Initial Safety Factor Assessment
Scrubber Solids Pond No. 3
Sherburne County Generating Plant

Introduction

This report presents the assessment and certification of the initial safety factor for Scrubber Solids Pond No. 3 (Pond 3) at the Sherburne County Generating Plant (Sherco) in Becker, Minnesota. Pond 3 is an "existing" surface impoundment comprised of two halves; Pond 3 North (Pond 3N) and Pond 3 South (Pond 3S). Both halves utilize a composite liner on the bottom and the west slope, and an inclined clay core supported by interior bottom ash and exterior common fill on the north, east and south dikes. The alignment of the dike elements of Pond 3N and 3S are the same, however, the starting elevation of the inclined clay core in the pond halves differ. As such, the critical sections of both Pond 3N and 3S were assessed.

Safety Factor Assessment

The Pond 3 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 interslice shear and normal forces.

Pond 3N and 3S were 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 1.20.

The analyses for Pond 3N and 3S were conducted through the critical cross section, located on the east side of each pond half. 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 analyses of each critical cross section were based on the following assumptions:

- The geometry of the Pond 3N and 3S at the critical section consist of 3H:1V slopes on the outside with a 25-foot wide top. The clay core that runs through the embankments has 1.5H:1V slopes on both sides.
- Circular failure analysis and a block failure analyses were used for both Conditions.
- The water table was determined from on-site 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 seismic event 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 hydrogeologic site investigations from the Pond area and historical information taken from previous slope stability analyses and soil testing reports. The results and assumptions for each soil are listed below.

Table 1: Material Geotechnical Properties

Material	Unit weight (pcf)	Friction Angle[2] (deg)	Cohesion (psf)	Pseudo-seismic Cohesion (psf)
Embankment Fill[1]	117	30	0	0
Clay Core[3]	119	27	230[4]	184
Native Soils[5]	115	30	0	0
CCR - Scrubber Solids[6]	107	35	0	0
CCR - Bottom Ash Solids[6]	103	30	0	0
Drainage Sand[6]	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 Pond 3. The embankment soils are typically classified as either SM, SP-SM, or SP.
2. Friction angles used are typical for the classified soil types with similar unit weights.
3. The clay core was taken from an offsite borrow area and is typically classified as either CL, CL-SC, or SC-CL. The values for unit weight and friction angle are based on this classification of the clay.
4. 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.

5. Soils have been collected and tested in the laboratory for unit weight, Atterberg limits, and soil classification during previous Pond 3 construction phases. The native soil material properties are based on the laboratory results. The construction certification reports are cited in the construction history document prepared in accordance with §257.73(c) and placed in the operating record and CCR website.
6. The properties for these materials were taken from previously completed slope stability analyses for Pond 3 and are derived from the results of soil testing completed during the construction on Pond 3N and 3S.

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 2.1: Pond 3 North Slope Stability Results

Condition	Static FOS	Minimum Allowable FOS	Seismic FOS	Minimum Allowable FOS	Analysis Method
Condition 1 Long Term, Maximum Storage Pool Loading	**1.77**	1.50	**1.72**	1.00	Circular Failure
Condition 1 Long Term, Maximum Storage Pool Loading	1.81	1.50	1.73	1.00	Block Failure
Condition 2 Maximum Surcharge Loading	**1.80**	1.40	**1.74**	1.00	Circular Failure
Condition 2 Maximum Surcharge Loading	1.83	1.40	1.76	1.00	Block Failure

Table 2.2: Pond 3 South Slope Stability Results

Condition	Static FOS	Minimum Allowable FOS	Seismic FOS	Minimum Allowable FOS	Analysis Method
Condition 1 Long Term, Maximum Storage Pool Loading	1.87	1.50	1.79	1.00	Circular Failure
Condition 1 Long Term, Maximum Storage Pool Loading	**1.83**	1.50	**1.77**	1.00	Block Failure
Condition 2 Maximum Surcharge Loading	**1.80**	1.40	**1.74**	1.00	Circular Failure
Condition 2 Maximum Surcharge Loading	1.85	1.40	1.78	1.00	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.

Daniel J. Riggs, PE — October 17, 2016 (Date)
License No. 49559

References

J Michael Duncan and Stephen G Wright (January 2005). “Soil Strength and Slope Stability” Austin, Texas.

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

Michael R Lindeburg (2001). “Civil Engineering Reference Manual for the PE Exam”.

Minnesota Division of Homeland Security and Emergency Management (2011). “Minnesota All-Hazard Mitigation Plan Update”.

University of Minnesota, Minnesota Geological Survey (2014). “Minnesota at a Glance: Earthquakes in Minnesota”.

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

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

United States Society on Dams (February 2007). “Strength of Materials for Embankment Dams”.

References (included in Operating Record and Website)

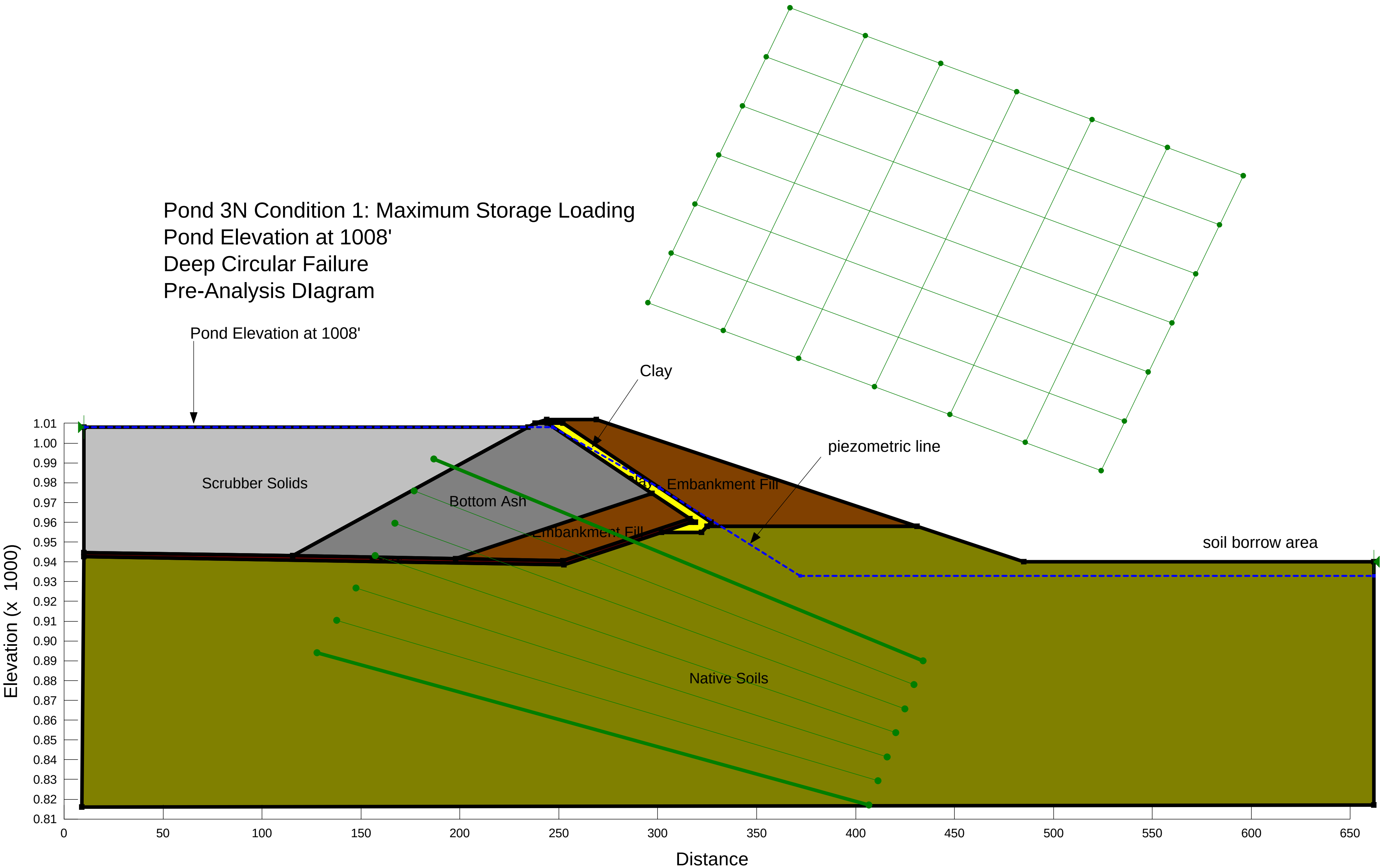
Carlson McCain, Inc. (October 2016). ”History of Construction, Scrubber Solids Pond 3, Sherburne County Generating Plant”, CCR compliance document, Plymouth, Minnesota.

Slope/W Graphical Results

Pond 3 North

Condition 1

Long Term, Maximum, Storage Pool Loading


Pond 3N Condition 1: Maximum Storage Loading
Pond Elevation at 1008'
Deep Circular Failure
Pre-Analysis DIagram
Pond Elevation at 1008'
Clay
piezometric line
Scrubber Solids
Bottom Ash
Embankment Fill
Embankment Fill
soil borrow area
Native Soils
Elevation (x 1000)
1.01
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
0.85
0.84
0.83
0.82
0.81
0
50
100
150
200
250
300
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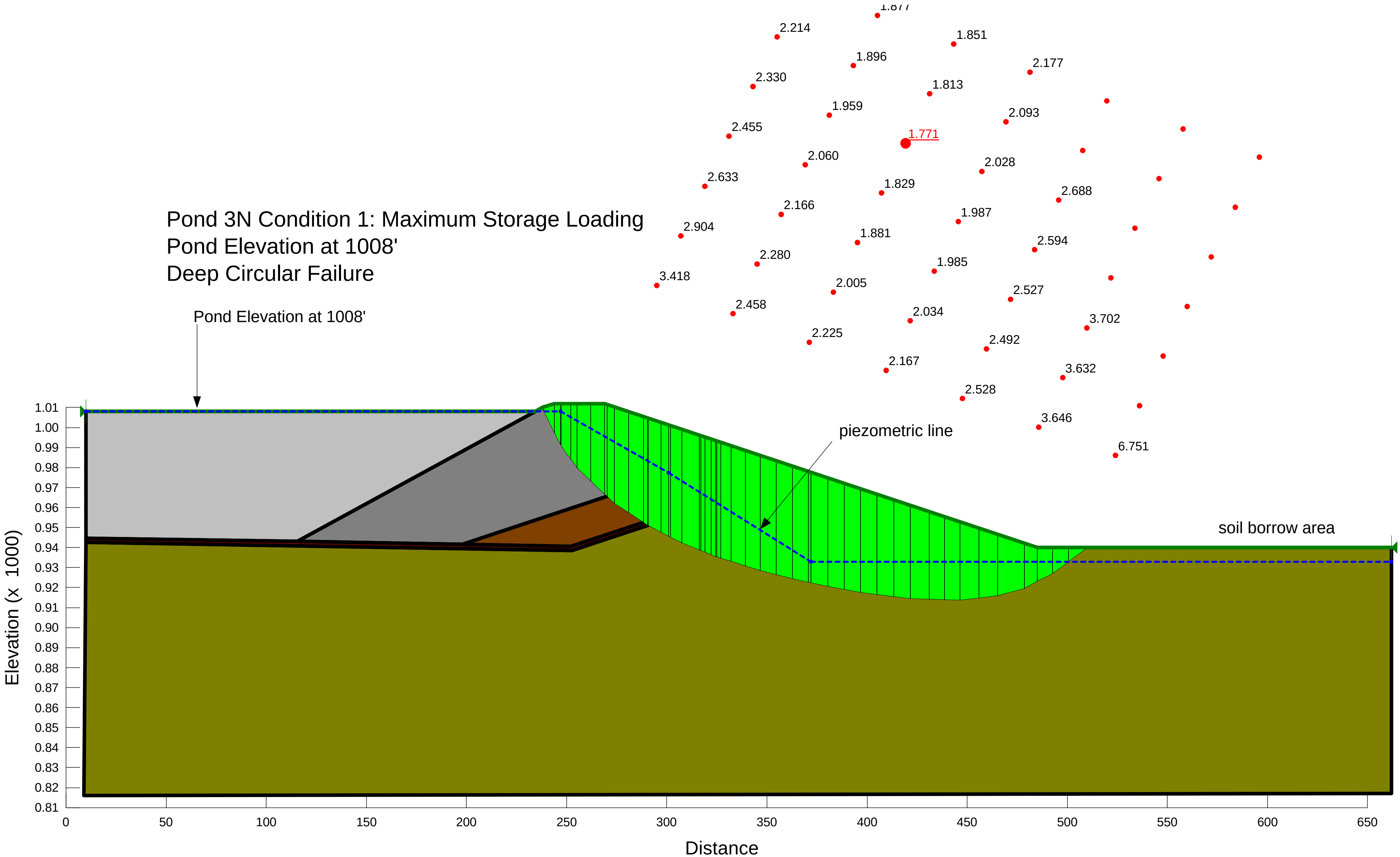
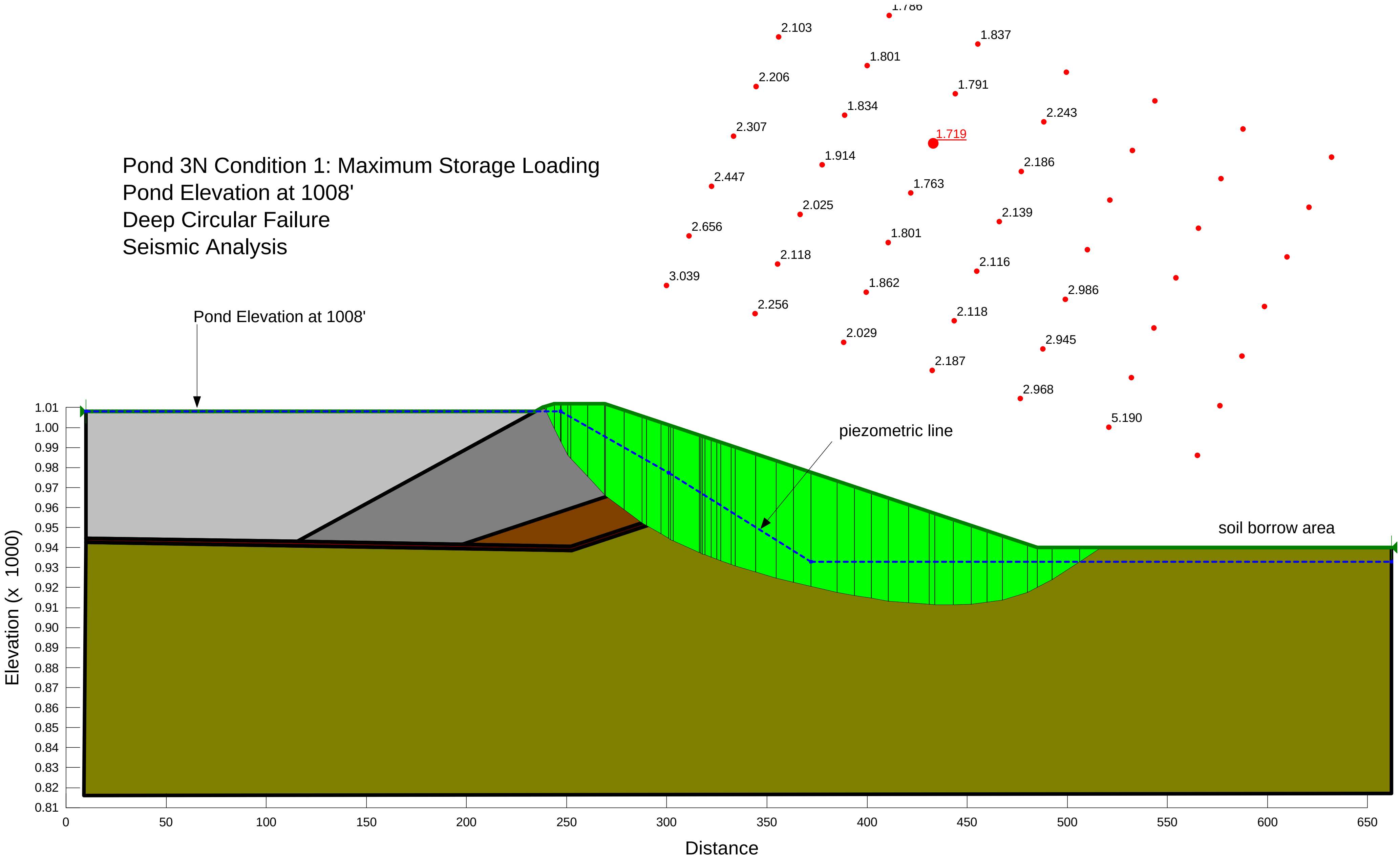
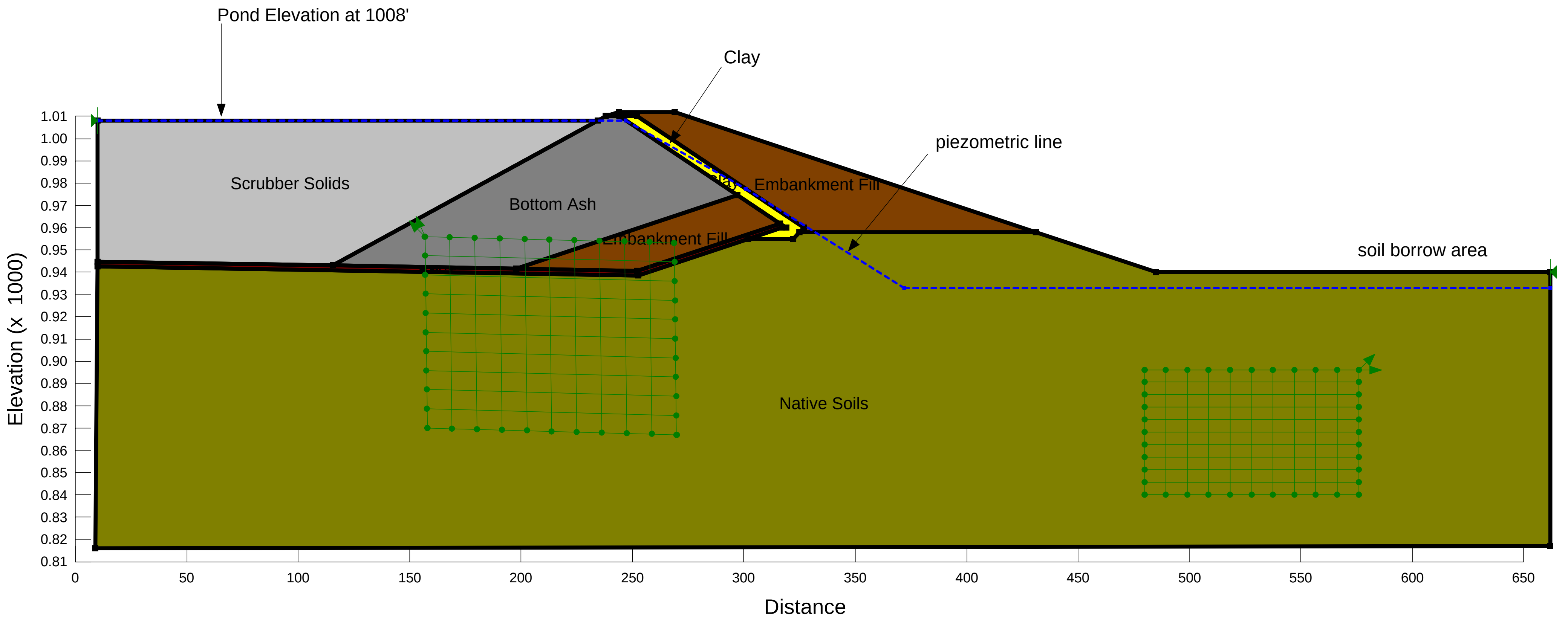
450
500
550
600
650
Distance


Pond 3N Condition 1: Maximum Storage Loading
Pond Elevation at 1008'
Deep Circular Failure
Pond Elevation at 1008'
piezometric line
soil borrow area
1.771
Elevation (x 1000)
Distance

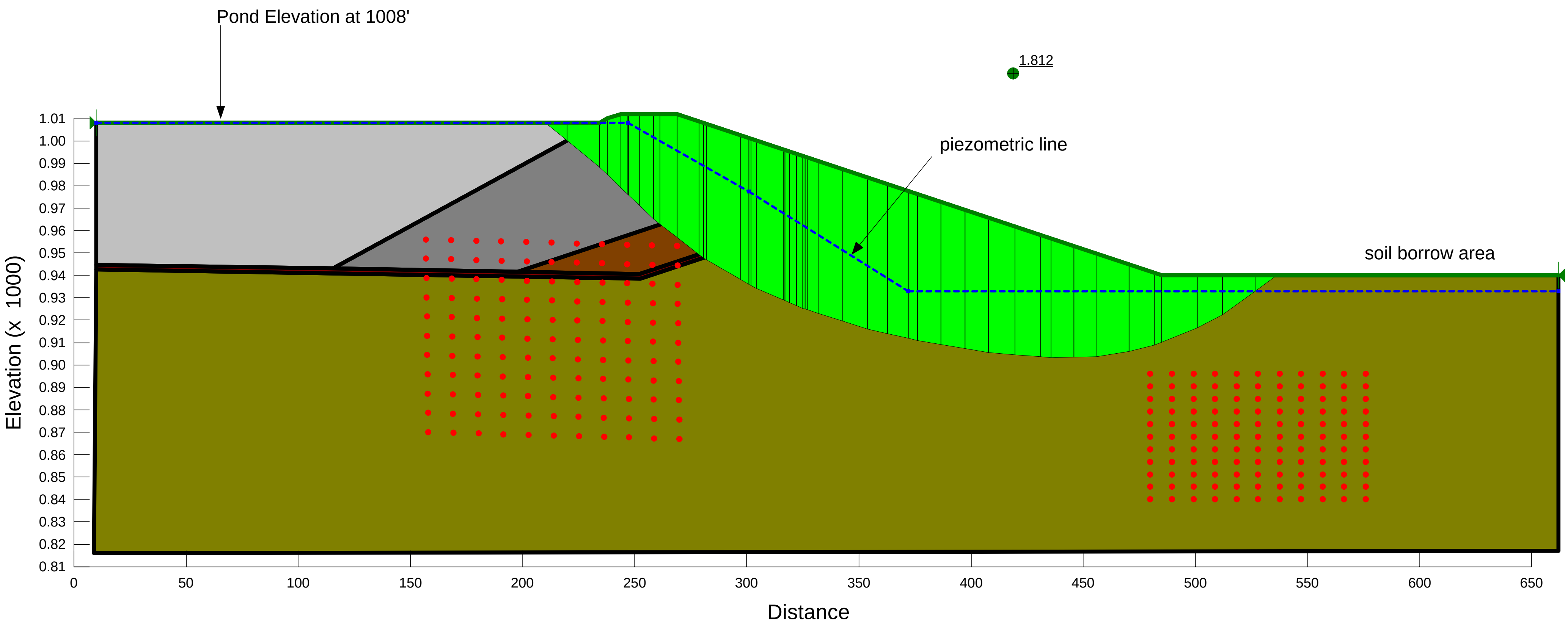


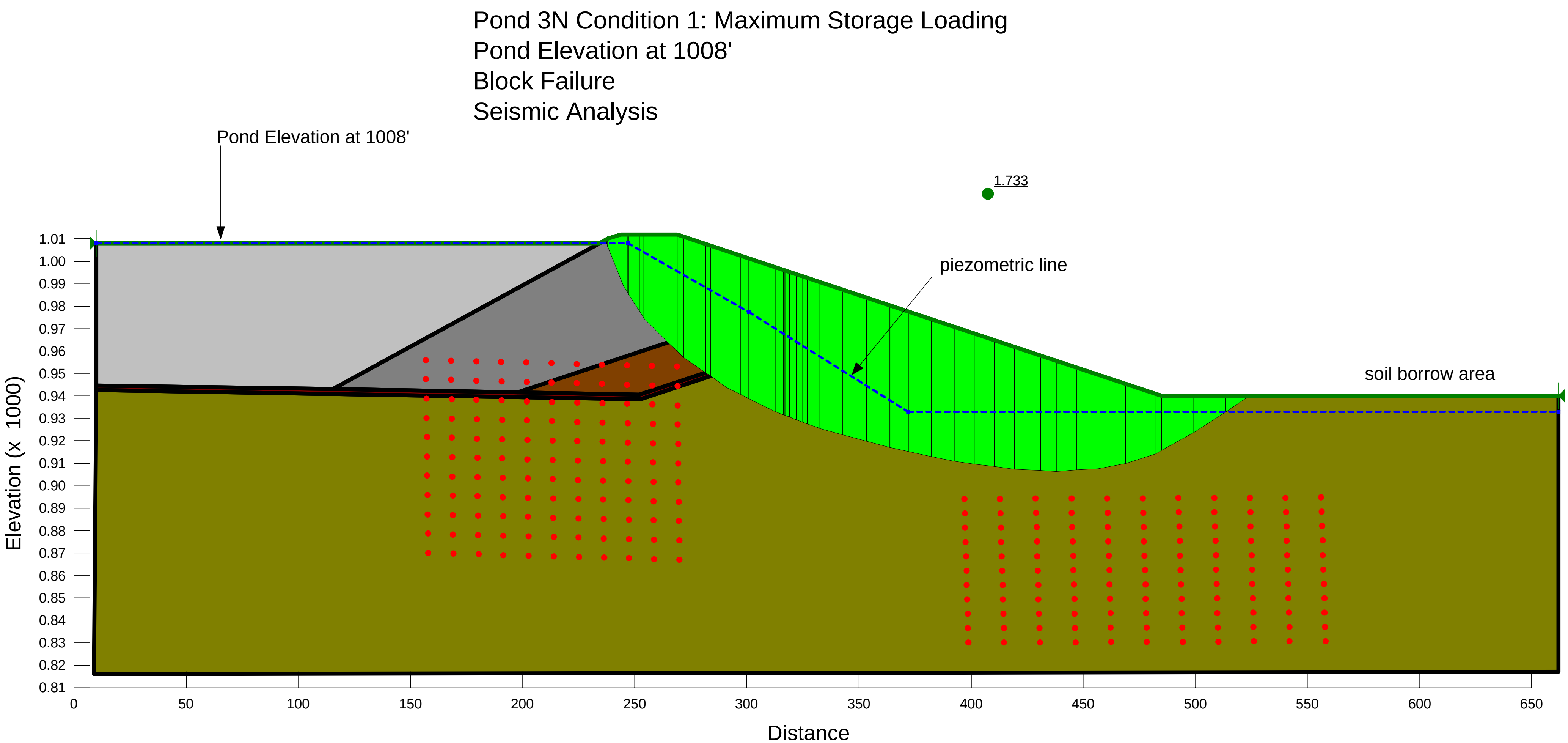
Pond 3N Condition 1: Maximum Storage Loading
Pond Elevation at 1008'
Deep Circular Failure
Seismic Analysis
Pond Elevation at 1008'
piezometric line
soil borrow area
2.103
1.837
1.801
2.206
1.791
1.834
2.243
2.307
1.719
1.914
2.186
2.447
1.763
2.025
2.139
2.656
1.801
2.118
2.116
3.039
1.862
2.986
2.256
2.118
2.029
2.945
2.187
2.968
5.190
Elevation (x 1000)
1.01
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
0.85
0.84
0.83
0.82
0.81
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Distance

Pond 3N Condition 1: Maximum Storage Loading
Pond Elevation at 1008'
Block Failure
Pre-Analysis Diagram



Pond 3N Condition 1: Maximum Storage Loading
Pond Elevation at 1008'
Block Failure

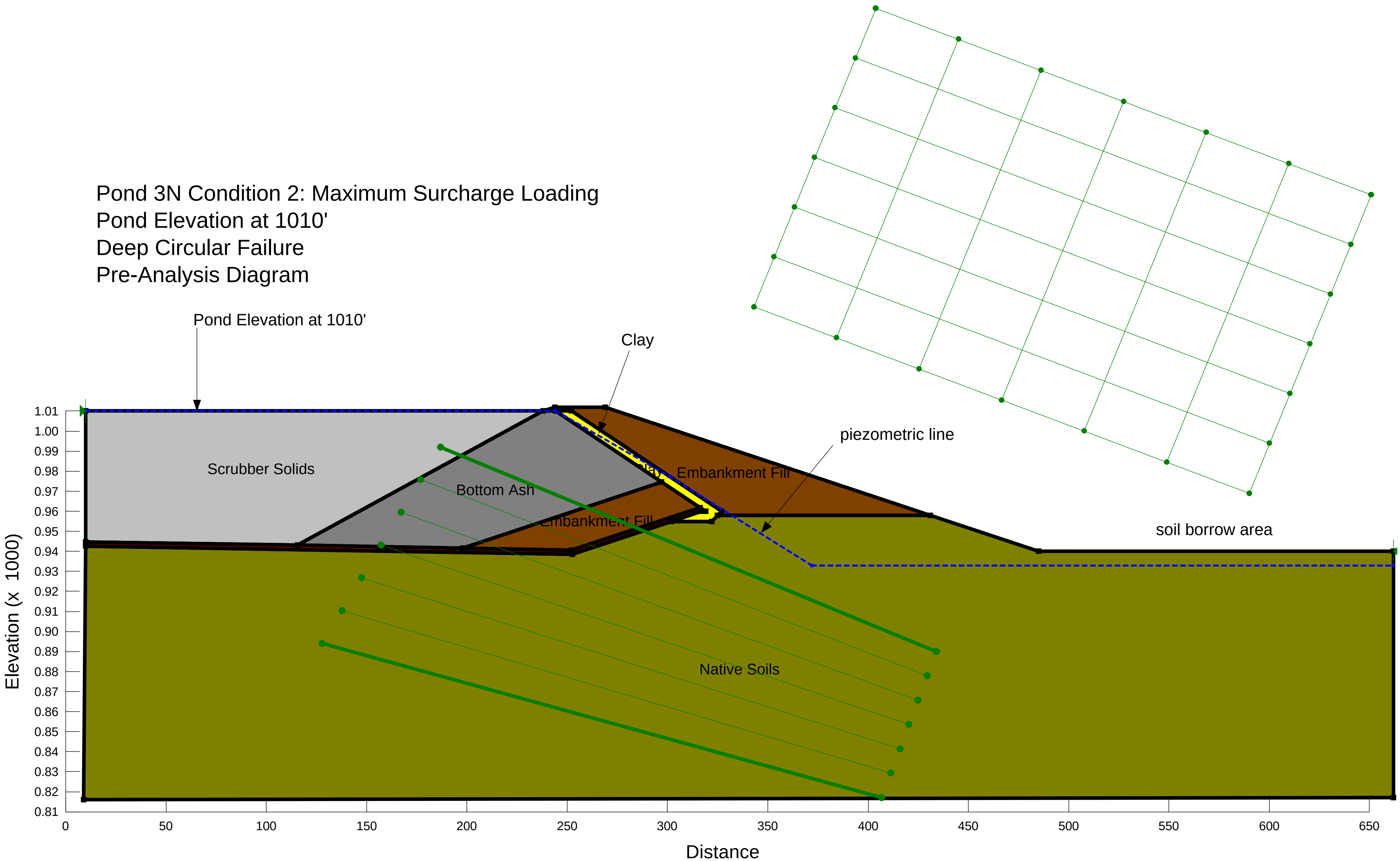


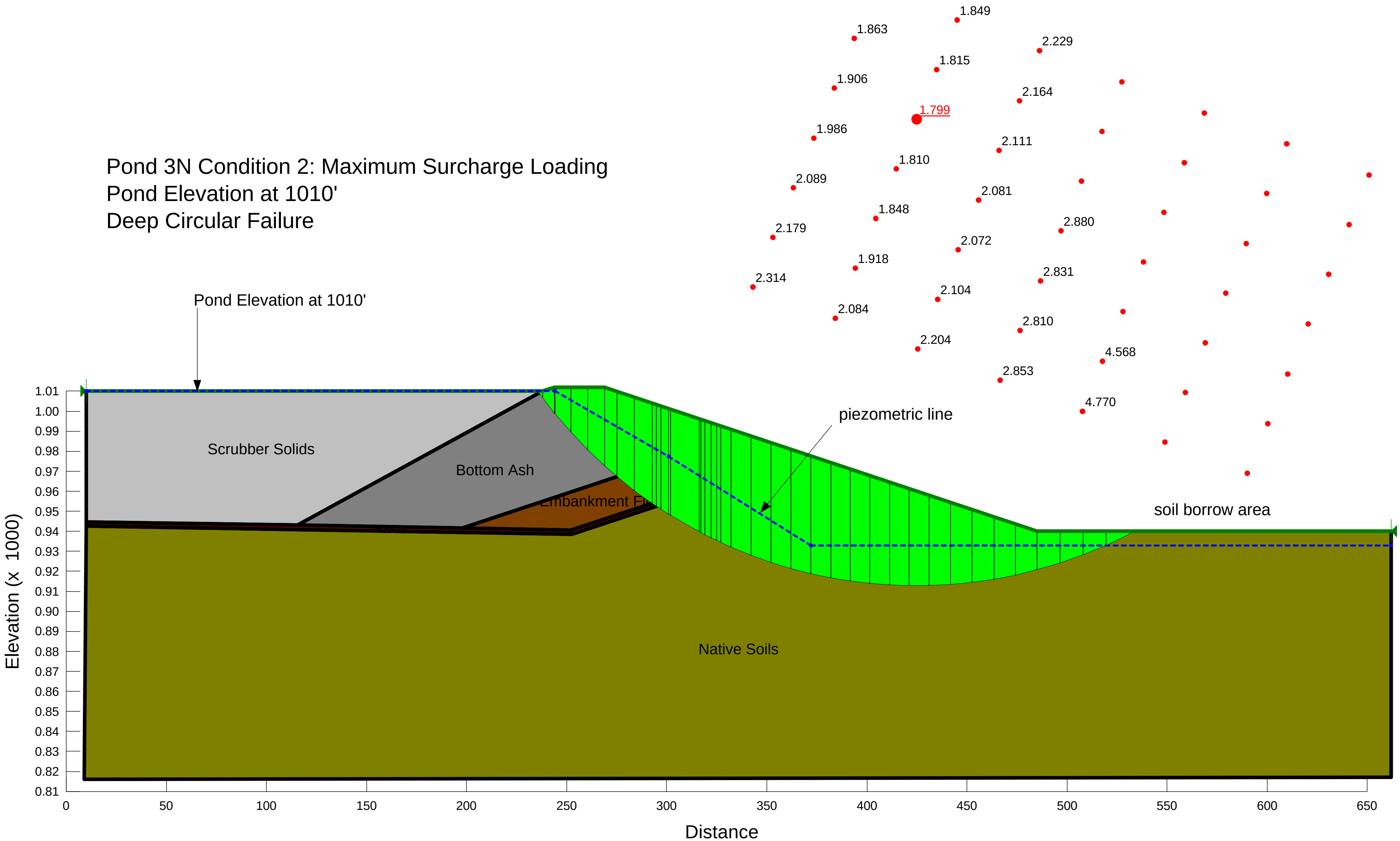

Pond 3N Condition 1: Maximum Storage Loading
Pond Elevation at 1008'
Block Failure
Seismic Analysis
Pond Elevation at 1008'
1.733
piezometric line
soil borrow area
Elevation (x 1000)
1.01
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.90
0.89
0.88
0.87
0.86
0.85
0.84
0.83
0.82
0.81
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Distance

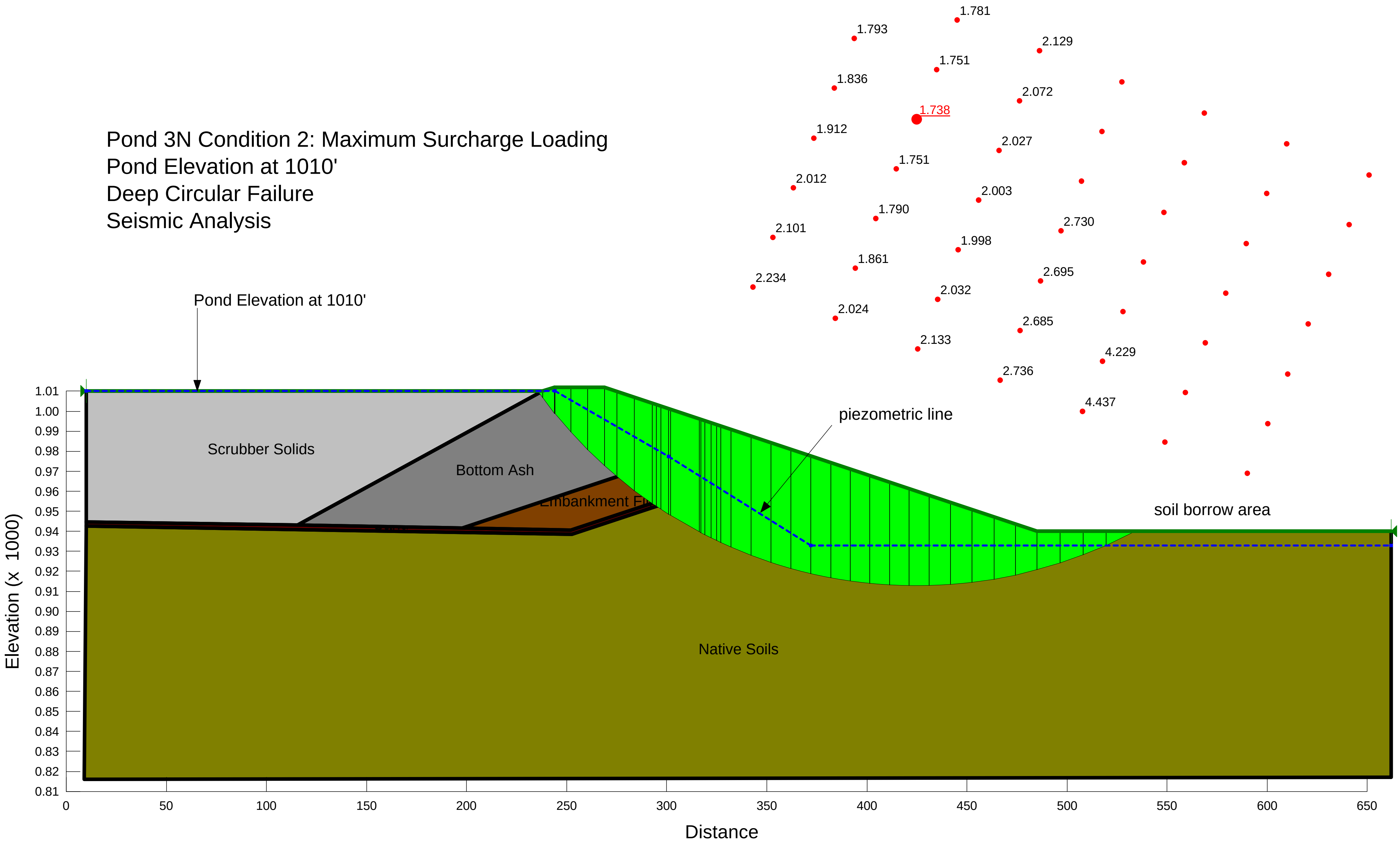
Pond 3 North

Condition 2

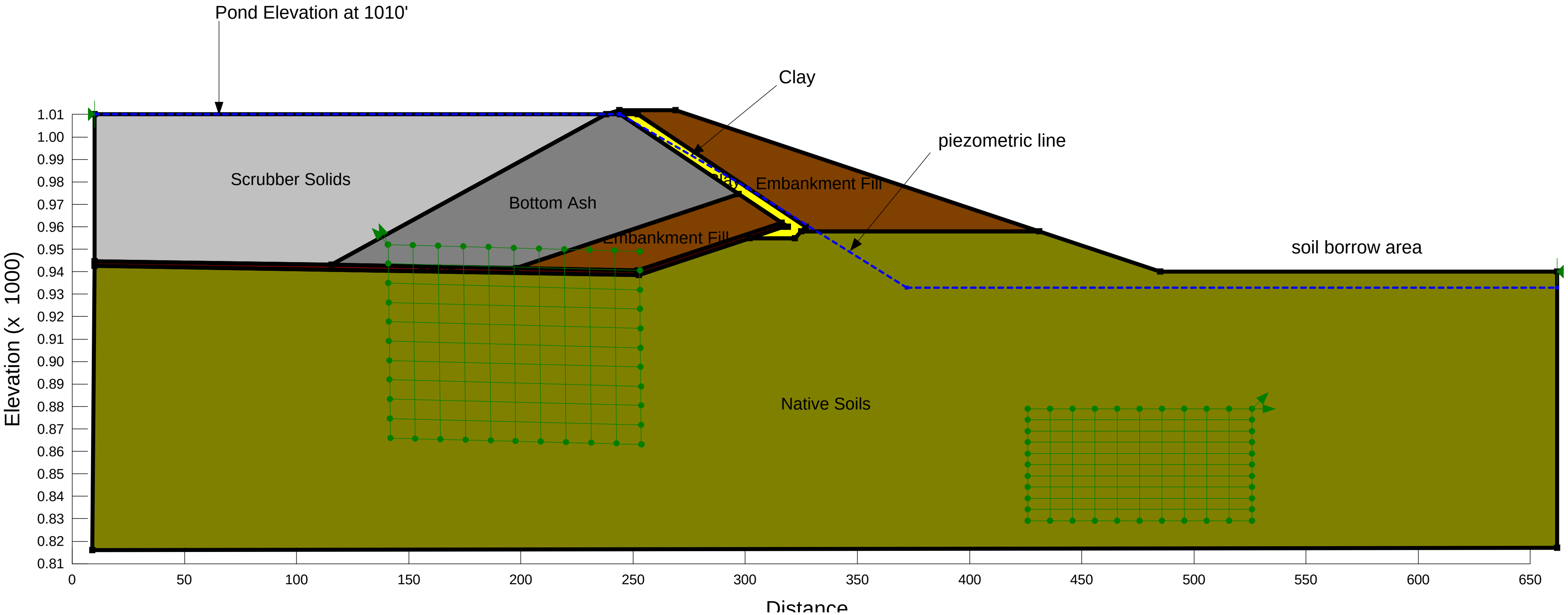
Maximum Surcharge Loading


Pond 3N Condition 2: Maximum Surcharge Loading
Pond Elevation at 1010'
Deep Circular Failure
Pre-Analysis Diagram
Pond Elevation at 1010'
Clay
piezometric line
Scrubber Solids
Bottom Ash
Embankment Fill
Embankment Fill
soil borrow area
Native Soils
Elevation (x 1000)
1.01
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
0.85
0.84
0.83
0.82
0.81
0 50 100 150 200 250 300 350 400 450 500 550 600 650
Distance

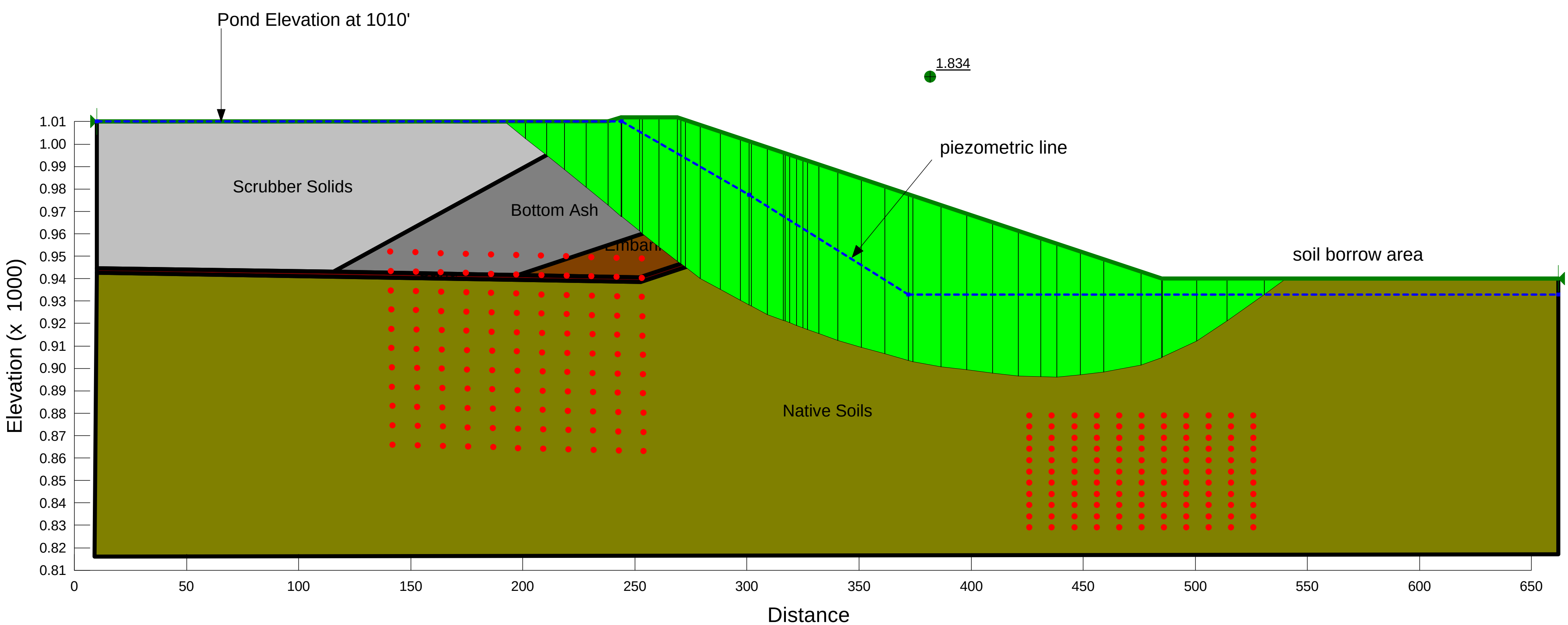

Pond 3N Condition 2: Maximum Surcharge Loading
Pond Elevation at 1010'
Deep Circular Failure
Pond Elevation at 1010'
1.849
1.863
2.229
1.815
1.906
2.164
1.799
1.986
2.111
1.810
2.089
2.081
1.848
2.179
2.880
2.072
1.918
2.314
2.831
2.104
2.084
2.810
2.204
4.568
2.853
4.770
piezometric line
Scrubber Solids
Bottom Ash
Embankment Fi
soil borrow area
Native Soils
Elevation (x 1000)
1.01
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
0.85
0.84
0.83
0.82
0.81
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Distance


Pond 3N Condition 2: Maximum Surcharge Loading
Pond Elevation at 1010'
Deep Circular Failure
Seismic Analysis
Pond Elevation at 1010'
1.781
1.793
2.129
1.751
1.836
2.072
1.738
1.912
2.027
1.751
2.012
2.003
1.790
2.730
2.101
1.998
1.861
2.695
2.234
2.032
2.024
2.685
2.133
4.229
2.736
4.437
piezometric line
Scrubber Solids
Bottom Ash
Embankment Fi
soil borrow area
Native Soils
Elevation (x 1000)
1.01
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
0.85
0.84
0.83
0.82
0.81
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Distance

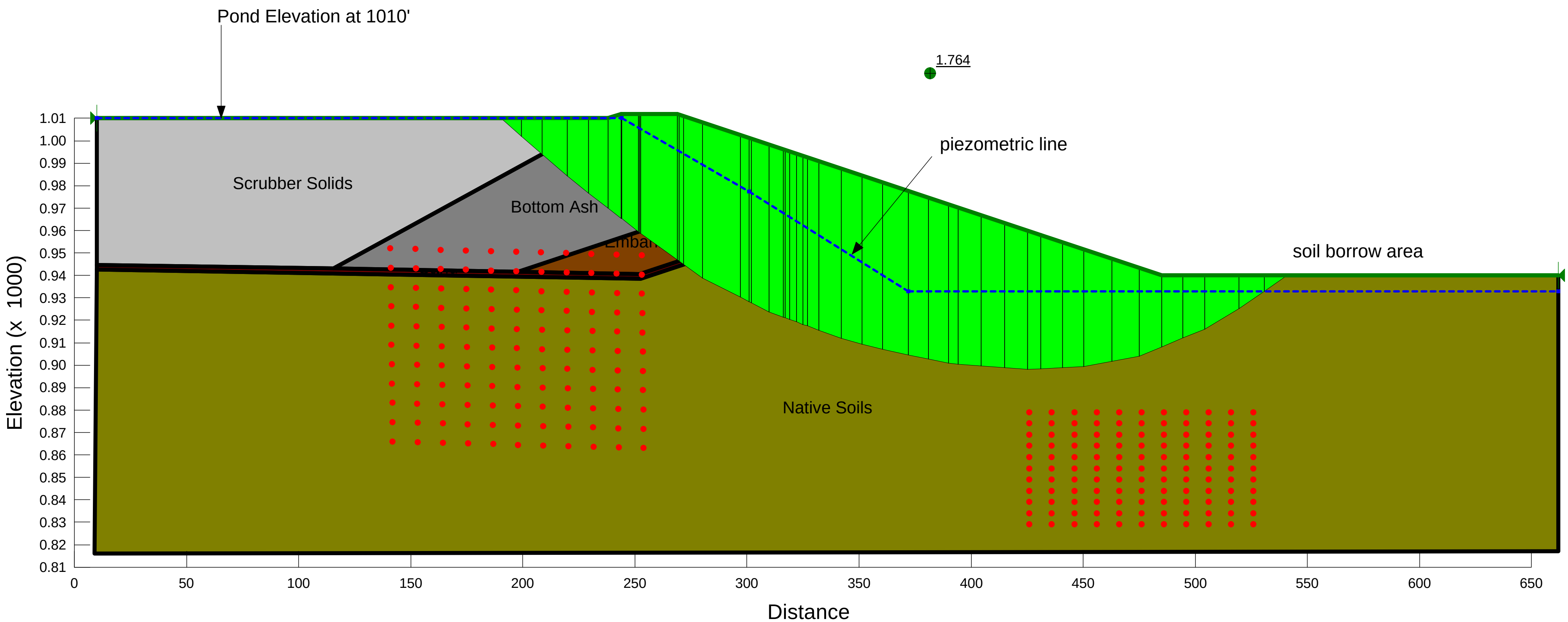
Pond 3N Condition 2: Maximum Surcharge Loading
Pond Elevation at 1010'
Block Failure
Pre-Analysis Diagram



Pond 3N Condition 2: Maximum Surcharge Loading
Pond Elevation at 1010'
Block Failure



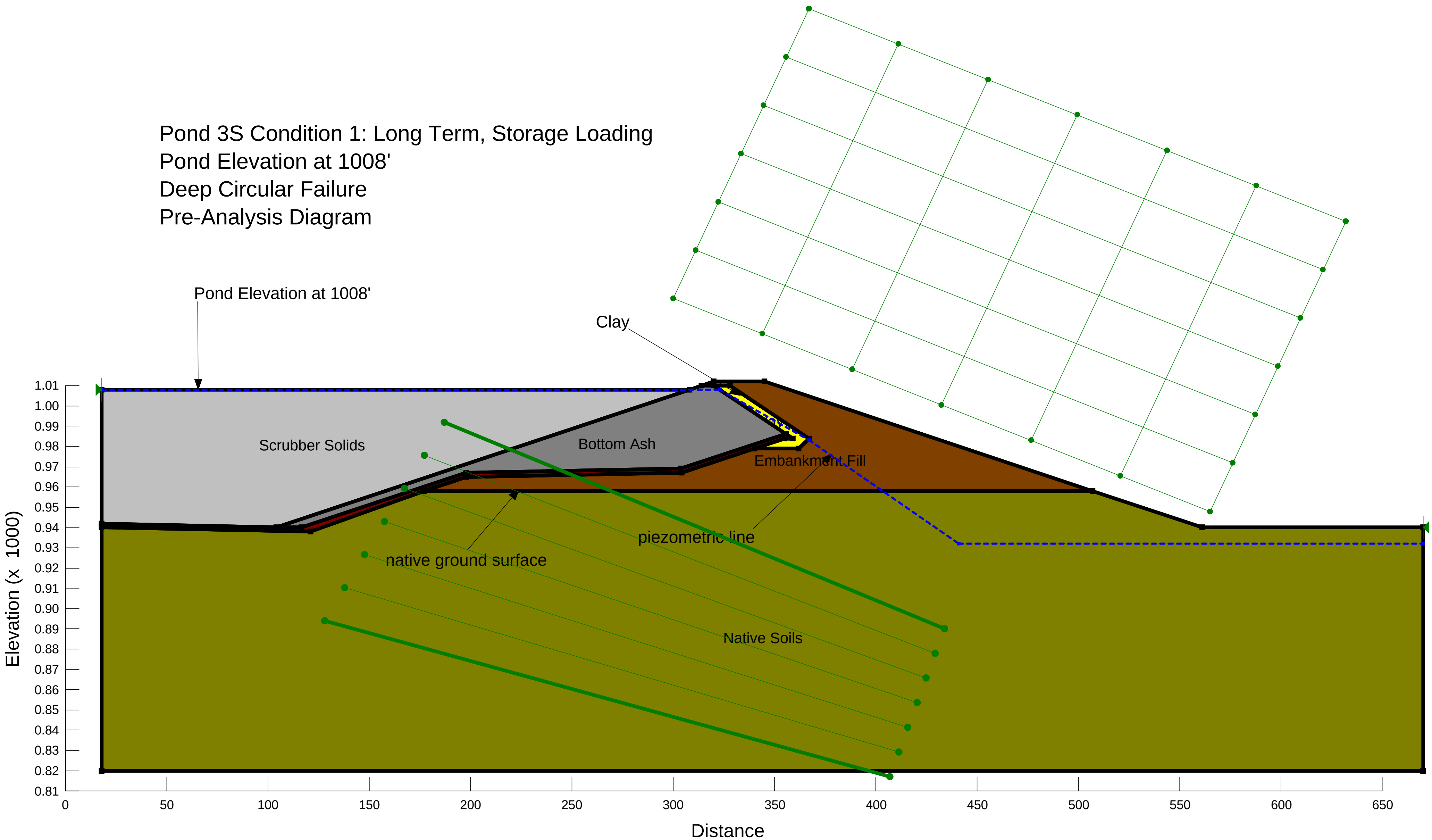
Pond 3N Condition 2: Maximum Surcharge Loading
Pond Elevation at 1010'
Block Failure
Seismic Analysis



Pond 3 South

Condition 1

Long Term, Maximum, Storage Pool Loading



Pond 3S Condition 1: Long Term, Storage Loading
Pond Elevation at 1008'
Deep Circular Failure
Pre-Analysis Diagram
Pond Elevation at 1008'
Clay
Scrubber Solids
Bottom Ash
Embankment Fill
piezometric line
native ground surface
Native Soils
Elevation (x 1000)
1.01
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
0.85
0.84
0.83
0.82
0.81
0
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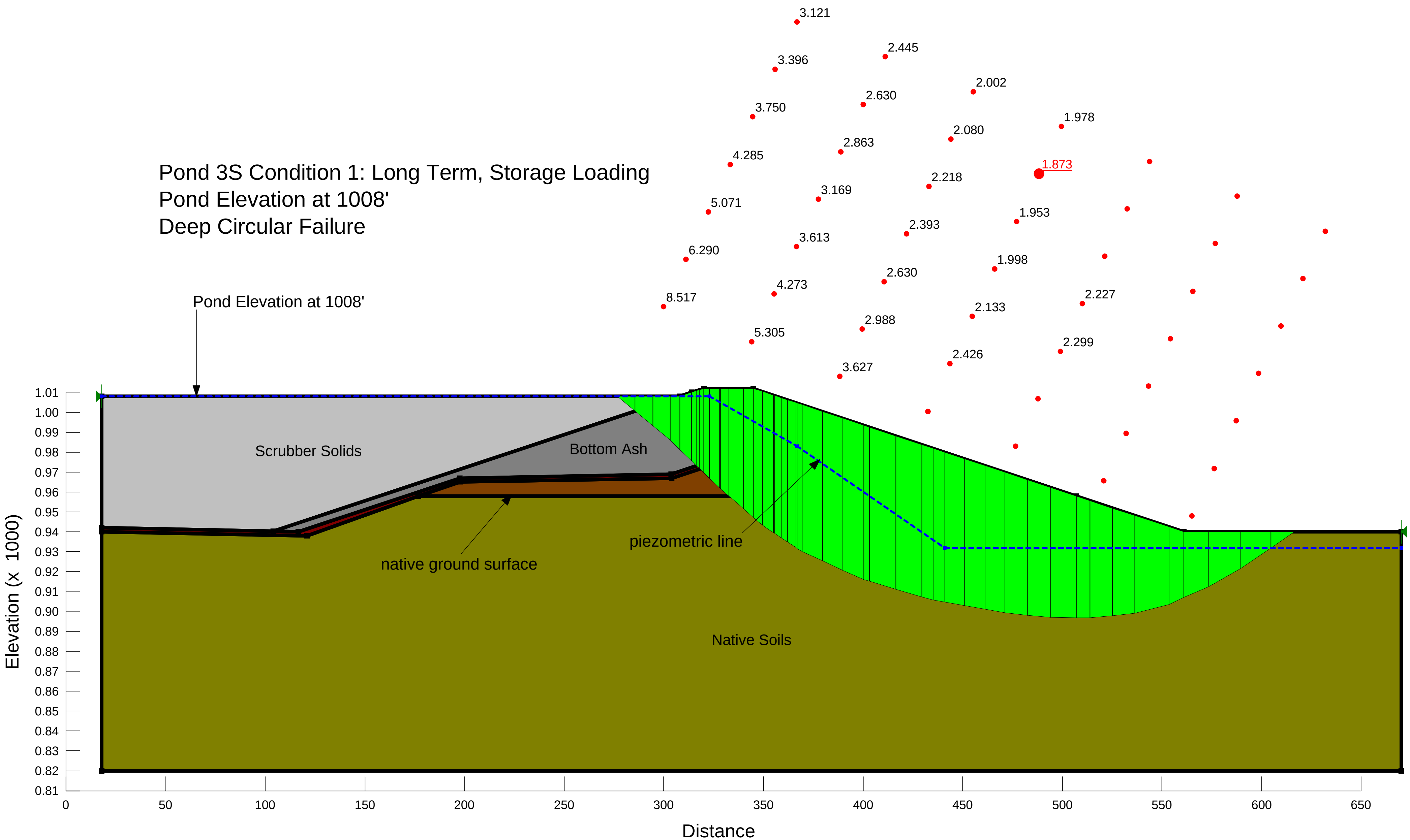
100
150
200
250
300
350
400
450
500
550
600
650
Distance



Pond 3S Condition 1: Long Term, Storage Loading
Pond Elevation at 1008'
Deep Circular Failure
Pond Elevation at 1008'
3.121
2.445
3.396
2.002
2.630
3.750
1.978
2.080
2.863
4.285
1.873
2.218
3.169
5.071
1.953
2.393
3.613
6.290
1.998
2.630
4.273
2.227
8.517
2.133
2.988
5.305
2.299
2.426
3.627
Scrubber Solids
Bottom Ash
native ground surface
piezometric line
Native Soils
Elevation (x 1000)
1.01
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
0.85
0.84
0.83
0.82
0.81
0
50
100
150
200
250
300
350
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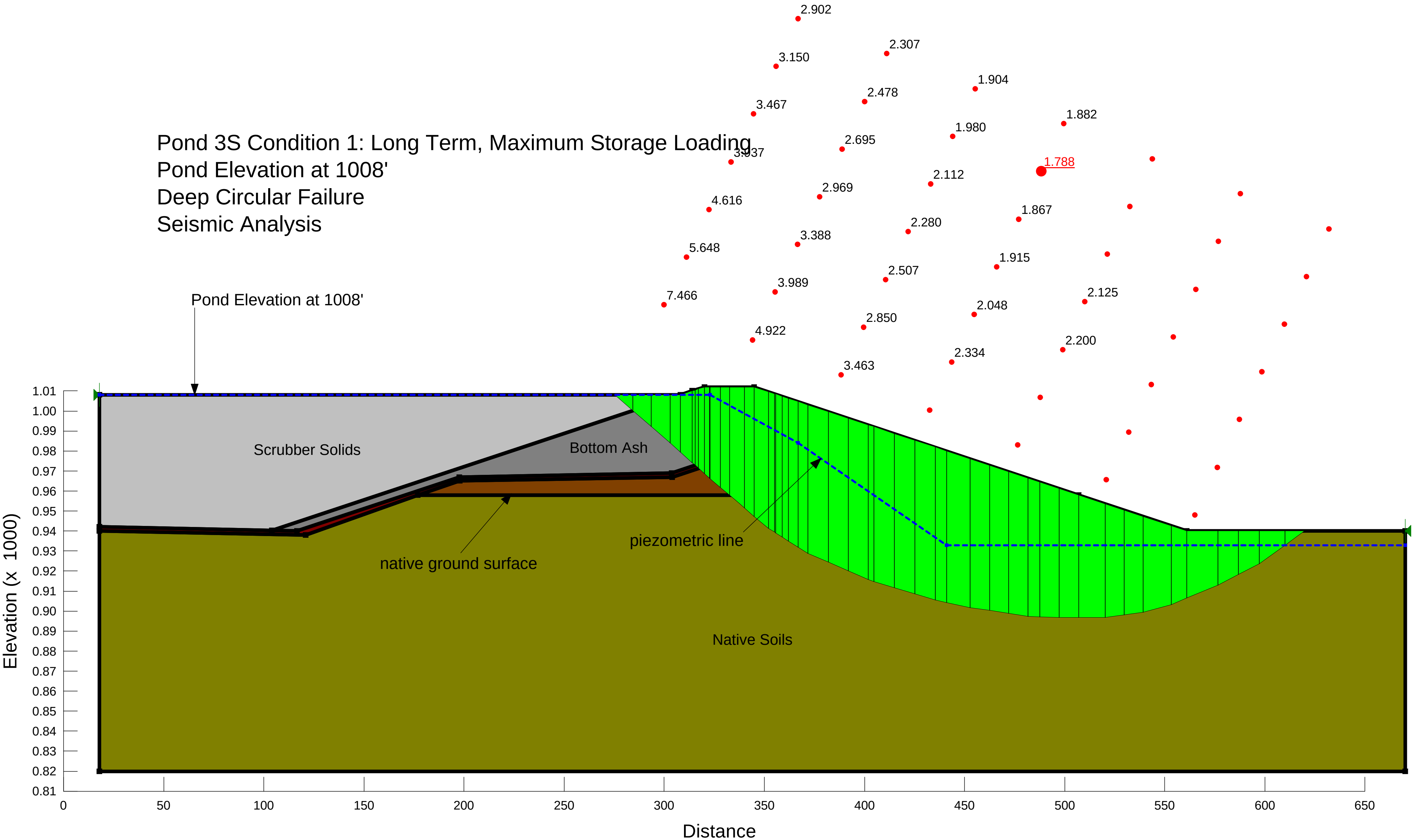
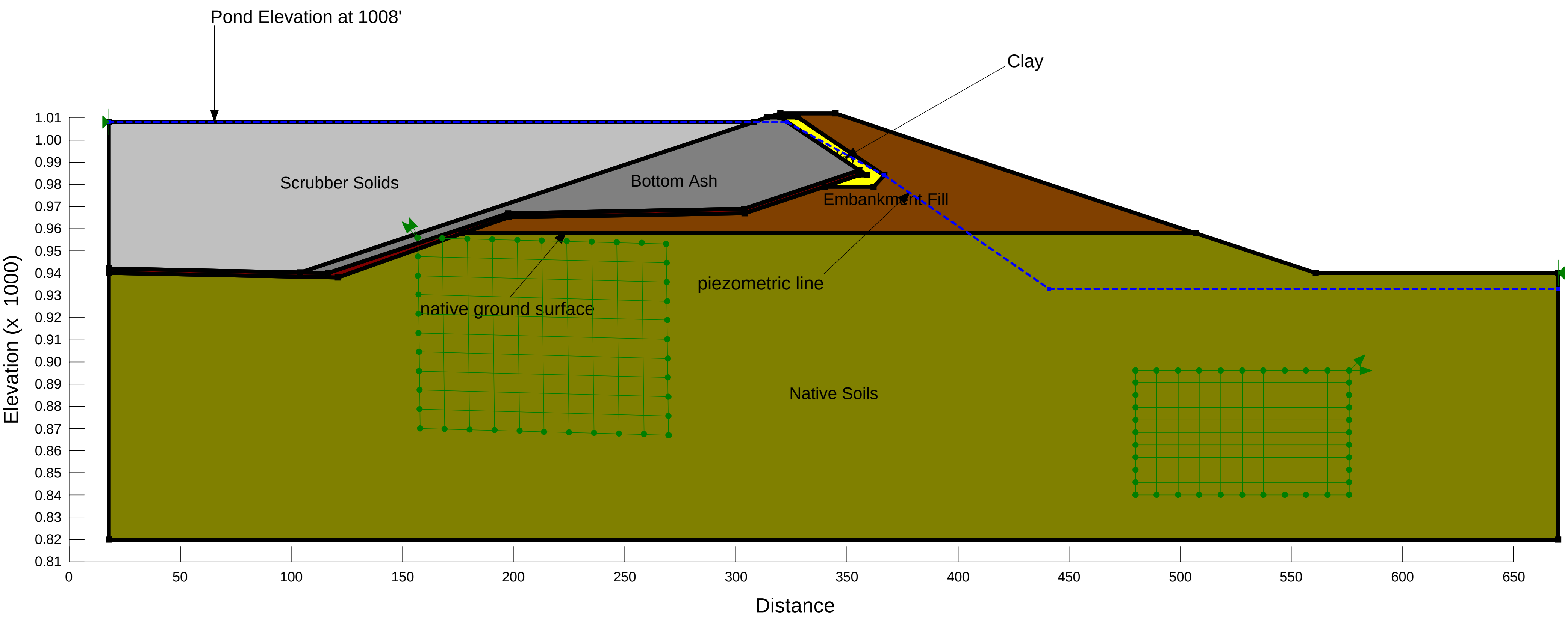
450
500
550
600
650
Distance

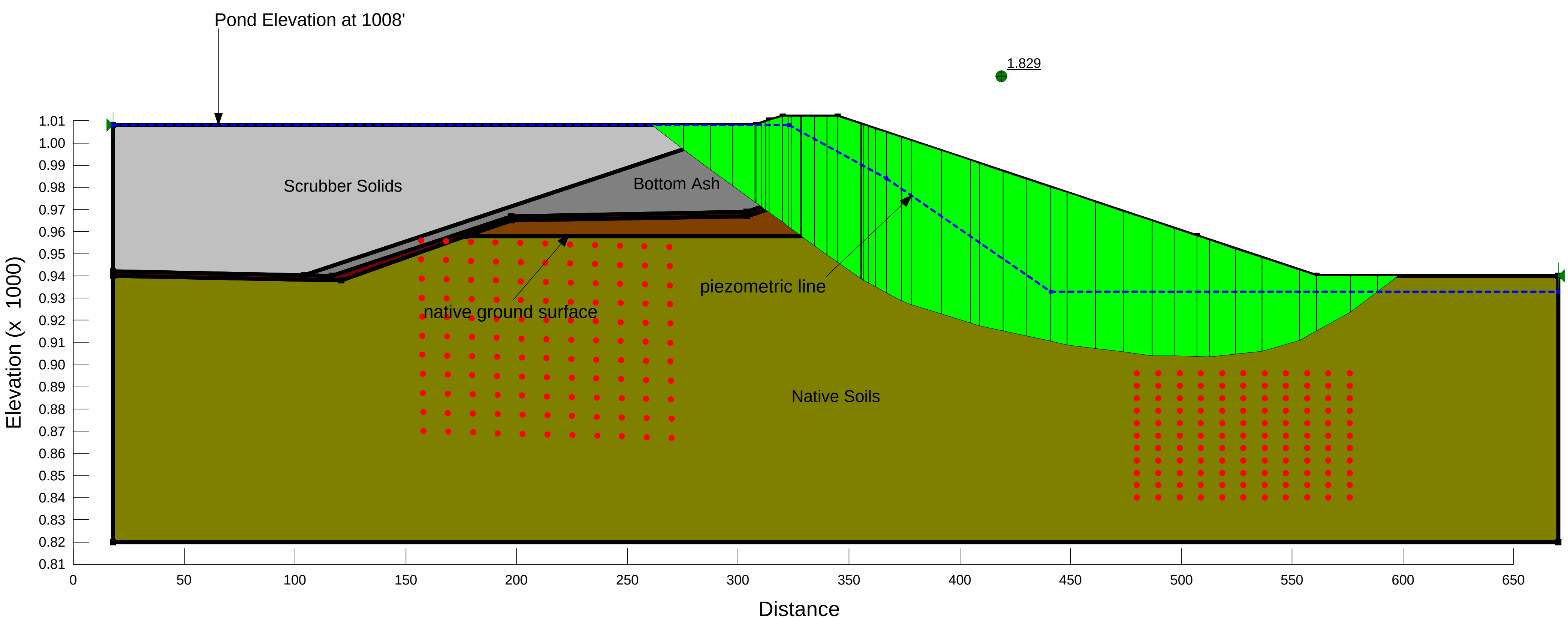


Pond 3S Condition 1: Long Term, Maximum Storage Loading
Pond Elevation at 1008'
Deep Circular Failure
Seismic Analysis
Pond Elevation at 1008'
Scrubber Solids
Bottom Ash
native ground surface
piezometric line
Native Soils
2.902
2.307
3.150
1.904
2.478
3.467
1.882
1.980
2.695
3.937
1.788
2.112
2.969
4.616
1.867
2.280
3.388
5.648
1.915
2.507
3.989
2.125
7.466
2.048
2.850
4.922
2.200
2.334
3.463
Elevation (x 1000)
Distance

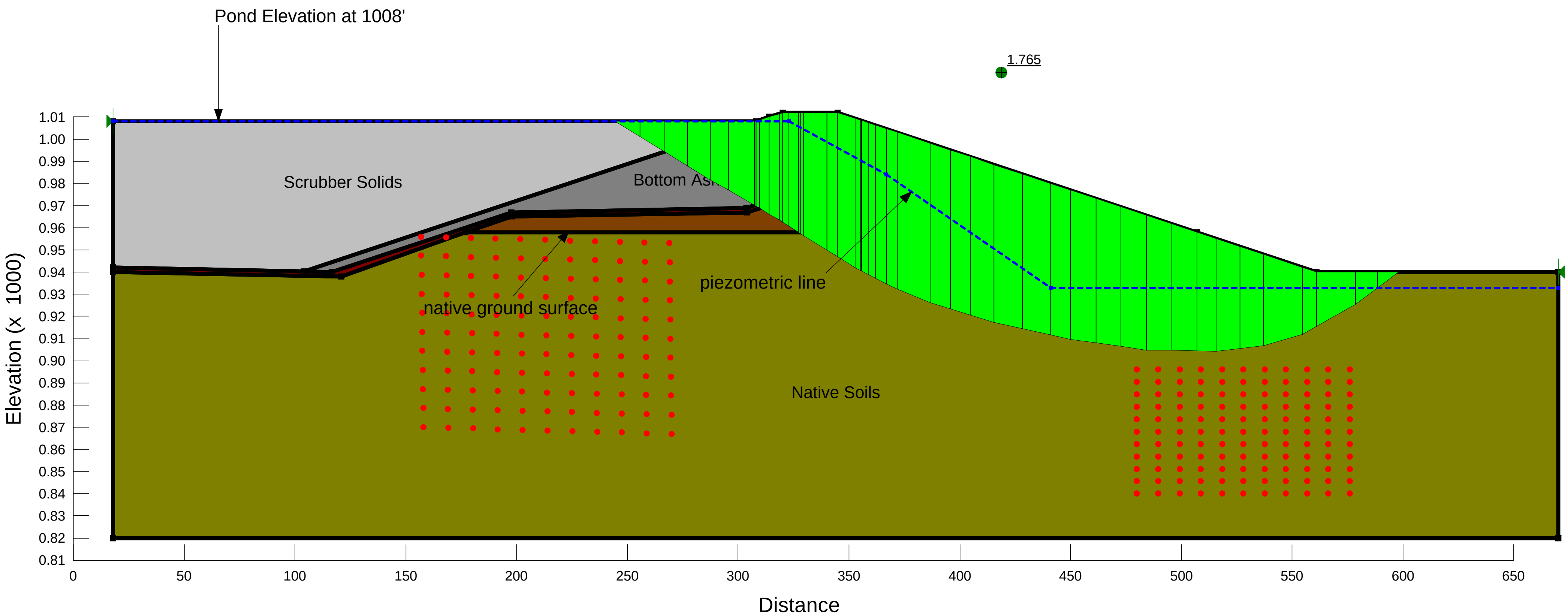
Pond 3S Condition 1: Long Term, Maximum Storage Loading
Pond Elevation at 1008'
Block Failure
Pre-Analysis Diagram



Pond 3S Condition 1: Long Term, Maximum Storage Loading
Pond Elevation at 1008'
Block Failure



Pond 3S Condition 1: Long Term, Maximum Storage Loading
Pond Elevation at 1008'
Block Failure
Seismic Analysis

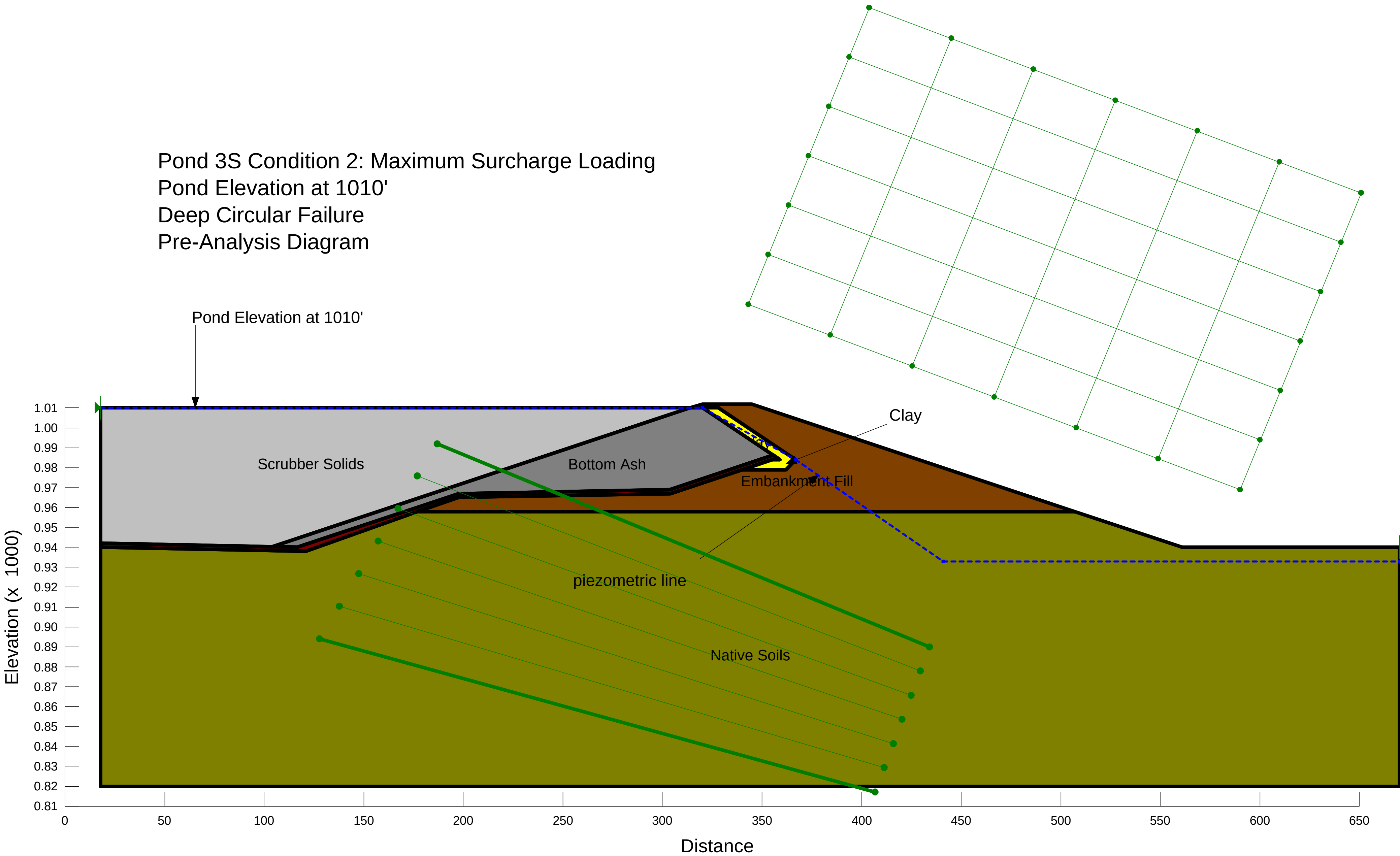


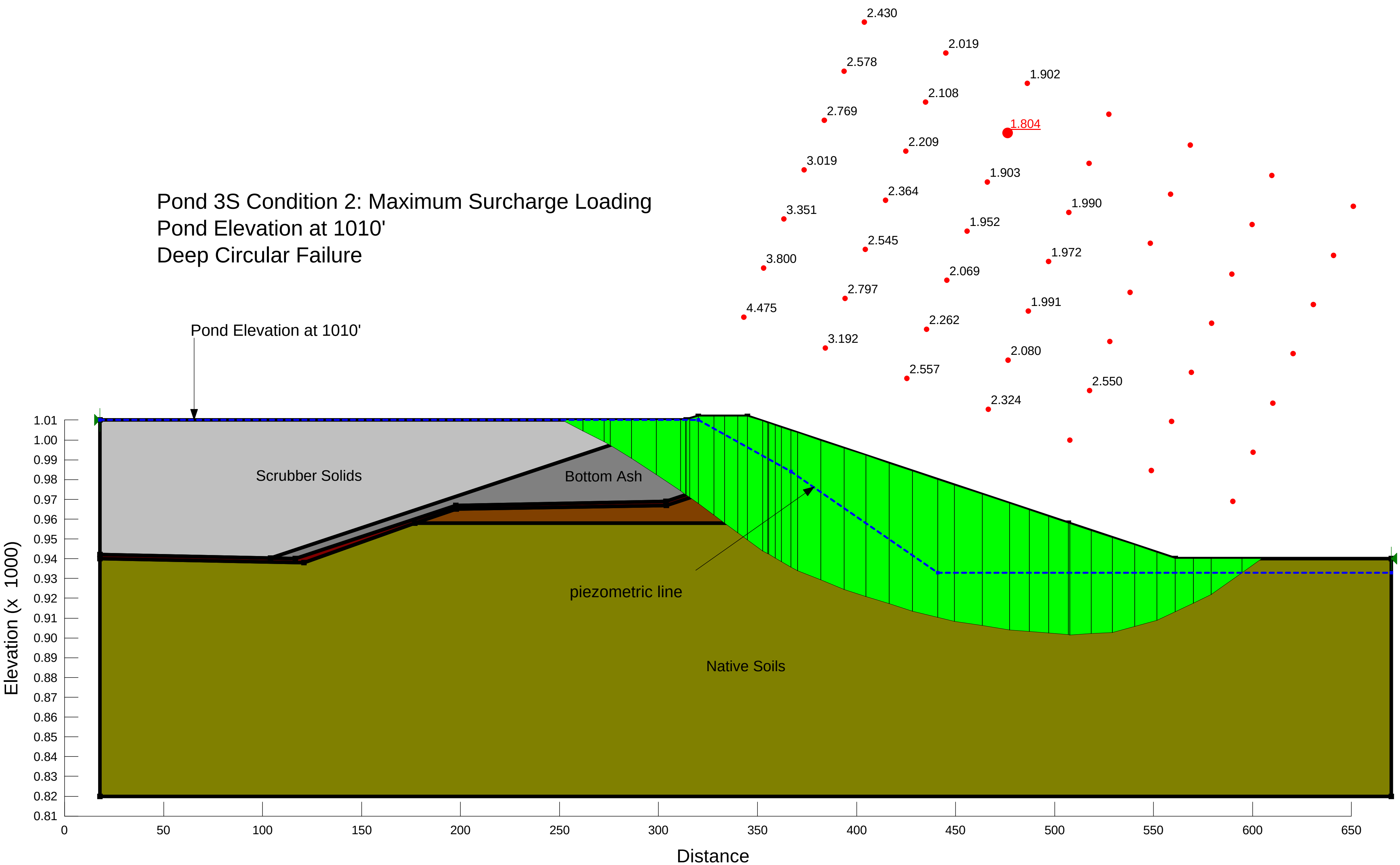
Pond 3 South

Condition 2

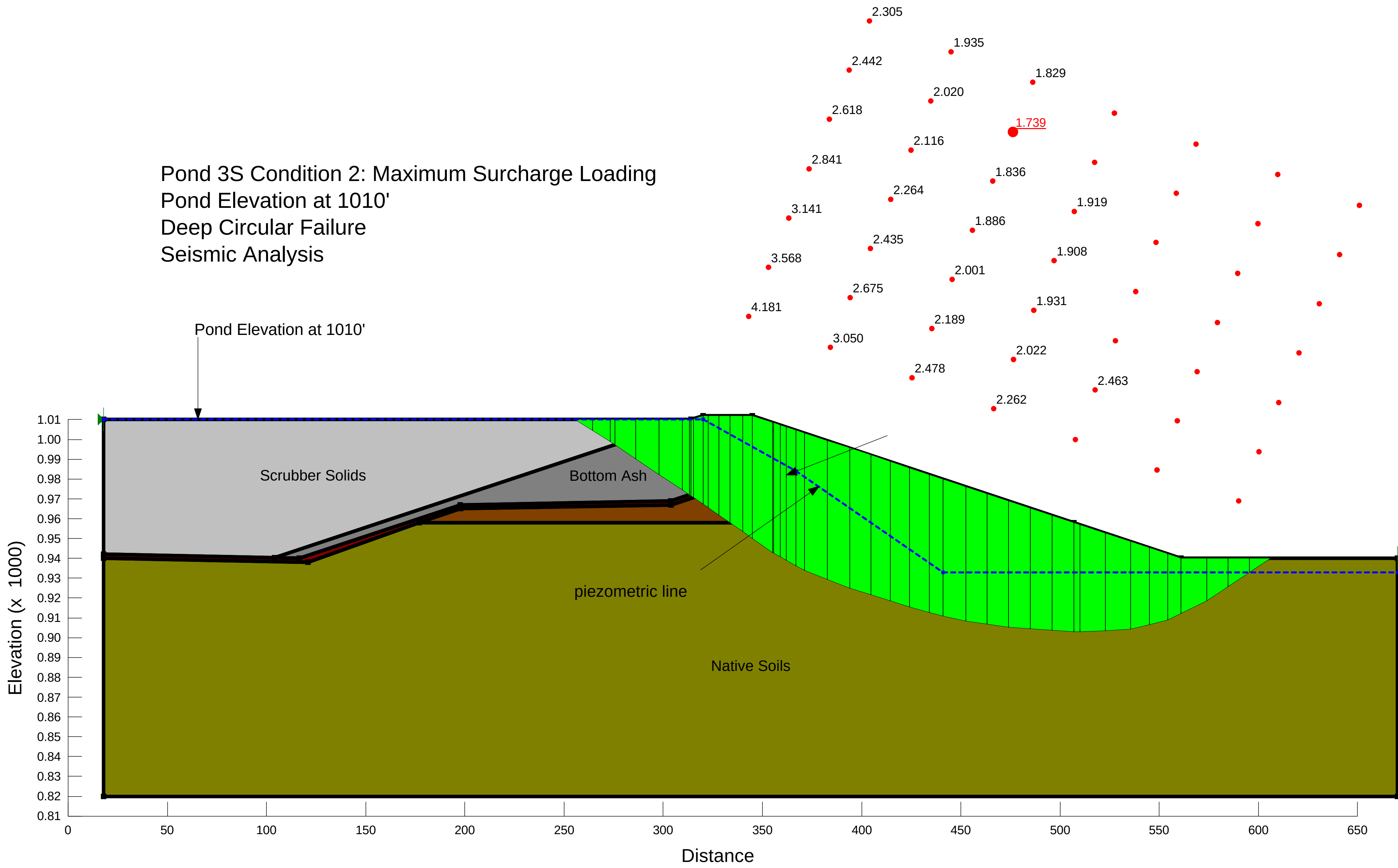
Maximum Surcharge Loading

Pond 3S Condition 2: Maximum Surcharge Loading
Pond Elevation at 1010'
Deep Circular Failure
Pre-Analysis Diagram



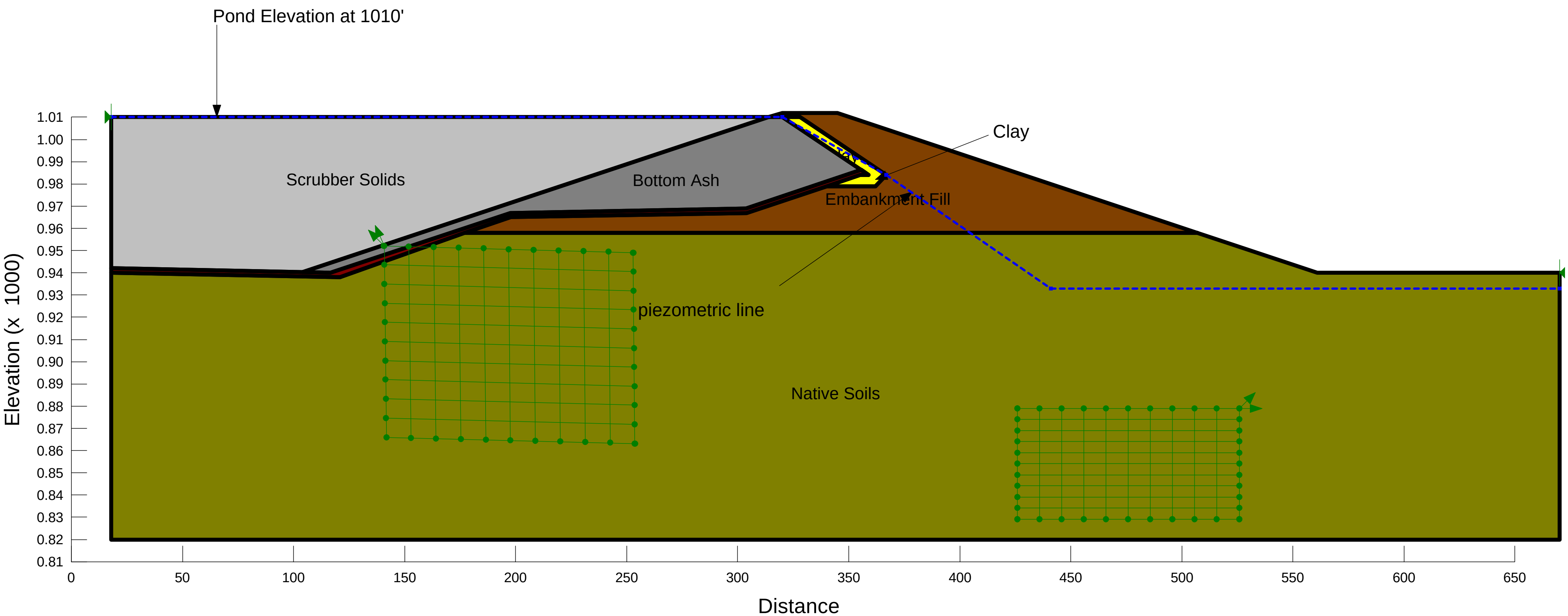


Pond 3S Condition 2: Maximum Surcharge Loading
Pond Elevation at 1010'
Deep Circular Failure
Pond Elevation at 1010'
Scrubber Solids
Bottom Ash
piezometric line
Native Soils
2.430
2.019
2.578
1.902
2.108
2.769
1.804
2.209
3.019
1.903
2.364
1.990
3.351
1.952
2.545
3.800
1.972
2.069
2.797
1.991
4.475
2.262
3.192
2.080
2.557
2.550
2.324
Elevation (x 1000)
1.01
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
0.85
0.84
0.83
0.82
0.81
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Distance

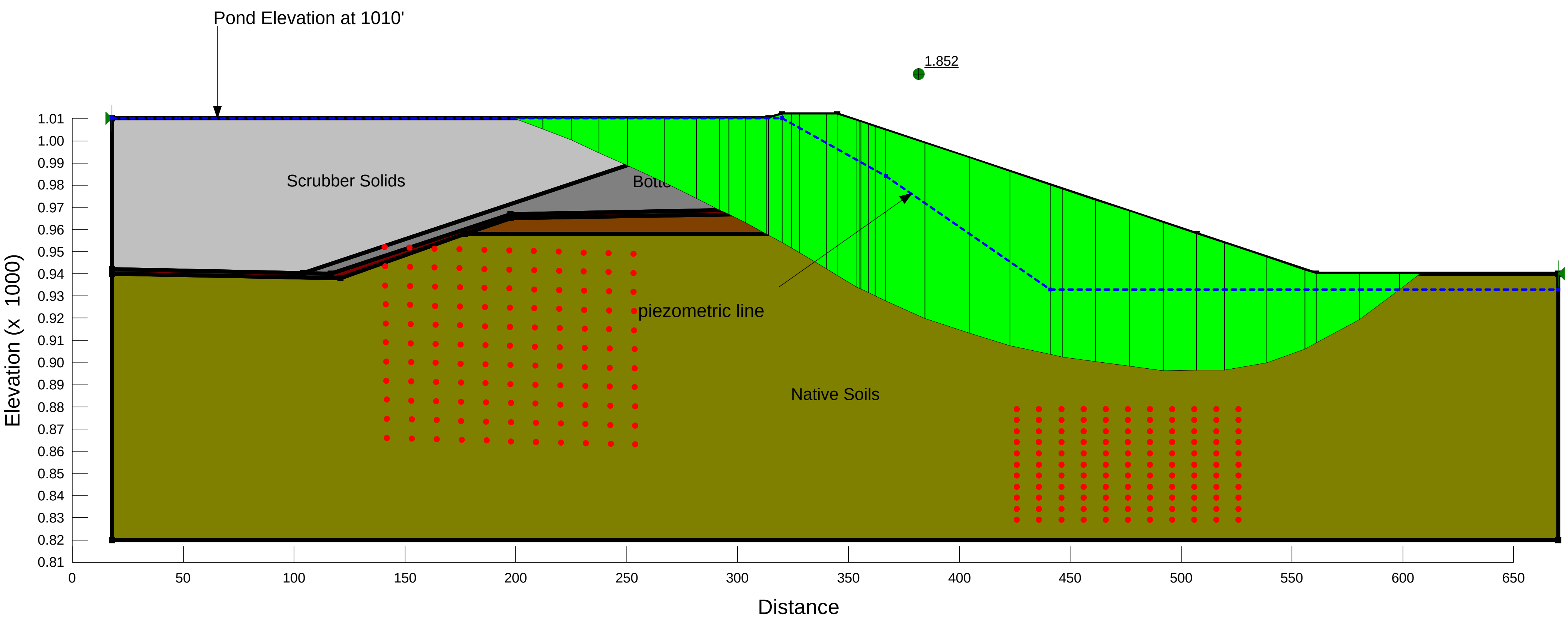


Pond 3S Condition 2: Maximum Surcharge Loading
Pond Elevation at 1010'
Deep Circular Failure
Seismic Analysis
Pond Elevation at 1010'
Scrubber Solids
Bottom Ash
piezometric line
Native Soils
2.305
1.935
2.442
1.829
2.020
2.618
1.739
2.116
2.841
1.836
2.264
1.919
3.141
1.886
2.435
1.908
3.568
2.001
2.675
1.931
4.181
2.189
3.050
2.022
2.478
2.463
2.262
Elevation (x 1000)
1.01
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
0.85
0.84
0.83
0.82
0.81
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Distance

Pond 3S Condition 2: Maximum Surcharge Loading
Pond Elevation at 1010'
Block Failure
Pre-Analysis Diagram



Pond 3S Condition 2: Maximum Surcharge Loading
Pond Elevation at 1010'
Block Failure



Pond 3S Condition 2: Maximum Surcharge Loading
Pond Elevation at 1010'
Block Failure
Seismic Analysis