Fly Ash Reservoir II Dam
Initial Safety Factor Assessment

Cardinal Power Plant
Brilliant, Ohio
S&ME Project No. 7217-15-006A

Prepared for:
American Electric Power
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Columbus, Ohio 43215

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September 18, 2015

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1.0 Introduction

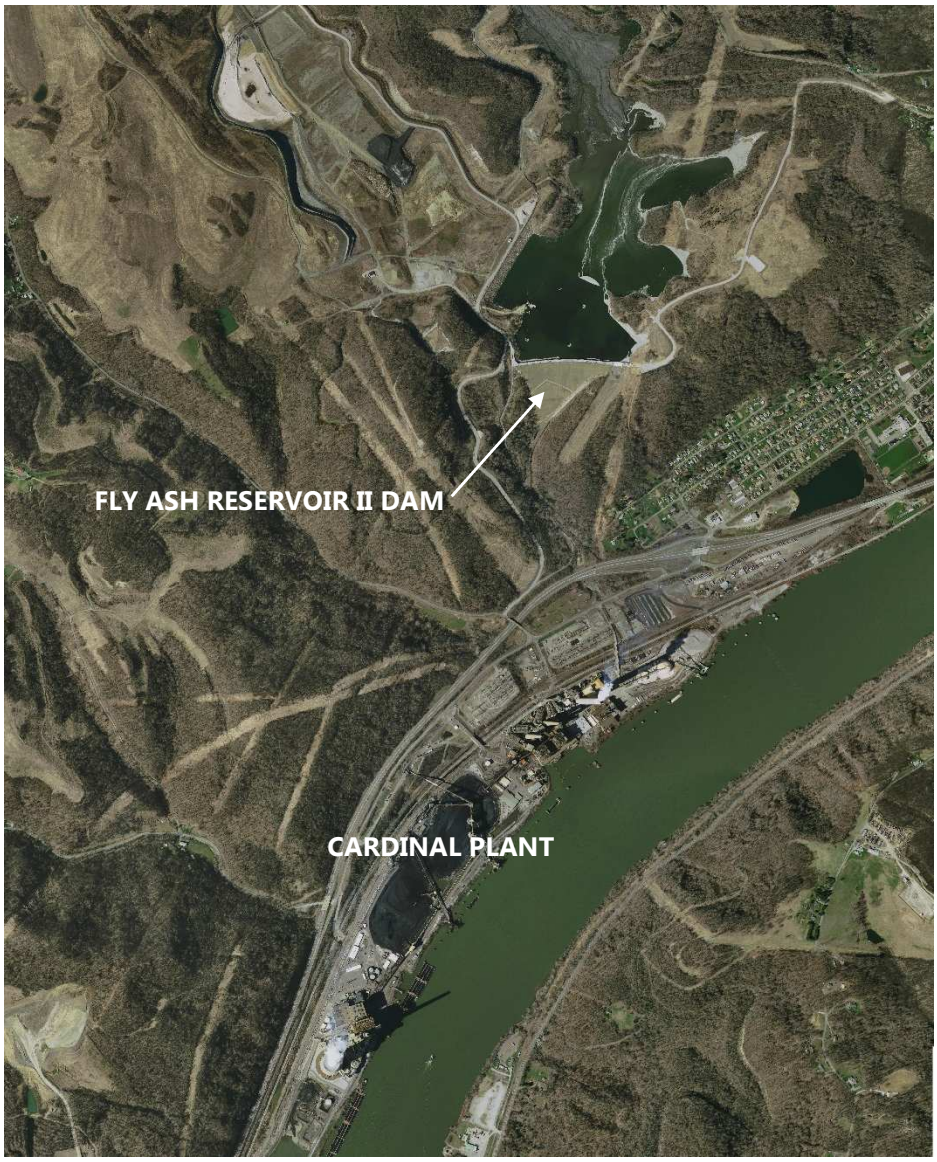
1.1 Background

In April of 2015, the US EPA formally published national regulations for disposal of coal combustion residuals (CCR) from electric facilities. As part of the rule, the owner or operator of the CCR unit must obtain a certification from a qualified professional engineer stating that aspects of the CCR impoundments are in accordance with the rules. Based on our understanding of the Request for Fee Estimate received from AEP on April 29, 2015, AEP specifically requested P.E. certification to fulfill the requirements of 40 CFR § 257.73(e), *Periodic Safety Factor Assessments*. S&ME performed the design and construction administration for the dam raising completed in 2014. Due to our familiarity with the site, S&ME was selected to perform the Safety Factor Assessment for this facility. S&ME understands that certification and/or documentation for other structural integrity criteria will be performed by AEP or other consultants.

1.2 Location and Historic Overview

The Cardinal Power Plant is located along the Ohio River, approximately 8 miles south of Steubenville in Jefferson County. Then Fly Ash Reservoir II is an on-stream reservoir within the east branch of Blockhouse Run, located approximately, three-quarters of a mile north of the plant. Completed in 1986, the original earth fill dam, referred to as Stage 1, consisted of a 180 feet high arched dam constructed as a conventional zoned earth embankment. At 925 feet NGVD, the dam featured a 70-foot wide by 1,055-feet long crest. The maximum operating pool that could be achieved with the original configuration was El. 913. Construction of the first dam raising, referred to as Stage 2, was completed in 1997 which brought the dam to a maximum height of 225 feet with a 30 foot wide crest at Elevation 970 feet and a maximum operating pool Elevation of 960 feet. The dam raising was achieved through the use of an upstream soil cement block (cement stabilized bottom ash) in conjunction with a downstream earth fill along with extensions of the upstream bottom ash filter, clay core, chimney drain and downstream mine spoil shell. At the completion of the 1997 raising, the upper portion of the entire dam crest consisted of a minimum of 9 feet of RCC to both protect the dam from erosion and serve as a roadway. In 2013, the dam was raised an additional 13 feet with the construction of a double-sided mechanically stabilized earth (MSE) wall system on top of the RCC, raising the maximum operating pool to Elevation 974 feet. To control seepage, a cement-bentonite slurry wall was constructed which penetrated into the existing clay core. A non-structural vinyl sheet pile wall was then inserted full depth through the slurry wall and extended to the top of the raised dam in between the MSE reinforced zones. The raised dam also includes a modified auxiliary spillway composed of mass concrete, and a precast service spillway extension.

Figure 1-1 – Location Map



1.3 Previous Investigations and Design Work

In 2010, the undersigned senior engineer, when in the employment of BBC&M Engineering, Inc., completed a supplemental geotechnical assessment of the FAR-II Dam. The assessment consisted of performing slope stability analysis for various steady-state, seismic, rapid drawdown, and surcharge loading cases load cases which were not previously addressed.

S&ME began design work for the FAR-II dam raising in 2011. In support of the design, S&ME conducted a subsurface investigation consisting of soil borings, test pits, and core samples of the soil cement block. S&ME then worked closely with AEP and state dam safety officials to permit this unique structure,

including evaluating a variety of seepage and stability failure modes as well as the potential for corrosion of the reinforced concrete wall panels. S&ME then served in a construction administration role for the duration of construction. Upon completion of the project in April of 2014, S&ME issued an Engineering Certification Letter to the Ohio Department of Natural Resources, Division of Soil and Water. S&ME also completed a First Filling Plan and updated the Operation, Maintenance, and Inspection Manual and Emergency Action Plan.

2.0 Scope of Work

In accordance with AEP's request, the following work items were performed by S&ME:

1. S&ME completed a cursory review of the previously conducted design work for the recent dam raising, as well as a previous design reports and construction documents made available by AEP.

2. S&ME visited the site along with personnel from AEP to observe the facility. It should be noted that the ODNR Division of Soil and Water, Dam Safety Section conducted the 1-year inspection of the dam in June of 2015 and concluded that construction was performed in accordance with the terms of the permit, plans, specifications, and approved changes.

3. Action values relating to instrumentation measurements were determined based on slope stability analyses using the critical cross-section and examination of historical piezometer readings provided by AEP.

4. Upon completing Tasks 1 through 4, S&ME's determined that there was sufficient information to certify the structural integrity of the surface impoundment in accordance with the requirements of 40 CFR § 257.73(e). A separate letter has been prepared to this effect.

3.0 Information Review and Site Visit

To support the safety factor assessment, S&ME conducted a cursory review of previous documents relating to the FAR-II Dam and conducted a site visit at the facility. While not a comprehensive list, AEP provided S&ME with the following documents during the course of our involvement with this facility:

- Design Report: Proposed Dam for Fly Ash Retention Pond II, December 1984
- Construction Plans, Fly Ash Dam 2
- Final Design Report: Proposed Earth Fill-Roller Compacted Concrete Raising of Dam for Fly Ash Retention Pond II, March, 1997
- Construction Plans, Dam Raising of Fly Ash Retention Dam II, March 1997
- RCC QA/QC Plan for 1997 Raising, July 1998
- 1997 Failure Repair Report
- 1999 Post Construction Performance Report
- 2004 Seepage Report

On August 18, 2015, the undersigned S&ME personnel met with Dr. Mohammad Ajlouni (AEP Civil Engineering) and Mr. Randy Sims (Landfill Operations) at the Cardinal Plant and conducted a site visit at the FAR-II Dam. The participants observed the site and discussed recent monitoring results, as well as

tentative plans to raise the pool level by adding additional stop logs. S&ME observed slight rutting along the wheel path on top of the dam, as well as minor settlement of the granular infill adjacent to the panels. Instrumentation readings from 12 tiltmeter sensors placed on the MSW wall panels indicate that both the upstream and downstream MSE wall panels are leaning outward slightly, however the rate of movement has now generally leveled off. This outward tilt appears to be an expression of the rotational movement needed to fully engage the geogrid reinforcement. S&ME understands that AEP is closely monitoring the ongoing instrumentation readings. While the site visit was not a formal inspection, visual observations of the FAR-II Dam did not reveal any dam safety concerns, and the downstream slopes appear to be in a similar condition as observed during construction of the recent dam raising.

4.0 Safety Factor Assessment

As part of the safety factor assessment, S&ME completed Parts 1 and 2 of Section 257.73(e) of the Final Rules for the Disposal of Coal Combustion Residuals from Electric Utilities published on April 17, 2015 in the Federal Register. In accordance with the Rule, the analysis was performed for the critical cross-sections(s) that are anticipated to be most susceptible of all cross-sections to structural failure based on appropriate engineering considerations. The Rule specified the following loading conditions for analysis:

i. Static Factor of Safety under the long-term, maximum storage pool loading condition must equal or exceed 1.50.
ii. Calculated static factor of safety under the maximum surcharge pool loading condition must equal or exceed 1.50
iii. The calculated seismic factor of safety must equal or exceed 1.00
iv. For dikes constructed of soils susceptible to liquefaction, the calculated liquefaction factor of safety must equal or exceed 1.20.

4.1 Limit Equilibrium Analyses

Our 2013 Dam Raising Design Report discusses in detail the subsurface investigation, laboratory testing, parameter justification, seepage analyses and limit equilibrium slope stability analyses that were performed to develop safety factors for the FAR-II Dam Raising design. S&ME focused on evaluating the cross-section through the high point of the dam with additional slope stability runs performed for the section through the existing emergency spillway. Two dimensional slope stability analyses were performed under End of Construction, Long Term Maximum Pool (Static), Maximum Surcharge Pool, Rapid Drawdown, and seismic loading conditions in conformance with the US Army Corps of Engineers Manual 1110-2-1902 entitled Slope Stability. The phreatic surface was modeled based on current piezometer data collected from at the site and the results of the finite element seepage analysis. However, the phreatic surface was entered manually to minimize the potential for computation uncertainty as compared to directly using the finite element analysis output pressures.

Shear strength parameters representing the existing dam zones were developed by AEP and their consultants for the design of the Stage 1 and Stage 2 dams. These values were used as the starting point for the Stage 3 global stability analyses but were modified in some cases to reflect the results of the current investigation or to investigate particular failure modes. Additionally, the Stage 3 raising included several new material zones: the MSE wall reinforced zone (No. 57 stone), ODOT Item 304 surface course,

the cement-bentonite slurry wall, and the vinyl sheet pile wall. The shear strength parameters for these new materials were estimated based on past experience. It should also be noted that the strength of these materials does not appreciably impact the global stability analyses. Additional discussion of the shear strength values for the most critical zones is provided in the 2013 Final Design Report.

4.2 Liquefaction Potential of Embankment Soils

S&ME reviewed the material and compaction specifications of the embankment fill for the original dam construction and subsequent raisings. The dam was constructed entirely of engineered materials and was designed in accordance with the methods used to design conventional water reservoirs. The embankment fill consists of fine grained overburden soil and mine spoil fill from near the project site. With the exception of the blanket drain, chimney drain, and rip rap zone, all earthen material was compacted to 100% of the standard proctor compaction test. Based on this understanding, the embankment soils are considered non-liquefiable. Furthermore, liquefaction of the foundation soils is not a concern as the overburden beneath the dam was removed prior to fill placement, with the dam supported directly on bedrock

4.3 Summary of Results

Based on our previous investigations and current assessment of the Bottom Ash Pond facility, S&ME certifies that this assessment meets the requirements of 40 CFR § 257.73(e), *Periodic Safety Factor Assessments*. A summary of the computed safety factors for the critical cross-section is provided in Table 5-1. Also included in the table are the minimum values defined in 40 CFR § 257.73(e)(1) subparts (i) through (iv). Graphical output corresponding to the analysis cases are presented in Appendix II.

Table 4-1 – Safety Factor Summary

Analysis Case	Minimum Safety Factor	Computed Safety Factor
Long-term, maximum storage pool	1.50	1.75
Maximum surcharge pool	1.40	1.68
Pseudo-static seismic loading	1.00	1.11
Embankment Liquefaction	1.20	Non-liquefiable

5.0 Certification

Based on our previous investigation, design, and construction administration work associated with the Fly Ash Reservoir II Dam, S&ME certifies that this assessment meets the requirements of 40 CFR § 257.73(e), *Periodic Safety Factor Assessments.* A summary of the computed safety factors for the critical cross-section is provided in the table below. Also included in the table are the minimum values defined in 40 CFR § 257.73(e)(1) subparts (i) through (iv).

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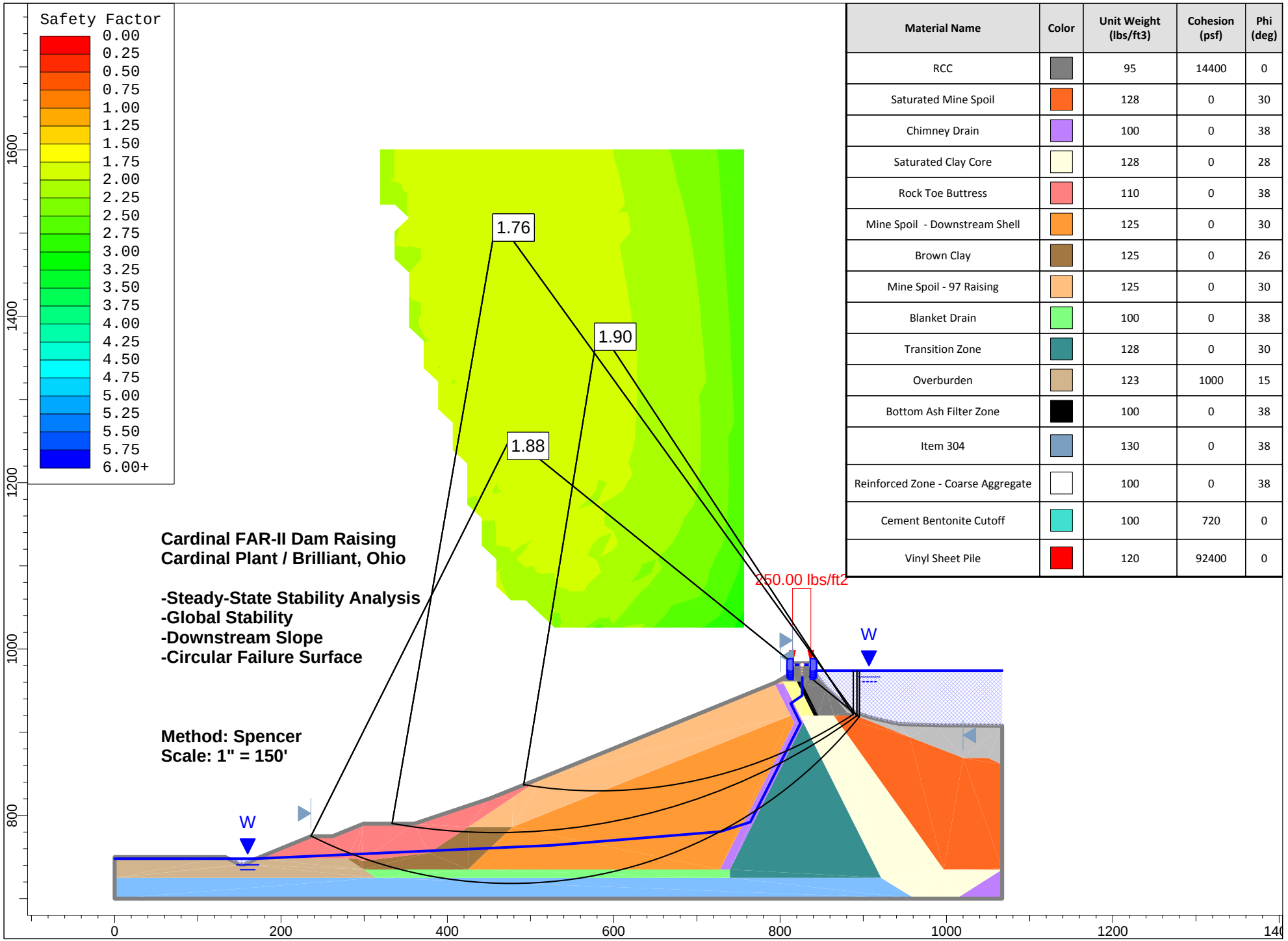
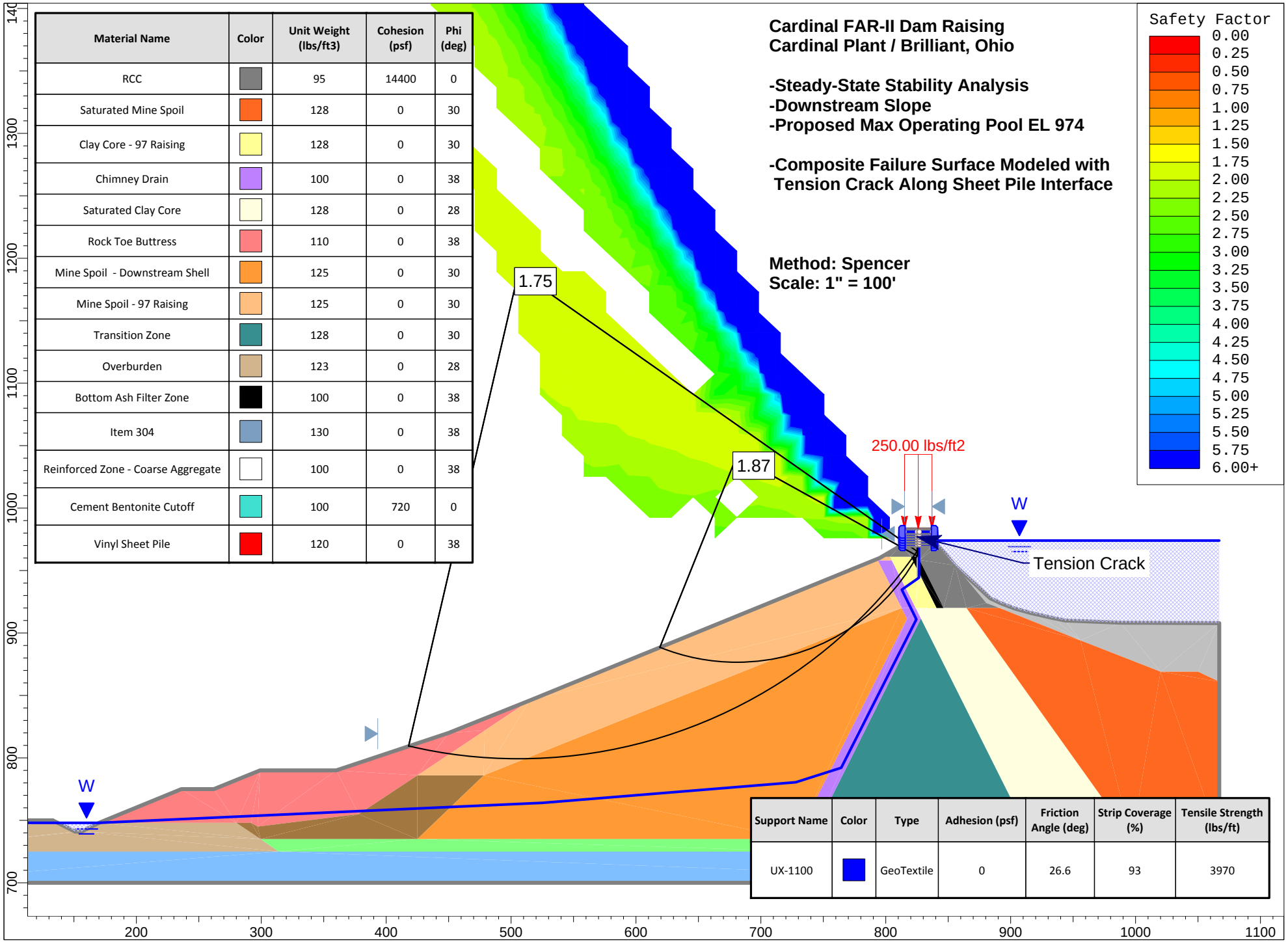
Appendices

Appendix I – Safety Factor Assessment Figures

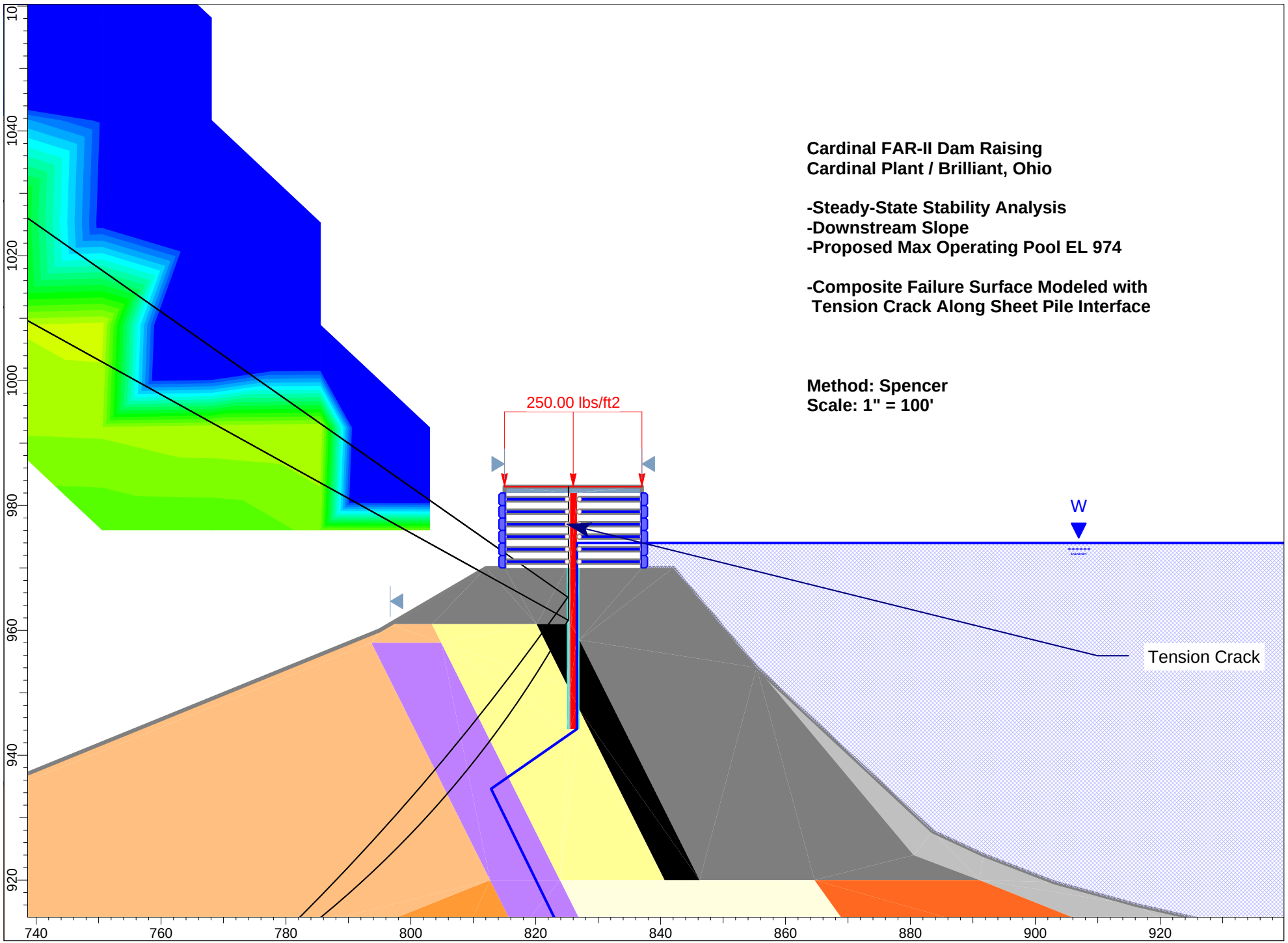


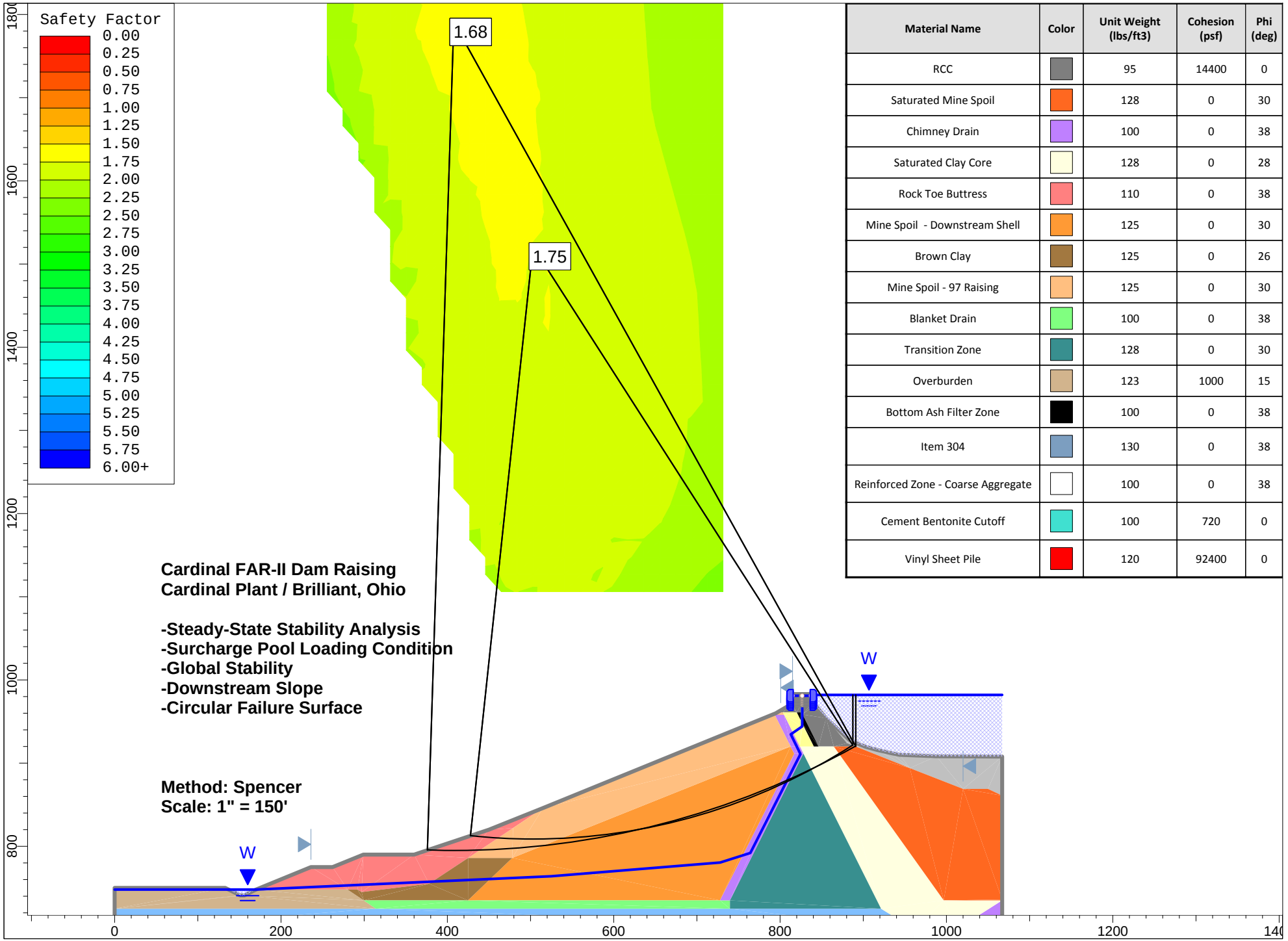
Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
RCC		95	14400	0
Saturated Mine Spoil		128	0	30
Chimney Drain		100	0	38
Saturated Clay Core		128	0	28
Rock Toe Buttress		110	0	38
Mine Spoil - Downstream Shell		125	0	30
Brown Clay		125	0	26
Mine Spoil - 97 Raising		125	0	30
Blanket Drain		100	0	38
Transition Zone		128	0	30
Overburden		123	1000	15
Bottom Ash Filter Zone		100	0	38
Item 304		130	0	38
Reinforced Zone - Coarse Aggregate		100	0	38
Cement Bentonite Cutoff		100	720	0
Vinyl Sheet Pile		120	92400	0



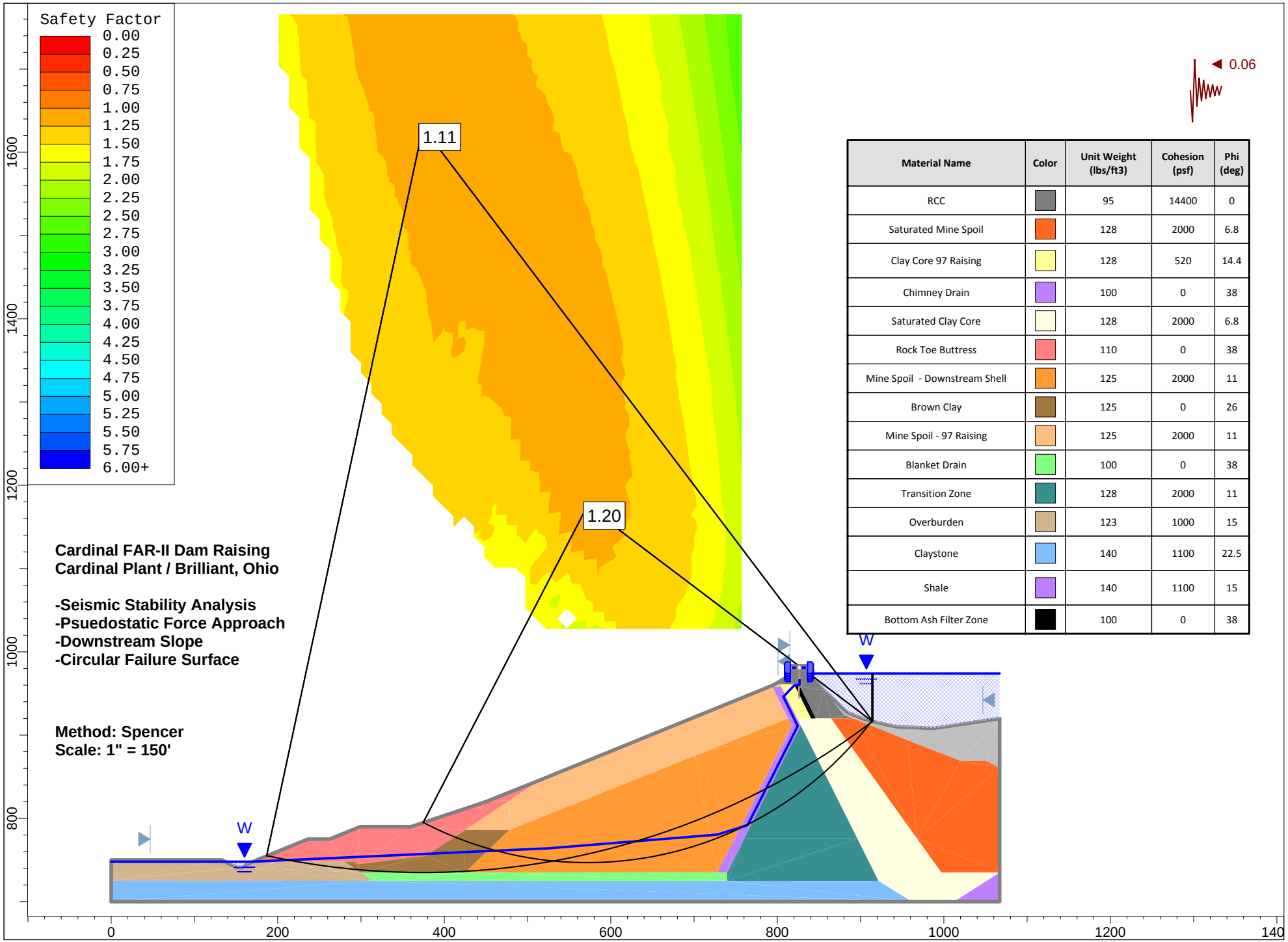
Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
RCC		95	14400	0
Saturated Mine Spoil		128	0	30
Clay Core - 97 Raising		128	0	30
Chimney Drain		100	0	38
Saturated Clay Core		128	0	28
Rock Toe Buttress		110	0	38
Mine Spoil - Downstream Shell		125	0	30
Mine Spoil - 97 Raising		125	0	30
Transition Zone		128	0	30
Overburden		123	0	28
Bottom Ash Filter Zone		100	0	38
Item 304		130	0	38
Reinforced Zone - Coarse Aggregate		100	0	38
Cement Bentonite Cutoff		100	720	0
Vinyl Sheet Pile		120	0	38

Support Name	Color	Type	Adhesion (psf)	Friction Angle (deg)	Strip Coverage (%)	Tensile Strength (lbs/ft)
UX-1100		GeoTextile	0	26.6	93	3970


Cardinal FAR-II Dam Raising
Cardinal Plant / Brilliant, Ohio
-Steady-State Stability Analysis
-Downstream Slope
-Proposed Max Operating Pool EL 974
-Composite Failure Surface Modeled with
Tension Crack Along Sheet Pile Interface
Method: Spencer
Scale: 1" = 100'
250.00 lbs/ft2
W
Tension Crack
1040
1020
1000
980
960
940
920
740
760
780
800
820
840
860
880
900
920

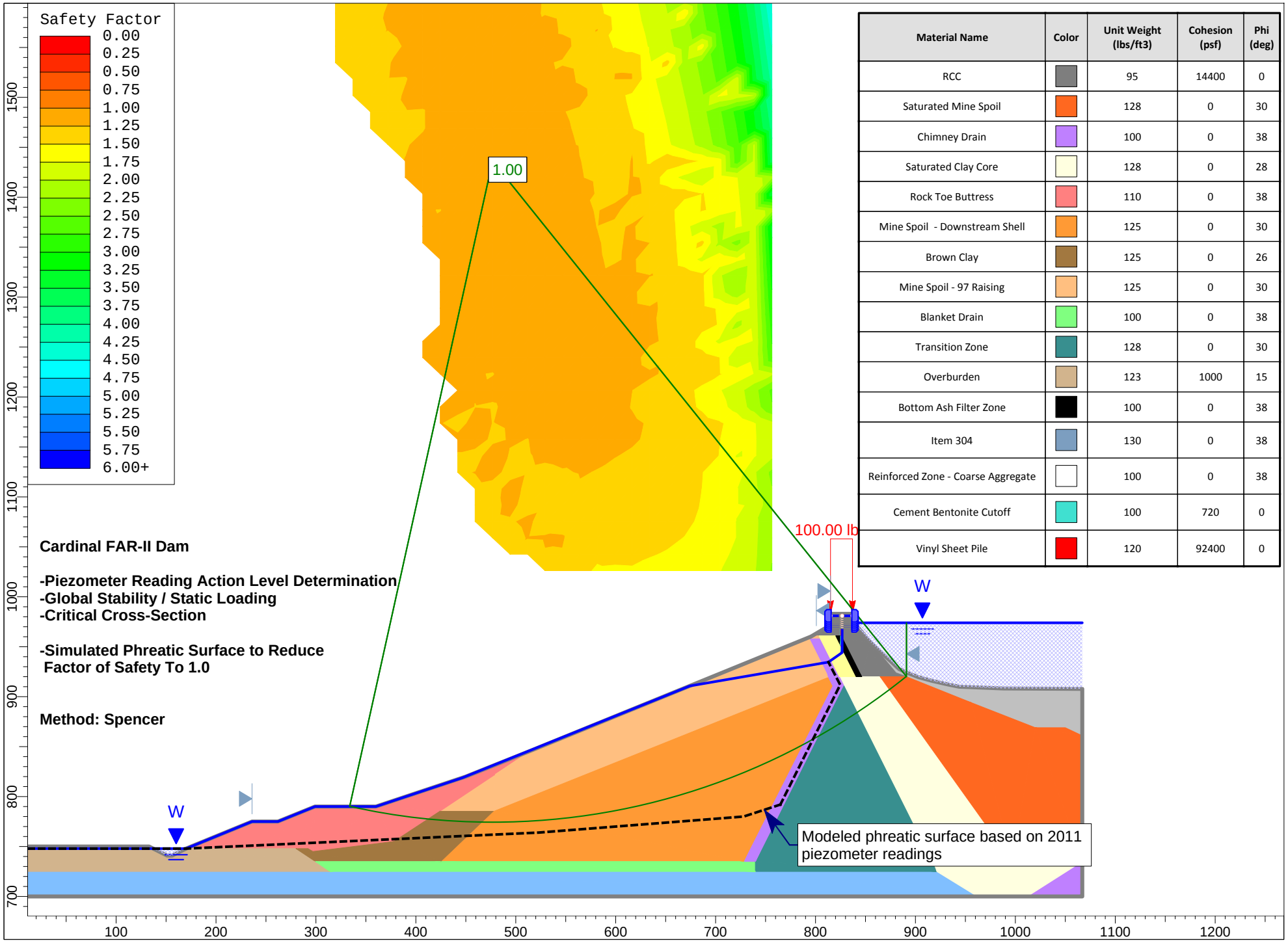


Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
RCC		95	14400	0
Saturated Mine Spoil		128	0	30
Chimney Drain		100	0	38
Saturated Clay Core		128	0	28
Rock Toe Buttress		110	0	38
Mine Spoil - Downstream Shell		125	0	30
Brown Clay		125	0	26
Mine Spoil - 97 Raising		125	0	30
Blanket Drain		100	0	38
Transition Zone		128	0	30
Overburden		123	1000	15
Bottom Ash Filter Zone		100	0	38
Item 304		130	0	38
Reinforced Zone - Coarse Aggregate		100	0	38
Cement Bentonite Cutoff		100	720	0
Vinyl Sheet Pile		120	92400	0

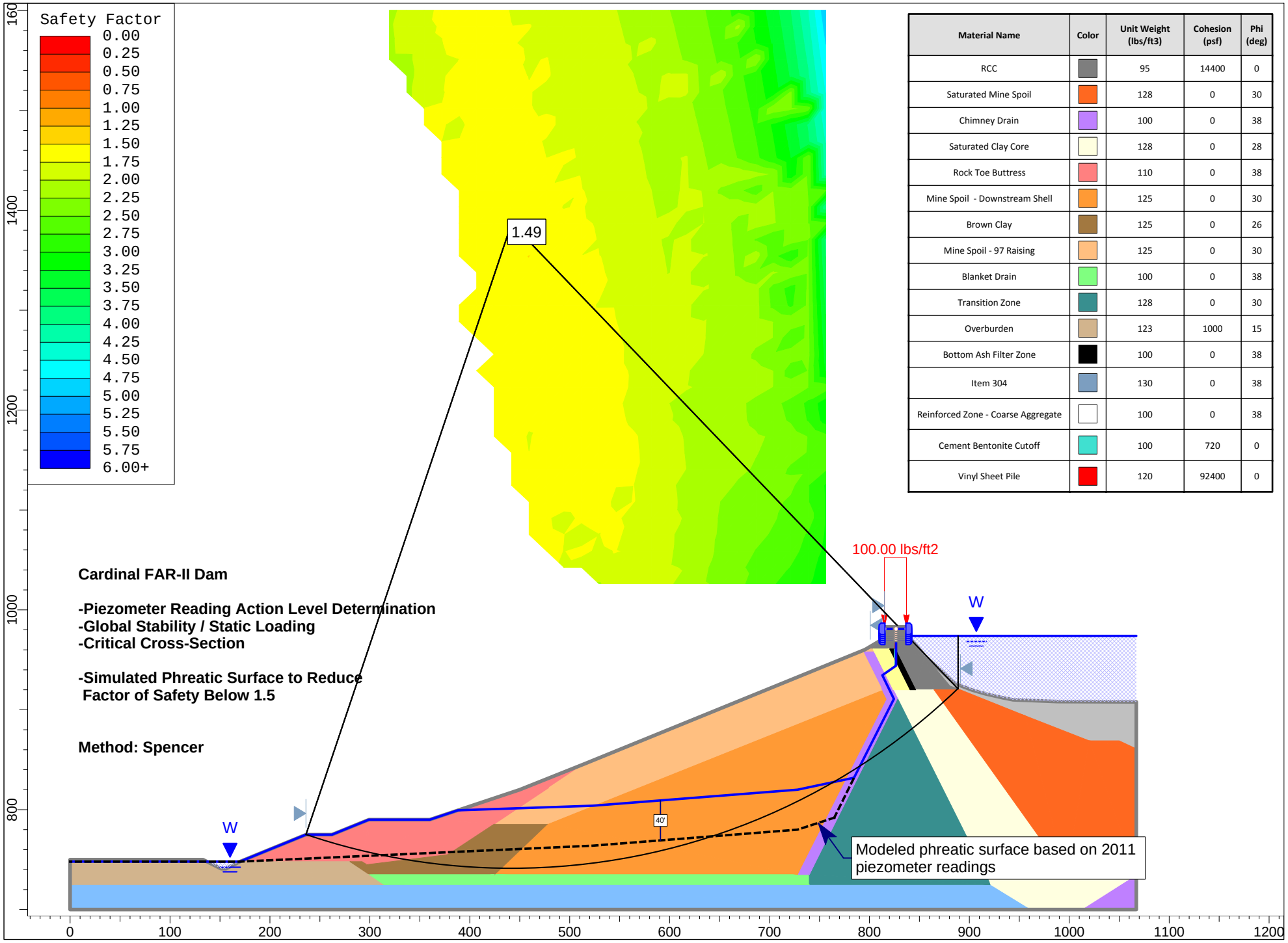


Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
RCC		95	14400	0
Saturated Mine Spoil		128	2000	6.8
Clay Core 97 Raising		128	520	14.4
Chimney Drain		100	0	38
Saturated Clay Core		128	2000	6.8
Rock Toe Buttress		110	0	38
Mine Spoil - Downstream Shell		125	2000	11
Brown Clay		125	0	26
Mine Spoil - 97 Raising		125	2000	11
Blanket Drain		100	0	38
Transition Zone		128	2000	11
Overburden		123	1000	15
Claystone		140	1100	22.5
Shale		140	1100	15
Bottom Ash Filter Zone		100	0	38

Appendix II – Action Value Recommendation Figures



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
RCC		95	14400	0
Saturated Mine Spoil		128	0	30
Chimney Drain		100	0	38
Saturated Clay Core		128	0	28
Rock Toe Buttress		110	0	38
Mine Spoil - Downstream Shell		125	0	30
Brown Clay		125	0	26
Mine Spoil - 97 Raising		125	0	30
Blanket Drain		100	0	38
Transition Zone		128	0	30
Overburden		123	1000	15
Bottom Ash Filter Zone		100	0	38
Item 304		130	0	38
Reinforced Zone - Coarse Aggregate		100	0	38
Cement Bentonite Cutoff		100	720	0
Vinyl Sheet Pile		120	92400	0



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
RCC		95	14400	0
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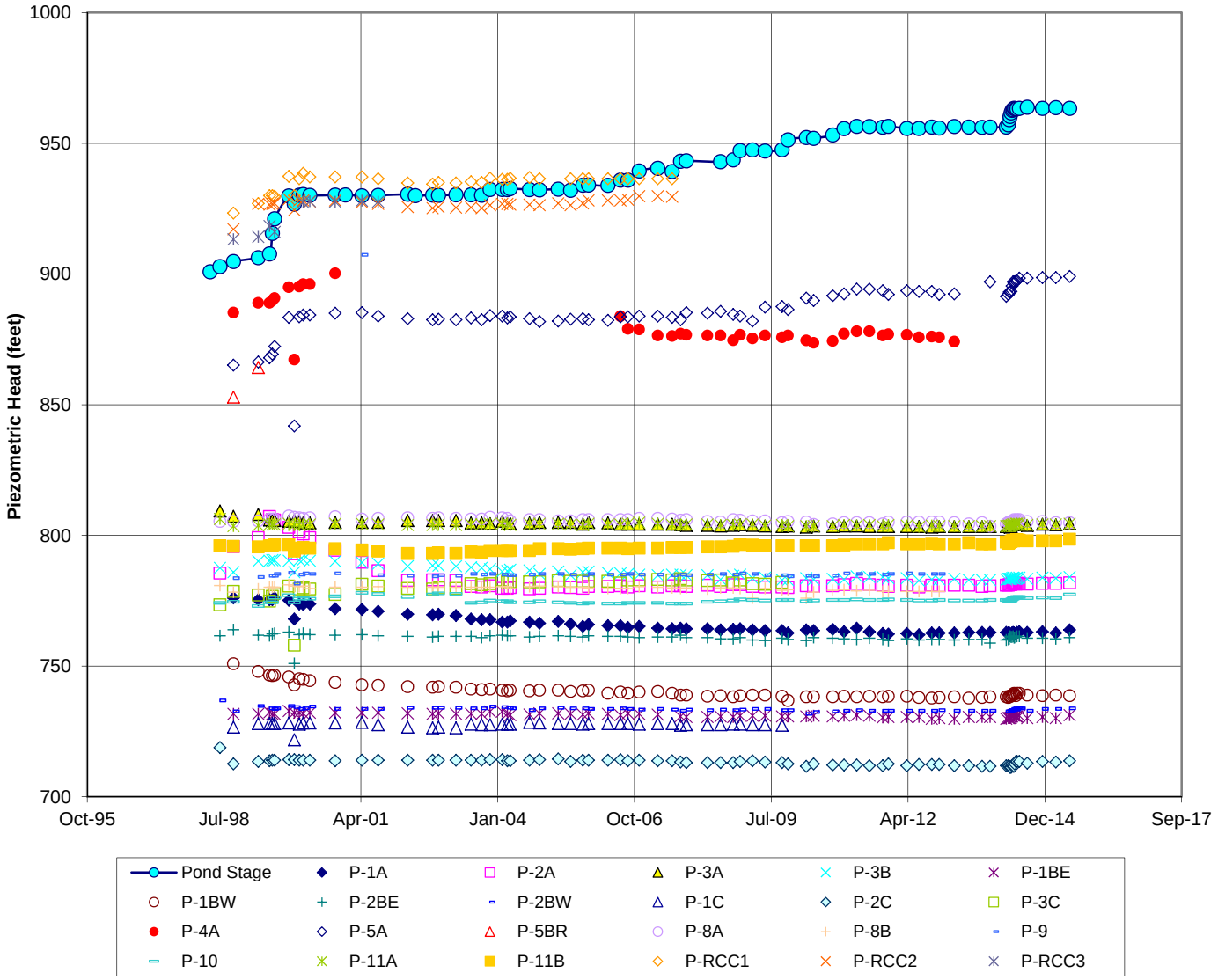
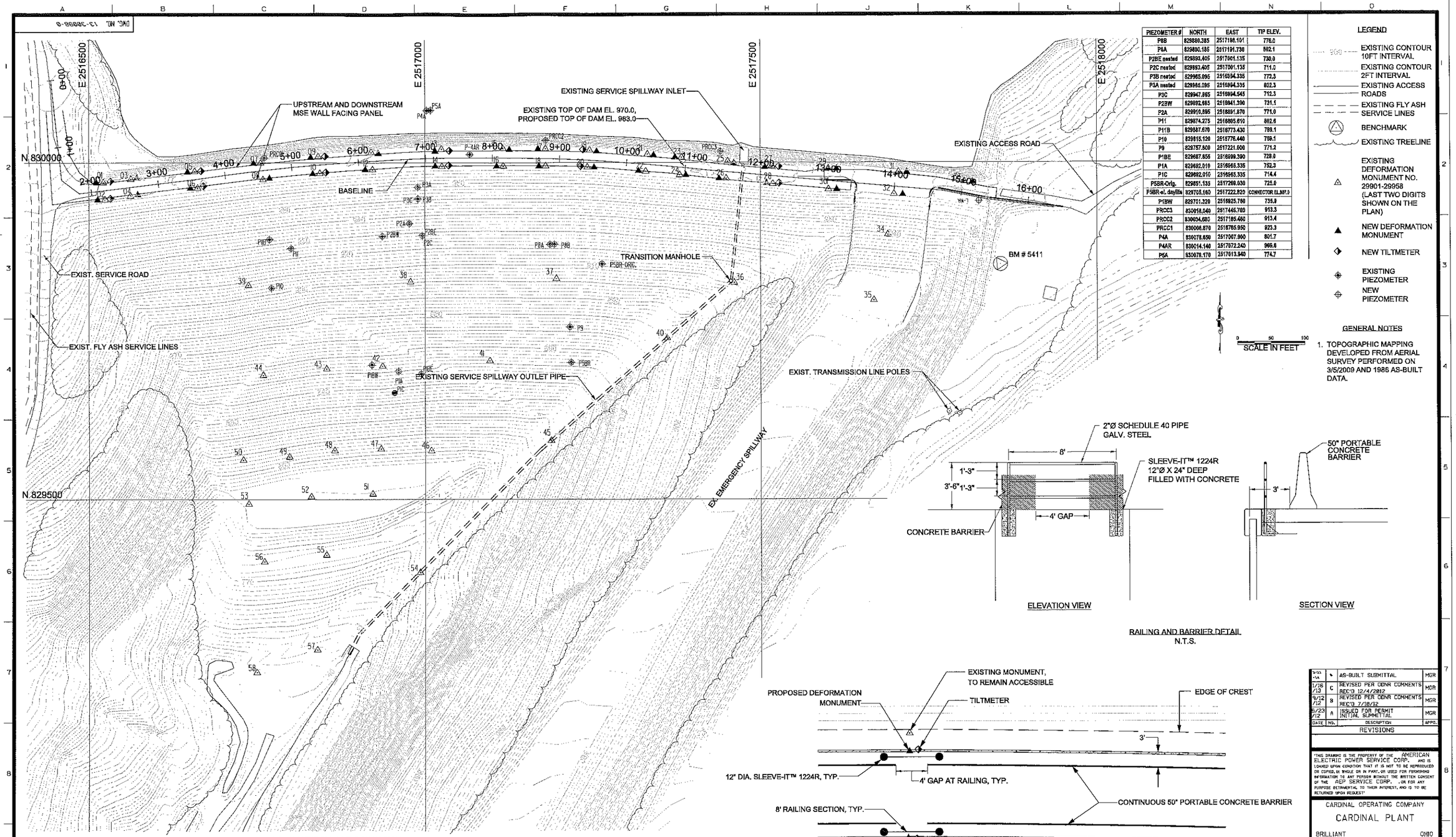
Chimney Drain		100	0	38
Saturated Clay Core		128	0	28
Rock Toe Buttress		110	0	38
Mine Spoil - Downstream Shell		125	0	30
Brown Clay		125	0	26
Mine Spoil - 97 Raising		125	0	30
Blanket Drain		100	0	38
Transition Zone		128	0	30
Overburden		123	1000	15
Bottom Ash Filter Zone		100	0	38
Item 304		130	0	38
Reinforced Zone - Coarse Aggregate		100	0	38
Cement Bentonite Cutoff		100	720	0
Vinyl Sheet Pile		120	92400	0

Figure 5a
Cardinal Far 2





PIEZOMETER #	NORTH	EAST	TIP ELEV.
P6B	829880.385	2517198.101	776.0
P6A	829890.185	2517191.730	802.1
P2BE nested	829893.405	2517001.135	730.0
P2C nested	829893.405	2517001.135	711.0
P3B nested	829965.095	2516994.335	772.3
P3A nested	829965.095	2516994.335	802.3
P3C	829947.895	2516994.545	712.3
P2BW	829892.985	2516941.390	731.1
P2A	829910.595	2516891.870	771.0
P1I	829874.275	2516805.610	802.6
P1B	829837.670	2516773.430	789.1
P1O	829815.120	2516776.440	759.1
P9	829757.800	2517221.600	771.2
P1BE	829687.855	2516899.390	728.0
P1A	829692.010	2516965.335	752.3
P1C	829692.010	2516965.335	714.4
P5BR-Orig.	829851.135	2517269.030	725.0
P5BR-el. daylite	829705.160	2517222.820	CONNECTOR EL.897.0
P1BW	829701.320	2516825.760	735.9
PRCC3	830018.040	2517445.700	913.3
PRCC2	830034.680	2517185.460	913.4
PRCC1	830006.870	2516765.950	923.3
P4A	830078.650	2517067.960	801.7
P4AR	830014.140	2517072.240	969.6
P5A	830078.170	2517013.940	774.7

LEGEND

- EXISTING CONTOUR 10FT INTERVAL
- EXISTING CONTOUR 2FT INTERVAL
- EXISTING ACCESS ROADS
- EXISTING FLY ASH SERVICE LINES
- BENCHMARK
- EXISTING TREELINE
- EXISTING DEFORMATION MONUMENT NO. 29901-29958 (LAST TWO DIGITS SHOWN ON THE PLAN)
- NEW DEFORMATION MONUMENT
- NEW TILTMETER
- EXISTING PIEZOMETER
- NEW PIEZOMETER

SCALE IN FEET 0 50 100

GENERAL NOTES

1. TOPOGRAPHIC MAPPING DEVELOPED FROM AERIAL SURVEY PERFORMED ON 3/5/2009 AND 1986 AS-BUILT DATA.

RAILING AND BARRIER DETAIL
N.T.S.

RAILING AND BARRIER PLAN
N.T.S.

NOTE: ALL EXISTING DEFORMATION MONUMENTS TO REMAIN ACCESSIBLE EXCEPT #29931 THROUGH #29934.

⚠ ALL OF EXISTING DEFORMATION MONUMENTS DESTROYED DURING CONSTRUCTION

⚠ NEW DEFORMATION MONUMENTS AND TILTMETERS ARE SHOWN NEAR AS-BUILT LOCATION

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STATE OF OHIO · MICHAEL GILBERT ROWLAND · E-65559 · REGISTERED PROFESSIONAL ENGINEER

MICHAEL GILBERT ROWLAND — E-65559 NUMBER — JAN 16, 2013 DATE

REV. NO.	DESCRIPTION	APPD.
A	AS-BUILT SUBMITTAL	MGR
C	REVISED PER ODNR COMMENTS REC'D 12/4/2012	MGR
B	REVISED PER ODNR COMMENTS REC'D 7/18/12	MGR
A	ISSUED FOR PERMIT INITIAL SUBMITTAL	MGR

REVISIONS

CARDINAL OPERATING COMPANY
CARDINAL PLANT
BRILLIANT OHIO

DAM RAISING
FLY ASH RETENTION DAM II
INSTRUMENTATION PLAN

DWG. NO. 13-38898-0

ARCH — ELEC — MECH — STR — CS

SCALE: AS SHOWN

CIVIL ENGINEERING DIVISION

APPROVED BY:

DATE:

PROJECT NUMBER:	011-11497-042	DRAWN BY:	EDV
DRAWING DATE:	9/28/12	ENGINEER:	MTR
LAST UPDATED:	1/18/13	APPROVED BY:	MGR
		SCALE:	AS NOTED

S&ME

AEP AMERICAN ELECTRIC POWER

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COLUMBUS, OH 43215