



U.S. Department of Energy
Office of Civilian Radioactive Waste Management



Proposed Ground Motions for Preclosure Seismic Design and Analysis

Presented to:

**Nuclear Waste Technical Review Board
Joint Meeting of the Natural System and
Engineered System Panels**

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Las Vegas, Nevada

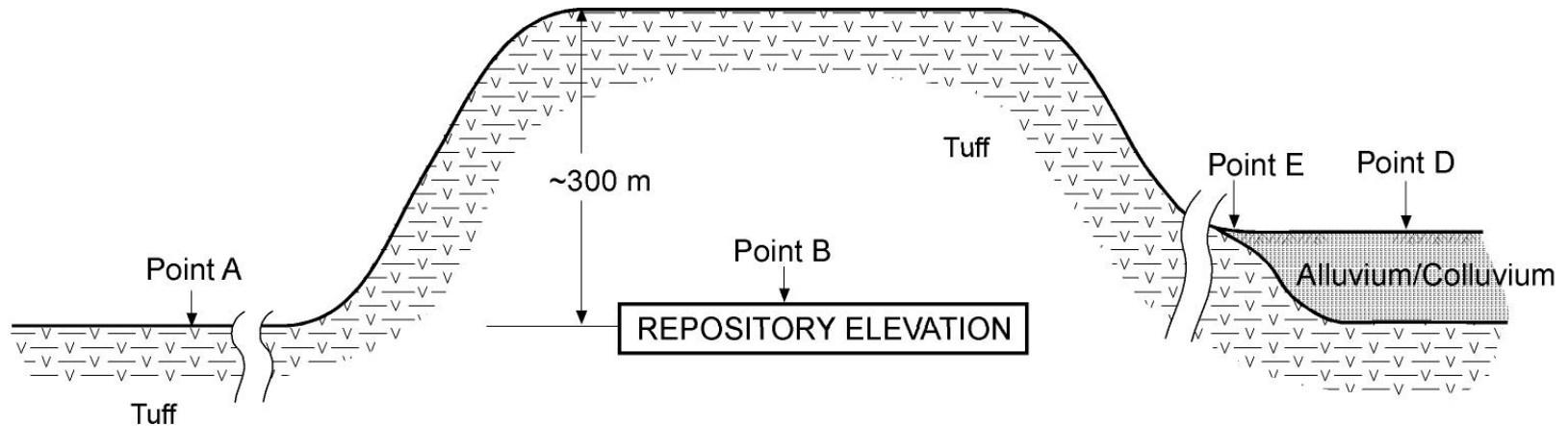
Objectives

Develop site-specific design ground motions for pre- and postclosure seismic analyses consistent with NUREG CR-6728

<i>Annual Exceedance Probability (AEP) (yr⁻¹)</i>	<i>Locations</i>	
	<i>Repository Block</i>	<i>Surface Facilities</i>
10⁻⁷	✓	
10⁻⁶	✓	
10⁻⁴	TBD	✓
5 x 10⁻⁴	✓	✓
10⁻³	TBD	TBD

TBD - To be determined

Locations of Specified Design Ground Motions



$V_s = 1900 \text{ m/sec}$

$K = 0.0186 \text{ sec}$

LEGEND

Point A - Reference rock outcrop at repository elevation

Point B - Repository elevation

Point D - Soil Surface at surface facilities site

Point E - Shallow soil/rock at surface facilities site

Scope of Work

- **Ground motions consist of:**

- **Two-component response spectra (H, V), 0.3 – 100.0 Hz (multiple dampings)**
- **Three-component time histories**
 - ◆ **Time histories selected from a subset of the NRC strong motion database**
 - ◆ **Preclosure, matched to design spectra NUREG / CR-6728**
 - » **Guidelines on component correlation, V/A and AD/V² ratios NUREG (CR-6728)**
- **Peak particle velocities (H=Horizontal, V=Vertical)**
- **Three-dimensional strains and curvatures versus depth**

Scope of Work

(Continued)

- **Design motion features**

- **Maintain consistency (hazard level) with rock outcrop Uniform Hazard Spectrum (UHS)**
- **Incorporate uncertainty and variability in site-specific dynamic material properties**

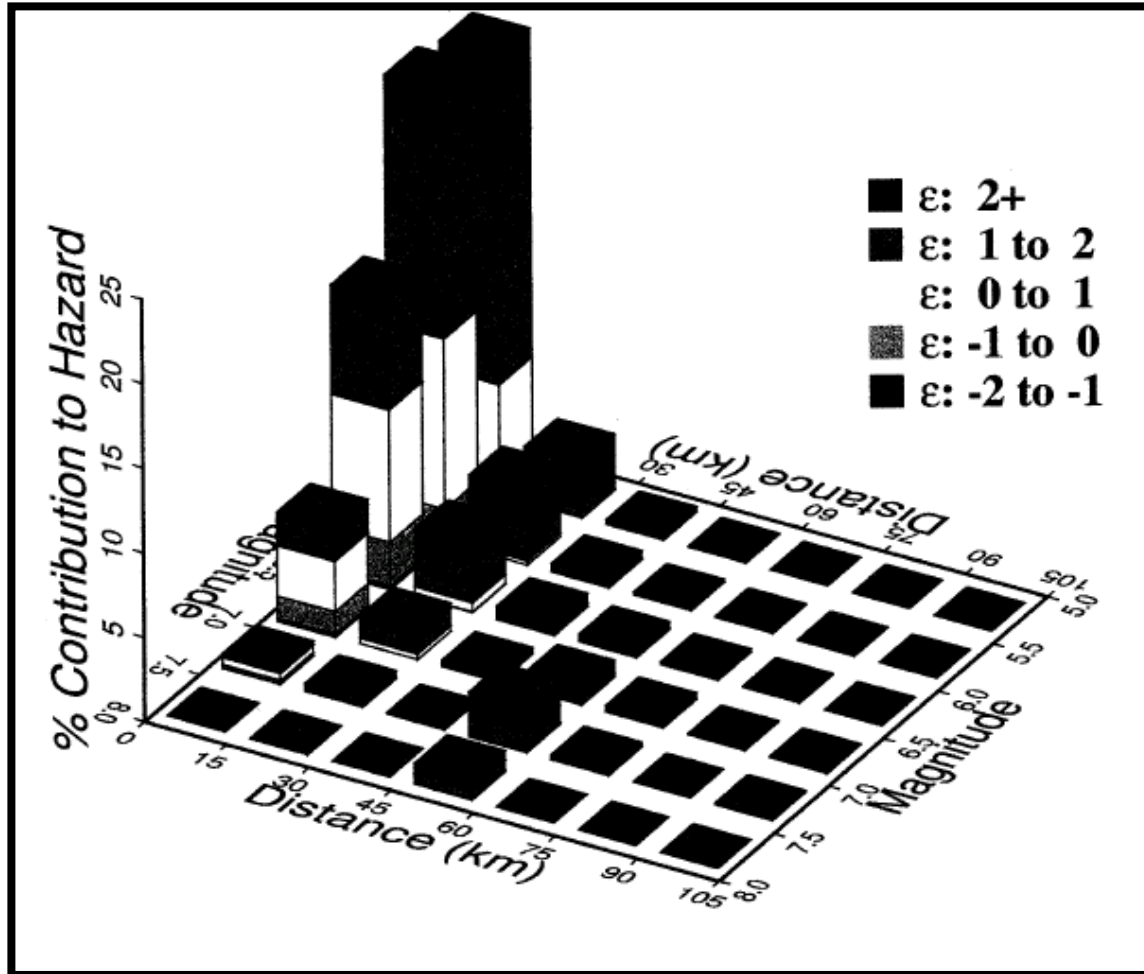
- **Issue (NUREG CR-6728)**

- **Site variability accommodated in rock UHS**
- **Double count site variability**
- **Overly conservative (unquantified)**

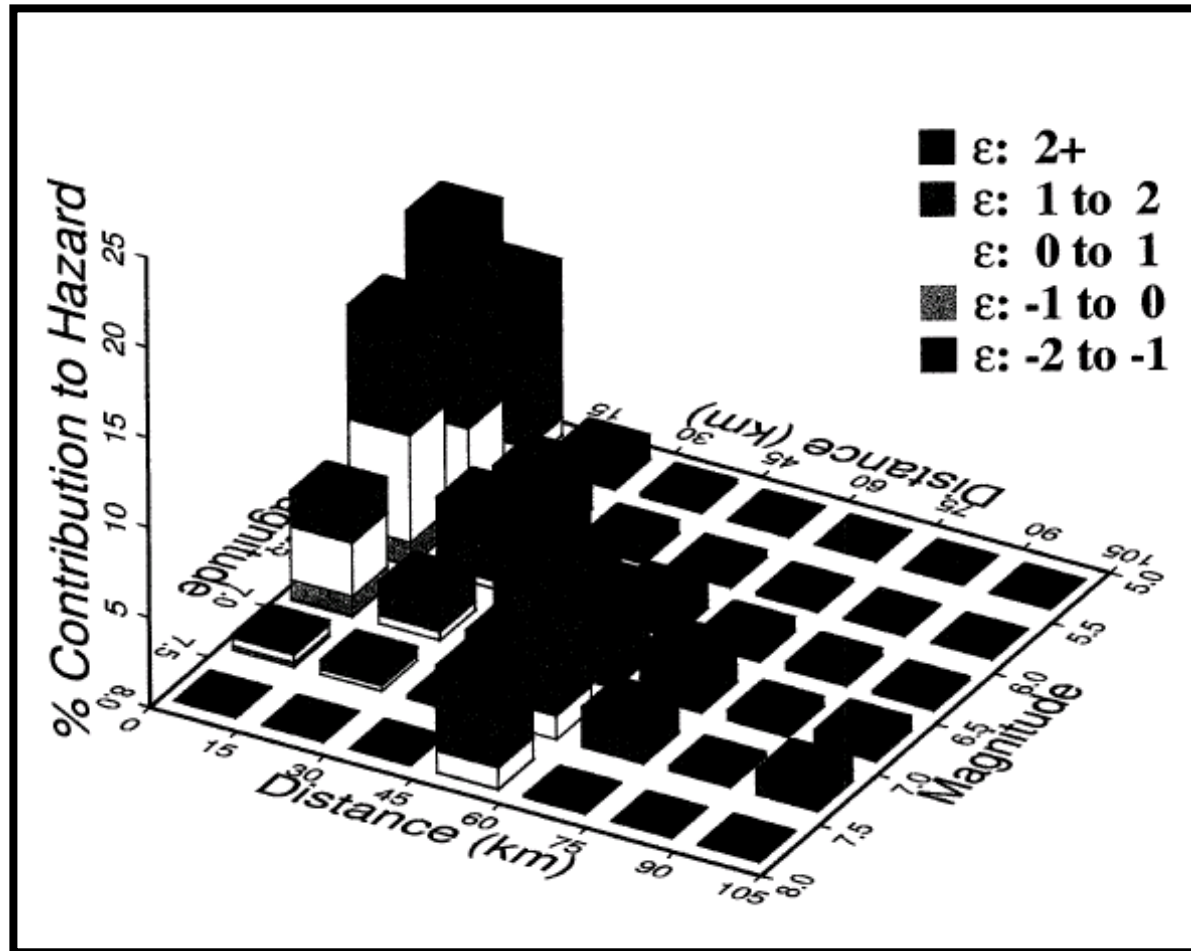
- **Desirable to accommodate magnitude distribution in rock UHS**

- **Include potential magnitude dependencies in nonlinearity**

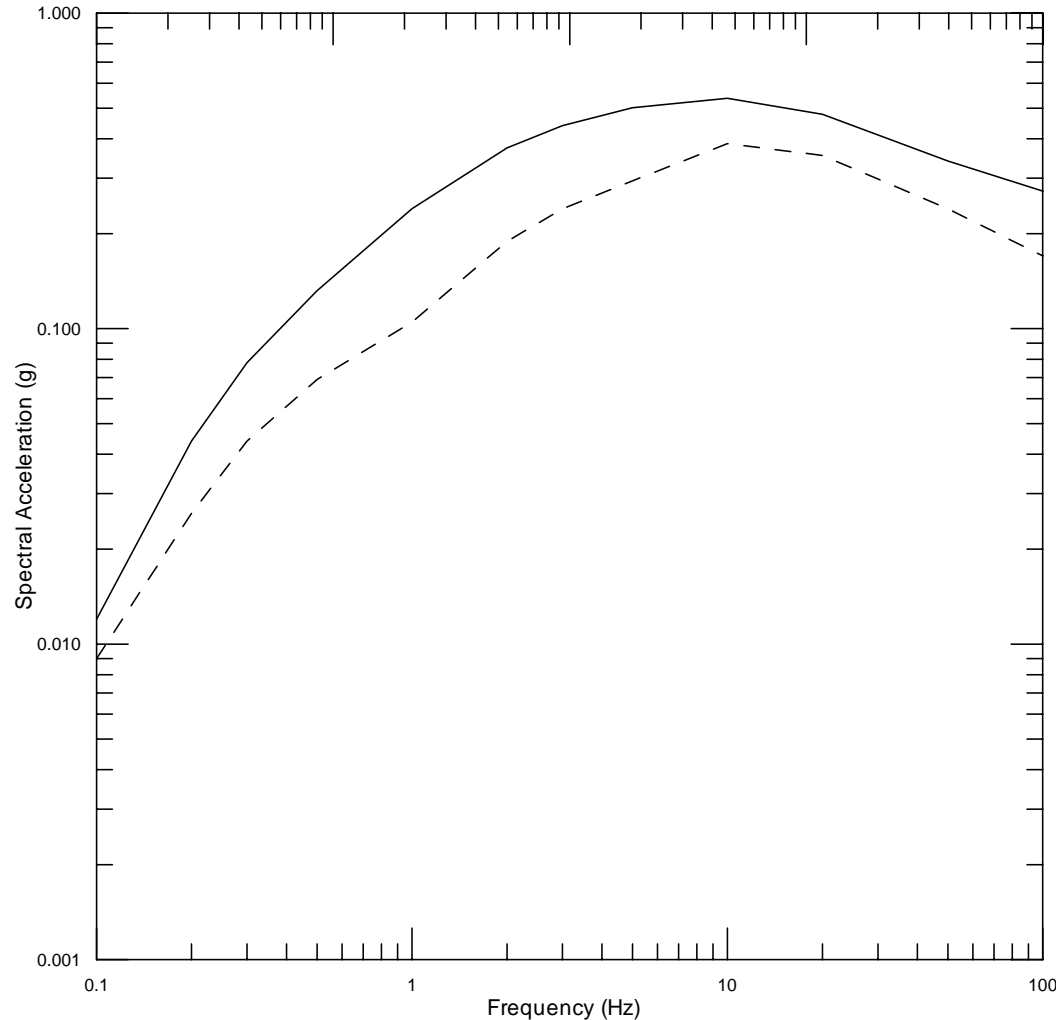
Annual Exceedence Probability 5×10^{-4} Hazard, 5-10 Hz Horizontal Deaggregation



Annual Exceedence Probability 5×10^{-4} Hazard, 1-2 Hz Horizontal Deaggregation

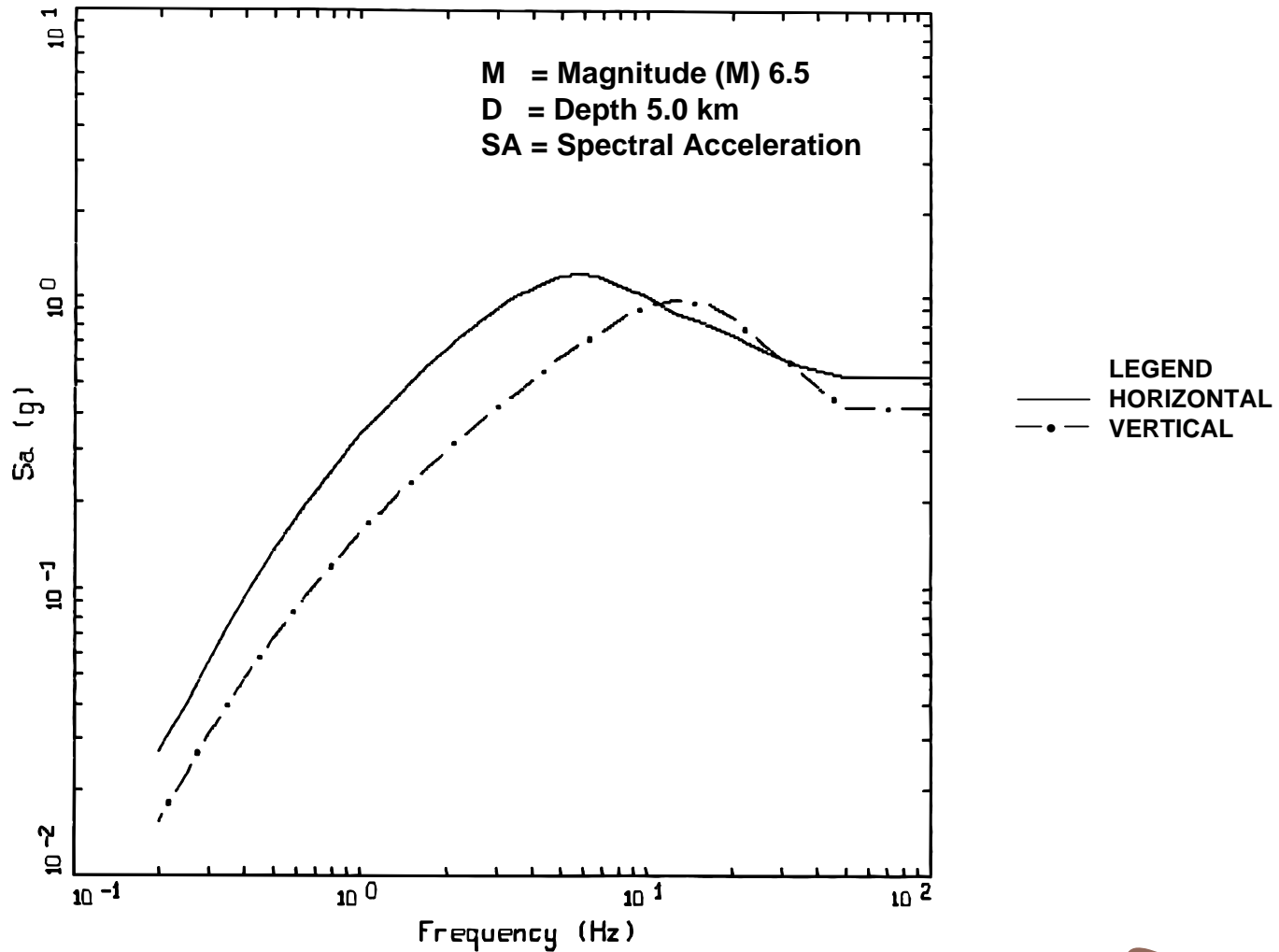


Annual Exceedence Probability 5×10^{-4} Point A Uniform Hazard Spectrum

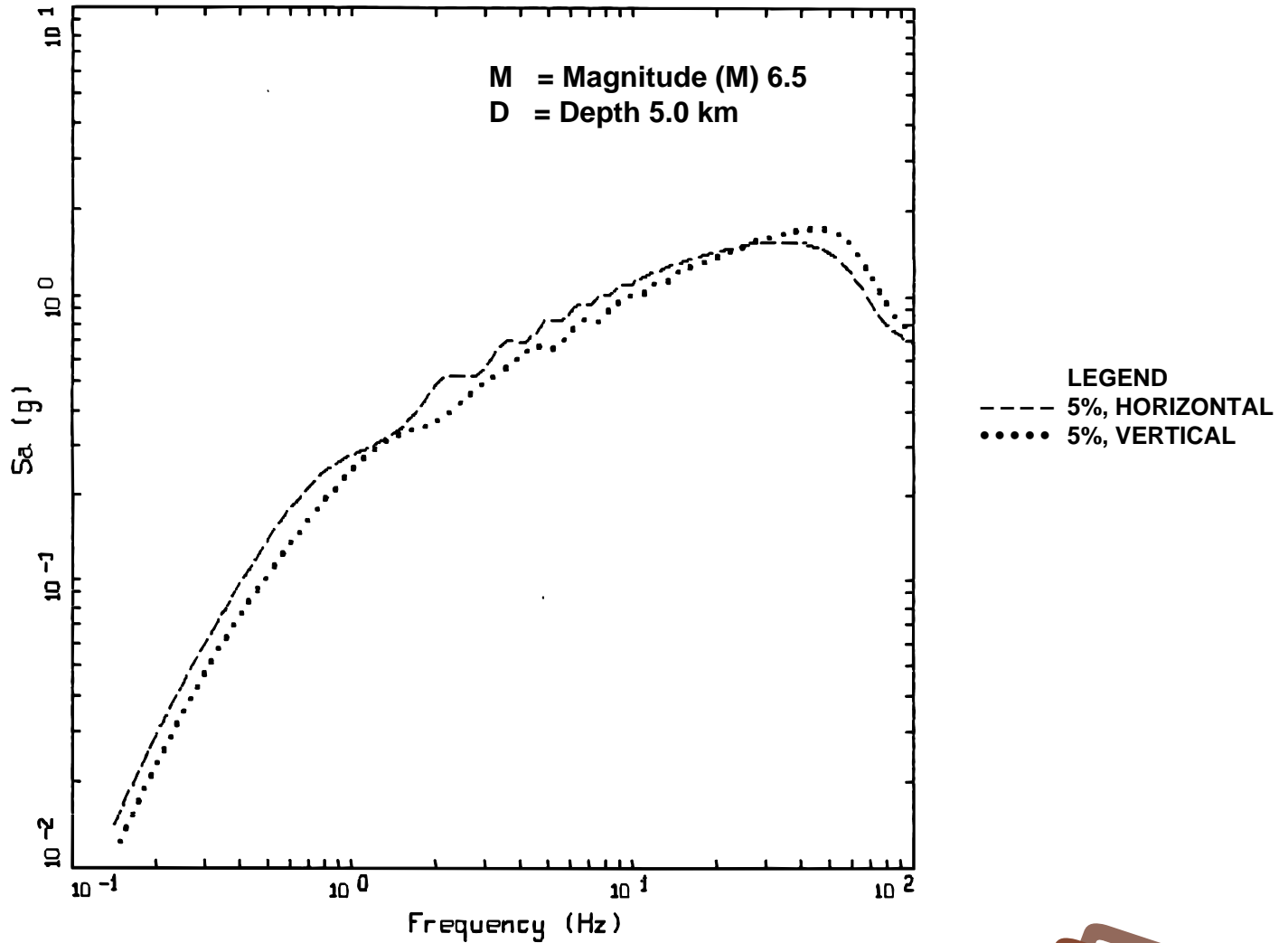


LEGEND
— HORIZONTAL, PEAK GROUND ACCELERATION (PGA) = 0.273 g (Acceleration due to gravity)
- - - VERTICAL, PGA = 0.170 g

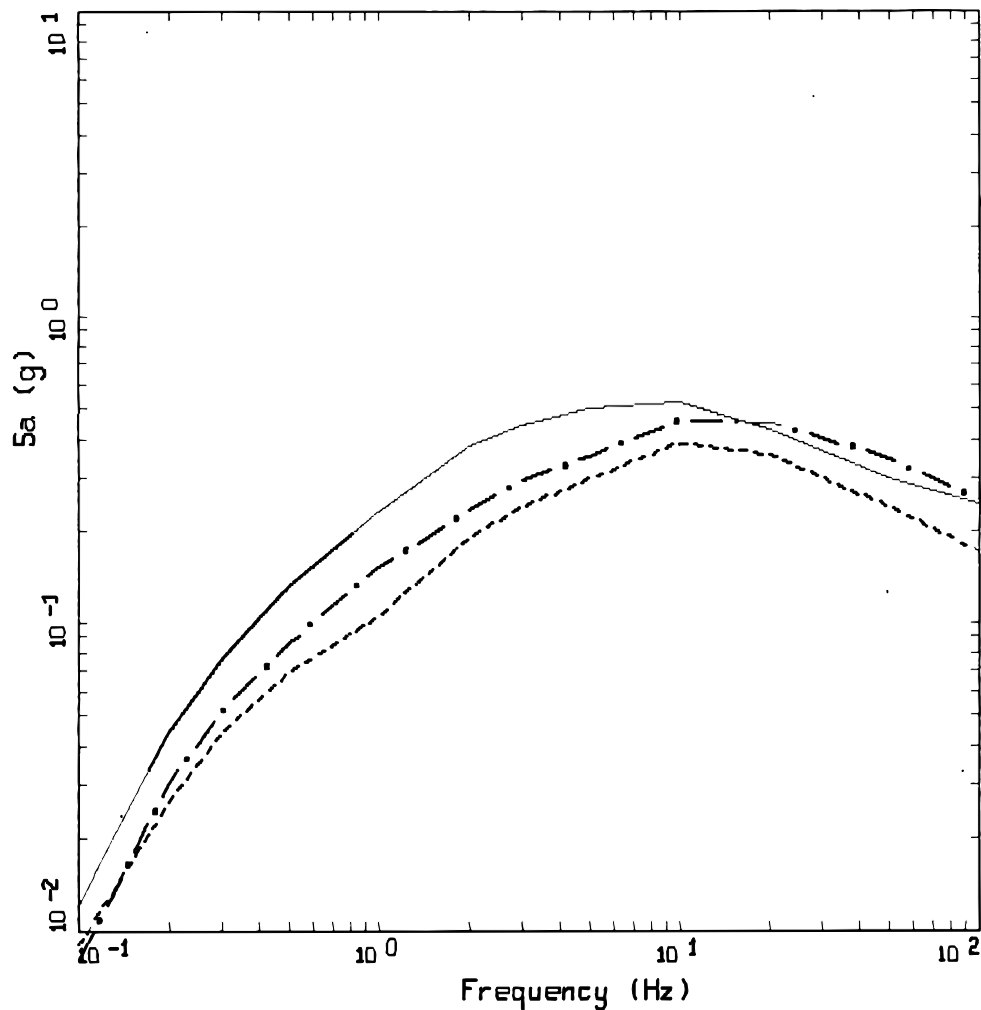
Western U.S. Horizontal and Vertical Spectra



Model Central and Eastern U.S. Rock

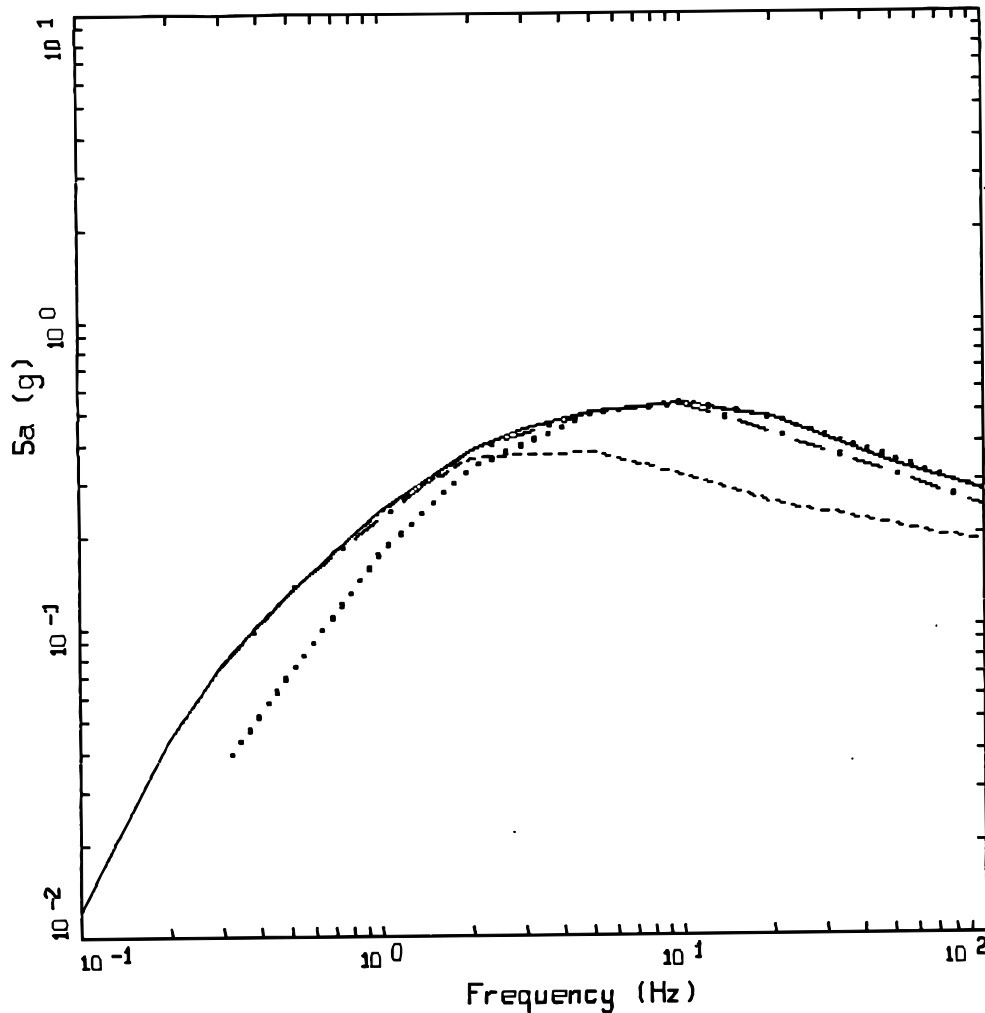


Revised Annual Exceedance Probability 5×10^{-4} Point A Vertical Spectrum



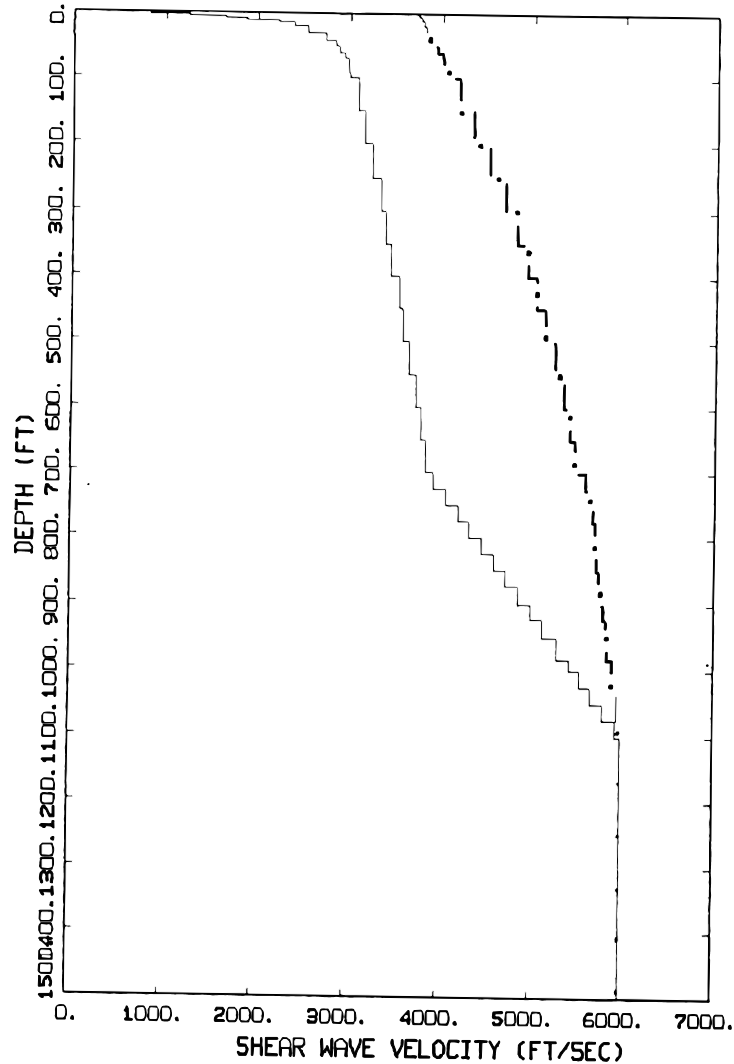
- LEGEND**
- HORIZONTAL UHS; PGA = 0.245 g
 - - - VERTICAL UHS; PGA = 0.170 g
 - REVISED VERTICAL; PGA = 0.254 g

Point A Annual Exceedence Probability 5×10^{-4} Horizontal Uniform Hazard Spectrum and Enveloped Spectrum



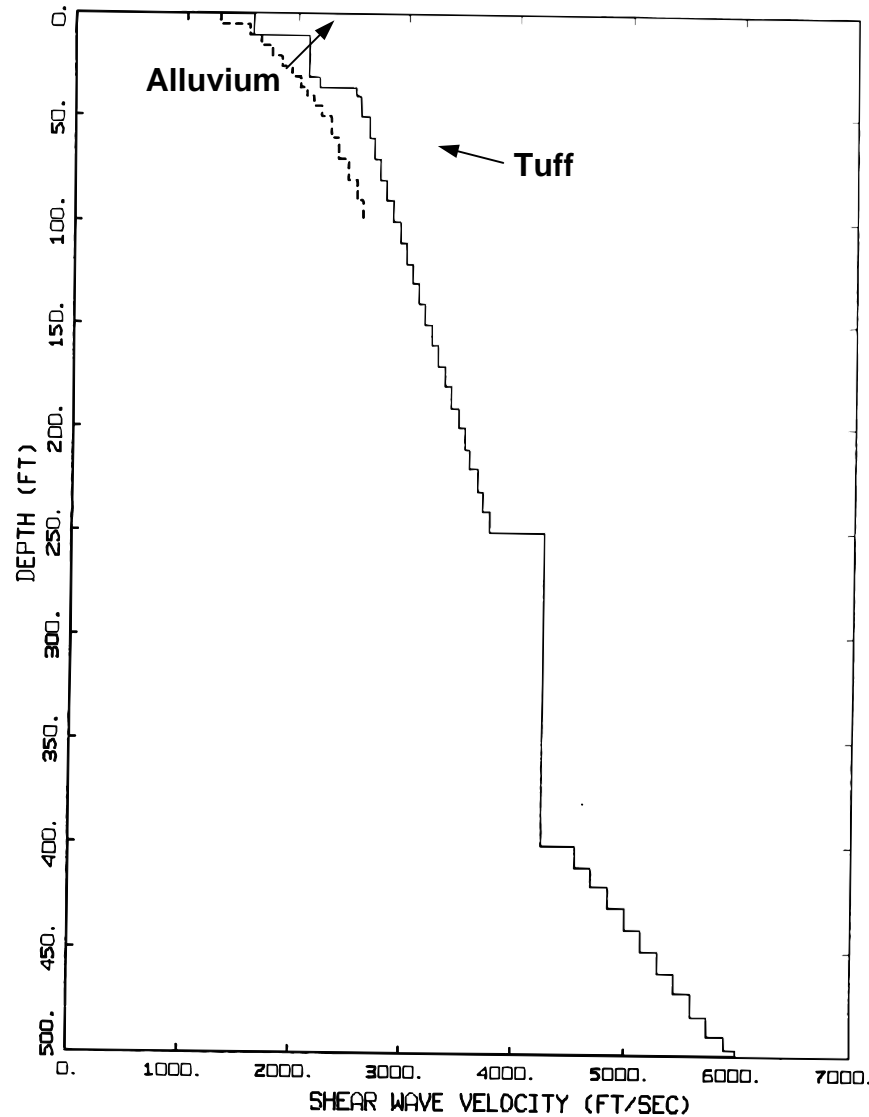
- LEGEND**
- • — UHS; PGA = 0.245 g
 - - - UHS 1-2 Hz; PGA = 0.186 g
 - UHS 5-10 Hz; PGA = 0.273 g
 - Enveloped UHS; PGA = 0.273 g

Repository Block Shear Wave Velocity Profile

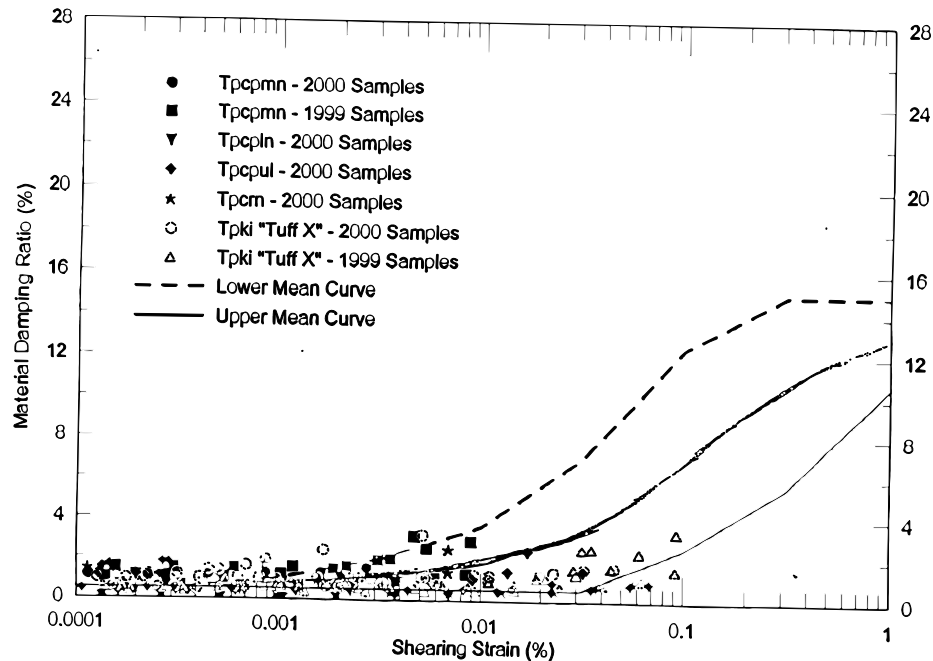
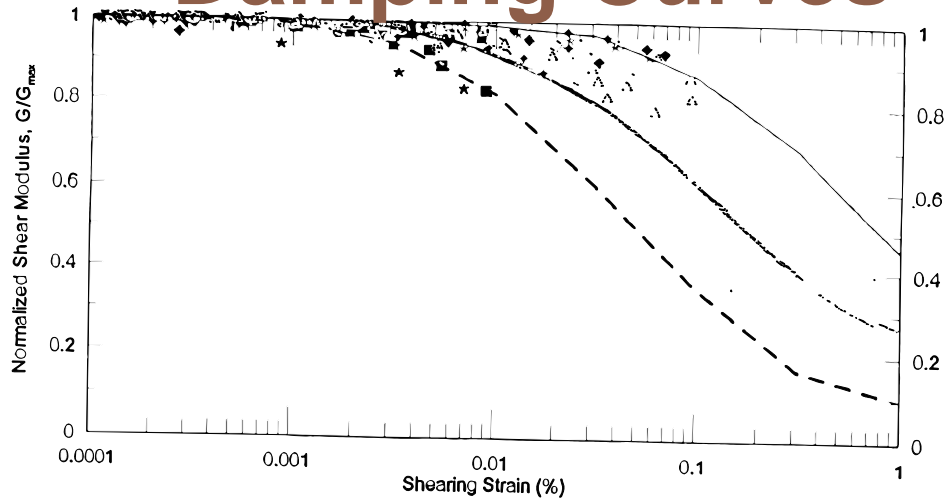


LEGEND
— BASE CASE #1
-•- BASE CASE #2

Surface Facilities Shear Wave Velocity Profiles - Alluvium and Tuff



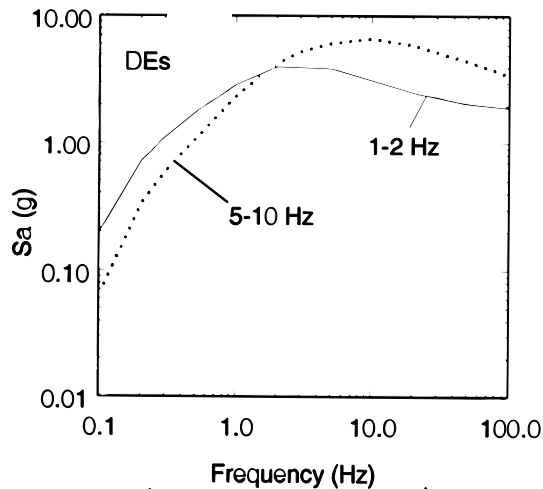
Tuff Shear Modulus Reduction and Damping Curves



Computational Models

- **Horizontal component**
 - Vertical and inclined horizontal component of shear wave (SH)
 - Equivalent-linear approximation to nonlinear response (rock, soil)
- **Vertical component**
 - Vertical and inclined incident P-waves
 - Inclined incident vertical component of shear wave (SV)
 - Linear analyses

Step 1



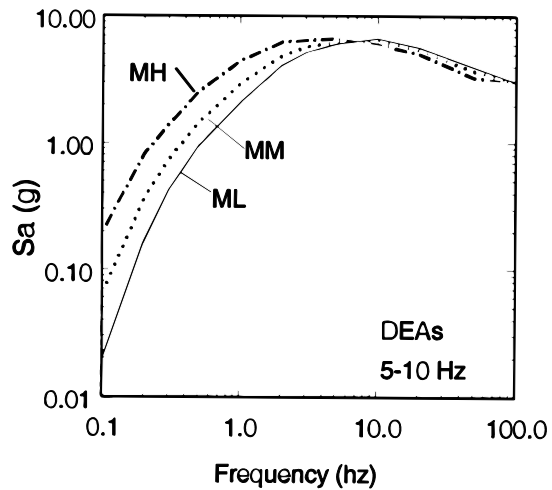
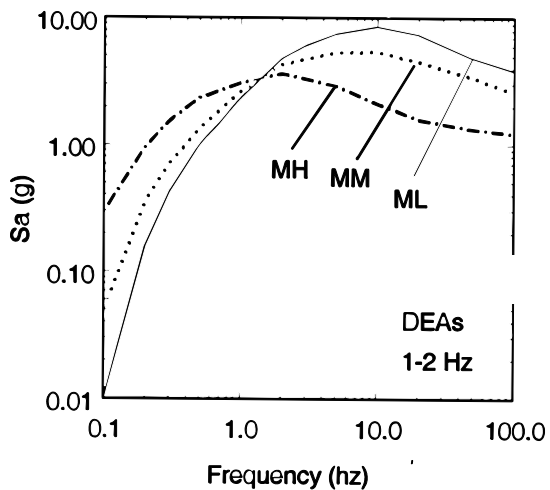
Reference Earthquakes

LEGEND

HM - High (95th percentile) Magnitude

MM - Medium (50th percentile) Magnitude

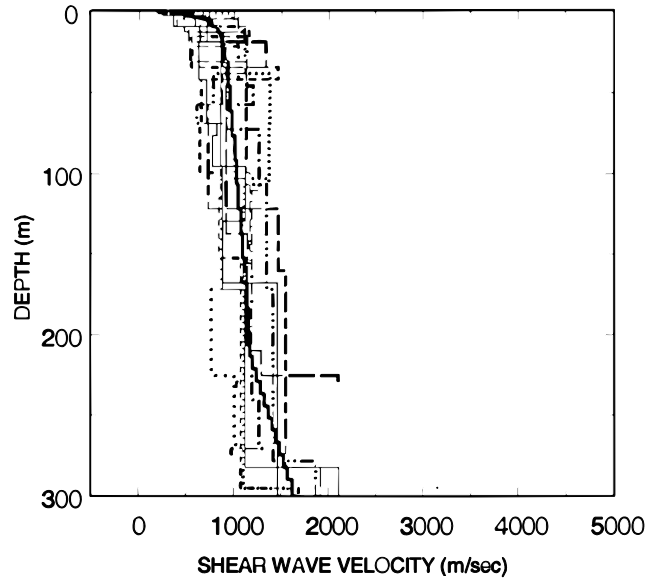
LM - High (5th percentile) Magnitude



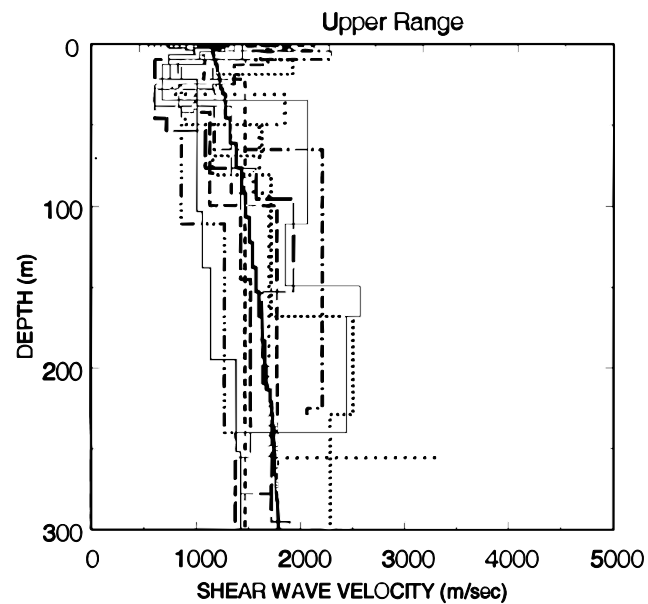
Deaggregation Earthquakes (DEA)



V_s Profile Randomization

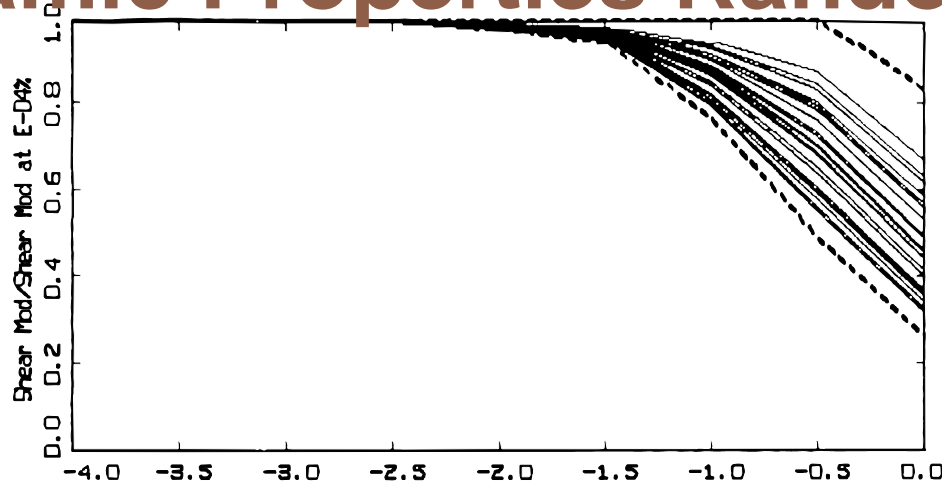


Base Case #1 (BC)

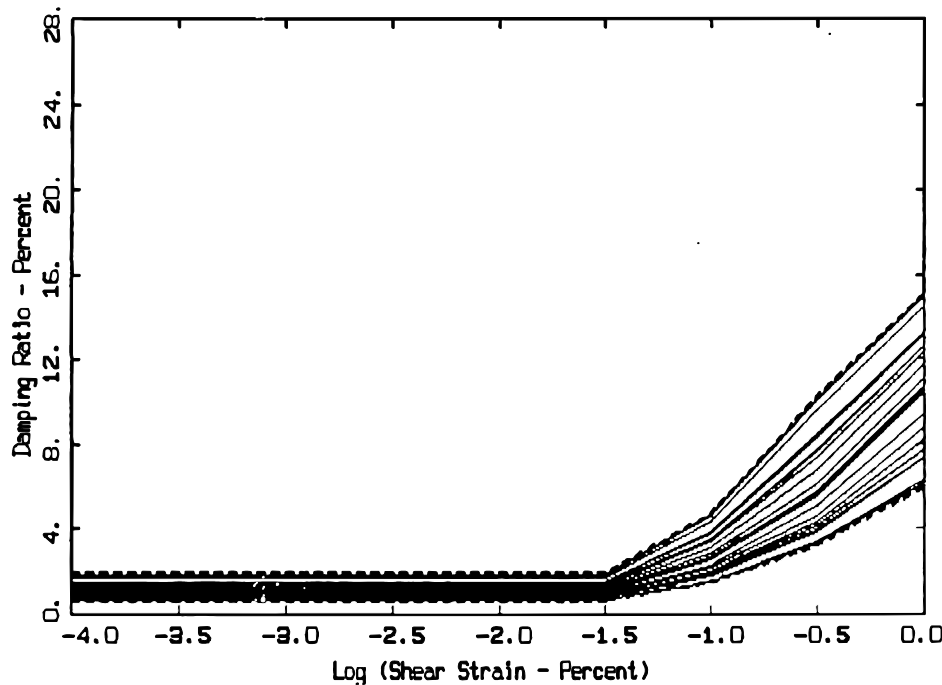


Base Case #2 (UR)

Dynamic Properties Randomization



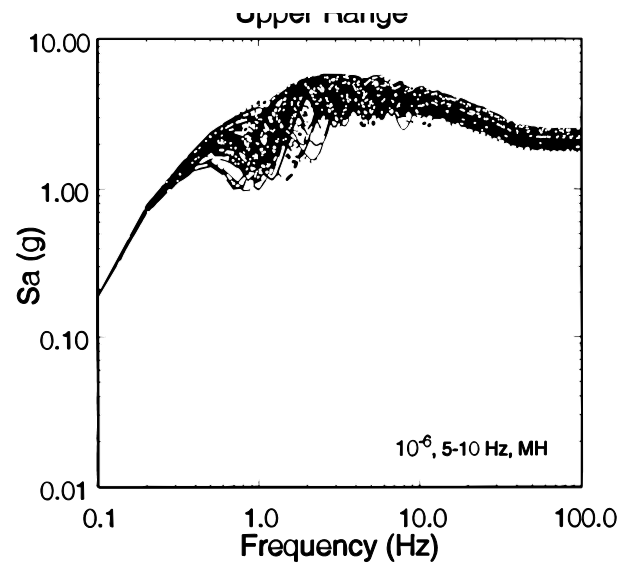
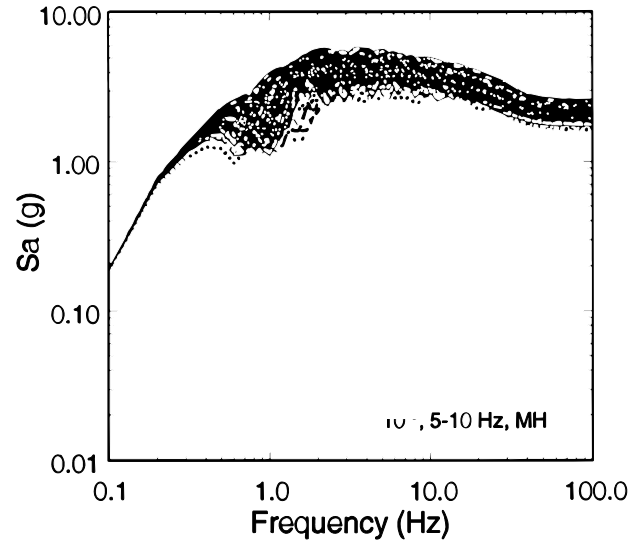
Shear Modulus Reduction



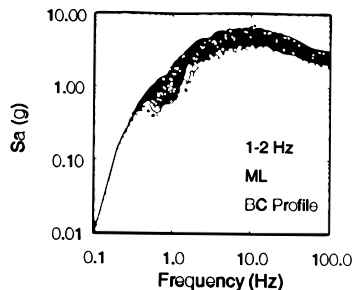
Damping



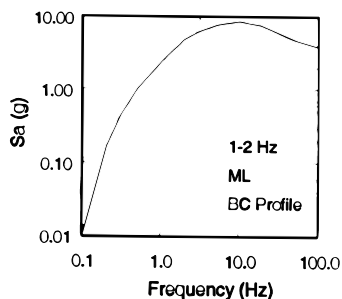
Step 2



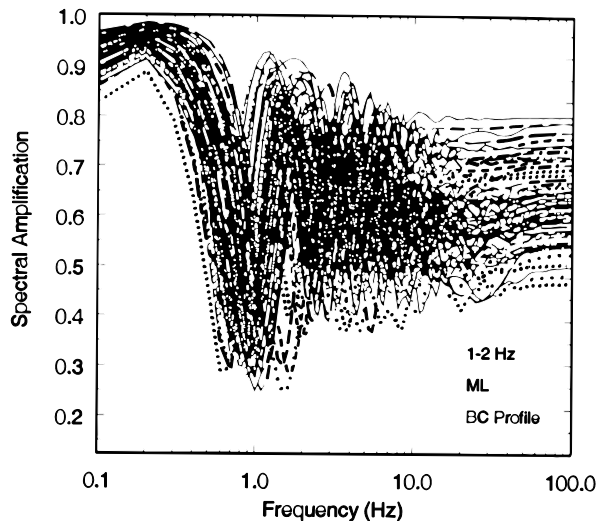
Step 3



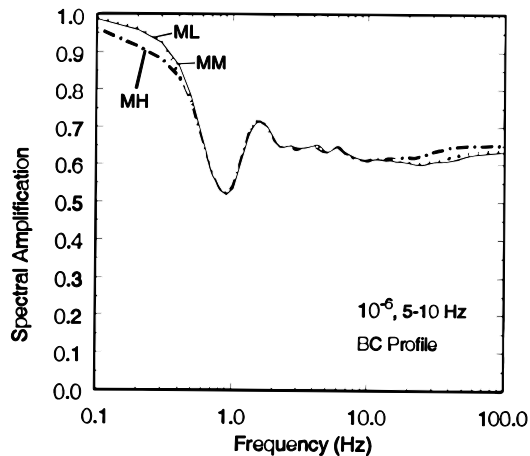
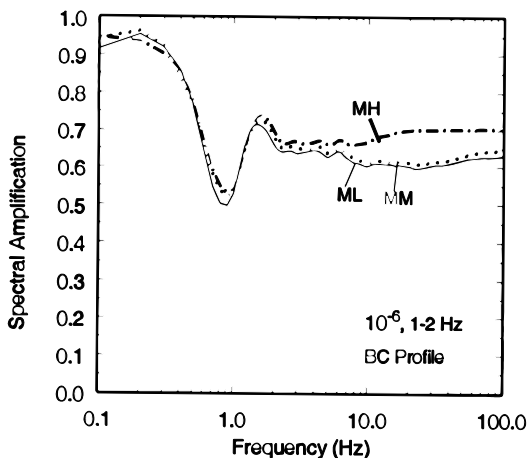
SAF =



=

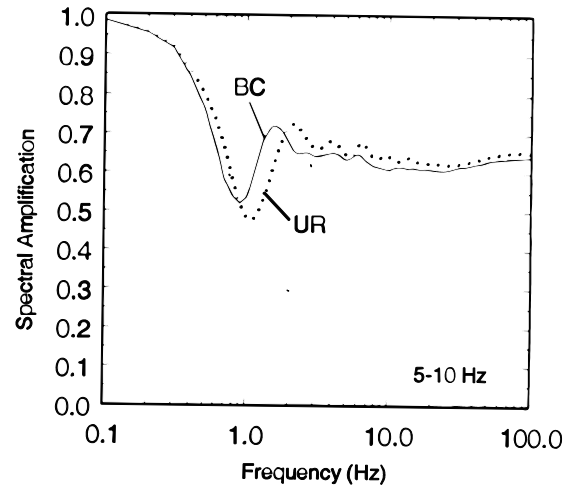
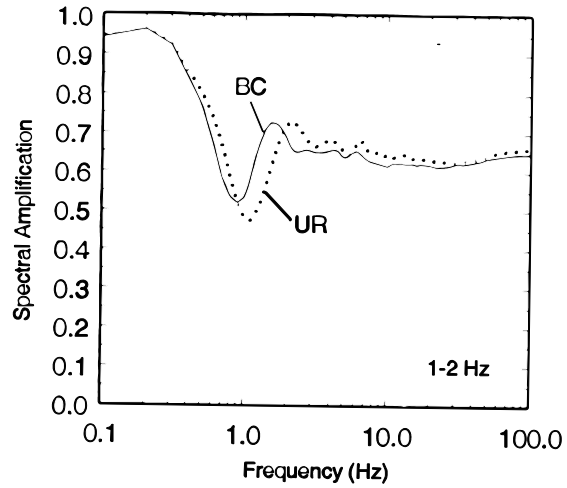


Compute for each DEA the ratio of 60 tuff outcrop responses to the reference rock outcrop control motion

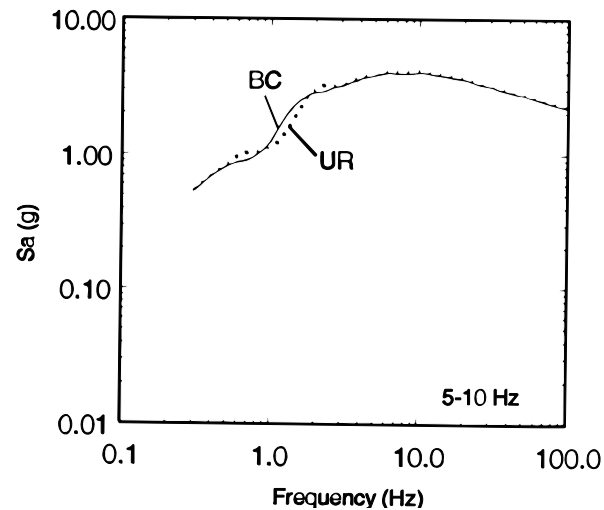
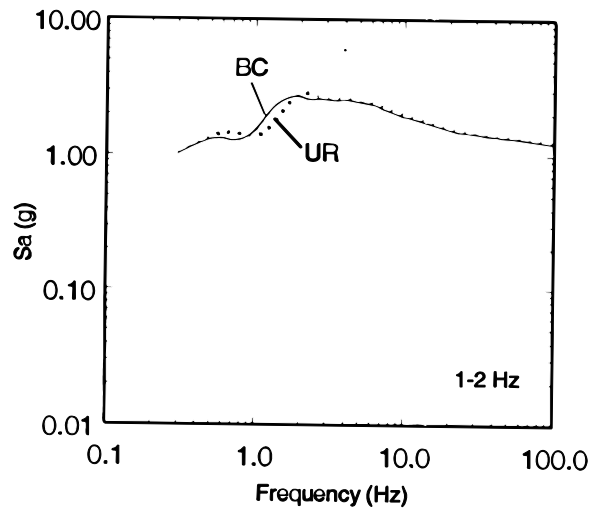


Compute the mean spectral amplification function (SAF) for all DEAs and base case profiles (MM, ML, and MH are Mmean, M5th, and M95th DEAs)

Step 4

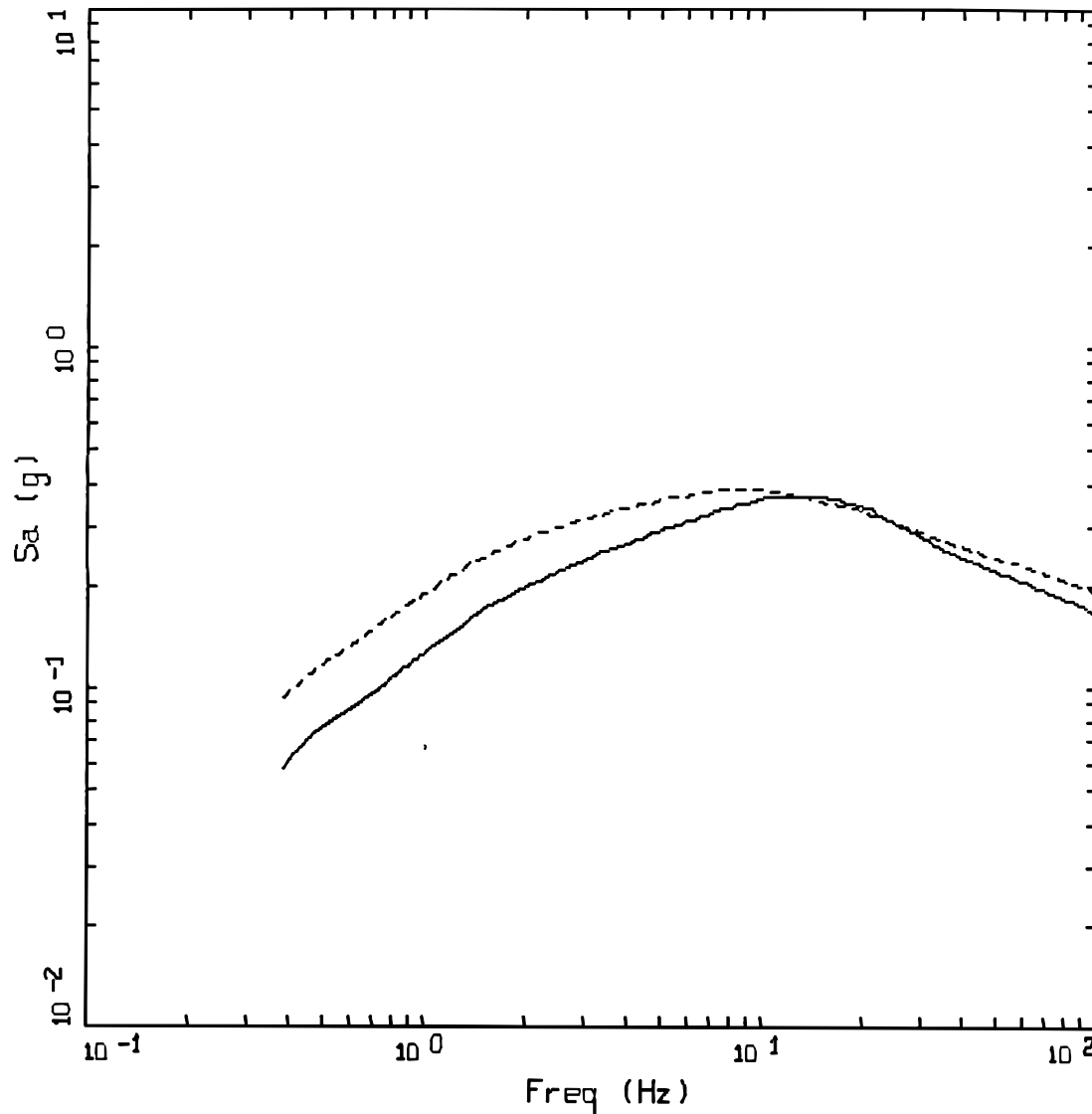


Combine DEA mean Spectral Amplification Functions (SAFs) using weighted average



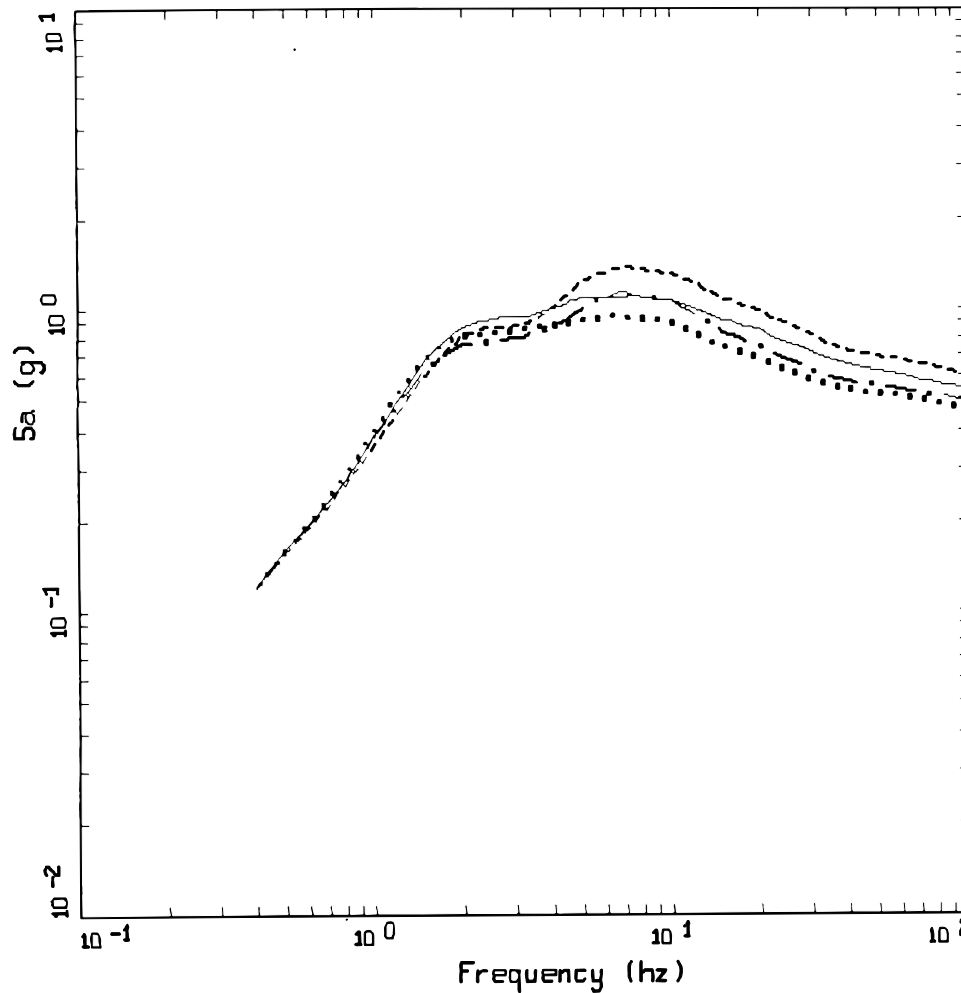
Apply magnitude-weighted mean SAF to the Reference Earthquake rock outcrop spectra

Repository AEP 5×10^{-4} Design Spectra



LEGEND
— VERTICAL, PGA = 0.165
- - - HORIZONTAL, PGA = 0.191

Surface Facilities AEP 5×10^{-4} 30 Ft Alluvium



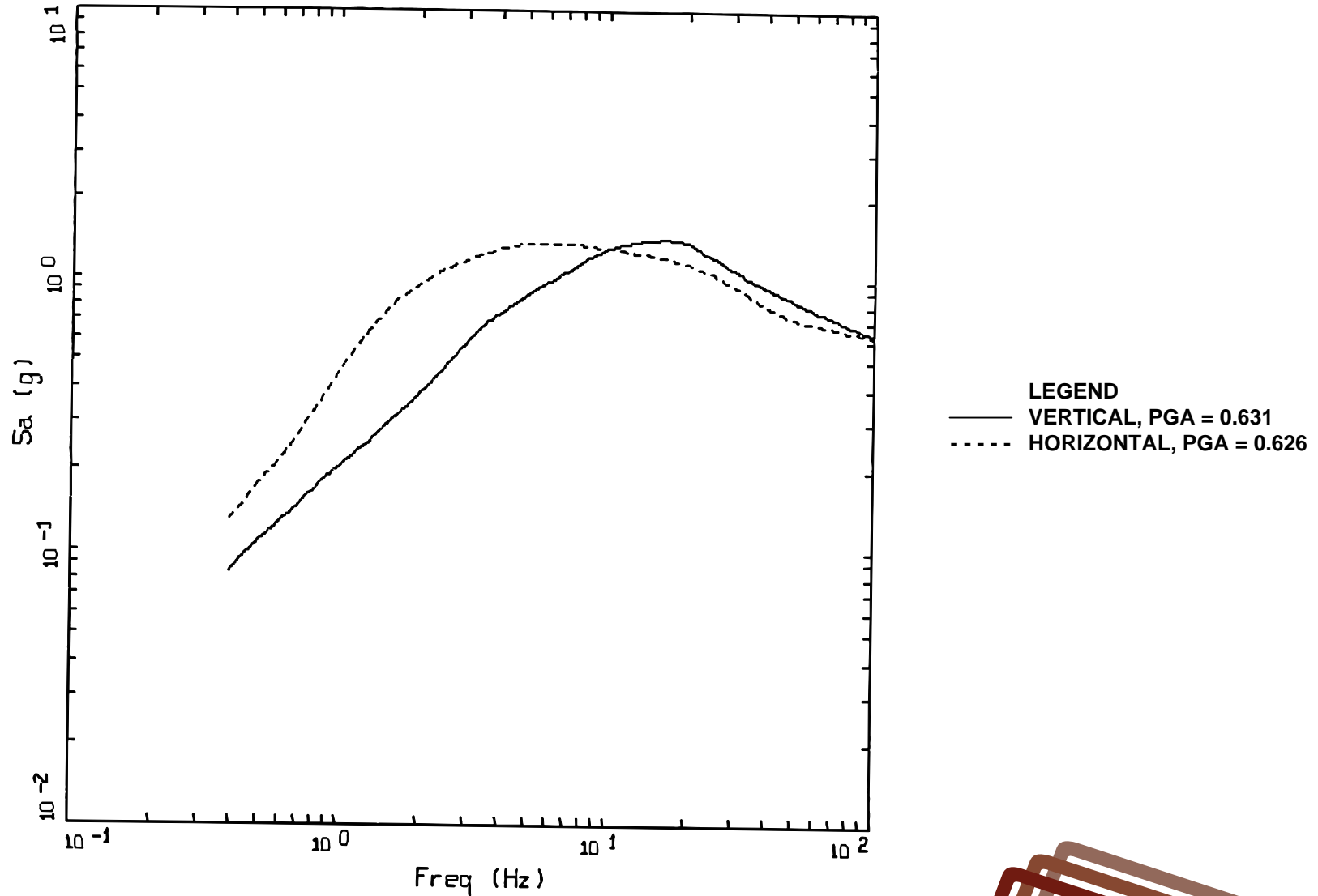
LEGEND

- HSHH, LMT, UMA
- HSHH, LMT, UMA
- HSHH, UMT, LMA
- HSHH, LMT, LMA

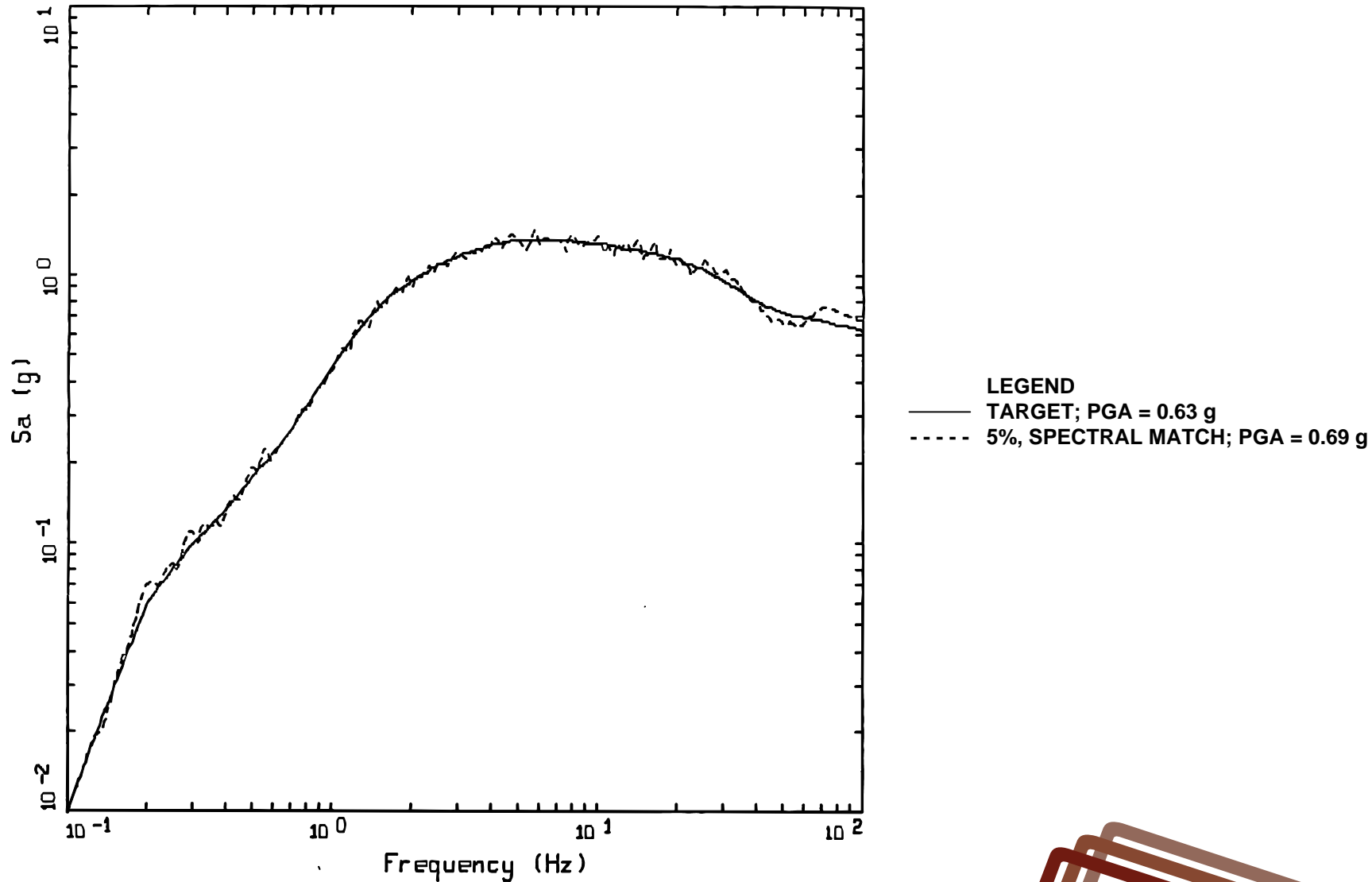
Wave Type Horizontal SH
Shear Modulus Reduction and
Dam Curves

LMT - Lower Mean Tuff
UMT - Upper Mean Tuff
LMA - Lower Mean Alluvium
UMA - Upper Mean Alluvium

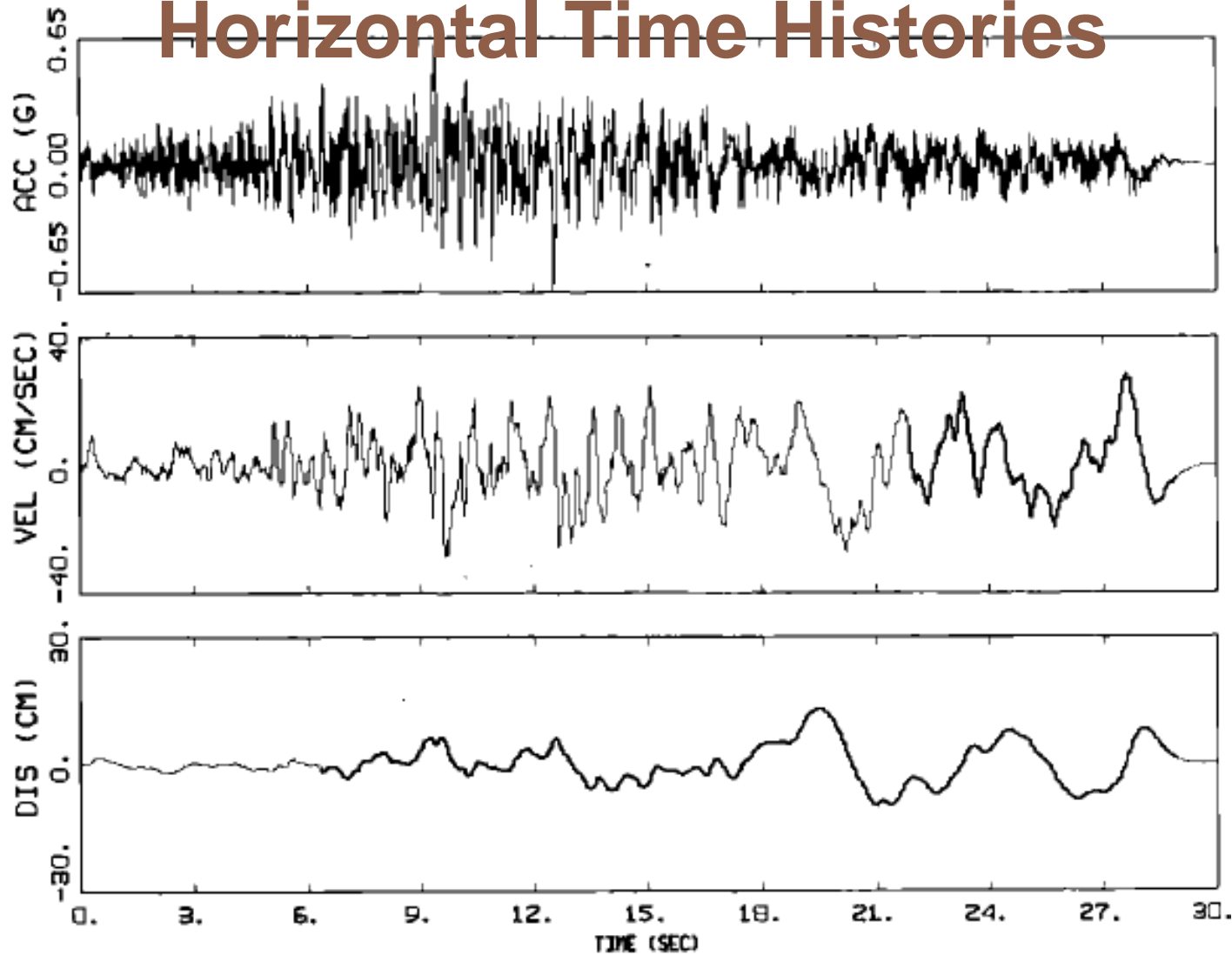
Surface Facilities AEP 5×10^{-4} Design Spectra



Surface Facilities Spectral Match AEP 5×10^{-4} Horizontal



Surface Facilities AEP 5×10^{-4} Horizontal Time Histories



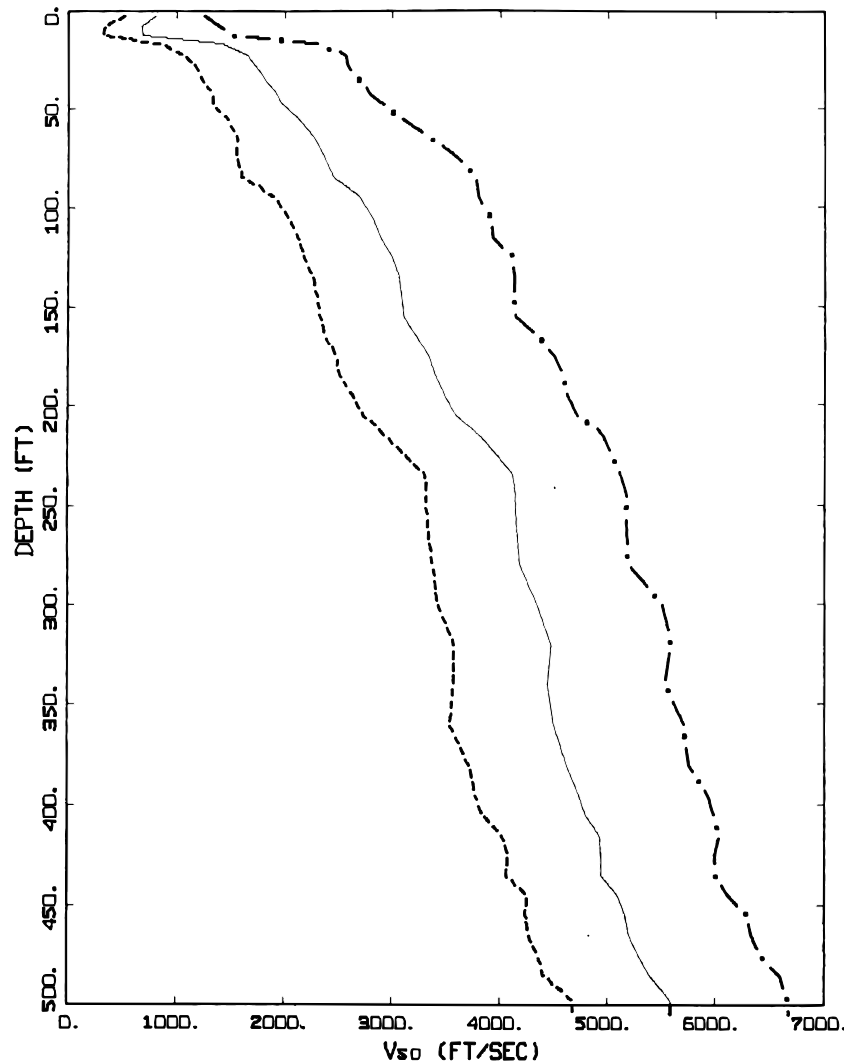
LEGEND

ACC = Acceleration

VEL = Velocity

DIS = Displacement

AEP 5×10^{-4} Strain-Compatible V_s Profile



LEGEND
— • — 94th PERCENTILE
— — — MEDIAN
- - - 16th PERCENTILE

Summary

Computed AEP 5×10^{-4} preclosure ground motions – design response, time histories, strains and curvatures versus depth, and surface facilities strain-compatible properties

<i>AEP 5×10^{-4}</i>	<i>Horizontal PGA</i>	<i>Vertical PGA</i>
Repository	0.19 g	0.17 g
Surface Facilities	0.63 g	0.63 g

Backup



Deaggregation

$5 \times 10^{-4} / \text{yr}$		
	1 – 2.5 Hz	5 – 10 Hz
M	5.3, 6.4, 7.6 (7.0)	5.1, 5.9, 7.1 (6.3)
D (km)	1, 19, 71 (51)	1, 9, 5 (5)
ε	1.6, 1.6, 1.6	1.3, 1.3, 1.3

$10^{-6} / \text{yr}$		
	1 – 2.5 Hz	5 – 10 Hz
M	5.2, 6.4, 7.8 (7.7)	5.4, 6.2, 7.0 (6.5)
D (km)	1, 4, 59 (51)	1, 4, 11 (1)
ε	2.6, 2.6, 2.6	2.7, 2.7, 2.7

$10^{-4} / \text{yr}$		
	1 – 2.5 Hz	5 – 10 Hz
M	5.2, 6.4, 7.8 (7.7)	5.2, 6.0, 7.1 (6.3)
D (km)	5, 20, 74 (52)	5, 10, 15 (5)
ε	2.1, 2.1, 2.1	0.9, 0.9, 0.9

$10^{-7} / \text{yr}$		
	1 – 2.5 Hz	5 – 10 Hz
M	5.2, 6.4, 7.8 (7.7)	5.5, 6.3, 7.0 (6.5)
D (km)	1, 4, 51 (51)	1, 4, 9 (1)
ε	2.8, 2.8, 2.8	2.5, 2.5, 2.5

M = Magnitude D = Depth ε = Residual Logarithmic Deviation

Recommended V/H Ratios

