Initial Safety Factor Assessment
Bottom Ash Pond
Sherburne County Generating Plant

Introduction
This report presents the assessment and certification of the initial safety factor for the Bottom Ash Pond at the Sherburne County Generating Plant (Sherco) in Becker, Minnesota. The Bottom Ash Pond is an "existing" surface impoundment.

Safety Factor Assessment
The Bottom Ash Pond safety factor assessment was conducted using Slope/W slope stability analysis software developed by Geo-Slope International, LTD. All safety factors were determined using the Morgenstern-Price method, as this method satisfies vertical and horizontal force equilibrium and moment equilibrium and considers both inter-slice shear and normal forces.

The Bottom Ash Pond was analyzed according to the following conditions in accordance with §257.73(e)(1)(i) through (iv).

(i) **Condition 1**: The calculated static factor of safety under the long-term, maximum storage pool loading must equal or exceed 1.5.
(ii) **Condition 2**: The calculated static factor of safety under the maximum surcharge pool loading condition must equal or exceed 1.4.
(iii) The calculated seismic factor of safety must equal or exceed 1.00. This was conducted on both Condition 1 and 2.
(iv) For dikes constructed of soils that have susceptibility to liquefaction, the calculated liquefaction factor of safety must equal or exceed 1.00.

The analyses for the Bottom Ash Pond were conducted through the critical cross section, located on the northern dike. The stability calculations for all Conditions were conducted using deep failure modes to determine the global stability of the dike, rather than localized sloughing that would not result in dike failure.

Assumptions:
The analysis of the critical section was based on the following assumptions:
- The geometry of the Bottom Ash Pond at the critical section consists of 2.5H:1V slopes on both sides with a 20-foot wide top. The clay core that runs through the embankment has been built with 1H:12V side slopes, a 10-foot wide top, and a 20-foot wide base.
- Circular failure analysis and a block failure analysis were used for both Conditions.
- The water table was determined from onsite monitoring wells measured on 10/20/2015.
- The seismic stability analysis was conducted using a seismic coefficient equal to one-half of the predicted peak bedrock acceleration during an earthquake with a 2% probability of exceedance in 50 years, or ½ of 0.022g (0.011g) (Hynes-Griffin and Franklin 1984).

- The shear strength of undrained clays during a pseudo-seismic even was reduced by 20% (Hynes-Griffin and Franklin, 1984).
- Conditions 1 and 2 were analyzed for global stability from left to right to determine the safety factor resistance to impounded water.
- The phreatic surface was input as shown with a near vertical downward flow based on the low permeability of the clay core and the high transmissivity of the embankment fill.

Material Properties:
Soil material properties are taken from information provided in historical design and construction reports, and hydrogeologic site investigations. The results and assumptions for each soil are listed below.

Table 1: Material Geotechnical Properties

Material	Unit weight (pcf)	Friction Angle[3] (deg)	Cohesion (psf)	Pseudo-seismic Cohesion (psf)
Embankment Fill[1]	117[2]	30	0	0
Clay Core[4]	119[5]	27	230[6]	184
Native Soils[7]	115	30	0	0
Foundation Material[8]	133	30	0	0
Filter Material[8]	120	30	0	0

Material Notes:
1. The embankment fill was taken from onsite excavation of native soils and re-compacted to produce the embankment fill of the Bottom Ash Pond. The embankment soils were typically classified as either SM or SP-SM.
2. During construction, compaction testing was completed on the embankment fill. Average measured unit weights during construction were between 116.5 and 118.5 pcf. This value takes into consideration the average unit weights for the embankment fill and the typical unit weight for a SM or SP-SM soil.
3. Friction angles used are typical for the classified soil types with similar unit weights.
4. The clay core was taken from an offsite borrow area and was typically classified as either CL, CL-SC, or SC-CL. During construction of the clay core, 8-inch thick loose lifts were placed and compacted to at least 90% standard proctor density.
5. Compaction testing was completed on the clay core during construction. Average measured unit weights ranged between 118 and 121 pcf. This value takes into consideration both the average unit weights and the typical unit weight for soils classified as either CL, CL-SC, or SC-CL.
6. It is assumed there is some additional cohesion of the clay at saturation. The value provided is taken from the typical saturated cohesion of a clay.
7. Native soils collected during previous site investigations were tested in the laboratory for unit weight, Atterberg limits, and soil classification. The native soil material properties are based on the laboratory results from the investigations.

8. The material characteristics for the soils were taken from the historical 1973 Slope Stability Report.

Compliance with §257.73(e)(1)(i) through (iii)

The results of the static and seismic analyses are summarized below in Table 2. The full graphical results can be found in the Attachments.

Table 2: Slope Stability Results

Facility Phase	Static FOS	Minimum Allowable FOS	Pseudo Seismic FOS	Minimum Allowable FOS	Analysis Method
Condition 1 Long Term, Maximum Storage Pool Loading	**1.93**	1.50	**1.92**	1.00	Deep-Circular Failure
Condition 1 Long Term, Maximum Storage Pool Loading	2.48	1.40	2.02	1.00	Deep-Block Failure
Condition 2 Maximum Surcharge Loading	**1.96**	1.40	**1.94**	1.00	Deep-Circular Failure
Condition 2 Maximum Surcharge Loading	2.08	1.40	1.99	1.00	Deep-Block Failure

Compliance with §257.73(e)(1)(iv)

The potential for liquefaction of the soils is considered low based on the surficial geology (both age and soil composition of the Anoka Sand Plain) and the low probability of a large earthquake occurring in Minnesota. According to the Minnesota Geological Survey (MGS), Minnesota has one of the lowest probabilities for an earthquake occurring, and since 1860, only 20 small to moderate earthquakes have been documented. Furthermore, MGS identifies that the potential for a severe earthquake in Minnesota is low, and the Seismic Risk Zone assigned to Minnesota is also zero (meaning lowest risk possible).

Summary

The factor of safety calculated for each of the three critical conditions outlined in the 40 CFR Part 257.73(e) were found acceptable during static and seismic analyses.

Certification

I hereby certify under penalty of law that this report was prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based upon my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

______________________________ October 17, 2016

Daniel J. Riggs, PE Date

License No. 49559

References

Duncan, Michael J. & Wright, Stephen G. 2005. Soil Strength and Slope Stability. John Wiley & Sons, Inc.

Hynes-Griffin, M.E. & A.G. Franklin. 1984. Rationalizing the Seismic Coefficient Method. Department of the Army, Waterways Experiment Station.

Lindeburg, Michael R. Civil Engineering Reference Manual for the PE Exam, 8th edition. 2001.

Minnesota Division of Homeland Security and Emergency Management, Minnesota All-Hazard Mitigation Plan Update, 2011.

Minnesota Geological Survey, Minnesota at a Glance: Earthquakes in Minnesota, University of Minnesota, 2014.

US EPA, RCRA Subtitle D (258) Seismic Design Guidance of Municipal Solid Waste Landfill Facilities, Officer of Research and Development, April 1995, Pages 74-80.

United States Geological Survey (USGS). 2008. PGA with 2% probability exceedance in 50 years

United States Society on Dams. Strength of Materials for Embankment Dams, February 2007.

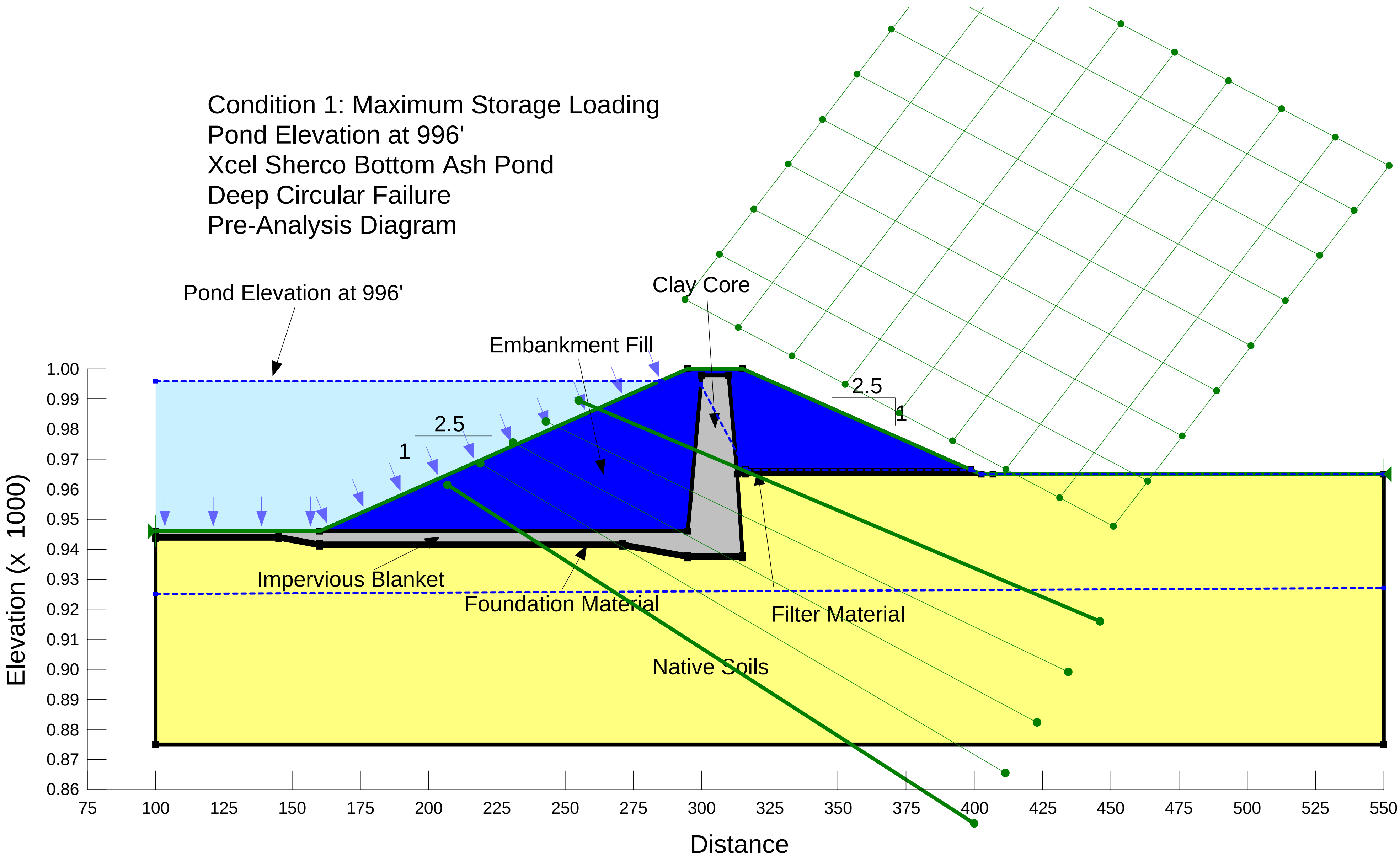
References (included in Operating Record and Website)

Carlson McCain, Inc. (October 2016). "History of Construction, Bottom Ash Pond, Sherburne County Generating Plant", CCR compliance document, Plymouth, Minnesota.

Slope/W Graphical Results

Condition 1

Long Term, Maximum, Storage Pool Loading



Condition 1: Maximum Storage Loading
Pond Elevation at 996'
Xcel Sherco Bottom Ash Pond
Deep Circular Failure
Pre-Analysis Diagram
Pond Elevation at 996'
Clay Core
Embankment Fill
2.5
1
2.5
1
Impervious Blanket
Foundation Material
Filter Material
Native Soils
Elevation (x 1000)
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.90
0.89
0.88
0.87
0.86
75
100
125
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475
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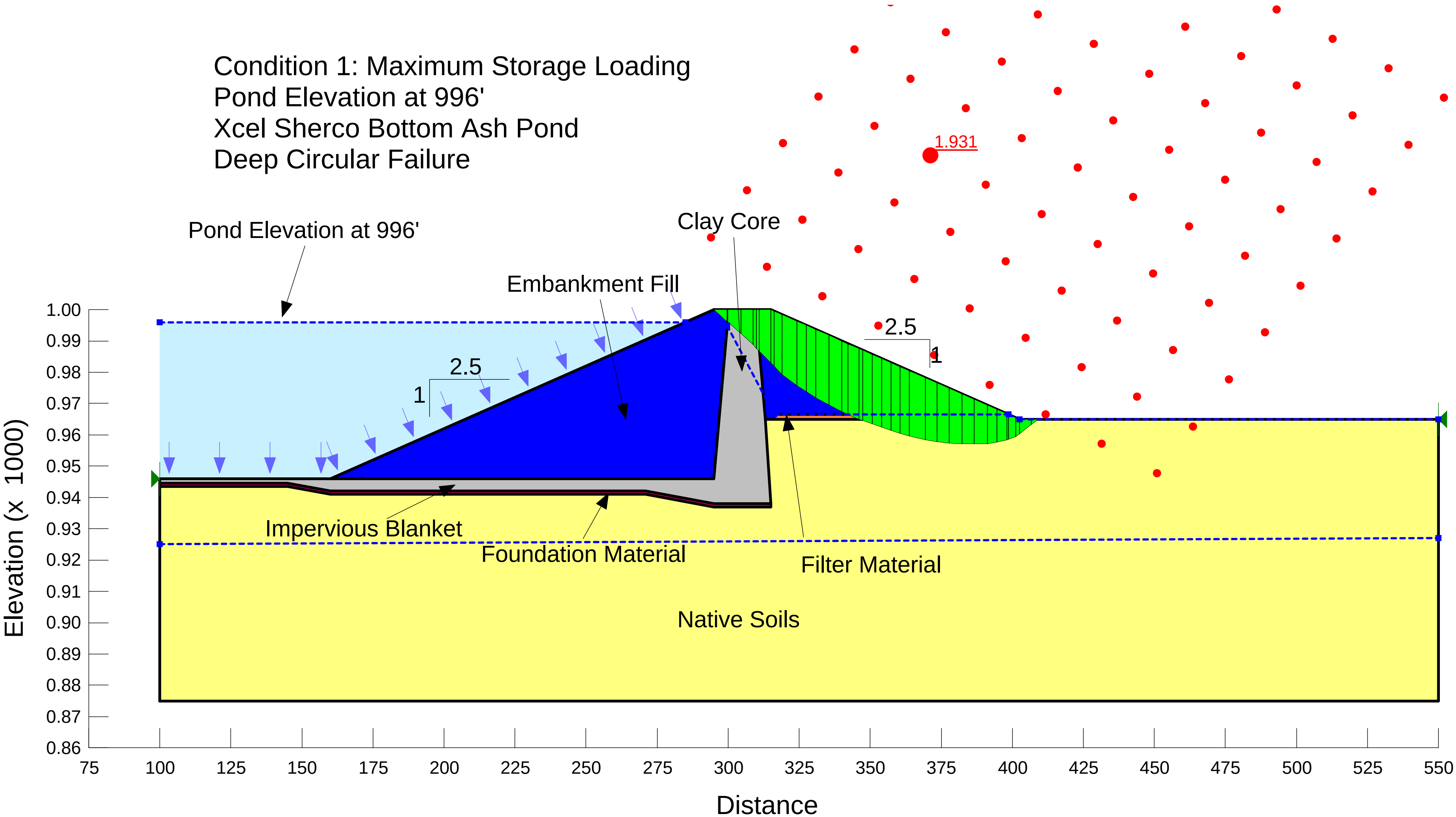
525
550
Distance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Pond Elevation at 996'
Xcel Sherco Bottom Ash Pond
Deep Circular Failure
1.931
Pond Elevation at 996'
Clay Core
Embankment Fill
2.5
1
2.5
1
Impervious Blanket
Foundation Material
Filter Material
Native Soils
Elevation (x 1000)
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.90
0.89
0.88
0.87
0.86
75
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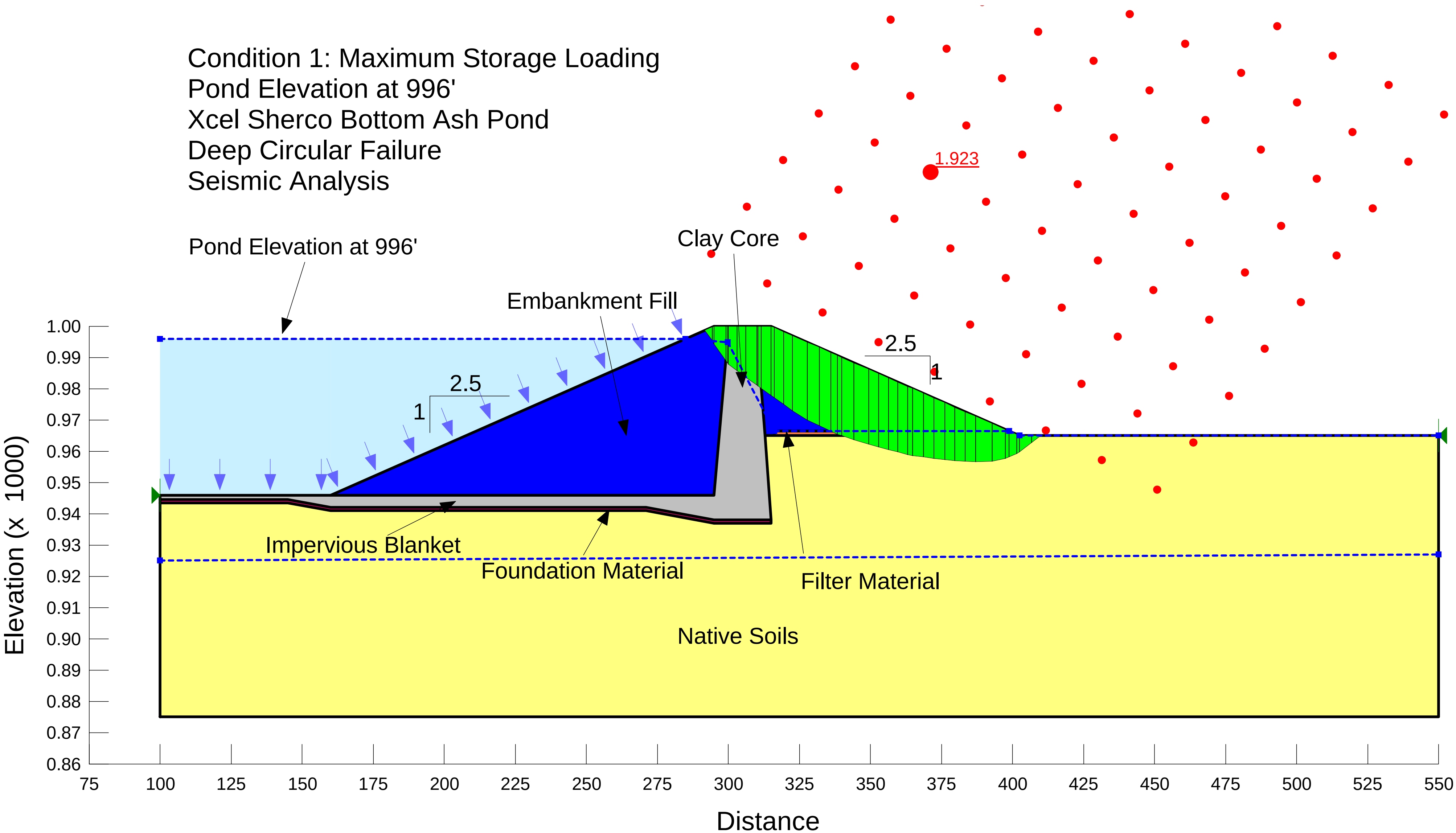
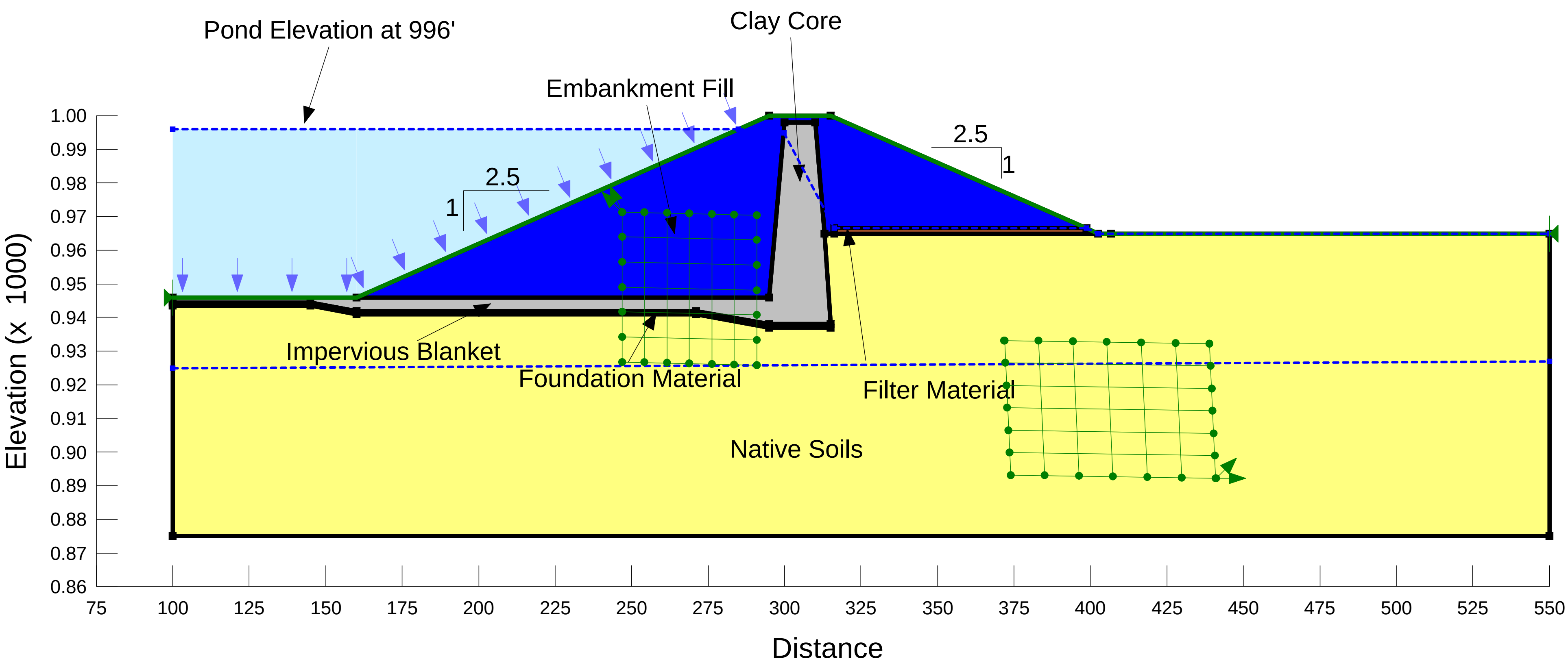
500
525
550
Distance

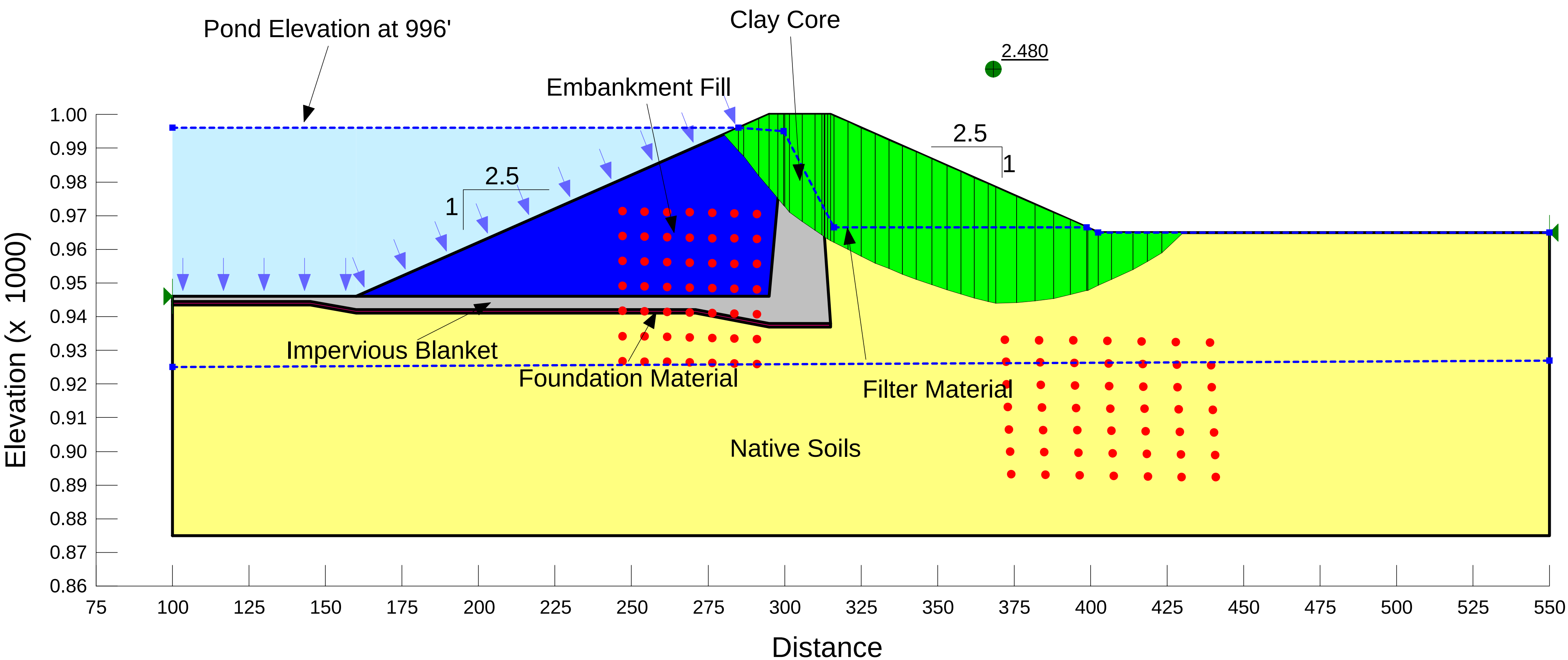


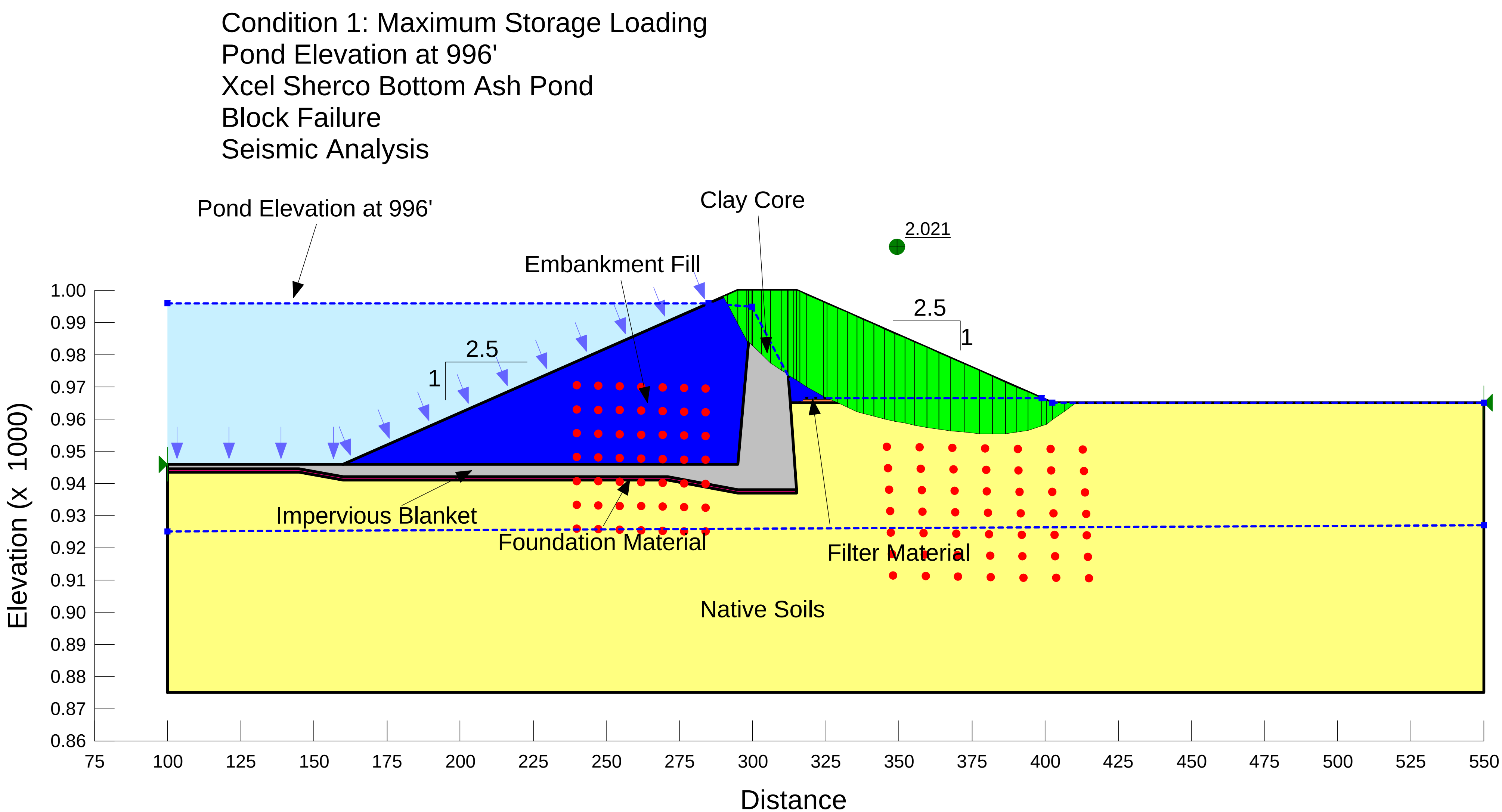
Condition 1: Maximum Storage Loading
Pond Elevation at 996'
Xcel Sherco Bottom Ash Pond
Deep Circular Failure
Seismic Analysis
Pond Elevation at 996'
Clay Core
Embankment Fill
1.923
2.5
1
2.5
1
Impervious Blanket
Foundation Material
Filter Material
Native Soils
Elevation (x 1000)
Distance
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.90
0.89
0.88
0.87
0.86
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
550

Condition 1: Maximum Storage Loading
Pond Elevation at 996'
Xcel Sherco Bottom Ash Pond
Block Failure
Pre-Analysis Diagram



Condition 1: Maximum Storage Loading
Pond Elevation at 996'
Xcel Sherco Bottom Ash Pond
Block Failure





Condition 1: Maximum Storage Loading
Pond Elevation at 996'
Xcel Sherco Bottom Ash Pond
Block Failure
Seismic Analysis
Pond Elevation at 996'
Clay Core
2.021
Embankment Fill
2.5
1
2.5
1
Impervious Blanket
Foundation Material
Filter Material
Native Soils
Elevation (x 1000)
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.90
0.89
0.88
0.87
0.86
75
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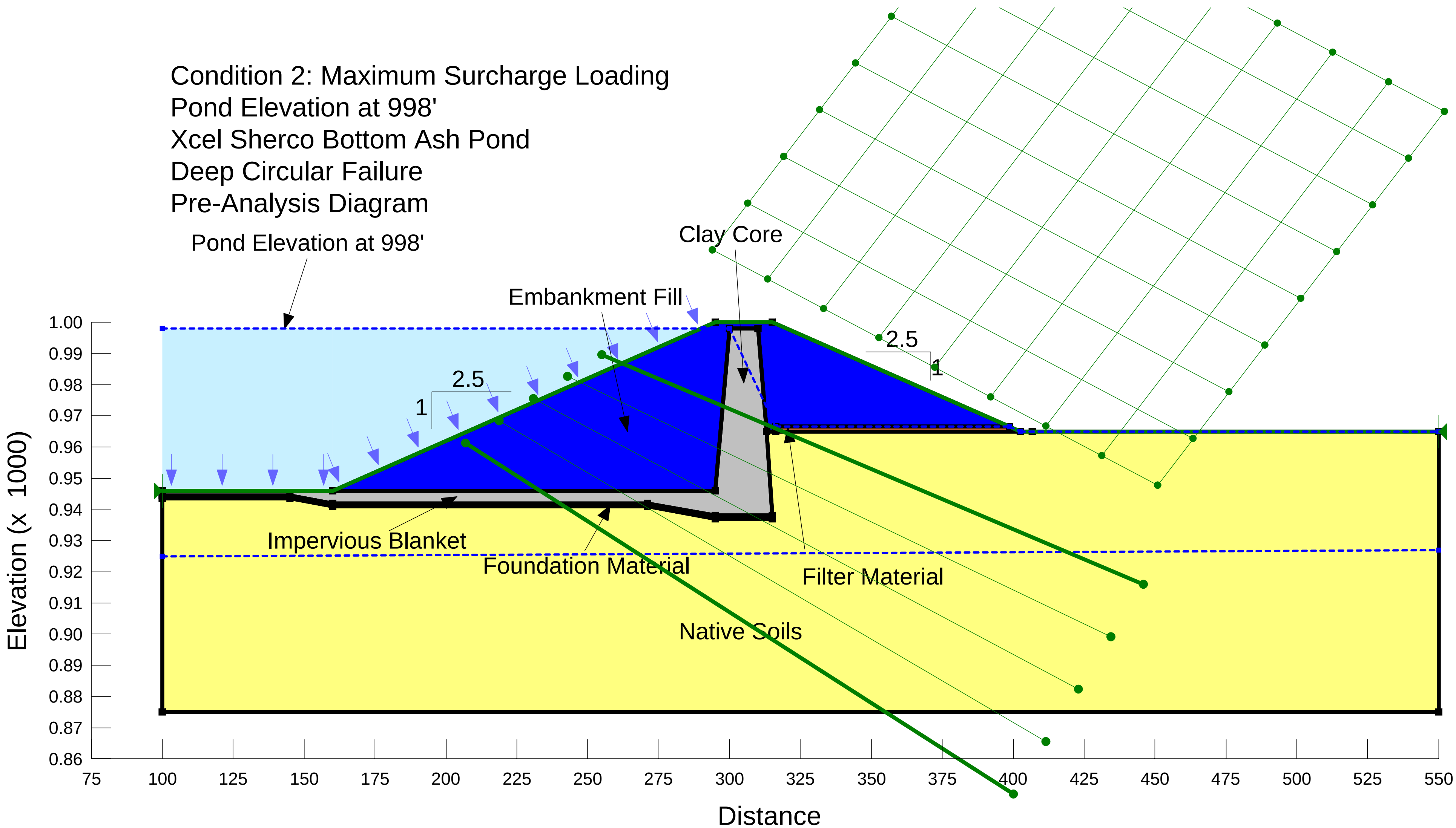
Distance

Condition 2

Maximum Surcharge Loading



Condition 2: Maximum Surcharge Loading
Pond Elevation at 998'
Xcel Sherco Bottom Ash Pond
Deep Circular Failure
Pre-Analysis Diagram
Pond Elevation at 998'
Clay Core
Embankment Fill
2.5
1
2.5
1
Impervious Blanket
Foundation Material
Filter Material
Native Soils
Elevation (x 1000)
1.00
0.99
0.98
0.97
0.96
0.95
0.94
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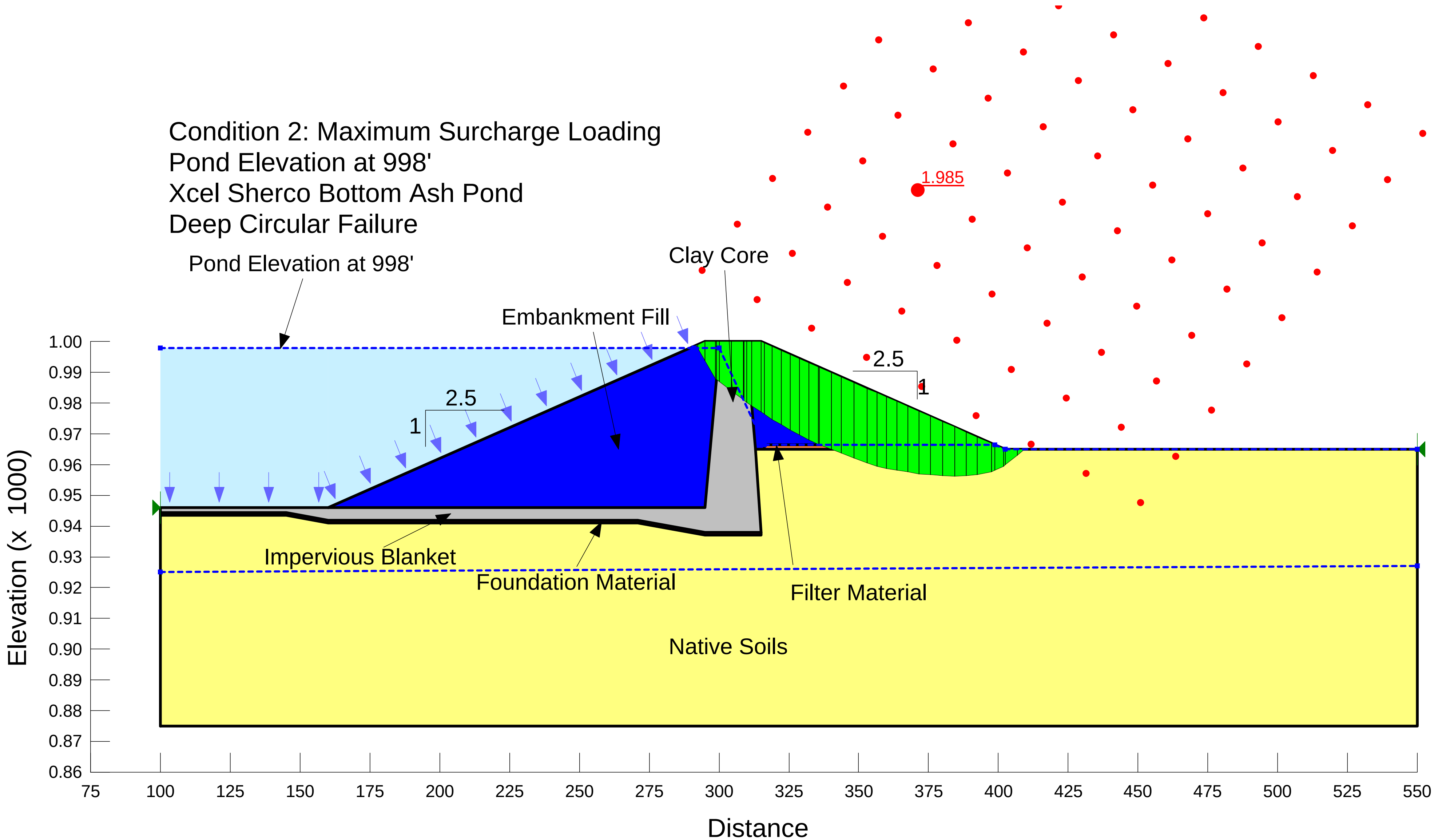
Distance



Condition 2: Maximum Surcharge Loading
Pond Elevation at 998'
Xcel Sherco Bottom Ash Pond
Deep Circular Failure
Pond Elevation at 998'
Clay Core
Embankment Fill
1.985
2.5
1
2.5
1
Impervious Blanket
Foundation Material
Filter Material
Native Soils
Elevation (x 1000)
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0.93
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0.90
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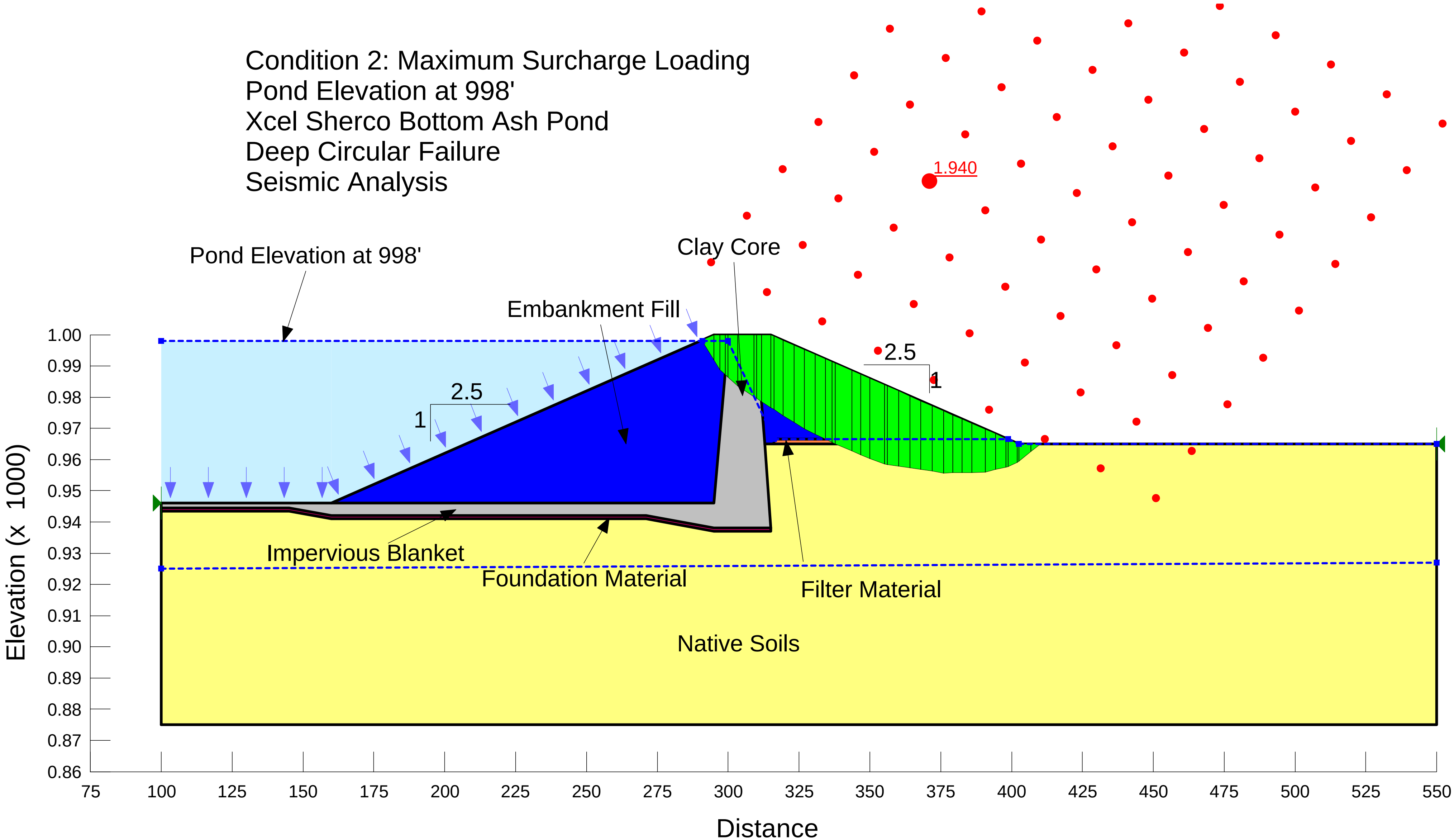
Distance



Condition 2: Maximum Surcharge Loading
Pond Elevation at 998'
Xcel Sherco Bottom Ash Pond
Deep Circular Failure
Seismic Analysis
1.940
Pond Elevation at 998'
Clay Core
Embankment Fill
2.5
1
2.5
1
Impervious Blanket
Foundation Material
Filter Material
Native Soils
Elevation (x 1000)
1.00
0.99
0.98
0.97
0.96
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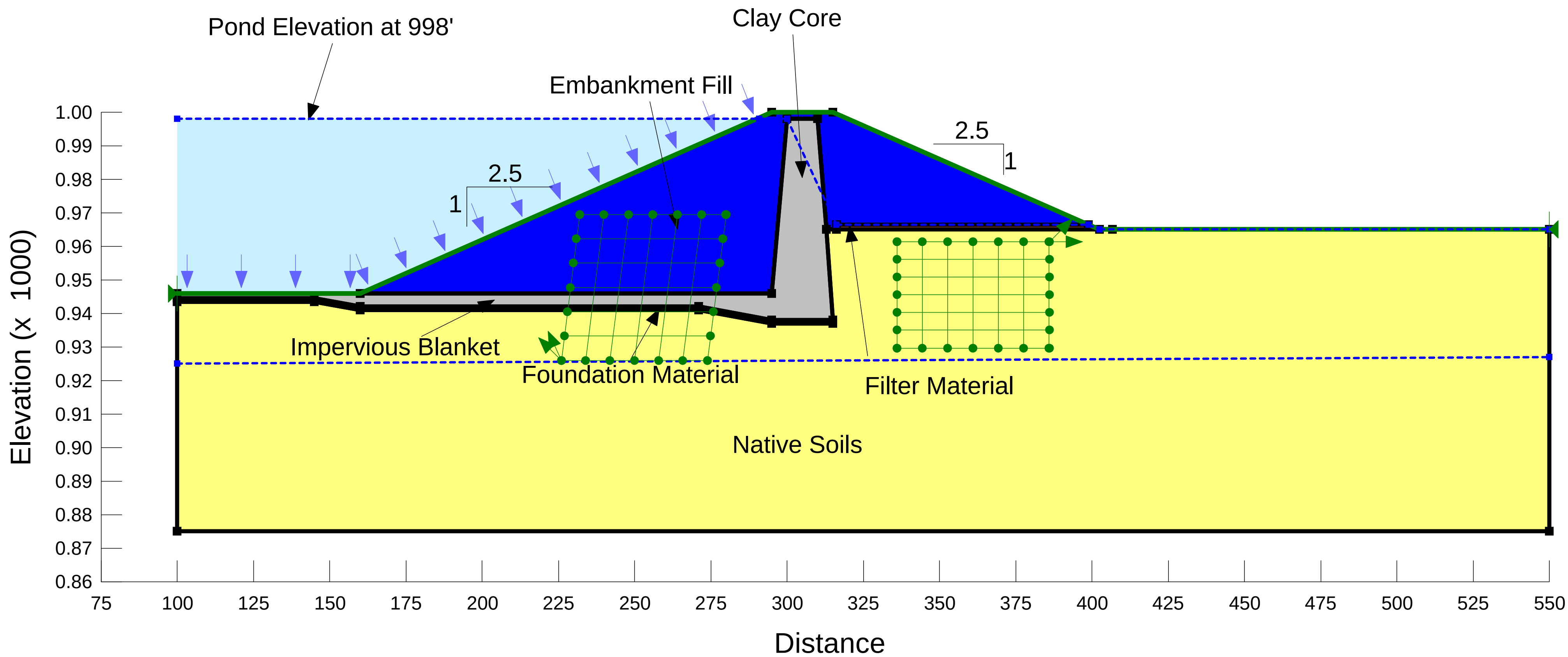
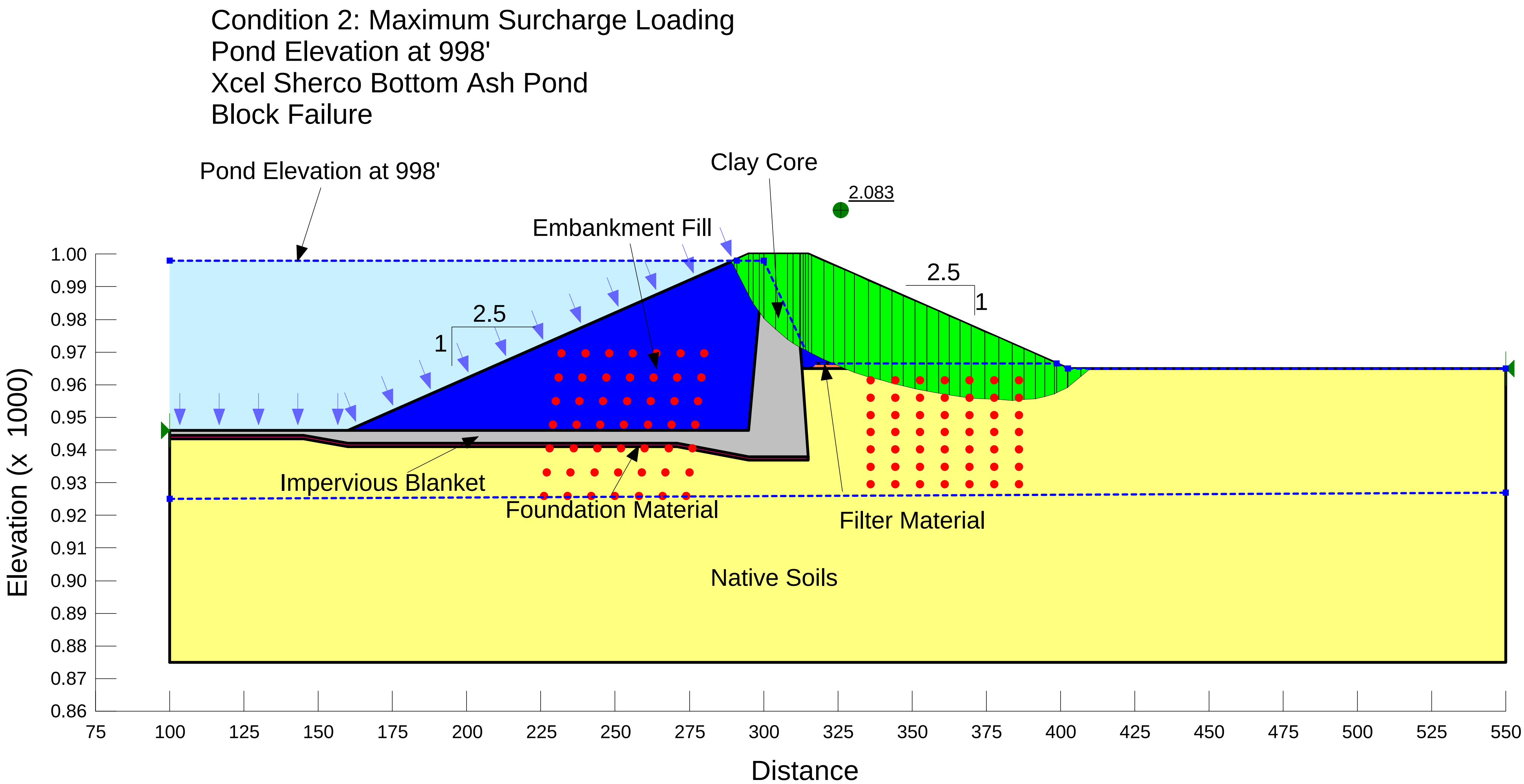
Distance

Condition 2: Maximum Surcharge Loading
Pond Elevation at 998'
Xcel Sherco Bottom Ash Pond
Block Failure
Pre-Analysis Diagram

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Pond Elevation at 998'
Xcel Sherco Bottom Ash Pond
Block Failure
Pond Elevation at 998'
Clay Core
2.083
Embankment Fill
2.5
1
2.5
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Impervious Blanket
Foundation Material
Filter Material
Native Soils
Elevation (x 1000)
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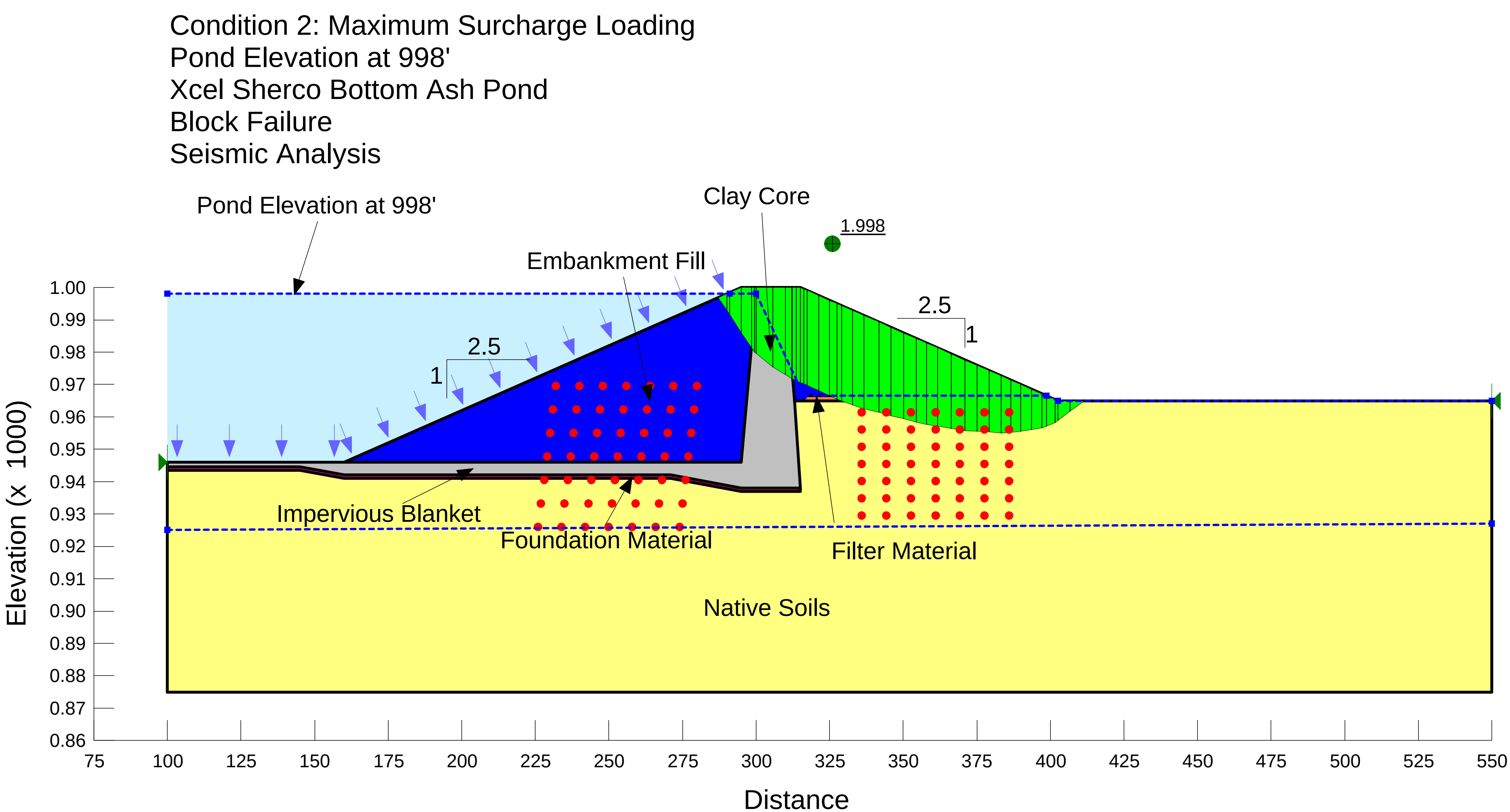

Condition 2: Maximum Surcharge Loading
Pond Elevation at 998'
Xcel Sherco Bottom Ash Pond
Block Failure
Seismic Analysis
Pond Elevation at 998'
Clay Core
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Embankment Fill
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Impervious Blanket
Foundation Material
Filter Material
Native Soils
Elevation (x 1000)
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