



Identifying Seismic Effects and Design Criteria:

Geotechnical Input for Seismic Design

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Overview

- Design Earthquake
- Site Characterization
- Site Response Design Parameters
- Assess Seismic Impacts at Site
- Mitigation of Seismic Impacts



Design Earthquake

- Select Reoccurrence Interval
 - Based on code used by Agency
 - 2009/12 International Building Code (IBC)
 - ASCE 7
- Select importance of structure
 - For IBC 2012: Water facilities are in Risk Category III or IV



Design Earthquake Parameters

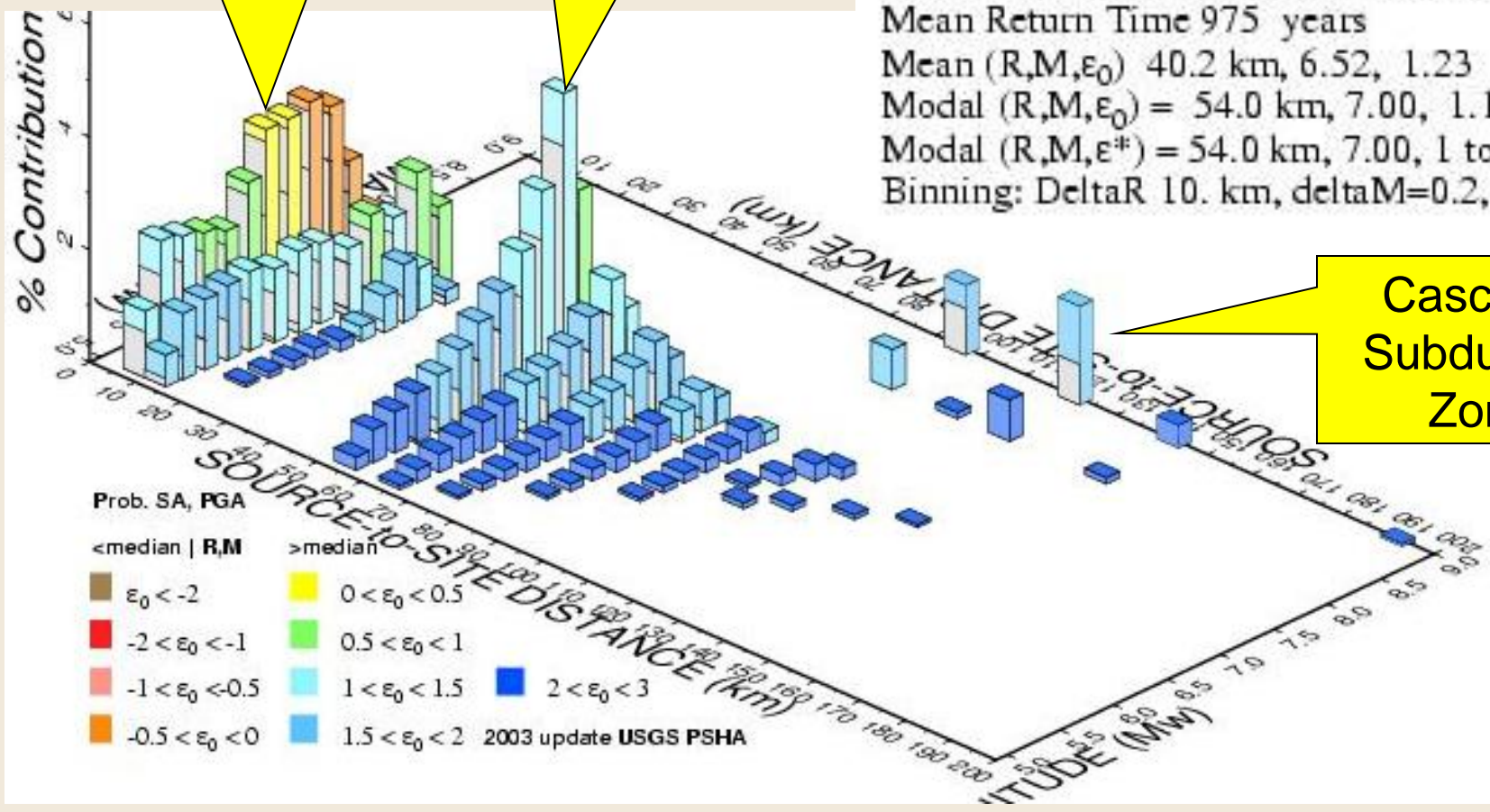
- Determine ground motion parameters for bedrock:
 - IBC 2012 = 2% probability of exceedance in 50 years
 - Return Period = 2,475 yrs
- Obtain from USGS Hazard Maps
 - Response acceleration for structural period of 0.2 sec (S_s)
 - Response acceleration for structural period of 1.0 sec (S_1)



Seattle/South Whidbey Fault

Intraplate

Prob. Seismic Hazard Deaggregation
 bothell 122.210° W, 47.760 N.
 Peak Horiz. Ground Accel. ≥ 0.3875 g
 Mean Return Time 975 years
 Mean (R,M, ϵ_0) 40.2 km, 6.52, 1.23
 Modal (R,M, ϵ_0) = 54.0 km, 7.00, 1.13 (from peak)
 Modal (R,M, ϵ^*) = 54.0 km, 7.00, 1 to 2 sigma (from peak)
 Binning: DeltaR 10. km, deltaM=0.2, Delta ϵ =1.0



Cascadia Subduction Zone



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Site Classification

- Develop a Subsurface Profile

Based on the characteristics of soils in
upper 100 feet

Peat

Highly plastic soft clays

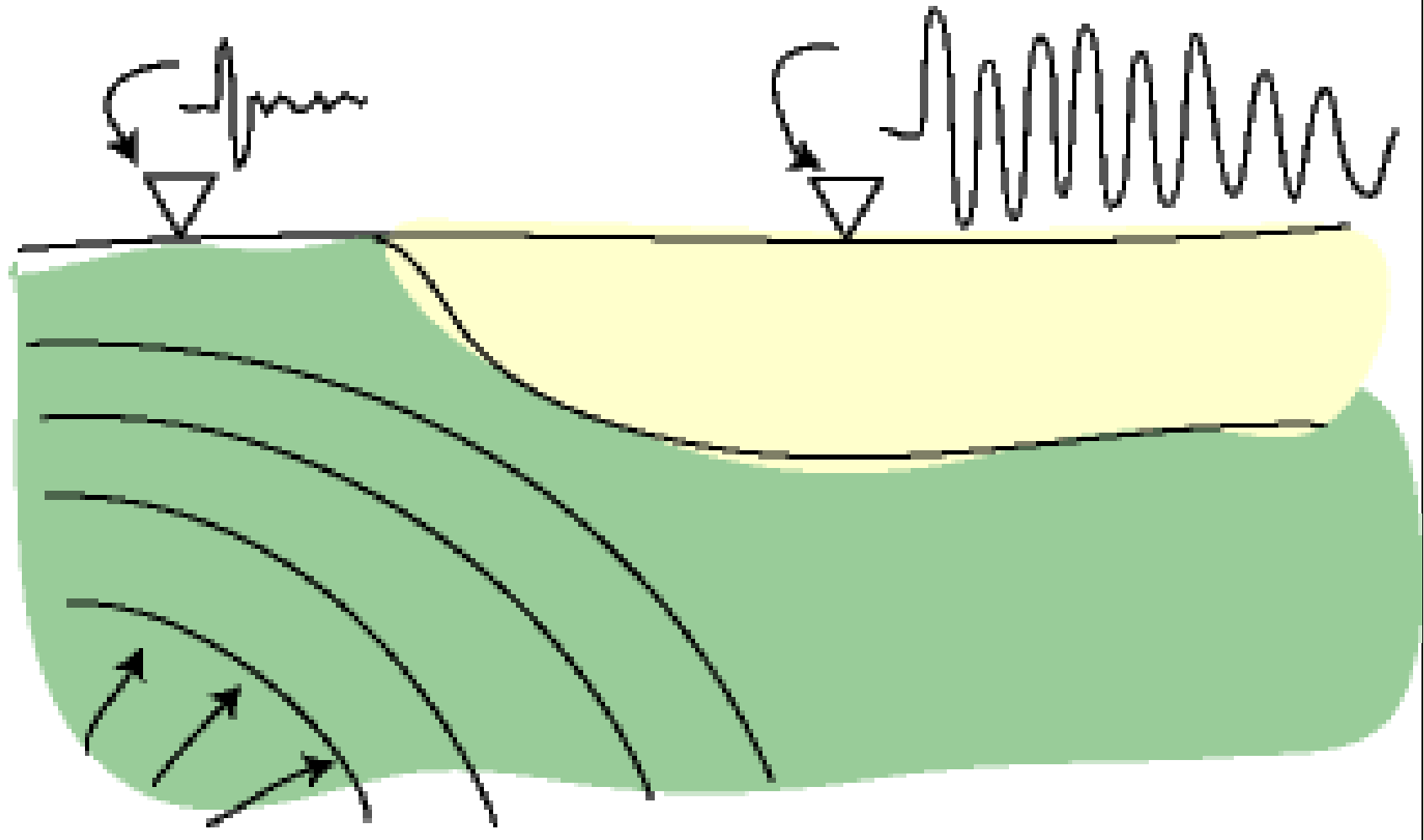
Liquefiable soils

Collapsible soils



Hard Rock Site

Soft Soil Site





Soil Properties to be Determined

- Soil classification
- Relative density (sands, non-plastic silt)
- Unit weight of the soil
- Shear strength (clay)
- Index properties
- Residual shear strength (clays)



Testing

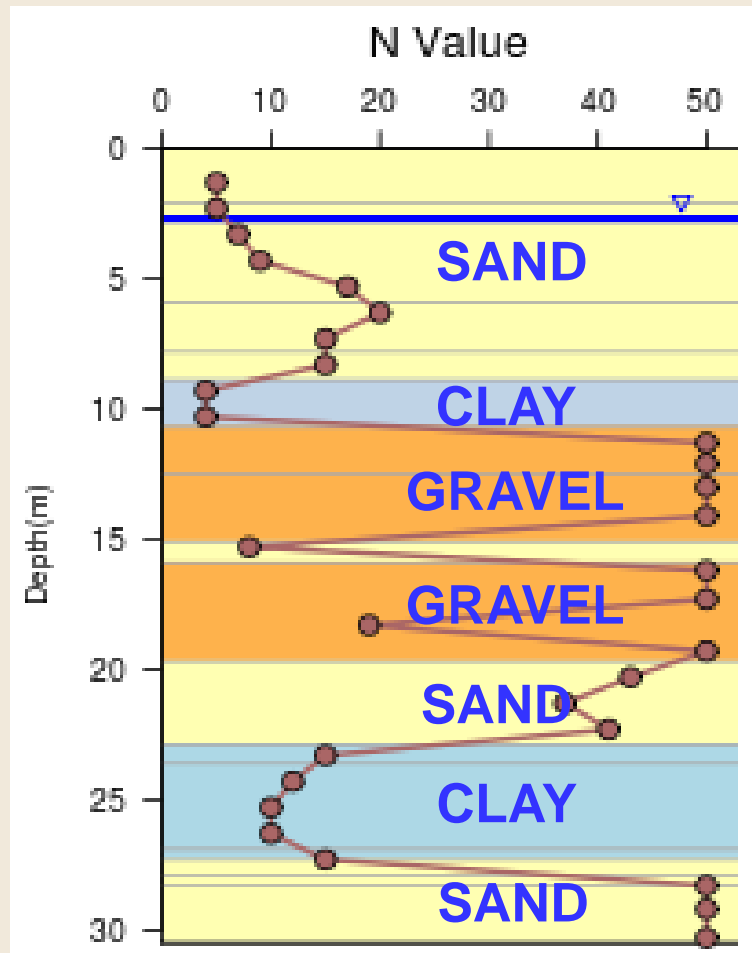
- In situ Methods
 - Borings with Standard Penetration Test (SPT)
 - Cone Penetration Test (CPT) - Sands, Clays
 - Becker Hammer - Gravel
- Lab Testing
 - Moisture Content
 - Grain Size Distribution
 - Atterberg Limits



Testing

- More detailed analyses may need
 - Shear wave velocity/Initial shear modulus
 - Crosshole / Downhole testing
 - Seismic CPT
 - Geophysical
 - Cyclic stress-strain behavior - lab testing
 - Cyclic triaxial, cyclic simple shear

Example Geologic Profile





**TABLE 1613.5.2
SITE CLASS DEFINITIONS**

| SITE CLASS | SOIL PROFILE NAME | AVERAGE PROPERTIES IN TOP 100 feet, SEE SECTION 1613.5.5 | | |
|------------|-------------------------------|---|--|--|
| | | Soil shear wave velocity, \bar{v}_s , (ft/s) | Standard penetration resistance, \bar{N} | Soil undrained shear strength, \bar{s}_u , (psf) |
| A | Hard rock | $\bar{v}_s > 5,000$ | N/A | N/A |
| B | Rock | $2,500 < \bar{v}_s \leq 5,000$ | N/A | N/A |
| C | Very dense soil and soft rock | $1,200 < \bar{v}_s \leq 2,500$ | $\bar{N} > 50$ | $\bar{s}_u \geq 2,000$ |
| D | Stiff soil profile | $600 \leq \bar{v}_s \leq 1,200$ | $15 \leq \bar{N} \leq 50$ | $1,000 \leq \bar{s}_u \leq 2,000$ |
| E | Soft soil profile | $\bar{v}_s < 600$ | $\bar{N} < 15$ | $\bar{s}_u < 1,000$ |
| E | — | Any profile with more than 10 feet of soil having the following characteristics: <ol style="list-style-type: none"> 1. Plasticity index $PI > 20$, 2. Moisture content $w \geq 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf | | |
| F | — | Any profile containing soils having one or more of the following characteristics: <ol style="list-style-type: none"> 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H > 10$ feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H > 25$ feet with plasticity index $PI > 75$) 4. Very thick soft/medium stiff clays ($H > 120$ feet) | | |

Application

Batch Mode

Help

Design Code Reference Document

Consult your local design official if you need help selecting this.

2012 IBC

Report Title (Optional)

This will appear at the top of the generated report.

Bothell

Site Soil Classification

This is not automatically selected based on site location.

Site Class D – “Stiff Soil” (Default)

Risk Category

Used to compute the seismic design category.

IV (e.g., essential facilities)

Site Latitude

Decimal degrees for the site location.

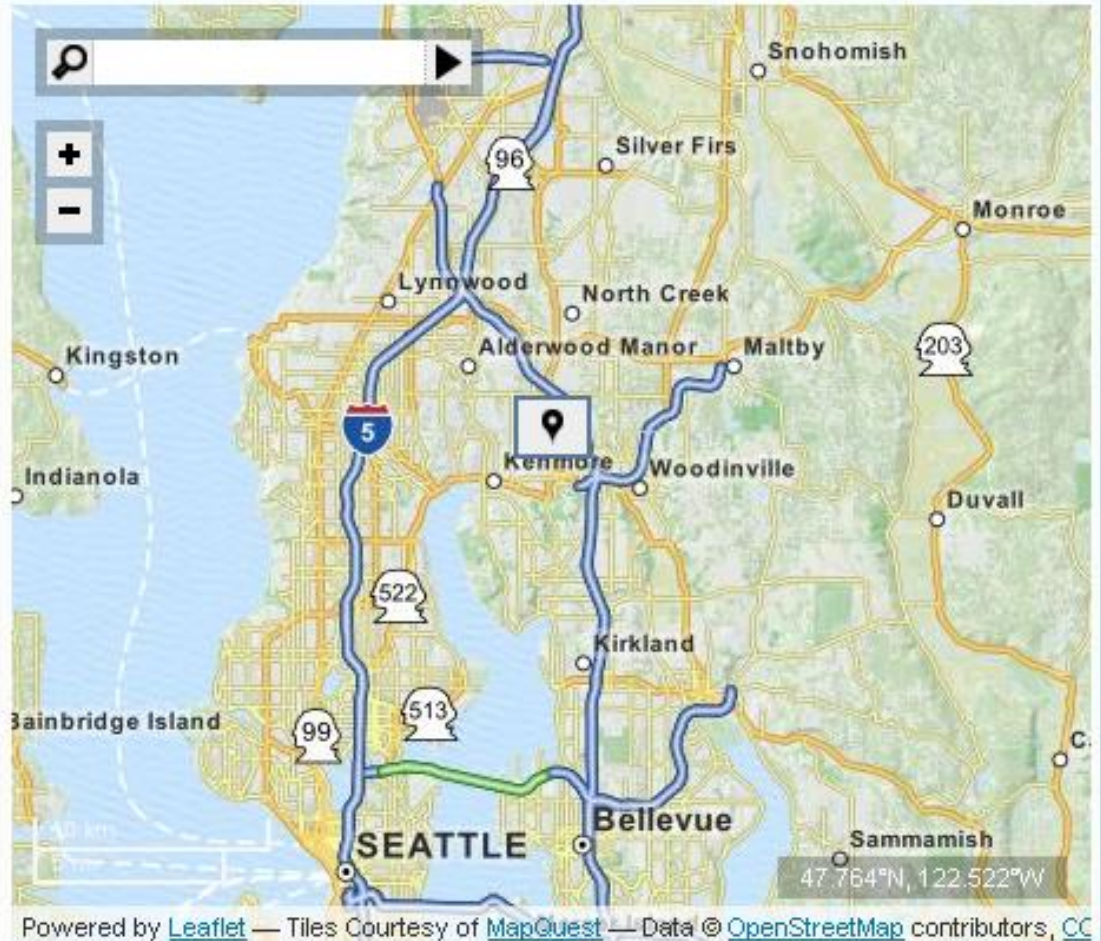
47.76

Site Longitude

Decimal degrees for the site location.

-122.21

Compute Values



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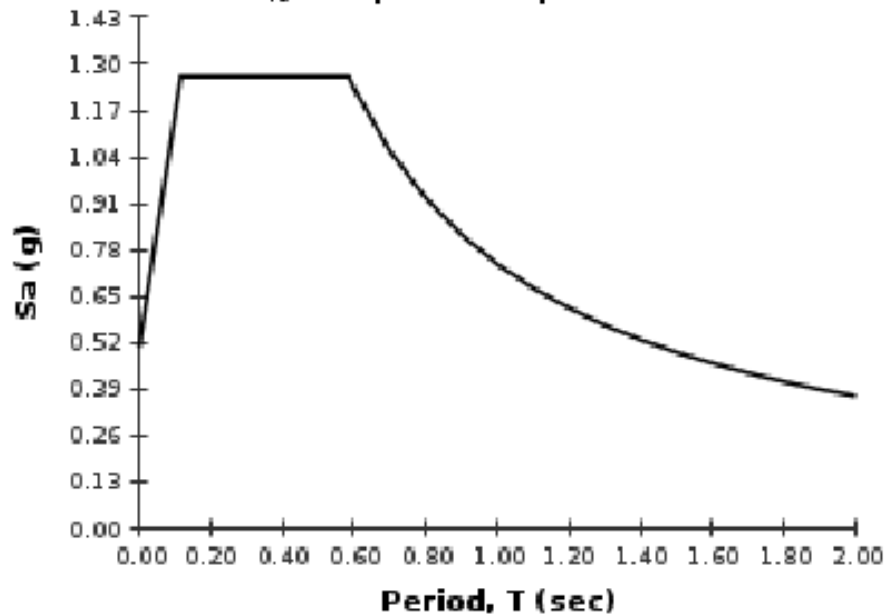


USGS-Provided Output

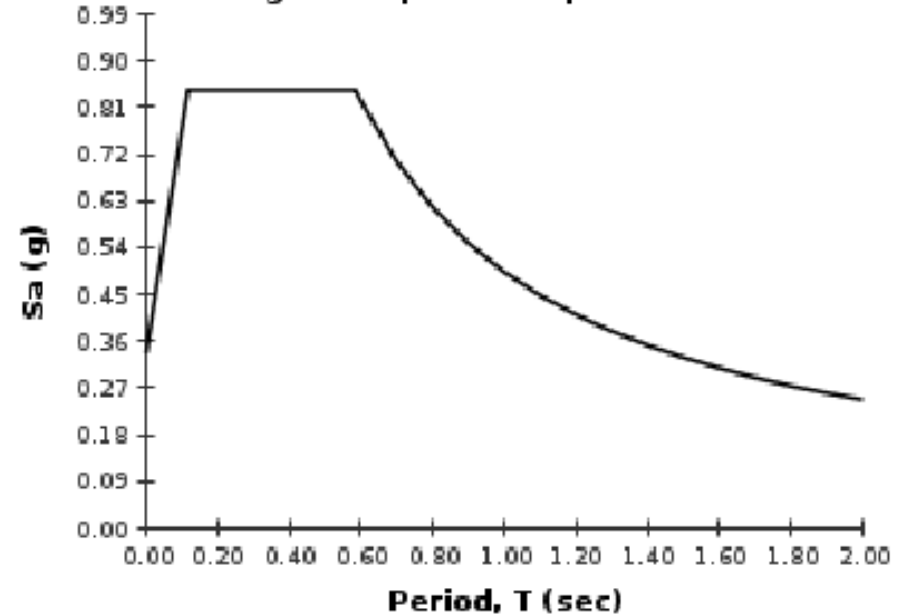
| | | |
|-------------------------|----------------------------|----------------------------|
| $S_s = 1.265 \text{ g}$ | $S_{MS} = 1.265 \text{ g}$ | $S_{OS} = 0.843 \text{ g}$ |
| $S_1 = 0.490 \text{ g}$ | $S_{M1} = 0.740 \text{ g}$ | $S_{O1} = 0.493 \text{ g}$ |

For information on how the S_S and S_1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.

MCE_R Response Spectrum



Design Response Spectrum

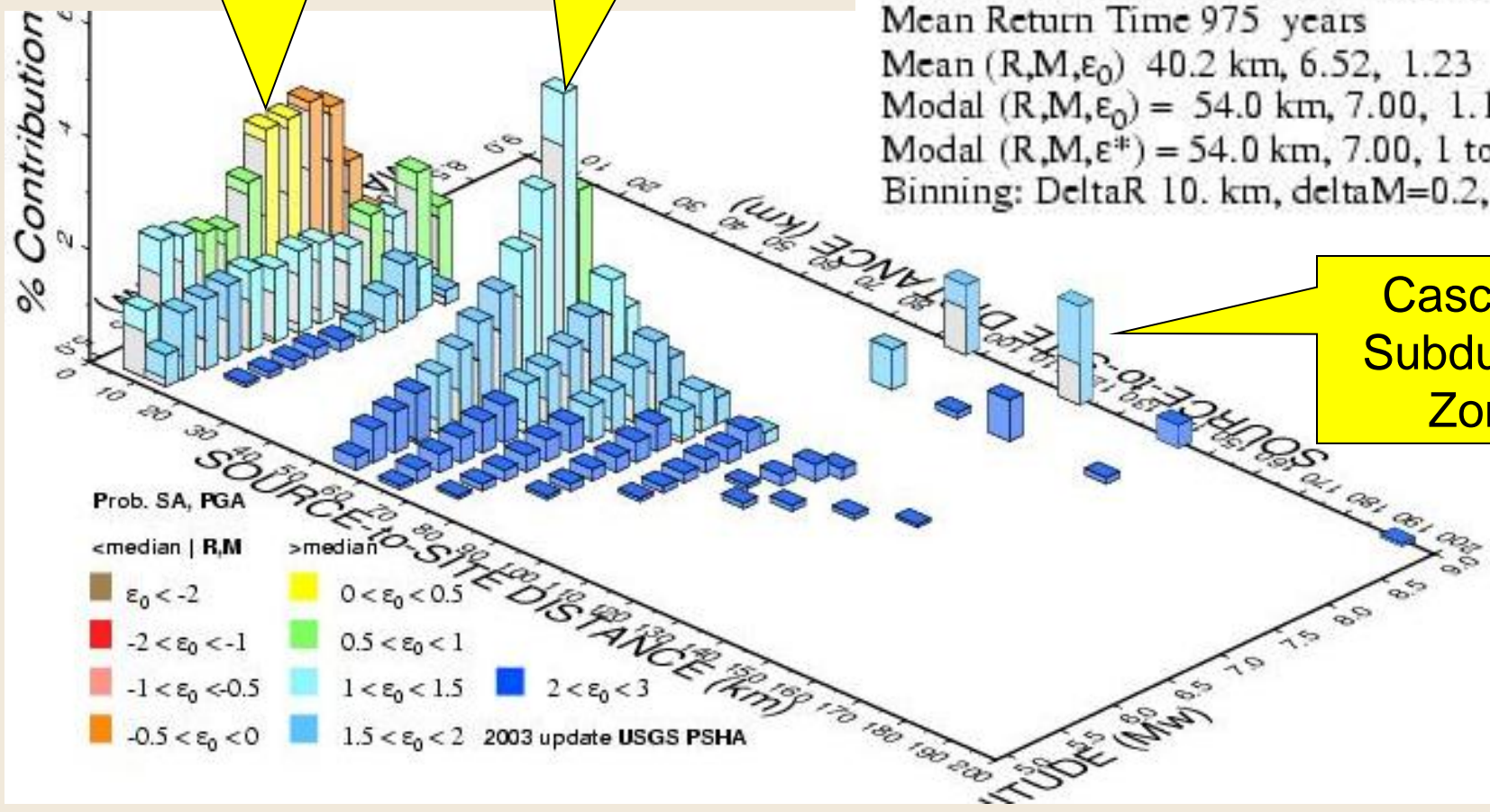




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Cascadia Subduction Zone



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Seismic Impacts at Site

- Ground Rupture
- Seismic Induced Landslides
- Liquefaction



Seismic Effects of Liquefaction

- Loss of bearing capacity
- Settlement
- Lateral Spreading
- Flow liquefaction
- Buoyancy



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Potential for Liquefaction

- Identify relative density
- Establish ground water elevation
- Determine fines content
- Atterberg Limits and water content
 - Plastic soils have less tendency to liquefy



Mitigation for Liquefaction

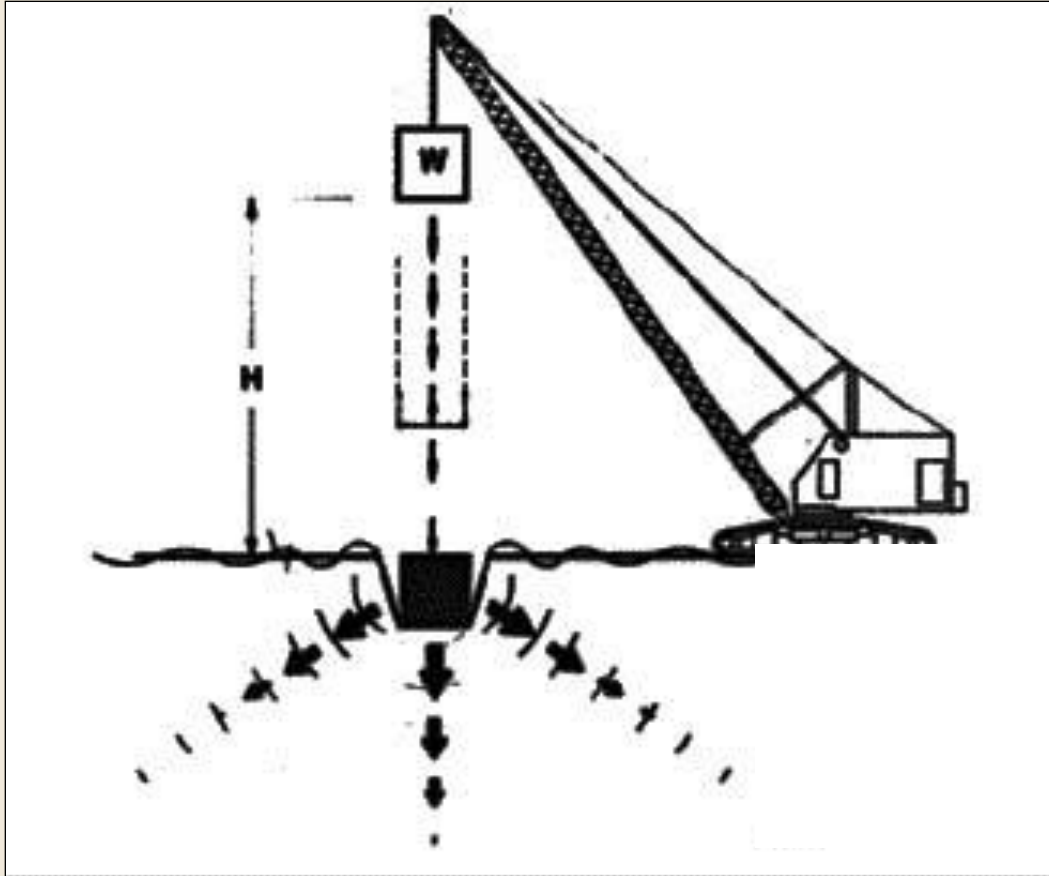
- Design for Liquefaction
 - Install deep foundations
- Reduce Liquefaction Potential
 - Remove and replace
 - Densify loose granular soils
 - Increase cohesion



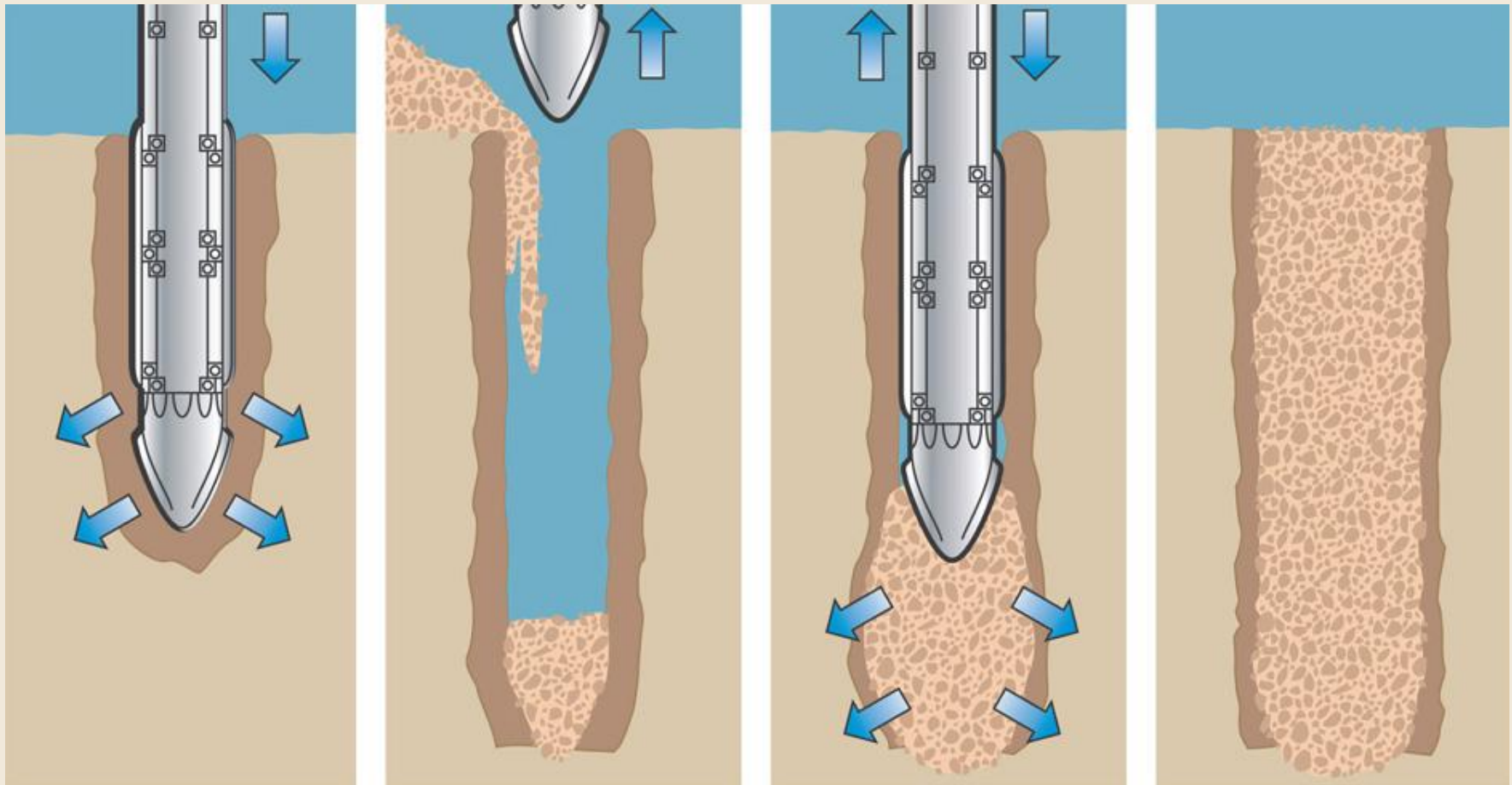
Soil Improvement Options

- Densification
 - Deep dynamic compaction
 - Vibro Compaction/Stone Columns
 - Compaction Grouting

Deep Dynamic Compaction



Stone Columns





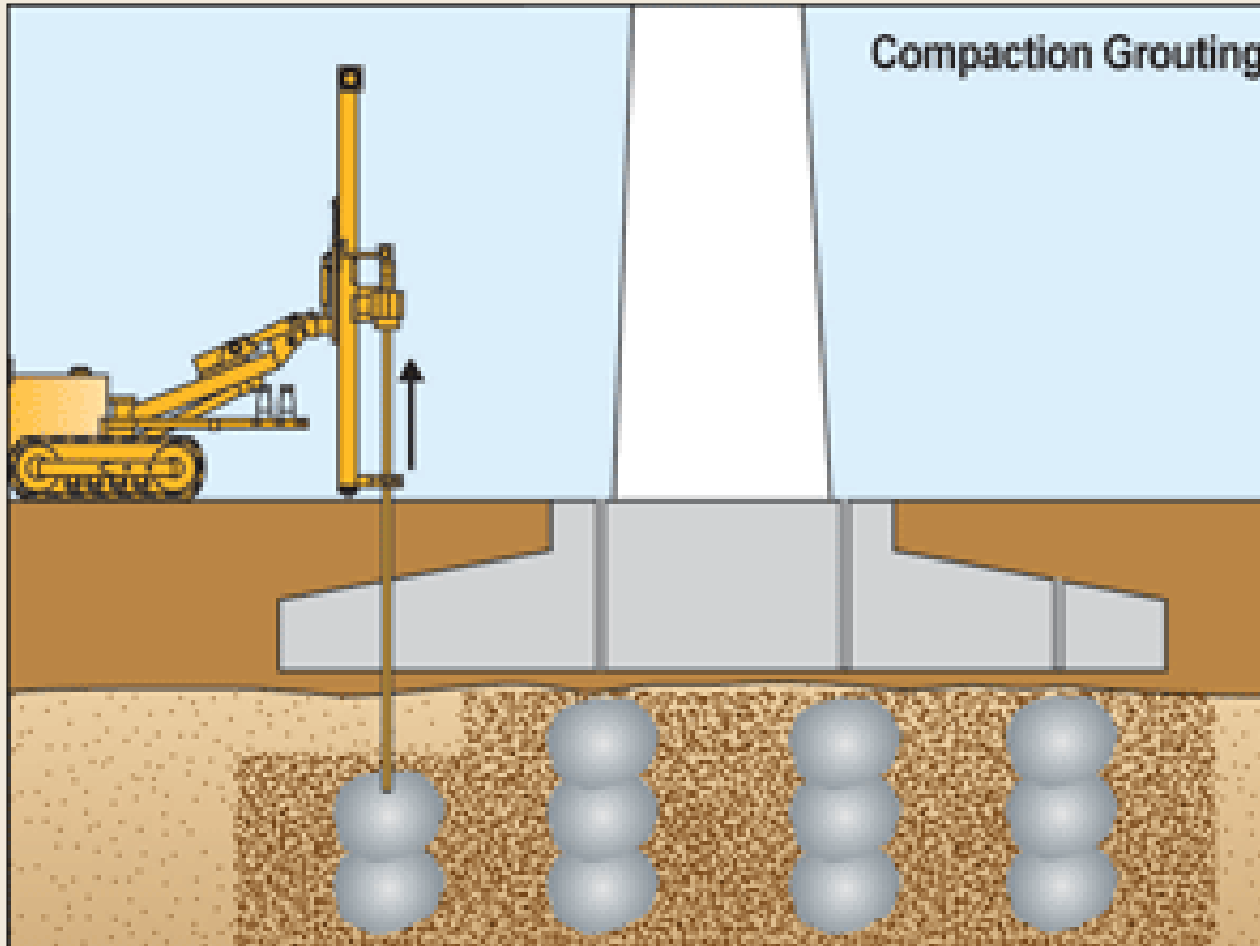
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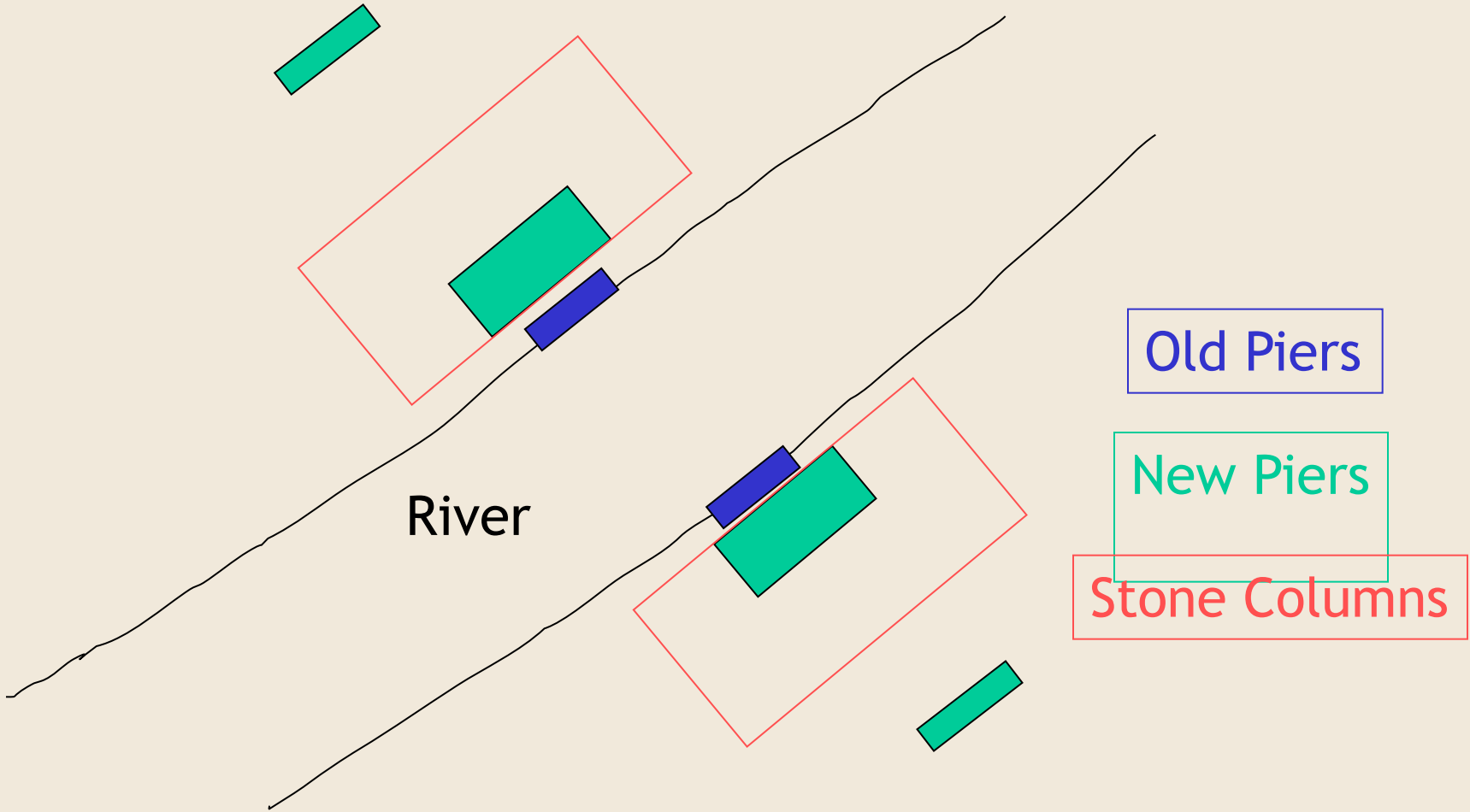


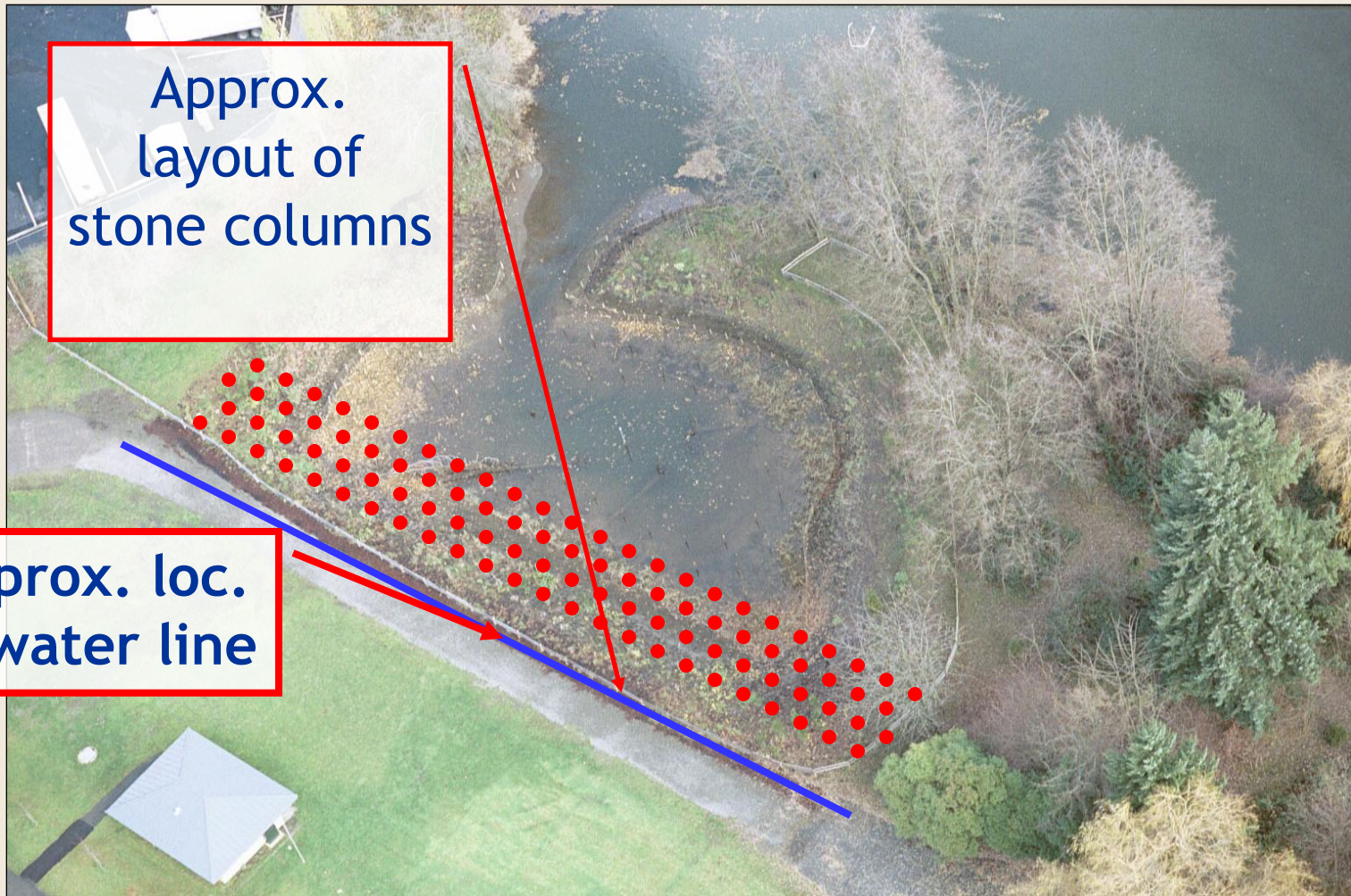
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Compaction Grouting





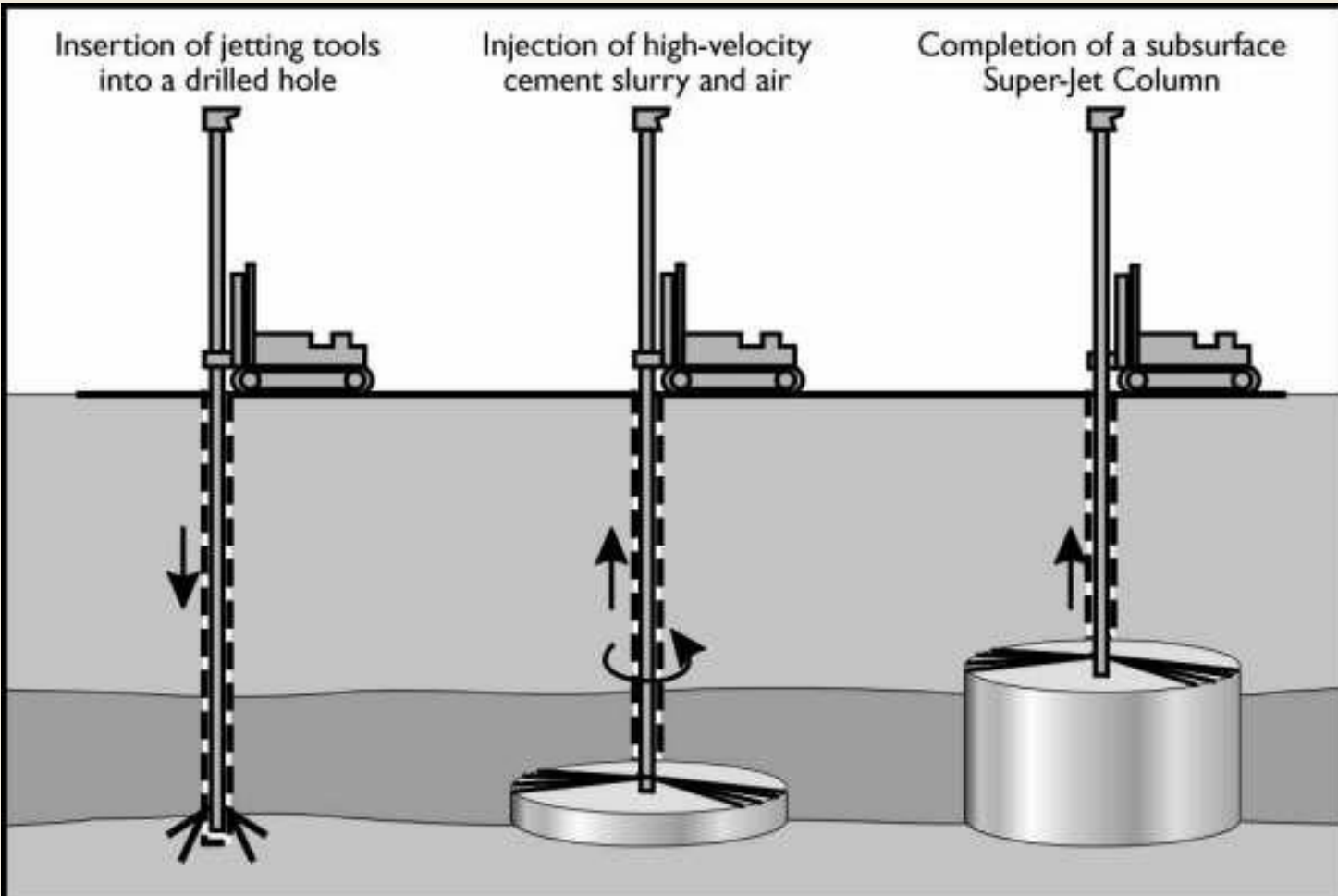




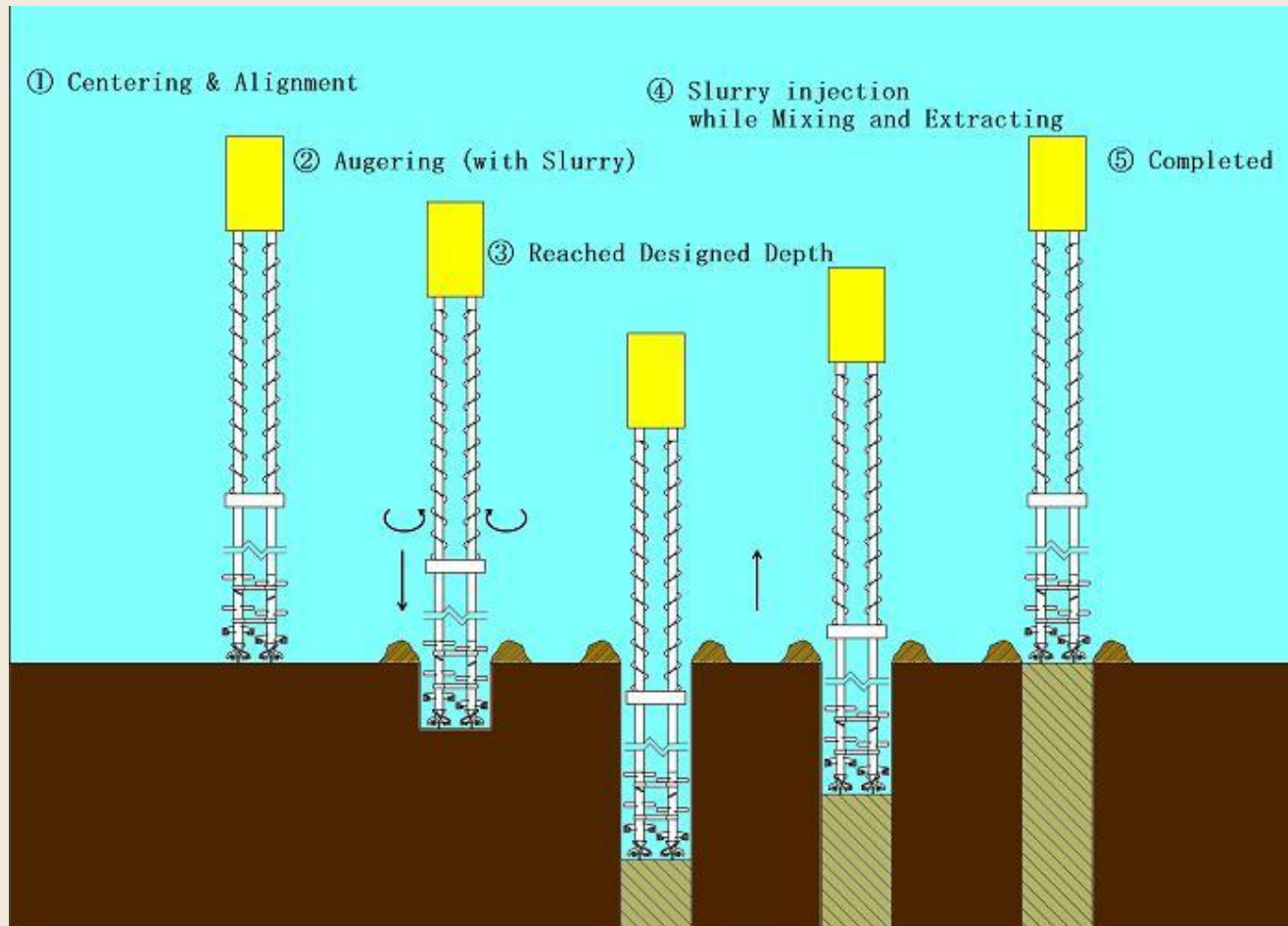
Soil Improvement Options

- Increase Cohesion
 - Deep soil mixing
 - Grouting
 - Permeation
 - Jet

Jet Grouting



Deep Soil Mixing





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Summary

- Provide Design Response Spectra
- Evaluate Potential Impacts
- Propose Mitigation Methods
- Work with Team to Select Preferred Mitigation Method



CHI-CHI EQ 1999

A 20-foot waterfall that
formed from fault rupture

Questions?