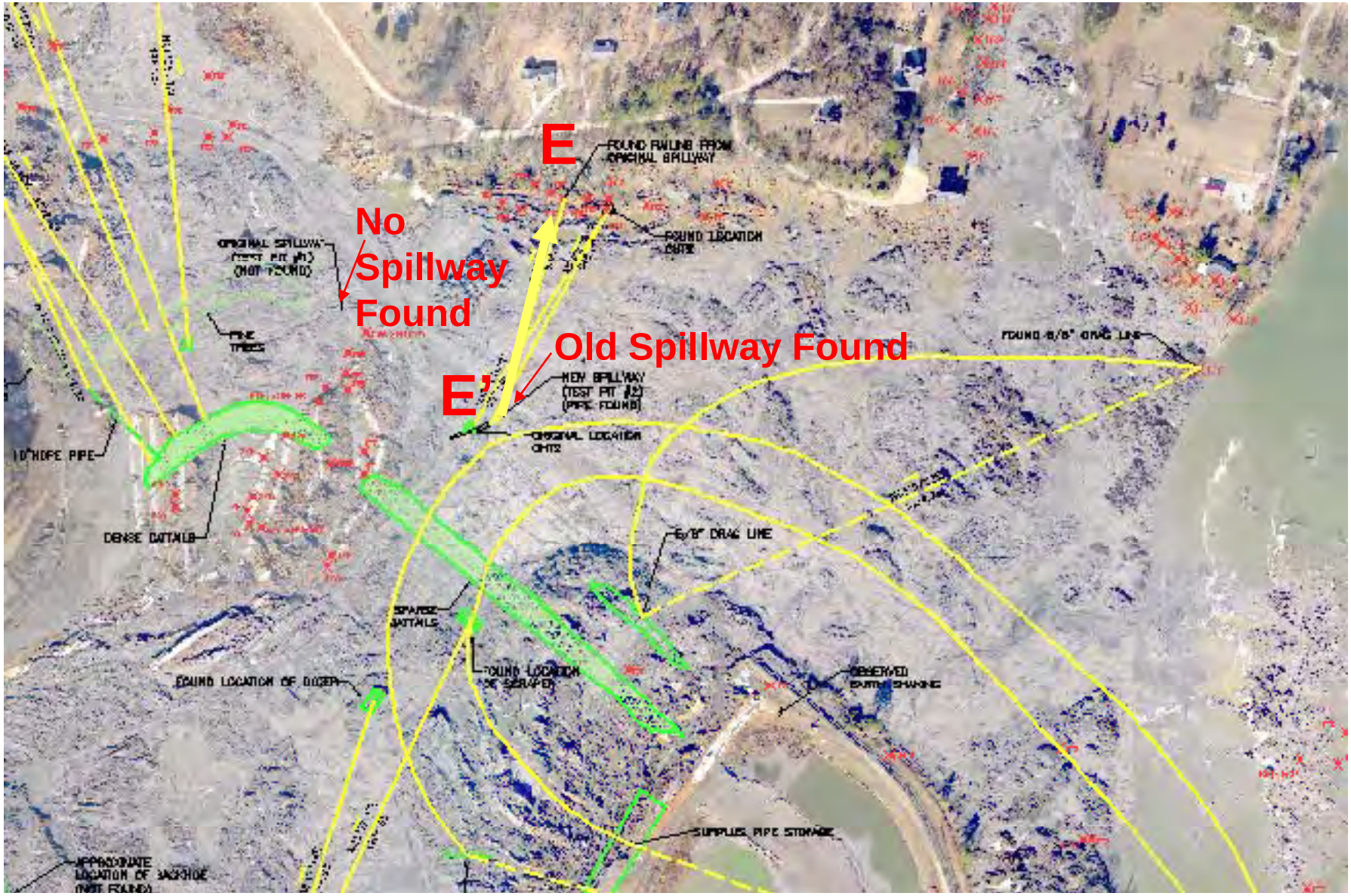
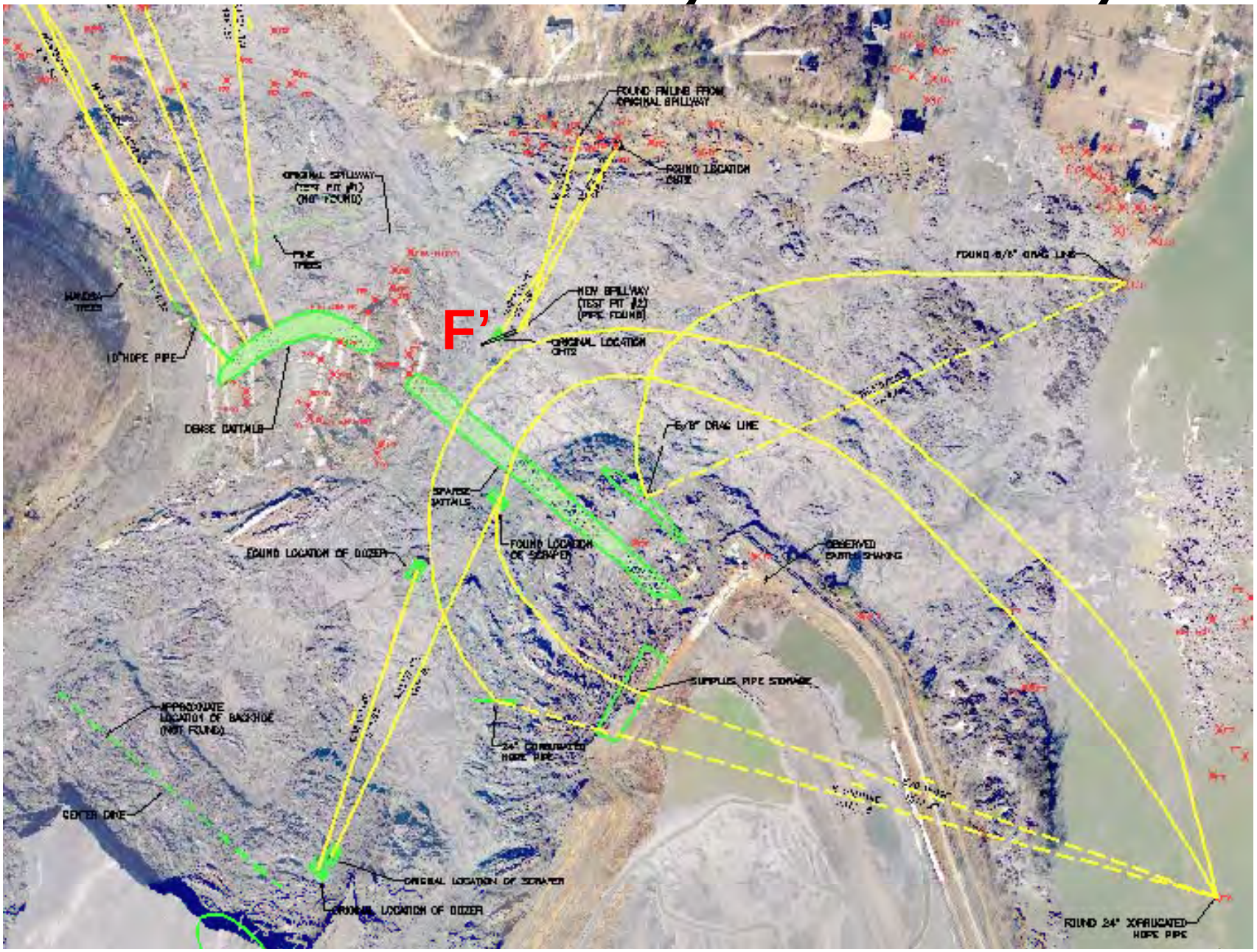
Relic Survey Summary

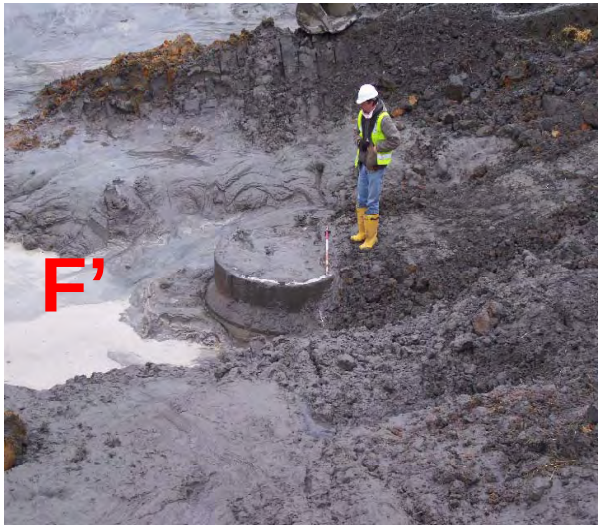


Dike C Spillway Outlet Wall Railing Before and After Failure

Relic Survey Summary

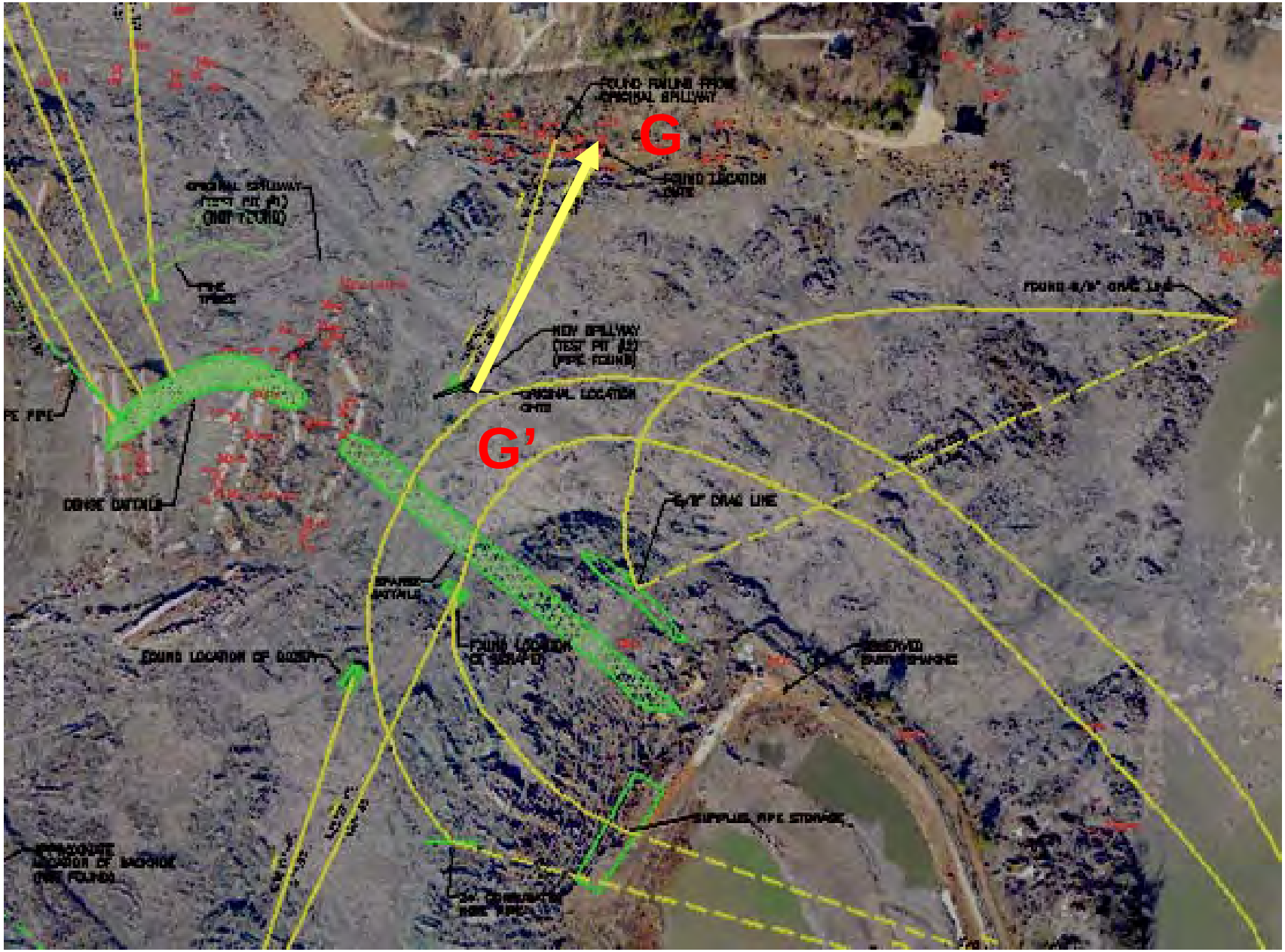


Dike C Intact 30-inch RCP Spillway in Native Clayey Silt Foundation



Pipe filled with water, riser plugged

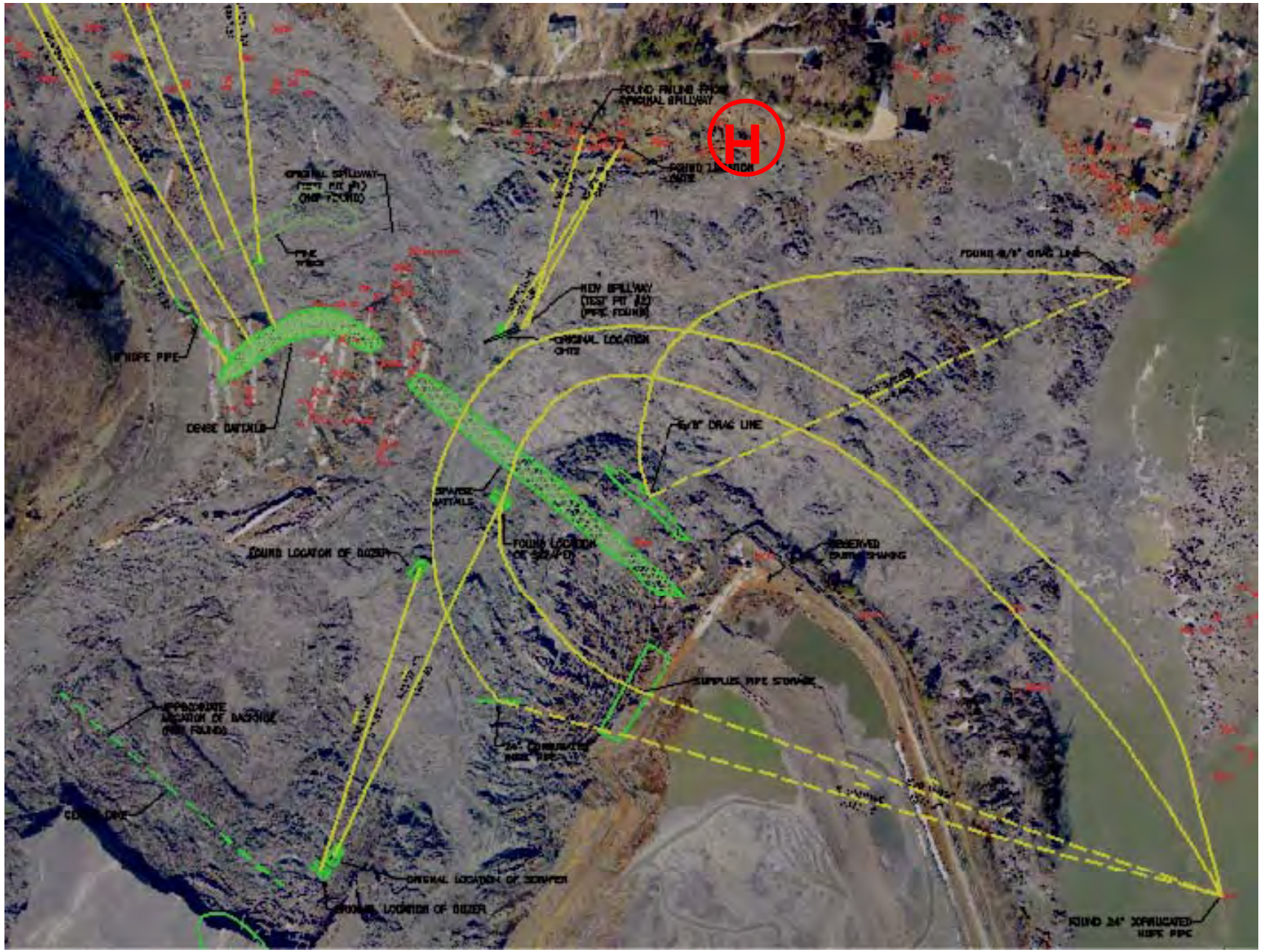
Relic Survey Summary



Top of Dike C TVA Survey Marker CHT-2

Dike C Rolled Earth Fill Moved 697.29 feet North, Dropped from El. 765.15 to 757.81

Relic Survey Summary



Displaced Dike C on Clay Foundation

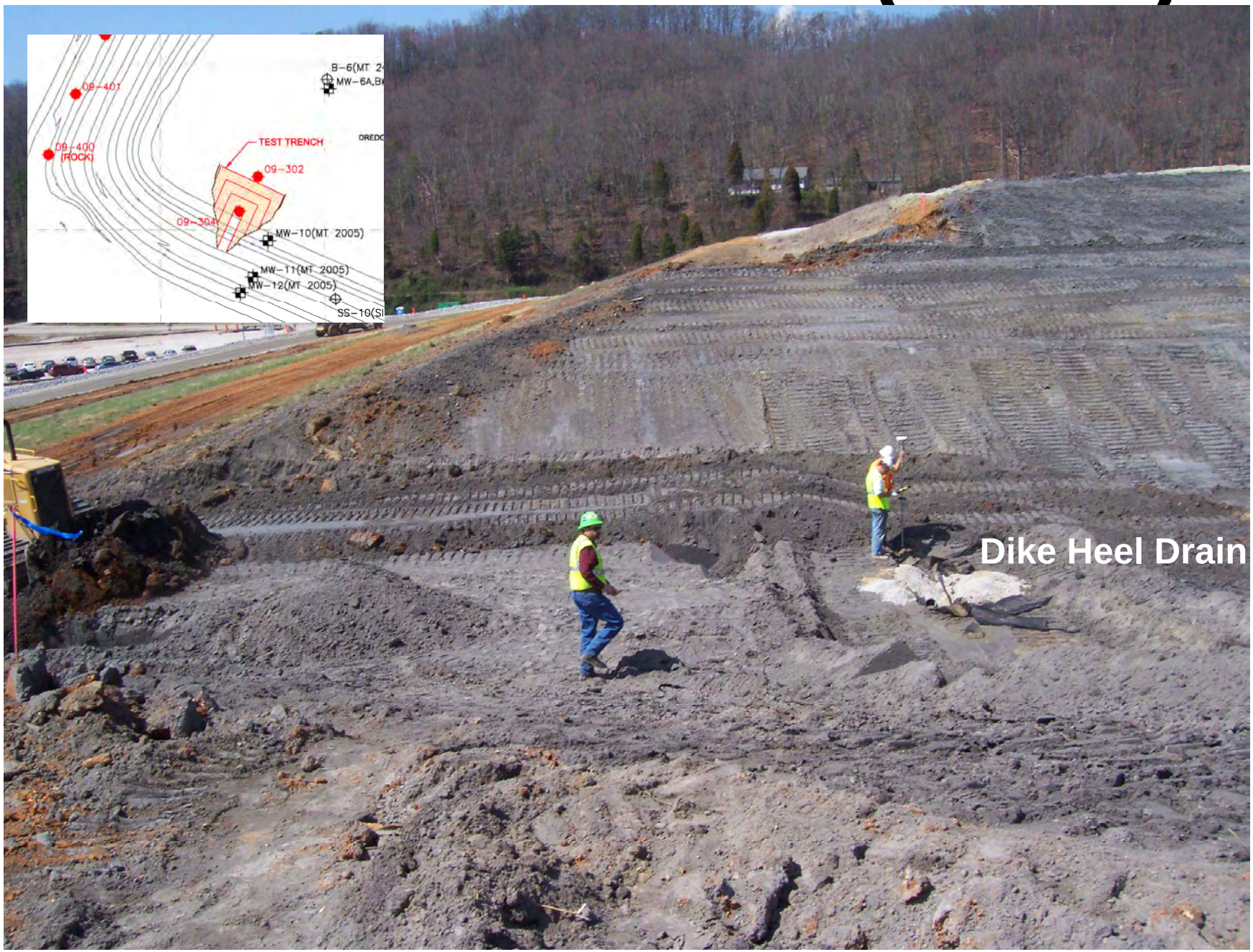
Relic Dike C Against North Slope

H

Cell 1 Test Trench Goals

- Confirm upstream dike construction geometry
- Compare as-built to TVA design drawings
- Make sure slip film woven geotextile was not present under base of dikes
- Confirm dike drainage system
- Check compaction of dike
- Measure densities of dike and sluiced ash
- Estimate flyash and bottom ash proportions

Cell 1 Test Trench (South)



Findings from Cell 1 Test Trench

- No slip-film woven fabric used under Dikes C1 through D2
- Dike heel drains were located, confirmed functional, and built to plan. Drain pipes were oval and not crushed
- No evidence of piping or plugging of pipe or of filter fabric-covered drainage gravel
- Majority of dikes constructed of flyash rim ditch with occasional layers of bottom ash.
- Construction of dikes generally matched the design cross section by TVA
- Mechanically placed ash generally denser than sluiced ash under dikes

Failure Modes Analysis

Potential Failure Modes Include:

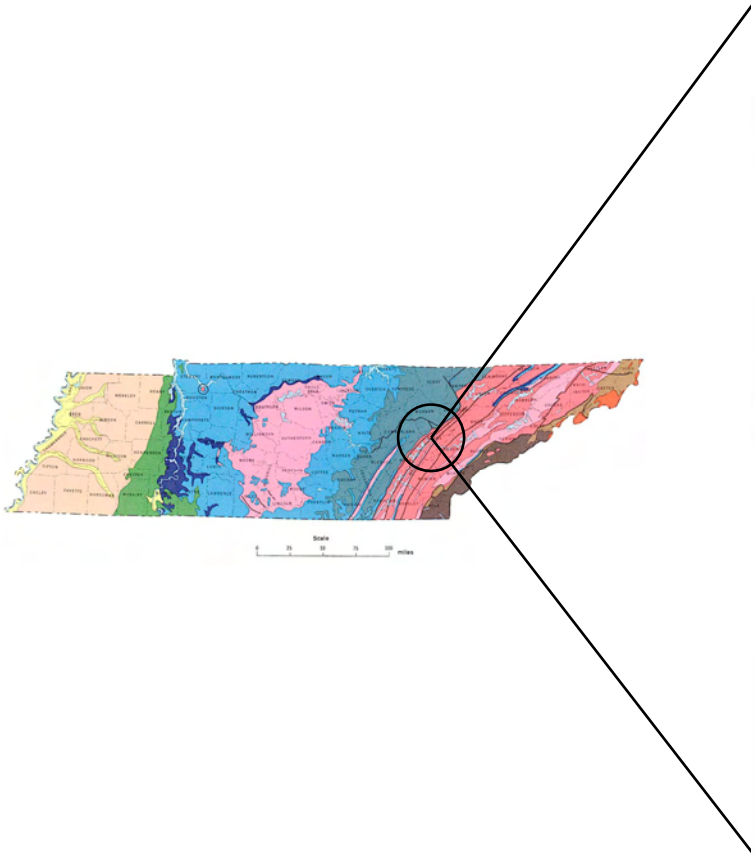
- Earthquake Instability
- Excess Rainfall
- Rapid Reservoir Drawdown
- Karstic Limestone Sinkhole or Bedrock Instability
- Artesian Groundwater Instability
- Shallow Dike Instability Due to Seepage Outbreak or Piping
- Intermediate Depth Instability of Dredge Cell or Dikes
- Deep Seated Instability of Dredge Cell through Ash Only
- Increased Filling Rates into Dredge Cells
- Deep Seated Foundation Instability Under Dredge Cells
- Consequential Undrained Failure of Ash Causing Flow Slide (Static Liquefaction)
- Progressive Failure after Initial Cell Breach or Slope Instability

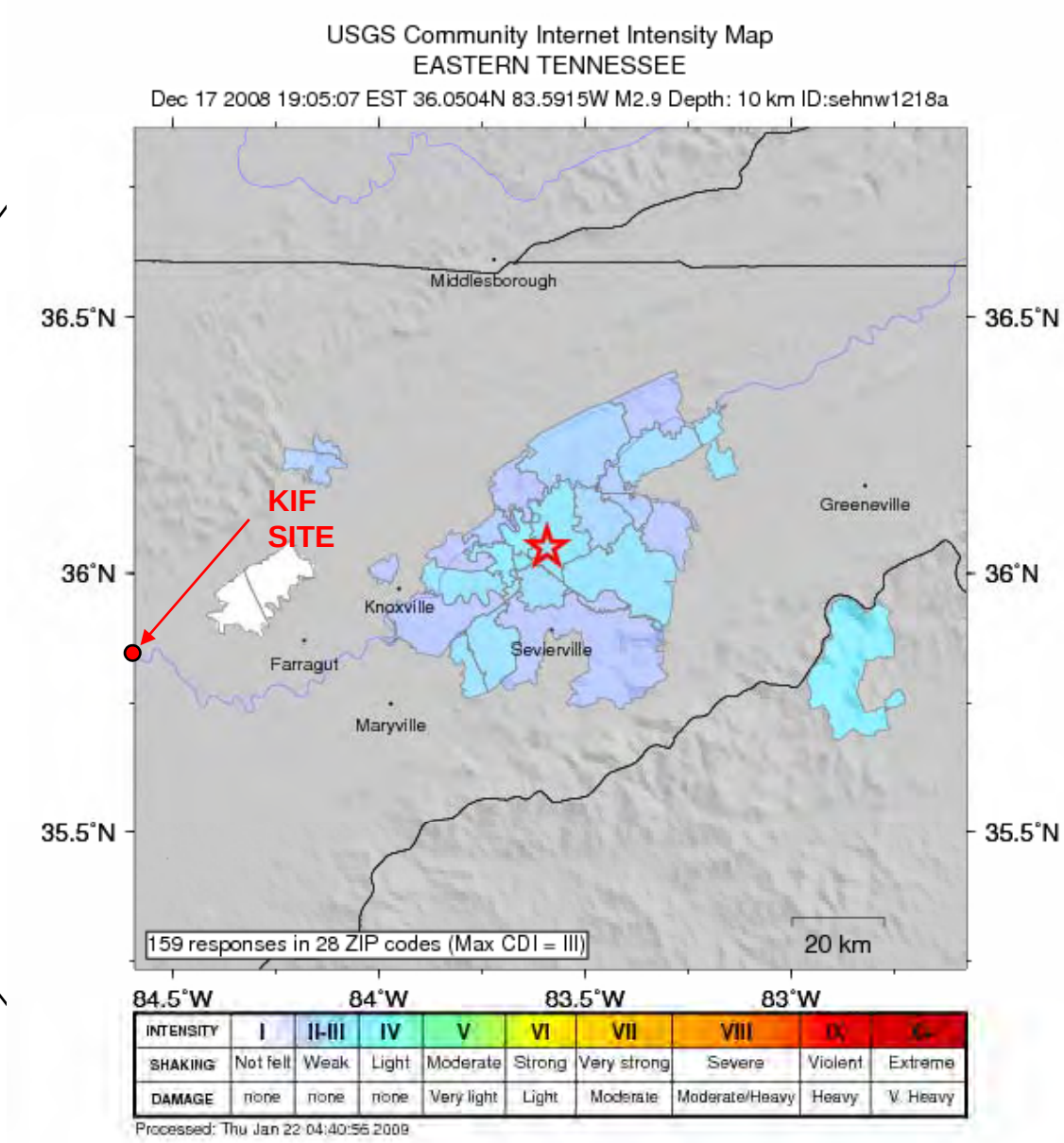
Key Failure Modes

December 2008 Seismicity

- Largest – Pre-failure Earthquake was on December 17, 2008 at New Market, TN. It was an M = 2.9 at 10 km depth located approximately 50 miles from KIF site
- Closest - Pre-failure Earthquake was on November 9, 2008 southeast of Rockwood, TN. It was an M = 2.5 Event at 25 km depth located approximately 8 miles south of KIF site

No large Earthquakes in TN on December 21 or 22, 2008




USGS Community Internet Intensity Map
EASTERN TENNESSEE
Dec 17 2008 19:05:07 EST 36.0504N 83.5915W M2.9 Depth: 10 km ID:sehnw1218a
Middlesborough
36.5°N
36.5°N
KIF
SITE
Greeneville
36°N
36°N
Knoxville
Sevierville
Farragut
Maryville
35.5°N
35.5°N
159 responses in 28 ZIP codes (Max CDI = III)
20 km
84.5°W
84°W
83.5°W
83°W
INTENSITY | I | II-III | IV | V | VI | VII | VIII | IX | X+
SHAKING | Not felt | Weak | Light | Moderate | Strong | Very strong | Severe | Violent | Extreme
DAMAGE | none | none | none | Very light | Light | Moderate | Moderate/Heavy | Heavy | V. Heavy
Processed: Thu Jan 22 04:40:56 2009

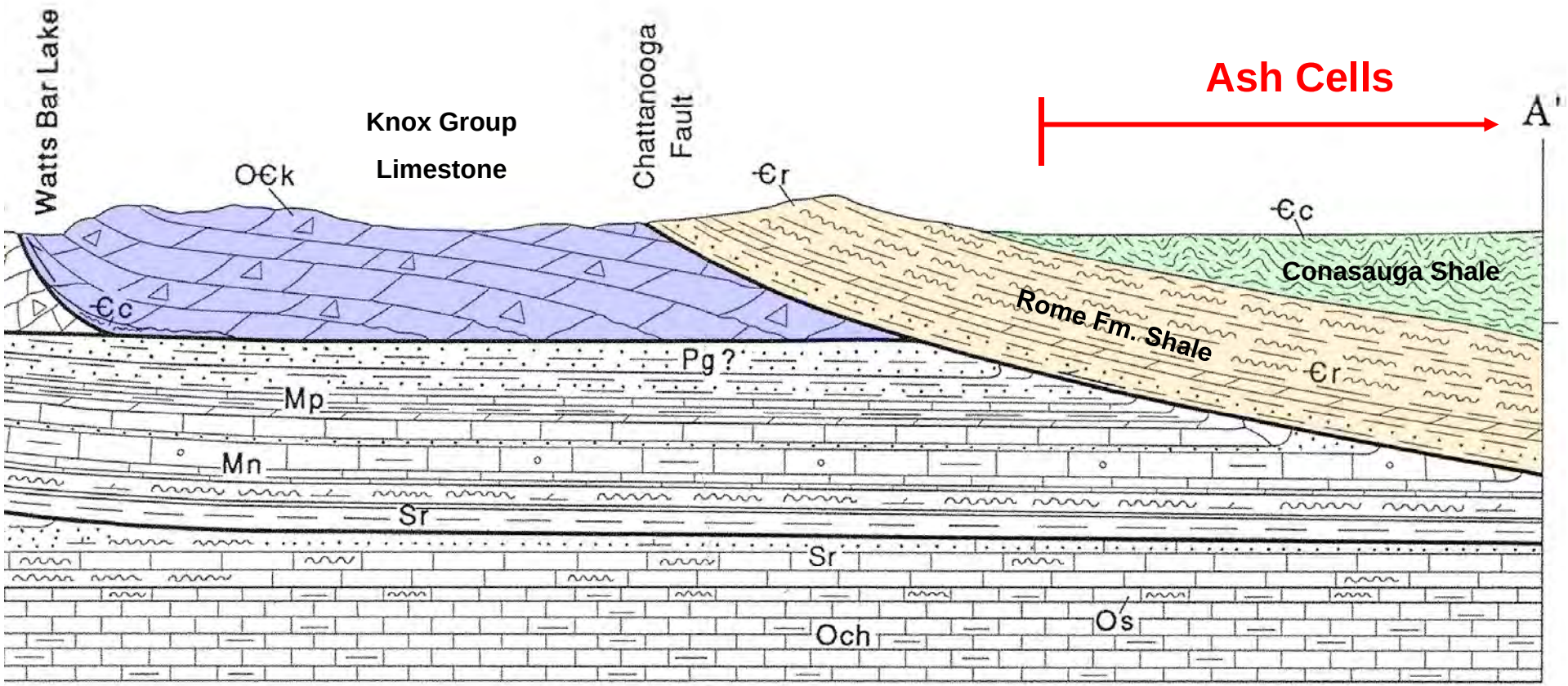
Ref. USGS

Karstic or Bedrock Instability

- No Limestone Immediately Beneath Overburden Under Dredge Cells
- Underlying Shale Bedrock not prone to sinkholes
- See Attached Cross Sketch from TN Division of Geology, 1993

No Impact

Geologic Cross Section



TN Div. of Geology, 1993

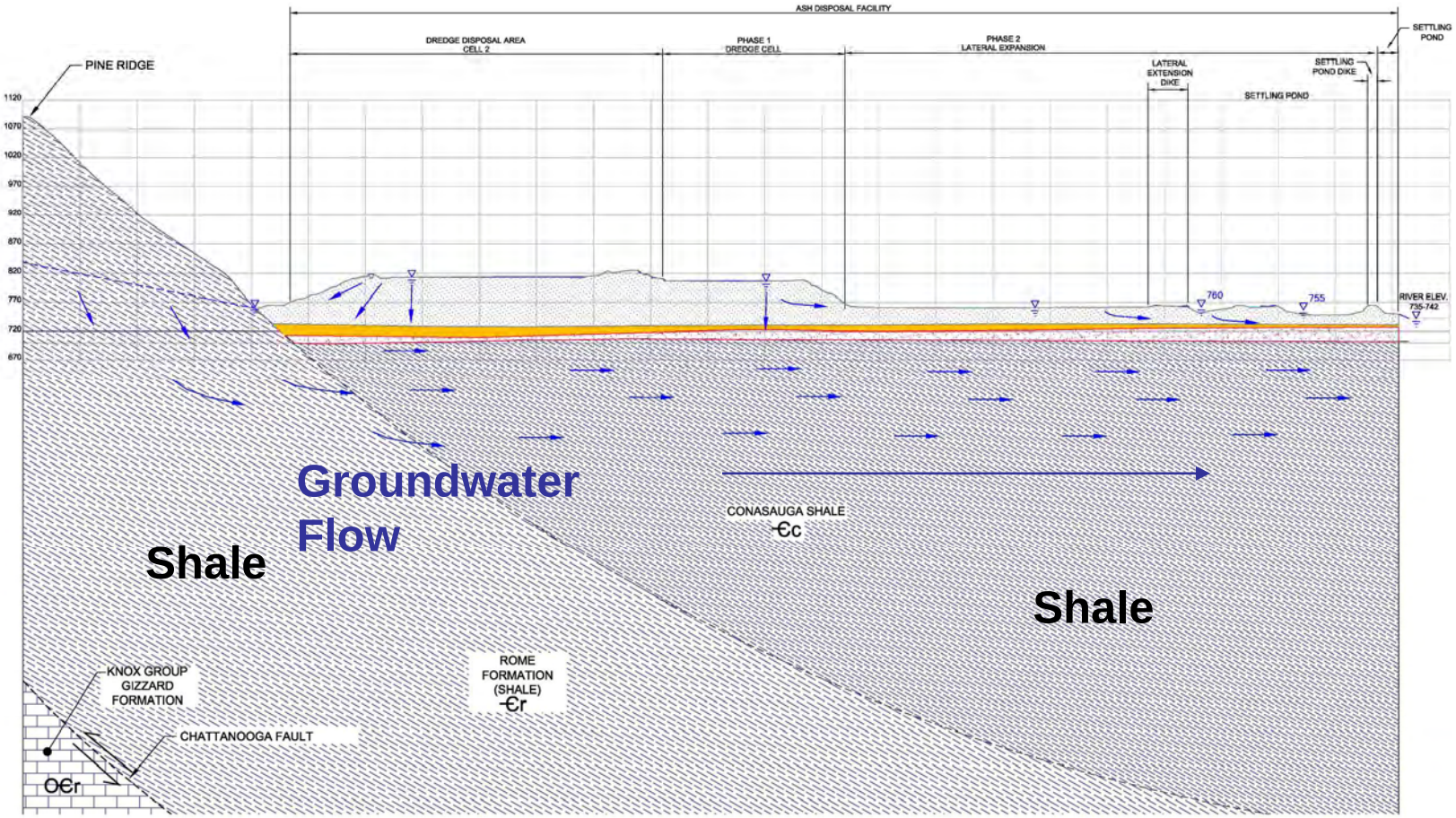
Artesian Impacts

- Dredge Cell 2 North Filled up to El. 815.5 with Water above Reservoir Levels El. 742 to 735
- Downward Gradient to Side Slopes & Alluvium
- Dredge Cells Filled with Process Water above Ash Collection Pond of El. 760
- Bedrock Shale Shows no Artesian Conditions

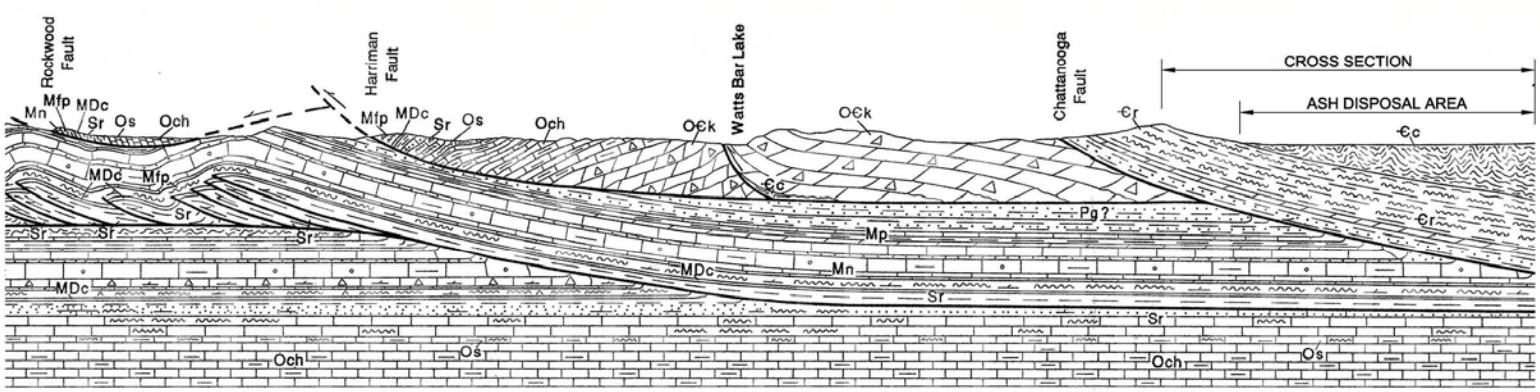
No Impact since Shale Bedrock is Impermeable

SECTION LOOKING NORTH

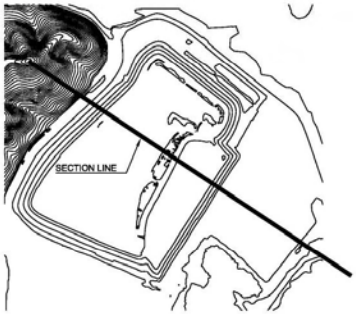
NOTE:
GEOLOGIC CROSS SECTION AFTER MOORE, J.L., et al., (1993) GEOLOGIC MAP OF THE HARRIMAN QUADRANGLE, TENNESSEE.



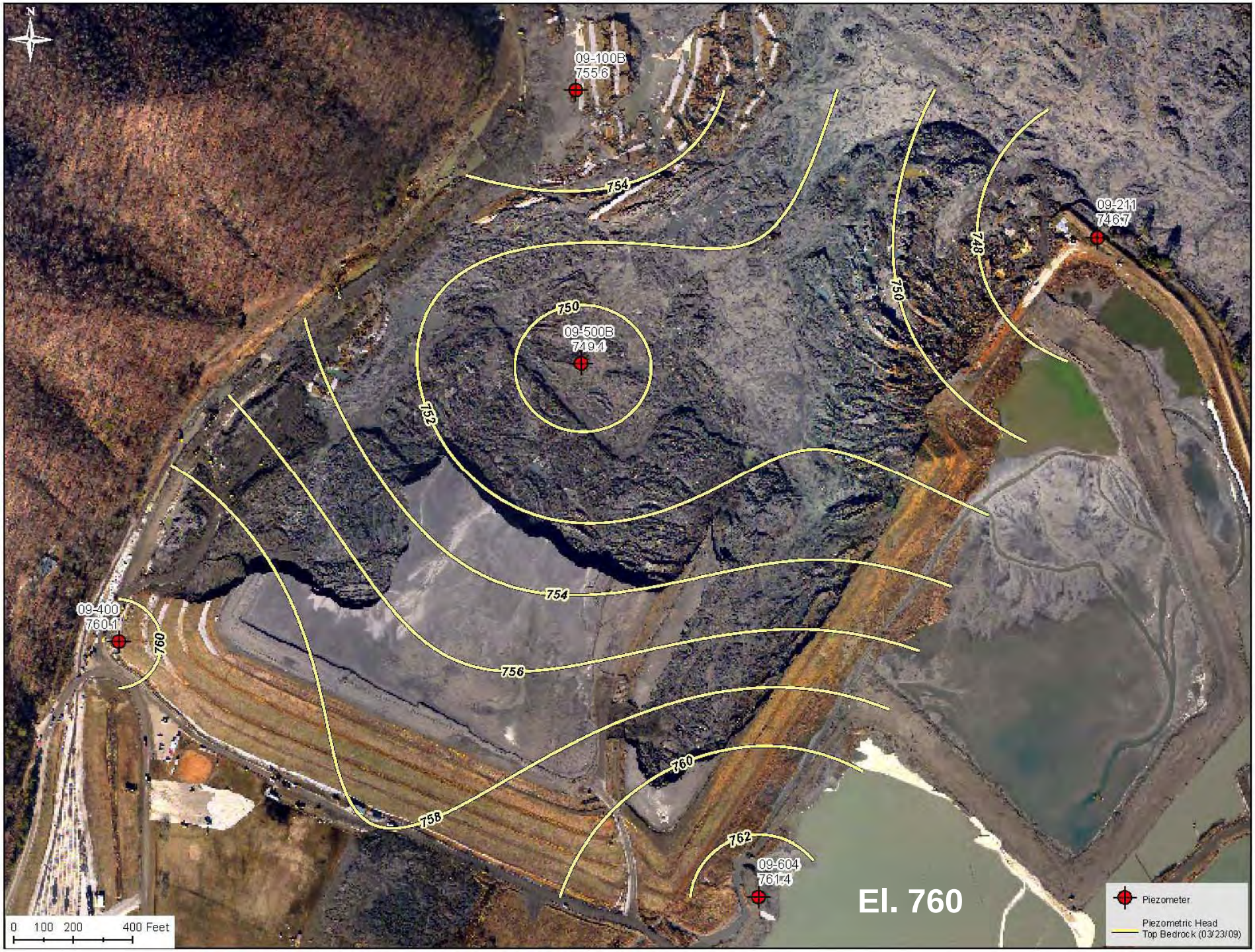
SCALE: 1H=4V



IN PROGRESS
5-4-2009



CROSS SECTION INDEX
SCALE : 1" = 800'


N
09-100B
755.6
754
09-211
746.7
748
750
750
09-500B
749.4
752
754
09-400
760.1
760
756
760
758
762
09-604
761.4
El. 760
0 100 200 400 Feet
Piezometer
Piezometric Head
Top Bedrock (03/23/09)

Evidence of Surface Seepage or Piping

- Wet and shallow slope instability in 2003 and 2006 along Swan Pond Road
- Nearly all West and South Piezometers and Wells readings in December 2008 do not show water levels above dike surface, except WP02
- No piping or reported excessive seepage on slopes in 2008
- Minor erosion noted on North Slope of Cell 2 during fall of 2008. Action taken by TVA
- Daily inspections did not see evidence of seepage or piping during 12/21/08 visual inspection by TVA

Minor Impact – West Slope Wetness Observed in 2008

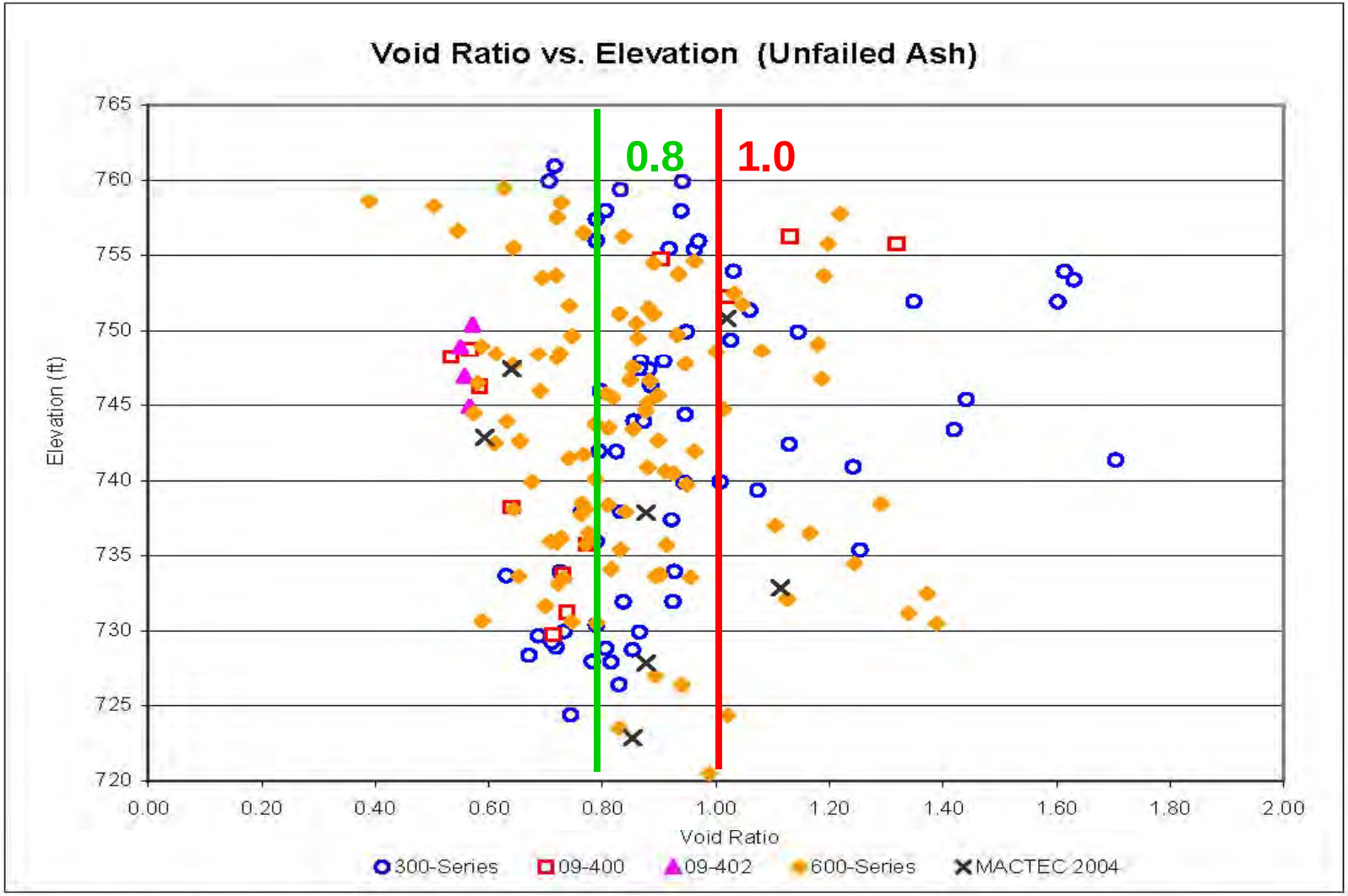
Existing Conditions and Strata

- Upstream Dike Fill (4H:1V Design Slopes)
- Loose Wet Ash
- Loose Structured Laminated Sensitive Silt (ML) and Flyash (Slimes)
- Medium to Stiff Alluvial Silty Clay
- Very loose to Dense Silts and Sands
- Shale

Sluiced Loose Ash Properties

- Sluiced Ash under Dredged Cells
- Rounded particles
- Loose Ash 85 feet thick
- Unfailed Void Ratios (e = 0.4 to 1.6, average 0.87)
- Average Wet Density 107 pcf (less than soil)
- Specific Gravity Gs = 2.37 Average
- Void Ratios do not Decrease with Depth
- Contractive Undrained Behavior Controls Stability
- Low Undrained Steady State Shear Strength
- Drained Friction Angle 30 degrees
- Relatively low permeability $k_h=2x10^{-1}$ feet/day, $k_v=1.5x10^{-1}$ feet/day

Unfailed Ash Void Ratios

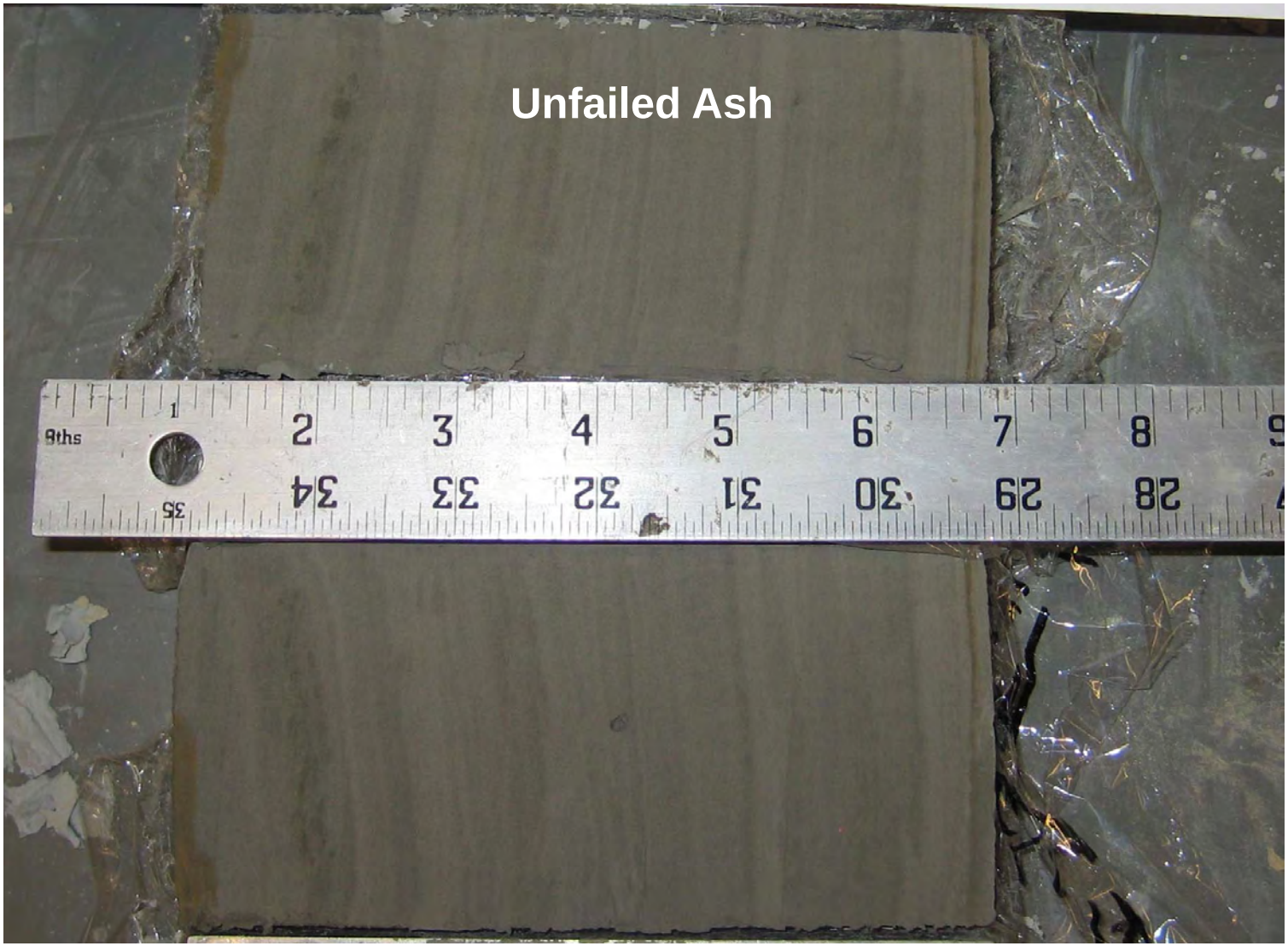


Unfailed Ash Average **0.87**

Majority of Data above 0.8

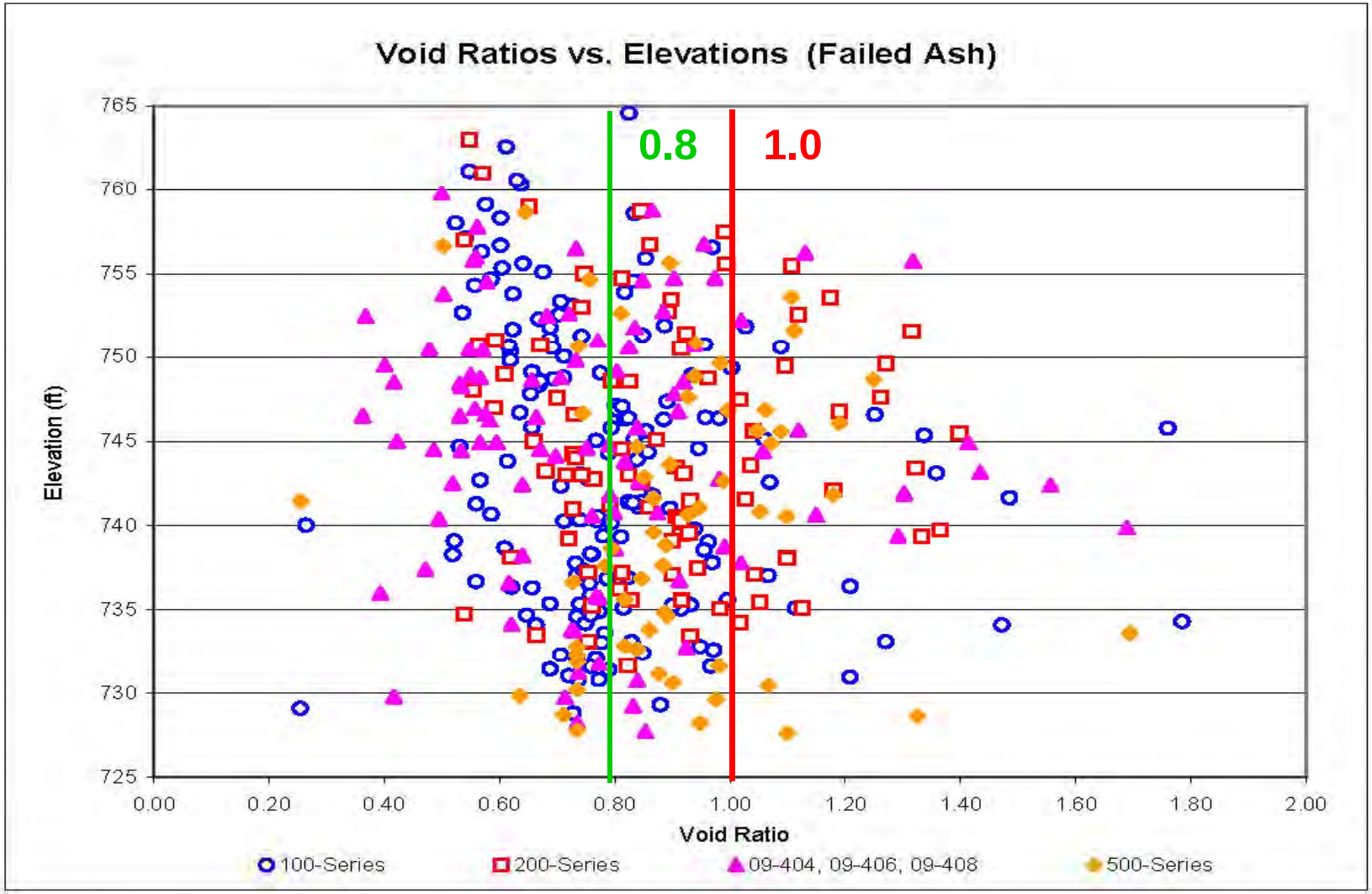
Note: 1. Only ash below Elev. 765 ft.
2. Assuming G_s=2.37 and 100% saturation
3. Unfailed Ash in 300-, and 600-Series, MACTEC 2004 data, and 09-400 and 09-402 borings of the 400-Series

Laminated Unfailed Ash Split Tube Sample



09-100B S5 – Bottom 7 inches cut open and air dried ash

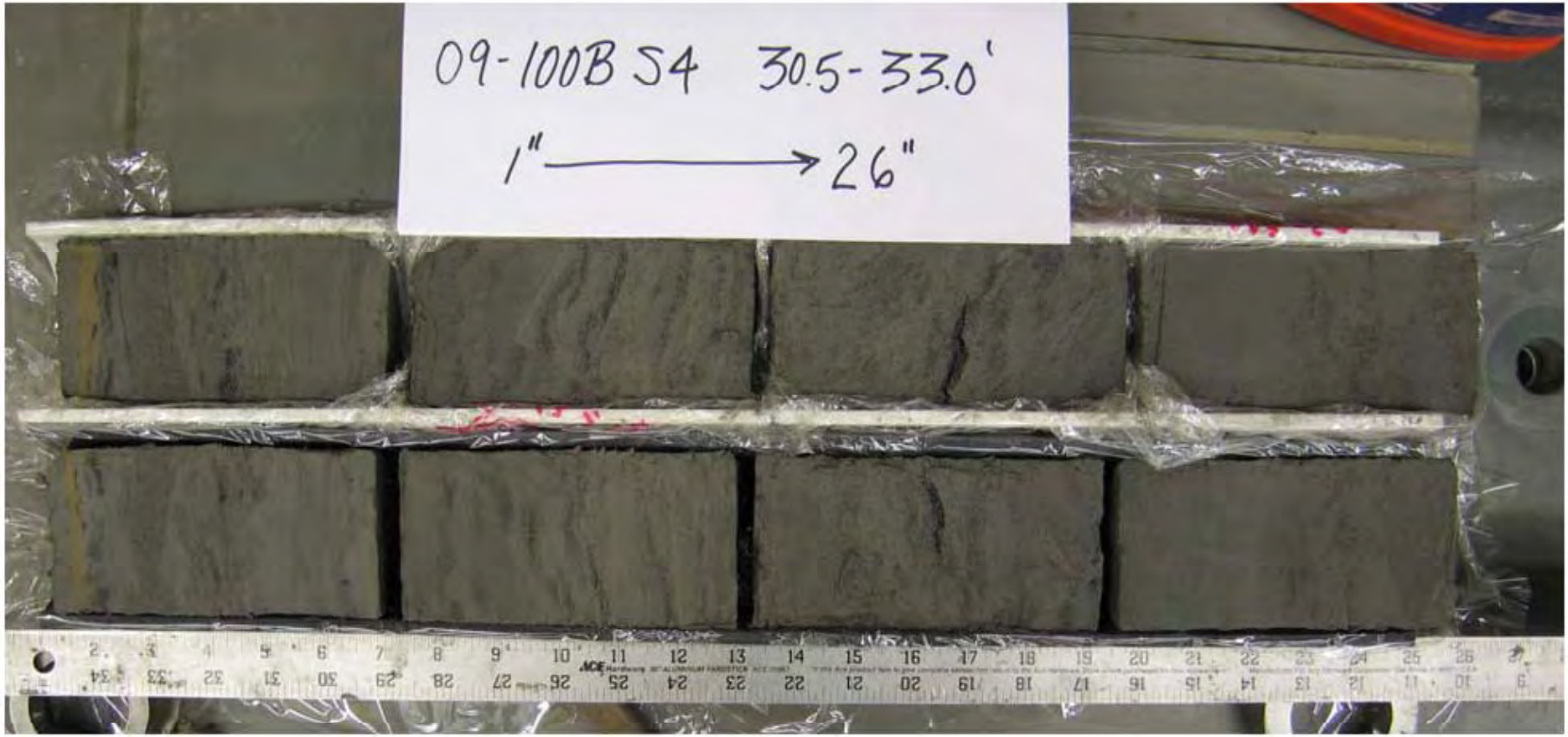
Failed Ash Void Ratios



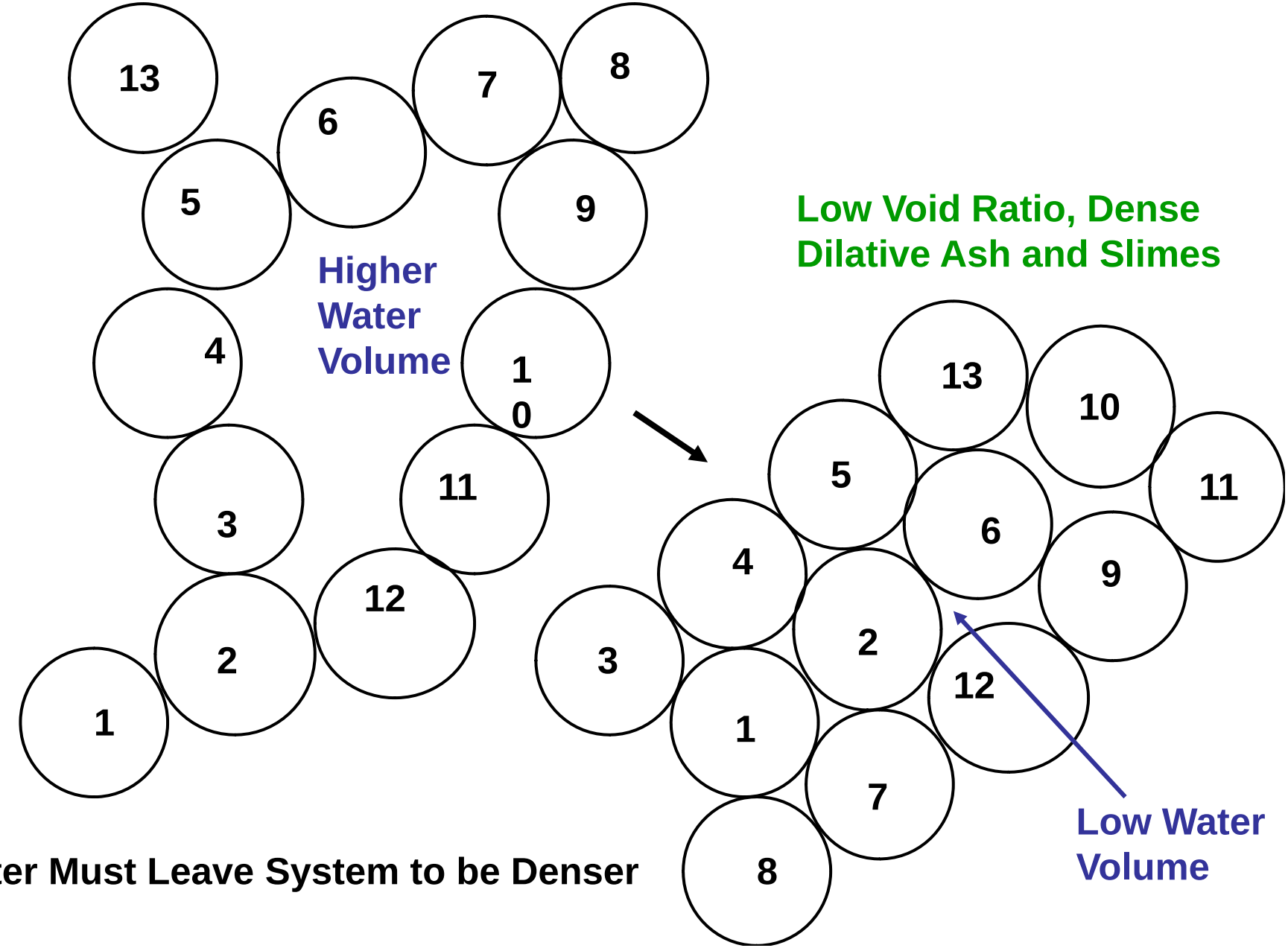
Failed Ash Average: **0.82**

Note: 1. Only ash below Elev. 765 ft. In 100- and 200-Series, ash below water table
2. Assuming G_s=2.37 and 100% saturation
3. Failed Ash in 100-, 200-, and 500-Series, and 09-404, 09-406, and 09-408 borings of the 400-Series

Failed Ash of Split Tube Sample



High Void Ratio, Loose Contractive Ash and Slimes



Water Must Leave System to be Denser

Loading Rate vs. System Drainage

- If fill heights or loading rates are slow enough there is time for pore water in ash to drain and allow drained behavior

Conversely,

- If fill heights or loading rates become too rapid there may not be time for pore water in ash to drain, and undrained behavior becomes a destabilizing impact

Applies to Slimes and Loose Ash