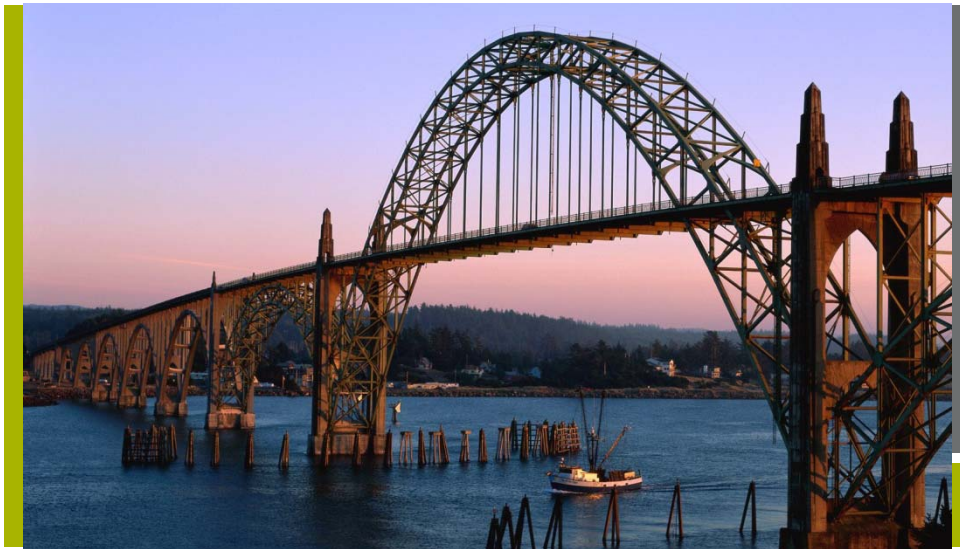
NEWPORT BIG CREEK DAMS

A Small Town & the Challenges of its Drinking Water Source



Presented by

Verena Winter, P.E. HDR Engineering

Chris Carpenter, P.E. Cornforth Consultants

Rich Hannan, P.E. HDR Engineering

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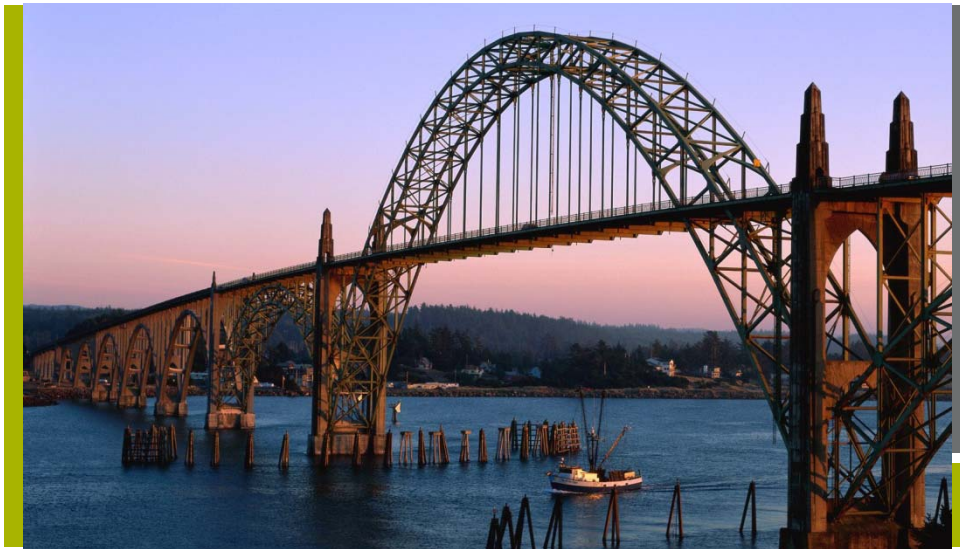
NEWPORT BIG CREEK DAMS



Unexpected Results from an Ordinary Boring

Presented by

Verena Winter, P.E. HDR Engineering

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Newport, OR

Big Creek Dams 1 & 2

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Big Creek Dam #1

- Constructed: 1951
- Type: homogeneous earthen dam
- Length: 315 ft
- Height: 21 ft
- Crest Width: 12 ft

Big Creek Dam #2

- Constructed: 1968
- Raised: 1976
- Type: zoned embankment dam
- Length: 455 ft
- Height: 56 ft
- Crest Width: 20 ft

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HDR

Who knew? - Discovery of the Problem

New Water Treatment Plant

Who knew? - Discovery of the Problem

Existing Intake on Big Creek #1

Who knew? - Discovery of the Problem

Ordinary Boring

Who knew? - Discovery of the Problem

Plan B

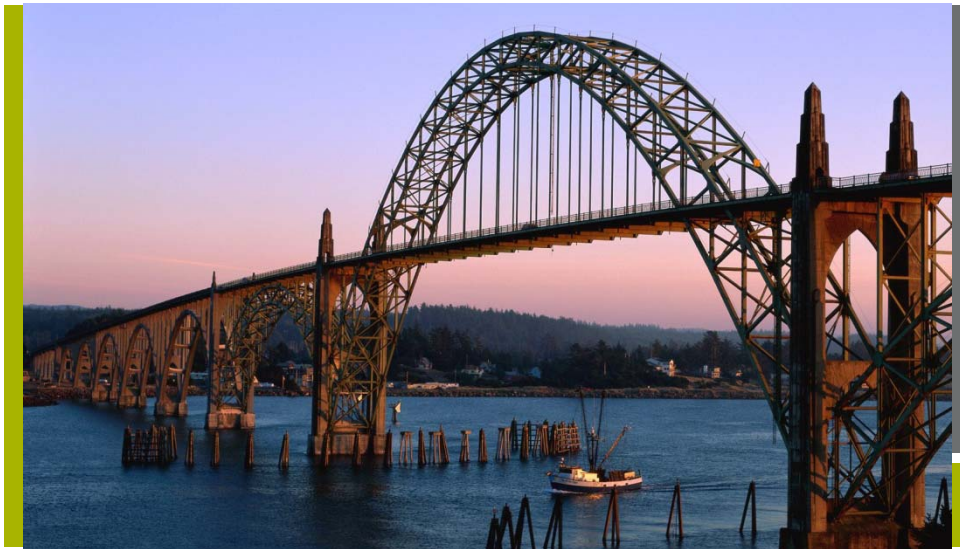
Who knew? - Discovery of the Problem

Explorations for Big Creek #1

Who knew? - Discovery of the Problem

Explorations for Big Creek #2

NEWPORT BIG CREEK DAMS



Developing Seismic Parameters for Big Creek Dams

Presented by

Chris Carpenter, P.E. Cornforth Consultants

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Seismic Parameter Development

- Principal Seismic Sources in Oregon
- Regional Seismicity
- Historical Earthquakes
- Evaluation of Ground Motions for Design
- Site Specific Earthquake Characteristics
  - Magnitude
  - Distance
  - Return Period
  - Response Spectra
  - Acceleration Time Histories
- Future Considerations
- Summary

Principal Seismic Sources in Oregon

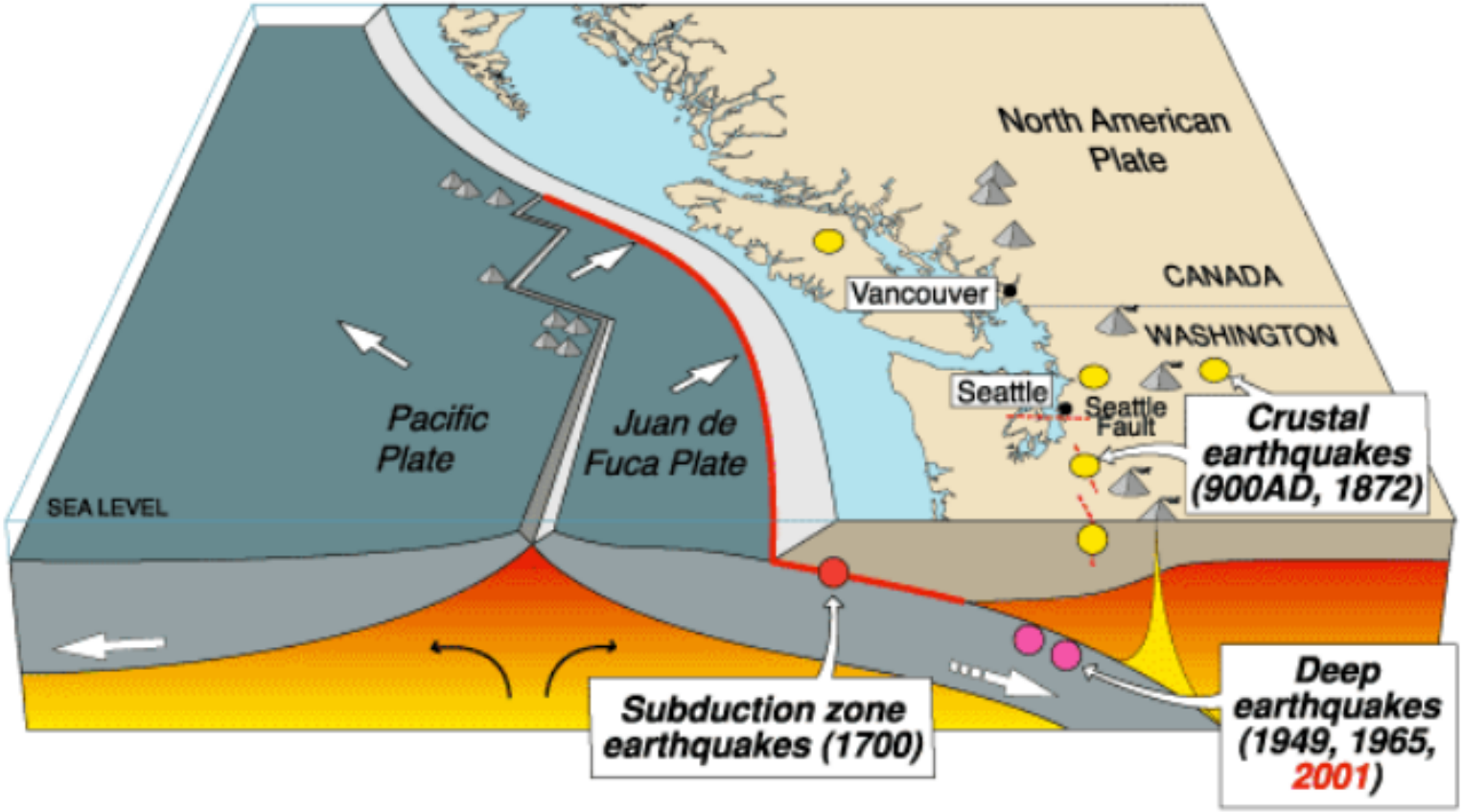
- Cascadia Subduction Zone
  - Interface
  - Deep Intraplate/Intraslab
- Crustal Sources
  - Known Faults – Regional Seismicity
  - Gridded/Random Seismicity
    - Accounts for random moderate-sized earthquakes based on historical seismicity patterns that are not associated with a known fault.

Cascadia Subduction Zone

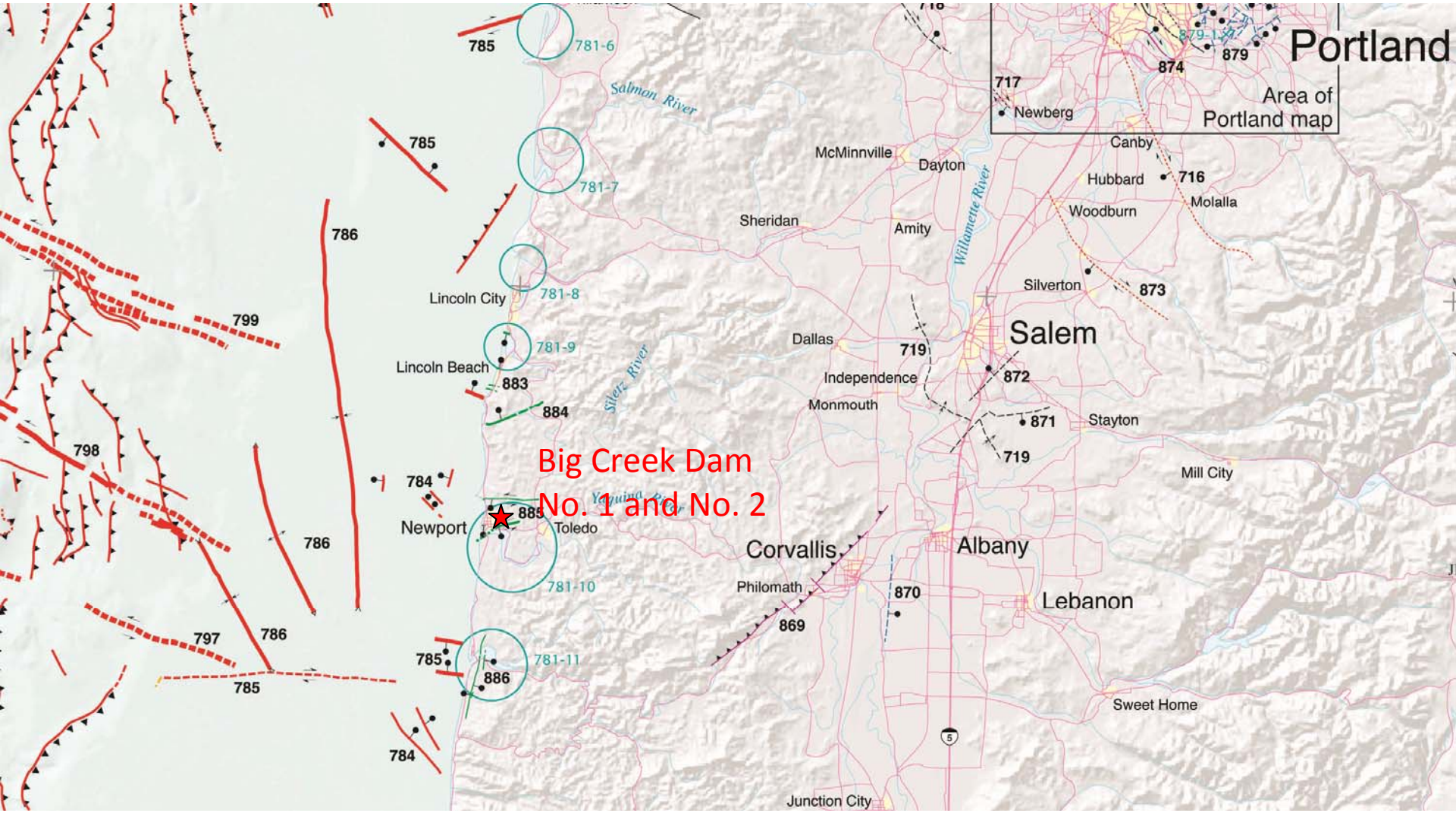
Oregonian Aug 2, 2012 THE ASSOCIATED PRESS

Regional Seismicity

Cascadia earthquake sources



Regional Fault Sources



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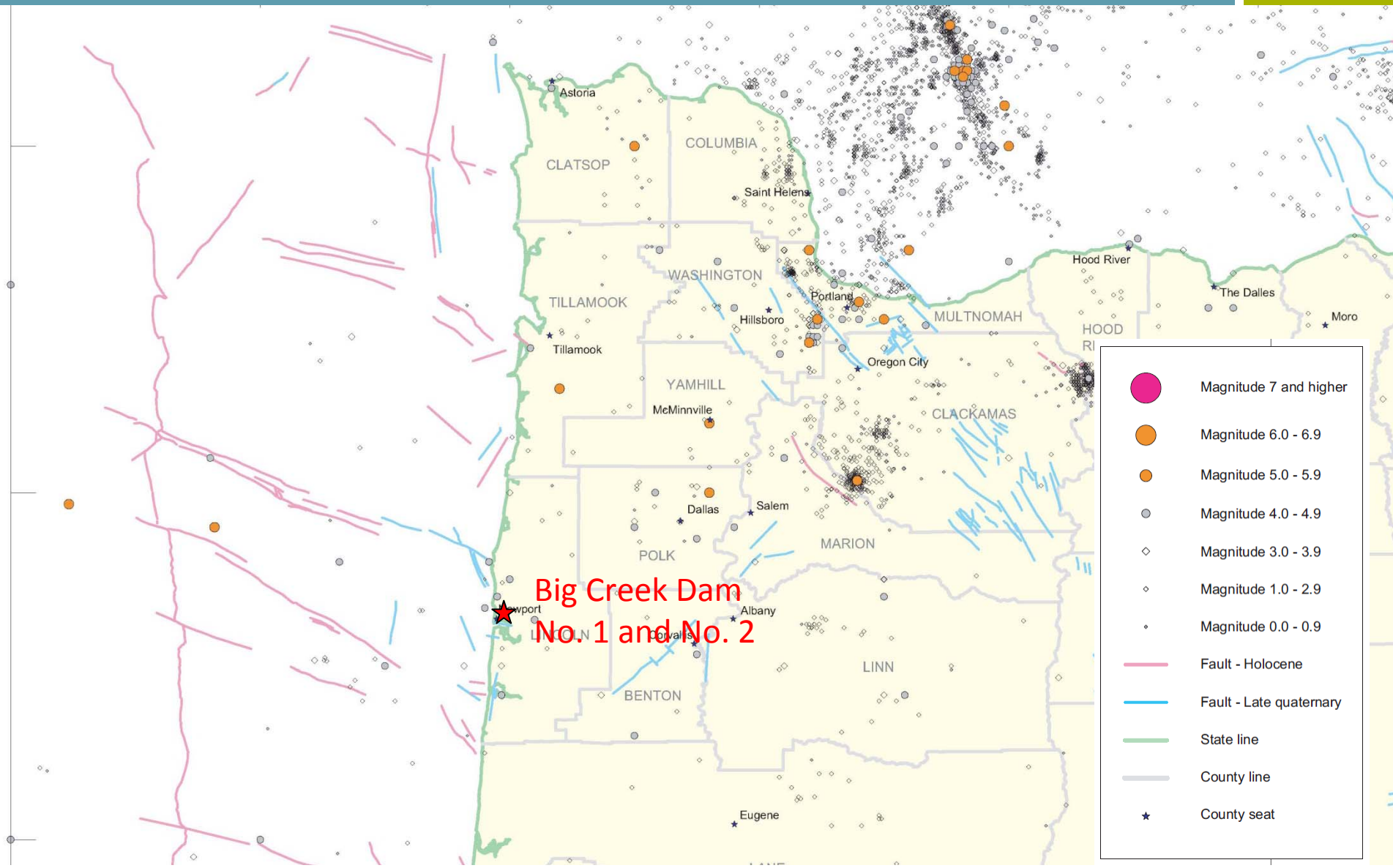
Historical Earthquake Epicenters

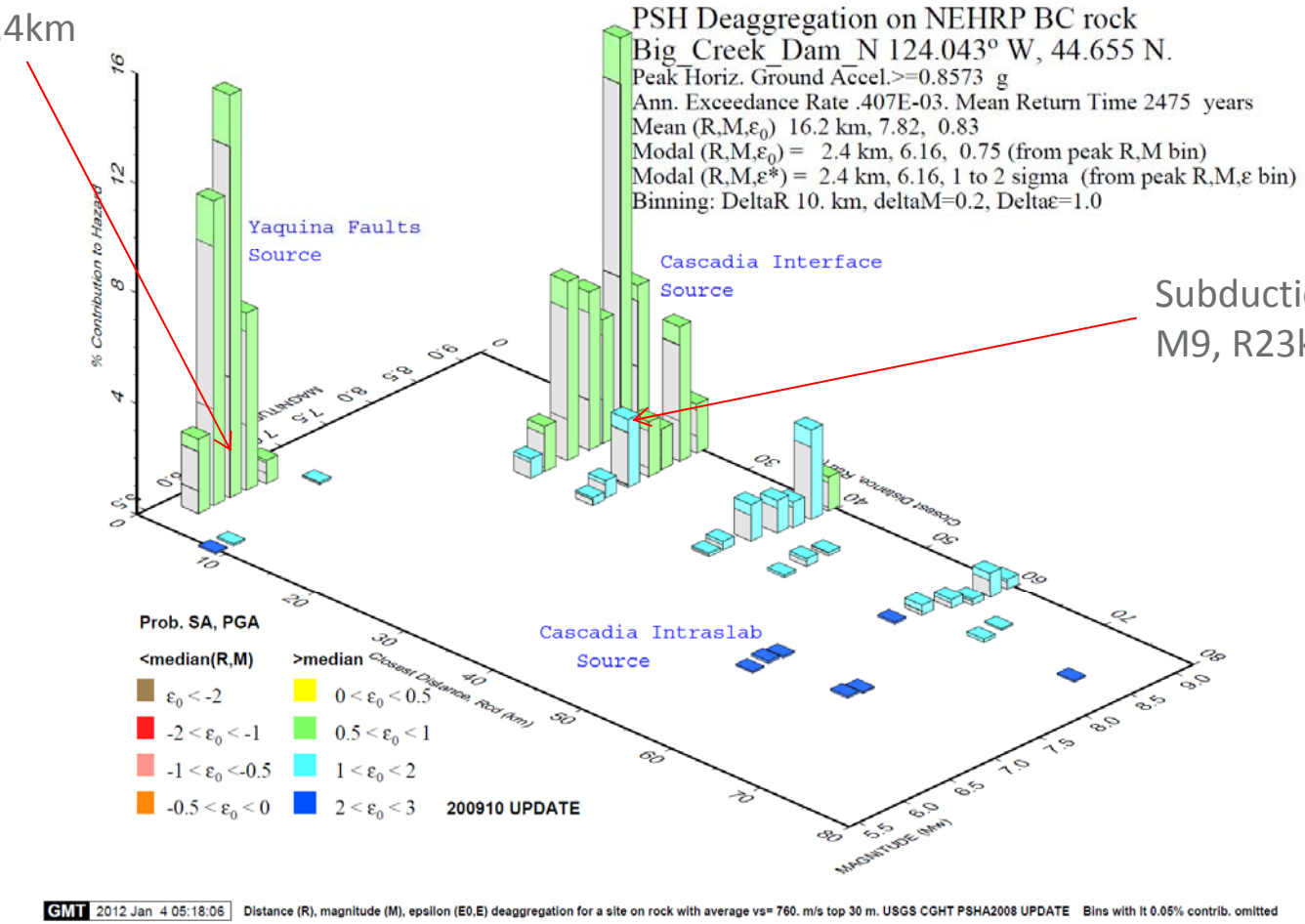


Selection of Seismic Ground Motions

- USGS National Seismic Hazard Maps
- Probabilistic Seismic Hazard Assessment
  - Provides a combined overall hazard for the site
  - Identifies contribution from multiple earthquake sources
  - Accounts for variability of motions
  - Accounts for occurrence rates earthquakes
  - Provides ground motions for differing “return periods”
  - For detailed dynamic response analyses need to separate sources contributing to the hazard (deaggregation)

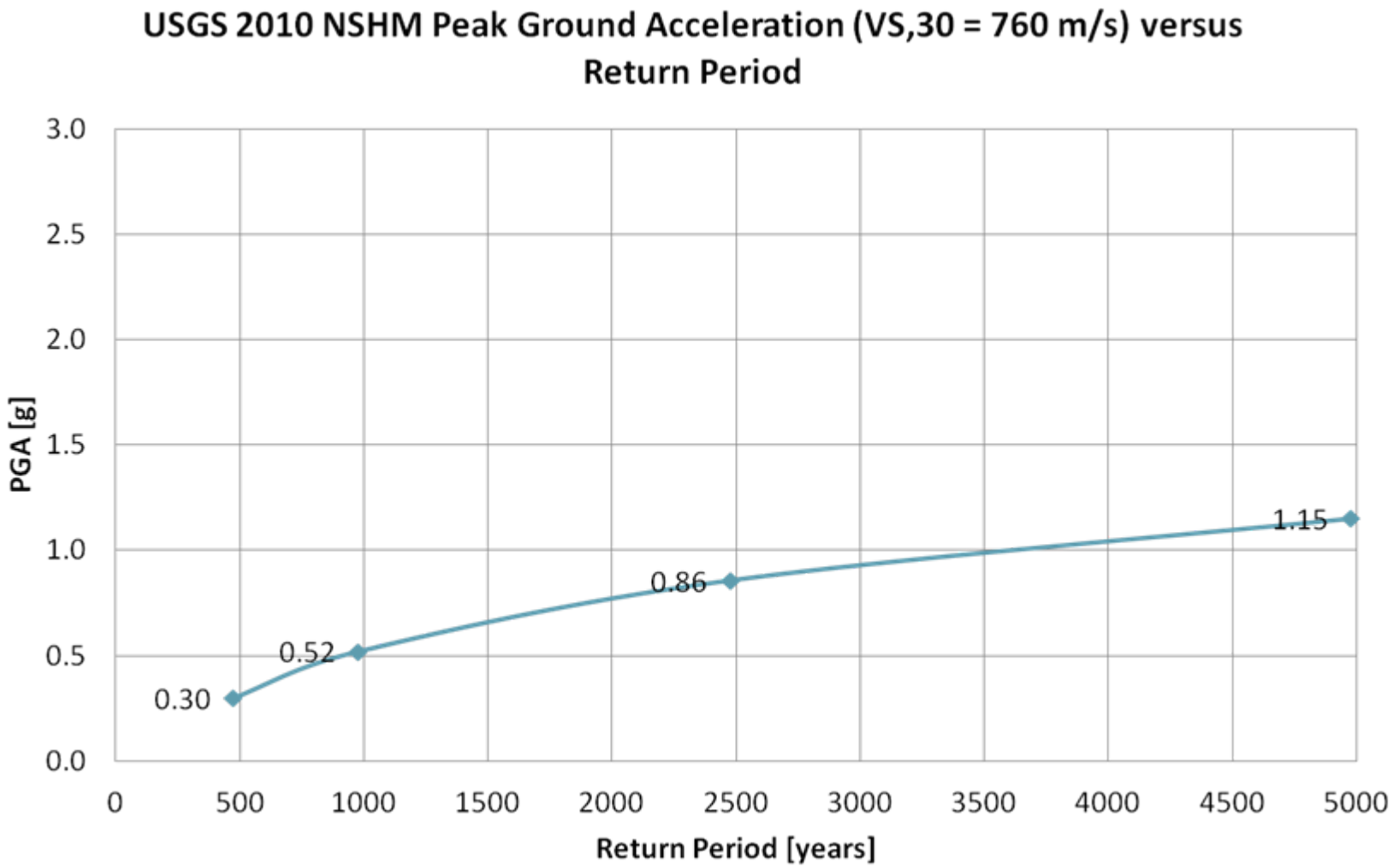
Probabilistic Seismic Hazard Results

Yaquina Fault Source
M6.2, R2.4km



Subduction Zone Interface
M9, R23km

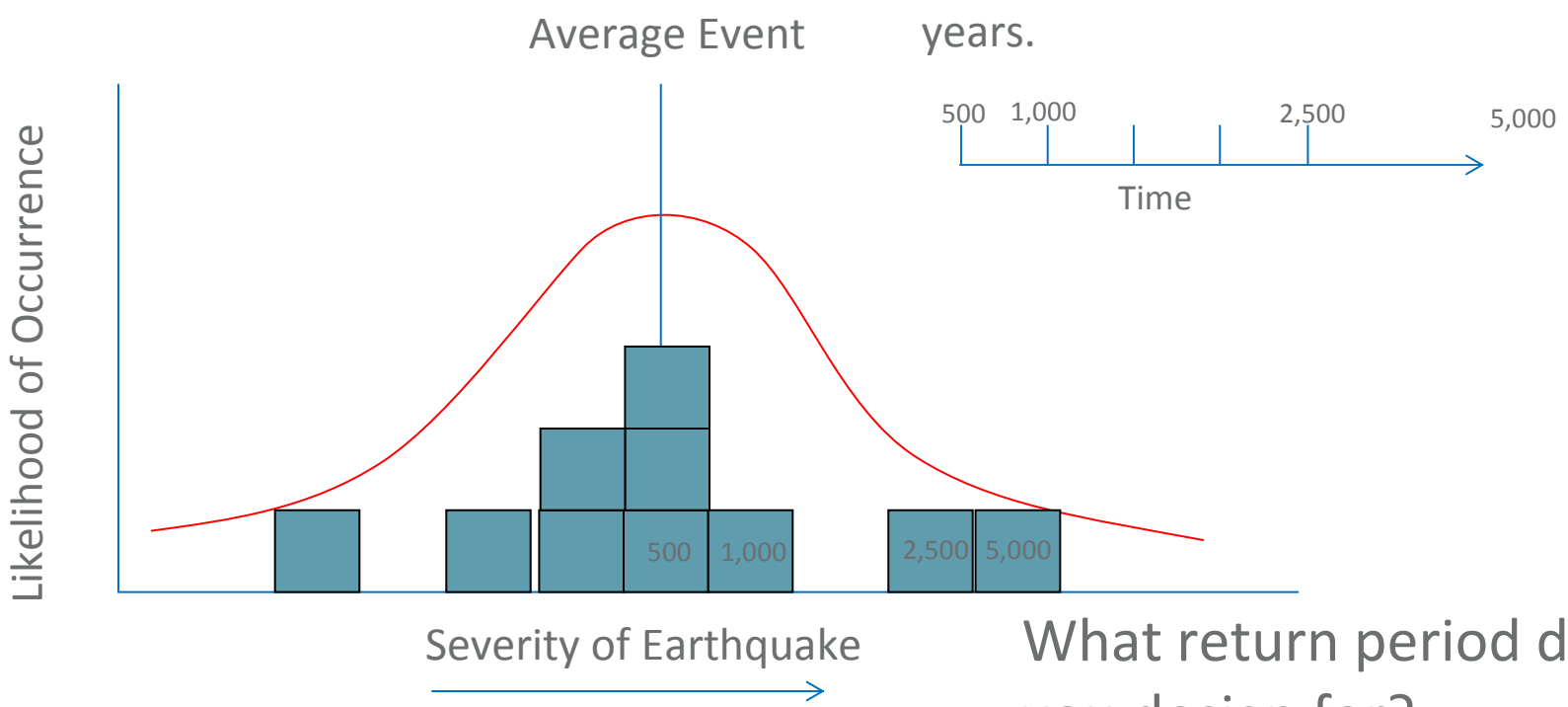
Probabilistic Seismic Hazard Results



Return Period

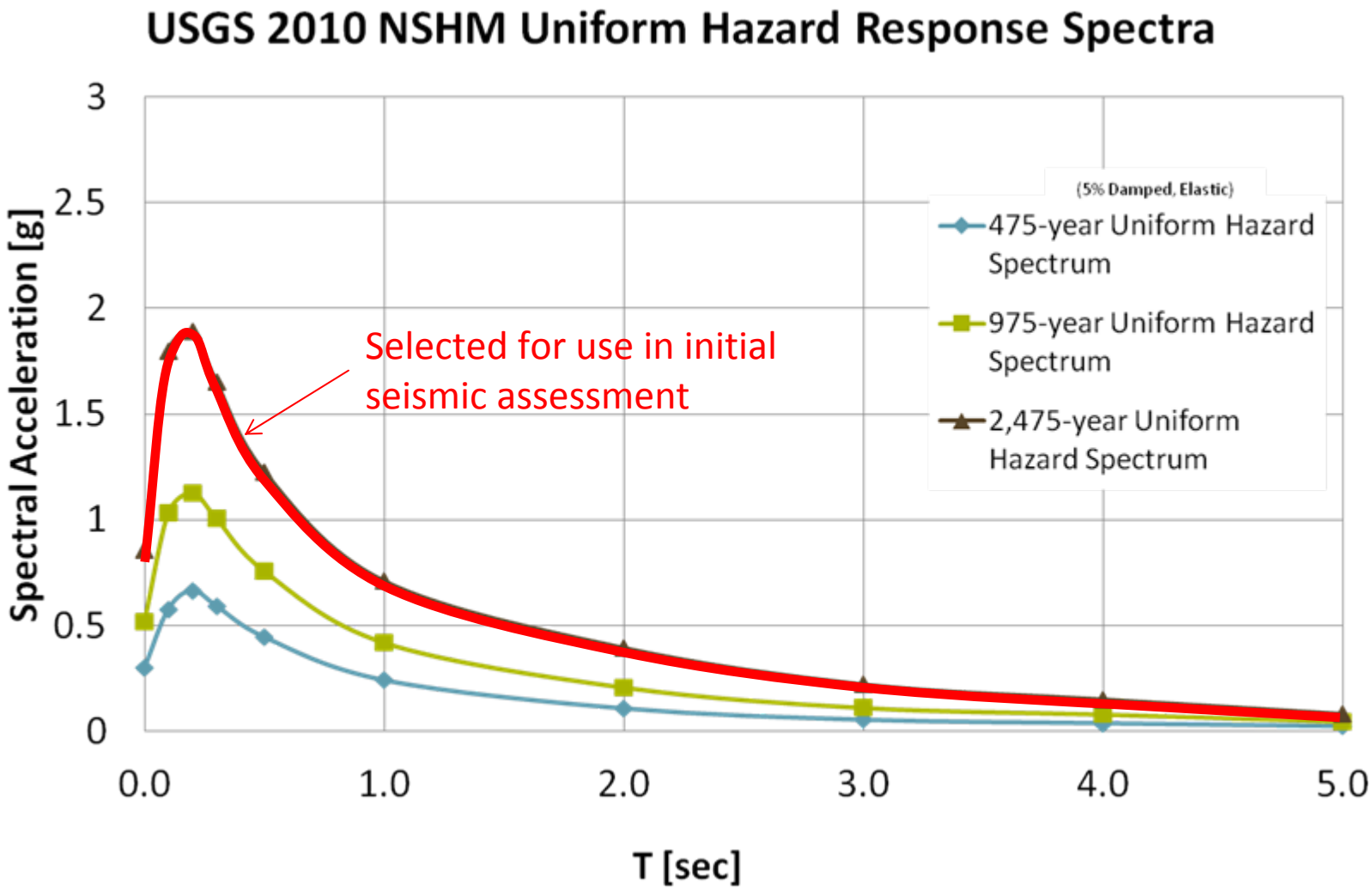
How does the return period change the earthquake ground motions?

Example Event:
M9 earthquake with a recurrence interval of 500 years.



What return period do you design for?

Probabilistic Seismic Hazard Results



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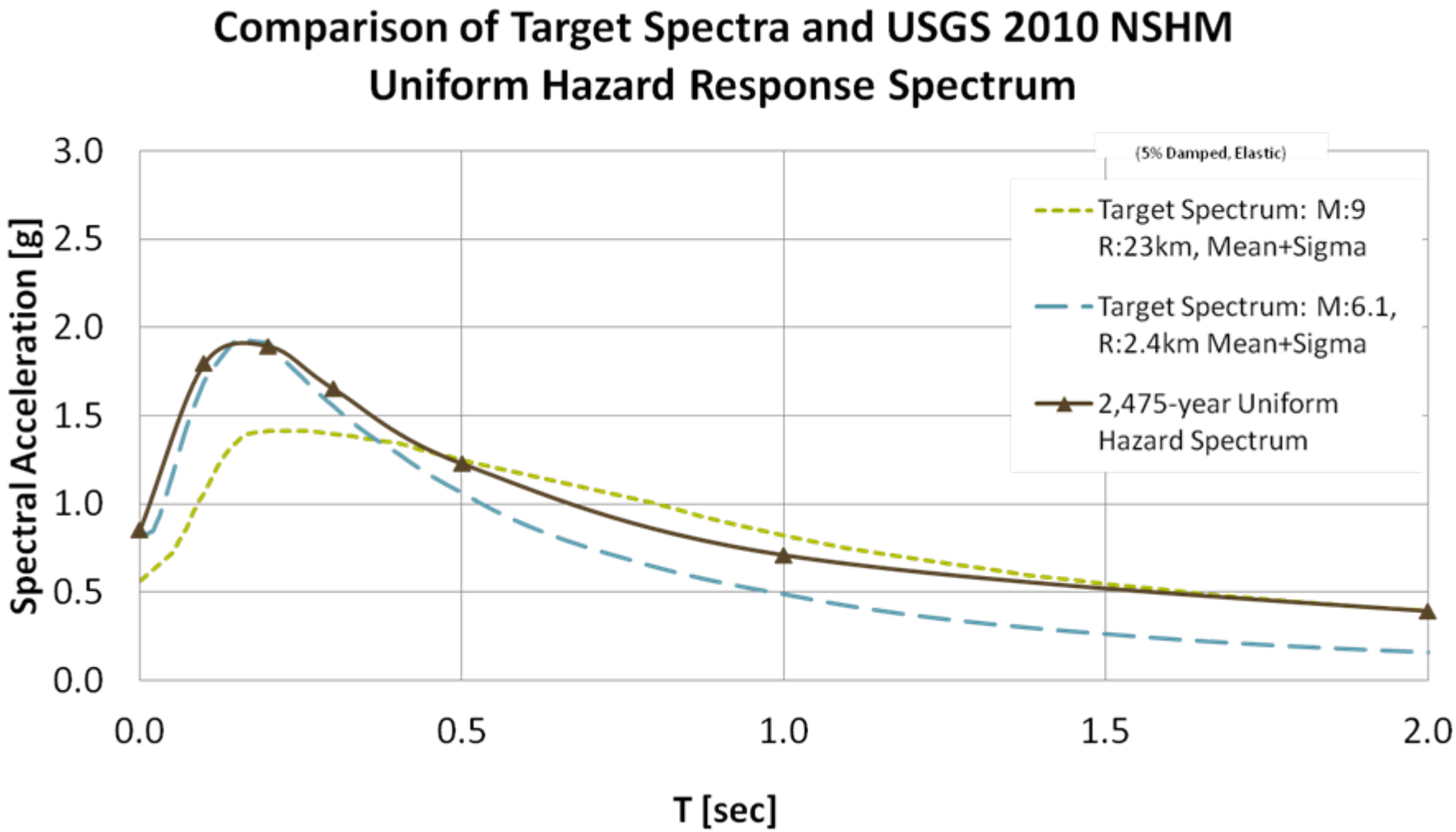
Site Specific Earthquake Characteristics



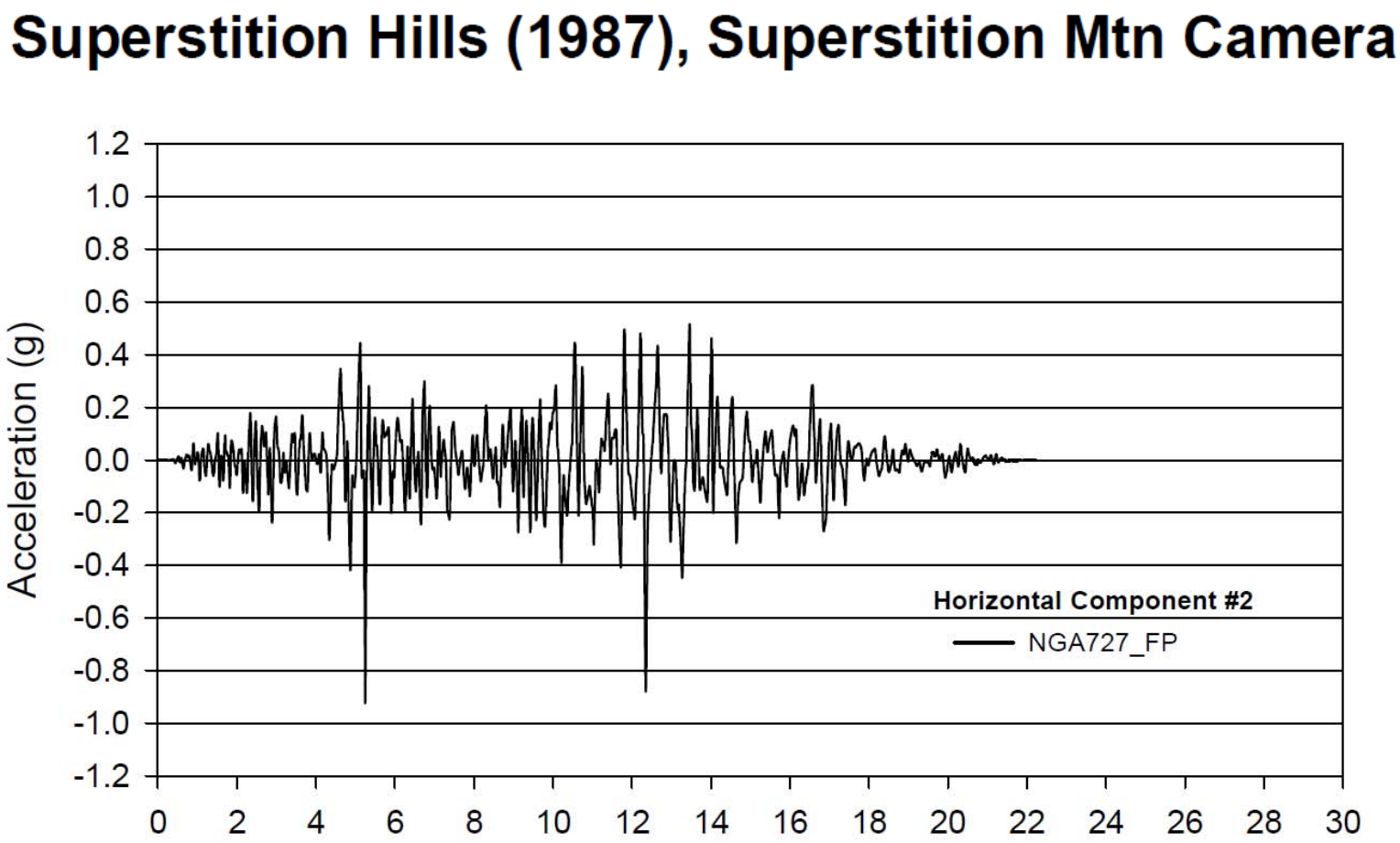
Site Specific Earthquake Characteristics

Deaggregated Earthquake Motions

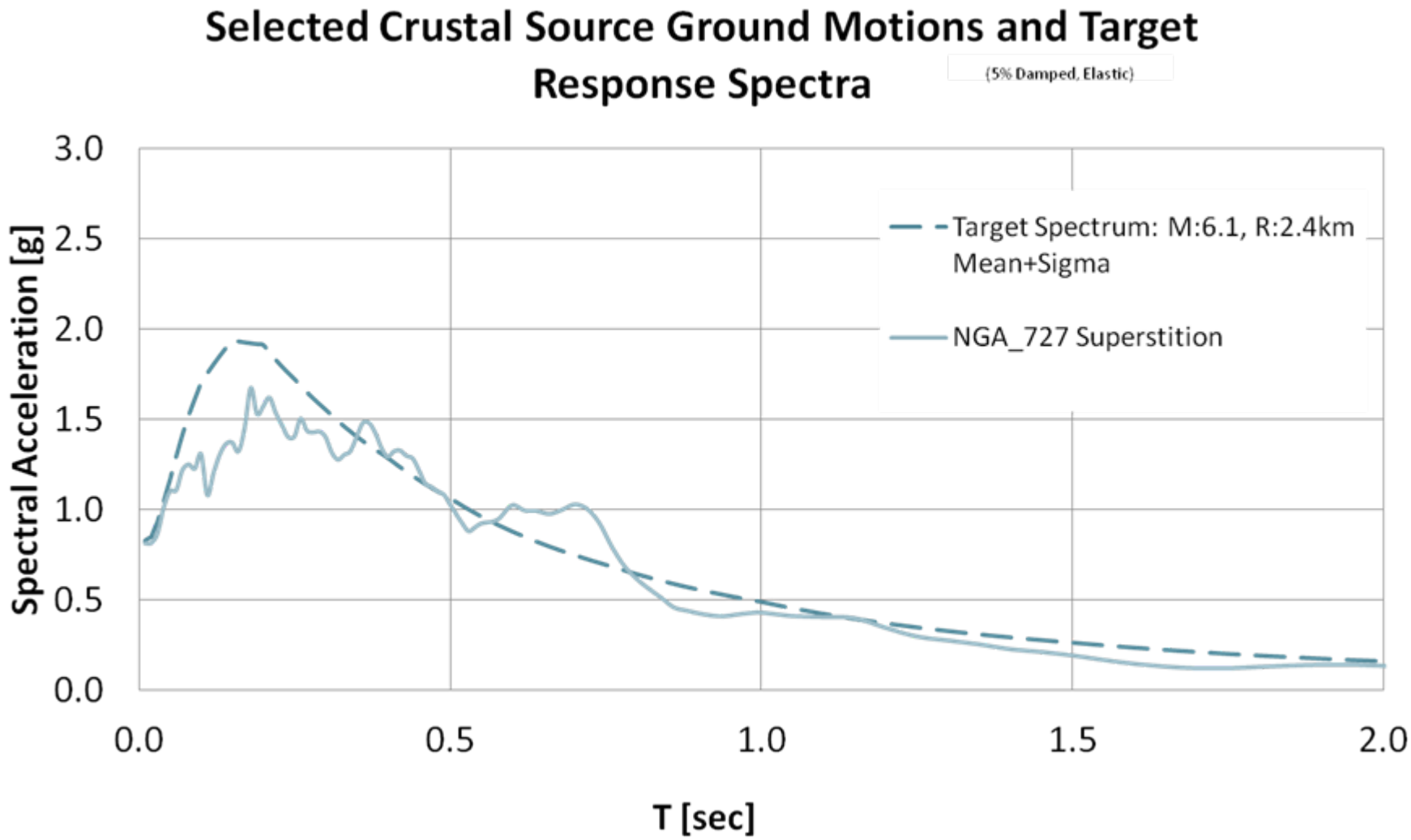
Earthquake Source	Motion Percentile	Period Range(s)	Geology	Earthquake Magnitude	Distance (km)	PGA[1](g)
Yaquina Faults	84th	0 to 0.6	Rock Site	6.1	2.4	0.83
CSZ Interface	84th	0.4 to 2	Rock Site	9.0	23	0.56

[1] PGA based on attenuation relationships

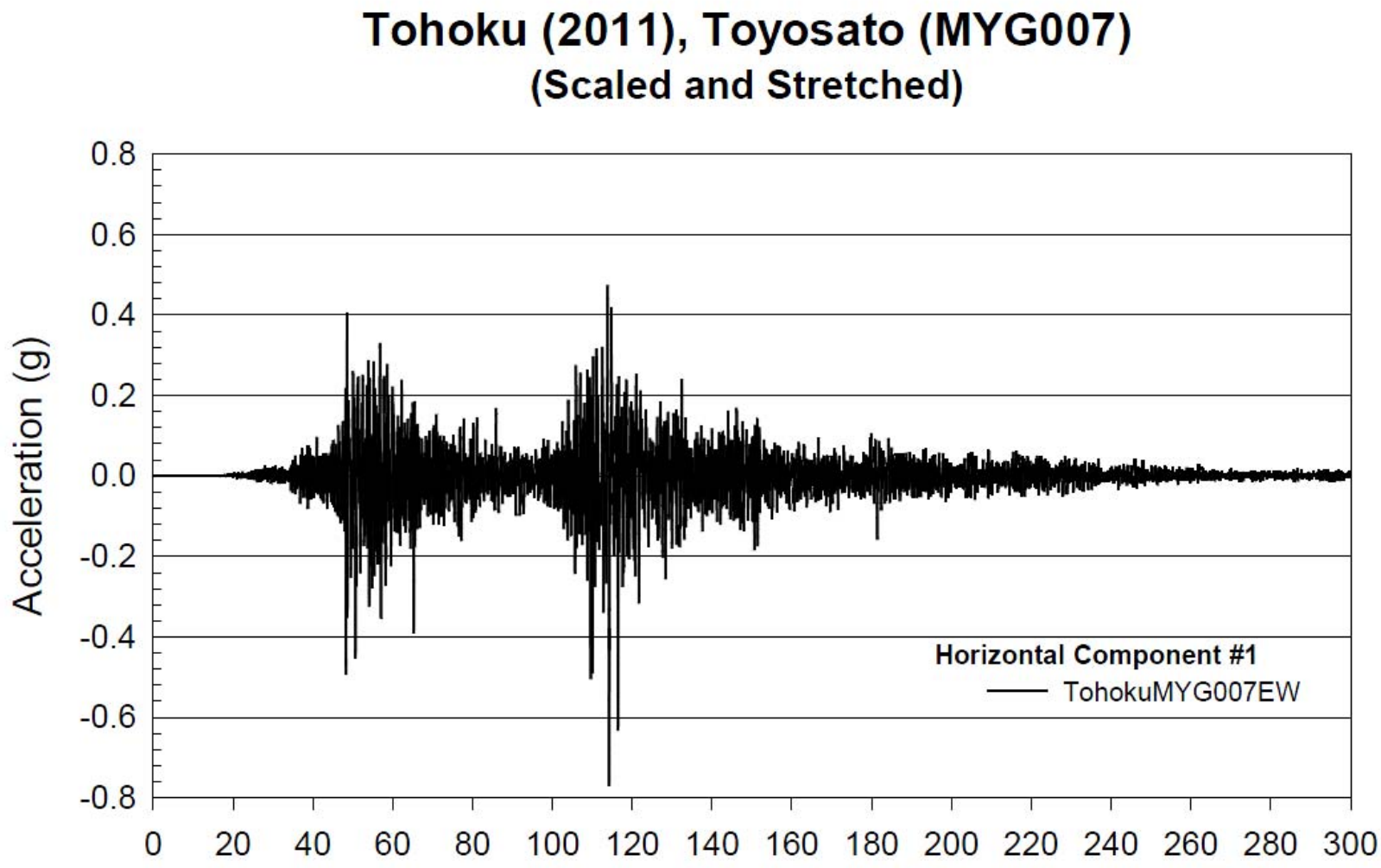
Selected Acceleration Time Histories



Selected Acceleration Time Histories



Selected Acceleration Time Histories



Future Considerations

- Impact of Recent Subduction Zone Earthquakes in Chile and Japan
  - Actual recorded data (fills in gaps)
  - Opportunity to revise ground motion prediction equations
  - New models will be biased to these new earthquakes, but some data is better than none
  - Better understanding of subduction zone rupture (possibly wider zone of rupture)
  - Potential for larger displacement on fault zone

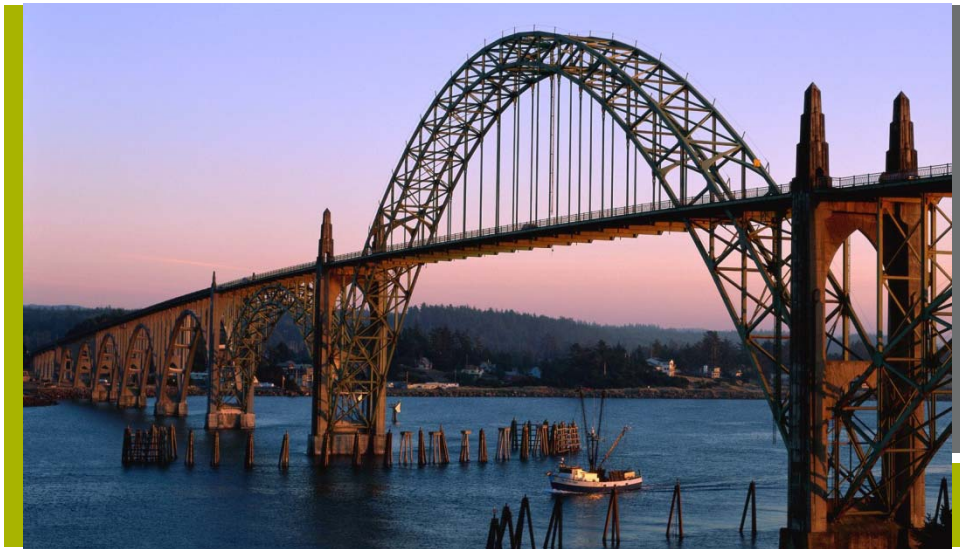
Future Considerations

- Latest Cascadia Subduction Zone Understanding (Goldfinger et al., 2012)
  - Investigation of large offshore landslide deposits
  - Indicates frequency of large earthquake occurrence
  - Full length rupture recurrence interval approximately 500 years
  - Southern portion more active, but smaller magnitude

Summary

- Significant Seismic Sources
  - Cascadia Subduction Zone Interface event
  - Yaquina Faults crustal source
- Provided design parameters for these two sources
- Provided acceleration time histories for use in dynamic site response analyses
- Seismic analyses by HDR

NEWPORT BIG CREEK DAMS



Big Creek Seismic Assessment – A Phase Approach

Presented by

Rich Hannan, P.E. HDR Engineering

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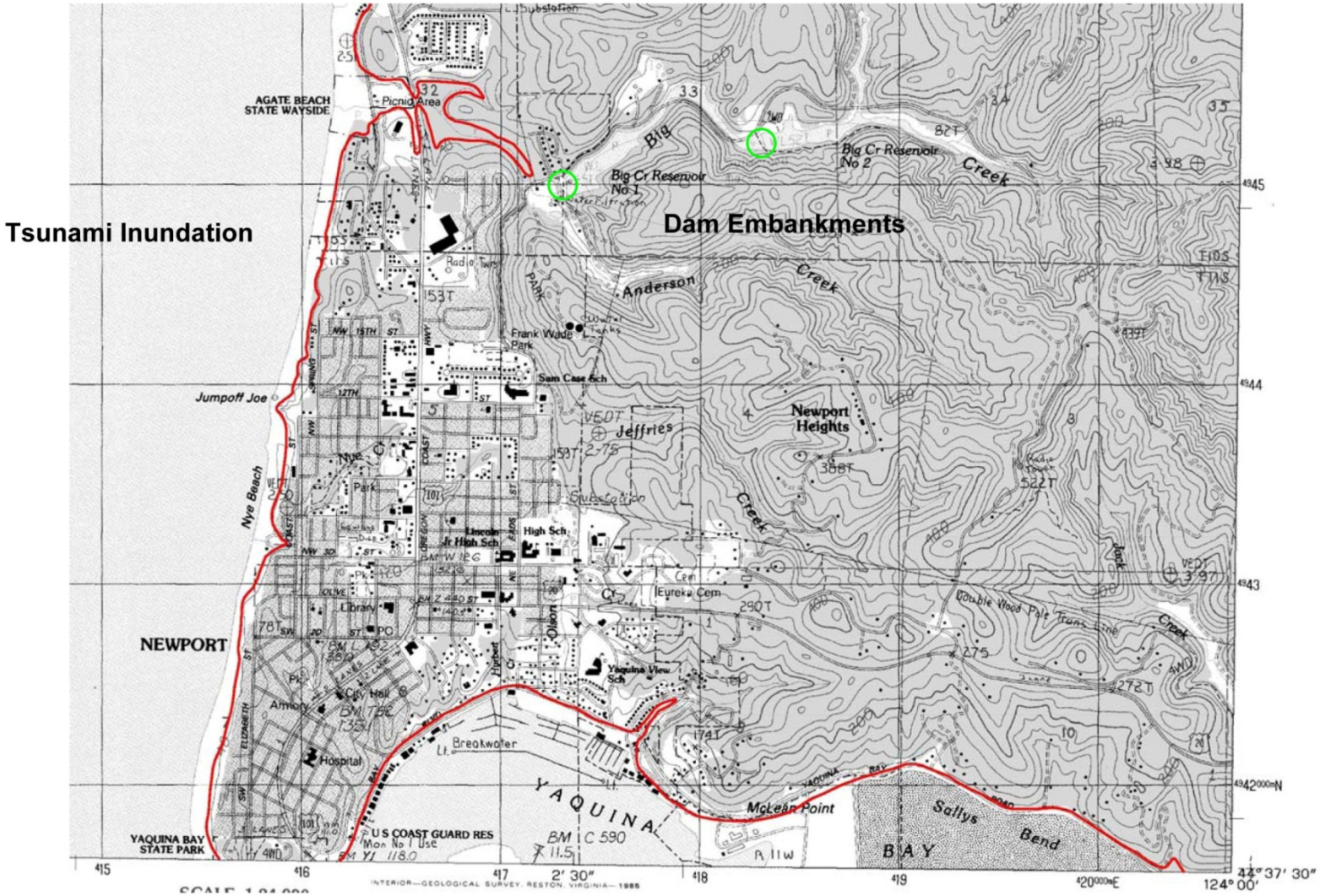
Overview

- General Site Conditions
- Site Characterization
- Material Characterization
- Failure Made Analysis
- Conclusions
- What Next

Site Location Map



Open File report O-95-28
Tsunami hazard Map of the Newport Quadrangle, Lincoln County, Oregon

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Site Characterization

Field Explorations

- Soil Borings with SPT's
- Cone Penetrometer Soundings (CPTu)
- Geophysical Survey

Lab Testing

- Classification Tests
- Consolidation
- Triaxial Compression
- Static, and Cyclic Simple Shear
- Carbon Dating

Big Creek 1

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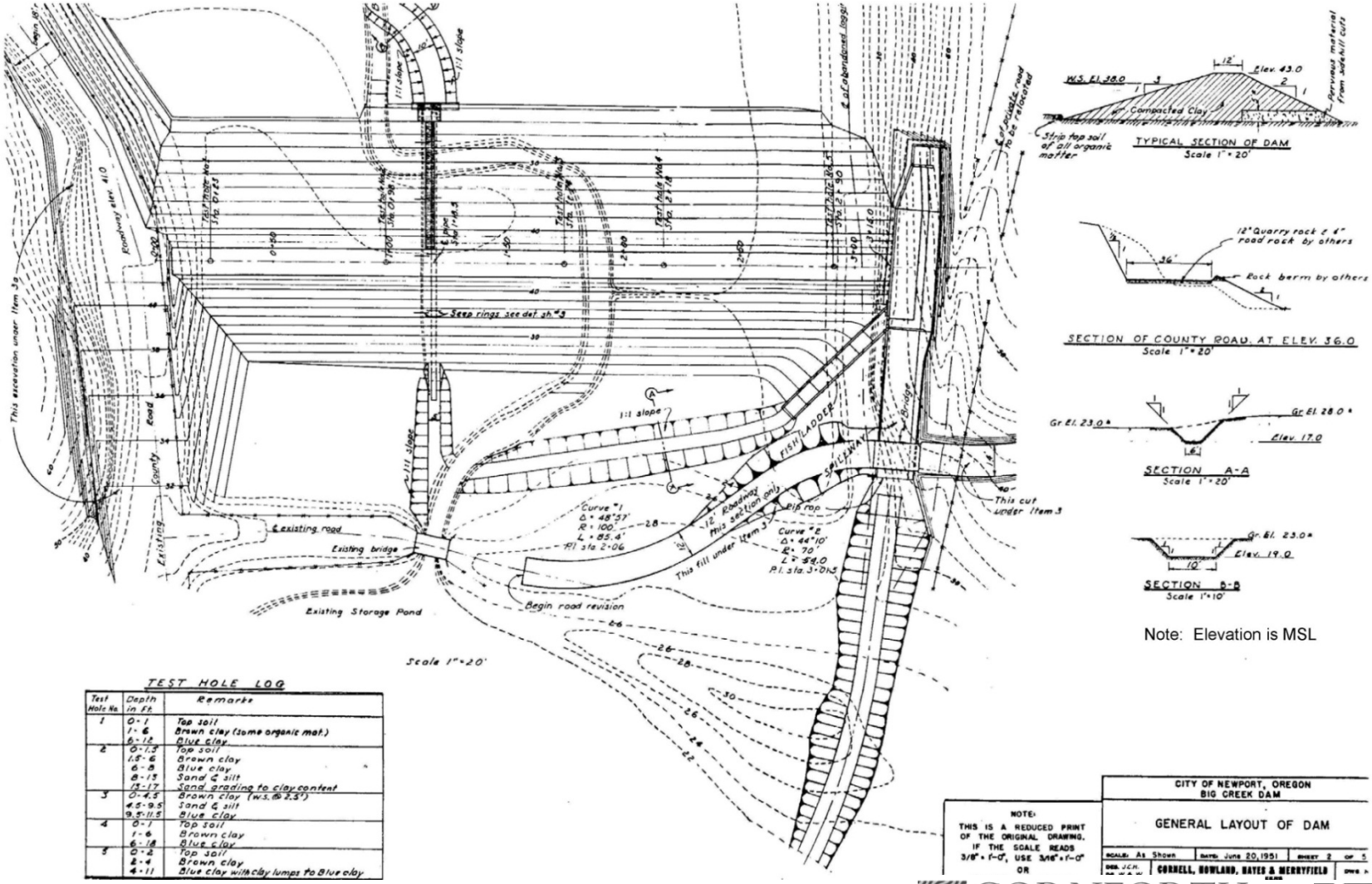
Dam Construction Characteristics

Big Creek #1 1951



TEST HOLE LOG

Test Hole No.	Depth in Ft.	Remarks
1	0-1	Top soil
	1-6	Brown clay (some organic mat.)
	6-18	Blue clay
2	0-1.5	Top soil
	1.5-6	Brown clay
	6-8	Blue clay
	8-13	Sand & silt
	13-17	Sand grading to clay content
3	0-4.5	Brown clay (W.S. El. 2.5')
	4.5-9.5	Sand & silt
	9.5-11.5	Blue clay
4	0-1	Top soil
	1-6	Brown clay
	6-18	Blue clay
5	0-2	Top soil
	2-4	Brown clay
	4-11	Blue clay with clay lumps to Blue clay

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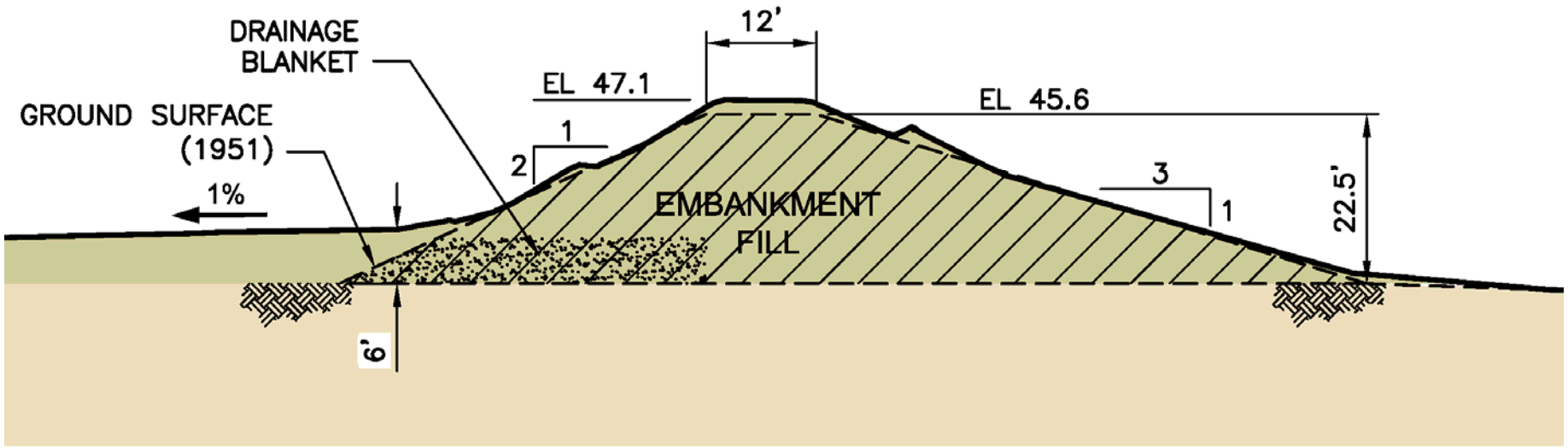
Dam Construction Characteristics

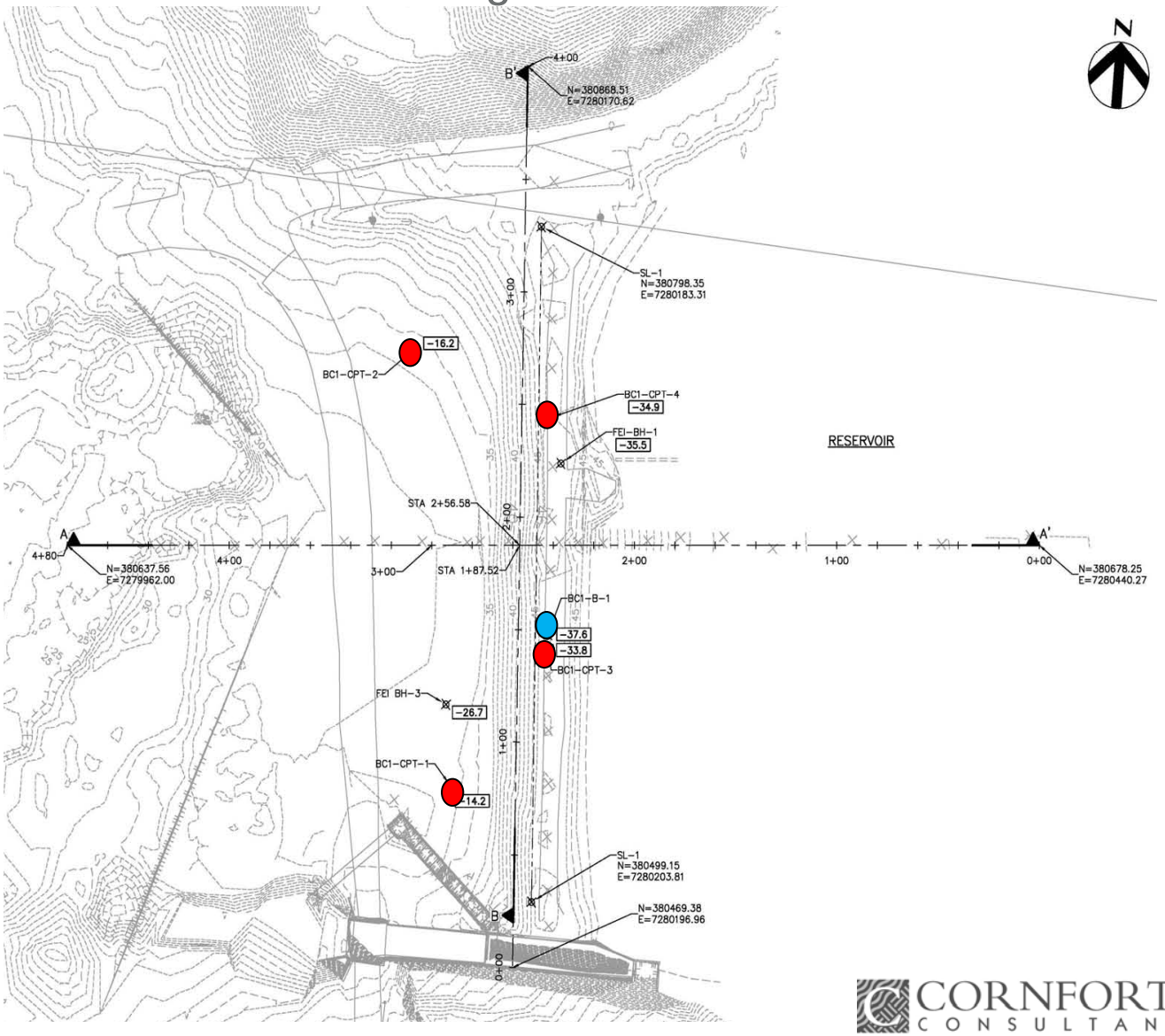
Big Creek #1



*EL NAVD 88

Site Boring Location Plan

Big Creek #1



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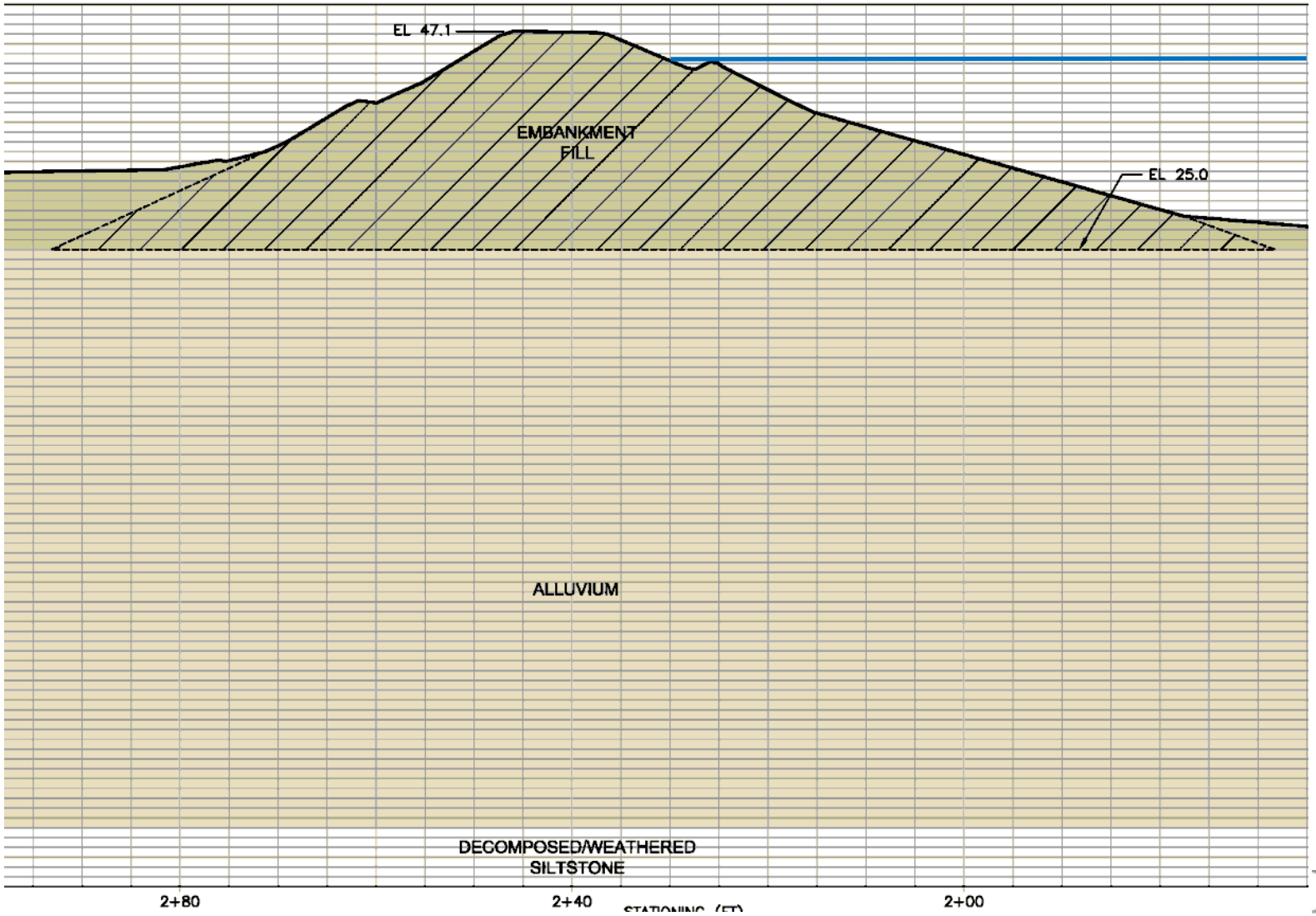
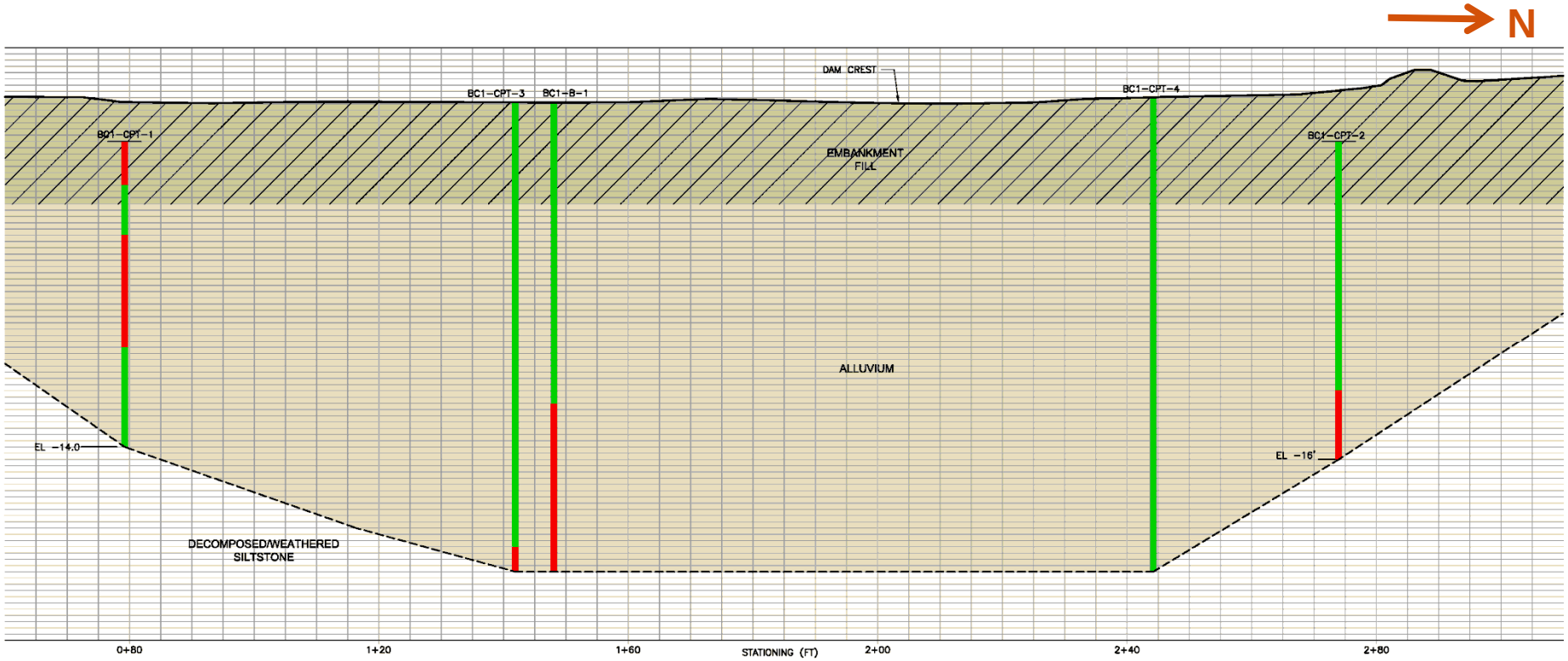
Site Geology

Big Creek #1



Site Geology

Big Creek #1



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Big Creek 2

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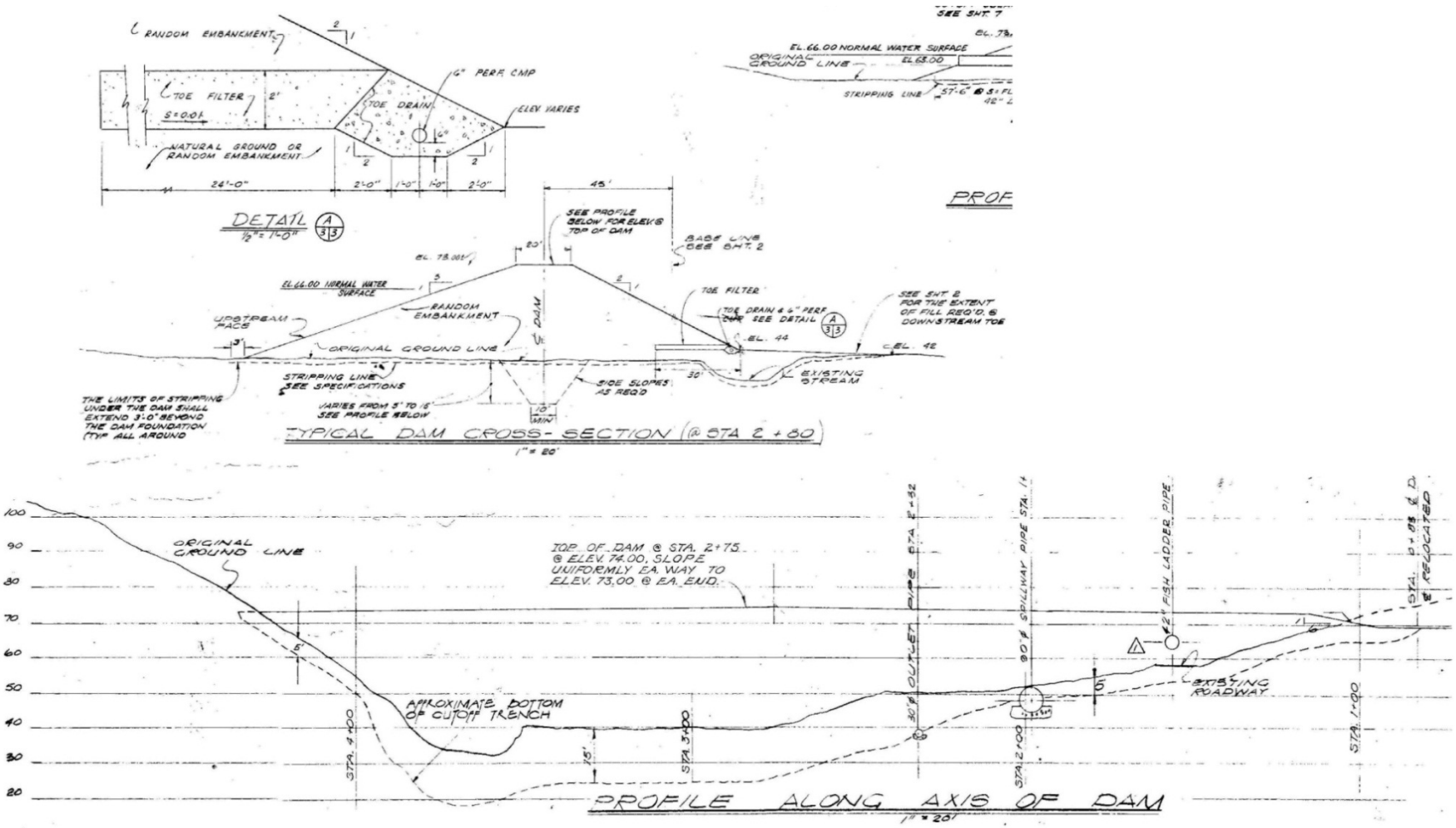
Dam Construction Characteristics

Big Creek #2 1968



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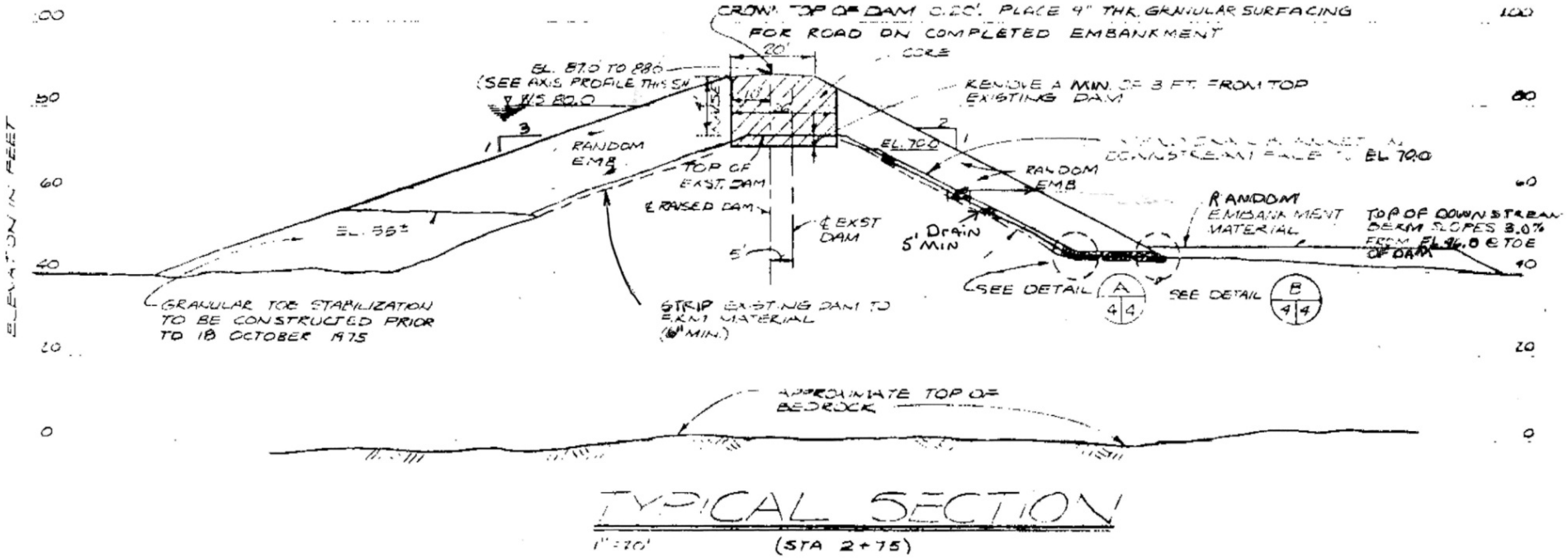
Dam Construction Characteristics

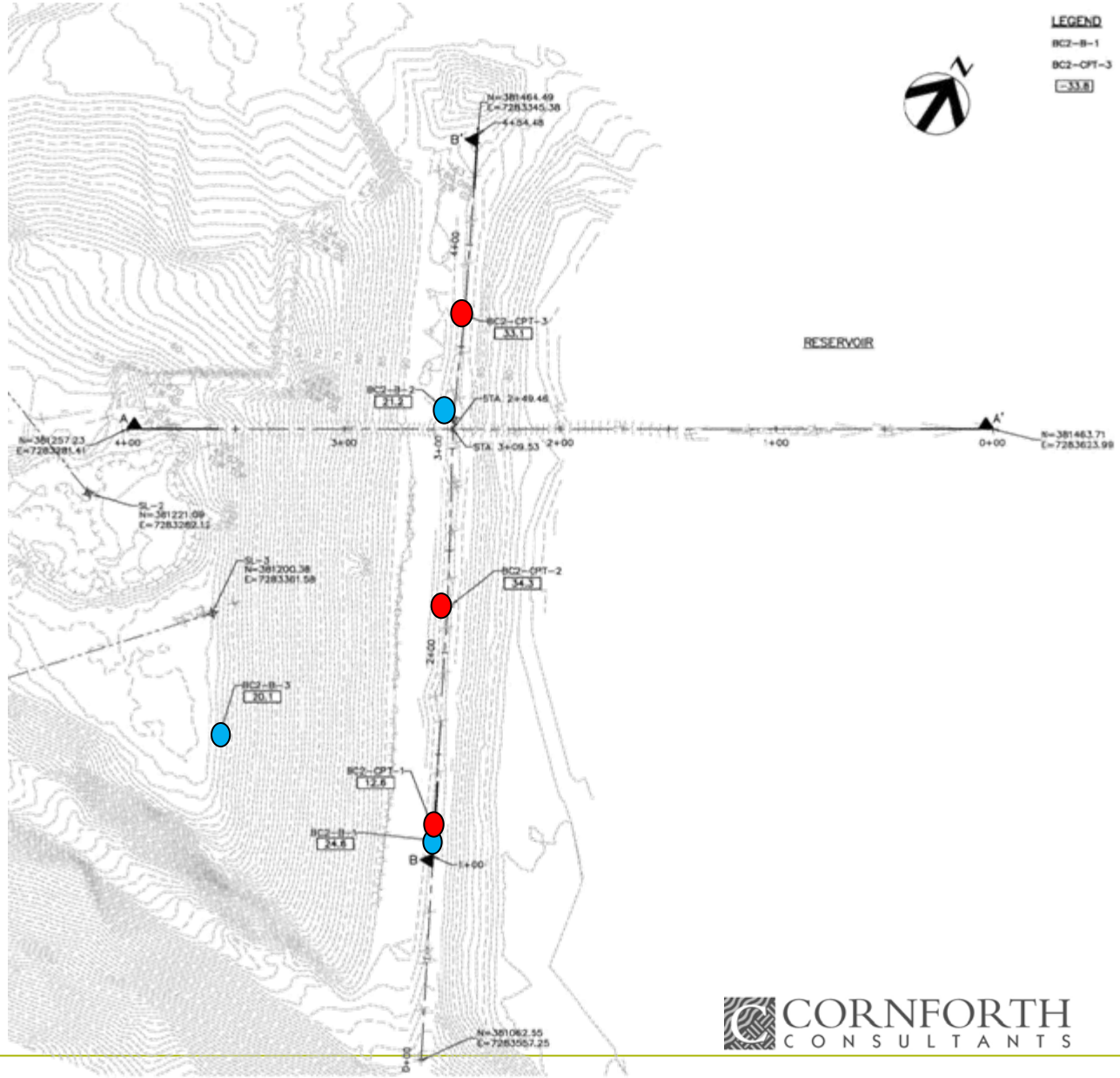
Big Creek #2 1976



Note: Elevation in MSL

Site Boring Location Plan

Big Creek #2



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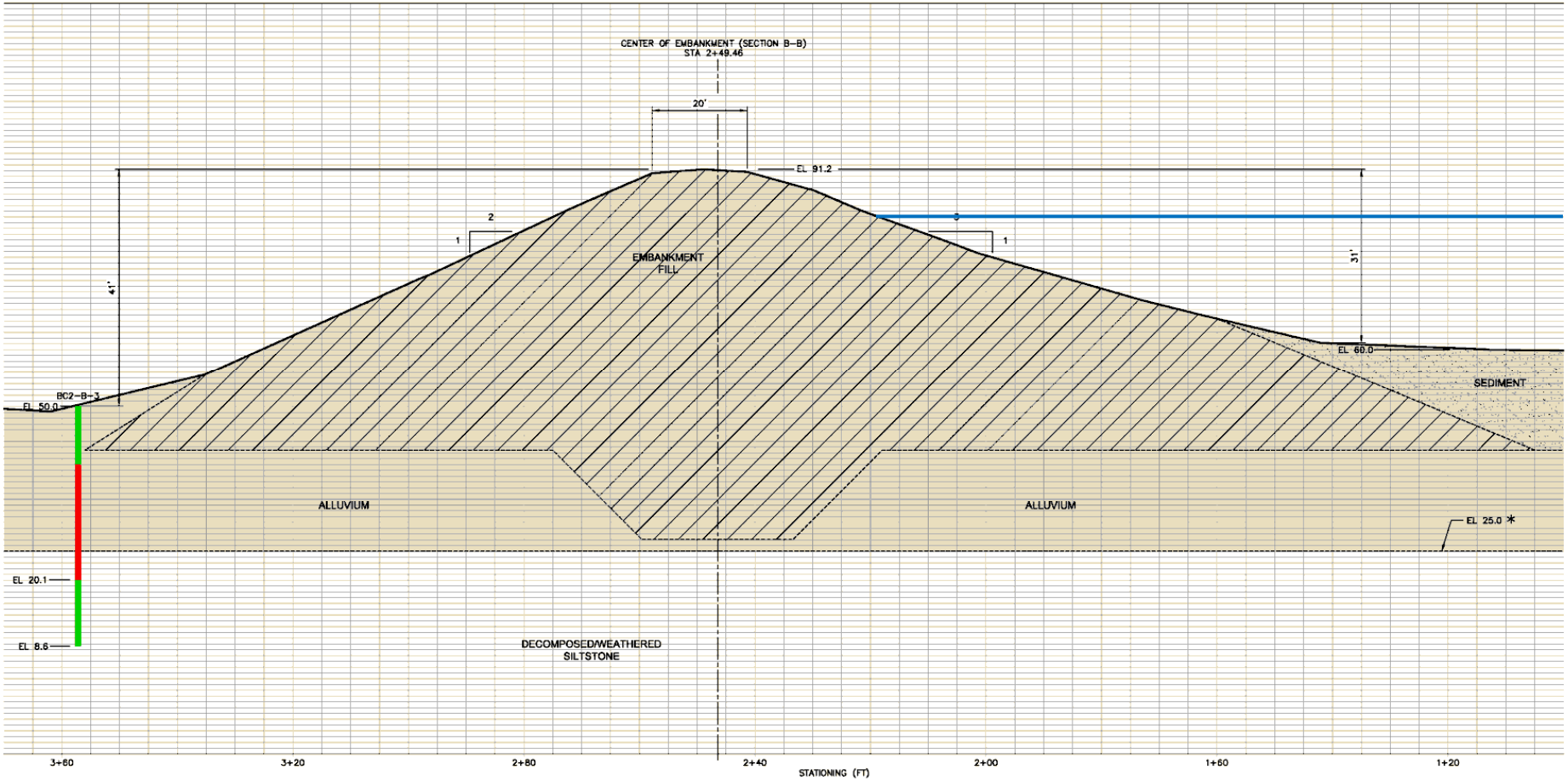
Site Geology

Big Creek #2



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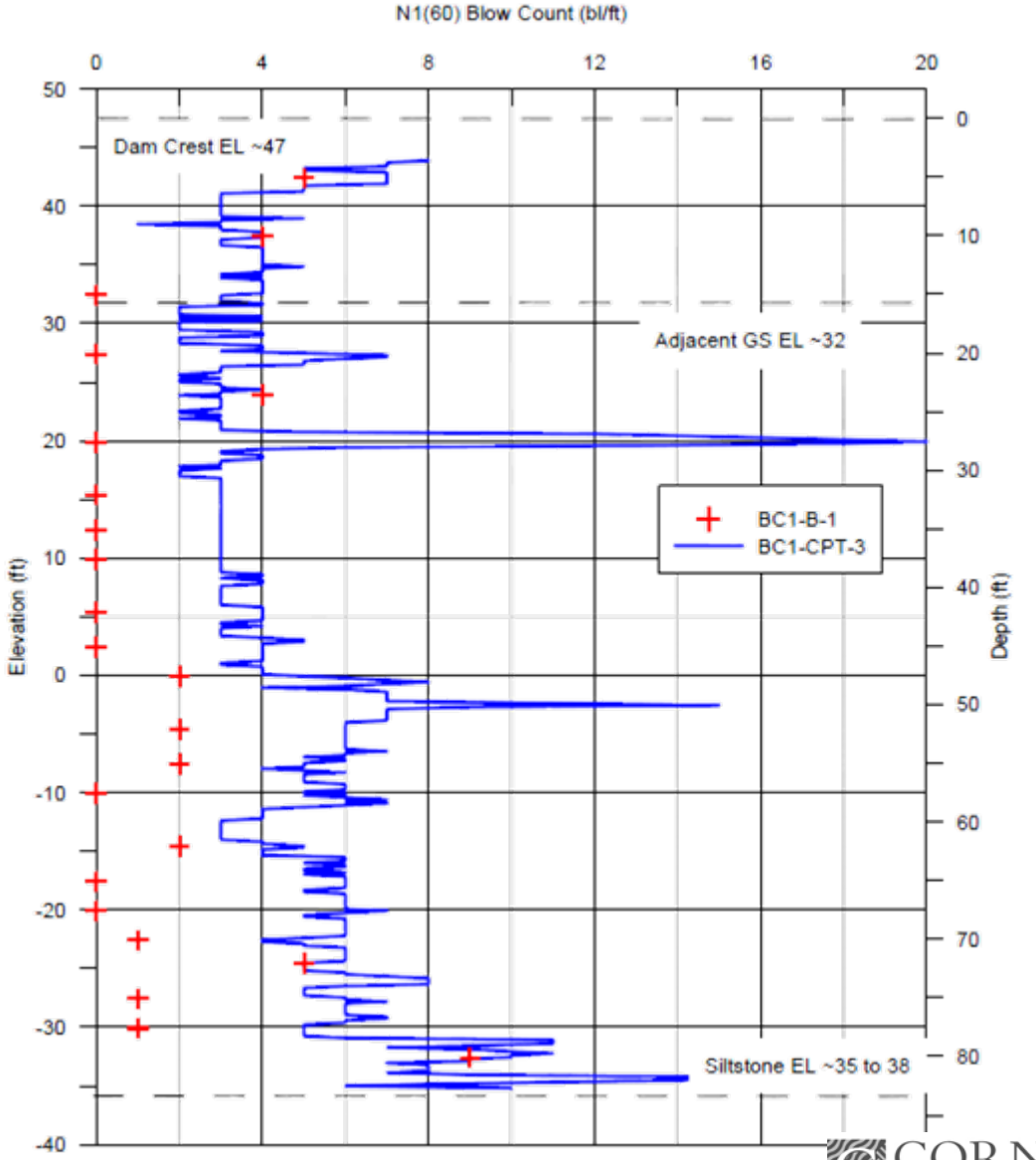
Site Specifics – Soil Borings



Note: N1(60) values based on correlations with CPTu data (Jefferies and Dav

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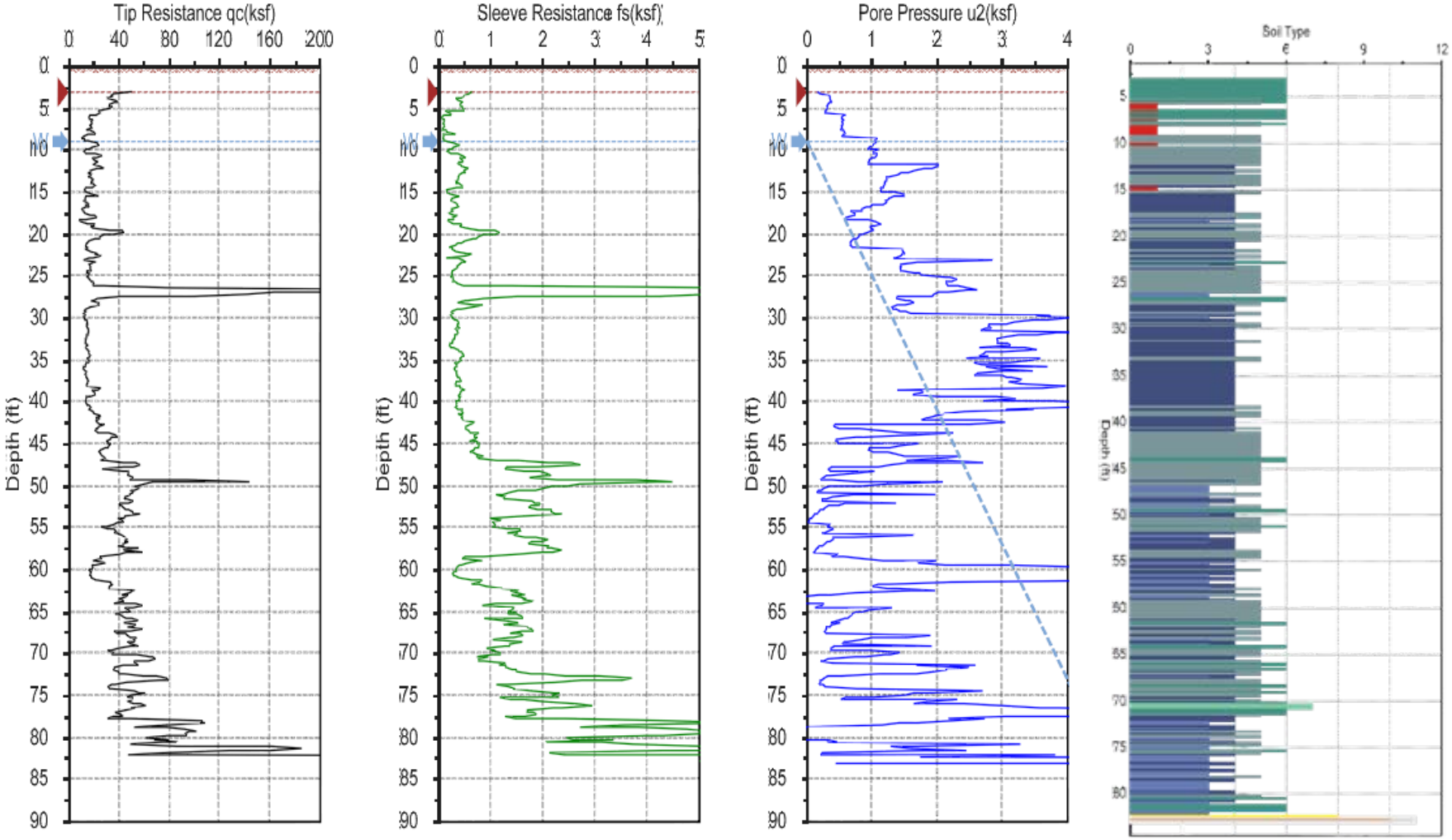
Site Specifics – CPT Results



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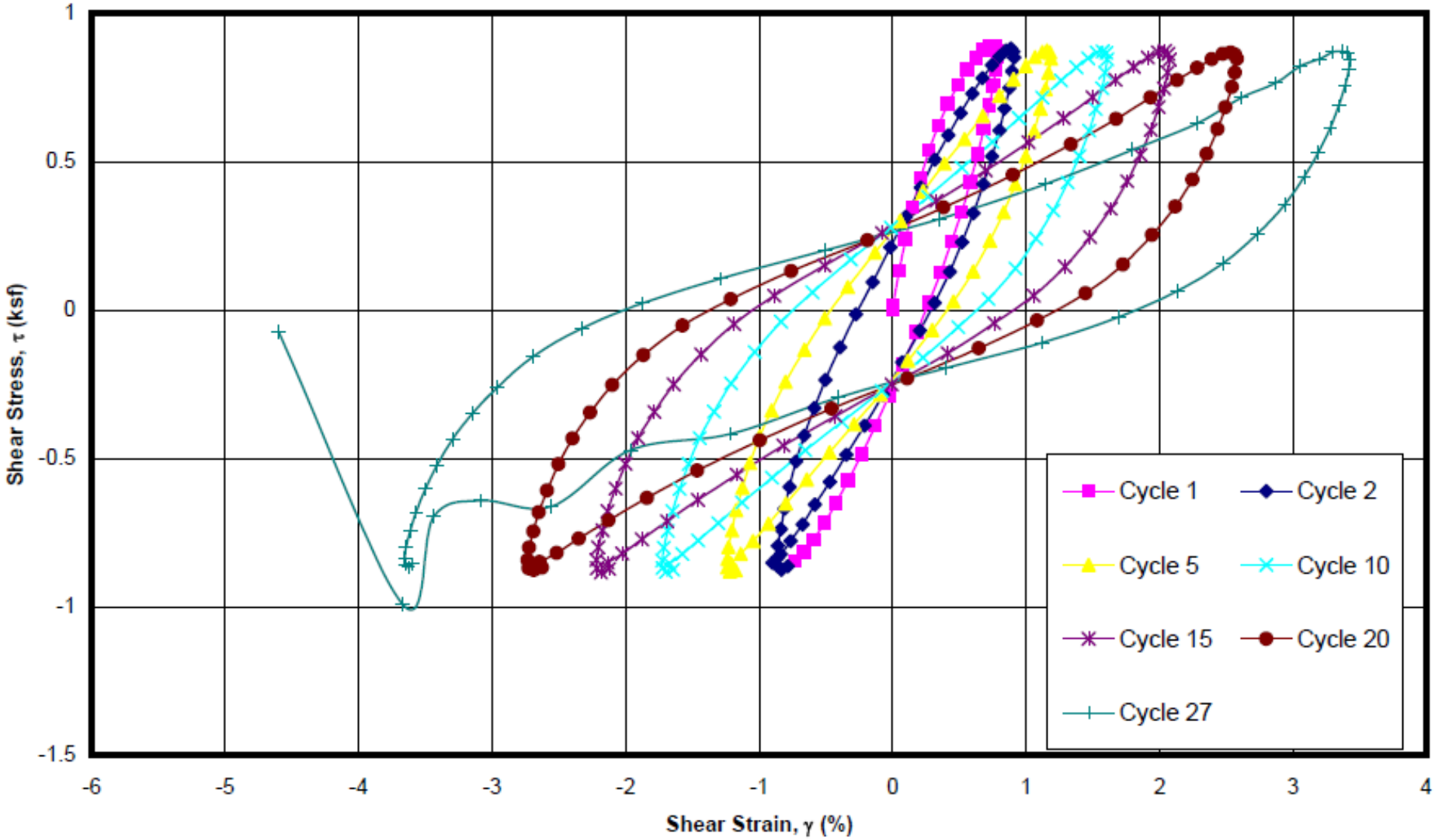
Site Specifics – Lab Testing



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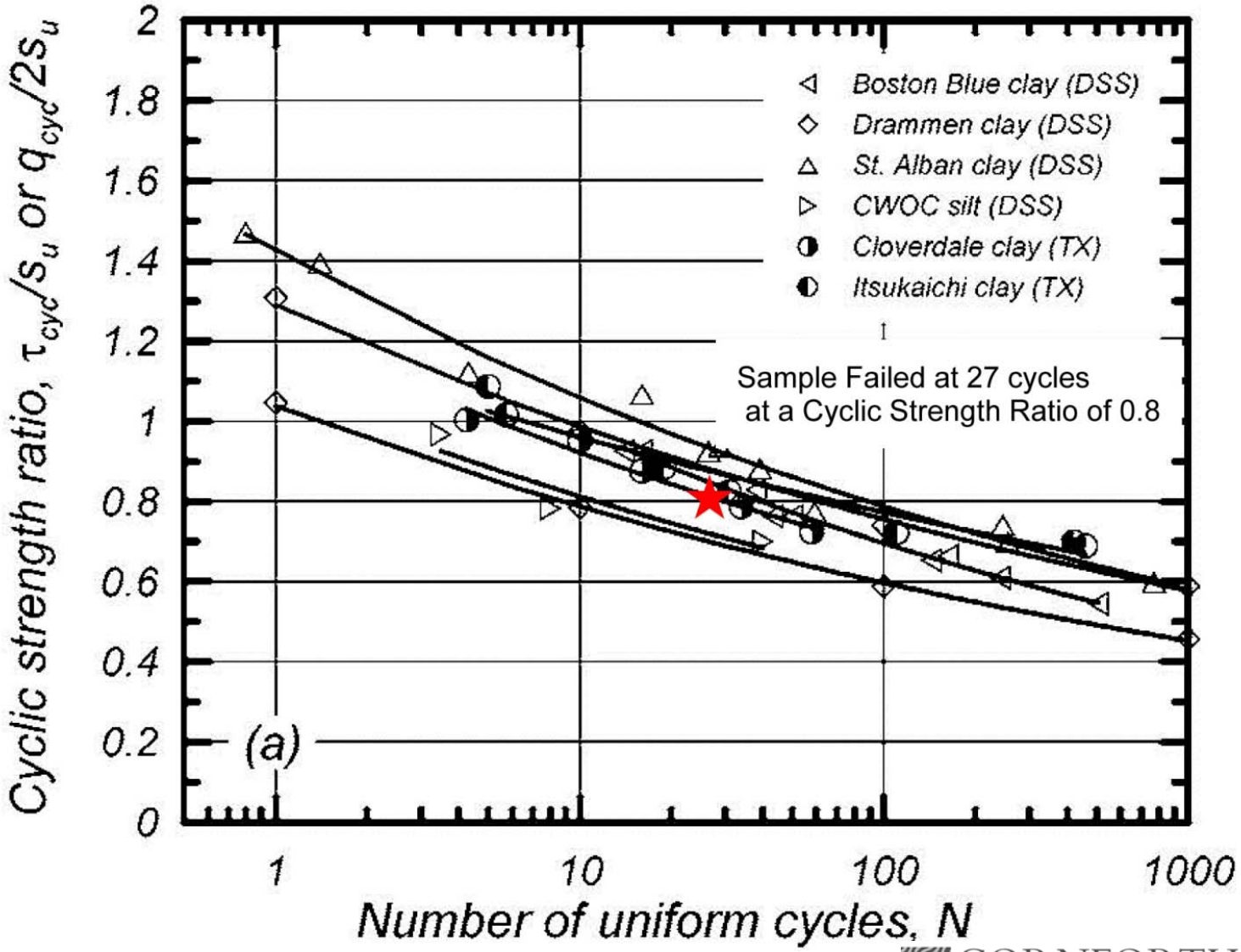
Site Specifics – Lab Testing Results



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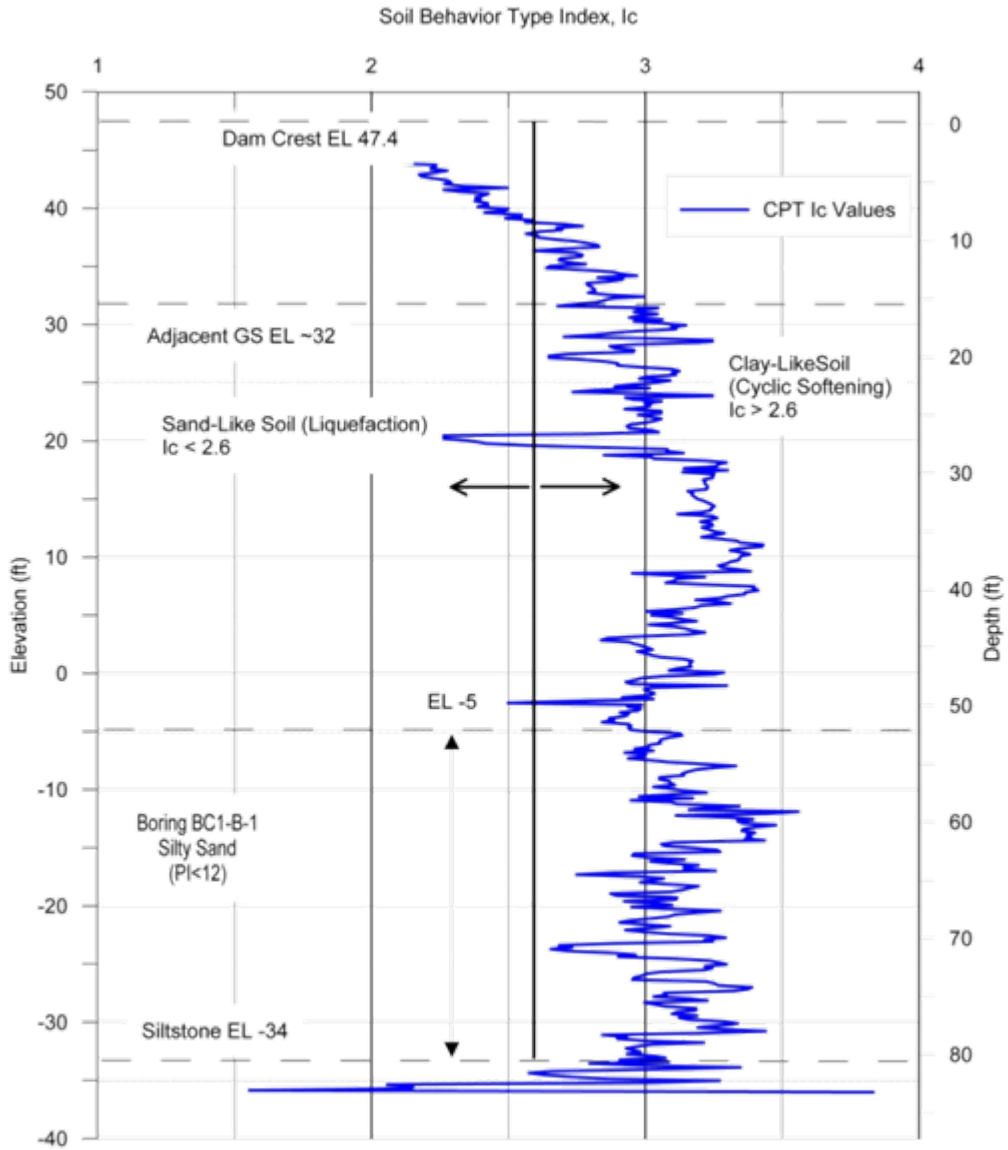
Site Specifics – Analysis / Modeling

BC1-B-1/BC1 – CPT-3



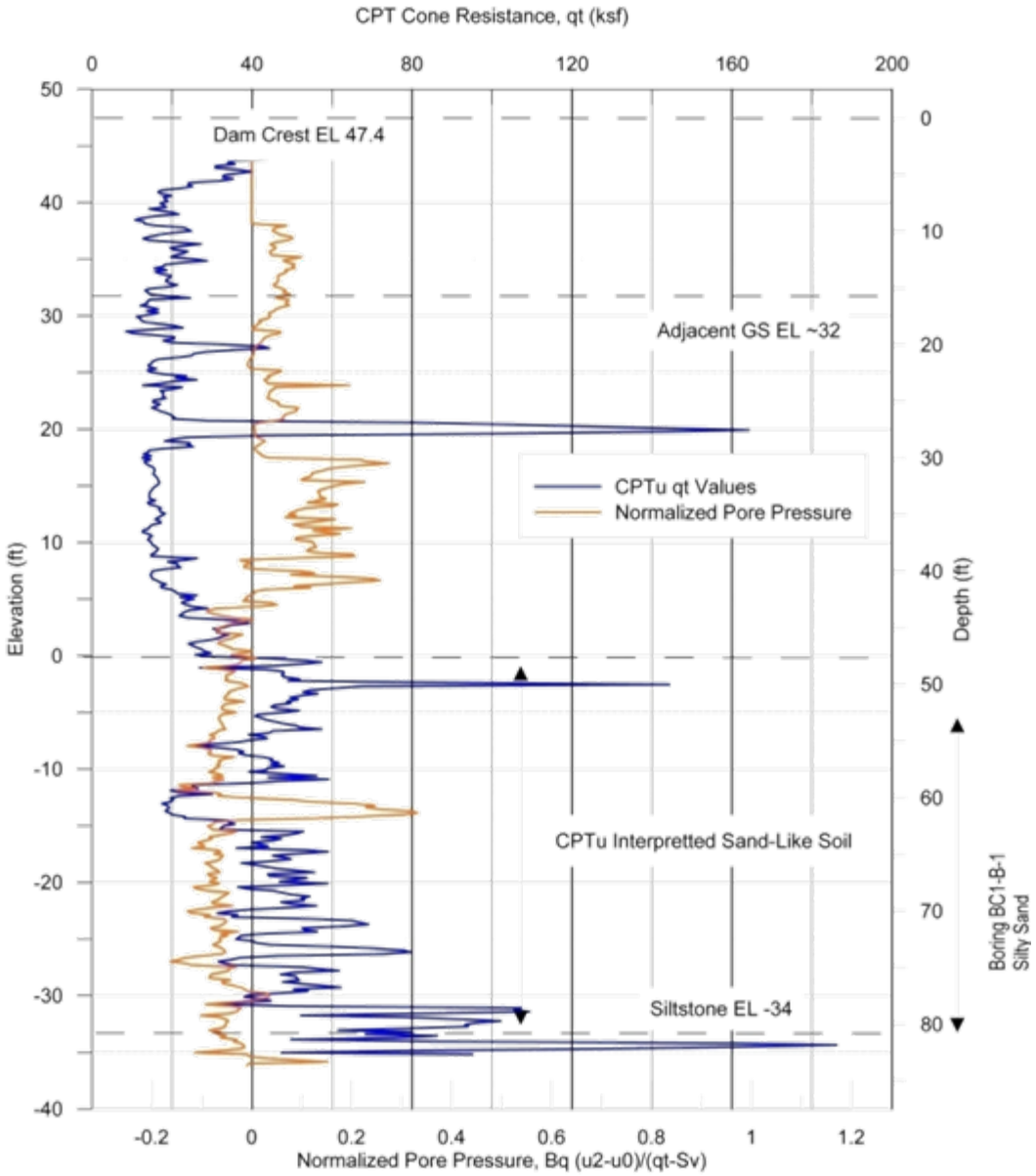
Note: Robertson and Wride (1998) identified potentially liquefiable soils with Soil Behavior Index, Ic < 2.6

Site Specifics – Analysis / Modeling

BC1-B-1/BC1 – CPT-3

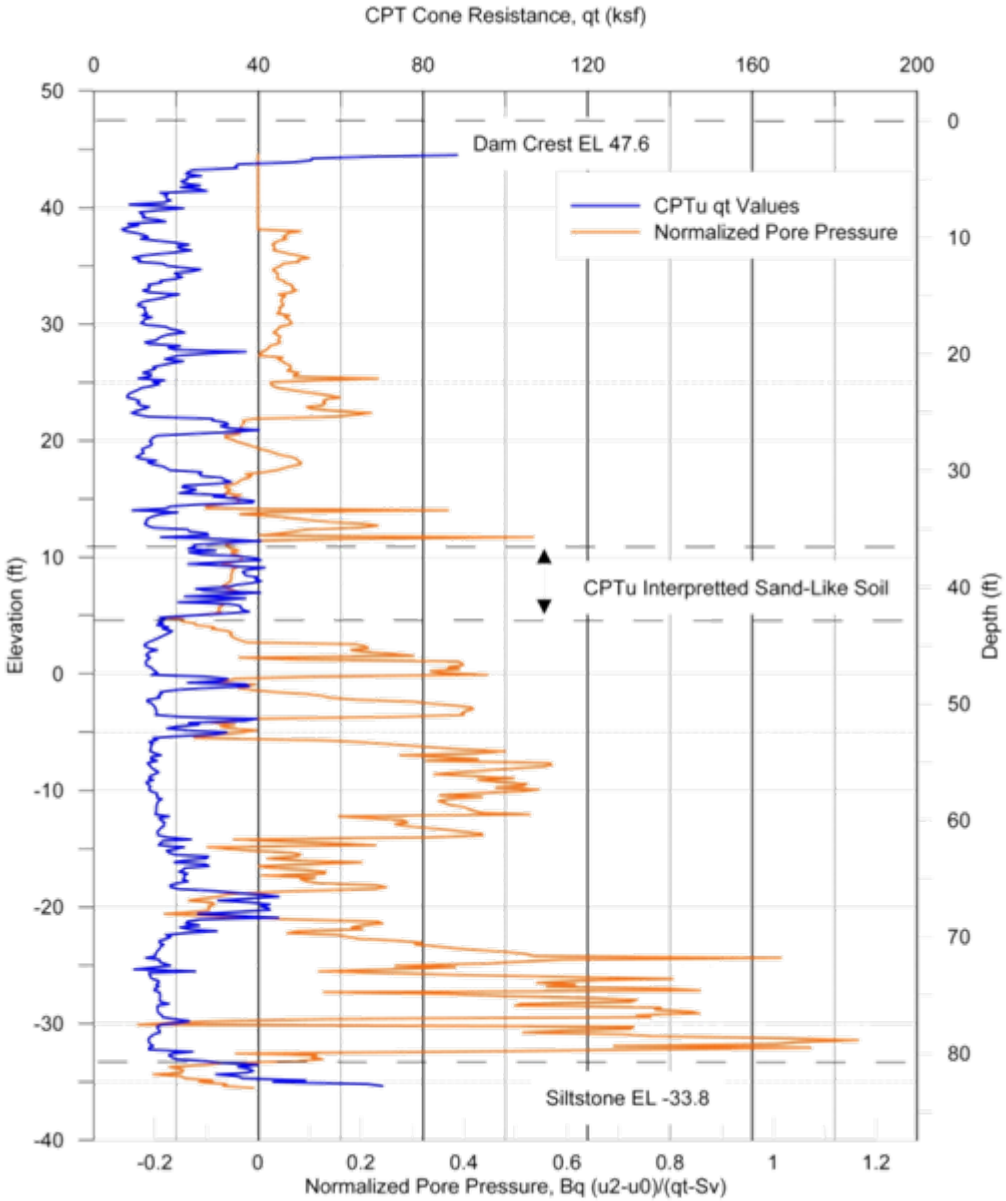
Sand-Like = PI<7
Clay-Like = PI>7

PI = Plasticity Index



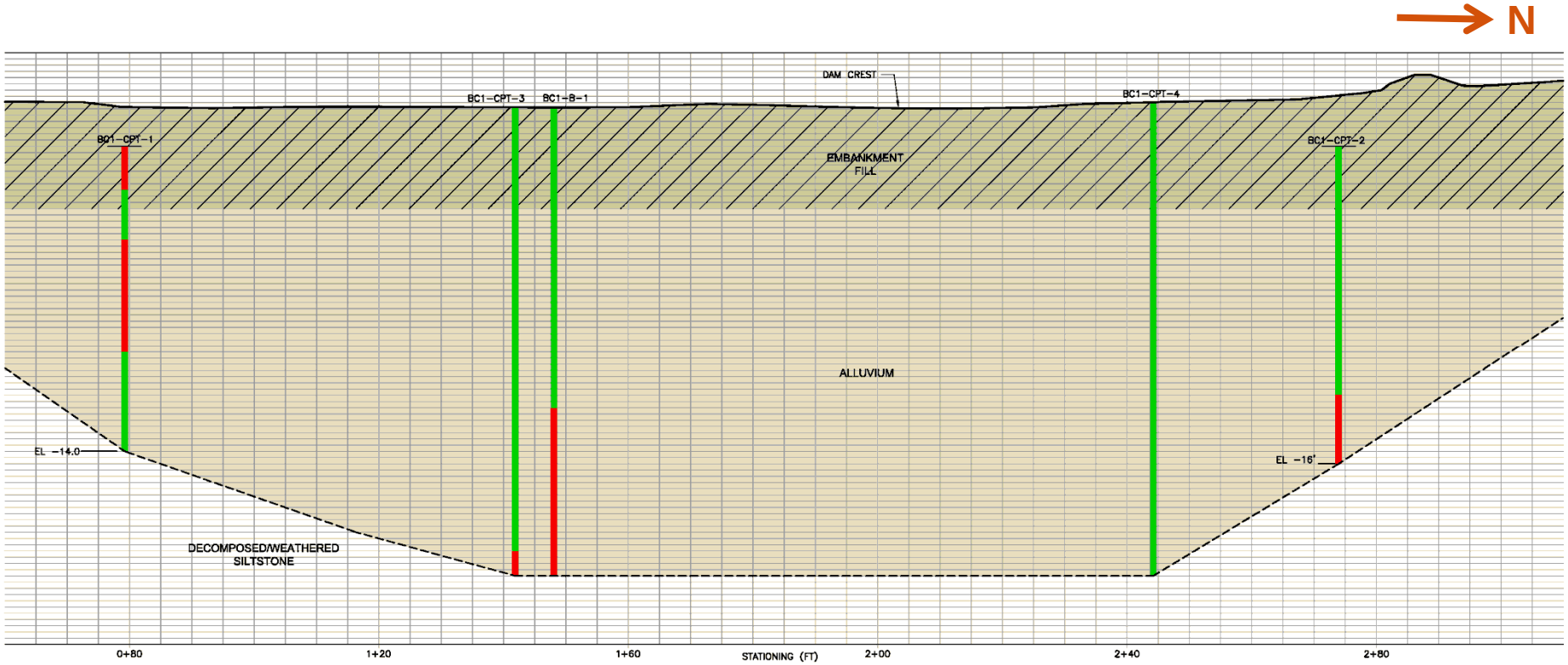
Site Specifics – Analysis / Modeling

BC1 – CPT – 4



Site Geology

Big Creek #1



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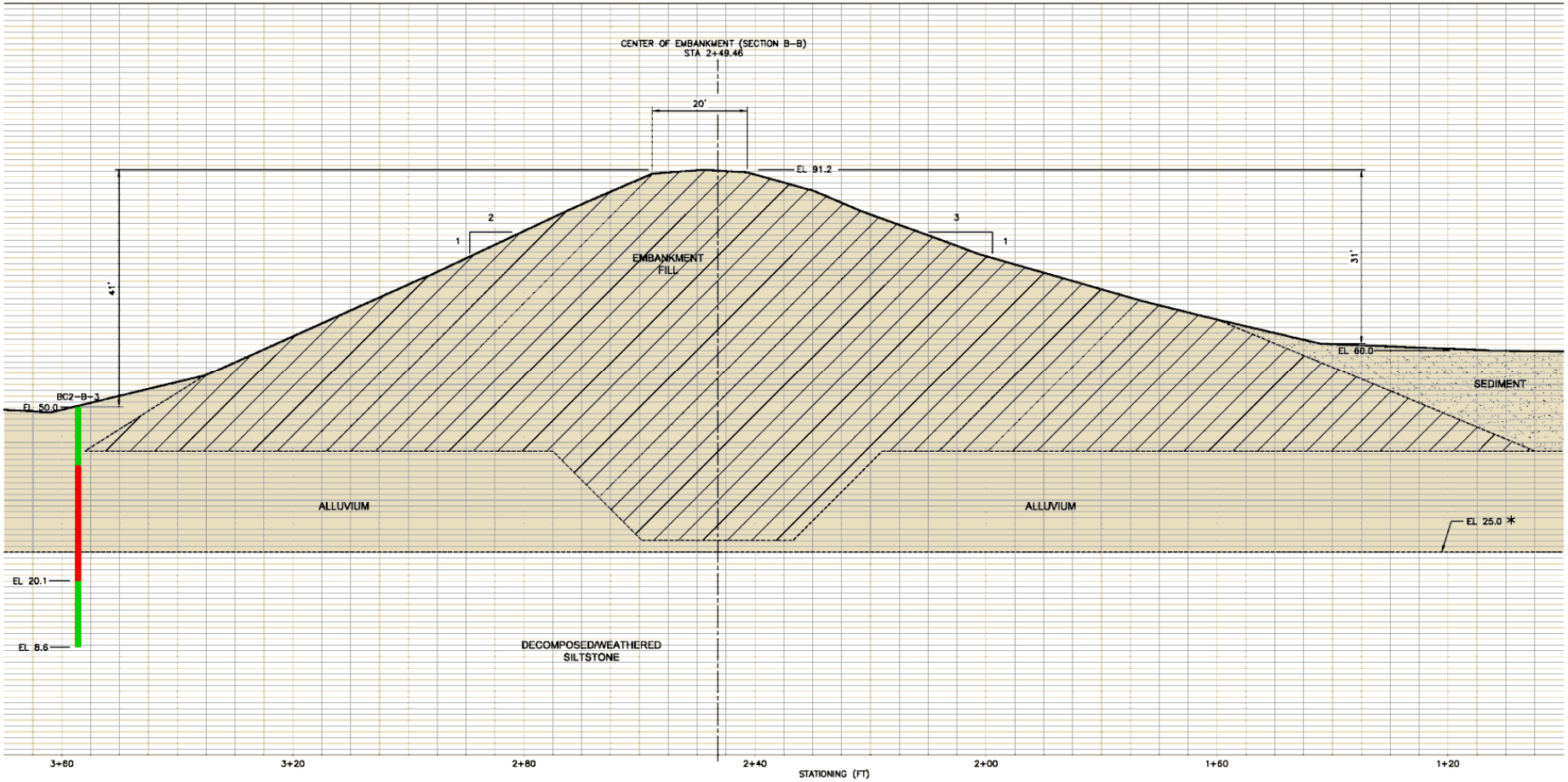
Dam Construction Characteristics

Big Creek #2



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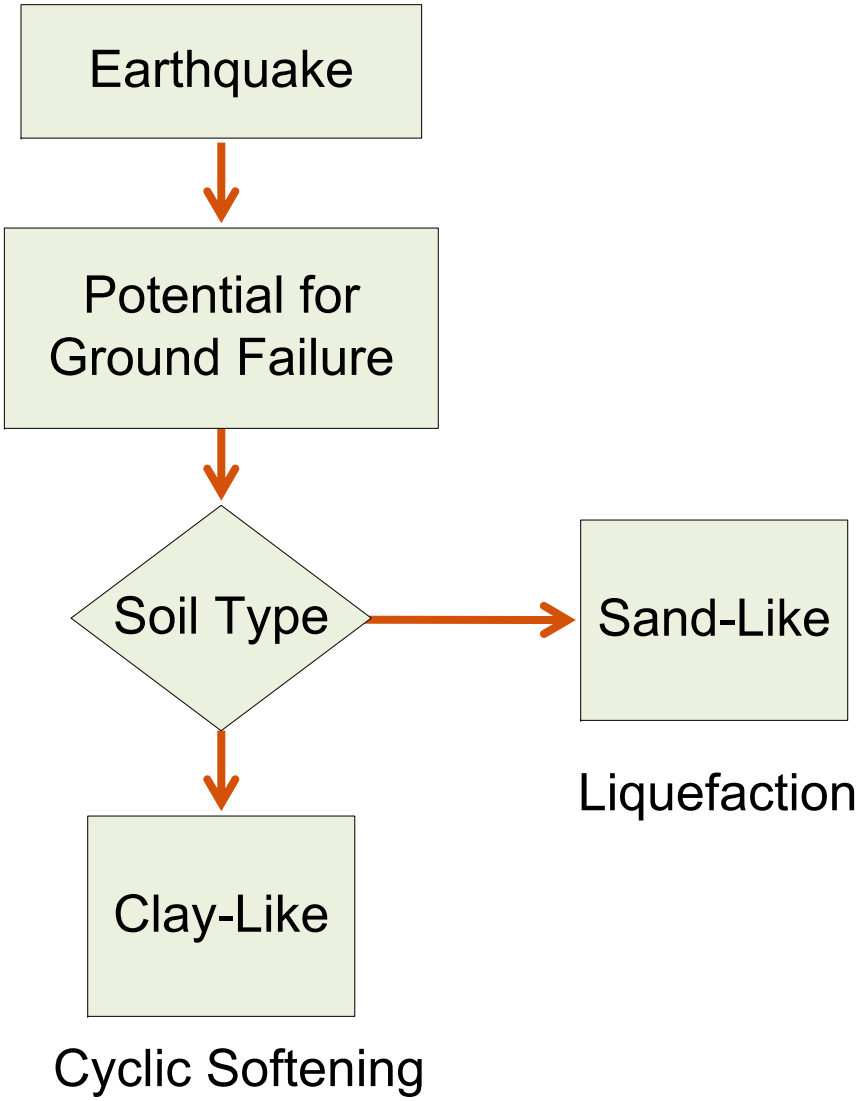
Procedure for Ground Failure Analysis



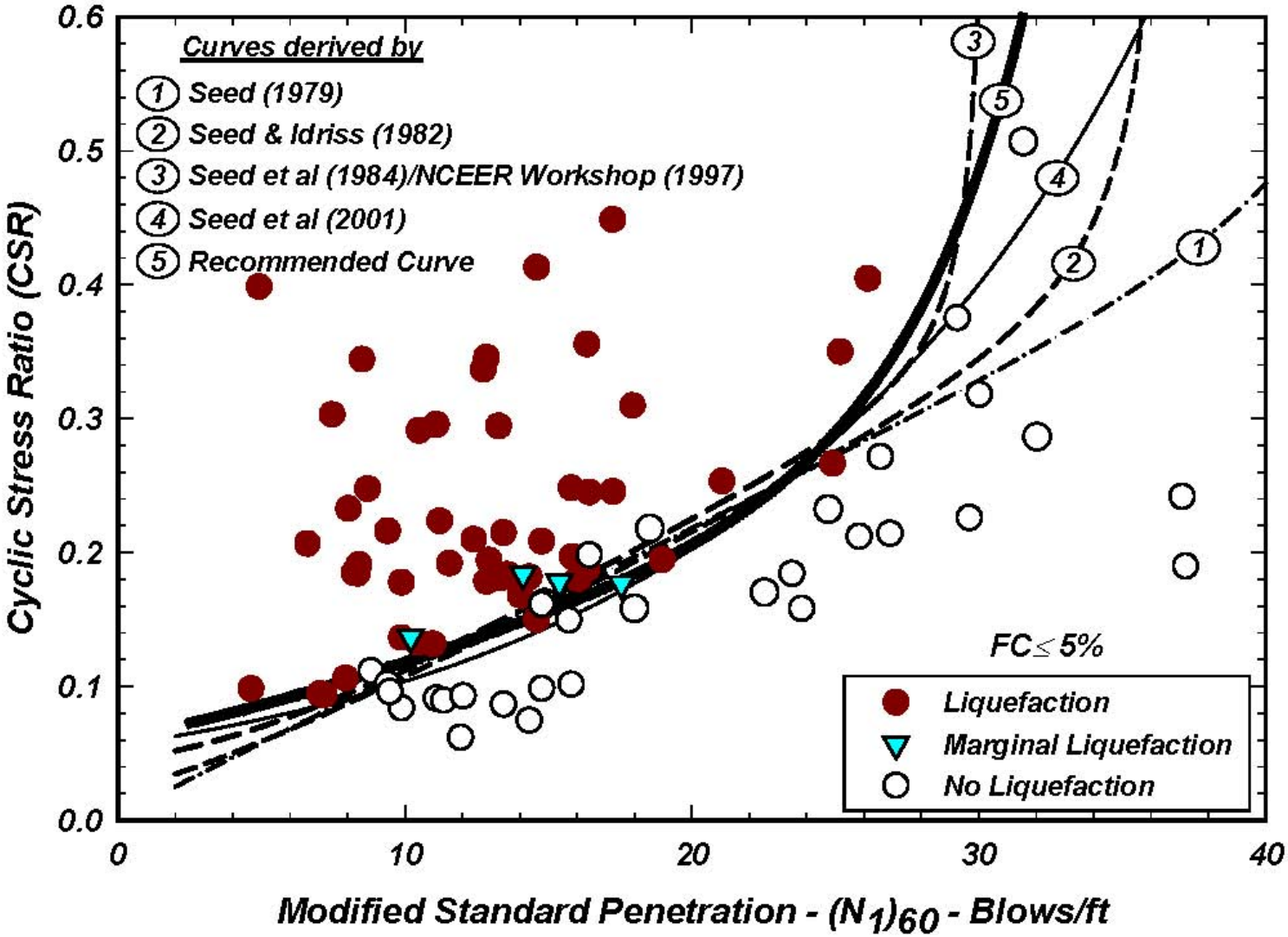
Procedure for Ground Failure Analysis

- Characterize Soil – Sand-Like or Clay-Like
- Cyclic Stress Ratio (CSR)
  - $CSR = 0.6 * (a_{max}/g) * (S_{vo}/S'_{vo}) * r_d * K_s * K_a$
- Cyclic Resistance Ratio (M7.5)
  - Sand-Like : Liquefaction

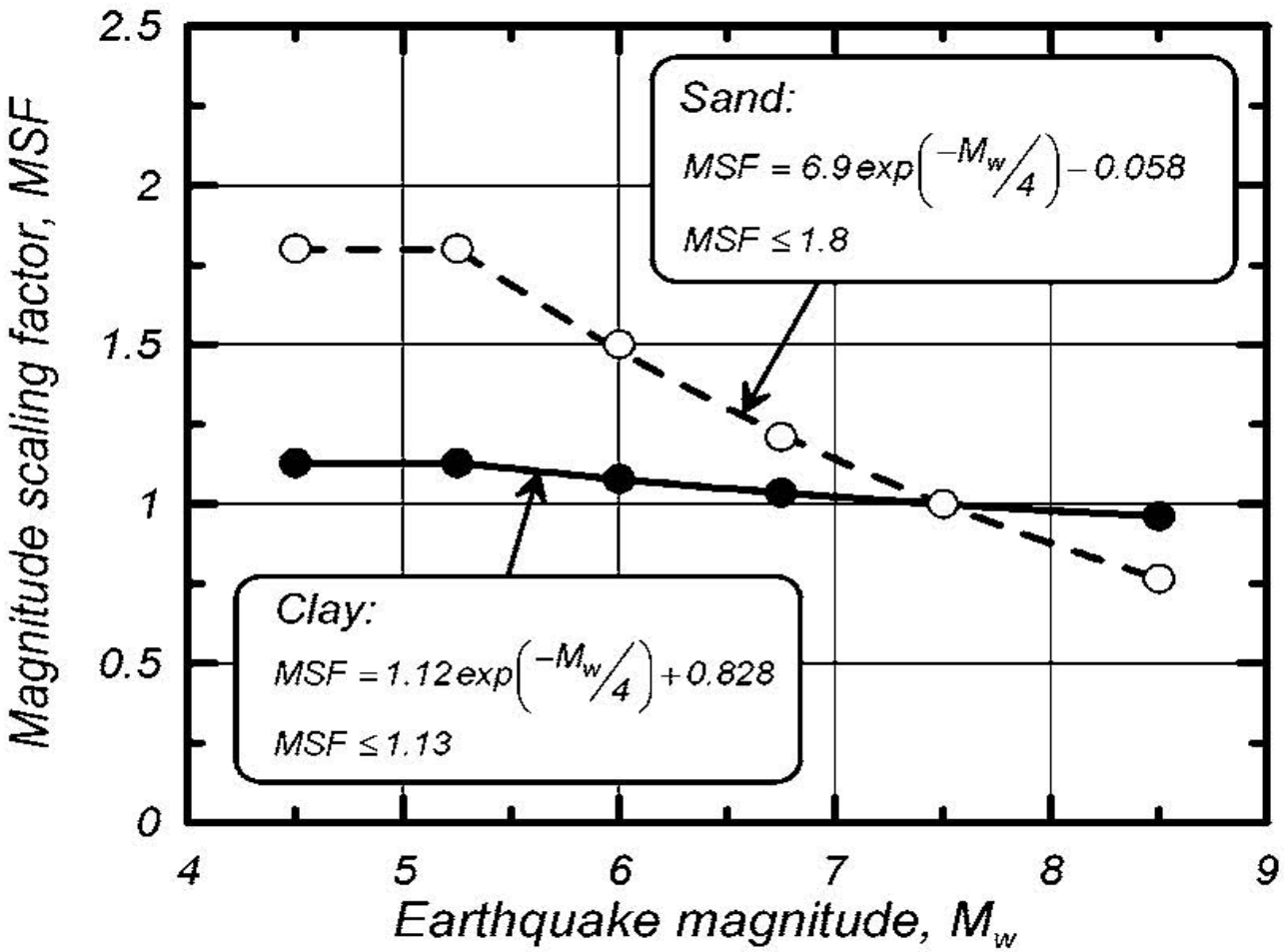
$$CRR = exp\left\{\frac{(N_1)_{60cs}}{14.1} + \left(\frac{(N_1)_{60cs}}{126}\right)^2 - \left(\frac{(N_1)_{60cs}}{23.6}\right)^3 + \left(\frac{(N_1)_{60cs}}{25.4}\right)^4 - 2.8\right\}$$

  - Clay-Like : Cyclic Softening
  - $CRR_{(M=7.5)} = 0.8 * S_u/S'_{vo} * K_a$
  - $CRR = CRR_{(M=7.5)} * MSF$

General Procedure for Ground Failure Analysis

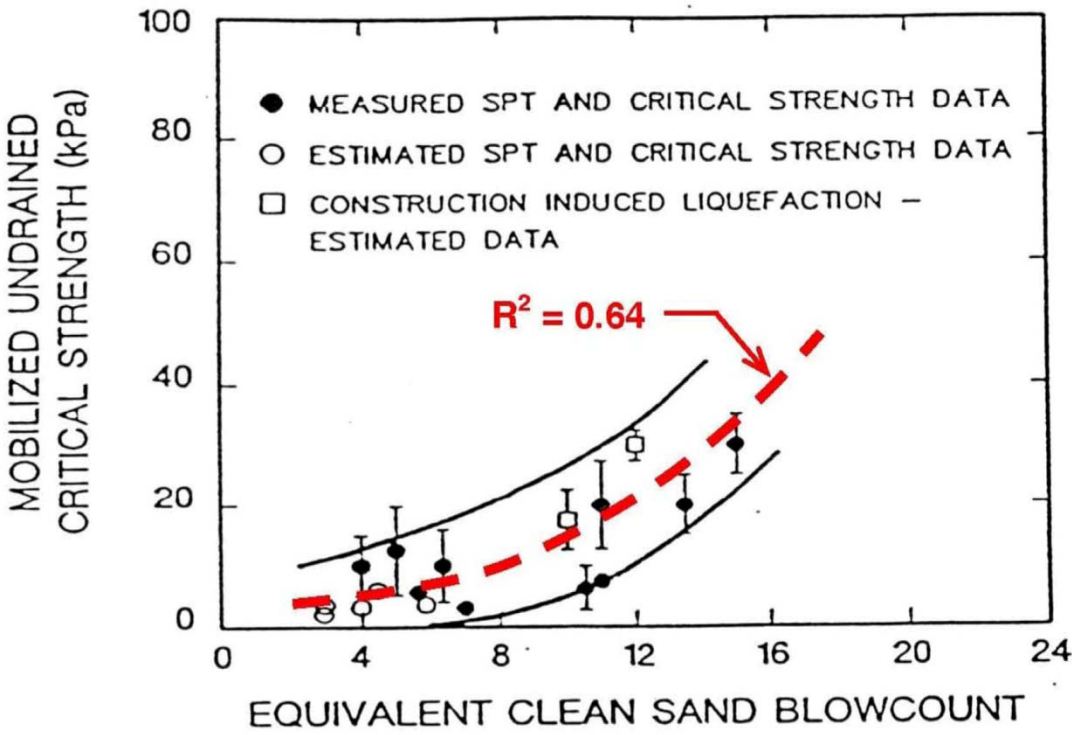


General Procedure for Ground Failure Analysis



Procedure for Ground Failure Analysis

- Calculated Factor of Safety
  - FOS = CRR/CSR
- Determine Post-Earthquake Strength
  - Sand-Like : Seed and Harder (1990)



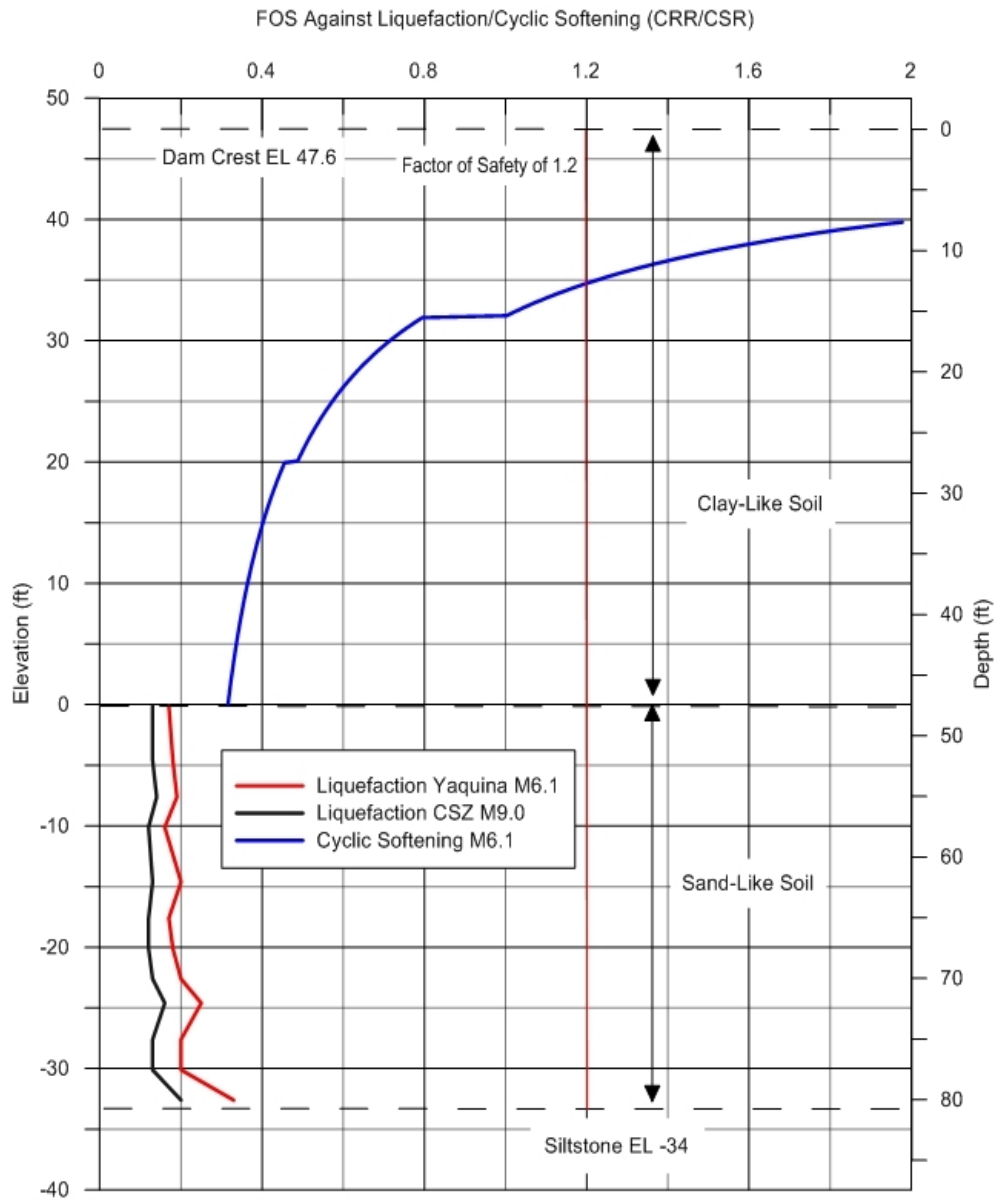
Procedure for Ground Failure Analysis

- Determine Post-Earthquake Strength
  - Clay-Like : Results of Laboratory Testing
    - Based on One Simple Shear Test:
      - S_u (Post-Earthquake)= 0.66 * S_u (Pre-Earthquake)
- Perform Post-Earthquake Stability Analyses

Results of Ground Failure Analysis

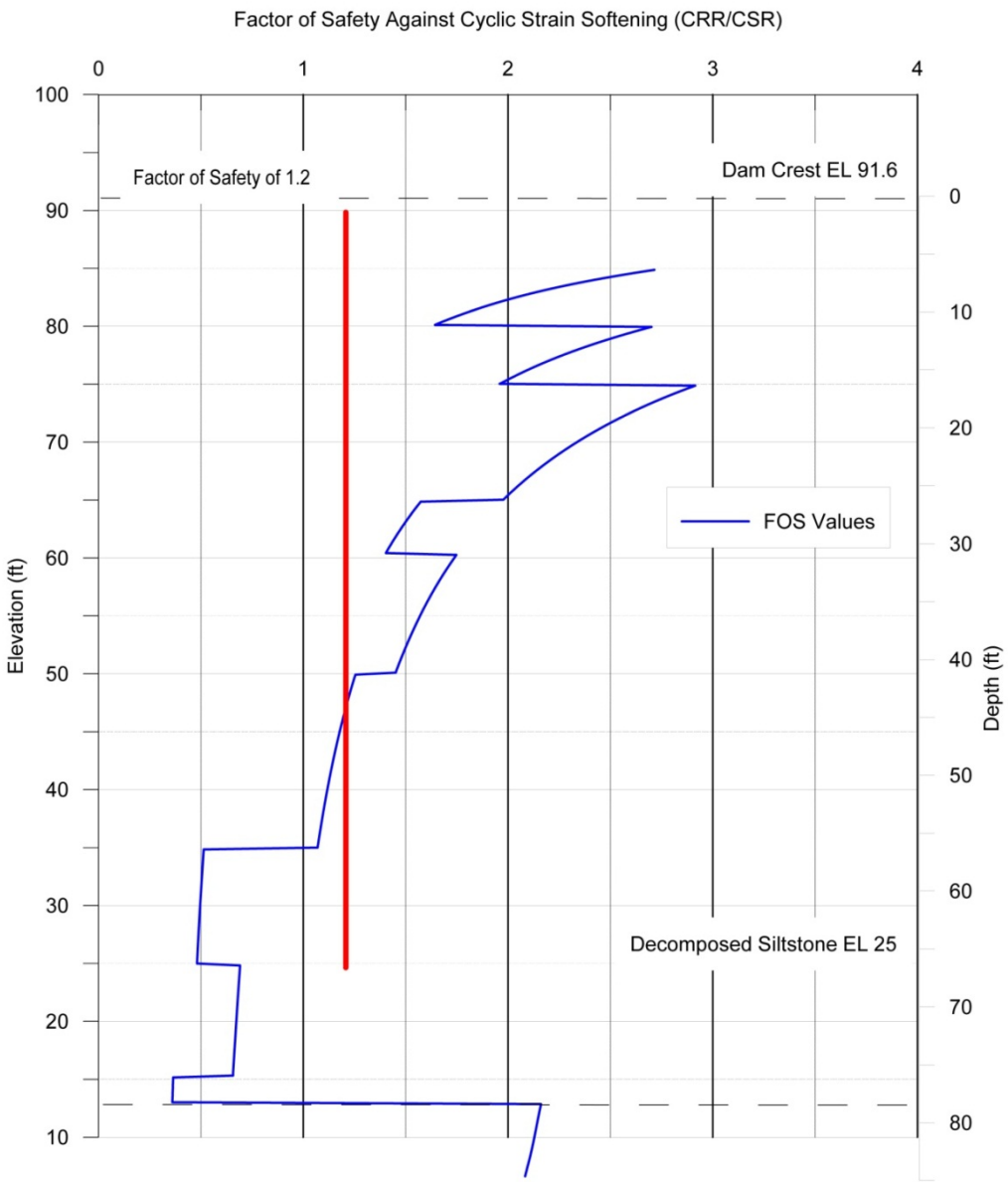
BC1 – B-1/

BC1-CPT-3



Results of Ground Failure Analysis

BC2 – CPT-1



Slope Stability Analysis

BC1 – CPT-3

FOS = 1.06

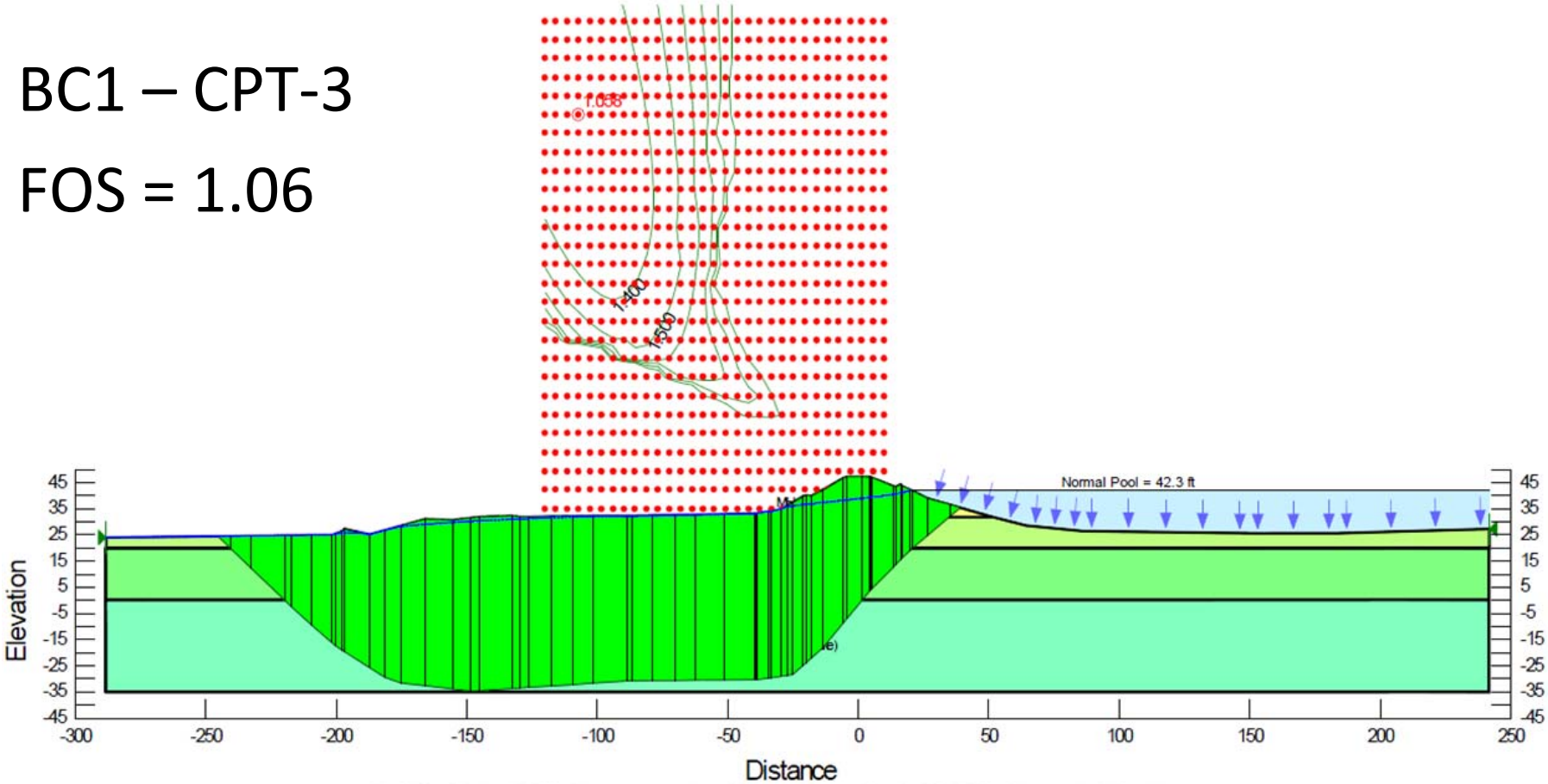


Fig. 21 Post Earthquake FOS of the downstream slope of Big Creek Dam # 1, Section BC1-CPT3 without toe drain (Case 1)

Slope Stability Analysis

BC1 – CPT-4

FOS = 1.44

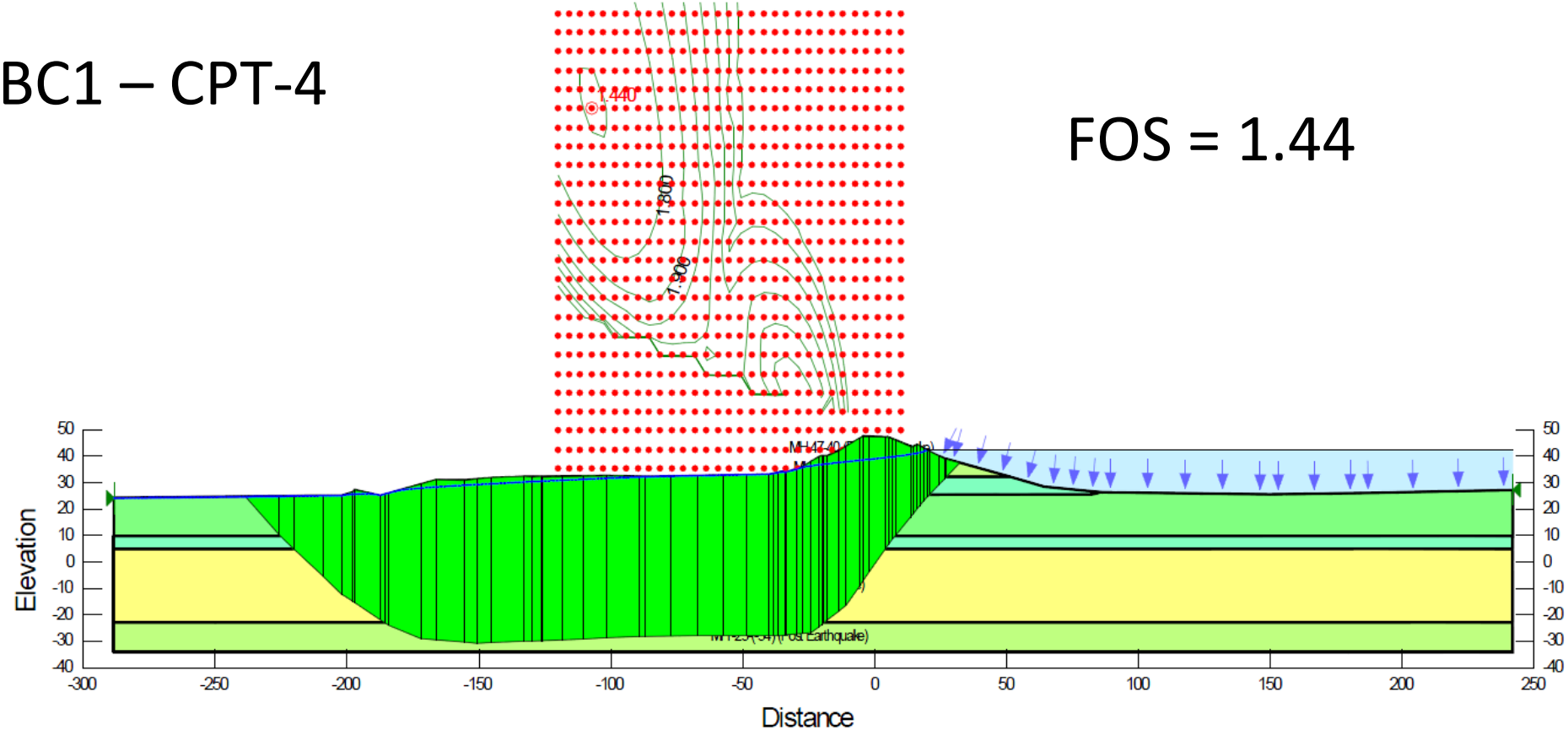


Fig. 33 Post Earthquake FOS of the downstream slope of Big Creek Dam # 1, Section BC1-CPT4 without toe drain (Case 1)

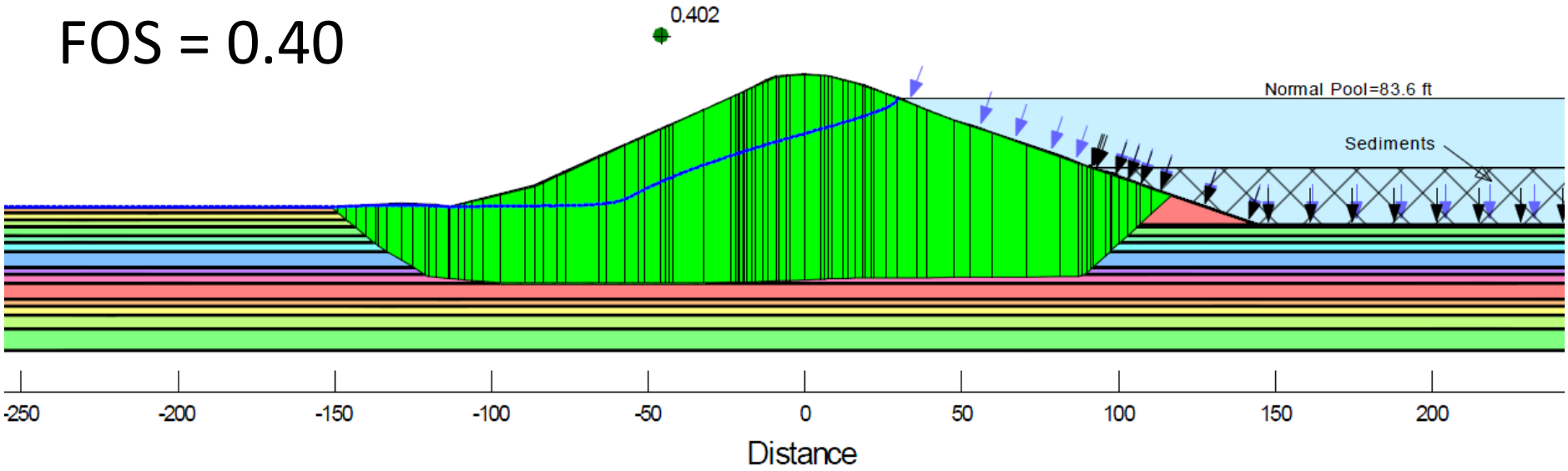
Big Creek 1

Slope Stability Analysis Results					
Section		Factor of Safety			
		Case 1[1]		Case 2[1]	
		DS	US	DS	US
BC1-B-1 Pre-Earthquake	Peak Undrained Strength Parameters	2.95	4.76	2.97	4.76
BC1-B-1 Static	Drained Strength Parameters	1.65	2.98	1.97	3.14
BC1-CPT-3 Post Earthquake	Reduced Undrained Strength Parameters	1.06	2.30	1.08	2.34
BC1-CPT-4 Pre-Earthquake	Peak Undrained Strength Parameters	2.20	4.02	2.18	4.01
BC1-CPT-4 Static	Drained Strength Parameters	1.66	2.97	2.00	3.14
BC1-CPT-4 Post Earthquake	Reduced Undrained Strength Parameters	1.44	2.16	1.44	2.11

Slope Stability Analysis

BC2

FOS = 0.40



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Big Creek 2

Slope Stability Analysis Results			
Section		Factor of Safety	
		DS	US
BC2-B-1 Pre-Earthquake	Peak Undrained Strength Parameters	-	-
BC2-B-3 Static	Drained Strength Parameters	1.83	3.38
BC2-B-3 Post Earthquake	Reduced Undrained Strength Parameters	0.40	2.30

Conclusions

- Proper Characterization of Soils “Sand-Like or Clay-Like” is Essential for Seismic Evaluation
- For Both Dams, Sand-Like Soils Will Liquefy and Majority of Clay-Like Soils will Lose Strength
- Based on Embankment Stability Analysis for Either Yakima or CSZ Earthquake:
  - BC-1 could be susceptible to damage due to a large seismic events
  - BC-2 is susceptible to significant damage and would likely experience a stability failure and an over topping breach of the dam
- Industry Understanding of CSZ Earthquake is Changing Based on Tohoku Earthquake

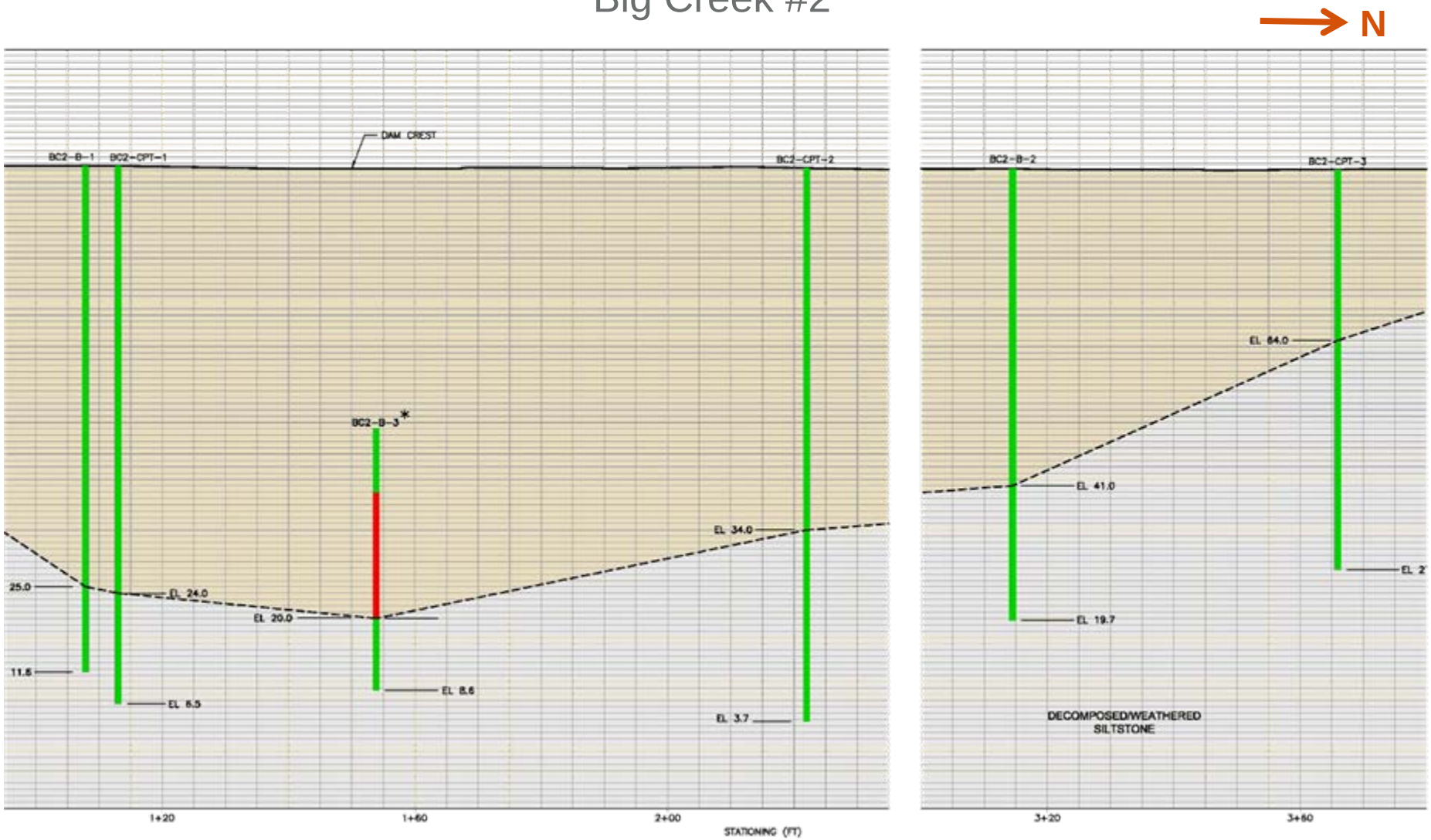
What Next

- Additional Site Characterization is Required to Improve Understanding of Soil Behavior Due to Seismic Loading
- Define Dam Failure Consequences
- Develop Dam Repair Alternative Analysis

Questions?

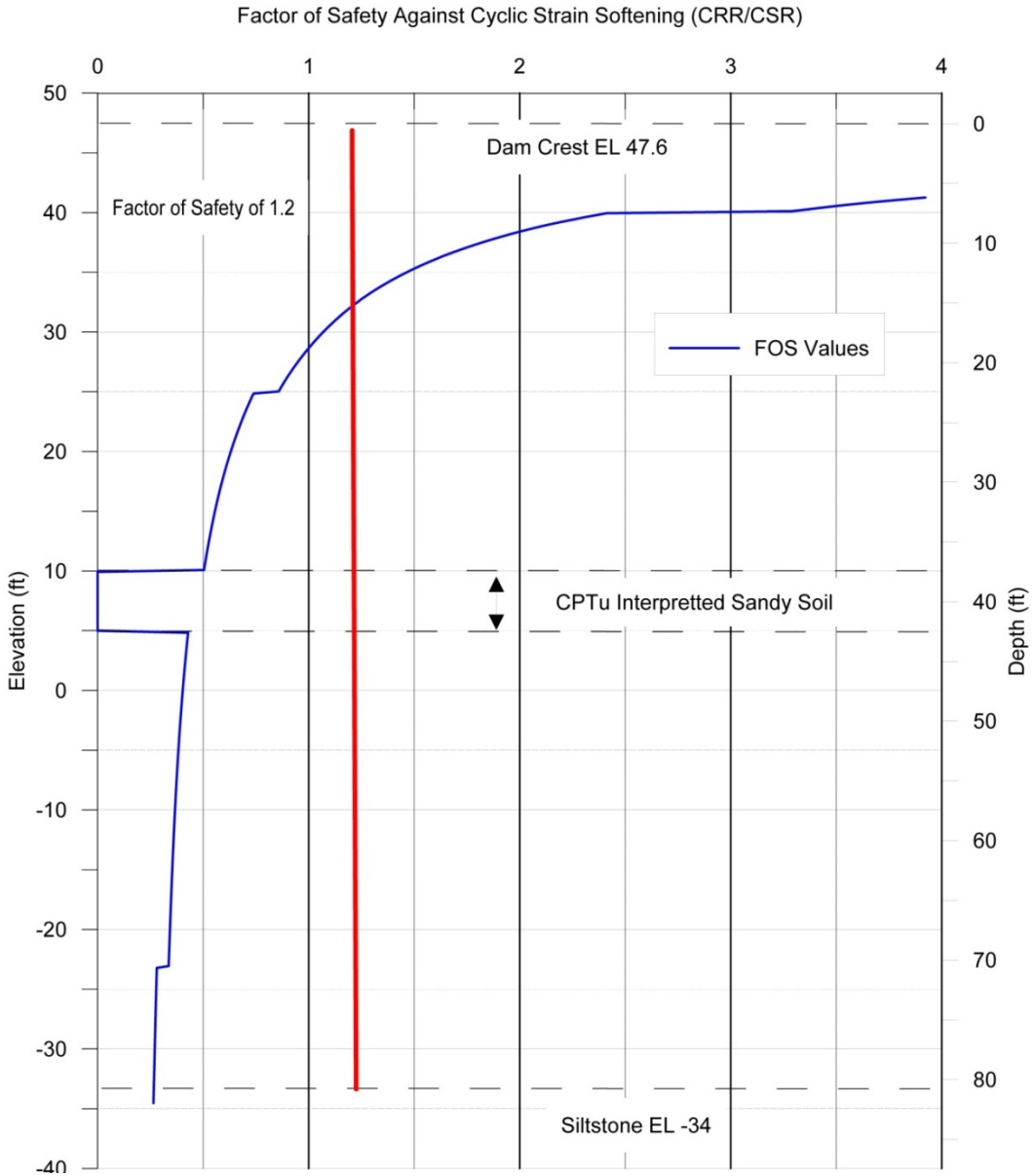
Site Geology

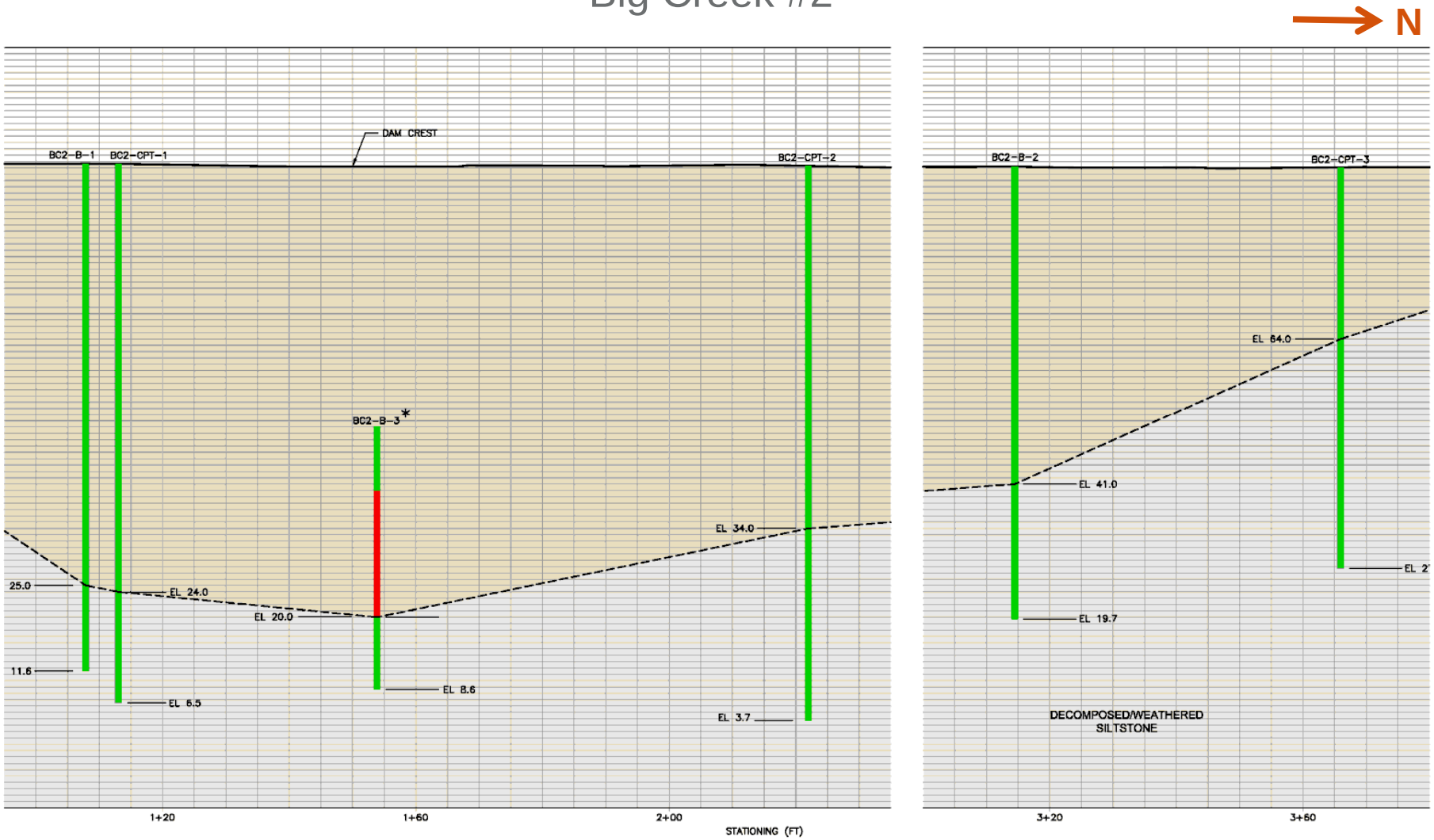
Big Creek #2



Results of Ground Failure Analysis

BC1-CPT-4



Site Geology

Big Creek #2