Stantec Consulting Services Inc.
1409 North Forbes Road, Lexington KY 40511-2024

October 12, 2016
File: rpt_001_let_175555010
Revision 0

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

RE: Initial Structural Stability Assessment
Ash Pond 2
EPA Final Coal Combustion Residuals (CCR) Rule
TVA Shawnee Fossil Plant
West Paducah, Kentucky

1.0 PURPOSE

This letter documents Stantec's certification of the initial structural stability assessment for the TVA Shawnee Fossil Plant's (SHF) Ash Pond 2. Based on this assessment, the Ash Pond 2 is in compliance with the structural stability requirements in the EPA Final CCR Rule at 40 CFR 257.73(d).

2.0 INITIAL STRUCTURAL STABILITY ASSESSMENT

As described in 40 CFR 257.73(d), documentation is required on how the Ash Pond 2 has been designed, constructed, operated, and maintained according to the structural stability requirements listed in the section. The combined capacity of all spillways must also be designed, constructed, operated, and maintained to adequately manage flow from the 1000-year storm event based upon a hazard potential classification of "significant."

3.0 SUMMARY OF FINDINGS

The attached report presents the initial structural stability assessment of the Ash Pond 2. The results show that the impoundment meets the structural stability requirements set forth in 40 CFR 257.73(d)(1)-(2).

4.0 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

I, Don Fuller, 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

Re: **Initial Structural Stability Assessment**
Ash Pond 2
EPA Final Coal Combustion Residuals (CCR) Rule
TVA Shawnee Fossil Plant
West Paducah, Kentucky

3. that the initial structural stability assessment for the TVA Shawnee Fossil Plant's Ash Pond 2 meets the requirements specified in 40 CFR 257.73(d)(1)-(2).

SIGNATURE [signature]

DATE 10/12/2016

STATE OF KENTUCKY
DON W. FULLER, II
18142
LICENSED
PROFESSIONAL ENGINEER

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ATTACHMENTS: Initial Structural Stability Assessment Report

CC: TBD

Initial Structural Stability Assessment

Shawnee Fossil Plant – Ash Pond 2
McCracken County, Kentucky

Stantec

Prepared for:
Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:
Stantec Consulting Services Inc.
Lexington, Kentucky

October 12, 2016
Revision 0

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1.0 PROJECT BACKGROUND

On April 17, 2015 the "Disposal of Coal Combustion Residuals (CCR) from Electric Utilities" (EPA Final CCR Rule) was published in the Federal Register. Stantec Consulting Services, Inc. (Stantec) was contracted by the Tennessee Valley Authority (TVA) to analyze the Structural Stability of the Ash Pond 2 associated with the Shawnee Fossil Plant (SHF) CCR surface impoundments (SI) and evaluate compliance with §257.73 (d) of the CCR Rule.

As required by §257.73 (d) of the EPA Final CCR Rule, an initial structural integrity evaluation is required by October 17, 2016. The evaluation must include an initial structural stability 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.

2.0 UNIT DESCRIPTION

The Shawnee Fossil Plant (SHF) is a coal-fired, electric generating plant. The plant is located in McCracken County, Kentucky along the south shore of the Ohio River near river mile 946 and just east (upstream) of the confluence of Little Bayou Creek with the Ohio River.

Ash Pond 2 is located at the northwest corner of the plant. It is bordered on the north by the Ohio River and the west by Little Bayou Creek. Ash Pond 2 is formed by the Perimeter Dike along the east, north, and west and a Divider Dike to the south that separates it from the fly ash stack. The Stilling Pond encompasses approximately 100 acres. TVA has determined that Ash Pond 2 is a CCR Surface Impoundment and therefore subject to the CCR rule.

The subsections under §257.73(d) address conditions of appurtenances categorized as embankments, spillways, or hydraulic structures. Sections 2.1 to 2.3 below provide descriptions of the individual unit elements that fall within these appurtenance categories. Figure 1 provides an overview of the Stilling Pond and appurtenances.

Elevations included in this document and appendices are referenced to the National Geodetic Vertical Datum of 1929 (NGVD29).

2.1 EMBANKMENTS

2.1.1 Perimeter Dike

Ash Pond 2 encompasses an approximate 106-acre area, and is enclosed by a perimeter dike system. The dike system is approximately 15,000 feet in total length; including the section within the pond along the closed Inactive Dredge Cell, Consolidated Waste Dry Stack, and Special Waste Landfill Expansion. The overall constructed height of the perimeter dike system varies from approximately 20 to 25 feet. Dike side slopes are approximately 2.5H:1V to 3H:1V down to approximate El. 335 feet, and then flatten to 5H:1V to 6H:1V.

The dike was originally constructed in 1971 and raised in 1979 to its current height and configuration. The dike is constructed of compacted clay.

2.1.2 Ash Pond/Stilling Pond Divider Dike

The divider dike was built as part of the Ash Pond 2 disposal area using bottom ash material obtained from dredging operations. This dike was initially built to El. 340 and later raised to El. 350. The divider dike separates the stilling pond used for decanting clarified water to the outlet spillway system and the impoundment ash pond area receiving sluiced ash from the power plant.

Legend

Disposal Area Approximate Limits

0 200 400 Feet

1:4,800 (At original document size of 11x17)

Project Location 175555010
Shawnee Fossil Plant
Paducah
McCracken County, Kentucky

Prepared by WSW on 2016-08-31
Independent Review by TG on 2016-08-31
Technical Review by TR on 2016-08-31

Client/Project
Tennessee Valley Authority
Structural Stability Assessment
Shawnee Fossil Plant

Figure No.
1

Title
Ash Pond 2
Shawnee Fossil Plant

Notes
1. Coordinate System: NAD 1983 StatePlane Kentucky South FIPS 1602 Feet
2. Imagery Provided by Client (Dated 2015)

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Based on review of the dike configuration and its role in current operations, it appears that failure of the Divider Dike would result in limited impacts to the remainder of the Stilling Pond/Perimeter Dike and would not lead to loss of containment of material off of TVA property. Therefore, no further assessment of the Internal Divider Dike under §257.73 of the EPA Final CCR Rule is included.

2.2 SPILLWAYS

2.2.1 Primary Spillway System

The primary spillway system for Ash Pond 2 consists of a cast-in-place concrete inlet structure with six individual 8 foot-wide by 4-feet-deep "boxes". Each inlet structure box has a 30-inch-diameter high-density polyethylene (HDPE) outlet pipe installed through the western embankment of the Stilling Pond. The outlet pipes discharge to an excavated ditch (Discharge Channel) located at the toe of the western and northern dikes. The Discharge Channel conveys flow from Ash Pond 2 to the main plant discharge channel located east of the pond (and in turn to the Ohio River).

2.2.2 Original Stilling Pond Spillways

The original primary spillway system for Ash Pond 2 consisted of five risers with 36-inch-diameter RCP outlet pipes. This spillway system was closed in 2011 once construction of the new primary spillway system was completed.

2.3 HYDRAULIC STRUCTURES

Other than the spillways described above, there are no hydraulic structures underlying or passing through the Perimeter Dike of Ash Pond 2.

3.0 FOUNDATIONS AND ABUTMENTS (§257.73(d)(1)(i))

Per §257.73(d)(1)(i), the initial structural stability assessment must document whether the unit has been designed, constructed, operated and maintained with stable foundations and abutments. The Ash Pond 2 unit has the following features that fall within this requirement:

- Perimeter Dike

Assessment of the foundations and abutments associated with these features considering the following criteria related to the CCR rule:

- Review inspection reports of the facility, considering frequency of inspections, and if the inspections included review and/or assessment of features including cracking, settlement, deformation or erosion of the foundations/abutments. Inspections should indicate that there are no significant signs of tension cracking, settlement, depressions, erosion, and/or deformations at the crest, slope and toe of the structure.
- Confirm that an assessment of seepage conditions of the foundation, with considerations for heave and vertical exit gradient, has been performed. Verify that the seepage assessment follows appropriate methodologies (such as USACE EM 1110-2-1901) and that the foundations exhibit acceptable factors of safety (i.e. FS for piping greater than or equal to 3.0).

3.1 PERIMETER DIKE

3.1.1 Background

The Perimeter Dike of Ash Pond 2, located on the northern portion of the Plant site, was designed to connect into the existing dikes of Ash Pond 1, therefore there are no natural abutments. Based on previous geotechnical work (TVA and Stantec), the foundation of the Perimeter Dike generally consists of Quaternary-age alluvial deposits that are up to 40 feet thick. These alluvial deposits consist of clean fine sands to sandy clays and silts. The alluvium is generally underlain by a thick layer of gravel and poorly sorted fine to coarse quartz and chert sand.

3.1.2 Assessment

Annual site inspections for Ash Pond 2, including the Perimeter Dike, were conducted and documented regularly from 1971 to 2014. A formal site inspection (5-year) was also conducted in 2015. Some of the inspection reports in the late 1980s and early 1990s are not available. However, over 40 years of inspections are available and document the operation and maintenance practices implemented for this facility. As reported by O'Brien & Gere in 2013, daily, weekly, monthly, and quarterly inspections of Ash Pond 2 (including the Perimeter Dike) are conducted by qualified TVA personnel; seepage areas are monitored on a quarterly basis.

No indications of foundation issues (i.e. cracking, settlement, depressions, and/or deformation) have been noted on historic inspection reports. Recent inspections of the Perimeter Dike, performed by Stantec (2010, 2011, 2014, and 2015) and O'Brien & Gere (O'Brien & Gere, 2013) note no significant signs of tension cracking, settlement, deformations or similar instabilities. A seepage area near the northeast corner of the Perimeter Dike was mitigated by TVA in 2011 (as described below).

Seepage analysis for the original dike construction is not available. Recent seepage analyses conducted for the Perimeter Dike, however, were available for review. These analyses were performed by Stantec in July 2010 and provided in *Report of Geotechnical Exploration and Slope Stability Evaluation* (Stantec, 2010b). Results from the analyses indicated that a majority of the dike had factors of safety greater than 4.0. However, the northeast portion of the dike, where previous seepage had been reported, had factors of safety for piping/heave of 2.0, which does not meet the recommended factor of safety of 3.0. Stantec recommended remedial measures to include construction of a graded filter system. The perimeter dike improvements were designed and constructed using a target factor of safety of 4.0 (with respect to piping/heave).

TVA completed construction of the graded filter along the northeast dike (extending towards the southeast) to collect and convey seepage. Construction of the proposed remedial measures was completed in November 2011, and a *Construction Certification Report* was issued by Stantec in February, 2012 (Stantec, 2012a).

3.1.3 Conclusion

Based on the assessment of the foundation and abutments for the Perimeter Dike, the CCR Rule-related criteria listed above have been met.

4.0 SLOPE PROTECTION (§257.73(d)(1)(ii))

Per §257.73(d)(1)(ii), the initial structural stability assessment must document whether the unit has been designed, constructed, operated and maintained with adequate slope protection to protect against surface erosion, wave action, and adverse effects of sudden drawdown. Ash Pond 2 has the following features that fall within this requirement:

- Perimeter Dike

Assessment of the slope protection associated with these features was completed considering the following criteria related to the CCR rule:

1. Regular (weekly) inspections for erosion. Inspections should show there are no significant signs of deterioration in the slope protection configuration of the Item.
2. Appropriate slope protection shall be provided based on anticipated flow velocities. [Hydrologic / hydraulic calculations of flow velocities on the slope of the Item for the appropriate erosive forces. Some common slope protection measures include: Rip rap, Gabions, Paving (concrete or asphalt), or appropriate vegetative cover.]
3. If slope protection is rip rap, filter layer(s) under the rip rap shall be designed according to established filter criteria. However, existing rip rap cover may be evaluated based on performance and observations during inspections.

4.1 PERIMETER DIKE

4.1.1 Background

Slope protection for the Perimeter Dike generally consists of a combination of grass vegetation cover or rip rap. The exterior slope is primarily vegetated cover with the area near the primary spillway being rip rap armored. The interior slope has a rip rap wave armoring.

4.1.2 Assessment

As reported by O'Brien & Gere in 2013, daily, weekly, monthly, and quarterly inspections of Ash Pond 2 (including the Perimeter Dike) are conducted by qualified TVA personnel, and areas of erosion are prioritized for appropriate repairs. Annual site inspections are conducted by TVA. Site inspection reports from 1971 to 2015 generally indicate appropriate maintenance of slope protection features of the dike, in accordance with the procedures outlined in TVA's Operations Support Document (July, 2011). See Section 6.0 for details about vegetated slopes.

The use of rip rap as wave armoring protection along the interior slope of the dike appears appropriate to address concerns of erosive wave action. Original design calculations for the rip rap and filter system used for the Perimeter Dike are not available.

As part of a January 2016 site visit, Stantec personnel observed the rip rap protection along the slopes. The rip rap was located along the interior slope of the western portion of Ash Pond 2 and the exterior slope at the Primary Spillway. The rip rap slope protection above the water surface was continuous and performing well.

4.1.3 Conclusion

Based on the assessment of the slope protection for the Perimeter Dike, the CCR Rule-related criteria listed above have been met.

5.0 EMBANKMENT DIKE COMPACTION (§257.73(d)(1)(iii))

Per §257.73(d)(1)(iii), the initial structural stability assessment must document whether the unit has been designed, constructed, operated and maintained with dikes mechanically compacted to a density sufficient to withstand the range of loading conditions in the CCR unit. The Ash Pond 2 has the following feature that fall within this requirement:

- Perimeter Dike

Assessment of the dike compaction associated with these features was completed considering the following criteria related to the CCR rule:

1. Documentation showing the dike was mechanically compacted. Acceptable documentation may include construction drawings, field notes, construction photographs, correspondences, or any evidence showing the dike was mechanically compacted during construction.
2. If no construction documentation is available specific data from geotechnical explorations of dike may be used. Geotechnical borings with continuous SPTs may be used to assess compaction of the dike. Appropriate methodology correlating blow counts and compaction (Density) should be used.

5.1 PERIMETER DIKE

5.1.1 Background

Construction records related to dike material placement or compaction were not available during this review. Certain TVA design drawings provide proposed dike construction and compaction methods and were referenced in the assessment described below. A subsurface exploration of the dike was also available that provided SPT data used in the assessment.

5.1.2 Assessment

TVA Drawings 10N271 R9 and 10N272 R5 provide documentation showing criteria related to the placement and compaction of dike materials that was to be used for the perimeter dike embankments. Construction criteria related to dike embankment materials and dike compaction as noted on these drawings include:

- Dike foundation materials were to exclude weak surface soils and rip rap and the prepared foundation was to bear the weight of loaded rubber-tired earth hauling equipment.

- Dike embankments were to be compacted using sheepsfoot rollers, to 95 percent of Standard maximum dry density (as per ASTM D698) with an allowable moisture content of 4 percent above optimum for new dike construction, and within 3 percent of optimum for raised dikes.
- Embankment clayey materials were to be obtained primarily from excavations within the planned perimeter dike, but not include pervious/coarse grained materials identified to be below El. 305. Any exposed pervious material exposed was to be blanketed with a 2-foot layer of compacted impervious soil.

Stantec completed a report of geotechnical exploration and slope stability evaluation for TVA in 2010. Their subsurface exploration program included drilling and sampling locations around the Ash Pond 2 Perimeter Dike. Continuous Standard Penetration (SP) Testing was performed at each boring location. The SP data from this study was used to estimate relative density of dike embankment materials, referencing NAVFAC DM-7.1.

The SP data reviewed shows an average N-value for the upper dike embankment (above approximate Elevation 340, representing the raised portion of the dike) of 25 blows per foot (bpf). An average N-value for the lower dike embankment (below Elevation 340) was indicated to be 17 bpf. The Stantec geotechnical exploration also evaluated the dike embankment materials using moisture-density testing. This evaluation showed that the in-situ dry densities of the dike materials vary from 93 to 100 percent of standard Proctor. Correlating the SP and moisture-density test results using NAVFAC DM-7.1 indicate that appropriate compaction exists within the embankment of the Perimeter Dike.

5.1.3 Conclusion

Based on the assessment of the embankment dike compaction for the Perimeter Dike of Ash Pond 2, the CCR Rule-related criteria listed above have been met.

6.0 VEGETATED SLOPES (§257.73(d)(1)(iv))

Per §257.73(d)(1)(iv), the initial structural stability assessment must document whether the unit has been designed, constructed, operated and maintained with vegetated slopes of dikes and surrounding areas, except for slopes which have an alternate form or forms of slope protection.

The Ash Pond 2 has the following features that fall within this requirement:

- Perimeter Dike

Assessment of the vegetated slopes associated with these features was completed considering the following criteria related to the CCR rule:

1. Regular inspection records showing vegetative cover sufficient to prevent surface erosion while allowing an unobstructed view to visually inspect the slope.

6.1 BACKGROUND

The exterior slope of the Perimeter Dike is vegetated excluding the area around the primary spillway which is armored with rip rap. The interior slope is armored with rip rap, as described in Section 4.0.

6.1.1 Assessment

Annual site inspections were conducted and documented regularly following construction of the perimeter and divider dikes. Annual inspection reports for over 40 years are available and document the vegetative cover over the dike structures. The vegetative cover of the dike exterior slopes is typically mowed twice annually as reported by TVA maintenance personnel. TVA Engineering performs the annual inspections and prepares reports addressing site conditions and directives for needed repairs and maintenance activities. These reports indicate that maintenance has been routinely performed.

In January 2016, Stantec personnel visited the site to observe existing conditions. The vegetation along the slopes of the dikes of Ash Pond 2 was 6 inches or less in height, and there was good coverage.

6.1.2 Conclusion

Based on the assessment of the vegetated slopes for the Ash Pond 2, the CCR Rule-related criteria listed above has been met.

7.0 SPILLWAY CONDITION AND CAPACITY (§257.73(d)(1)(v))

Per §257.73(d)(1)(v), the initial structural stability assessment must document whether the unit has been designed, constructed, operated and maintained with a single spillway or combination of spillways that meet the condition and capacity requirements as outlined in this section of the CCR Rule. The combined capacity of all spillways are to be designed, constructed, operated, and maintained to adequately manage flow during and following the peak discharge from the event specified in this section. Ash Pond 2 has the following features that fall within this requirement:

- Primary Spillway System

Assessment of the spillway condition and capacity associated with these features was completed considering the following criteria related to the CCR rule:

1. Outlet channel must be of non-erodible material designed to carry sustained flow velocities based on the required flood events. [Estimate flow velocities and select appropriate material using hydraulic analysis for the following flood events: PMF (high hazard potential unit), 1000-year flood (Significant hazard unit), 100-year flood (low hazard potential unit).]
2. Must adequately manage flow during and following the peak discharge. [Estimate combined capacity of all spillways based of hydraulic analysis for the following flood events: PMF (High hazard potential unit), 1000-year flood (Significant hazard potential unit), and 100-year flood (Low hazard potential unit).]
3. Must be structurally stable. [Assess stability of structure using stability and stress analyses according to an appropriate methodology. Some acceptable methodologies may include: EM 1110-2-2400, EM 1110-2-2100, ACI 350, etc.]
4. Must maintain structural integrity. [Structural integrity may be warranted by periodic inspections of existing conduits. Inspections must show no significant presence of deformation, distortions, cracks, joint separation, etc.]
5. Must be free from significant amounts of obstruction and anomaly which may affect the operation of the hydraulic structure [Perform periodic pipe inspections to detect deterioration, deformation, distortion, bedding deficiencies, and sediment, and debris accumulations.]

7.1 PRIMARY SPILLWAY SYSTEM

7.1.1 Background

Ash Pond 2 is classified as a significant hazard structure requiring the combined capacity of all spillways be adequate to manage the flow during and following the peak discharge from a 1000-year flood.

Construction of the primary spillway system for Ash Pond 2 is documented in a construction certification report prepared by Stantec (Stantec, 2012b). The primary spillway system was constructed in 2010 and 2011 to replace the Original Stilling Pond Spillways. The spillway system consists of a cast-in-place concrete inlet structure with six individual 8-feet-wide by 4-feet-deep "boxes". Each inlet structure box has three removable fiberglass-encased stop logs for controlling the pool elevation of Ash Pond 2. Each spillway structure has a 30-inch-diameter, DR 17 HDPE outlet pipe installed through the embankment. The outlet pipes are encased in concrete through the crest of the embankment and a sand filter diaphragm is installed just downstream of the encasement. The outlet pipes discharge through a single concrete headwall to a cast-in-place concrete stilling basin and grouted rip rap outlet channel at the downstream end. Two, 4 inch-diameter Schedule 40 polyvinyl chloride (PVC) pipes convey seepage from the filter diaphragm through the headwall.

7.1.2 Assessment

7.1.2.1 Spillway Capacity

The Inflow Design Flood Control System Plan for Ash Pond 2 (Stantec 2016a) documents the assessment of the Primary Spillway System related to the capacity requirements outlined in §257.73(d)(1)(v) of the CCR Rule. The assessment demonstrates that the Primary Spillway does meet the capacity requirements.

7.1.2.2 Structural Stability

As shown in the SHF Spillway Replacement Construction Certification Report (Stantec, 2012b), new concrete stop-log spillways and siphon spillways were recently installed to lower the pool elevation of the ash pond and the existing spillways were closed by cleaning, inspecting, and filling pipe sections using flowable sand-cement grout. The completion date was October 31, 2011.

In the SHF Spillway Replacement Design Calculations (in Appendix B4), it is demonstrated that the new spillway designs are adequate for stability. The structure was designed and constructed in 2011 to be sufficient for overturning, eccentricity, and sliding.

The spillway outlet has a cast-in-place concrete stilling basin designed to dissipate energy by creating a hydraulic jump below the outlet headwall. Additionally, an apron constructed of grouted channel lining located below the outlet structure provides erosion protection.

The 2015 formal inspection report (Stantec, 2015a) stated the outlet headwall was in good condition. Minor cracking was also observed traversing vertically from the pipe inlet to the top of Box Inlet No. 4. Cracking was also observed adjacent to handrail attachment points at Box Inlet Nos. 2, 3, and 4. The 2015 formal inspection report recommended monitoring the observed cracking and repairing the cracks if conditions worsen. The headwall, stilling basin, and outlet channel were submerged due to flood conditions on the Ohio River during the January 2016 site visit; therefore, the condition of these structures could not be observed.

7.1.3 Conclusion

Based on the assessment of the spillway condition and capacity for the Ash Pond 2 Primary Spillway System, the CCR Rule-related criteria listed above have been met.

7.2 ORIGINAL STILLING POND SPILLWAYS

7.2.1 Background

Upon completion of the new primary spillway system for the Ash Pond 2 Stilling Pond, operation of the Original Stilling Pond Spillways was ceased in 2011.

7.2.2 Assessment

Closure of the Original Stilling Pond Spillways is documented in the Construction Certification Report for the Spillway Replacement Project (Stantec, 2012b). Record drawings show the outlet pipes and 8 to 10 vertical feet of the risers were filled with grout. In their current condition, the Original Stilling Pond Spillways can no longer convey flow from Ash Pond 2.

7.2.3 Conclusion

Based on the assessment of the hydraulic structure condition for the Ash Pond 2 Original Stilling Pond Spillways, the CCR Rule-related criteria listed above have been met.

8.0 SUDDEN DRAWDOWN ASSESSMENT (§257.73(d)(1)(vii))

Per §257.73(d)(1)(vii), the initial structural stability assessment must document whether the unit has been designed, constructed, operated, and maintained with downstream slopes that can be inundated by an adjacent water body (such as a river, stream, or lake) to determine if structural stability is maintained during low pool or sudden drawdown of the adjacent water body. Ash Pond 2 has the following features that fall within this requirement:

- Perimeter Dike

Assessment of the sudden drawdown associated with these features was completed considering the following criteria related to the CCR rule:

1. Maintain slope stability during sudden drawdown of adjacent water body.

Guidance provided by USEPA (2015) described the basis of the CCR Rule's factor of safety criteria and methodology as EM 1110-2-1902 (USACE, 2003) or other appropriate methodologies. Table 3-1 of USACE (2003) recommends a required minimum factor of safety of 1.1 for maximum surcharge pool under rapid drawdown conditions.

8.1 BACKGROUND

Ash Pond 2 has a potential sudden drawdown loading from the Ohio River, Little Bayou Creek, and discharge channels along the western, northern, and eastern toes of its perimeter dike. A sudden drawdown slope stability analysis of the downstream slope is required under the CCR Rule §257.73(d)(1)(vii). The sudden drawdown slope stability analysis was performed in conjunction with the static safety factor assessment discussed in Stantec (2016b).Assessment

8.1.1 Material Properties

An overview of the subsurface conditions of the perimeter dike of Ash Pond 2 is summarized in Table 1. A more in-depth review is found in Stantec (2010b).

Table 1 Generalized Subsurface Conditions – Ash Pond 2 Perimeter Dike

Approximate Elevation	Materials	General Consistency/Density
El. 340 to El. 351	Upper Dike fill – lean clay, lean clay with sand, and sandy lean clay	Stiff to very stiff
Native Ground to El. 340	Lower Dike fill – lean clay, lean clay with sand, poorly graded sand with silt	Medium stiff to very stiff / medium dense
Various	Native soils – lean clay, lean clay with sand, sandy lean clay, sand silt, silt, poorly graded sand, poorly graded sand with silt, poorly graded sand with gravel, poorly graded sand with silt and gravel, and silty sand	Soft to very stiff
Below El. 340	Sluiced fly ash and bottom ash – silty sand with gravel and silt with sand	Very soft to medium stiff / loose to medium dense

During the September 2009 and early 2010 geotechnical explorations, Stantec performed a laboratory testing program consisting of natural moisture content determinations, sieve and hydrometer analyses, Atterberg limits, specific gravity determinations, consolidated-undrained triaxial compression tests, and permeability tests. The strength parameters derived using the laboratory data and used in this sudden drawdown slope stability evaluation are presented in Table 2. The results of the laboratory testing and derivation of the strength parameters can be found in Stantec (2010b).

Table 2 Strength Parameters for Stability Analysis – Ash Pond 2 Perimeter Dike

Soil Horizon	Unit Weight (pcf)	Effective Stress Strength Parameters		Total Stress Strength Parameters	
		c' (psf)	ϕ' (degrees)	c (psf)	ϕ (degrees)
Upper Dike	130	200	30	800	19
Lower Dike	127	130	26	460	17
Sluiced Ash	85	0	26	400	10
Native Clay	128	110	28	325	13
Native Sand	130	0	32	0	32
Native Silt	110	0	29	0	29
Divider Dike	100	0	38	0	38
Native Sand and Gravel	130	0	35	0	35

8.1.1.1 Critical Cross-Section Selection

Slope stability analyses were available from Stantec (2010b) and Stantec and URS (2014). Seven primary cross sections were analyzed under steady state and sudden drawdown conditions. The seven sections that were analyzed were A-A', C-C', E-E', N-N', P-P', R-R', and U-U' and are shown below in Figure 2 Two additional sections (F-F' and H-H') that were included in Ash Pond 2 from Stantec (2010b) are no longer considered a part of Ash Pond 2 because of landfill operations.

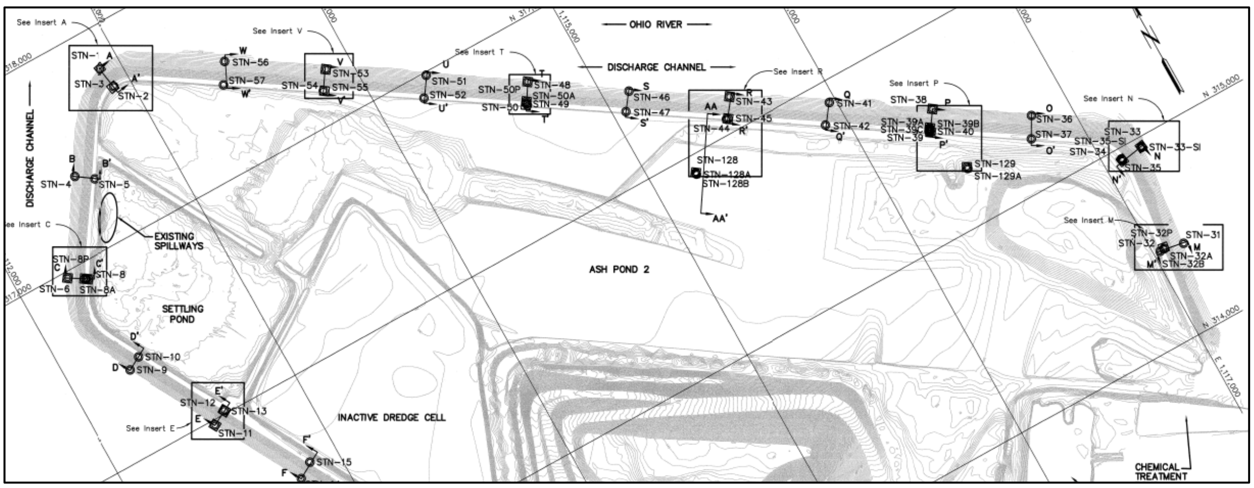

Figure 2 SHF Ash Pond 1 – Plan View of Cross Sections (Stantec, 2010b)

To determine if these cross sections along the perimeter dike of Ash Pond 2 were still representative of field conditions, a review of recent construction activities, topographic, and bathymetric information was performed. The following modifications were made since the 2009 and 2010 geotechnical explorations:

- A graded filter was constructed along the southeast perimeter dike of Ash Pond 2 (Work Plan 4) in November of 2011 (Stantec and URS, 2014).
- The Ash Pond 2 pool level was lowered from the Spillway Improvements Project (Work Plan 5) in October of 2011 (Stantec and URS, 2014)).
- Various maintenance activities, including cutting and maintaining vegetation, and repairing depressions (Stantec, 2015a).

- The graded filter that was constructed as a part of Work Plan 4 changed the geometry of Section N-N'. The threshold analysis performed in the Instrumentation Monitoring Plan (Stantec and URS, 2014) reflects this change in geometry. Recent topographic data (Tuck Mapping Solutions, 2015) and bathymetric data (The RLS Group, 2015) indicate negligible changes in the cross section geometry. The model surface geometry and material properties provided in the historical reports have been deemed appropriate for use in this slope stability assessment.

The summary of the historic slope stability results are listed in Table 3. For the sudden drawdown conditions, the Ash Pond 2 pool elevation was set at 346 feet, and the high and low tailwater elevations were set at 334 feet and 321.4 feet, respectively.

Table 3 Historic Slope Stability Results

Cross-Section	Sudden Drawdown Factor of Safety	Reference
A-A'	1.7	(Stantec, 2010b)
C-C'	1.9	(Stantec, 2010b)
E-E'	1.6	(Stantec, 2010b)
N-N'	1.6	(Stantec, 2010b)
P-P'	1.7	(Stantec, 2010b)
R-R'	1.8	(Stantec, 2010b)
U-U'	1.7	(Stantec, 2010b)

Sections E-E' and N-N' produced the lowest factors of safety. Since then, the geometry of Section N-N' has changed with the addition of a graded filter at the toe of the embankment (Stantec and URS, 2014), likely changing the stability of Section N-N'. Section E-E' is located near the divider dike between the Settling Pond and the Inactive Dredge Cell. New sudden drawdown stability analyses are required for both Sections E-E' and N-N' based on the proposed water levels discussed in 9.1.1.3 to determine the critical cross section.

8.1.1.2 Water Levels

The sudden drawdown slope stability analyses require assessment of changes in headwater and tailwater levels. In Stantec (2016a), the water elevations for Ash Pond 2 were redefined to meet the requirements of the EPA CCR Rule inflow design flood cases. The maximum surcharge pool elevation was selected as the high water level within Ash Pond 2. The 1000-year flood elevation was used for the flood pool elevation of Ash Pond 2 (Stantec, 2016a). Normal pool or the maximum storage pool elevation was selected as the low water level for the facility. Headwater elevations are listed in Table 4.

The tailwater corresponds to the Ohio River, Little Bayou Creek, or discharge channels. The tailwater at section E-E' is the Little Bayou Creek, which flows into the Ohio River. The tailwater at section N-N' is a discharge channel that flows into the Ohio River. The 100-year flood level for the Ohio River was used for the tailwater flood pool elevation (Stantec, 2016a). Low pool for the Ohio River was based on Stantec (2010b), using piezometer readings within the native soils along the toe of the ash pond. Tailwater elevations are listed in Table 4.

Table 4 SHF Water Elevations for Stability Modeling

CCR Rule Criteria	Headwater Ash Pond 2 Elevation (feet, NGVD29)	Tailwater Ohio River Elevation (feet, NGVD29)
Maximum surcharge pool loading condition	348.8	337.0
Long-term maximum storage pool loading condition	344.4	321.4

8.1.1.3 Analysis Methodology

Stantec performed the sudden drawdown slope stability analyses using the GeoStudio 2007, Version 7.23 software package developed by GEO-SLOPE International, Ltd. of Calgary, Alberta, Canada (GEO-SLOPE International, Ltd., 2007). This package includes the SLOPE/W module for slope stability analysis. The analyses were performed in accordance with the recommendations and criteria outlined in the USACE Design Manuals EM 1110-2-1902 "Slope Stability" (USACE, 2003) and in the Stantec Engineer's Certification of Safety Factor Assessment Report (Stantec, 2015b).

8.1.1.4 Acceptance Criteria

A minimum factor of safety is not explicitly specified within the EPA Final CCR Rule §257.73(d)(1)(vii). In the CCR Rule discussion, USACE (2003) is considered the basis for the slope stability analyses. Table 3-1, Minimum Required Factors of Safety: New Earth and Rock-Fill Dams, requires a factor of safety of 1.1 for a rapid drawdown condition from maximum surcharge pool (USACE, 2003).

8.1.1.5 Analysis Results

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 Ash Pond 2. The search for a critical slip surface in the slope stability assessments is thus restricted to consider only potential surfaces where the depth (measured at the base of at least one slice) is more than ten feet vertically below the ground surface. Table 5 summarizes the sudden drawdown safety factor evaluation results at Ash Pond 2.

Table 5 Factor of Safety Assessment Results

Plant	Facility	Critical Cross Section	EPA Criteria	Recommended Factor of Safety Criteria	Calculated Factor of Safety
SHF	Ash Pond 2	E-E'	Sudden Drawdown	1.1	1.6
SHF	Ash Pond 2	N-N'	Sudden Drawdown	1.1	1.9

8.1.2 Conclusion

Based on the assessment of the sudden drawdown for the Ash Pond 2 western, northern, and eastern perimeter dike, the CCR Rule-related criteria listed above have been met.

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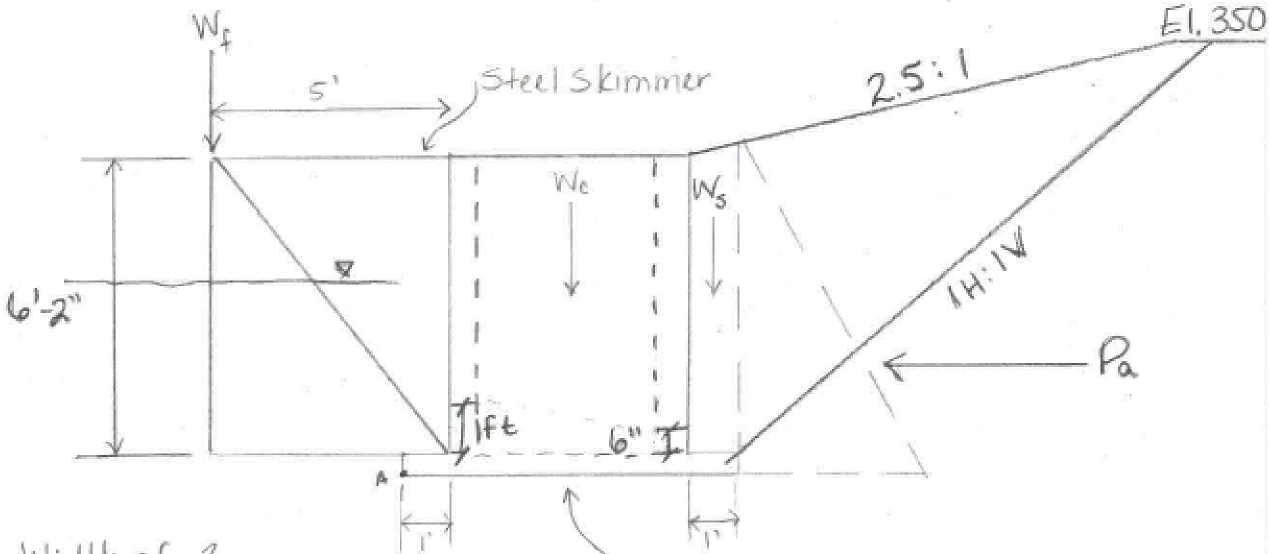
APPENDIX A
SPILLWAY CONDITION AND CAPACITY

Appendix B4: Cast-In-Place Inlet Structure Overturning, Eccentricity, and Sliding Checks

SHF Spillway Replacement
Overturning, Eccentricity, + Sliding Check



Width of 2 boxes is 18.7'

- Assume no drainage and an unsupported soil condition.
- Assume $\gamma_{w soil} = 125$ pcf and $\phi = 28°$

Determine Equivalent Fluid Pressure (EFP)

EFP for drained soil with 2.5:1 backslope = 65 pcf

So, for undrained, EFP = $\frac{65}{2} + 62.4 = 94.9$, Use EFP = 95

$W_s = \frac{1}{2}(1')(18.7')(6.33')(0.125\,kcf) + (1')(6.17')(18.7')(0.125) = 14.8\,k$

$W_c = (155.8\,ft^3)(0.150\,k/ft)(2) = 46.7$

$W_f = 2.5\,k$ (from steel skimmer calculation sheets)

Designed by: LJW Checked by:

$P_a = \frac{1}{2}[95\,(7.17')](7.17')(18.7') \Rightarrow P_a = 45.7\text{ kips}$

Area	Force	Arm	Moment
W_s	14.8 k	6.83'	101.1 k·ft
W_c	46.7k	3.67'	171.4 k·ft
W_f	2.5	4.0'	-10 k·ft
P_a	45.7k	2.4'	-106.6 k·ft
			ΣM = 155.9 k·ft

$FS_{overturning} = \frac{\circlearrowright \Sigma M}{\circlearrowleft \Sigma M} = \frac{101.1 + 171.4}{10 + 106.6} = 2.34 > 1.5$ ok

$e = \frac{L}{2} - \frac{\Sigma M}{\Sigma V} = \frac{7.33}{2} - \frac{155.9}{14.8 + 46.7 + 2.5} = 1.23$ Which is close enough to $\frac{L}{6} = 1.22$. ✓OK (Resultant inside the middle third.)

$q_{max} = \frac{64}{(7.33)(18.7')}\left(1 + \frac{6(1.23)}{7.33}\right) = 0.937\text{ ksf}$

$q_{min} = \frac{64}{(7.33)(18.7)}\left(1 - \frac{6(1.23)}{7.33}\right) = -0.003\text{ ksf}$

Close to zero, OK

Check sliding:

$F_{RESISTING} = \Sigma V \tan\delta + C_a BL = 64k(0.35) + 0.5\text{ ksf}(7.33\text{ft})(18.7\text{ft})$
$\Rightarrow F_{RESISTING} = 90.9k$

$F_{Acting} = 45.7K$

$FS_{sliding} = \frac{90.9k}{45.7k} = 1.99 > 1.5$ OK

Designed by: LJW Checked by:

APPENDIX B
SUDDEN DRAWDOWN ASSESSMENT

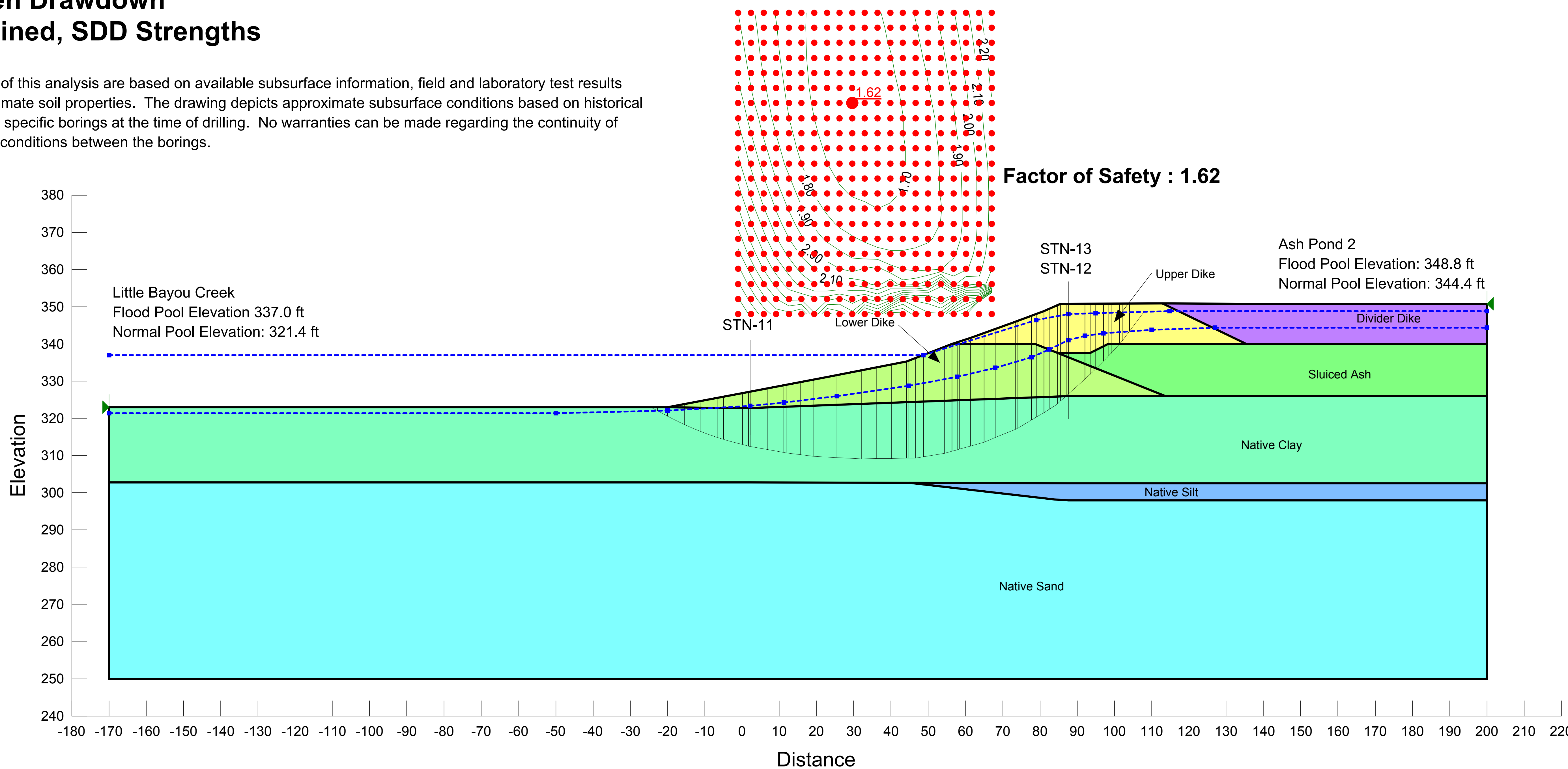
Tennessee Valley Authority
Shawnee Fossil Plant Ash Pond 2
Paducah, Kentucky
Section E-E'

Sudden Drawdown

Material Type	Sat. Unit Wt.	Effective - c'	Effective - phi'	Total - c	Total - phi
Upper Dike	130 pcf	200 psf	30 °	800 psf	19 °
Lower Dike	127 pcf	130 psf	26 °	460 psf	17 °
Sluiced Ash	85 pcf	0 psf	26 °	400 psf	10 °
Native Clay	128 pcf	110 psf	28 °	325 psf	13 °
Native Sand	130 pcf	0 psf	32 °	0 psf	32 °
Native Silt	110 pcf	0 psf	29 °	0 psf	29 °
Divider Dike	100 pcf	0 psf	38 °	0 psf	38 °

Existing Geometry;
Sudden Drawdown
Undrained, SDD Strengths

Note:
The results of this analysis are based on available subsurface information, field and 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 between the borings.



Project No. 175555021, 202.10

Tennessee Valley Authority
Shawnee Fossil Plant Ash Pond 2
Paducah, Kentucky
Section N-N'

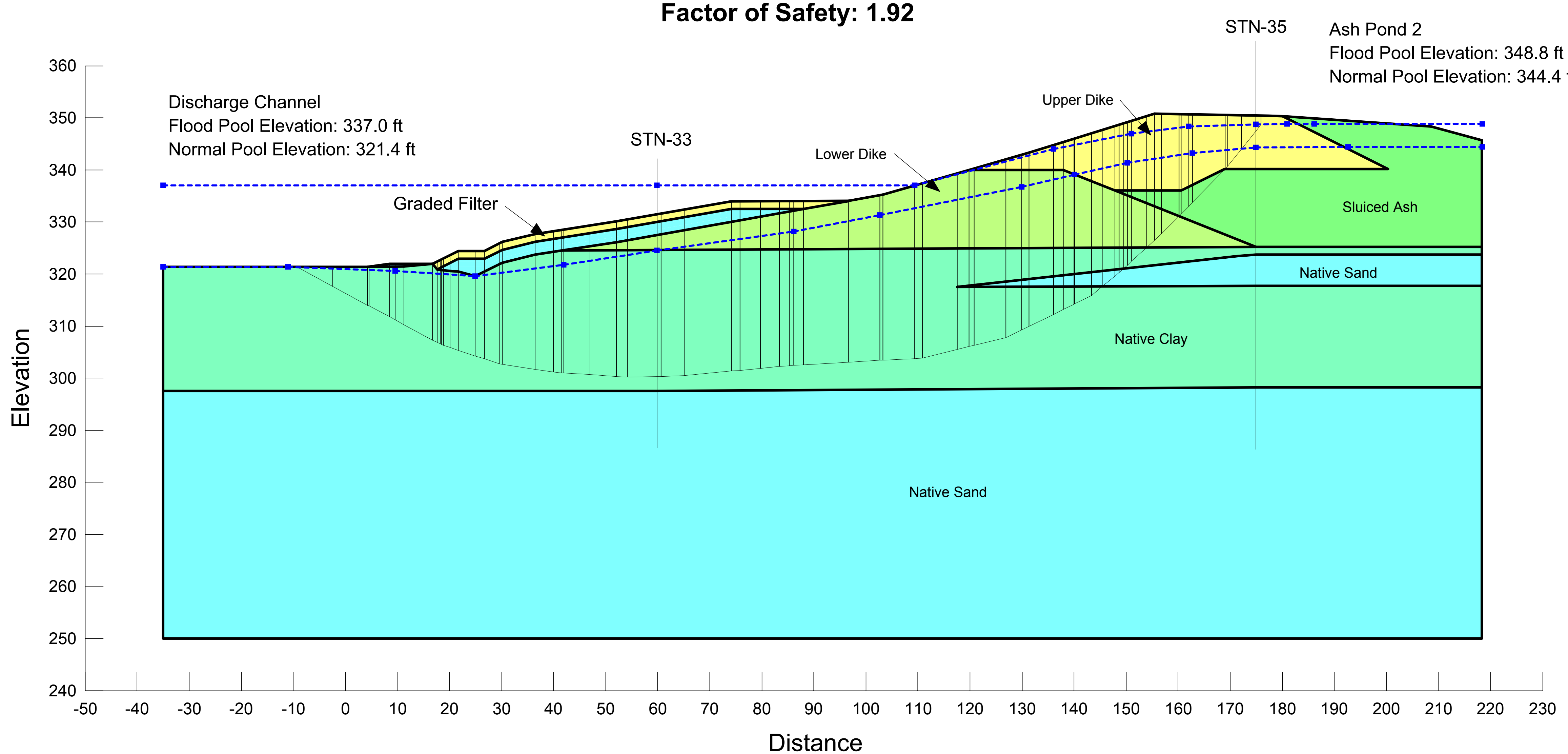
Sudden Drawdown

Material Type	Sat. Unit Wt.	Effective - c'	Effective - phi'	Total - c	Total - phi
Upper Dike	130 pcf	200 psf	30 °	800 psf	19 °
Lower Dike	127 pcf	130 psf	26 °	460 psf	17 °
Sluiced Ash	85 pcf	0 psf	26 °	400 psf	10 °
Native Clay	128 pcf	110 psf	28 °	325 psf	13 °
Native Sand	130 pcf	0 psf	32 °	0 psf	32 °

Existing Geometry;
Sudden Drawdown
Undrained, SDD Strengths

Note:
The results of this analysis are based on available subsurface information, field and 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 between the borings.

Factor of Safety: 1.92



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