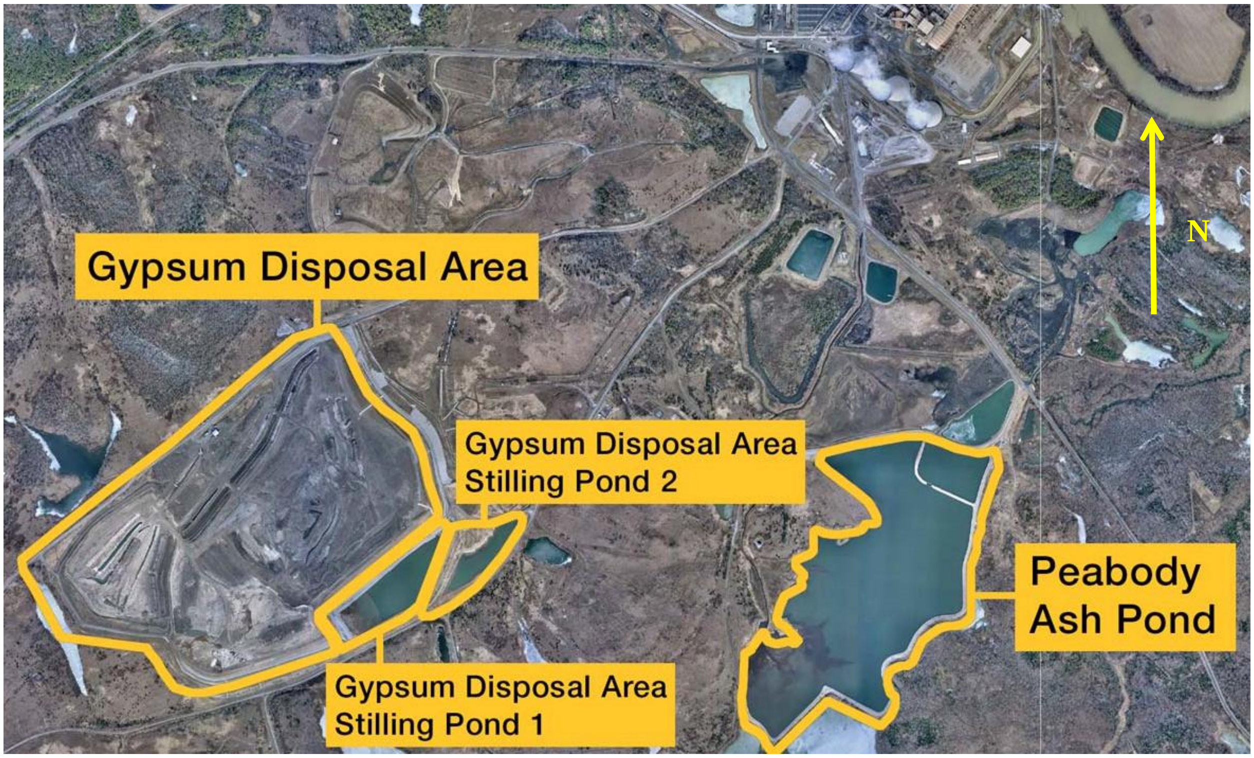

Figure 1: Aerial View of Peabody Ash Pond

The Peabody Ash Pond began operations in 1997 and encompasses approximately 100 acres in area. The dike which forms the Peabody Ash Pond is approximately 5,500 feet in length and varies in height from 12 to 20 feet.

The dike slopes are inclined approximately 2.5H:1V (horizontal:vertical) to 3H:1V. The toe of the upstream slope of the dike is armored with riprap, and well-maintained grassy vegetation is present between the riprap and crest. The downstream slope of the dike has an intermediate bench which appears to be the crest of the original dike. The upper portion of the downstream slope consists of well maintained, grassy vegetation, while the lower portions of the downstream slope consists of rip-rap along the majority of the length of the dike.

2.0 Project Reconnaissance

2.1 Review of Existing Data

As part of this demonstration, AECOM reviewed available historical information and completed a site reconnaissance visit. The existing data review included the following documents and drawings:

- AECOM, 2015. Report of Geotechnical Exploration for CCR Compliance, Peabody Ash Pond, Paradise Fossil Plant, Muhlenburg County, Kentucky.
- Stantec, 2010. Report of Geotechnical Exploration, Peabody Ash Pond, Paradise Fossil Plant, Muhlenberg County, Kentucky.,

- Stantec, 2009. Report of Phase 1 Facility Assessment, Coal Combustion Product Impoundments and disposal Facilities, Various Locations, Kentucky. Accessed from TVA public records.
- URS, 2012. Intermediate Dam Safety Inspection Report. Accessed from AECOM internal files.
- AECOM, 2015. Annual Instrumentation and Monitoring Program Final Report.
- TVA, 2014. Peabody Ash Pond Spillway and Slope Improvements, Sheets 1, drawing 10W720-04 through 10W720-14, May 16, 2014.
- TVA, 1995. Ash Disposal Area and Stilling Pond Extension Plan Details, 10W3274 Drawings 1-5.
- TVA, 1995. Ash Disposal Area, drawing 10N3259-SHT-REV 2.
- TVA, 1995. Ash Disposal Area Extension Plan, drawing 10N3259-1-SHT-REV-1.
- TVA, 1995. Ash Disposal Area Plan Discharge Spillways, drawing 10N3259-SHT-REV.
- TVA, 1996. Dike Construction, drawing 10W-3274-3.

2.2 Data Gaps

During review of the existing data, AECOM did not identify data gaps that would require additional geotechnical drilling/sampling, instrumentation, laboratory testing, or field surveying.

3.0 Summary of Field Investigations and Laboratory Testing

Two geotechnical explorations have been performed to characterize the Peabody Ash Pond. Stantec (2010) performed drilling and sampling including twenty-two hollow stem auger borings along the crest and exterior toe of the dike. In addition, nine of the borings were completed as piezometers.

AECOM (2015) performed an additional geotechnical exploration to supplement the existing data. The exploration included advancing four Cone Penetration Test (CPT) soundings with pore pressure dissipation testing along the crest of the dike.

These geotechnical explorations, laboratory testing, and conclusions were used as the basis of this analysis and are referenced in **Section 2.1**.

Recent topographic and bathymetric data was provided for Peabody Ash Pond (Tennessee Valley Authority, 2015; Tuck Mapping Solutions, Inc., 2014,). Additional topographic information was provided by TVA (2014) as part of the Ash Pond Spillway and Slope Improvements project.

Seismic stability analyses are being performed by another consultant as part of the 40 CFR §257.73(e)(1)(iii) and (iv).

4.0 Detailed Task Analysis Criteria

4.1 Material Properties

Based upon the results of the subsurface explorations, the subsurface materials that make up the Peabody Ash Pond dike are summarized below in **Table 1**. A more in-depth review is found in the above referenced AECOM Report of Geotechnical Exploration for CCR Compliance (2015).

Table 1: Generalized Subsurface Conditions

Materials	Approximate Elevation (feet MSL)	Consistency/ Relative Density
Raised Embankment – Mine Spoils generally consisting of moist, lean clay (CL) with some rock fragments.	408 to 395	Stiff
Original Embankment – Mine Spoils generally consisting of moist, lean, clay (CL) with irregular quantities of silt, sand, coal and rock fragments.	400 to 394	Stiff
Clayey Mine Spoils- Mine Spoils generally consisting of moist to wet lean clay (CL) with varying quantities of coal and rock fragments.	395 to 356	Medium Stiff to Very Stiff
Bottom Ash- generally consists of poorly graded sand sized particles (SP)	395 to 392	Loose to Medium Dense
Sluiced Ash-generally consists of silt sized particles (ML)	389 to 381	Soft to Medium
Sandy Mine Spoils- Mine Spoils generally consisting of clayey sand (SC) with varying quantities of rock and coal fragments.	378 to 373	Very loose to medium dense
Shale-fine grained, weathered, light gray.	356 to 346	Moderately hard

The 2010 geotechnical exploration performed by Stantec included a laboratory testing program consisting of natural moisture content testing, sieve and hydrometer analysis, Atterberg Limits, specific gravity, consolidated-undrained triaxial compression tests, and permeability testing was performed. Stantec used the laboratory test results to determine shear strength parameters for the subsurface materials. As part of the 2015 exploration performed by AECOM, the results of the Stantec analysis were used as a baseline and subsurface conditions were re-assessed based on the results of the CPT exploration. AECOM also re-assessed shear strength parameters for stability analysis by constructing p-q plots as described in Appendix D of the United States Corps of Engineers Manual EM-1110-2-1902 “and considering the CPT data. Overall, the subsurface conditions and shear strength parameters determined by AECOM were very similar to those determined by Stantec. The shear strength parameters developed by AECOM were used for this analysis and are summarized in **Table 2.**

Table 2: Strength Parameters for Stability Analysis

Soil Horizon	Wet Unit Weight (pcf)	Effective Stress Strength Parameters		Total Stress Strength Parameters	
		c' (psf)	ϕ' (degrees)	c (psf)	ϕ (degrees)
Raised Embankment	134	0	32	100	24
Original Embankment	134	0	32	100	24
Clayey Mine Spoils	124	0	30	100	22
Sandy Mine Spoils	129	0	32	0	27
Compacted Bottom Ash	125	0	33	0	30
Sluiced Fly Ash	100	0	24	0	20
Rip-rap	135	0	40	0	40
Bedrock (Shale)	Impenetrable				

4.2 Critical Cross Section Selection

Historic analyses were available for review from Stantec (2010) and AECOM (2015). Four primary cross sections have been constructed and analyzed as part of these studies. One cross section was constructed by Stantec and the remaining three were constructed by AECOM. The cross sections are discussed and summarized below.

Section A-A' was constructed by Stantec (2010) and reflects the geometry of the terminus of the Peabody Ash Pond dike with the lagoon to the south off TVA property as tailwater. AECOM (2015) replicated this cross section.

Section B-B' was constructed by AECOM (2015) and reflects the geometry of southern portion of the Peabody Ash Pond dike with Jacob's Creek as tailwater.

Section C-C' was constructed by AECOM (2015) and reflects the geometry of the central portion of the Peabody Ash Pond dike with Jacob's Creek as tailwater. This section was chosen because Jacob's Creek widens into a broad channel, providing minimal resistant force at and beyond the toe in comparison to other sections. In addition, this section contains the thickest interval of ash as determined from the geotechnical explorations.

Section D-D' was constructed by AECOM (2015) and the geometry of the northern portion of the dike with Jacob's Creek as tailwater.

Each cross section constructed and analyzed as part of Peabody Ash Pond is shown in plan view in **Figure 2.**

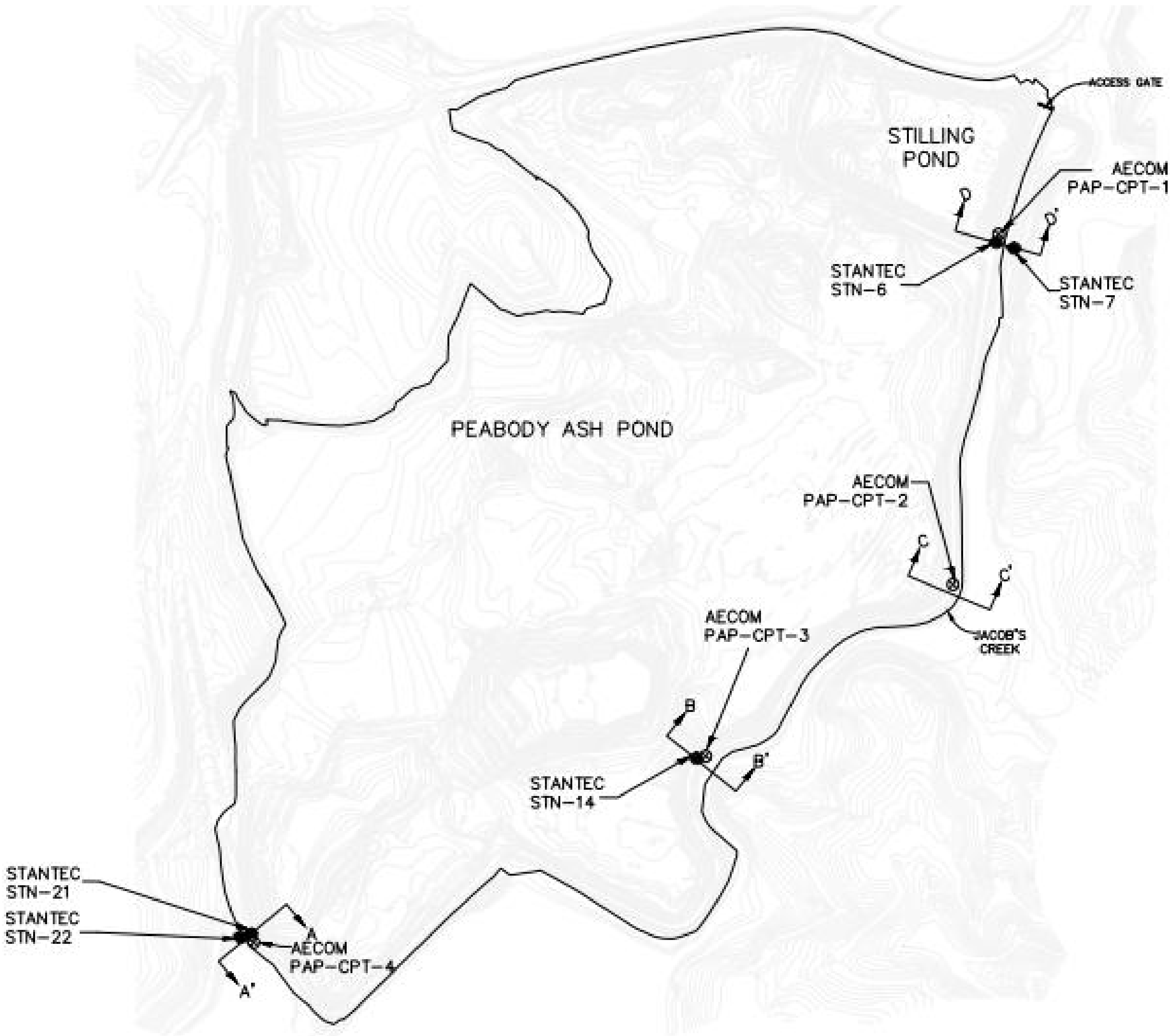

Figure 2: Plan View of Cross Sections

The summary of the historic stability analyses are provided below in **Table 3**.

Table 3: Historic Slope Stability Results

Cross Section	CCR Unit	CCR Rule Loading Condition	Factor of Safety (Global Failure, Exterior Slope)	Reference
A-A’	Peabody Ash Pond	Long-term Maximum Storage Pool	1.7[1]	Stantec (2010)
		Long-term Maximum Storage Pool	1.64	AECOM (2015)
		Maximum Surcharge Pool	1.61	AECOM (2015)
B-B’	Peabody Ash Pond	Long-term Maximum Storage Pool	1.91	AECOM (2015)
		Maximum Surcharge Pool	1.81	AECOM (2015)
C-C’	Peabody Ash Pond	Long-term Maximum Storage Pool	1.56	AECOM (2015)
		Maximum Surcharge Pool	1.50	AECOM (2015)
D-D’	Peabody Ash Pond	Long-term Maximum Storage Pool	1.69	AECOM (2015)
		Maximum Surcharge Pool	1.61	AECOM (2015)

[1]-Analysis was performed to only one significant figure.

As demonstrated in **Table 3**, Section C-C’ resulted in the lowest factor of safety when analyzed under static conditions. Therefore, Section C-C’ was selected as the critical cross section.

4.3 Water Levels

In consideration of the Initial Inflow Design Flood (IDF) analysis performed by AECOM (2016), the water elevation for Peabody Ash Pond was defined to meet the requirements of the EPA CCR Rule §257.82(a). The long term maximum storage pool elevation is the normal operating pool of Peabody Ash Pond, while the Maximum Surcharge Pool is the pool level determined from the IDF analysis (1,000 year, 6-hour storm). The pond elevations proposed for the static slope analyses are summarized below in **Table 4**.

Table 4: PAF Peabody Ash Pond Water Elevations for Stability Modeling

Loading Condition	Peabody Ash Pond Elevation (feet, MSL)
Long-term Maximum Storage Pool	405.0
Maximum Surcharge Pool	407.1

Jacobs Creek flows along the downstream toe of the Peabody Ash Pond dike from the off-property lagoon to the north and east toward its discharge point near the Green River. The ordinary high water elevation of Jacobs Creek varies from 396 feet to approximately 387 feet MSL near its discharge point based on surveying completed as part of the Peabody Ash Pond Spillway and Slope Improvements project (TVA 2014). At Section C-C', the ordinary high water elevation of Jacob's Creek was found to be elevation 395.2 feet. Generally, Jacob's Creek features a relatively narrow channel and width of flow.

4.4 Analysis Methodology

AECOM performed the static and seismic slope stability analyses using the GeoStudio 2012, Version 8.15.5.11777 software package developed by Geoslope, Inc. of Calgary, Alberta, Canada. The analysis was performed using the boundary conditions provided in Table 4. This package includes the SLOPE/W module for slope stability analysis. The analyses were performed in accordance with the guidelines in USACE Design Manuals EM 1110-2-1902 "Slope Stability" (United States Army Corps of Engineers, 2003).

The phreatic surface used in each stability analysis was based on a seepage analysis model performed using the SEEP/W module of the above referenced GeoStudio software. Seepage analysis parameters were determined from information published by the United States Bureau of Reclamation and historic laboratory testing. Values were then adjusted to calibrate the seepage models to the existing piezometer and field CPT dissipation data. The calibration process was completed until parameters were determined which yielded a reasonable correlation to field readings.

4.4.1 Long-Term Maximum Storage Pool §257.73(e)(i)

A drained, effective stress analysis was performed for this load case to evaluate slope stability in the downstream direction. This assessment used a phreatic surface based on the seepage analysis discussed in Section **4.4** and data provided in Table **4** and Section **4.3**.The required minimum factor of safety corresponds to the entry for "long-term maximum storage pool" in **Table 5**.

4.4.2 Maximum Surcharge Pool §257.73(e)(ii)

The maximum surcharge pool load condition is created by a rapid pool level rise during a flood. It is a temporary water level, higher than the normal pool, which does not last long enough to develop steady-state seepage within the impoundment embankment and foundation (USACE, 2003). The pool is assumed to rise faster than water can flow in or out of fine-grained soils, and the surcharge pressure may cause shear-induced, excess pore pressures in the saturated zones. This assumption is based on the significance of the surcharge pressure with respect to the size of the dike. Surcharge pressures are discussed further in **Section 5.0**.

Materials below the phreatic surface were considered saturated and modeled using undrained material properties. The partially saturated zones above the phreatic surface were modeled using drained material properties. This assessment used a phreatic surface based on the seepage analysis discussed in Section **4.4** and data provided in Table **4** and Section **4.3**.The required minimum factor of safety corresponds to the entry for “Maximum Surcharge Pool” loading condition in **Table 5**.

4.5 Acceptance Criteria

The following summary is taken from the EPA’s CCR Rule §257.73(e). The factor of safety assessment criteria are outlined in **Table 5** below.

Table 5: Factor of Safety Criteria

Loading Condition	CCR Rule Required Factor of Safety	CCR Rule Reference
Long-term, maximum storage pool	1.50	§257.73(e)(1)(i)
Maximum surcharge pool	1.40	§257.73(e)(1)(ii)

5.0 Analysis Assumptions

The following assumptions apply to this analysis.

- The goal of the analyses was to identify failures which would likely result in the release of ash. Therefore, incipient motion in the downstream direction was considered, and upstream directional failures were not included.
- The long-term maximum storage pool elevation is the normal operating pool elevation for Peabody Ash Pond.
- The maximum surcharge pool elevations were applied to the model based on the flood pool level determined for the 6-hour, 1,000 year storm for Peabody Ash Pond. The surcharge pool was assumed not to last long enough for steady-state conditions to develop. Therefore, the phreatic surface obtained from the seepage analysis for the long-term maximum storage pool analysis was utilized within the embankment. A surcharge pressure was applied to the slow-draining soils along the ground surface, reflecting the difference in elevation between the flood pool and normal pool.
- During maximum surcharge pool loading analysis, the tailwater elevation of Jacob’s Creek was conservatively maintained at the ordinary high water elevation, neglecting potential added resistance at the toe resulting from short term, surcharge loading conditions

- The slope stability assessments presented in this report are focused on the potential for slope failures of significant mass, which could directly impact potential release of water and CCR materials from Peabody Ash Pond. The search for a critical slip surface in the slope stability assessments was therefore restricted to consider only potential surfaces where the depth (measured at the base of at least one slice) is more than 10 feet vertically below the ground surface.

6.0 Analysis Results

A summary of the static safety factor evaluation results at the Peabody Ash Pond critical section (Section C-C') is provided below in **Table 6**.

Table 6: Initial Factor of Safety Assessment Results

Facility	Critical Cross Section	Loading Condition	CCR Rule Required Factor of Safety	Calculated Factor of Safety
Peabody Ash Pond	C-C'	Long-term maximum storage pool [§257.73(e)(1)(i)]	1.50	1.56
		Maximum surcharge pool [§257.73(e)(1)(ii)]	1.40	1.50

7.0 Conclusions

This report documents the static safety factor evaluation of PAF's Peabody Ash Pond. The evaluation was performed in accordance with section §257.73(e) of the CCR Rule.

The static safety factor evaluation resulted in safety factors for all four cross section locations, including the critical cross section, that met or exceeded both the long-term maximum storage pool §257.73(e)(1)(i) and for the maximum surcharge pool §257.73(e)(1)(ii) loading conditions. These results demonstrate that the Peabody Ash Pond meets the initial static safety factor requirements of EPA 40 CFR §257.73(e).

8.0 References

1. Stantec, 2010. Report of Geotechnical Exploration, Peabody Ash Pond, Paradise Fossil Plant, Muhlenberg County, Kentucky, February 9, 2010, Accessed from TVA public records.
2. Stantec, 2009. Report of Phase 1 Facility Assessment, Coal Combustion Product Impoundments and disposal Facilities, Various Locations, Kentucky, June 24, 2009, Accessed from TVA public records.
3. AECOM, 2015. Report of Geotechnical Exploration for CCR Compliance, Peabody Ash Pond, Paradise Fossil Plant, Muhlenburg County, Kentucky.
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6. USACE, 2003. EM 1110-2-1902. Slope Stability. Engineering and Design. October 31, 2003.
7. TVA, 2014. Peabody Ash Pond Spillway and Slope Improvements, Sheets 1, drawing 10W720-04 through 10W720-14, May 16, 2014.
8. TVA, 1995. Ash Disposal Area and Stilling Pond Extension Plan Details, 10W3274 Drawings 1-5.
9. TVA, 1995. Ash Disposal Area, drawing 10N3259-SHT-REV 2.
10. TVA, 1995. Ash Disposal Area Extension Plan, drawing 10N3259-1-SHT-REV-1.
11. TVA, 1995. Ash Disposal Area Plan Discharge Spillways, drawing 10N3259-SHT-REV.
12. TVA, 1996. Dike Construction, drawing 10W-3274-3. January, 1996.
13. University of Kentucky Geological Survey, 2015. Online Geologic Interactive Map Accessed at: http://kgs.uky.edu/kgsmap/kgsgeoserver/viewer.asp on January 21, 2015.
14. Kentucky Mine Mapping Service, 2015. Online Interactive Mine Mapping Accessed at: http://eppcgis.ky.gov/flexviewers/minemapping/ on January 21, 2015.
15. Robertson, Guide to Cone Penetration Testing for Geotechnical Engineering 6th Edition, Gregg Drilling & Testing, Inc., December 2014.
16. Mitchell & Katti, Soil Improvement: State of the Art Report. June, 1981.
17. Bureau of Reclamation (2014), Design Standards No. 13, Embankment Dams, Chapter 8, Seepage, January, 2014.

APPENDIX A
SLOPE STABILITY ANALYSIS

Tennessee Valley Authority
Paradise Fossil Plant- Peabody Ash Pond Complex
Paradise, KY
Cross Section C-C'

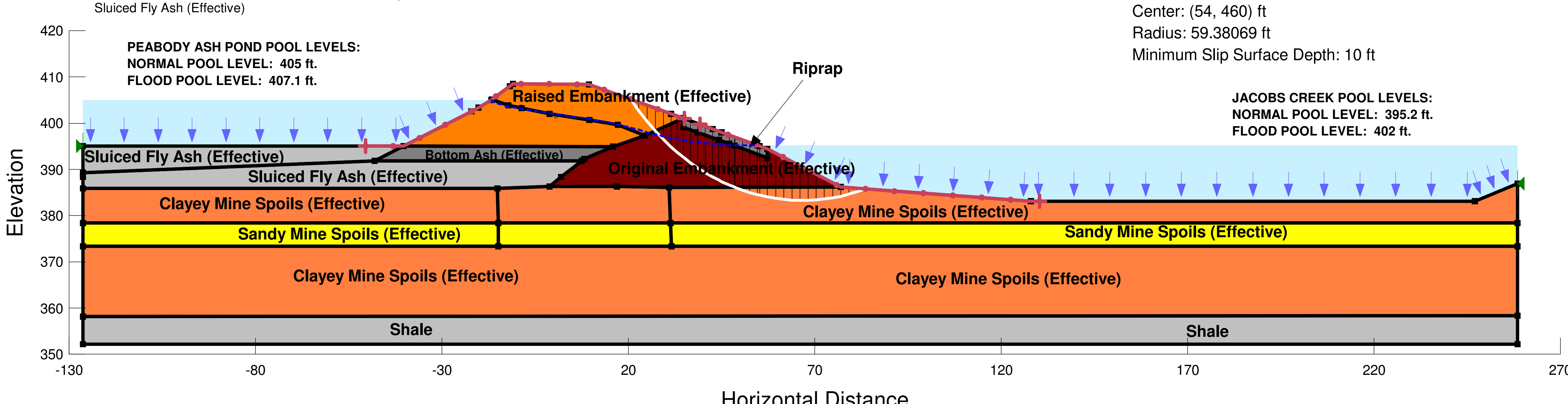
Long Term, Maximum Storage Pool Loading Condition

Note: The results of the analysis shown here are based on laboratory test results and approximate soil properties.
The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling.
No warranties can be made regarding the continuity of subsurface conditions.

Material	Unit Weight (pcf)	Cohesion (psf)	Phi (deg.)
Raised Embankment (Effective)	134	0	32
Original Embankment (Effective)	134	0	32
Sandy Mine Spoils (Effective)	129	0	32
Bottom Ash (Effective)	125	0	33
Shale Bedrock	------Bedrock (Impenetrable)--------		
Clayey Mine Spoils (Effective)	124	0	30
Riprap	135	0	40
Sluiced Fly Ash (Effective)	100	0	24

1.56

Method: Spencer
F of S: 1.56
Center: (54, 460) ft
Radius: 59.38069 ft
Minimum Slip Surface Depth: 10 ft



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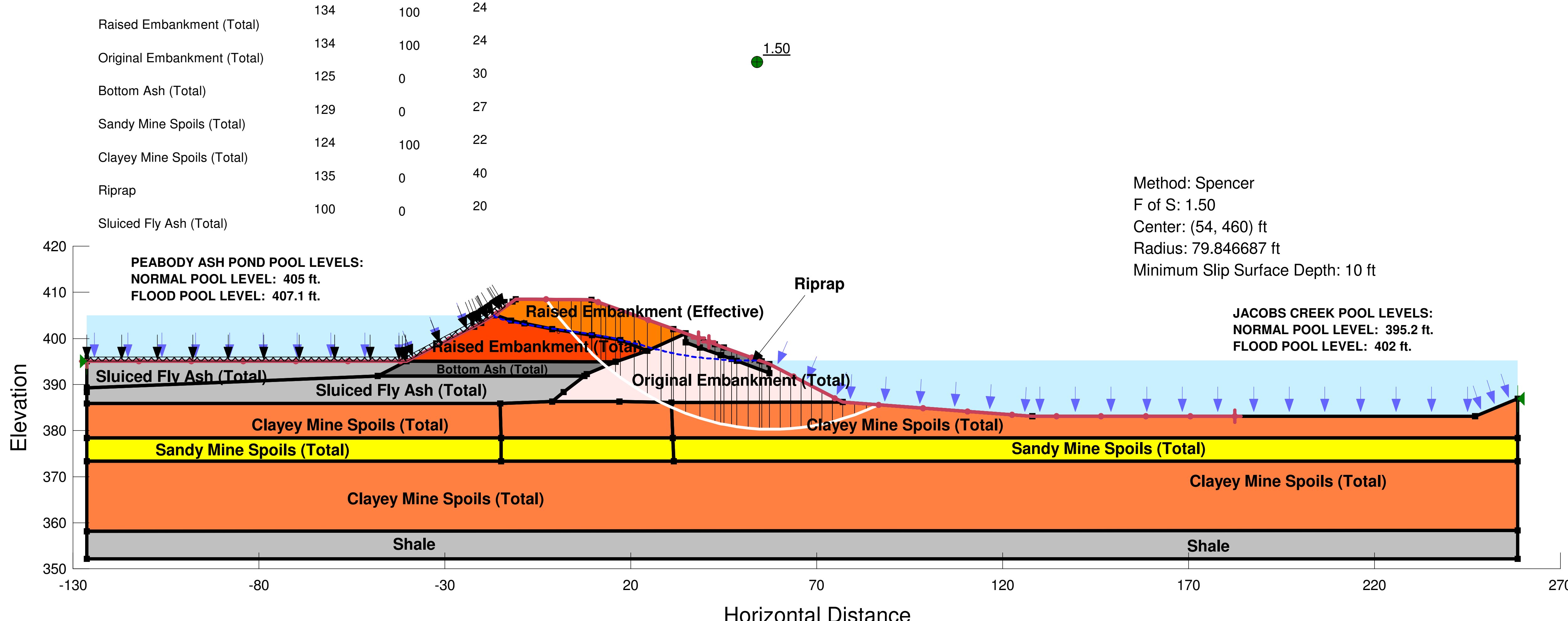
Tennessee Valley Authority
Paradise Fossil Plant- Peabody Ash Pond Complex
Paradise, KY
Cross Section C-C'

Maximum Surcharge Pool Loading Condition

Note: The results of the analysis shown here are based on laboratory test results and approximate soil properties.
The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling.
No warranties can be made regarding the continuity of subsurface conditions.

Material	Unit Weight (pcf)	Cohesion (psf)	Phi (deg.)
Raised Embankment (Effective)	134	0	32
Shale Bedrock	------Bedrock (Impenetrable)--------		
Raised Embankment (Total)	134	100	24
Original Embankment (Total)	134	100	24
Bottom Ash (Total)	125	0	30
Sandy Mine Spoils (Total)	129	0	27
Clayey Mine Spoils (Total)	124	100	22
Riprap	135	0	40
Sluiced Fly Ash (Total)	100	0	20



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