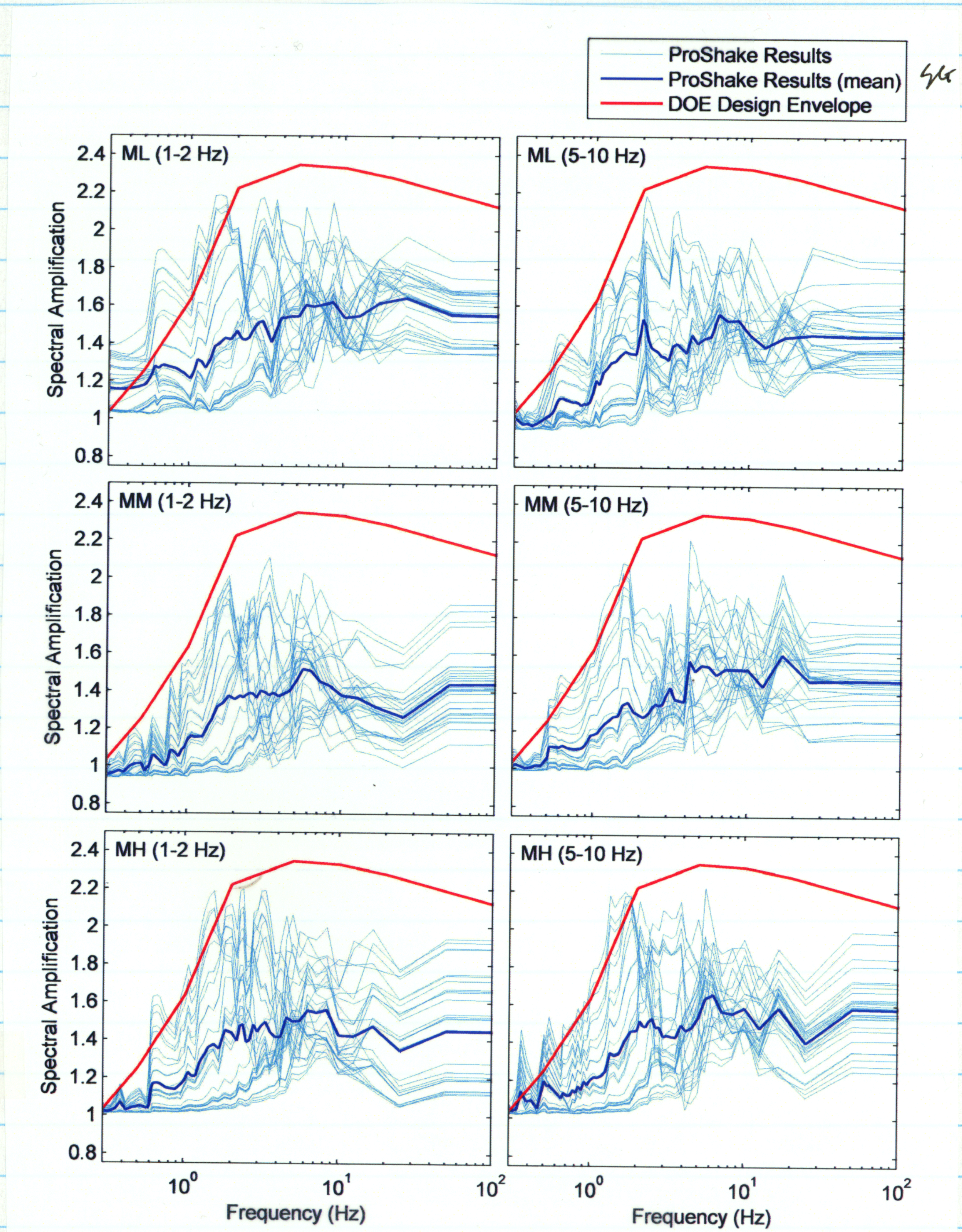

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FIGURE 9. PROSHAKE RESULTS FOR LINEAR MATERIAL PROPERTIES (0.5% MATERIAL DAMPING)

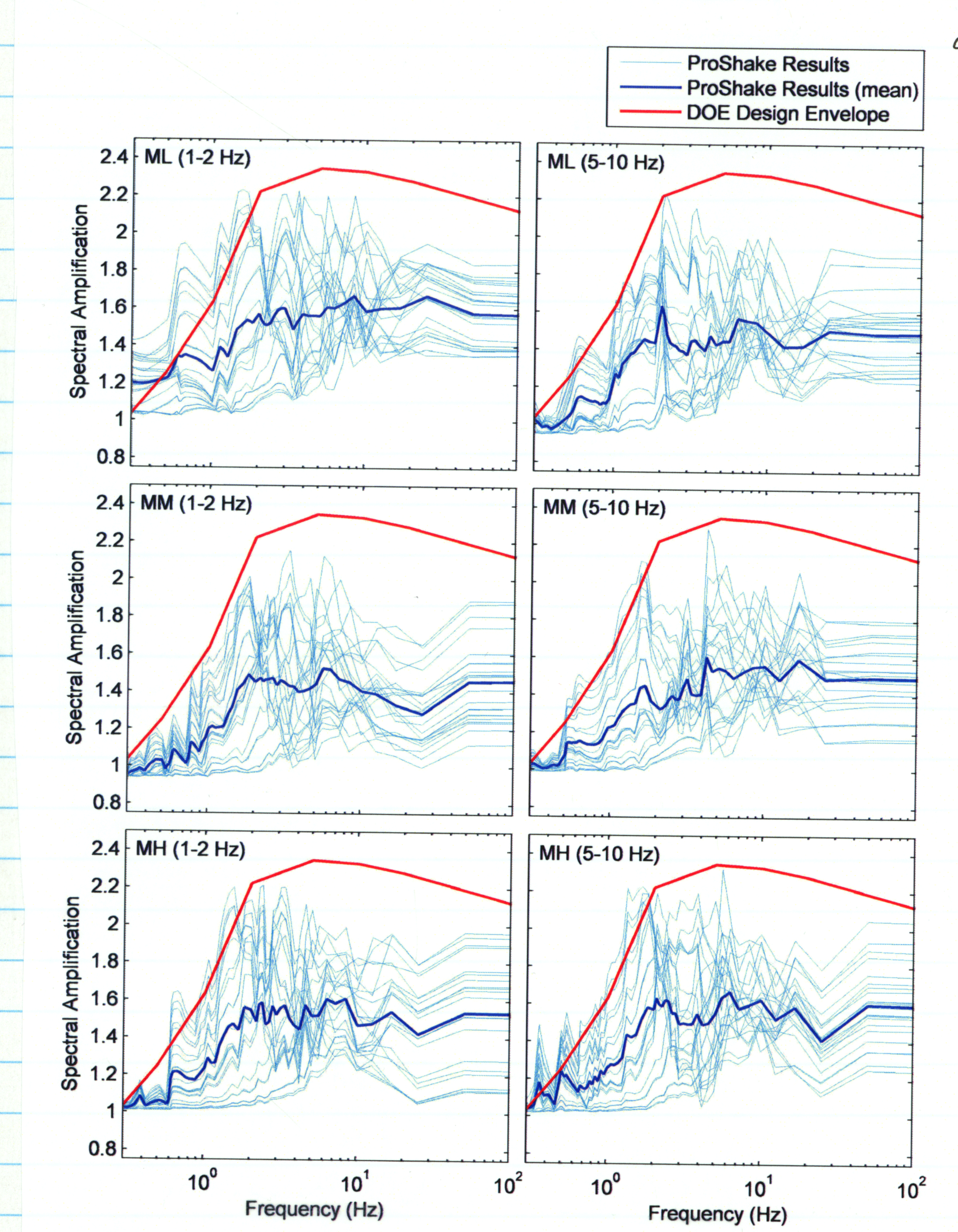

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FIGURE 10. PROSHAKE RESULTS FOR UPPER MEAN TUFF AND UPPER MEAN ALLUVIUM

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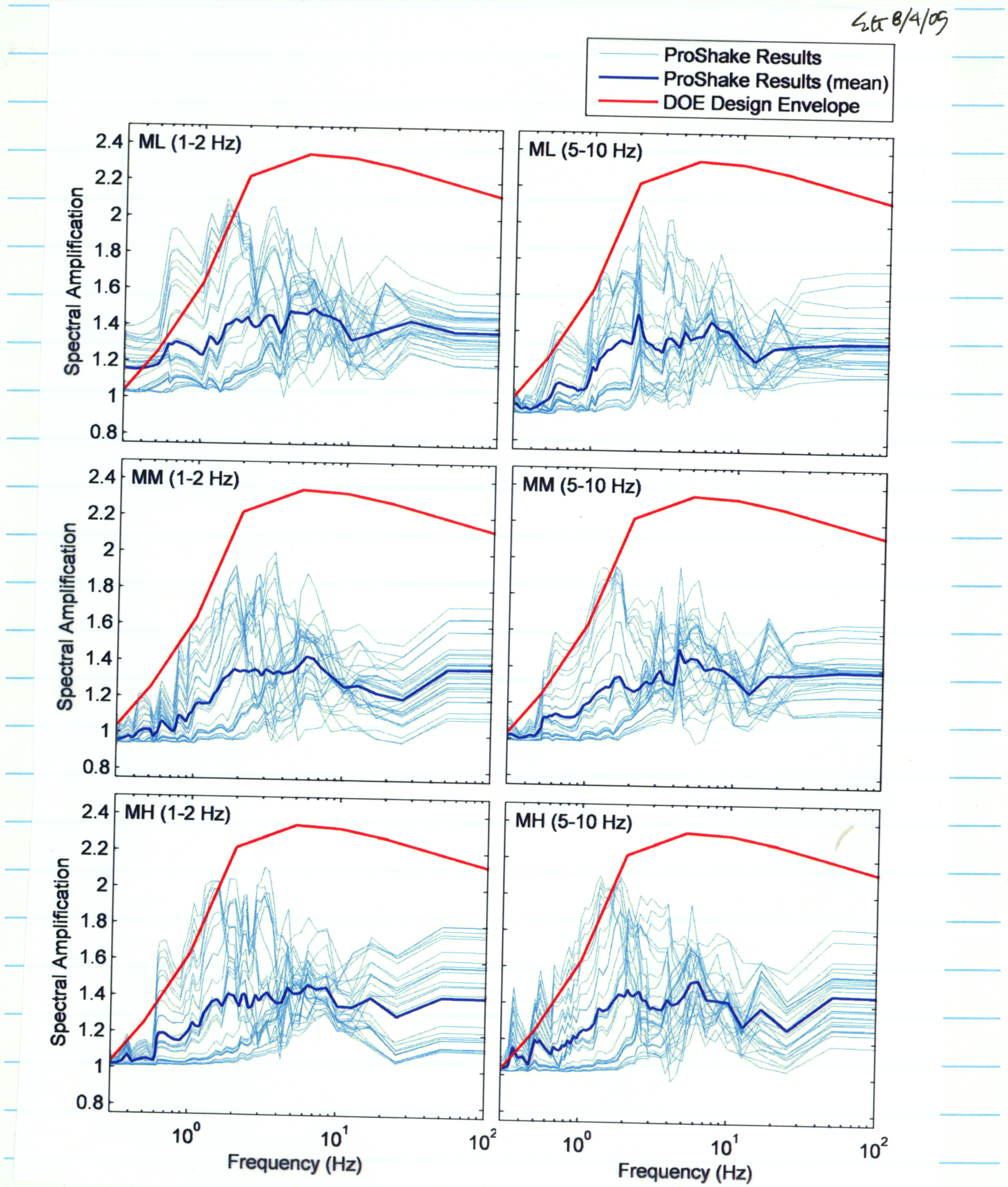

FIGURE 11. PROSHAKE RESULTS FOR LOWER MEAN TUFF AND UPPER MEAN ALLUVIUM

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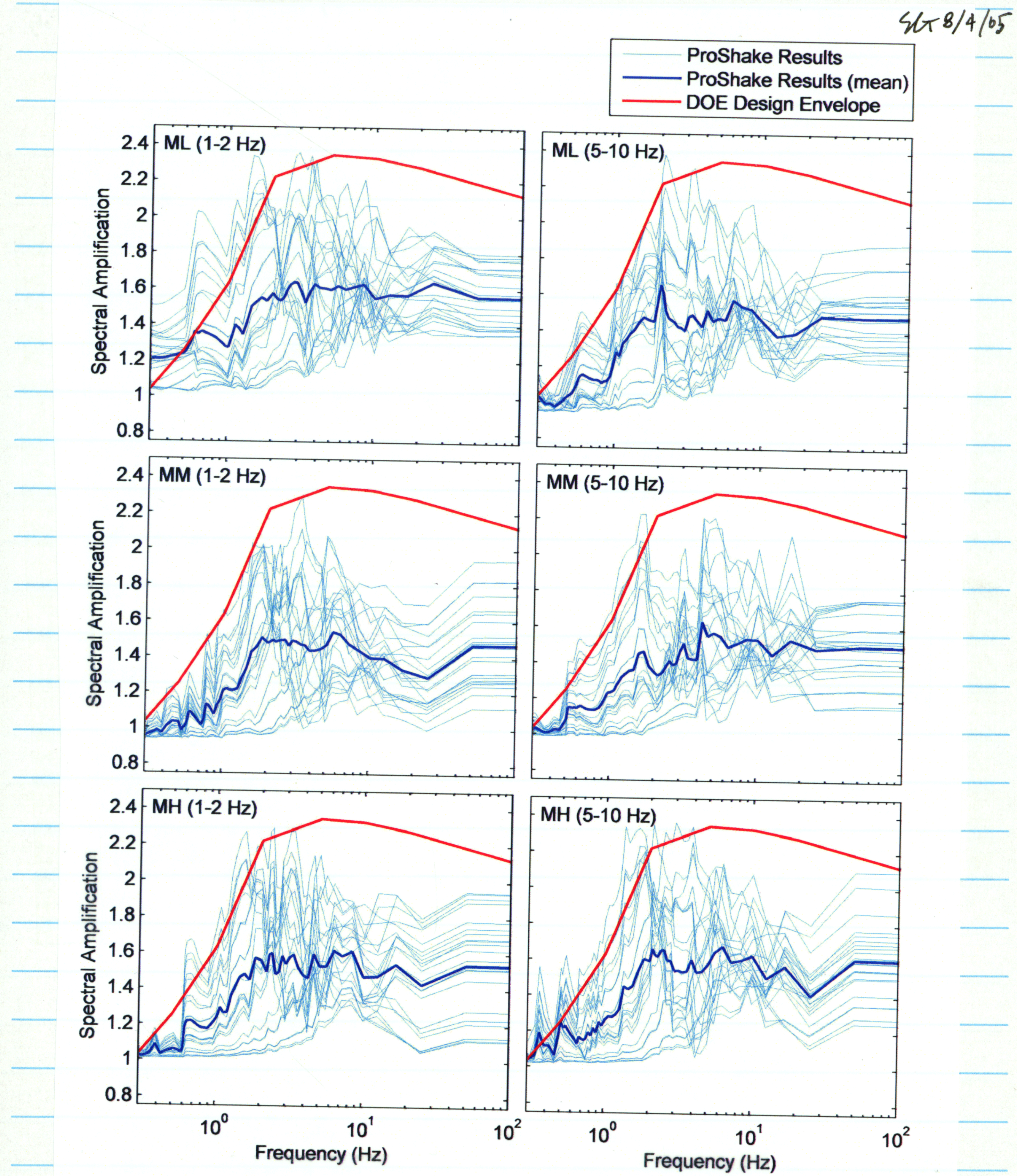

FIGURE 12. PROSHAKE RESULTS FOR UPPER MEAN TUFF AND LOWER MEAN ALLUVIUM

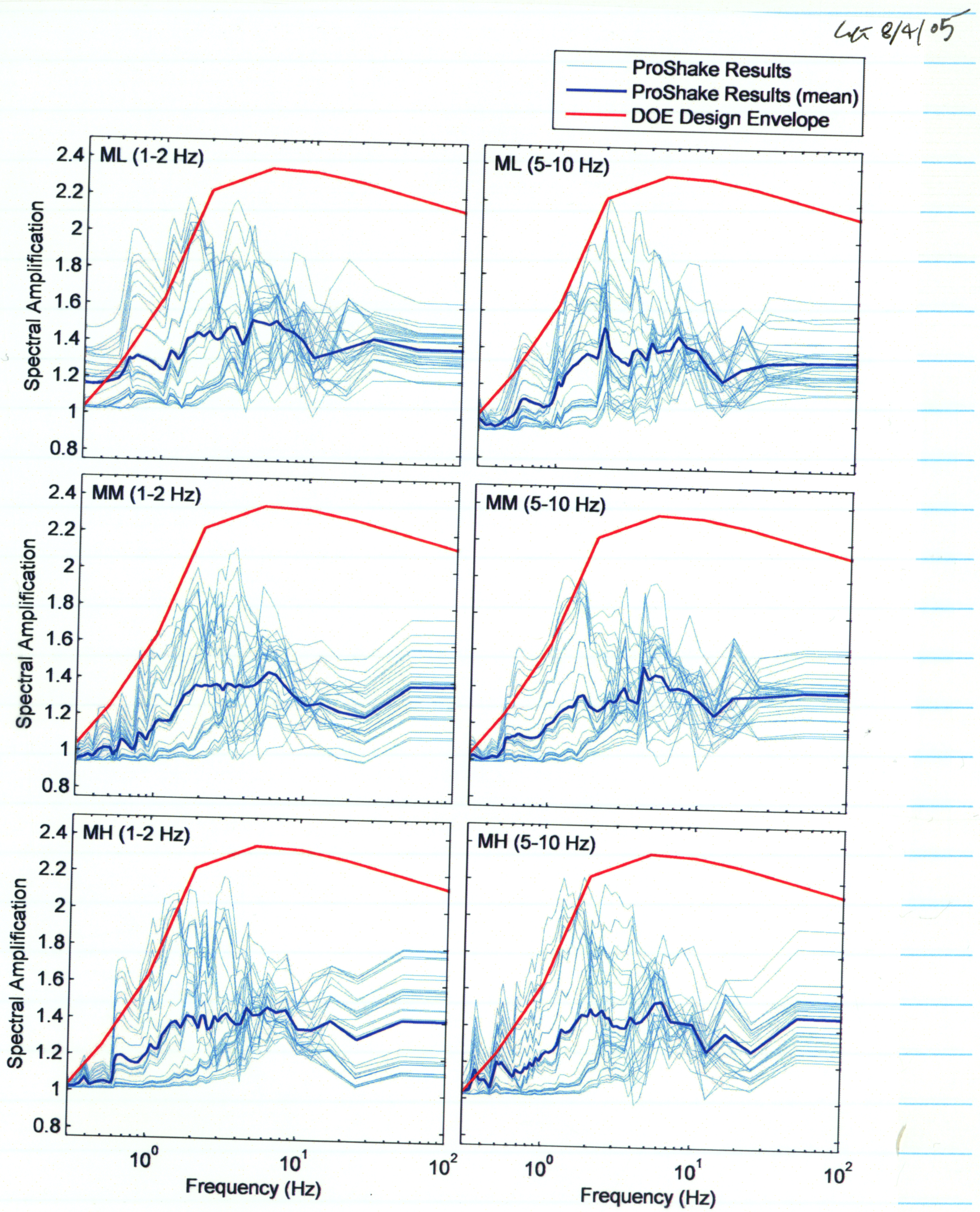

FIGURE 13. PROSHAKE RESULTS FOR LOWER MEAN TUFF AND LOWER MEAN ALLUVIUM

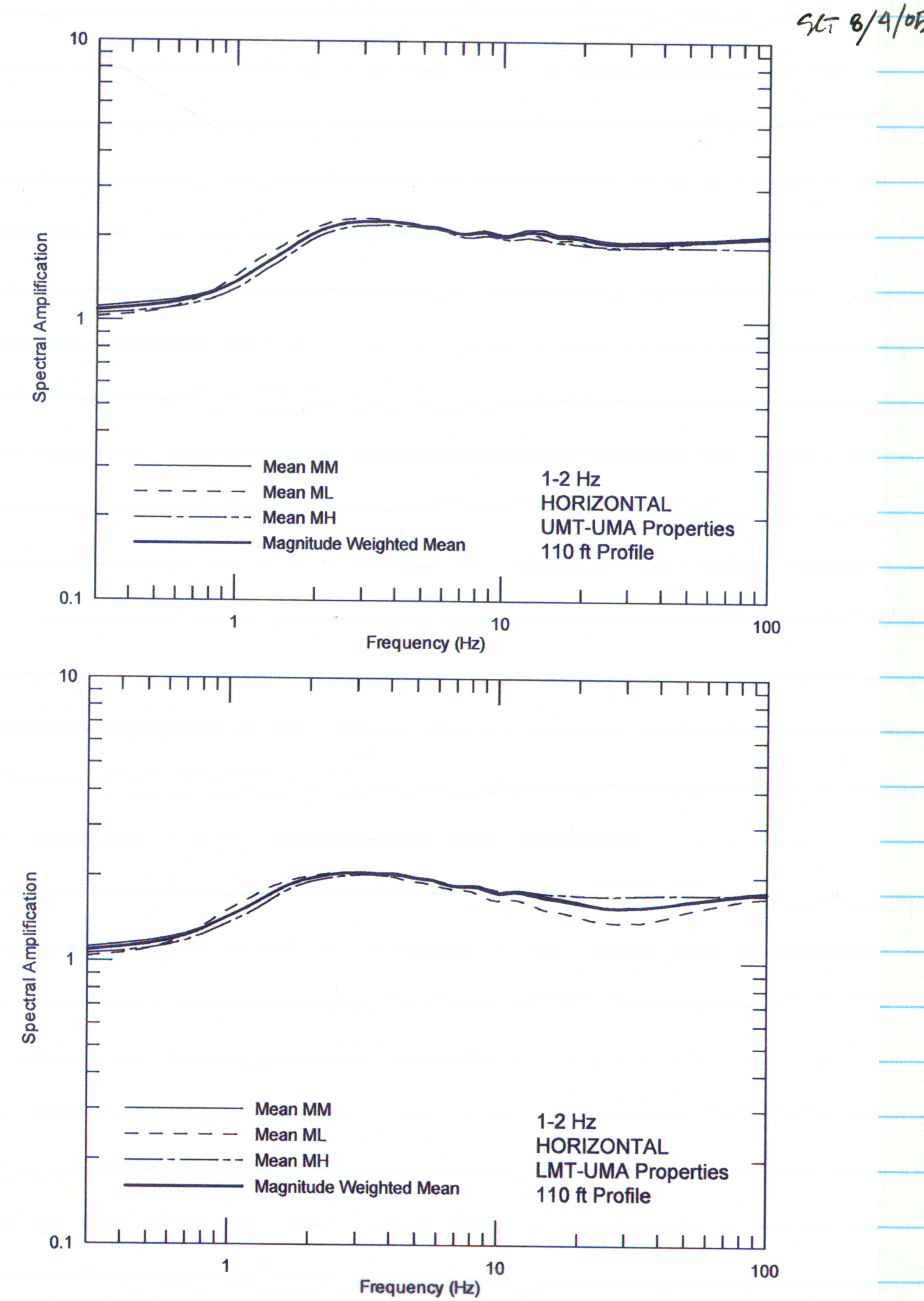

FIGURE 14. DOE TRANSFER FUNCTIONS FOR 1-2HZ STRUCTURAL RESPONSE FREQUENCY RANGE, 110 FT OF ALLUVIUM, FOR THE 5×10^{-4} ANNUAL EXCEEDANCE FREQUENCY LEVEL (FROM BSC, 2004A)

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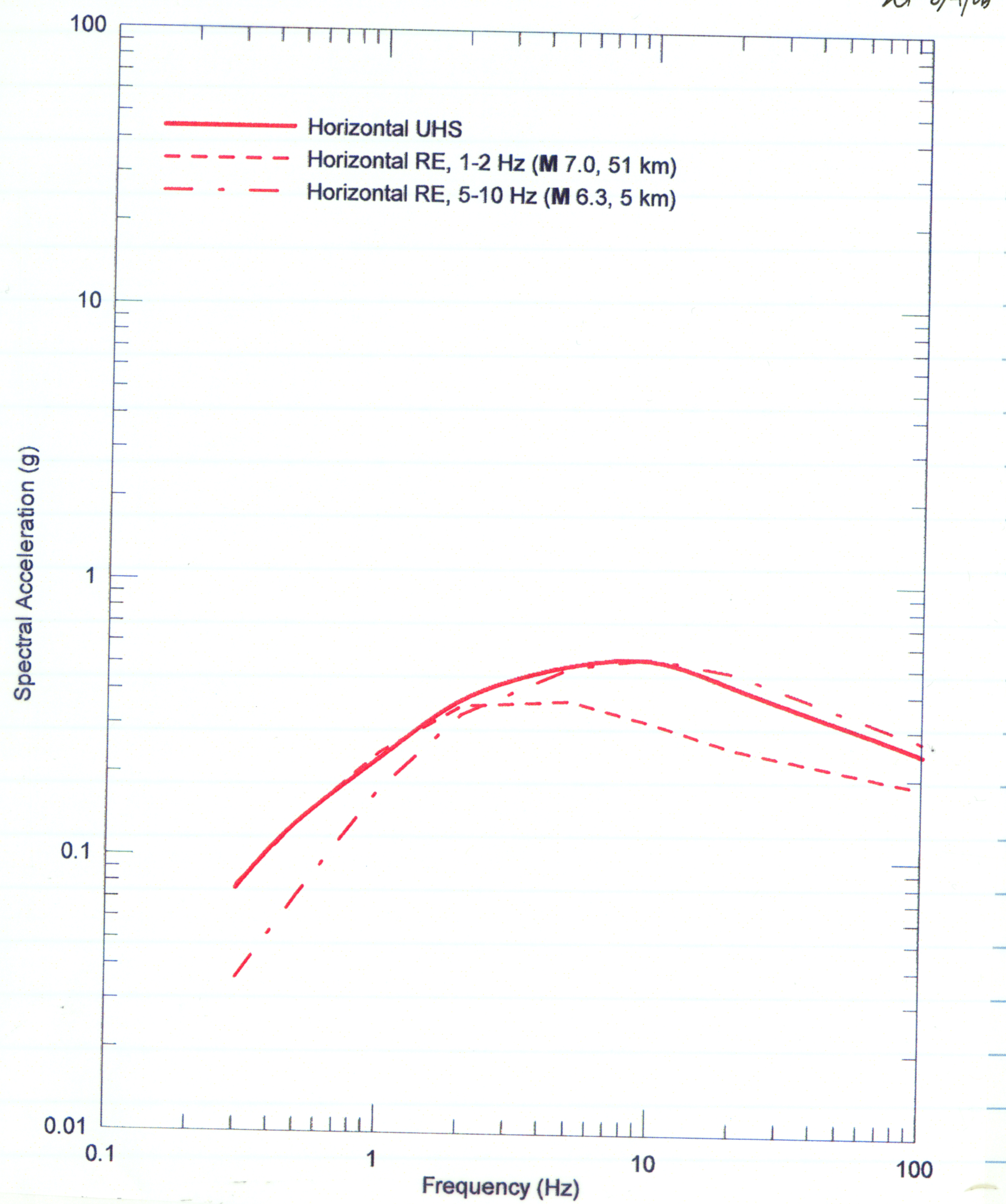

FIGURE 15. DOE REFERENCE EARTHQUAKE RESPONSE SPECTRA AND UHS FOR THE 5×10^{-4} ANNUAL EXCEEDANCE FREQUENCY LEVEL (FROM BSC, 2004A)

TABLE 5. DESCRIPTION OF DOE MAGNITUDE WEIGHTED MEAN TRANSFER FUNCTIONS

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Location	Alluvium Thickness	Tuff Base Case Dynamic Material Property Curve	Alluvium Base Case Dynamic Material Property Curve
Site D	35 ft [10.668 m]	UMT	UMA
Site D	35 ft [10.668 m]	LMT	UMA
Site D	35 ft [10.668 m]	UMT	LMA
Site D	35 ft [10.668 m]	LMT	LMA
Site D	110 ft [33.53 m]	UMT	UMA
Site D	110 ft [33.53 m]	LMT	UMA
Site D	110 ft [33.53 m]	UMT	LMA
Site D	110 ft [33.53 m]	LMT	LMA
Site E	15 ft [4.572 m]	UMT	—
Site E	15 ft [4.572 m]	LMT	—

TABLE 6. DOE REFERENCE EARTHQUAKES (FROM BSC, 2004A)

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Structural Frequency Range	1-2 Hz	5-10 Hz
Magnitude	7.0	6.3
Distance (km)	51	5

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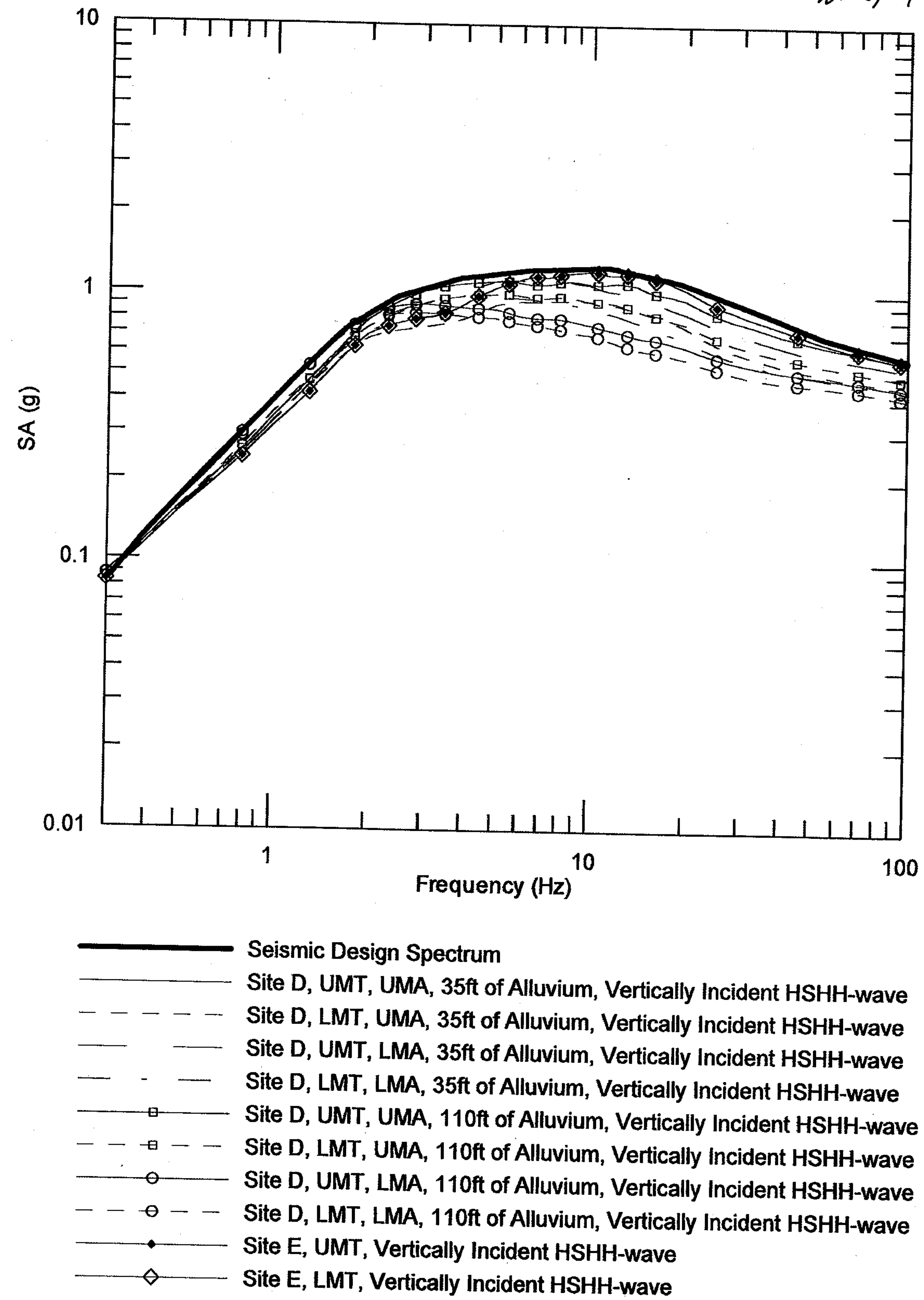

FIGURE 16. DOE MAGNITUDE WEIGHTED MEAN RESPONSE SPECTRA AND DESIGN SPECTRUM FOR THE 5×10^{-4} ANNUAL EXCEEDANCE FREQUENCY LEVEL (FROM BSC, 2004A)

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The ProShake input and output files are located in the directory *"ProShake Calculations"* on the attached CD. The contents of the directories "Run 1" to Run 7" within the *"ProShake Calculations"* directory are listed below:

Run 1 - Linear material properties (0.5 % damping)
Run 2 - Linear material properties (1 % damping)
Run 3 - Linear material properties (2 % damping)
Run 4 – Upper Mean Tuff and Upper Mean Alluvium material property curves
Run 5 – Lower Mean Tuff and Upper Mean Alluvium material property curves
Run 6 – Upper Mean Tuff and Lower Mean Alluvium material property curves
Run 7 – Lower Mean Tuff and Lower Mean Alluvium material property curves

Figures 9, 10, 11, 12 and 13 on pages 30 to 34 of this notebook correspond to Runs 1, 4, 5, 6, 7 and 8, respectively. Matlab was used to plot the ProShake results shown in Figure 9 to 13. The Matlab m-files which were created to plot the data are also provided in the *"ProShake Calculations"* directory.

The data used to plot the DOE deaggregation response spectra in Figure 8 on page 28 of this notebook are in the directory *"DOE Point A Spectra"*. Specifically, the DOE excel spreadsheet *"MO0208UNHZ5X10.000 (5E-4 Point A Response Spectra).xls"* was used. The data from this excel spreadsheet which were used to plot Figure 8 were copied into a separate excel spreadsheet named *"DOE_control_motions.xls"* which is located in the directory *"Input Response Spectral Plots"*. The response spectra for the input time histories, also shown in Figure 8, were calculated in ProShake and are also located in this directory along with the Matlab m-file which was created to plot Figure 8.

The data used to calculate the DOE design spectral amplification envelope, shown in Figures 9 to 13, were also obtained from the file *"MO0208UNHZ5X10.000 (5E-4 Point A Response Spectra).xls"*. The calculations are provided in the excel file *"DOE_envelope.xls"* which is located the *"ProShake Calculations"* directory.

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SPECTRAL MATCHING

A major limitation of the comparison of our 1D site response results with DOE's results, provided on pages 17 to 39 of this notebook, is that we did not use hazard consistent time histories in our analysis. Comparison of response spectra in Figure 8 (page 28) shows that there are large differences in response spectral values particularly at frequencies less that ~2 Hz. For this reason we plan to repeat parts of this analysis with spectrally matched time histories developed using the software RASCAL (Silva and Lee, 1987). A preliminary calculation was performed using RASCAL to spectrally match the Montenegro earthquake time history with the MH (5-10 Hz) deaggregation earthquake response spectrum. This result is shown in Figure 17. The RASCAL input and output files are in the directory *"Spectral Matching"*. The RASCAL output spectrally matched time history corresponds to the file *"TEST.A04"*. This file was converted to ProShake format using ProShake's "Convert Earthquake File" utility. The response spectrum was then calculated in ProShake.

We then repeated several site response calculations using this spectrally matched time history for the case shown in Figure 13 (page 34) of this notebook (Lower Mean Tuff and Lower Mean Alluvium material property curves). These results are shown in Figure 18. The ProShake input and output files are located in the directory *"ProShake Calculations"* in the directory "*Run 8*".

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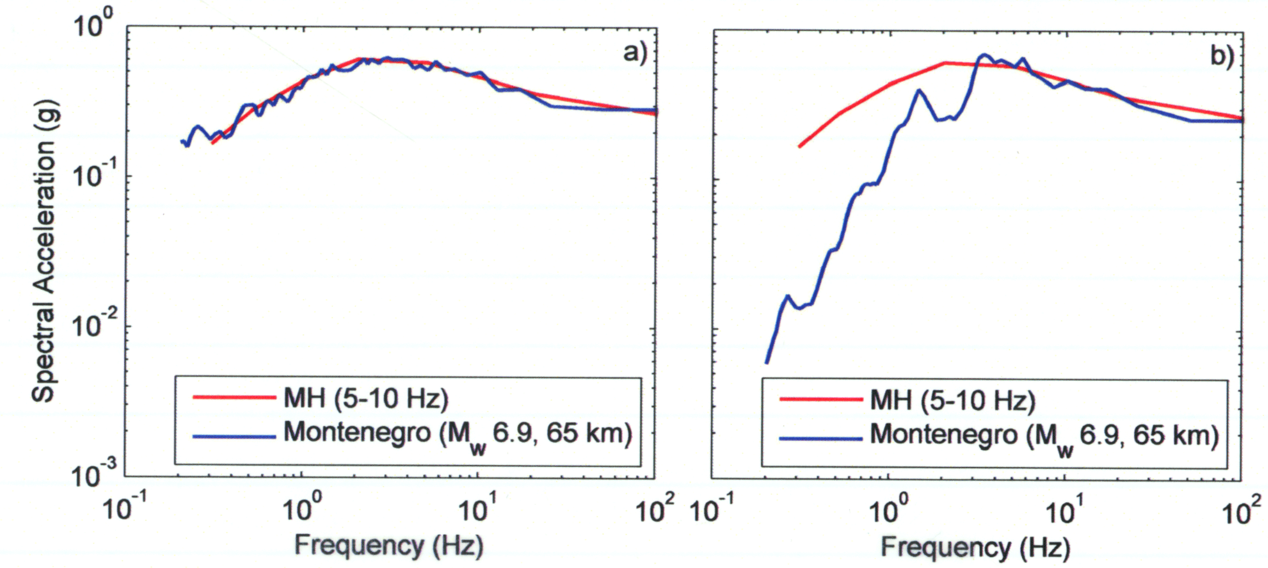

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FIGURE ~~X~~. COMPARISON OF SPECTRALLY MATCHED TIME HISTORY RESPONSE SPECTRUM (A) WITH UNMATCHED RESPONSE SPECTRUM (B).

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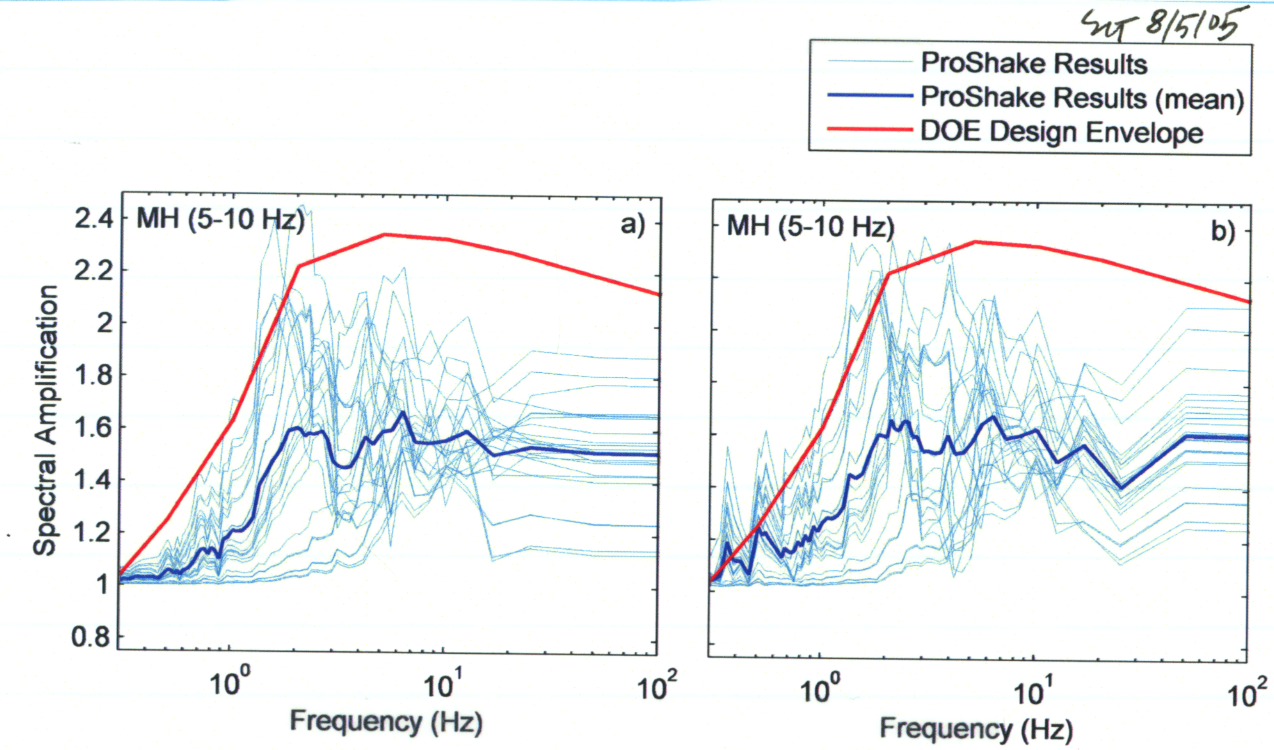

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FIGURE ~~Z~~. COMPARISON OF ~~+~~ PROSHAKE RESULTS USING SPECTRALLY MATCHED INPUT TIME HISTORY (A) WITH UNMATCHED TIME HISTORY RESULTS (B)

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REFERENCES FOR *ONE-DIMENSIONAL SITE RESPONSE MODELING* AND *SPECTRAL MATCHING* ENTRIES

BSC (Bechtel SAIC Company) 2002. Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analyses for the Yucca Mountain Site Characterization Project. ANL-MGR-GE-000003 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20020923.0175.

BSC (Bechtel SAIC Company) 2004a. Development of Earthquake Ground Motion Input for Preclosure Seismic Design and Postclosure Performance Assessment of a Geologic Repository at Yucca Mountain, NV. MDL-MGR-GS-000003 REV 01. Las Vegas, Nevada: Bechtel SAIC Company.

BSC (Bechtel SAIC Company) 2004b. Technical Basis Document No.14: Low Probability Seismic Revision 0.1. Las Vegas, Nevada: Bechtel SAIC Company.

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EduPro Civil Systems, 2001. ProShake. Version 1.11. Sammamish, WA.

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Schnabel, P.B., J. Lysmer, and H.B. Seed. "SHAKE: A Computer Program for Earthquake Response Analysis of Horizontally Layered Sites." Report No. UCB/EERC-72/12. Earthquake Engineering Research Center, University of California, Berkeley. Pp 102p. 1972.

Silva, W.J. and Lee, K. L. "State-of-the-Art for Assessing Earthquake Hazards in the United States; Report 24: WES RASCAL Code for Synthesizing Earthquake Ground Motions." US Army Corps of Engineers. 1987.

Stepp, J.C., I. Wong, J. Whitney, R. Quittmeyer, N. Abrahamson, G. Toro, R. Youngs, K. Coppersmith, J. Savy, T. Sullivan, and Yucca Mountain PSHA Project Members. "Probabilistic Seismic Hazard Analyses for Ground Motions and Fault Displacement at Yucca Mountain, Nevada." Earthquake Spectra. Vol, 17, No. 1. pp 113-151. 2001.

Two-Dimensional Finite Element Analyses (continued)

Finite Element Models with Geologically Realistic Subsurface Geometry

After our successful tests with the simple horizontal stratigraphy, we moved on to the more realistic (i.e., geologically accurate but complicated) dipping stratigraphy. The basic geometry (Figure 10) comes from the EarthVision GFM developed by K. Murphy as documented in Gonzalez et al. (2004). This GFM focuses on the surface waste handling facility site and was based on data provided by BSC (2002).

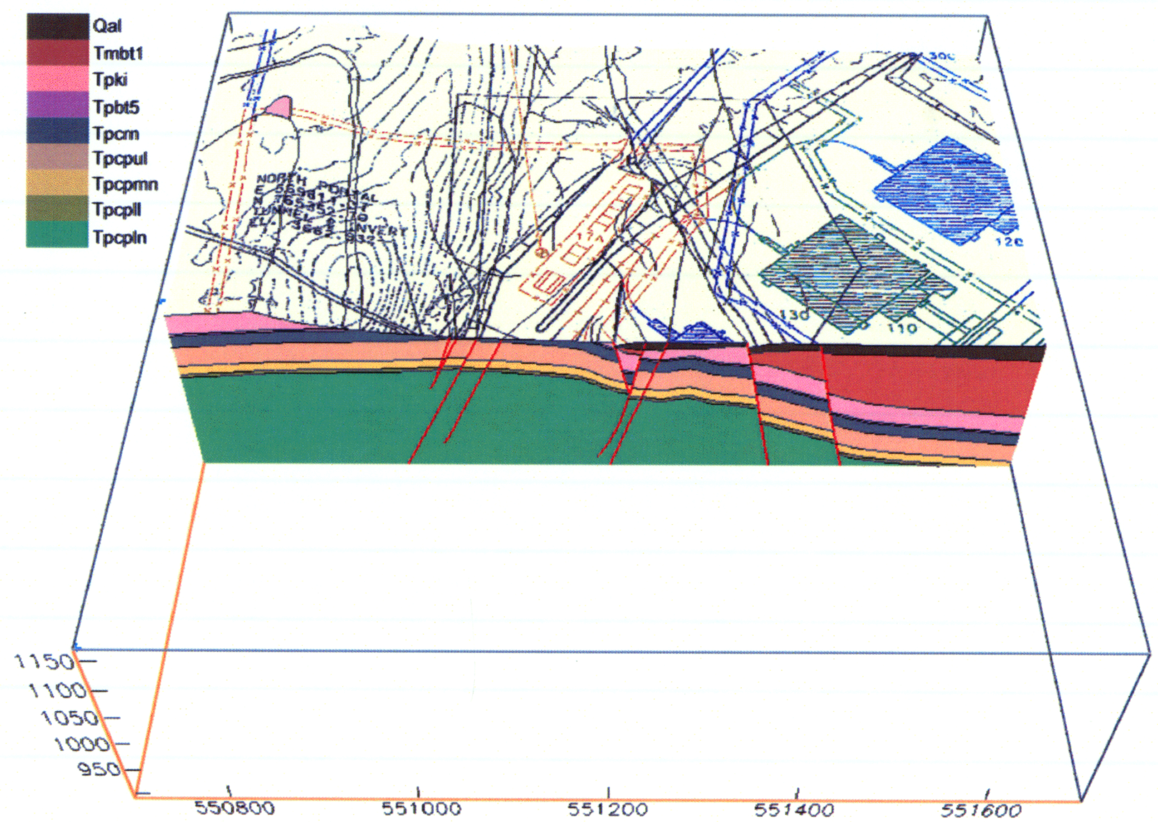

Figure 10. Illustration showing location of geologic cross section within EarthVision geologic framework model.

An east-west cross section was extracted from the geologic framework model (UTM coordinate N4,078,461) and each stratigraphic interval within a fault block was exported as a polygon in AutoCAD DXF format. The individual polygons were imported into *ABAQUS/CAE* as "parts" and then assembled into the full model (Figure 11). As with the horizontal stratigraphy models, the dipping stratigraphy model uses 6 distinct stratigraphic intervals with the elastic properties defined in Table 1. The thickness values in Table 1 are no longer appropriate since the model is geologically realistic and the thickness for most intervals varies with spatial location along the cross section. For simplicity, the faults in the geologic cross section are not explicitly incorporated into the finite element model. This approach is warranted since the faults themselves do not have any specific properties that influence the seismic behavior at the scale of these models. Rather, it is the juxtaposition of different stratigraphic layers across larger displacement faults that is important and this aspect is captured by the modeling approach.

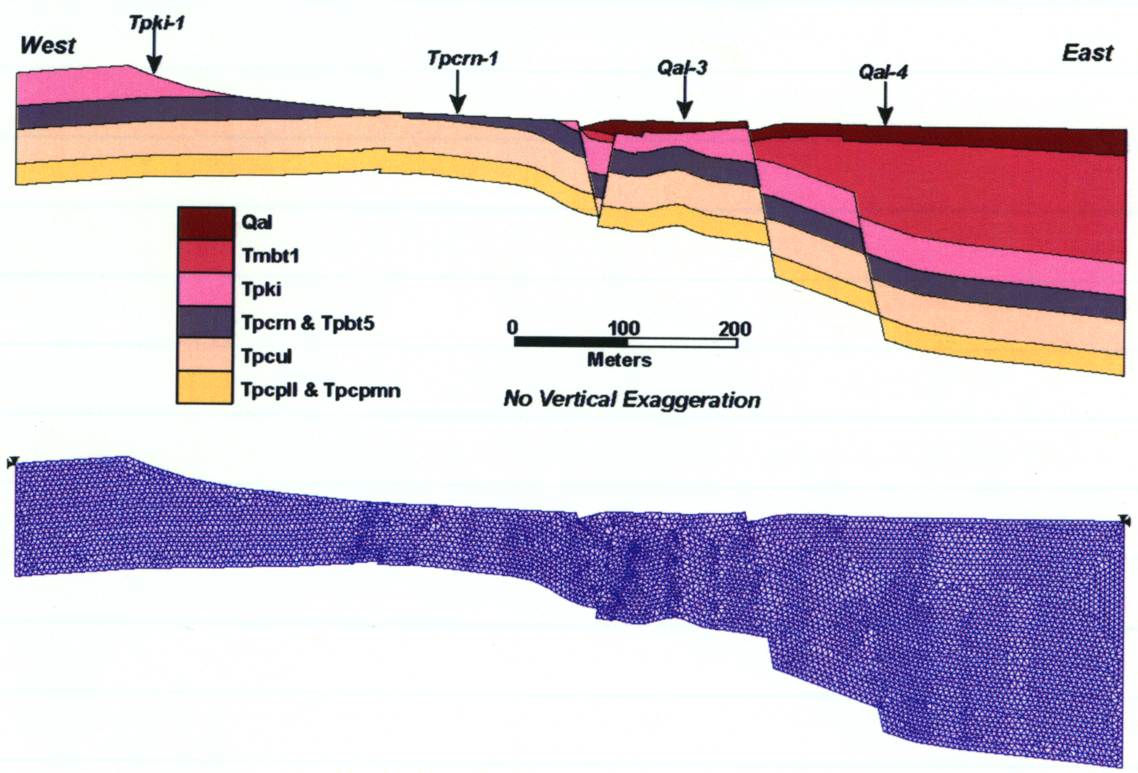

Figure 11. Geometry (top) and finite element mesh (bottom) for *ABAQUS* model with geologically realistic dipping stratigraphy. Vertical arrows on ground surface show locations where horizontal accelerations were monitored in the finite element model.

The stratigraphy was discretized with 3-node linear plane strain triangular elements because the irregular layer shapes do not lend themselves to quadrilaterals. The uppermost right and left nodes in the mesh were assigned fixed (zero) displacement boundary conditions. The same mass-proportional and stiffness-proportional damping coefficients for the earlier models were assigned, so that the overall system achieved 2% damping at frequencies of 1 and 5 Hz. Again, the seismic loading was achieved with a imposed horizontal acceleration time history that was applied to the base of the "Tpcpll + Tpcpmn" interval. Resulting ground accelerations were monitored at four different surface locations that represent a range of subsurface geometries and exposed stratigraphic intervals. As discussed in the previous section, all analyses employed *ABAQUS/Explicit*.

Preliminary results for two-dimensional site response models with geologically realistic subsurface geology are shown in Figures 12 and 13. The acceleration time histories derived from the two-dimensional site response model differ from one site location to another, and are also consistently larger than the input accelerations for that site. The maximum peak ground accelerations occur at surface locations where the unconsolidated Quaternary alluvium deposits is exposed (i.e., sites Qal-3 and Qal-4) with values are 1.5 to 2 times greater than those at sites lacking Quaternary alluvium. The smallest peak ground acceleration is associated with site Tpcrn-1, which consists primarily of well-lithified tuff and has the thinnest overall stratigraphic thickness. Results are consistent with expectations in that the largest amplifications occur where the velocity and density contrasts are largest. We note, however, that these results are preliminary and that a move comprehensive evaluation is needed before explicit conclusions of the two-dimensional site response effects can be made.

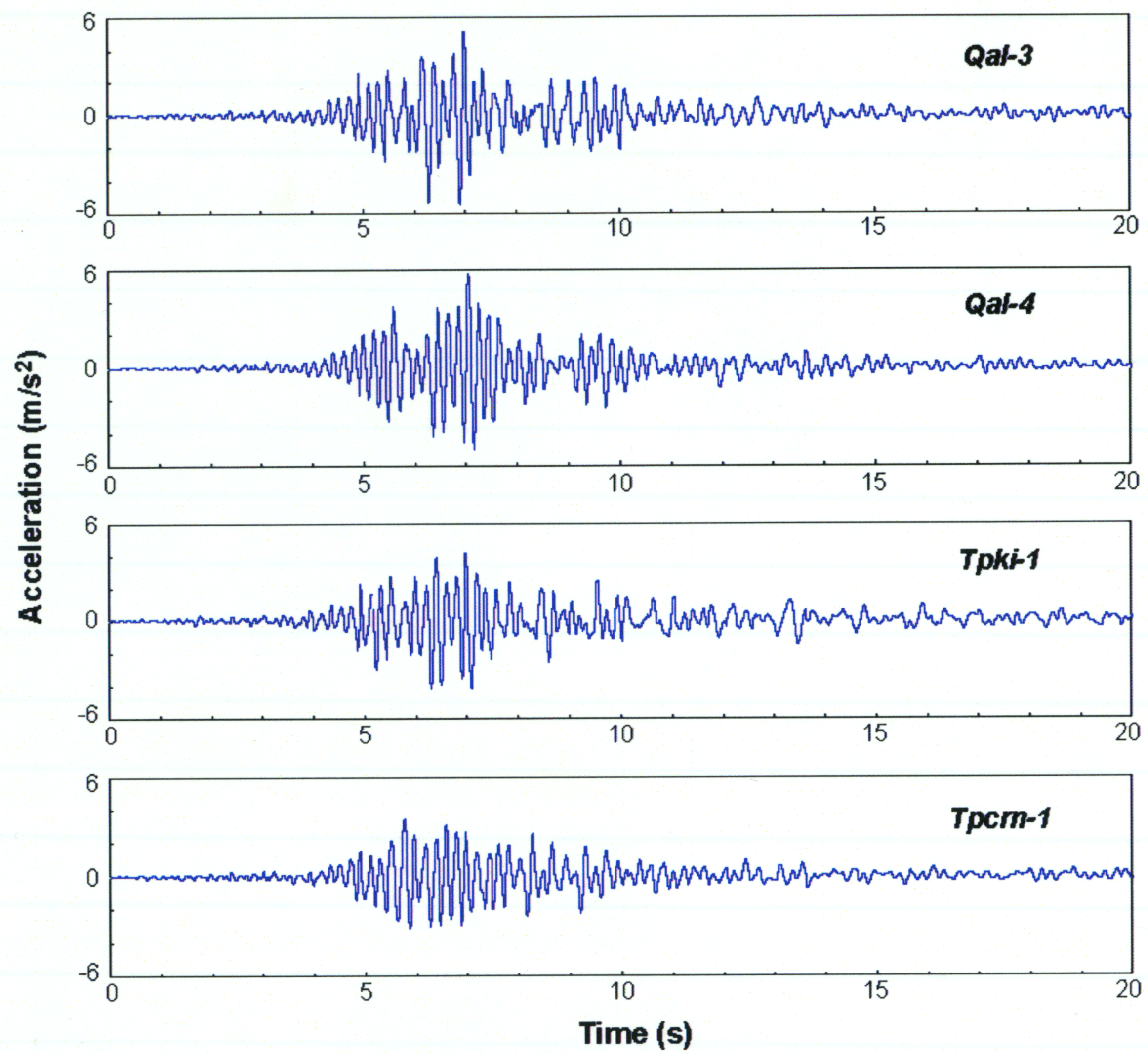

Figure 12. Comparison of horizontal surface acceleration histories derived from two-dimensional *ABAQUS* simulation. Peak ground accelerations predicted from two-dimensional analysis are largest for sites with Quaternary alluvium (i.e., Qal-3, Qal-4).

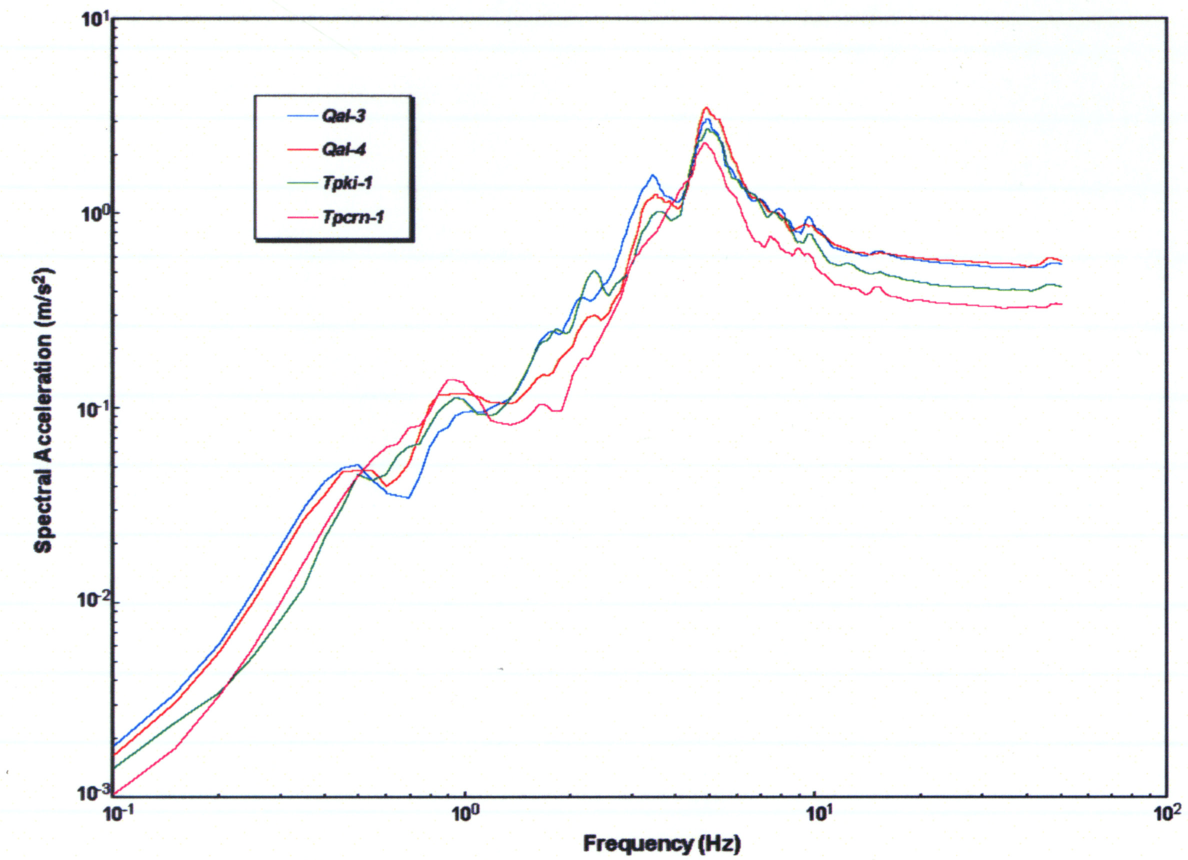

Figure 13. Comparison of response spectra derived from time histories in Figure 12. Two-dimensional analysis results predict that the largest peak ground accelerations will be found at those sites with Quaternary alluvium (i.e., Qal-3 and Qal-4).

KJ Smart 09/19/05

References:

BSC (Bechtel SAIC Company). "Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analyses for the Yucca Mountain Site Characterization Project." ANL-MGR-GE-000003 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20020923.0175. 2004.

Gonzalez, S.H., J.A. Stamatakos, K.R. Murphy, H.L McKague."Preliminary Evaluation and Analyses of the U.S. Department of Energy Geotechnical Data for the Waste Handling Building Site at the Potential Yucca Mountain Repository." San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. 2004.

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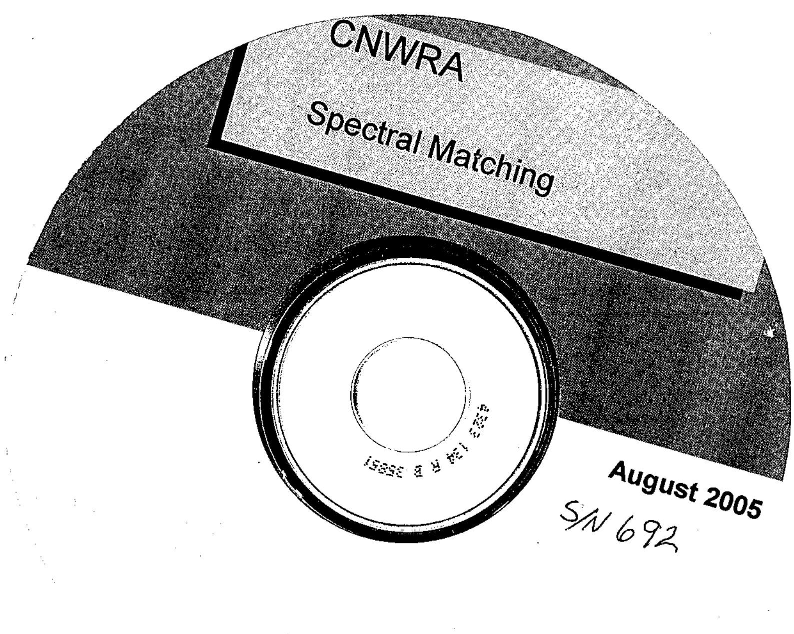
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