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Title: INTERIM REPORT
UPDATE OF THE PROBABILISTIC SEISMIC HAZARD ANALYSIS AND DEVELOPMENT OF CMRR DESIGN GROUND MOTIONS
LOS ALAMOS NATIONAL LABORATORY, NEW MEXICO

Author(s): Michael W. Salmon, LANL D-5
Ivan Wong, URS Corporation
Mark Dober, URS Corporation

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INTERIM REPORT

UPDATE OF THE PROBABILISTIC SEISMIC HAZARD ANALYSIS AND DEVELOPMENT OF CMRR DESIGN GROUND MOTIONS LOS ALAMOS NATIONAL LABORATORY, NEW MEXICO

Prepared for

LOS ALAMOS NATIONAL LABORATORY

Prepared by

Ivan Wong and Mark Dober
URS Corporation
Seismic Hazards Group
1333 Broadway, Suite 800
Oakland, CA 94612

Walter Silva, Bob Darragh, and Nick Gregor
Pacific Engineering and Analysis
856 Seaview Drive
El Cerrito, CA 94530

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At the request of the Los Alamos National Laboratory (LANL), the horizontal and vertical design ground motions for the Chemistry and Metallurgical Research Replacement (CMRR) site and a dacite rock outcrop at CMRR have been updated and revised. The CMRR design ground motions were first developed in 2007 as part of the "Update of the LANL Probabilistic Seismic Hazard Analysis" Project (Wong *et al.*, 2007). Both Uniform Hazard Response Spectra (UHRS) and Design Response Spectra (DRS) have been calculated per ASCE/SEI 43-05. DRS were calculated for Seismic Design Categories (SDC)-3 (25,000-year return period), SDC-4 (2,500 years), and SDC-5 (10,000 years).

A comparison of the results from 2007 (Wong *et al.*, 2007) to those from 1995 (Wong *et al.*, 1995) indicate that the ground motions, on average, increased in amplitude by about 40% at the annual frequency of exceedance of $4x10^{4}$ per year. Because of this large increase, LANL has initiated additional studies to evaluate potential conservatisms in the 2007 study. Issues addressed in this phase of ongoing studies include:

1) Use of the Next Generation of Attenuation (NGA) ground motion predictive equations (GMPEs; also called attenuation relationships) models.

2) Addition of epistemic uncertainty (σ_{ln} 0.25) to the NGA models.

3) The use of a refined suite of site-specific and empirical generic soil V/H ratios based on the mean magnitudes and distances.

4) Calculation of additional structural frequencies in the probabilistic hazard to better predict peak vertical response.

This report presents the approach and results of this most recent update.

1.1 SSHAC CONCURRENCE

The 2007 update was conducted as a SSHAC (1997) Level 2 study. The Technical Integrator (TI) was composed of two groups of individuals: one for seismic source characterization and one for ground motion characterization. The Project Leader was Ivan Wong and the Project Sponsor was Mike Salmon, LANL. A participatory peer review was provided by the Project Steering Committee that consisted of Walter Arabasz, Carl Costantino, and Michael Machette, consistent with a SSHAC Level 2 study.

In this current update of the CMRR design ground motions (both ground surface and a dacite rock outcrop), a Level 1 study is being performed because the TI, in this case Ivan Wong, in consultation with the Project Steering Committee, made the assessment that the issues to be addressed were noncontroversial (degree "A"; SSHAC, 1997). In the 2007 update, two significant issues, the use of the NGA models and the addition of epistemic uncertainty to the NGA models, were recognized as being needed to be revisited once the NGA models were published and became available and when further studies of the epistemic uncertainty in the models had been performed. Hence this current update is a result of that earlier recognition.

This report has been reviewed by both the Project Steering Committee and the Defense Nuclear Facility Safety Board (DNFSB) staff and their comments have been addressed in the final report.

Responses to their comments have been prepared and are contained in Appendices A and B, respectively.

1.2 ACKNOWLEDGMENTS

This work was performed under the LANL Requests for Offsite Services to Washington Management Safety Solutions and URS Group Inc. Our thanks to Mike Salmon, Richard Lee, and Larry Goen for their support and to Melinda Lee and Danielle Lowenthal-Savy for their assistance in the preparation of this report. Also our thanks to the Project Steering Committee for their review of the draft report.

The probabilistic horizontal hazard at CMRR has been recomputed using the recently developed Pacific Earthquake Engineering Research (PEER) Center's NGA GMPEs and additional epistemic uncertainty has been included in the ground motions attenuation models.

The 2007 seismic source model (Wong *et al.*, 2007) was used without modification as input. The probabilistic hazard previously calculated in 2007 using the site-specific stochastic attenuation relationships for CMRR, TA-55, and dacite (Wong *et al.*, 2007) were also used in this update. The hazard calculated from the empirical NGA models and the site-specific stochastic models were weighted equally as was done in 2007.

The hazard was calculated at the spectral periods of 0.01 (PGA), 0.02, 0.05, 0.06, 0.075, 0.085, 0.10, 0.15, 0.20, 0.30, 0.40, 0.50, 0.75, 1.00, 1.50, 2.00, 3.00, 5.00, and 10.00 sec. In 2007 due to the limited number of spectral periods in the pre-NGA models, the hazard was calculated at PGA, 0.05, 0.10, 0.20, 0.30, 0.40, 0.50, 0.75, 1.0, 1.5, and 2.0 sec. The hazard calculations were made using the computer program HAZ38 developed by Norm Abrahamson. The program is an updated version of the validated and verified code used in the 2007 study. This version contains the NGA models. It has undergone extensive testing and evaluation as part of project being performed with Bob Youngs of AMEC Geomatrix Consultants. A verification and validation of the computer program has been completed under the URS DOE Western Branch Quality Assurance Program, which meets NQA-1 standards.

2.1 NGA MODELS

In the 2007 update, pre-NGA empirical ground motion attenuation models were used in the computation of hazard. These models included Abrahamson and Silva (1997) adjusted for normal faulting, Spudich *et al.* (1999), Boore *et al.* (1997), Campbell and Bozorgnia (2003), and Sadigh *et al.* (1997). In the planning of the 2007 update, it was intended to use the NGA models (Wong *et al.*, 2007); however, they were still being developed and so they were not available at the time the update was being performed.

The NGA models have a substantially better scientific basis than current relationships (e.g., Abrahamson and Silva, 1997) because they were developed through the efforts of five selected attenuation relationship developer teams working in a highly interactive process with other researchers who have: (a) developed an expanded and improved database of strong ground motion recordings and supporting information on the causative earthquakes, the source-to-site travel path characteristics, and the site and structure conditions at ground motion recording stations; (b) conducted research to provide improved understanding of the effects of various parameters and effects on ground motions that are used to constrain attenuation models; and (c) developed improved statistical methods to develop attenuation relationships including uncertainty quantification. The relationships have benefited greatly from a large amount of new strong motion data from large earthquakes (**M** > 7) at close distances (< 25 km). Data include records from the 1999 **M** 7.6 Chi Chi, Taiwan, 1999 **M** 7.4 Kocaeli, Turkey, and 2002 **M** 7.9 Denali, Alaska earthquakes. Review of the NGA relationships indicate that, in general, ground motions are significantly reduced particularly for very large magnitudes (**M** ≥ 7.5) compared to current relationships.

The four NGA models used in this PSHA were those of Abrahamson and Silva (2008), Campbell and Bozorgnia (2008), Chiou and Youngs (2008), and Boore and Atkinson (2008). The models were equally weighted in the PSHA. The model by Idriss (2008) was not used because it does not use V_S30 as a variable and it was developed to be appropriate for rock (V_S30 450 to 900 m/sec) not soil.

A V_S30 (average shear-wave velocity of the top 30 m) of 270 m/sec, the same generic deep soil value used in the 2007 study, was used in the NGA models in the PSHA. Another NGA input parameter includes $Z_{2.5}$, the depth to a V_S of 2.5 km/sec (a proxy for basin effects), which is only used in one model, Campbell and Bozorgnia (2008). We have used the default value of 2.0 km as recommended by the authors in lieu of site-specific data. In addition, Abrahamson and Silva (2008) and Campbell and Bozorgnia (2008) use $Z_{1.0}$, the depth to a V_S of 1.0 km/sec. In the absence of site-specific data, the authors provide equations for default values based on the V_S30 at the site. An average of the two models, 0.41 km, was used in the PSHA. Other parameters such as depth to the top of rupture (zero for all faults that intersect the surface unless specified otherwise), dip angle, rupture width, and aspect ratio were specified for each fault or calculated within the PSHA code.

2.2 EPISTEMIC UNCERTAINTY ADDED TO NGA MODELS

As discussed in Section 6.1 of Wong *et al.* (2007), it has been recognized that there may be insufficient epistemic uncertainty provided by current empirical attenuation models and this is particularly true of the NGA models. In the 2007 study, an additional sigma (ln) of 0.4 was incorporated into the PSHA (Wong *et al.*, 2007). (The 2007 report incorrectly states that the pre-NGA models were scaled to obtain a total epistemic uncertainty of 0.4 [sigma ln].) In this analysis, discussions were held with Bob Youngs and Norm Abrahamson in addition to a review of published and unpublished reports to assess current views on what constitutes a sufficient amount of added epistemic uncertainty to use in PSHA.

A review panel on the NGA models convened by the U.S. Geological Survey (USGS) for the National Hazard Maps recommended that additional epistemic uncertainty be incorporated into the hazard estimates for the maps because of data limitations and the considerable interaction among the model developers (Petersen *et al.*, 2008). Petersen *et al.* (2008) calculated the epistemic uncertainty based on the number of earthquakes in magnitude-distance bins in the NGA database that were used by Campbell and Bozorgnia (2008) and Chiou and Youngs (2008). The USGS assumed that the ground motion uncertainty was 50% for **M** > 7 and R < 10 km (Petersen *et al.*, 2008). This is an additive factor of 0.4 in log-space (90% confidence limits).

To incorporate the additional epistemic uncertainty in the hazard analysis for the National Hazard Maps, the USGS computed a scaling factor called "dgnd," which is the logarithm of the median spectral acceleration (SA) or peak horizontal ground acceleration (PGA) for a given ground motion model. The dgnd is applied symmetrically to the ground motion models (gnd) and weighted in a logic tree approach as follows:

unmodified gnd model	0.63 wt (50th percentile)
gnd + dgnd	0.185 wt (95th percentile
gnd dgnd	0.185 wt (5th percentile)

The magnitude-distance-dependent average dgnd terms used by the USGS ranged from 0.225 to 0.40 (Petersen *et al.*, 2008). The latter value was for the bin **M** ≥ 7 and R ≤ 10 km, a bin relevant to LANL because of the relationship of the site to the Pajarito fault. The dgnd terms were derived based on the number of observations in a magnitude and distance bin relative to the bin **M** ≥ 7 and R ≤ 10 km. A dgnd of 0.40 translates to an additional epistemic uncertainty of about 0.25 (ln) (0.40 divided by 1.605) where 1.605 is the number of standard deviations for 90% confidence limits. The same dgnd was applied to all NGA models.

Bob Youngs of Geomatrix Consultants and co-developer of the Chiou and Youngs (2008) NGA attenuation model has evaluated the uncertainty in median ground motions based on the degree to which the model parameters are constrained by the data. These estimates are shown in Figure 1 for **M** 5.5, 6.5, and 7.5, three styles of faulting, and PGA and 1.0 sec SA. The epistemic uncertainty (sigma μ) for strike-slip faulting is lower than it is for normal faulting in the hanging wall of the fault (< 10 km) (Figure 1). Based on the above analysis, Youngs suggests that an additional epistemic uncertainty of 0.15 (ln) should be assigned to each of the NGA models in PSHAs because the models were based on similar datasets. The uncertainty in the individual models combined with the variability among the models represents the uncertainty in the median motions for crustal earthquakes incorporated in the PSHA model (B. Youngs, Geomatrix Consultants, written communications, 2009). Based on an epistemic uncertainty of 0.15 (ln) and applying it in a three-point approximation with weights of 0.185, 0.63, and 0.185 for the 5th, median, and 95th percentiles, respectively, results in a dgnd of 0.25.

Values of dgnd were calculated in this study as a function of 13 spectral periods (Table 1). They were calculated in the same manner as in Wong *et al.* (2007) for the mean **M** and mean D for that spectral period assuming a site location in the hanging wall of a fault (Pajarito). The mean **M** and mean D were averaged over four return periods (2,500, 10,000, 25,000, and 100,000 years). The dgnd values are listed in Table 1.

For this study we have adopted a somewhat conservative additional epistemic uncertainty of 0.25 (ln) because there is precedence in that the USGS used this value for the magnitude and distance bin of interest to this study (**M** ≥ 7, R ≤ 10 km) in the National Hazard Maps and because sites in the hanging wall of normal faults have a larger uncertainty due to limited data (Figure 1). However, the analysis by Bob Youngs could be interpreted such that a value of 0.25 (ln) is too conservative. An unpublished study by Jennie Watson-Lamprey, provided to us by Norm Abrahamson, describes an estimate of the epistemic uncertainty in median ground motions in the Basin and Range and an approach to estimate what additional epistemic uncertainty would be appropriate. Her approach requires evaluation before applying to LANL and future studies may want to consider adopting a less conservative value for the added epistemic uncertainty. Note though sensitivity analyses show that the mean hazard up to a return period of 100,000 years is not very sensitive to the amount of additional epistemic uncertainty as shown on Figures 2 to 6 for the additional sigma(ln) of 0.4 and 0.25 (Wong *et al.*, 2009).

2.3 RECOMPUTED HAZARD

Figures 7 to 10 show the CMRR mean and fractile hazard curves using only the NGA models for PGA and periods of 0.2, 1.0, and 10.0 sec SA for the added epistemic uncertainty of 0.25 (ln). By deaggregating the mean hazard by magnitude and distance bins, Figures 11 to 25 illustrate the

event contributions for PGA, 0.2 sec, and 1.0 sec SA and for the return periods of 1,000, 2,500, 10,000, 25,000, and 100,000 years. As the return period increases, the magnitudes shift to larger values (~ **M** 7) and the distances decrease to less than 5 km. In other words, larger events on the Pajarito fault system become increasingly more dominant as the return period increases. Based on the magnitude (M) and distance (D) deaggregation, the controlling earthquakes as defined by the mean M and mean D can be calculated (Table 2). The pattern of increasing M and decreasing D with increasing return period is reflected in Table 2.

Figures 26 to 28 show the mean hazard curves using the pre-NGA models with an additional epistemic uncertainty of 0.4 (ln) as was the case in the 2007 study compared to the NGA mean hazard curves with an added epistemic uncertainty of 0.25 (ln). As expected, the pre-NGA models with the larger added epistemic uncertainty show higher hazard increasing with longer return periods particularly at 1.0 sec SA compared to the NGA models (Figures 26 to 28).

Figure 29 shows a comparison between the 2007 Uniform Hazard Spectra (UHS) for the return periods of 1,000, 2,500, and 10,000 years and the updated UHS from this analysis. The NGA spectra are lower than the 2007 pre-NGA UHS at generally all spectral periods and the differences increase with return period.

In addition to recomputing the probabilistic hazard using the NGA models, the hazard was calculated using the site-specific stochastic attenuation models for CMRR, TA-55, and dacite (Wong *et al.*, 2007). The site-specific hazard was recomputed because of an error in the 2007 study where the distance metric for the stochastic models was mistakenly considered to be rupture distance rather than Joyner-Boore distance. The difference in hazard using the two distance metrics was 12% at a return period of 10,000 years. Figures 30 to 41 show the hazard using the site-specific models.

2.4 COMPARISON OF EMPIRICAL HORIZONTAL AND VERTICAL HAZARD

In an earlier request from DFNSB, the probabilistic horizontal and vertical hazard at CMRR was recalculated using the two empirical attenuation models used in the 2007 study, Abrahamson and Silva (1997) and Campbell and Bozorgnia (2003) (NGA models do not contain regressions on vertical-component response). The site condition assumed was firm soil. The 2007 seismic source model was used in the calculations. The aleatory uncertainty (sigma) as recommended by the model developers was used in the PSHA. The resulting hazard curves for PGA, 0.1 sec, 0.2 sec and 1.0 sec SA are shown on Figures 42 to 45. As indicated on Figures 42 and 43, the vertical hazard using the Abrahamson and Silva (1997) model becomes significantly higher than the horizontal hazard as the return period increases as compared to Campbell and Bozorgnia (2003). At 0.1 sec SA, the Campbell and Bozorgnia (2003) model also shows the vertical hazard significantly above the horizontal hazard (Figure 43). At 0.2 sec SA, the differences are smaller for both attenuation models although the horizontal hazard is now higher than the vertical hazard at all return periods reflecting the shift in the vertical spectral peak to shorter periods (Figure 44). At 1.0 sec SA, the differences between the vertical and horizontal hazard are at their greatest for the two models with the horizontal hazard being higher then the vertical hazard (Figure 45).

These patterns are reflected in the implied ratios of the vertical to horizontal hazard curves as a function of return period for PGA, 0.1 sec, 0.2 sec, and 1.0 sec SA as shown on Figures 46 to 49. For PGA, both models yield V/H ratios exceeding 1.0 for a range of return period (Figure 46). The Abrahamson and Silva (1997) model results show a V/H ratio as high as 1.6. A similar pattern emerges for 0.1 sec SA (Figure 47) but here the V/H ratio using Abrahamson and Silva (1997) is greater than 2. At 0.2 sec and 1.0 sec SA, the V/H ratios are all less than 1 for both models (Figures 48 and 49).

While it is not appropriate to make a direct comparison of the inferred V/H using generic site conditions to the site-specific V/H evaluation of this report for the oscillator frequencies evaluated, the probabilistically-derived vertical and horizontal spectral accelerations and inferred V/H range are reasonably consistent with the implied V/H from Section 3.2.

The update of the hazard at the proposed CMRR facility reflects the use of the recent NGA GMPEs (Power *et al*., 2008) to develop the reference site horizontal hazard (Section 2) as well as a refined suite of site-specific and empirical generic soil V/H ratios used to develop the site-specific vertical hazard. The refined suite of V/H ratios incorporates a denser sampling of magnitudes and distances in developing the vertical uniform hazard response spectra (UHRS) than used in the 2007 hazard analyses (Wong *et al*., 2007). The denser sampling was intended to more accurately incorporate the changes in source size and distance across structural as well as annual exceedance frequency (AEF). To reduce computational demands in the 2007 analyses (Wong *et al*., 2007), the same sampling in magnitude (**M** 7.0, Table 3) and distance was used for both the horizontal amplification factors as well as the site-specific V/H ratios. The 2007 sampling, while sufficiently dense for application of the horizontal amplification factors in terms of loading levels, as Table 3 shows, resulted in a coarse sampling in both magnitude as well as distance within 10 km for the V/H ratios. Since the V/H ratios increase with magnitude and decreasing distance, the coarse sampling in distance and the use of a single conservative magnitude (**M** 7.0, Table 3; Wong *et al*., 2007) resulted in conservative V/H ratios and, consequently, conservative vertical hazard. This update addresses this issue with much denser suites of magnitudes and distances that more closely approximate source contributions reflected in the deaggregations.

In addition to the selection of denser suites of magnitudes and distances, the NGA GMPEs provide more spectral periods than were available in the models used in the 2007 analyses (Wong *et al*., 2007). Periods added with the use of the NGA models include 0.075, 0.150, 3.00, 5.00, and 10.00 sec. The additional periods resulted in a more accurate estimate of the amplitude and periods of the short period peak in the vertical UHRS and DRS, which occurred near 0.1 sec. At longer periods, the additional ground motions beyond 2.0 sec provided by the NGA equations permitted an accurate extension of the UHRS and DRS to 10 sec.

3.1 DEVELOPMENT OF VERTICAL HAZARD

The methodology implemented to develop the vertical UHRS follows closely that used to develop fully probabilistic site-specific horizontal design motions for the CMRR site (Wong *et al*., 2007). The methodology preserves the exceedance levels of the reference site (generic soil) PSHA, while properly incorporating aleatory (random) and epistemic (uncertain) variabilities in site-specific dynamic material properties. For application to horizontal motions, the fully probabilistic approach was implemented by first developing relative amplification factors (or transfer functions) between motions computed for the reference site profile and a profile representative of site-specific dynamic material properties. Typically site-specific aleatory variability (randomness across a site) is accommodated by randomizing dynamic material properties (shear-wave velocities, layer thickness, depth to basement material, and modulus reduction and hysteretic damping curves), resulting in a distribution for the amplification factors which is characterized by estimates of the median and standard deviation.

To cover the range in motions developed in the reference site PSHA, amplification factors (median and σ estimates) were developed for a range in loading levels with a sufficiently dense sampling to permit linear (log) interpolation between loading levels. In developing both the horizontal amplification factors as well as the V/H ratios in the 2007 analyses (Wong *et al*., 2007), the suite of loading levels listed in Table 3 was used. A single magnitude, **M** 7.0, was

used for both the horizontal amplification factors and V/H ratios based on the 2007 deaggregations listed in Table 2. While the horizontal amplification factors are not highly sensitive to magnitude (spectral shape), conditional on peak acceleration (Bazzuro and Cornell, 2007), and **M** 7.0 was retained in the update of the horizontal motions, the V/H ratios at close distances (≤ 10 km) are sensitive to both magnitude and distance (Silva, 1997). As a result, a denser sampling in magnitude and distance for both the empirical and site-specific V/H ratios was used in the update to more closely approximate the deaggregations.

In the second step, the distributions of amplification factors are integrated with the derivative of the entire reference site hazard curve (Lee *et al*., 1999; Tsai, 2000; Cramer, 2003; Bazzurro and Cornell, 2004). The result of this process is a site-specific hazard curve reflecting the effects of local dynamic material properties as well as their associated aleatory variabilities. To properly accommodate site-specific epistemic variability reflecting uncertainty in mean dynamic material properties for the site, multiple base case models (e.g., base case profiles, modulus reduction and hysteretic damping curves, equivalent-linear verses nonlinear models, etc.) were developed along with their associated amplification factors (median and sigma estimates) (Wong *et al*., 2007). For each set of alternative base case dynamic material properties, corresponding site-specific hazard curves were developed using the fully probabilistic approach (Bazzurro and Cornell, 2004). Finally, mean estimates of the site-specific hazard was produced by assigning weights to each hazard curve. The relative weights reflect our judgment of how well each model reflects *in situ* material behavior. The suite of weighted site-specific hazard curves was then averaged over exceedance frequency to produce a single hazard curve which properly incorporated both aleatory and epistemic variabilities in site-specific dynamic material properties while maintaining the desired hazard levels of the reference site PSHA. This last step in incorporating the epistemic variability in dynamic material properties is strictly analogous to the logic tree approach used to address uncertainty in the characterization of both earthquake source processes as well as attenuation of reference site ground motions.

For application to the development of site-specific vertical hazard, the same fully probabilistic approach was used with V/H ratios (median and sigma estimates) substituted for horizontal amplification factors. In this case the distributions of V/H ratios were applied to the site-specific horizontal hazard curves. As with the development of the site-specific horizontal hazard, epistemic variability, uncertainty in median V/H ratios was properly incorporated by developing vertical hazard curves for each model of V/H ratios. Multiple models were incorporated through site-specific V/H ratios developed with alternative base case shear- and compressional-wave velocity (V_S and V_P) profiles as well as multiple empirical (generic site) models in both the 2007 (Wong *et al*., 2007) and current analyses. As with the development of the site-specific horizontal hazard, epistemic variability was properly accommodated in the vertical hazard though relative weights applied to the resulting suite of vertical hazard curves. However, for the aleatory variability about each mean (log) V/H ratio, some attention is required as the contribution of site-specific aleatory variability to the hazard has already been accommodated in developing the site-specific horizontal component hazard. To avoid potential double-counting of the site-specific aleatory variability, the standard deviation of the V/H ratios was limited to a value of 0.2 (σ_{ln}), to accommodate the observation that vertical motions reflect a slightly larger randomness than horizontal motions (Abrahamson and Silva, 1997).

Another important distinction between the horizontal amplification factors and the V/H ratios lies in the manner of which the effects of loading level are accommodated in the integration of the reference site hazard. In developing the horizontal hazard, amplification factors are required that cover the entire range in reference site ground motions (Table 3). However, because vertical motions change with distance in a slightly different manner than horizontal motions (Abrahamson and Silva, 1997; Campbell, 1997), V/H ratios vary slowly with both distance as well as magnitude for deep firm soil and soft rock site conditions (Silva, 1997; Campbell and Bozorgnia, 2003). As a result, as exceedance and structural frequency vary, the magnitude and distance contributions to the reference site hazard, rather than magnitude (control motion spectral shape) alone and ground motion level alone, become the primary controlling criteria for the selection of the suite of V/H ratios which are integrated with the site-specific horizontal site hazard. The appropriate levels of site-specific horizontal motion for the numerical V/H ratios and reference site horizontal motions for the empirical V/H ratios are implicitly accommodated through the independent variables of magnitude and closest rupture distance. Provided the development of the fully probabilistic site-specific horizontal hazard does not greatly alter the reference site hazard deaggregations, they may be used in the selection and application of both the empirical as well as numerical V/H ratios.

3.1.1 Development of V/H Ratios For CMRR

In computing the vertical hazard for the CMRR site, both site-specific as well as empirical V/H ratios were used in both the 2007 analyses (Wong *et al*., 2007) and the update. In the current analysis, which used the recent NGA models (Power *et al*., 2008) to compute the reference site horizontal hazard, the 1997 empirical deep soil V/H ratios were used, albeit at a denser distribution of magnitudes and distances than in the 2007 analyses (Wong *et al*., 2007), as the NGA models were developed for horizontal components only.

3.1.1.1 Site-Specific V/H Ratios

For the site-specific V/H ratios, the point-source stochastic model (Boore, 1983; EPRI, 1993; Silva *et al*., 1996) was used to compute both horizontal and vertical motions. The point-source model for the horizontal motions used the same suite of reference site levels of motion as used in developing the amplification factors for the CMRR site (Wong *et al*., 2007). The reference site expected PGAs as well as distances are listed on Table 3 along with the point-source model parameters. For the horizontal motions, the RVT equivalent-linear site response with vertically propagating shear-waves (EPRI, 1993; Silva *et al*., 1996) was used for both the reference site simulations for generic deep firm soil WNA soil (Wong *et al*., 2007) as well as the two base case V_S velocity profiles developed for the CMRR site, profiles A and B (Wong *et al*., 2007). The three V_S profiles are shown in Figure 50.

Additionally, in the RVT equivalent-linear analysis for the CMRR site, epistemic variability in G/G_{max} and hysteretic damping curves, intended to approximately account for sample disturbance, was accommodated with two sets of curves (Wong *et al*., 2007). In this approach, the ratio of the small-strain laboratory V_S computed at the approximate *in-situ* confining stress to that measured in the field was used to adjust the curves derived from the RCTS (resonant column torsional shear) laboratory tests. The curve adjustment or correction involved applying the

velocity ratio to the reference strain which, for ratios less than 1, results in a set of more linear modulus reduction and lower damping curves (Wong *et al*., 2007).

Vertical Motions

To model vertical motions, incident inclined P-SV waves were modeled from the source to the site using the plane-wave propagators of Silva (1976) assuming a shear-wave point-source spectrum (Boore, 1983; EPRI, 1993; Silva *et al*., 1996; Wong *et al*., 2007). The angles of incidence were computed by two-point ray tracing through the crust and site-specific profile. To model site response, the near-surface V_P and V_S profiles (Section 4.2, Wong *et al*., 2007), were placed on top of the crustal structure (Section 6.3, Wong *et al*., 2007), the incident P-SV wavefield is propagated to the surface, and the vertical motions were computed.

For typical crustal structures without strong near-surface V_P gradients and at close distances, the predominant motion on the vertical component is principally due to the SV wavefield. However, because there is usually a large V_P gradient (larger for P-waves than for S-waves as Poisson ratio generally decrease with increasing depth) in a soil column (particularly deep profiles), the vertical component is generally controlled by the compressional wavefield at high-frequency (Silva, 1997; Beresnev *et al*., 2002).

In the implementation of the equivalent-linear approach to estimate V/H response spectral ratios, the horizontal component analyses were performed for vertically-propagating shear waves. To compute the vertical motions, a linear analysis was performed for incident inclined P-SV waves using low-strain V_P and V_S derived from the base case profiles. The P-wave damping was assumed to be equal to the low strain S-wave damping (Johnson and Silva, 1981). The horizontal component and vertical component analyses were assumed to be independent (EPRI, 1993).

The approximations of linear analysis for the vertical component and uncoupled vertical and horizontal components have been validated in two ways. Fully nonlinear modeling using a 3-D soil model shows that the assumption of largely independent horizontal and vertical motions for loading levels up to about 0.5g (soil surface, horizontal component) for moderately stiff profiles is appropriate (EPRI, 1993). Additionally, validation exercises with recorded motions have been conducted at over 50 sites that recorded the 1989 **M** 6.9 Loma Prieta and 1992 **M** 6.7 Northridge earthquakes (EPRI, 1993). These validations show the overall bias and variability is acceptably low for engineering applications but is higher than that for horizontal motions. An indirect validation was also performed by comparing V/H ratios from Western North America (WNA) empirical attenuation relations with model predictions over a wide range in loading conditions (Silva, 1997). The results showed a favorable comparison with the model exceeding the empirical V/H ratios at high-frequency by about 20 to 25% (≥ 10 Hz), particularly at soil sites and at high loading levels. For engineering design applications, this reflects a conservative bias, likely resulting from the assumed linearity in the vertical analyses. In the V/H comparisons with empirical relations, the model also showed a small underprediction at low-frequency (≤ 1 Hz) and at large distance (≥ 20 km). To accommodate this potential unconservatism, a lower bound of 0.5 was used, an increase of 67% above the value of 0.3 used in the 2007 analysis, which was based on the minimum empirical deep soil V/H ratio (Section 3.1.2). The increase in the lower bound, which was also applied to the empirical generic deep soil V/H ratios, reflects a

recommendation by the DFNSB staff and the LANL Project Leader for the confirmatory studies project.

To model the site-specific V/H ratios, the same **M**, stress drop, and suite of distances were used as in developing horizontal amplification factors (Table 3). For the vertical analyses, a total kappa value of 0.017 sec, half that of the horizontal (Wong *et al*., 2007), was used. This factor of 50% is based on observations of kappa at strong motion sites (Anderson and Hough, 1984), validation exercises (Silva *et al*., 1996), and the observation that the peak in the vertical spectral acceleration (5% damped) for WNA rock and soil sites is generally near 10 to 12 Hz compared to the horizontal motion peak that occurs at about 5 Hz, conditional on **M** 6.5 at a distance of about 10 to 30 km. This difference of about two in peak frequency may be directly attributable to differences in kappa of about two (Silva and Darragh, 1995).

As with the horizontal analyses, multiple base cases were run: site-specific velocity profiles A and B for CMRR (Figure 50, Wong *et al*., 2007). Multiple G/G_{max} and hysteretic damping curves were not run for the verticals; linear site response analyses were performed, using the lowest small strain damping between uncorrected and corrected curves (Wong *et al*., 2007). However V/H ratios do reflect multiple base case modulus reduction and hysteretic damping curves in the denominator, or horizontal motions.

Site Aleatory Variability

To accommodate random fluctuations in velocity, depth to basement, G/Gmax, and hysteretic damping values across the site, 30 realizations were developed for dynamic material properties. The profile randomization scheme for V_S was developed in 1993 (EPRI, 1993) and updated in 1996 for the Savannah River site (Silva *et al*., 1996). This scheme was based on an analysis of variance on over 500 measured V_S profiles and varies both velocity and layer thickness. The model includes a velocity distribution at depth coupled with a velocity correlation with depth. The depth correlation is intended to eliminate unnatural velocity variations at a given depth that are independent of realizations above and below. Driven by measured velocities, the correlation length (distance) increases with depth with a corresponding decrease in the velocity coefficient of variation (COV) at a given depth. Profiles vary less as depth increases and become more uniform, on average.

For the CMRR base cases A and B, Figure 51 and Figure 52 show the suites of 30 random profiles respectively. Figures 51 and 52 each begin with the median and $\pm 1\sigma$ profiles as well as the respective base-cases. Following each plot of the statistics are the random profiles with five realizations displayed per plot.

For the CMRR analyses, the velocity profiles were randomized with depth to basement (taken as dacite) randomized from about 600 ft to about 900 ft, assuming a uniform distribution (Wong *et al*., 2007) and resulting in a mean depth to dacite of 750 ft. A footprint correlation model was assumed which has a V_S COV near the surface of about 0.25, decreasing to about 0.15 at depth. The footprint model was based on variability in velocity sampled in borings over large footprint (H Area at the DOE Savannah River Site (Silva *et al*., 1997), about 300 by 600 ft.

To accommodate random fluctuations in V_P when modeling vertical motions, Poisson ratio was held constant at the base case values and random V_P generated based on V_S realizations and the

base case Poisson ratios. In reality Poisson ratio will vary but is likely correlated with V_S. As a result, varying Poisson ratio when properly correlated with V_S will likely not result in a greater variation in V_P than assumed here. Additionally, variation in V_P has a much less significant effect on motions than V_S as the wavelengths typically are 2 to 5 times greater. A correlated V_S and V_P randomization scheme is desirable but not yet available.

To capture random fluctuations in modulus reduction and hysteretic damping curves, values were randomized assuming a log-normal distribution consistent with V_S and material damping (EPRI, 1993). Based on random variations in laboratory dynamic testing for soils of the same type or classification (Silva *et al*., 1996) a σ_{ln} of 0.15 and 0.3 is used for G/G_{max} and hysteretic damping, respectively. These standard deviations are taken at a cyclic shear-strain of 0.03%, where the G/G_{max} curves typically show significant reduction. Suites of curves were generated by sampling the distribution, applying the random perturbation to the base case (initial) curve at 0.03% shear strain, and preserving the shape of the base case curve to generate an entire random curve. Bounds are placed at $\pm 2\sigma$ over the entire strain range to prevent nonphysical excursions.

Shear-wave damping was separately (independently) randomized following the same procedure. The randomization code can accommodate coupling or correlation of any degree (1 to 1) between modulus reduction and hysteric damping, which is expected to occur between mean or base case curves reflecting different material type curves. However, for random fluctuations within the same material type the correlation is likely low; that is, a randomly linear curve is not necessarily associated with a randomly low damping. Additionally, because modulus reduction is far more significant than material damping in site response (Silva, 1992), the issue of coupling is not significant.

3.1.1.2 Empirical V/H Ratios

Empirical WNA V/H ratios for deep firm soils were included in the development of vertical motions in addition to site-specific point-source simulations. The use of WNA empirical V/H ratios implicitly assumes similarity in V_S and V_P as well as nonlinear dynamic material properties between deep firm soils in WNA and site-specific soil columns. While this may not be the case for the average WNA deep firm soil (Silva, 1997), evidenced by the comparison in Figure 50 showing CMRR base case V_S A and B as well as the median estimates for deep firm WNA soils (Walling *et al*., 2008), the range in soil conditions sampled by the WNA empirical generic soil relations likely accommodates the local soils at the CMRR site. Additionally, because the model for vertical motions is not as thoroughly validated as the model for horizontal motions (EPRI, 1993; Silva, 1997), inclusion of empirical models is warranted. The additional epistemic variability introduced by inclusion of both analytical and empirical models also appropriately reflects the difficulty and lack of industry consensus on developing (modeling) site-specific vertical motions. In the implementation of fully probabilistic approach to develop vertical hazard curves, the epistemic variability is properly accommodated in the vertical mean UHRS, reflecting a weighted average over multiple vertical hazard curves computed for each model. The vertical DRS (and UHRS) then maintain the desired risk and hazard levels, consistent with the horizontal DRS and UHRS.

3.1.2 Application of the V/H Ratios, Initial Analyses

For the initial analyses in developing the vertical UHRS (Wong *et al*., 2007) the site-specific V/H ratios computed for the CMRR site for base case profiles A and B as well as unadjusted and adjusted curves are shown in Figure 53. The empirical WUS V/H ratios for deep firm soil are shown in Figure 54. Conditional on **M**, the V/H ratios are dependent on distance or, equivalently, expected PGA (Silva, 1997). Similarity in shape and trends is seen between the site-specific and empirical WUS deep firm soil V/H ratios for equivalent or similar PGA values. The maximum empirical PGA at the minimum closest rupture distance of 1 km is about 0.5 g. For the stochastic point-source model, larger values (up to 3.0 g) were accommodated by reducing the mean point-source depth of 8 km (Table 3). The resulting V/H ratios for expected median PGA values exceeding about 0.5 g are considered very conservative due to the linear site response analyses performed in computing the vertical motions. The increase in the ratio as loading level increases (source distance decreases) is primarily due to the reduced motions in the horizontal component and to a decrease in incidence angle for the P-SV wavefield, dominated by compressional-waves at high-frequency (Silva, 1997; Beresnev *et al*., 2002).

As previously discussed, the model predictions of V/H ratios may be slightly unconservative at low-frequency and conservative at high-frequency. While it is important to include site-specific effects on the vertical hazard, potential model deficiencies are compensated with inclusion of empirical V/H ratios computed from WNA generic soil site attenuation relations. Additionally a lower bound of 0.5 was placed on all V/H ratios based on examination of the full suite of **M**, *D*, and site conditions for which empirical relations are currently available.

It is important to note that the site-specific and generic empirical V/H ratios have significantly different shapes as illustrated in Figures 53 and 54, respectively. The site-specific V/H ratios generally show broader and higher-frequency peaks than the empirical V/H ratios. For a direct comparison of the empirical and site-specific V/H ratios, Figure 55 shows the largest ratios for each set at the two distances used to accommodate the hazard deaggregations listed in Table 2 for the 2007 analyses (Wong *et al*., 2007). In general the trends with frequency are similar with the site-specific V/H ratios showing somewhat broader high-frequency (> 1 Hz) levels than the empirical V/H ratios. The site-specific V/H ratio at the closest distance of 0 km (used at AEF 10^{5} and below, Table 4, 2007 analyses) exceeds the empirical by a significant degree and is likely quite conservative. Although this ratio was used only at AEF 10^{5} and below and reflects a horizontal peak acceleration of 0.75g (Figure 55), 50% above the 0.50g reflected in the empirical V/H ratios (Figure 54b), the large increase in the site-specific V/H ratio from 0.50g to 0.75g suggests that a denser sampling in distance as well as magnitude, or acceleration level above 0.5 g, could have been more appropriate in developing the site-specific V/H ratios as is discussed in Section 3.1.3. Use of empirical V/H ratios alone would underestimate the vertical hazard over some frequency ranges above about 1 Hz, based on the numerical model predictions.

In assigning the V/H ratios in the fully probabilistic development of the vertical hazard, the source **M** and *D* change with AEF and structural frequency (Table 2, 2007 analyses). To accommodate the deaggregation in integrating the horizontal hazard with the distributions of V/H ratios, the **M** and *D* selection was conservatively based on the mean deaggregation listed in Table 2. The mean deaggregation for sites where the hazard is dominated by a single fault at close distances and largely controlled by a characteristic magnitude distribution with multiple maximum magnitudes is considered more appropriate in applying V/H ratios to develop vertical

hazard. For these cases, the mean magnitudes and distances across exceedance and structural frequency appropriately reflect the expected source contributions to the site. Alternatively, when the hazard is dominated by multiple sources such as a small magnitude background or fault source as well as distant large magnitude sources, modal deaggregations are more appropriate as they more accurately reflect actual source locations and magnitudes.

Since the V/H ratios vary slowly with distance, only a smooth approximation to the hazard deaggregation is necessary. To conservatively capture the change in mean **M** and *D* with annual exceedance and structural frequency in the V/H ratios, only two distance bins were used: 5 km and 8 km for the empirical and 0 km and 8 km for the site-specific, with the change in distance taken at a return period of 100,000 years and more (Table 4, 2007 analyses). The coarse sampling was intended to permit use of the loading levels (distance bins) used in developing the horizontal amplification factors (Table 3) as well as a standard suite of distances used for the empirical V/H ratios (Figure 54). The sampling was also motivated by the similarity in magnitude and distance deaggregations at peak acceleration (100 Hz) and 1 Hz (Table 2, 2007 analyses). This approach permitted the simplification of using the same suite of V/H ratios across structural frequency, albeit resulting in some conservatism, largely centered in the selection of a single magnitude **M** 7.0, larger than most of the deaggregation magnitudes listed in Table 2 (2007 analyses). As previously discussed, while the mean magnitude deaggregation ranged from about **M** 6+ to about **M** 7 for return periods of 1,000 to 100,000 years and structural frequency from peak acceleration (nominally 100 Hz) to 1 Hz (Table 4, 2007 analyses), a single conservative magnitude, **M** 7, was used for the V/H ratios from PGA (100 Hz) to the lowest frequency defined in the reference site hazard (0.5 Hz) (Section 2; Wong *et al*., 2007). The entire suite of site-specific V/H ratios used in developing the 2007 vertical hazard (**M** 7.0, distances of 0 km and 8 km) is shown in Figure 56. Figure 57 shows the corresponding suite of empirical V/H ratios (**M** 7.0, distances of 5 km and 8 km). This sparse selection, based principally on distance and indirectly on level of motion, was intended to be slightly conservative overall in view of the magnitude selected, the lack of sensitivity of the empirical V/H ratios to distance within 8 km (Figure 54), and the large increase in the numerical V/H ratios from 8 km to 0 km (Figure 53).

The relative weights applied between the empirical and site-specific V/H ratios are listed in Table 5 (see Appendix A for response to comment F-1). Also listed in Table 5 are the relative weights applied to vertical hazard curves reflecting the site-specific epistemic variability in dynamic material properties.

3.1.3 Refined Suite of V/H Ratios

To more closely approximate the mean magnitude and distance deaggregations computed for the NGA horizontal hazard analyses (Section 2) listed in Table 2 (NGA), an additional suite of both site-specific and empirical ratios were computed. The nine additional magnitudes and distances are listed in Table 6 and range in magnitude from **M** 6.0 to **M** 7.0 and distances of 3.0 km to 7.0 km. The suite of additional V/H ratios are shown in Figures 58 and 59 for the site-specific and empirical ratios, respectively. To simplify the figures, both the site-specific (Figure 58) and empirical (Figure 59) show only the largest ratios, profile A and adjusted curves (Wong *et al*., 2007) for the site-specific ratios (e.g., Figure 56) and Abrahamson and Silva (1997) for the empirical ratios (e.g., Figure 54).

For the site-specific V/H ratios, the suite using the refined samplings of magnitudes and distances in Figure 58 are generally close to the coarse suite used in the 2007 analyses shown in Figure 56 at a distance of 8 km and lower than the ratios at a distance of 0 km, especially at high frequency (≥ 5 Hz). In a similar fashion, the refined suite of empirical V/H ratios (Figure 59) for the largest of the two empirical V/H ratios, Abrahamson and Silva (1997) lies somewhat below the largest empirical ratios used in the 2007 analyses, Abrahamson and Silva (1997) at distances of both 8 km and 5 km. Table 4 (update) lists the distribution of the refined suite of V/H ratios used in the update to more closely accommodate the hazard deaggregations shown in Table 2 (NGA). As a result, conditional on the site-specific horizontal hazard, the vertical hazard, reflecting the less conservative and denser sampling in magnitude and distance for the V/H ratios, would be expected to result in lower motions than in the 2007 vertical hazard, provided the horizontal site-specific hazard remained the same.

3.2 HORIZONTAL AND VERTICAL HAZARD UPDATE

The hazard update for CMRR consisted of two components. The first reflects a change in the generic soil reference site horizontal hazard using the recent NGA models (Power *et al*., 2008) accompanied by a reduced epistemic uncertainty for each median equation from σ_{ln} of 0.4 (Wong *et al*., 2007) to 0.25 (Section 2). The second component reflects denser distributions in both magnitude and distance in the V/H ratios (Section 3.1.3) to more closely approximate the mean magnitude deaggregations (Table 2). The refined distributions resulted in lower V/H ratios, particularly at high-frequency, than the conservative coarse sampling (single conservative magnitude **M** 7.0 and two distances) used in the 2007 analyses (Wong *et al*., 2007).

The first component will result in a change in the horizontal site-specific hazard at CMRR while the second component is expected to result in lower vertical hazard (ground motion conditional on AEF) for the same site-specific horizontal hazard.

Another aspect in the update which may result in a slight change in the UHRS and DRS spectral shapes at high-frequency is the addition of two structural frequencies, 6.7 Hz and 13.3 Hz (Table 7). These two additional frequencies were included to better define the shape of the vertical UHRS and DRS near the frequency of the peak SA, about 10 Hz in the 2007 analyses (Wong *et al*., 2007), which may have been the result of sampling in the 2007 analyses.

To compare the 2007 hazard with that of the update, using the NGA models with reduced epistemic uncertainty (Section 2) and refined V/H ratios (Section 3.1.3), Figure 60 shows the horizontal and vertical UHRS for both analyses at return periods of 1,000, 2,500, 10,000, 50,000, and 100,000 years over the range in structural frequencies for which the horizontal reference site hazard was defined (Table 7). For the horizontal hazard at CMRR, there is a modest decrease at 1,000 years at low-frequency (≤ 3 Hz) using the NGA models with an expected larger decrease in the vertical UHRS. The increase in the updated vertical UHRS compared to the 2007 hazard near 1 Hz is attributed to the increase in the minimum V/H ratio from 0.3 to 0.5 (Section 3.1.1.1). Additionally, in the vertical UHRS, the peak frequency has increased from 10 Hz in 2007 to 13 Hz in the update, due to the denser sampling in period (Table 7). For return periods longer than 1,000 years, there is generally a greater reduction in the horizontal UHRS over a broader frequency range. This trend is not directly reflected in the vertical UHRS, due to the denser sampling of the V/H ratios in magnitude and distance, combined with the more refined

application of the V/H ratios with structural frequency (Table 4). The smooth increase in the implied V/H ratios (vertical UHRS divided by horizontal UHRS) with increasing return period is seen in Figure 61 and correctly accommodates the effects of the increased magnitude and decreased source distance with increasing return period.

For the DRS, similar trends with the horizontal and vertical UHRS are seen in Figure 62 for SDC-3, SDC-4, and SDC-5.

3.2.1 TA-55 Site-Specific Hazard

Following a recommendation by the DFNSB staff, the design motions for CMRR were based on the envelope of the site-specific CMRR hazard and the hazard computed for the nearby TA-55 profile (Wong *et al*., 2007). The horizontal hazard at TA-55 was updated with the NGA models (Section 2), revised epistemic variability (Section 2), and denser sampling of structural periods (Table 7). As with CMRR, the vertical hazard for TA-55 was updated with the revised suite of magnitudes and distances used in computing the V/H ratios (Table 4).

Following the 2007 analyses (Wong *et al*., 2007), three sets of modulus reduction and hysteretic damping curves were used in developing the horizontal motions: TA-55 specific curves (Wong *et al*., 1995) and CMRR unadjusted and adjusted curves (Wong *et al*., 2007). The site-specific horizontal hazard curves developed with each set of nonlinear dynamic material property curves were given equal weight (Table 5) in developing both the horizontal motions as well as the V/H ratios (Figure 63). Following CMRR, the site-specific V/H ratios (Figure 63) were supplemented with empirical generic deep firm soil V/H ratios computed from Abrahamson and Silva (1997) (Figure 59) and Campbell and Bozorgnia (2003) models. As with CMRR, the hazard curves computed with the site-specific and empirical V/H ratios were given equal weight (Table 5).

The horizontal and vertical UHRS developed for TA-55 are shown in Figure 64 for the suite of return periods of 1,000, 2,500, 10,000, 50,000, and 100,000 years compared to the 2007 analyses (Wong *et al*., 2007). The implied V/H ratios are shown in Figure 65 with the DRS at SDC-3, SDC-4, and SDC-5 shown in Figure 66.

The final design UHRS computed as the envelope of the CMRR hazard and TA-55 are shown in Figure 67 compared to the 2007 analyses (Wong *et al*., 2007) for the suite of return periods. Figure 68 shows the corresponding implied V/H ratios and Figure 69 shows the corresponding DRS computed for SDC-3, SDC-4, and SDC-5. Table 8 lists the CMRR DRS for SDC-3, SDC-4, and SDC-5 as well as the UHRS at return periods of 1,000, 2,500, 10,000, 50,000, and 100,000 years.

To illustrate the effects of the site-specific profile (CMRR and TA-55), Figure 70 compares the updated envelope UHRS (Figure 67) with that computed with the NGA models for generic deep firm soil ($\overline{V}_S$(30m) 270m/sec, Section 2) for 1,000, 2,500, and 10,000-year return periods. In general the site-specific UHRS significantly exceeds the generic soil UHRS over much of the frequency range below about 2 Hz. For frequencies exceeding about 2 Hz the site-specific and generic soil UHRS are quite similar at 1,000 and 2,500-years return periods. At the high loading levels, 10,000-year return period and at frequencies beyond about 5 Hz, the site-specific exceeds the generic deep firm soil UHRS by about 10 to 20% (14% at peak acceleration).

3.3 STRAIN-COMPATIBLE PROPERTIES

In the current approach to develop site-specific design motions (UHRS, DRS), a probabilistic method was used which correctly preserves the annual exceedance probabilities of the generic site PSHA (Section 2), while properly incorporating variabilities (aleatory and epistemic) in site-specific dynamic material properties. For structural analyses, strain-compatible material properties are desired which are consistent with the probabilistically-based design motions. To achieve hazard consistency in the strain-compatible properties, they must reflect both the hazard level (ground motion and exceedance probability) as well as the aleatory and epistemic components in site-specific dynamic material properties incorporated in developing the design motions.

Simply using control motions based on a generic rock site hazard to drive the site-specific soil column (McGuire *et al.*, 2001; RG 1.165, NRC, 1997) will, in general, not result in strain-compatible properties consistent with the site-specific soil hazard developed using a fully probabilistic approach. Additionally, this approach is not viable when the generic hazard is developed for soil or soft rock site conditions. For such cases, the rock control motions which are appropriate for the base of the soil conditions are not generally available.

As a result an approach has been developed that is intended to develop hazard-consistent strain compatible properties that are consistent with the probabilistic site-specific hazard. The approach assumes strain-compatible properties are approximately lognormally-distributed, consistent with observed strong ground motion parameters (Abrahamson and Shedlock, 1997), and makes use of the distributions of strain-compatible properties catalogued during development of the suites of amplification factors. Specifically, the approximate approach examines the site-specific horizontal or vertical hazard curves at the AEF of interest, determines the ground motion (interpolating logarithmically as necessary), and locates the corresponding amplification factors and associated strain-compatible properties at the ground motion levels determined from the hazard curve. For each case of epistemic variability, median and sigma estimates (over aleatory variability) are interpolated (logarithmically) to the appropriate ground motion as specified by the site-specific hazard curve at the desired annual exceedance probability. To accommodate epistemic variability in site-specific properties, the same weights used in developing the site-specific hazard curves are applied to the corresponding strain compatible properties. The weighted median (mean log) set of strain compatible properties (for each layer) is given by Equation 1 while the associated variance includes both the aleatory component for each epistemic case as well as the variability of mean properties for each base case (Equation 2).

The approach approximately accommodates both the median estimates as well as aleatory and epistemic variabilities in strain-compatible properties that are consistent with the site-specific horizontal and vertical hazard used for design. The approach results in a suite of hazard-consistent strain-compatible properties (HCSCP). To examine consistency in strain-compatible properties across structural frequency, as the magnitude contributions can vary, the entire process is performed at PGA (typically 100 Hz), and again at low frequency, typically 1 Hz. Since amplification factors are typically developed for a range in magnitude reflecting contributions at low (≤ 2 Hz) and high (≥ 2 Hz) frequencies, the consistency check at PGA and 1 Hz covers the typical range in control motions. If the differences in properties at high- and low- frequency is less than 10%, the high-frequency properties are used since this frequency range typically has the

greatest impact on soil nonlinearity. If the difference exceeds 10%, two sets of properties are developed with the recommendation that separate structural analyses be performed. For all of the LANL technical areas, the 100 Hz and 1 Hz sets of strain-compatible properties were within 10%.

In summary, the properties are interpolated to the desired peak acceleration (mean hazard) and a consistency check is performed at 1.0 sec. The properties are calculated for each case of epistemic uncertainty. Each case has median (μ_i) and $\pm\ \sigma_i$ properties. Each case of epistemic uncertainty is then combined by the weighted median properties

$$\overline{\mu_{ln}} = \Sigma\, \mathrm{W_i}\, \mu_{ln_i} \tag{1}$$

The weighted variances include site epistemic uncertainty (different medians) in combined properties through

$$\mathrm{Var}(ln) = \Sigma\left[\mathrm{W_i}\ \sigma_{ln_i}^2 + \mathrm{W_i}\left(\mu_{ln_i} - \overline{\mu}\right)^2\right] \tag{2}$$

Strain-compatible properties including V_S, V_S sigma, S-wave damping, S-wave damping sigma, V_P, V_P sigma, P-wave damping, P-wave damping sigma and effective strains as a function of depth are shown on Figures 71 and 72 for 2,500-year return period.

3.4 UPDATE OF HORIZONTAL AND VERTICAL DESIGN MOTIONS FOR DACITE OUTCROPPING

The dacite outcrop hazard reflects the firm rock conditions which underlie the surficial soils at the LANL. The material has a V_S of about 5,600 ft/sec and occurs at a depth of about 750 ft at CMRR (Figure 50). The dacite outcrops hazard was computed with the overburden removed and reflects dacite outcrop at the ground surface.

For the development of site-specific V/H ratios, Figure 73 shows the update suite of magnitudes and distances (Table 4) computed with the unadjusted dacite G/G_{max} and hysteretic damping curves. Empirical generic soft rock V/H ratios were also used in developing the vertical hazard for the dacite outcrop. Figure 74 shows the empirical V/H ratios computed at the update suite of magnitudes and distances (Table 4) with the Abrahamson and Silva (1997) and Campbell and Bozorgnia (2004) models.

To provide the greatest flexibility for future analyses, the dacite hazard was computed without topographic effects (Wong *et al*., 2007) as well as including the topographic amplification in a fully probabilistic manner (Wong *et al*., 2007). The dacite outcrop UHRS are shown in Figure 75 for the suite of return periods of 1,000, 2,500, 10,000, 50,000, and 100,000 years with the corresponding implied V/H ratio shown in Figure 76. The DRS are shown in Figure 77 for SDC-3, -4, and -5. The DRS and UHRS are listed in Table 9.

To illustrate the effects of the topographic amplification, Figure 78 compares DRS (SDC-3, -4, and -5) computed for dacite outcrop (overburden removed) including and without topographic amplification. As Figure 78 demonstrates, the topographic amplification is larger for the vertical component compared to the horizontal component (Wong *et al*., 2007). Additionally, due to the

fully probabilistic implementation, the topographic amplification increases with increasing return period as evidenced in Figure 78 with SDC-3, -4, and -5. This trend is both expected and appropriate, being due to the epistemic variability associated with the median topographic amplification (Wong *et al*., 2007). The suite of dacite UHRS at return periods of 1,000, 2,500, 10,000, 50,000, and 100,000 years, and 10^5 computed without topographic amplification are shown in Figure 79. Table 10 lists the DRS and UHRS for the dacite computed without topographic amplification.

3.4.1 Dacite Outcrop Spectral Match Time Histories

The spectral matching criteria followed that recommended in ASCE/SEI 43-05. In this project the maximum correlation (absolute) for the acceleration time histories of 0.3, based on recorded motions specified in ASCE/SEI 43-05, was decreased to 0.16. Additionally, to maintain time history risk levels consistent with the DRS at high frequency, particularly for the vertical component, the spectral match criteria were extended from 25 Hz to 50 Hz. For the spectral matching, the seed recorded time histories were the same as used in the 2007 analysis: the 23 November 1980 **M** 6.9 Irpinia, Italy earthquake recorded at the Sturno site. The earthquake was a normal faulting earthquake recorded at a rupture distance of 11 km (Wong *et al*., 2007). For the dacite motions that include topographic amplification, the resulting three-component time histories, spectral matches, and ratios of time history spectra to target spectra are shown in Figures 80 to 82 for SDC-3, -4, and -5, respectively. The peak time domain values (absolute) as well as the cross correlations (zero lagged) are listed in Table 11a.

For the dacite outcrop spectral match to target spectra computed without topographic amplification, Figures 83 to 85 show the time histories, spectral matches, and ratios of spectral matches to target spectra for the three components at SDC-3, -4, and -5, respectively. The corresponding peak time domain values and cross correlations are listed in Table 11b. The same basis motion, Irpimia, Italy earthquake recorded at the Sturno site, was used for the spectral match.

3.5 DRS AT MULTIPLE DAMPING RATIOS

DRS at dampings of 0.5, 1, 2, 3, 7, and 10% were computed from the 5%-damped DRS using the empirical damping ratio model of Abrahamson and Silva as described in Appendix A of Silva *et al*. (1996). The damping ratios were computed for a **M** 6.75 earthquake based on the deaggregations at return periods of 1,000, 2,500, 10,000, 50,000, and 100,000 years across structural frequency and do not have a significant dependence on site condition or distance. Model coefficients for both horizontal and vertical components are listed in Appendix A of Silva *et al*. (1996). The damped horizontal and vertical spectra are shown in Figure 86 to 93 for CMRR, TA-55, envelope of CMRR and TA-55, and dacite, including topographic amplification, for each SDC. The corresponding DRS spectral values are listed in Tables 12 to 19. For the dacite design spectra (SDC-3, -4, and -5) computed without topographic amplification, Figures 94 and 95 show the horizontal and vertical components at multiple dampings, respectively, and Tables 20 and 21 list the corresponding spectra.

3.6 CMRR AT-DEPTH MOTIONS

To provide guidance on the development of embedment design motions, Appendix C shows fully probabilistic CMRR spectra (SDC-3, -4, and -5 as well as UHRS at return periods of 1,000, 2,500, 10,000, 50,000, and 100,000 years) computed at depths of 65, 69, and 75 ft compared to the fully probabilistic spectra computed at the surface of CMRR (Figures 60 and 62). These depths reflect current considerations for the CMRR overburden and tuff removal and foundation location. At each depth, three suites of spectra were computed corresponding to: 1) outcrop motion with the overburden and tuff removed to the depth specified, 2) outcrop motion (upgoing waves only) with the overlying materials present, and in-layer motion (total motion or sum of upgoing and downgoing waves) with the overlying materials present.

In the development of the CMRR foundation motions, the fully probabilistic approach (Section 3.1) was used to maintain consistency with the surface hazard at CMRR (Section 3.2). To develop the horizontal component foundation hazard at CMRR, transfer functions were generated between the at-depth motions at CMRR (profiles A and B as well as two sets of G/G_{max} hysteretic damping curves [Wong *et al*., 2007]) and the generic soil of the NGA models (V_S30 of 270m/sec). These transfer functions were then integrated with the generic soil site hazard curves to produce fully probabilistic hazard curves for CMRR at the foundation level.

For the site-specific hazard computed with the CMRR stochastic attenuation relationships for surface motions (Wong *et al*., 2007), transfer functions were developed for CMRR foundation motions relative to CMRR surface motions. These transfer functions were then integrated with the hazard curves developed in the updated PSHA using the CMRR site-specific stochastic models. In a similar fashion as the CMRR hazard at the surface (Wong *et al*., 2007), two sets of hazard curves were produced for foundation hazard, those based on the NGA models and conditioned to CMRR foundation hazard and those based on the CMRR stochastic models and conditioned to CMRR foundation hazard. The two sets of hazard curves for CMRR foundation hazard were then weighted (Wong *et al*., 2007) to produce the mean horizontal component foundation hazard at CMRR. Finally the resultant foundation horizontal hazard curves were conditioned for horizontal component topographic amplification (Wong *et al*., 2007).

For the vertical component, the at-depth motions (as well as motions reflecting material removal) are considered approximate as the surface V/H ratios were used in integrations with the horizontal component foundation horizontal hazard (without topographic amplification). While this approximation was not expected to significantly impact the at-depth vertical hazard, the vertical motions computed for the material removed to the specific depths are likely somewhat conservative as V/H ratios generally decrease with increasing site stiffness (Silva, 1997). This trend was expected to have a less significant impact on the at-depth motions computed with the overlying materials present. Finally, as with the horizontal foundation hazard, the vertical component foundation hazard was conditioned for topographic amplification (Wong *et al*., 2007).

The site-specific UHRS, DRS, time histories, and strain-compatible properties described in this report (excluding at-depth motions) are appropriate for use in design of SDC-3, -4, and -5 structures, systems and components located on the TA-55 mesa at LANL. At-depth motions are not directly applicable to design because the process described in Section 3.6 were applied to the CMRR-specific DRS and not the CMRR/TA-55 envelope. However, the surface to at-depth ratios implied in Section 3.6 should provide guidance for at-depth design using enveloping surface UHRS and DRS.

There were a number of likely conservative assumptions made in the development of the design basis ground motions. These assumptions include assumed linear vertical component site response, analysis using the most conservative of two viable site kappa values, possible double counting of aleatory variability using the Method 3 approach to site response, and possible conservatism in the epistemic uncertainty used for the stochastic ground motion models. These possible conservatisms were not addressed in the current update. It is likely that these assumptions introduce a conservative bias in the design basis.

In this update of the seismic design ground motions for the CMRR facility, the horizontal probabilistic hazard for a generic deep firm soil condition (V_S30 270 m/sec) has been computed using the NGA models and an additional epistemic uncertainty of 0.25 (ln) was included in the PSHA. This horizontal hazard has been modified for the CMRR site-specific conditions using Approach 3 and amplification factors as was done in the previous 2007 study. A refined suite of site-specific and empirical V/H ratios based on the mean magnitudes and distances from the hazard deaggregation were computed and applied in a fully probabilistic manner to both the horizontal hazard based on the NGA models and the hazard computed using the site-specific stochastic attenuation relationships. Site-specific UHRS, DRS, time histories, and strain-compatible properties for CMRR were developed based on the final horizontal and vertical hazard results. At-depth motions were also calculated for CMRR to be used as a guide, not design, for development of embedment design motions.

In addition to the recommendations for future studies made in Wong *et al*. (2007), there are a number of studies that if performed, would likely reduce potential conservative bias in the recommended design ground motions:

1) Nonlinear P-wave site response effects should be incorporated into the vertical ground motions. Preliminary studies on how to develop such an approach have been completed.

2) Evaluate the impact of the alternate kappa value (0.08 sec) that was estimated from the LANL seismic data but not used because of time and budget constraints (Wong *et al*., 2007). The hazard results from the alternate kappa estimate should be incorporated as epistemic uncertainty and appropriate weights should be developed with the Steering Committee.

3) An evaluation of the epistemic uncertainty used in the stochastic ground motion median models should be completed. The stochastic ground motion attenuation model used medium, high and low stress drop models to develop uncertainty in median ground motion. The stress drops inferred from the NGA relationships can be used to refine this model and provide consistency with the NGA models.

4) The site component of the aleatory variability incorporated in the Method 3 approach in this study should be corrected. The current approach may double-count some portion of the variability of the site response.

5) The NGA Abrahamson and Silva (2008) model has been recently revised to correct the hanging wall effect (N. Abrahamson, written communication, November 2009). As a result, hazard for sites in the hanging wall using the revised model will have reduced ground motions. Because LANL is located in the hanging wall of the Pajarito fault, the probabilistic hazard should be updated resulting in lower ground motions from the Abrahamson and Silva (2008) model. This model was weighted 0.125 in the final hazard.

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Table 1

"dgnd" Scale Factors

Period	**PGA**	**0.05**	**0.075**	**0.1**	**0.15**	**0.2**	**0.3**	**0.4**	**0.5**	**0.75**	**1**	**1.5**	**2**
Frequency	**100.00**	**20.00**	**13.33**	**10.00**	**6.67**	**5.00**	**3.33**	**2.50**	**2.00**	**1.33**	**1.00**	**0.67**	**0.50**
M mean	6.51	6.39	6.30	6.26	6.32	6.42	6.55	6.61	6.65	6.70	6.73	6.76	6.79
D mean	2.62	4.02	4.27	4.46	4.64	4.50	4.42	4.20	4.11	4.04	4.29	4.10	4.18
dgnd	1.45	1.45	1.440	1.40	1.44	1.48	1.48	1.46	1.445	1.41	1.37	1.26	1.15
dgnd Ln	0.3716	0.3716	0.3646	0.3365	0.3646	0.3887	0.3893	0.3812	0.3681	0.3415	0.3148	0.2311	0.1398

Table 2

Deaggregations

	1,000 Year	2,500 Year	10,000 Year	25,000 Year	100,000 Year
2007 Analyses (Empirical)					
PGA					
M	6.03	6.36	6.64	6.70	6.91
D	7.66	4.84	3.27	2.87	2.39
***T*1.0**					
M	6.25	6.54	6.81	6.90	7.02
D	13.11	7.02	3.45	2.77	2.28
NGA					
PGA					
M mean	5.87	6.18	6.50	6.61	6.73
D mean	8.47	5.64	3.76	3.37	3.07
***T*0.1**					
M mean	—	6.04	6.28	6.35	6.35
D mean	—	6.05	4.42	3.91	3.47
***T*0.2**					
M mean	5.85	6.15	6.42	6.52	6.59
D mean	9.82	6.64	4.52	3.83	2.99
***T*1.0**					
M mean	6.11	6.43	6.76	6.83	6.92
D mean	12.27	6.71	4.05	3.42	2.97

Table 3

Point Source Parameters
M 7.0, Single-Corner Source Reference Site PGA, Distance, and Depth

Peak Acceleration (g)	Distance (km)	Depth (km)
3.00	0.0	1.05
2.00	0.0	1.60
1.50	0.0	2.40
1.25	0.0	3.00
1.00	0.0	4.40
0.75	0.0	6.75
0.50	8.0	8.00
0.40	14.0	8.00
0.30	19.0	8.00
0.20	31.0	8.00
0.10	60.0	8.00
0.05	115.0	8.00
0.01	310.0	8.00

$\Delta\sigma$ 60 bars

κ 0.040 sec

Q_o 370 $f^{0.35*}$

Table 4

Application of V/H Ratios

2007 Analyses								
Empirical			**Model**					
M	***R*** (km)		**M**		***R*** (km)			
7	8.0		7		8.0			
7	8.0		7		8.0			
7	8.0		7		8.0			
7	5.0		7		0.0			
Update								
Period (sec)	**≤ 2,500 Year***		**10,000 Year**		**25,000 Year**		**≥ 100,000 Year**	
	M	*D*(km)	**M**	*D*(km)	**M**	*D*(km)	**M**	*D*(km)
PGA	6.2	6.0	6.5	4.0	6.5	4.0	6.75	3.0
0.050	6.2	6.0	6.5	4.0	6.5	4.0	6.75	3.0
0.075	6.2	6.0	6.5	4.0	6.5	4.0	6.75	3.0
0.100	6.0	6.0	6.2	4.0	6.5	4.0	6.5	3.0
0.150	6.0	6.0	6.2	4.0	6.5	4.0	6.5	3.0
0.200	6.2	6.0	6.5	4.0	6.5	4.0	6.5	3.0
0.300	6.2	6.0	6.5	4.0	6.5	4.0	6.5	3.0
0.400	6.2	6.0	6.5	4.0	6.5	4.0	6.5	3.0
0.500	6.2	6.0	6.5	4.0	6.5	4.0	6.5	3.0
0.750	6.5	7.0	6.75	4.0	6.75	3.0	7.0	3.0
1.000	6.5	7.0	6.75	4.0	6.75	3.0	7.0	3.0
1.500	6.5	7.0	6.75	4.0	6.75	3.0	7.0	3.0
2.000	6.5	7.0	6.75	4.0	6.75	3.0	7.0	3.0

* For intermediate AEF the V/H ratios were interpolated.

Table 5

V/H Ratio Relative Weights

CMRR	
Stochastic	
Profile	**Weight**
A	0.5
B	0.5
G/G_{max} and Hysteretic Damping Curves	
Uncorrected	0.5
Corrected	0.5
Empirical	
Abrahamson and Silva (soil, hanging wall), 1997	0.5
Campbell and Bozorgnia (soil), 2003	0.5
TA-55	
Stochastic	
Profile	**Weight**
TA-55*	1.0
G/G_{max} and Hysteretic Damping Curves	
CMRR Uncorrected	0.33
CMRR Corrected	0.33
TA-55*	0.33
Empirical	
Abrahamson and Silva (soil, hanging wall), 1997	0.5
Campbell and Bozorgnia (soil), 2003	0.5
Dacite	
Stochastic	
Profile	**Weight**
Dacite	1.0
G/G_{max} and Hysteretic Damping Curves	
CMRR Uncorrected Dacite	1.0
Empirical	
Abrahamson and Silva (soft rock, hanging wall), 1997	0.5
Campbell and Bozorgnia (soft rock), 2003	0.5

* Wong *et al*., 1997

Table 6

Empirical and Numerical V/H Ratios Used in The Update

M	*D* (km)
6.00	6.0
6.20	4.0, 6.0
6.50	3.0, 4.0, 7.0
6.75	3.0, 4.0
7.00	3.0

Table 7

Suite of UHRS and DRS Periods and Frequencies

Period (sec)	Frequency (Hz)
0.010 (PGA)	100.000
0.020*	50.000
0.030*	33.333
0.050	20.000
0.075	13.330**
0.100	10.000
0.150	6.667**
0.200	5.000
0.300	3.333
0.400	2.500
0.500	2.000
0.750	1.333
1.000	1.000
1.500	0.667
2.000	0.500
3.000	0.333**
5.000	0.200**
10.000	0.100**

* Taken as equal to PGA (100 Hz) for the horizontal component. For the vertical component, PGA taken at 50 Hz.

** Not available for the GMPEs used in the 2007 hazard analyses (Wong *et al*., 2007)

Table 8a

CMRR Design Spectra Envelope of CMRR and TA-55 Hazard

Period (Sec)	SDC-3		SDC-4		SDC-5	
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.41883	0.47309	0.62778	0.73831	1.03331	1.29030
0.020	0.41883	0.47309	0.62778	0.73831	1.03331	1.29030
0.030	0.41883	0.65538	0.62778	1.02872	1.03331	1.81866
0.050	0.51813	0.98816	0.77821	1.56239	1.30750	2.80251
0.060	0.56515	1.14052	0.84709	1.80297	1.40818	3.22417
0.075	0.64230	1.26564	0.95242	1.99562	1.56060	3.56219
0.085	0.69330	1.25242	1.02433	1.96090	1.66967	3.43744
0.100	0.77002	1.09880	1.13490	1.75942	1.82278	2.98512
0.150	0.88703	0.97086	1.31923	1.55024	2.17958	2.65348
0.200	0.79737	0.80526	1.20617	1.29146	1.99172	2.26075
0.300	0.81121	0.57885	1.21909	0.93418	2.06247	1.65739
0.400	0.76681	0.50254	1.16285	0.80708	1.94888	1.43644
0.500	0.80530	0.51926	1.24190	0.83128	2.14129	1.44762
0.750	0.75495	0.43680	1.20617	0.70032	2.18343	1.22926
1.000	0.72384	0.41161	1.15298	0.64708	2.12088	1.13518
1.500	0.55115	0.31159	0.98351	0.54785	1.99401	1.03222
2.000	0.26929	0.15477	0.51904	0.29651	1.12743	0.62720
3.000	0.15075	0.08759	0.28230	0.16262	0.63668	0.35326
5.000	0.10552	0.06145	0.19894	0.11513	0.46183	0.26155
10.000	0.02109	0.01229	0.04132	0.02381	0.10455	0.06039

Table 8b

CMRR UHRS Envelope of CMRR and TA-55 Hazard

Period (sec)	1,000 Yr RP		2,500 Yr RP		10,000 Yr RP		50,000 Yr RP		100,000 Yr RP	
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.27207	0.29171	0.46571	0.50525	0.90150	1.03450	1.28100	1.53720	2.02470	2.58220
0.020	0.27207	0.29171	0.46571	0.50525	0.90150	1.03450	1.28100	1.53720	2.02470	2.58220
0.030	0.27207	0.40384	0.46571	0.69589	0.90150	1.42924	1.28100	2.14805	2.02470	3.65784
0.050	0.34036	0.60838	0.57494	1.04160	1.10840	2.14760	1.58960	3.27430	2.58050	5.67230
0.060	0.37771	0.70863	0.62841	1.20240	1.20250	2.48080	1.72850	3.77810	2.77400	6.51900
0.075	0.43561	0.79623	0.72192	1.33780	1.35380	2.76220	1.93290	4.17650	3.06220	7.18860
0.085	0.47584	0.79420	0.78208	1.33320	1.45440	2.72950	2.07510	4.08940	3.27280	6.89580
0.100	0.53605	0.67631	0.87076	1.14370	1.60250	2.45770	2.29630	3.71060	3.56480	5.93440
0.150	0.59914	0.60035	0.99405	1.01330	1.86220	2.16740	2.68140	3.26490	4.29300	5.28560
0.200	0.52120	0.48548	0.87854	0.83684	1.69350	1.76740	2.47240	2.72590	3.92790	4.55290
0.300	0.53073	0.34876	0.89967	0.59780	1.71550	1.25720	2.49080	1.97790	4.08980	3.36310
0.400	0.50156	0.30604	0.84276	0.52153	1.64060	1.09460	2.38670	1.70470	3.85300	2.91150
0.500	0.50305	0.30922	0.87031	0.54059	1.75430	1.14980	2.57040	1.75300	4.26220	2.90380
0.750	0.44277	0.25498	0.78754	0.45406	1.66980	0.97100	2.54100	1.47790	4.42150	2.46930
1.000	0.41010	0.23691	0.75739	0.43637	1.57620	0.90280	2.42520	1.35220	4.32560	2.27640
1.500	0.24083	0.13904	0.51476	0.29535	1.35260	0.75878	2.18980	1.21070	4.16080	2.11100
2.000	0.10517	0.06063	0.23285	0.13464	0.69317	0.39447	1.20100	0.68402	2.41110	1.33370
3.000	0.06113	0.03565	0.13417	0.07864	0.37263	0.21454	0.64386	0.36931	1.37840	0.75781
5.000	0.04157	0.02429	0.09328	0.05466	0.25976	0.15053	0.45527	0.26264	1.00990	0.56865
10.000	0.00867	0.00502	0.01794	0.01057	0.05092	0.02943	0.09641	0.05525	0.23700	0.13688

Table 9a

Dacite DRS Including Topographic Amplification

Period (sec)	SDC-3		SDC-4		SDC-5	
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.25816	0.24180	0.43046	0.40639	0.76802	0.74072
0.020	0.25816	0.24180	0.43046	0.40639	0.76802	0.74072
0.030	0.25816	0.35482	0.43046	0.60090	0.76802	1.10469
0.050	0.42215	0.57523	0.70485	0.98354	1.24697	1.82782
0.060	0.49306	0.68310	0.82915	1.18467	1.44781	2.20996
0.075	0.57535	0.77384	0.98326	1.36577	1.75166	2.58227
0.085	0.62133	0.89982	1.07305	1.61862	1.90213	3.05766
0.100	0.66682	0.77570	1.18333	1.46382	2.13748	2.72701
0.150	0.73240	0.62601	1.37052	1.20088	2.56010	2.22884
0.200	0.67983	0.48332	1.29269	0.89658	2.46317	1.71244
0.300	0.56245	0.35363	0.99425	0.62045	1.99244	1.21394
0.400	0.48924	0.29129	0.82105	0.49474	1.62458	0.96553
0.500	0.43984	0.25534	0.73415	0.42676	1.41514	0.82010
0.750	0.34359	0.19975	0.58320	0.33993	1.11124	0.64694
1.000	0.27318	0.15871	0.47197	0.27464	0.90204	0.52493
1.500	0.19857	0.11538	0.35562	0.20710	0.71590	0.41820
2.000	0.15295	0.09288	0.28014	0.17548	0.58992	0.37665
3.000	0.11057	0.06435	0.20254	0.11794	0.44770	0.25808
5.000	0.08115	0.04719	0.15435	0.08953	0.36601	0.20982
10.000	0.01835	0.01069	0.03587	0.02082	0.09318	0.05418

Table 9b

Dacite UHRS Including Topographic Amplification

Period (sec)	1,000 Yr RP		2,500 Yr RP		10,000 Yr RP		50,000 Yr RP		100,000 Yr RP	
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.13562	0.12439	0.25804	0.23978	0.60770	0.57115	0.92642	0.87809	1.54210	1.49690
0.020	0.13562	0.12439	0.25804	0.23978	0.60770	0.57115	0.92642	0.87809	1.54210	1.49690
0.030	0.13562	0.17533	0.25804	0.34919	0.60770	0.84151	0.92642	1.30328	1.54210	2.23922
0.050	0.20545	0.27020	0.42140	0.56071	1.00750	1.37120	1.51790	2.14340	2.49060	3.71920
0.060	0.23446	0.31217	0.48868	0.65648	1.17520	1.63740	1.79200	2.60020	2.88850	4.51070
0.075	0.26496	0.34120	0.56110	0.73075	1.39710	1.89990	2.14230	3.02400	3.51000	5.28000
0.085	0.28307	0.38922	0.59962	0.83370	1.51580	2.24470	2.35020	3.61810	3.81240	6.25540
0.100	0.29601	0.32068	0.62626	0.68509	1.67780	2.01980	2.62730	3.35140	4.30040	5.56660
0.150	0.31773	0.26622	0.65232	0.54390	1.86370	1.62910	3.12470	2.77200	5.24850	4.56480
0.200	0.31560	0.22824	0.59588	0.43423	1.64570	1.17040	2.97090	2.03520	5.15930	3.56650
0.300	0.29315	0.18391	0.53030	0.33593	1.25930	0.80830	2.20320	1.36970	4.23170	2.54490
0.400	0.26230	0.15396	0.48587	0.28585	1.08430	0.65803	1.77270	1.07460	3.40370	2.01240
0.500	0.23254	0.13465	0.43920	0.25463	0.98471	0.57619	1.58080	0.91952	2.93420	1.69630
0.750	0.17132	0.09933	0.33738	0.19562	0.80543	0.46772	1.26640	0.73909	2.28070	1.32860
1.000	0.13113	0.07579	0.26352	0.15287	0.65045	0.37598	1.03390	0.60212	1.85370	1.08060
1.500	0.08781	0.05078	0.18479	0.10713	0.48176	0.27857	0.79317	0.46244	1.49680	0.87662
2.000	0.06363	0.03733	0.13917	0.08194	0.37507	0.23090	0.63189	0.40199	1.25100	0.80606
3.000	0.04617	0.02692	0.10061	0.05852	0.26940	0.15606	0.45688	0.26612	0.96257	0.55423
5.000	0.03191	0.01862	0.07111	0.04146	0.20003	0.11624	0.35478	0.20554	0.80613	0.46056
10.000	0.00742	0.00427	0.01565	0.00914	0.04380	0.02545	0.08358	0.04844	0.21311	0.12394

Table 10a

Dacite DRS Without Topographic Effects

Period (sec)	SDC-3		SDC-4		SDC-5	
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.23774	0.20299	0.38830	0.33567	0.66628	0.58995
0.020	0.23774	0.20299	0.38830	0.33567	0.66628	0.58995
0.030	0.23774	0.29769	0.38830	0.49523	0.66628	0.88150
0.050	0.38802	0.48223	0.63319	0.80834	1.07118	1.46201
0.060	0.45443	0.57313	0.74480	0.97381	1.24707	1.76462
0.075	0.53030	0.65130	0.88622	1.12607	1.51677	2.04979
0.085	0.57315	0.67716	0.96657	1.17995	1.64796	2.13212
0.100	0.61504	0.65394	1.06474	1.20829	1.85011	2.11627
0.150	0.67856	0.52422	1.24617	0.98112	2.23088	1.70738
0.200	0.63234	0.40694	1.18854	0.74494	2.14974	1.33170
0.300	0.51920	0.29802	0.91330	0.52024	1.77638	0.97248
0.400	0.45160	0.24461	0.75185	0.41195	1.45461	0.77945
0.500	0.40641	0.21451	0.67206	0.35490	1.26839	0.66186
0.750	0.31717	0.16820	0.52970	0.28259	0.99044	0.52462
1.000	0.25245	0.13365	0.42852	0.22788	0.80157	0.42742
1.500	0.18447	0.09760	0.32510	0.17280	0.64336	0.34236
2.000	0.14247	0.07897	0.25733	0.14754	0.53412	0.31195
3.000	0.10306	0.05477	0.18625	0.09933	0.40842	0.21504
5.000	0.07582	0.04033	0.14249	0.07587	0.33719	0.17621
10.000	0.01722	0.00915	0.03344	0.01779	0.08683	0.04585

Table 10b

Dacite UHRS Without Topographic Effects

Period (sec)	1,000 Yr RP		2,500 Yr RP		10,000 Yr RP		50,000 Yr RP		100,000 Yr RP	
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.12706	0.10626	0.24260	0.20458	0.55521	0.47307	0.82709	0.71941	1.32060	1.18060
0.020	0.12706	0.10626	0.24260	0.20458	0.55521	0.47307	0.82709	0.71941	1.32060	1.18060
0.030	0.12706	0.15036	0.24260	0.29823	0.55521	0.69938	0.82709	1.06460	1.32060	1.76872
0.050	0.19499	0.23285	0.39630	0.47948	0.91457	1.14450	1.34810	1.74430	2.11030	2.94330
0.060	0.22194	0.26904	0.46211	0.56218	1.07600	1.36560	1.58920	2.11560	2.45030	3.56280
0.075	0.25156	0.29441	0.52888	0.62784	1.27530	1.58670	1.90940	2.46780	2.99950	4.13830
0.085	0.26820	0.30347	0.56643	0.64769	1.39050	1.66140	2.09200	2.59600	3.25610	4.29740
0.100	0.27997	0.27623	0.59212	0.58987	1.54840	1.69900	2.33490	2.73740	3.66300	4.23380
0.150	0.30004	0.22835	0.61581	0.46682	1.72520	1.38200	2.81460	2.23710	4.50500	3.40870
0.200	0.29498	0.19479	0.56071	0.37049	1.53250	0.99498	2.71580	1.67980	4.43040	2.71240
0.300	0.27393	0.15672	0.49193	0.28453	1.16690	0.68187	2.01880	1.14560	3.73650	2.01250
0.400	0.24602	0.13118	0.45209	0.24208	0.99999	0.55207	1.61680	0.89101	3.02510	1.60890
0.500	0.21834	0.11518	0.40960	0.21610	0.90288	0.48138	1.44040	0.76080	2.61500	1.35720
0.750	0.16143	0.08523	0.31653	0.16686	0.73659	0.39018	1.14090	0.61047	2.01970	1.06980
1.000	0.12369	0.06516	0.24786	0.13065	0.59785	0.31535	0.93050	0.49593	1.63340	0.87333
1.500	0.08319	0.04384	0.17446	0.09187	0.44532	0.23491	0.71930	0.38323	1.33570	0.71236
2.000	0.06040	0.03226	0.13147	0.07045	0.34791	0.19623	0.57638	0.33610	1.12580	0.66333
3.000	0.04385	0.02327	0.09505	0.05034	0.24733	0.13188	0.41729	0.22293	0.87674	0.46017
5.000	0.03036	0.01611	0.06724	0.03573	0.18481	0.09859	0.32555	0.17345	0.74211	0.38583
10.000	0.00706	0.00371	0.01478	0.00785	0.04068	0.02168	0.07767	0.04133	0.19875	0.10470

Table 11a

Dacite Spectral Match Including Topographic Amplification
Peak (Absolute) Time Domain Values

SDC-3			
	PGA(g)	**PGV(cm/sec)**	**PGD(cm)**
H1	0.241	27.693	19.865
H2	0.264	29.836	22.016
V	0.255	23.141	10.968
SDC-4			
H1	0.415	52.416	38.955
H2	0.446	53.889	41.245
V	0.403	41.804	20.591
SDC-5			
H1	0.791	118.608	93.926
H2	0.824	120.289	97.518
V	0.746	91.725	49.375
Cross Correlations			
SDC-3			
H1 - H2		0.1158	
H1 - V		-0.0568	
H2 - V		-0.0563	
SDC-4			
H1 - H2		0.1374	
H1 - V		-0.0439	
H2 - V		-0.0416	
SDC-5			
H1 - H2		0.1382	
H1 - V		-0.0355	
H2 - V		-0.0627	

Table 11b

Dacite Spectral Match
Peak (Absolute) Time Domain Values

SDC-3			
	PGA(g)	**PGV(cm/sec)**	**PGD(cm)**
H1	0.222	25.030	18.649
H2	0.242	27.698	20.549
V	0.211	19.572	9.371
SDC-4			
H1	0.377	48.036	36.298
H2	0.409	49.551	38.035
V	0.332	35.350	17.318
SDC-5			
H1	0.689	109.403	87.151
H2	0.671	112.185	90.074
V	0.595	74.626	41.139
Cross Correlations			
SDC-3			
H1 - H2		0.12035	
H1 V		-0.05373	
H2 - V		-0.07500	
SDC-4			
H1 - H2		0.13555	
H1 - V		-0.04286	
H2 - V		-0.04514	
SDC-5			
H1 - H2		0.10152	
H1 - V		-0.05807	
H2 - V		-0.06006	

Table 12a
CMRR Horizontal DRS SDC-3 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.4027	0.4027	0.4027	0.4027	0.4027	0.4027	0.4027	0.4027	0.4027
0.0200	0.4027	0.4027	0.4027	0.4027	0.4027	0.4027	0.4027	0.4027	0.4027
0.0300	0.4027	0.4421	0.4331	0.4217	0.4138	0.3945	0.3852	0.3737	0.3650
0.0400	0.4631	0.5475	0.5278	0.5031	0.4864	0.4464	0.4276	0.4050	0.3882
0.0500	0.5162	0.6440	0.6136	0.5759	0.5507	0.4917	0.4645	0.4323	0.4088
0.0600	0.5625	0.7335	0.6922	0.6414	0.6080	0.5307	0.4957	0.4547	0.4252
0.0750	0.6376	0.8775	0.8184	0.7468	0.7002	0.5945	0.5476	0.4937	0.4554
0.0900	0.7088	1.0189	0.9413	0.8482	0.7883	0.6545	0.5962	0.5298	0.4834
0.1000	0.7457	1.0997	1.0103	0.9037	0.8356	0.6847	0.6196	0.5462	0.4951
0.1200	0.7361	1.1347	1.0325	0.9119	0.8357	0.6694	0.5989	0.5204	0.4665
0.1500	0.7246	1.1497	1.0396	0.9106	0.8296	0.6548	0.5815	0.5005	0.4454
0.1700	0.7100	1.1484	1.0340	0.9007	0.8175	0.6389	0.5646	0.4829	0.4277
0.2000	0.6915	1.1184	1.0070	0.8772	0.7961	0.6222	0.5499	0.4703	0.4165
0.2400	0.7138	1.1545	1.0395	0.9055	0.8218	0.6423	0.5676	0.4855	0.4300
0.3000	0.7421	1.2002	1.0807	0.9414	0.8544	0.6677	0.5901	0.5048	0.4470
0.3600	0.7149	1.1563	1.0411	0.9069	0.8231	0.6433	0.5685	0.4863	0.4306
0.4000	0.6996	1.1316	1.0189	0.8876	0.8055	0.6295	0.5563	0.4759	0.4214
0.4600	0.7401	1.1969	1.0778	0.9388	0.8520	0.6659	0.5885	0.5034	0.4458
0.5000	0.7653	1.2377	1.1145	0.9708	0.8811	0.6886	0.6085	0.5205	0.4610
0.6000	0.7588	1.2272	1.1050	0.9626	0.8736	0.6827	0.6034	0.5161	0.4571
0.7500	0.7509	1.2145	1.0935	0.9526	0.8645	0.6756	0.5971	0.5107	0.4523
0.8500	0.7302	1.1775	1.0607	0.9250	0.8400	0.6574	0.5814	0.4979	0.4413
1.0000	0.7042	1.1299	1.0190	0.8899	0.8090	0.6349	0.5621	0.4821	0.4279
1.5000	0.5512	0.8677	0.7860	0.6900	0.6296	0.4988	0.4439	0.3831	0.3415
2.0000	0.2693	0.4159	0.3783	0.3339	0.3059	0.2448	0.2189	0.1901	0.1703
3.0000	0.1507	0.2244	0.2057	0.1836	0.1694	0.1381	0.1247	0.1096	0.0991
4.0000	0.1233	0.1776	0.1640	0.1477	0.1372	0.1138	0.1036	0.0920	0.0839
5.0000	0.1055	0.1475	0.1371	0.1246	0.1164	0.0980	0.0899	0.0807	0.0741
10.0000	0.0211	0.0295	0.0274	0.0249	0.0233	0.0196	0.0180	0.0161	0.0148

Table 12b
CMRR Horizontal DRS SDC-4 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.6124	0.6124	0.6124	0.6124	0.6124	0.6124	0.6124	0.6124	0.6124
0.0200	0.6124	0.6124	0.6124	0.6124	0.6124	0.6124	0.6124	0.6124	0.6124
0.0300	0.6124	0.6723	0.6587	0.6413	0.6293	0.6000	0.5857	0.5683	0.5551
0.0400	0.7004	0.8279	0.7983	0.7608	0.7356	0.6751	0.6467	0.6125	0.5871
0.0500	0.7772	0.9697	0.9239	0.8671	0.8293	0.7404	0.6995	0.6510	0.6156
0.0600	0.8458	1.1029	1.0408	0.9645	0.9142	0.7979	0.7453	0.6837	0.6394
0.0750	0.9501	1.3075	1.2195	1.1127	1.0433	0.8858	0.8160	0.7356	0.6786
0.0900	1.0544	1.5159	1.4005	1.2619	1.1728	0.9737	0.8869	0.7882	0.7191
0.1000	1.1160	1.6459	1.5120	1.3525	1.2505	1.0248	0.9273	0.8174	0.7409
0.1200	1.1125	1.7149	1.5604	1.3781	1.2629	1.0117	0.9051	0.7864	0.7050
0.1500	1.1083	1.7584	1.5899	1.3926	1.2688	1.0014	0.8894	0.7655	0.6813
0.1700	1.0956	1.7720	1.5955	1.3899	1.2614	0.9858	0.8712	0.7452	0.6599
0.2000	1.0794	1.7457	1.5719	1.3693	1.2427	0.9712	0.8583	0.7342	0.6502
0.2400	1.1104	1.7959	1.6170	1.4086	1.2784	0.9991	0.8829	0.7552	0.6688
0.3000	1.1495	1.8592	1.6741	1.4583	1.3235	1.0343	0.9141	0.7819	0.6924
0.3600	1.1183	1.8087	1.6286	1.4186	1.2875	1.0062	0.8892	0.7606	0.6736
0.4000	1.1006	1.7801	1.6028	1.3962	1.2671	0.9903	0.8752	0.7486	0.6630
0.4600	1.1542	1.8668	1.6809	1.4642	1.3289	1.0385	0.9178	0.7851	0.6952
0.5000	1.1874	1.9205	1.7293	1.5064	1.3671	1.0684	0.9442	0.8077	0.7153
0.6000	1.1949	1.9325	1.7401	1.5158	1.3757	1.0751	0.9501	0.8127	0.7197
0.7500	1.2040	1.9473	1.7534	1.5274	1.3862	1.0834	0.9574	0.8189	0.7253
0.8500	1.1768	1.8976	1.7095	1.4908	1.3538	1.0595	0.9370	0.8025	0.7113
1.0000	1.1424	1.8331	1.6531	1.4437	1.3124	1.0299	0.9119	0.7820	0.6941
1.5000	0.9835	1.5485	1.4027	1.2313	1.1235	0.8901	0.7922	0.6836	0.6094
2.0000	0.5190	0.8015	0.7291	0.6436	0.5895	0.4718	0.4219	0.3664	0.3282
3.0000	0.2823	0.4203	0.3853	0.3438	0.3172	0.2587	0.2335	0.2052	0.1856
4.0000	0.2318	0.3339	0.3084	0.2777	0.2579	0.2139	0.1948	0.1730	0.1578
5.0000	0.1989	0.2781	0.2585	0.2348	0.2194	0.1848	0.1696	0.1521	0.1397
10.0000	0.0413	0.0578	0.0537	0.0488	0.0456	0.0384	0.0352	0.0316	0.0290

Table 12c
CMRR Horizontal DRS SDC-5 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	1.0270	1.0270	1.0270	1.0270	1.0270	1.0270	1.0270	1.0270	1.0270
0.0200	1.0270	1.0270	1.0270	1.0270	1.0270	1.0270	1.0270	1.0270	1.0270
0.0300	1.0270	1.1274	1.1047	1.0756	1.0554	1.0062	0.9823	0.9530	0.9308
0.0400	1.1766	1.3909	1.3410	1.2782	1.2357	1.1342	1.0864	1.0289	0.9863
0.0500	1.3075	1.6312	1.5543	1.4587	1.3951	1.2455	1.1767	1.0951	1.0355
0.0600	1.4082	1.8362	1.7329	1.6058	1.5221	1.3285	1.2409	1.1384	1.0645
0.0750	1.5606	2.1476	2.0030	1.8277	1.7137	1.4549	1.3403	1.2082	1.1146
0.0900	1.7192	2.4716	2.2834	2.0575	1.9122	1.5875	1.4461	1.2852	1.1725
0.1000	1.8145	2.6759	2.4584	2.1990	2.0332	1.6661	1.5077	1.3290	1.2047
0.1200	1.8213	2.8074	2.5545	2.2562	2.0676	1.6563	1.4818	1.2875	1.1542
0.1500	1.8298	2.9031	2.6250	2.2993	2.0949	1.6533	1.4684	1.2639	1.1248
0.1700	1.8235	2.9493	2.6556	2.3133	2.0994	1.6408	1.4500	1.2403	1.0984
0.2000	1.8154	2.9363	2.6438	2.3030	2.0901	1.6335	1.4436	1.2348	1.0936
0.2400	1.8847	3.0483	2.7447	2.3909	2.1699	1.6958	1.4987	1.2819	1.1353
0.3000	1.9731	3.1912	2.8734	2.5030	2.2716	1.7754	1.5689	1.3421	1.1885
0.3600	1.9357	3.1308	2.8190	2.4556	2.2286	1.7417	1.5392	1.3166	1.1660
0.4000	1.9144	3.0963	2.7880	2.4286	2.2041	1.7226	1.5223	1.3021	1.1532
0.4600	2.0105	3.2517	2.9279	2.5505	2.3147	1.8090	1.5987	1.3675	1.2110
0.5000	2.0701	3.3481	3.0147	2.6261	2.3833	1.8626	1.6461	1.4080	1.2469
0.6000	2.1203	3.4293	3.0878	2.6898	2.4411	1.9078	1.6860	1.4422	1.2772
0.7500	2.1834	3.5314	3.1797	2.7698	2.5138	1.9646	1.7362	1.4851	1.3152
0.8500	2.1554	3.4756	3.1310	2.7305	2.4795	1.9406	1.7162	1.4698	1.3027
1.0000	2.1196	3.4009	3.0669	2.6785	2.4350	1.9108	1.6918	1.4509	1.2878
1.5000	1.9940	3.1394	2.8438	2.4963	2.2777	1.8047	1.6060	1.3859	1.2356
2.0000	1.1274	1.7411	1.5836	1.3980	1.2805	1.0248	0.9165	0.7958	0.7129
3.0000	0.6367	0.9479	0.8690	0.7753	0.7154	0.5835	0.5267	0.4628	0.4186
4.0000	0.5314	0.7654	0.7069	0.6366	0.5913	0.4904	0.4465	0.3965	0.3617
5.0000	0.4618	0.6456	0.6001	0.5451	0.5094	0.4290	0.3936	0.3531	0.3244
10.0000	0.1046	0.1462	0.1359	0.1234	0.1153	0.0971	0.0891	0.0799	0.0734

Table 13a
CMRR Vertical DRS SDC-3 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.4322	0.4322	0.4322	0.4322	0.4322	0.4322	0.4322	0.4322	0.4322
0.0200	0.4322	0.4322	0.4322	0.4322	0.4322	0.4322	0.4322	0.4322	0.4322
0.0300	0.6109	0.7850	0.7431	0.6910	0.6569	0.5795	0.5454	0.5059	0.4775
0.0400	0.7810	1.1364	1.0468	0.9391	0.8705	0.7216	0.6590	0.5888	0.5401
0.0500	0.9448	1.4403	1.3133	1.1624	1.0674	0.8645	0.7806	0.6879	0.6243
0.0600	1.0700	1.6975	1.5342	1.3424	1.2228	0.9709	0.8682	0.7559	0.6798
0.0750	1.1371	1.8864	1.6886	1.4583	1.3164	1.0220	0.9042	0.7768	0.6913
0.0900	1.0466	1.8088	1.6046	1.3695	1.2261	0.9326	0.8170	0.6933	0.6113
0.1000	1.0503	1.8632	1.6434	1.3922	1.2397	0.9308	0.8102	0.6821	0.5979
0.1200	0.9468	1.7046	1.4988	1.2641	1.1224	0.8365	0.7255	0.6081	0.5312
0.1500	0.8339	1.5141	1.3286	1.1180	0.9910	0.7354	0.6365	0.5322	0.4640
0.1700	0.7813	1.4124	1.2406	1.0452	0.9273	0.6897	0.5977	0.5004	0.4367
0.2000	0.7180	1.2793	1.1273	0.9537	0.8486	0.6357	0.5528	0.4648	0.4070
0.2400	0.6475	1.1389	1.0065	0.8547	0.7624	0.5749	0.5014	0.4232	0.3717
0.3000	0.5706	0.9937	0.8800	0.7494	0.6699	0.5076	0.4438	0.3757	0.3307
0.3600	0.5169	0.9001	0.7972	0.6789	0.6068	0.4598	0.4020	0.3404	0.2996
0.4000	0.4882	0.8502	0.7529	0.6412	0.5731	0.4343	0.3797	0.3215	0.2830
0.4600	0.4860	0.8464	0.7496	0.6384	0.5706	0.4324	0.3781	0.3201	0.2817
0.5000	0.4847	0.8442	0.7476	0.6367	0.5691	0.4313	0.3771	0.3192	0.2810
0.6000	0.4617	0.8040	0.7120	0.6064	0.5420	0.4107	0.3591	0.3040	0.2676
0.7500	0.4349	0.7574	0.6707	0.5712	0.5106	0.3869	0.3383	0.2864	0.2521
0.8500	0.4193	0.7274	0.6448	0.5497	0.4917	0.3733	0.3267	0.2769	0.2439
1.0000	0.3998	0.6895	0.6118	0.5225	0.4681	0.3564	0.3123	0.2652	0.2340
1.5000	0.3116	0.5251	0.4683	0.4027	0.3624	0.2792	0.2460	0.2104	0.1866
2.0000	0.1548	0.2546	0.2283	0.1977	0.1787	0.1394	0.1235	0.1064	0.0949
3.0000	0.0876	0.1377	0.1247	0.1094	0.0999	0.0796	0.0714	0.0623	0.0562
4.0000	0.0717	0.1082	0.0989	0.0878	0.0808	0.0658	0.0596	0.0527	0.0479
5.0000	0.0615	0.0893	0.0822	0.0738	0.0685	0.0568	0.0519	0.0464	0.0426
10.0000	0.0123	0.0178	0.0164	0.0148	0.0137	0.0114	0.0104	0.0093	0.0085

Table 13b
CMRR Vertical DRS SDC-4 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.6834	0.6834	0.6834	0.6834	0.6834	0.6834	0.6834	0.6834	0.6834
0.0200	0.6834	0.6834	0.6834	0.6834	0.6834	0.6834	0.6834	0.6834	0.6834
0.0300	0.9723	1.2494	1.1826	1.0998	1.0454	0.9223	0.8680	0.8051	0.7600
0.0400	1.2487	1.8170	1.6738	1.5016	1.3918	1.1539	1.0537	0.9415	0.8636
0.0500	1.5161	2.3112	2.1074	1.8652	1.7129	1.3873	1.2526	1.1038	1.0018
0.0600	1.7138	2.7189	2.4575	2.1501	1.9586	1.5551	1.3906	1.2107	1.0889
0.0750	1.7997	2.9857	2.6725	2.3081	2.0834	1.6176	1.4311	1.2294	1.0942
0.0900	1.6686	2.8838	2.5582	2.1834	1.9548	1.4869	1.3025	1.1053	0.9745
0.1000	1.7045	3.0237	2.6671	2.2594	2.0119	1.5106	1.3149	1.1070	0.9703
0.1200	1.5450	2.7816	2.4457	2.0627	1.8315	1.3650	1.1839	0.9924	0.8668
0.1500	1.3700	2.4875	2.1827	1.8367	1.6280	1.2081	1.0457	0.8743	0.7623
0.1700	1.2913	2.3341	2.0502	1.7274	1.5325	1.1399	0.9877	0.8269	0.7217
0.2000	1.1958	2.1306	1.8774	1.5884	1.4133	1.0588	0.9206	0.7741	0.6778
0.2400	1.0678	1.8782	1.6599	1.4095	1.2574	0.9480	0.8269	0.6980	0.6130
0.3000	0.9297	1.6192	1.4339	1.2212	1.0916	0.8271	0.7232	0.6123	0.5389
0.3600	0.8448	1.4713	1.3030	1.1096	0.9919	0.7516	0.6571	0.5564	0.4897
0.4000	0.7993	1.3921	1.2328	1.0499	0.9385	0.7111	0.6218	0.5264	0.4633
0.4600	0.7888	1.3738	1.2166	1.0361	0.9262	0.7018	0.6136	0.5195	0.4573
0.5000	0.7826	1.3630	1.2071	1.0280	0.9189	0.6963	0.6088	0.5154	0.4537
0.6000	0.7440	1.2957	1.1475	0.9772	0.8735	0.6619	0.5787	0.4900	0.4313
0.7500	0.6993	1.2179	1.0785	0.9185	0.8210	0.6221	0.5440	0.4605	0.4054
0.8500	0.6732	1.1680	1.0353	0.8827	0.7895	0.5995	0.5246	0.4447	0.3916
1.0000	0.6408	1.1052	0.9807	0.8375	0.7503	0.5713	0.5007	0.4252	0.3751
1.5000	0.5478	0.9232	0.8234	0.7081	0.6372	0.4908	0.4326	0.3699	0.3280
2.0000	0.2965	0.4878	0.4375	0.3787	0.3424	0.2670	0.2367	0.2039	0.1818
3.0000	0.1626	0.2556	0.2315	0.2031	0.1854	0.1478	0.1325	0.1157	0.1043
4.0000	0.1339	0.2019	0.1845	0.1638	0.1508	0.1228	0.1111	0.0983	0.0894
5.0000	0.1151	0.1673	0.1541	0.1383	0.1283	0.1064	0.0972	0.0869	0.0798
10.0000	0.0238	0.0346	0.0319	0.0286	0.0265	0.0220	0.0201	0.0180	0.0165

Table 13c
CMRR Vertical DRS SDC-5 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	1.1976	1.1976	1.1976	1.1976	1.1976	1.1976	1.1976	1.1976	1.1976
0.0200	1.1976	1.1976	1.1976	1.1976	1.1976	1.1976	1.1976	1.1976	1.1976
0.0300	1.7194	2.2093	2.0913	1.9449	1.8487	1.6310	1.5349	1.4237	1.3439
0.0400	2.2224	3.2339	2.9790	2.6724	2.4771	2.0536	1.8753	1.6756	1.5371
0.0500	2.7118	4.1339	3.7694	3.3362	3.0637	2.4814	2.2405	1.9743	1.7918
0.0600	3.0575	4.8506	4.3842	3.8359	3.4942	2.7743	2.4808	2.1600	1.9425
0.0750	3.1552	5.2344	4.6854	4.0465	3.6527	2.8359	2.5089	2.1554	1.9183
0.0900	2.8771	4.9723	4.4109	3.7647	3.3705	2.5638	2.2458	1.9057	1.6803
0.1000	2.8836	5.1153	4.5120	3.8222	3.4036	2.5555	2.2245	1.8728	1.6415
0.1200	2.6668	4.8012	4.2214	3.5604	3.1612	2.3560	2.0435	1.7129	1.4961
0.1500	2.4235	4.4004	3.8613	3.2491	2.8800	2.1372	1.8498	1.5467	1.3485
0.1700	2.3037	4.1642	3.6577	3.0818	2.7342	2.0336	1.7621	1.4752	1.2875
0.2000	2.1570	3.8433	3.3866	2.8652	2.5493	1.9099	1.6607	1.3965	1.2227
0.2400	1.9160	3.3701	2.9783	2.5291	2.2561	1.7011	1.4837	1.2524	1.0998
0.3000	1.6574	2.8865	2.5563	2.1770	1.9459	1.4745	1.2892	1.0915	0.9607
0.3600	1.5134	2.6358	2.3342	1.9879	1.7769	1.3465	1.1773	0.9967	0.8773
0.4000	1.4360	2.5010	2.2148	1.8862	1.6860	1.2776	1.1170	0.9457	0.8324
0.4600	1.3926	2.4254	2.1479	1.8293	1.6351	1.2390	1.0833	0.9171	0.8073
0.5000	1.3674	2.3814	2.1090	1.7961	1.6054	1.2165	1.0636	0.9005	0.7926
0.6000	1.3035	2.2701	2.0104	1.7121	1.5304	1.1597	1.0139	0.8584	0.7556
0.7500	1.2293	2.1409	1.8960	1.6147	1.4433	1.0937	0.9562	0.8096	0.7126
0.8500	1.1866	2.0588	1.8249	1.5560	1.3916	1.0567	0.9247	0.7838	0.6903
1.0000	1.1335	1.9549	1.7347	1.4813	1.3272	1.0105	0.8856	0.7520	0.6634
1.5000	1.0322	1.7394	1.5515	1.3342	1.2005	0.9248	0.8151	0.6969	0.6181
2.0000	0.6272	1.0319	0.9254	0.8010	0.7243	0.5647	0.5006	0.4312	0.3845
3.0000	0.3533	0.5552	0.5029	0.4412	0.4027	0.3212	0.2878	0.2513	0.2266
4.0000	0.2983	0.4498	0.4111	0.3650	0.3359	0.2736	0.2476	0.2189	0.1992
5.0000	0.2615	0.3800	0.3501	0.3143	0.2914	0.2417	0.2209	0.1974	0.1812
10.0000	0.0604	0.0878	0.0808	0.0726	0.0673	0.0558	0.0510	0.0456	0.0418

Table 14a
TA-55 Horizontal DRS SDC-3 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188
0.0200	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188
0.0300	0.4188	0.4598	0.4505	0.4386	0.4304	0.4103	0.4006	0.3886	0.3796
0.0400	0.4685	0.5538	0.5340	0.5090	0.4920	0.4516	0.4326	0.4097	0.3928
0.0500	0.5111	0.6376	0.6076	0.5702	0.5453	0.4868	0.4600	0.4281	0.4048
0.0600	0.5557	0.7246	0.6839	0.6337	0.6007	0.5242	0.4897	0.4492	0.4201
0.0750	0.6344	0.8731	0.8143	0.7430	0.6967	0.5915	0.5448	0.4912	0.4531
0.0900	0.7160	1.0294	0.9510	0.8569	0.7964	0.6612	0.6023	0.5352	0.4883
0.1000	0.7701	1.1358	1.0434	0.9333	0.8630	0.7072	0.6399	0.5641	0.5113
0.1200	0.8207	1.2650	1.1510	1.0166	0.9316	0.7463	0.6677	0.5801	0.5200
0.1500	0.8870	1.4074	1.2726	1.1146	1.0156	0.8015	0.7119	0.6127	0.5453
0.1700	0.8469	1.3697	1.2333	1.0743	0.9750	0.7620	0.6734	0.5760	0.5101
0.2000	0.7974	1.2897	1.1612	1.0116	0.9180	0.7175	0.6341	0.5424	0.4803
0.2400	0.8036	1.2997	1.1703	1.0194	0.9252	0.7231	0.6390	0.5466	0.4841
0.3000	0.8113	1.3122	1.1815	1.0292	0.9340	0.7300	0.6451	0.5518	0.4887
0.3600	0.7831	1.2666	1.1405	0.9935	0.9016	0.7046	0.6227	0.5327	0.4717
0.4000	0.7673	1.2410	1.1174	0.9734	0.8834	0.6904	0.6101	0.5219	0.4622
0.4600	0.7909	1.2792	1.1518	1.0033	0.9106	0.7116	0.6289	0.5380	0.4764
0.5000	0.8053	1.3025	1.1728	1.0216	0.9272	0.7246	0.6404	0.5478	0.4851
0.6000	0.7779	1.2581	1.1328	0.9868	0.8956	0.6999	0.6185	0.5291	0.4686
0.7500	0.7455	1.2058	1.0857	0.9458	0.8584	0.6708	0.5928	0.5071	0.4491
0.8500	0.7333	1.1824	1.0651	0.9289	0.8435	0.6602	0.5838	0.5000	0.4432
1.0000	0.7176	1.1514	1.0383	0.9068	0.8243	0.6469	0.5728	0.4912	0.4360
1.5000	0.4963	0.7814	0.7079	0.6214	0.5670	0.4492	0.3998	0.3450	0.3075
2.0000	0.2362	0.3648	0.3318	0.2929	0.2683	0.2147	0.1920	0.1667	0.1494
3.0000	0.1441	0.2146	0.1967	0.1755	0.1619	0.1321	0.1192	0.1048	0.0947
4.0000	0.1180	0.1699	0.1569	0.1413	0.1313	0.1089	0.0991	0.0880	0.0803
5.0000	0.1010	0.1412	0.1313	0.1192	0.1114	0.0938	0.0861	0.0772	0.0709
10.0000	0.0202	0.0283	0.0263	0.0239	0.0223	0.0188	0.0172	0.0154	0.0142

Table 14b
TA-55 Horizontal DRS SDC-4 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278
0.0200	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278
0.0300	0.6278	0.6891	0.6752	0.6574	0.6451	0.6150	0.6004	0.5825	0.5690
0.0400	0.6974	0.8245	0.7949	0.7577	0.7325	0.6723	0.6440	0.6099	0.5847
0.0500	0.7568	0.9442	0.8996	0.8443	0.8075	0.7209	0.6811	0.6338	0.5994
0.0600	0.8198	1.0690	1.0089	0.9348	0.8861	0.7734	0.7224	0.6627	0.6197
0.0750	0.9291	1.2786	1.1925	1.0882	1.0203	0.8662	0.7979	0.7193	0.6636
0.0900	1.0517	1.5119	1.3968	1.2586	1.1698	0.9711	0.8846	0.7862	0.7173
0.1000	1.1350	1.6738	1.5377	1.3755	1.2718	1.0422	0.9431	0.8313	0.7535
0.1200	1.2144	1.8719	1.7033	1.5044	1.3786	1.1044	0.9880	0.8584	0.7696
0.1500	1.3192	2.0931	1.8926	1.6578	1.5104	1.1920	1.0587	0.9113	0.8110
0.1700	1.2688	2.0521	1.8478	1.6096	1.4608	1.1417	1.0089	0.8630	0.7643
0.2000	1.2062	1.9508	1.7566	1.5301	1.3887	1.0853	0.9591	0.8204	0.7266
0.2400	1.2121	1.9603	1.7651	1.5376	1.3955	1.0906	0.9638	0.8244	0.7301
0.3000	1.2193	1.9720	1.7757	1.5468	1.4038	1.0971	0.9695	0.8293	0.7345
0.3600	1.1840	1.9149	1.7242	1.5020	1.3631	1.0653	0.9415	0.8053	0.7132
0.4000	1.1640	1.8827	1.6952	1.4767	1.3402	1.0474	0.9256	0.7918	0.7012
0.4600	1.2123	1.9607	1.7654	1.5379	1.3957	1.0908	0.9640	0.8246	0.7302
0.5000	1.2420	2.0087	1.8087	1.5756	1.4299	1.1175	0.9876	0.8448	0.7481
0.6000	1.2123	1.9607	1.7655	1.5379	1.3957	1.0908	0.9640	0.8246	0.7302
0.7500	1.1769	1.9035	1.7140	1.4930	1.3550	1.0590	0.9359	0.8005	0.7089
0.8500	1.1572	1.8660	1.6810	1.4659	1.3312	1.0418	0.9214	0.7891	0.6994
1.0000	1.1320	1.8164	1.6380	1.4305	1.3005	1.0206	0.9036	0.7749	0.6878
1.5000	0.8976	1.4131	1.2801	1.1237	1.0253	0.8123	0.7229	0.6238	0.5562
2.0000	0.4627	0.7146	0.6500	0.5738	0.5256	0.4206	0.3762	0.3266	0.2926
3.0000	0.2697	0.4015	0.3680	0.3284	0.3030	0.2471	0.2231	0.1960	0.1773
4.0000	0.2213	0.3188	0.2945	0.2652	0.2463	0.2043	0.1860	0.1652	0.1507
5.0000	0.1899	0.2655	0.2468	0.2242	0.2095	0.1764	0.1619	0.1452	0.1334
10.0000	0.0396	0.0553	0.0514	0.0467	0.0436	0.0367	0.0337	0.0302	0.0278

Table 14c
TA-55 Horizontal DRS SDC-5 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	1.0327	1.0327	1.0327	1.0327	1.0327	1.0327	1.0327	1.0327	1.0327
0.0200	1.0327	1.0327	1.0327	1.0327	1.0327	1.0327	1.0327	1.0327	1.0327
0.0300	1.0327	1.1337	1.1108	1.0816	1.0613	1.0118	0.9878	0.9583	0.9361
0.0400	1.1513	1.3610	1.3122	1.2507	1.2091	1.1098	1.0630	1.0068	0.9651
0.0500	1.2526	1.5627	1.4890	1.3974	1.3364	1.1932	1.1273	1.0491	0.9920
0.0600	1.3532	1.7645	1.6653	1.5431	1.4627	1.2766	1.1924	1.0939	1.0229
0.0750	1.5062	2.0728	1.9332	1.7640	1.6540	1.4042	1.2935	1.1661	1.0757
0.0900	1.6967	2.4392	2.2535	2.0305	1.8872	1.5667	1.4271	1.2683	1.1572
0.1000	1.8237	2.6895	2.4709	2.2102	2.0435	1.6746	1.5154	1.3357	1.2108
0.1200	1.9759	3.0457	2.7713	2.4477	2.2430	1.7968	1.6076	1.3967	1.2521
0.1500	2.1796	3.4582	3.1269	2.7389	2.4954	1.9694	1.7492	1.5055	1.3398
0.1700	2.0958	3.3897	3.0521	2.6587	2.4129	1.8858	1.6665	1.4255	1.2624
0.2000	1.9917	3.2214	2.9006	2.5267	2.2931	1.7921	1.5838	1.3547	1.1997
0.2400	2.0233	3.2724	2.9465	2.5667	2.3294	1.8205	1.6088	1.3762	1.2187
0.3000	2.0625	3.3359	3.0037	2.6165	2.3746	1.8558	1.6401	1.4029	1.2424
0.3600	1.9879	3.2152	2.8950	2.5218	2.2887	1.7887	1.5807	1.3521	1.1974
0.4000	1.9460	3.1474	2.8340	2.4687	2.2405	1.7510	1.5474	1.3236	1.1722
0.4600	2.0662	3.3417	3.0090	2.6211	2.3788	1.8591	1.6429	1.4054	1.2446
0.5000	2.1414	3.4634	3.1185	2.7165	2.4654	1.9268	1.7027	1.4565	1.2899
0.6000	2.1181	3.4258	3.0846	2.6870	2.4386	1.9059	1.6843	1.4407	1.2759
0.7500	2.0901	3.3804	3.0437	2.6514	2.4063	1.8806	1.6619	1.4216	1.2590
0.8500	2.0583	3.3189	2.9899	2.6074	2.3677	1.8531	1.6388	1.4035	1.2440
1.0000	2.0177	3.2374	2.9195	2.5497	2.3179	1.8190	1.6105	1.3812	1.2259
1.5000	1.7824	2.8062	2.5420	2.2314	2.0360	1.6131	1.4356	1.2388	1.1045
2.0000	1.0271	1.5863	1.4428	1.2737	1.1666	0.9337	0.8350	0.7250	0.6495
3.0000	0.6043	0.8997	0.8247	0.7358	0.6789	0.5538	0.4999	0.4392	0.3972
4.0000	0.5041	0.7261	0.6706	0.6039	0.5609	0.4652	0.4236	0.3762	0.3431
5.0000	0.4380	0.6122	0.5691	0.5170	0.4831	0.4068	0.3733	0.3348	0.3076
10.0000	0.0998	0.1396	0.1297	0.1178	0.1101	0.0927	0.0851	0.0763	0.0701

Table 15a
TA-55 Vertical DRS SDC-3 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731
0.0200	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731
0.0300	0.6554	0.8422	0.7972	0.7413	0.7047	0.6217	0.5851	0.5427	0.5123
0.0400	0.8259	1.2018	1.1071	0.9931	0.9206	0.7632	0.6969	0.6227	0.5712
0.0500	0.9881	1.5063	1.3735	1.2156	1.1163	0.9042	0.8164	0.7194	0.6529
0.0600	1.1412	1.8105	1.6364	1.4317	1.3042	1.0355	0.9260	0.8062	0.7251
0.0750	1.2679	2.1033	1.8827	1.6260	1.4677	1.1395	1.0082	0.8661	0.7708
0.0900	1.1967	2.0682	1.8347	1.5659	1.4020	1.0664	0.9342	0.7927	0.6989
0.1000	1.0988	1.9492	1.7193	1.4564	1.2969	0.9738	0.8476	0.7136	0.6255
0.1200	1.0393	1.8712	1.6452	1.3876	1.2320	0.9182	0.7964	0.6676	0.5831
0.1500	0.9709	1.7630	1.5470	1.3017	1.1538	0.8562	0.7411	0.6196	0.5403
0.1700	0.8951	1.6179	1.4211	1.1974	1.0623	0.7901	0.6847	0.5732	0.5003
0.2000	0.8054	1.4350	1.2644	1.0698	0.9518	0.7131	0.6200	0.5214	0.4565
0.2400	0.6841	1.2032	1.0633	0.9029	0.8055	0.6073	0.5297	0.4471	0.3927
0.3000	0.5602	0.9756	0.8640	0.7358	0.6577	0.4984	0.4358	0.3689	0.3247
0.3600	0.5170	0.9004	0.7974	0.6791	0.6070	0.4600	0.4022	0.3405	0.2997
0.4000	0.4936	0.8596	0.7613	0.6483	0.5795	0.4391	0.3839	0.3251	0.2861
0.4600	0.5096	0.8875	0.7860	0.6694	0.5983	0.4534	0.3964	0.3356	0.2954
0.5000	0.5194	0.9046	0.8011	0.6822	0.6098	0.4621	0.4040	0.3421	0.3011
0.6000	0.4761	0.8291	0.7343	0.6253	0.5590	0.4235	0.3703	0.3135	0.2760
0.7500	0.4279	0.7453	0.6600	0.5621	0.5024	0.3807	0.3329	0.2818	0.2481
0.8500	0.4200	0.7287	0.6459	0.5507	0.4926	0.3740	0.3273	0.2774	0.2443
1.0000	0.4100	0.7071	0.6274	0.5358	0.4800	0.3655	0.3203	0.2720	0.2400
1.5000	0.2829	0.4768	0.4253	0.3657	0.3291	0.2535	0.2234	0.1910	0.1694
2.0000	0.1364	0.2244	0.2012	0.1742	0.1575	0.1228	0.1089	0.0938	0.0836
3.0000	0.0839	0.1318	0.1194	0.1048	0.0956	0.0763	0.0684	0.0597	0.0538
4.0000	0.0687	0.1036	0.0947	0.0841	0.0774	0.0630	0.0570	0.0504	0.0459
5.0000	0.0589	0.0855	0.0788	0.0707	0.0656	0.0544	0.0497	0.0444	0.0408
10.0000	0.0118	0.0172	0.0158	0.0142	0.0132	0.0109	0.0100	0.0089	0.0082

Table 15b
TA-55 Vertical DRS SDC-4 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.7384	0.7384	0.7384	0.7384	0.7384	0.7384	0.7384	0.7384	0.7384
0.0200	0.7384	0.7384	0.7384	0.7384	0.7384	0.7384	0.7384	0.7384	0.7384
0.0300	1.0288	1.3219	1.2513	1.1637	1.1061	0.9759	0.9184	0.8519	0.8041
0.0400	1.3017	1.8942	1.7449	1.5653	1.4509	1.2028	1.0984	0.9815	0.9003
0.0500	1.5624	2.3817	2.1717	1.9221	1.7651	1.4296	1.2909	1.1375	1.0323
0.0600	1.8045	2.8627	2.5874	2.2639	2.0622	1.6373	1.4641	1.2748	1.1464
0.0750	2.0011	3.3198	2.9716	2.5664	2.3166	1.7986	1.5912	1.3670	1.2167
0.0900	1.8890	3.2646	2.8960	2.4718	2.2130	1.6833	1.4745	1.2513	1.1032
0.1000	1.7594	3.1211	2.7530	2.3322	2.0767	1.5592	1.3573	1.1427	1.0016
0.1200	1.6622	2.9926	2.6312	2.2192	1.9704	1.4685	1.2737	1.0676	0.9325
0.1500	1.5505	2.8153	2.4704	2.0788	1.8426	1.3674	1.1835	0.9895	0.8628
0.1700	1.4321	2.5886	2.2738	1.9158	1.6997	1.2642	1.0954	0.9171	0.8004
0.2000	1.2917	2.3015	2.0281	1.7158	1.5267	1.1437	0.9945	0.8363	0.7322
0.2400	1.0840	1.9067	1.6850	1.4308	1.2764	0.9624	0.8394	0.7085	0.6222
0.3000	0.8746	1.5233	1.3490	1.1489	1.0269	0.7782	0.6804	0.5760	0.5070
0.3600	0.8114	1.4131	1.2515	1.0658	0.9527	0.7219	0.6312	0.5344	0.4703
0.4000	0.7769	1.3531	1.1983	1.0205	0.9122	0.6912	0.6044	0.5117	0.4504
0.4600	0.8108	1.4120	1.2505	1.0650	0.9519	0.7213	0.6307	0.5339	0.4700
0.5000	0.8316	1.4484	1.2827	1.0924	0.9764	0.7399	0.6469	0.5477	0.4821
0.6000	0.7547	1.3143	1.1640	0.9913	0.8861	0.6714	0.5870	0.4970	0.4375
0.7500	0.6701	1.1670	1.0335	0.8802	0.7868	0.5962	0.5212	0.4413	0.3884
0.8500	0.6577	1.1411	1.0115	0.8624	0.7713	0.5857	0.5125	0.4344	0.3826
1.0000	0.6419	1.1071	0.9824	0.8389	0.7516	0.5723	0.5015	0.4259	0.3757
1.5000	0.5061	0.8528	0.7606	0.6541	0.5886	0.4534	0.3996	0.3417	0.3030
2.0000	0.2662	0.4379	0.3927	0.3400	0.3074	0.2397	0.2125	0.1830	0.1632
3.0000	0.1558	0.2449	0.2219	0.1946	0.1776	0.1417	0.1270	0.1109	0.0999
4.0000	0.1282	0.1933	0.1767	0.1569	0.1444	0.1176	0.1064	0.0941	0.0856
5.0000	0.1102	0.1601	0.1475	0.1324	0.1228	0.1019	0.0931	0.0832	0.0763
10.0000	0.0229	0.0333	0.0306	0.0275	0.0255	0.0212	0.0193	0.0173	0.0159

Table 15c
TA-55 Vertical DRS SDC-5 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	1.2904	1.2904	1.2904	1.2904	1.2904	1.2904	1.2904	1.2904	1.2904
0.0200	1.2904	1.2904	1.2904	1.2904	1.2904	1.2904	1.2904	1.2904	1.2904
0.0300	1.8187	2.3369	2.2121	2.0572	1.9555	1.7252	1.6236	1.5060	1.4215
0.0400	2.3202	3.3762	3.1101	2.7900	2.5861	2.1439	1.9578	1.7494	1.6047
0.0500	2.8025	4.2722	3.8955	3.4478	3.1662	2.5644	2.3155	2.0404	1.8517
0.0600	3.2395	5.1393	4.6451	4.0642	3.7021	2.9394	2.6285	2.2885	2.0582
0.0750	3.6073	5.9844	5.3567	4.6263	4.1760	3.2422	2.8684	2.4642	2.1932
0.0900	3.3053	5.7123	5.0674	4.3251	3.8722	2.9453	2.5801	2.1894	1.9304
0.1000	2.9852	5.2955	4.6710	3.9569	3.5235	2.6455	2.3029	1.9388	1.6994
0.1200	2.8319	5.0985	4.4828	3.7808	3.3570	2.5019	2.1700	1.8189	1.5887
0.1500	2.6549	4.8207	4.2301	3.5595	3.1551	2.3413	2.0265	1.6944	1.4773
0.1700	2.4757	4.4750	3.9307	3.3119	2.9382	2.1854	1.8937	1.5854	1.3836
0.2000	2.2608	4.0283	3.5496	3.0031	2.6720	2.0018	1.7406	1.4637	1.2815
0.2400	1.8815	3.3095	2.9247	2.4835	2.2155	1.6704	1.4570	1.2298	1.0800
0.3000	1.5028	2.6172	2.3178	1.9739	1.7644	1.3370	1.1690	0.9897	0.8711
0.3600	1.3954	2.4302	2.1521	1.8328	1.6383	1.2414	1.0854	0.9189	0.8089
0.4000	1.3369	2.3283	2.0619	1.7560	1.5696	1.1894	1.0399	0.8804	0.7749
0.4600	1.4053	2.4475	2.1675	1.8459	1.6500	1.2503	1.0931	0.9255	0.8146
0.5000	1.4478	2.5215	2.2330	1.9017	1.6999	1.2881	1.1262	0.9535	0.8392
0.6000	1.3097	2.2809	2.0199	1.7202	1.5377	1.1652	1.0187	0.8625	0.7592
0.7500	1.1584	2.0175	1.7866	1.5216	1.3601	1.0306	0.9011	0.7629	0.6715
0.8500	1.1375	1.9736	1.7494	1.4915	1.3340	1.0129	0.8864	0.7513	0.6617
1.0000	1.1110	1.9161	1.7002	1.4519	1.3008	0.9904	0.8680	0.7371	0.6503
1.5000	0.9588	1.6156	1.4411	1.2392	1.1151	0.8590	0.7571	0.6474	0.5741
2.0000	0.5780	0.9509	0.8527	0.7381	0.6674	0.5204	0.4613	0.3974	0.3543
3.0000	0.3385	0.5319	0.4818	0.4227	0.3858	0.3077	0.2758	0.2408	0.2170
4.0000	0.2850	0.4298	0.3928	0.3488	0.3209	0.2614	0.2366	0.2092	0.1903
5.0000	0.2494	0.3624	0.3338	0.2997	0.2779	0.2305	0.2106	0.1883	0.1728
10.0000	0.0579	0.0841	0.0774	0.0695	0.0645	0.0535	0.0489	0.0437	0.0401

Table 16a
CMRR and TA-55 Envelope Horizontal DRS SDC-3 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188
0.0200	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188	0.4188
0.0300	0.4188	0.4598	0.4505	0.4386	0.4304	0.4103	0.4006	0.3886	0.3796
0.0400	0.4721	0.5581	0.5381	0.5129	0.4959	0.4551	0.4359	0.4129	0.3958
0.0500	0.5181	0.6464	0.6159	0.5780	0.5528	0.4936	0.4663	0.4339	0.4104
0.0600	0.5652	0.7369	0.6955	0.6444	0.6109	0.5331	0.4980	0.4569	0.4272
0.0750	0.6423	0.8839	0.8244	0.7522	0.7053	0.5988	0.5516	0.4973	0.4587
0.0900	0.7194	1.0342	0.9554	0.8609	0.8001	0.6643	0.6051	0.5377	0.4906
0.1000	0.7700	1.1356	1.0433	0.9332	0.8628	0.7071	0.6398	0.5640	0.5112
0.1200	0.8206	1.2649	1.1509	1.0165	0.9315	0.7462	0.6676	0.5801	0.5200
0.1500	0.8870	1.4074	1.2726	1.1146	1.0155	0.8015	0.7119	0.6127	0.5453
0.1700	0.8468	1.3697	1.2333	1.0743	0.9750	0.7620	0.6734	0.5760	0.5101
0.2000	0.7974	1.2896	1.1612	1.0115	0.9180	0.7175	0.6340	0.5424	0.4803
0.2400	0.8036	1.2997	1.1702	1.0194	0.9251	0.7230	0.6390	0.5466	0.4840
0.3000	0.8112	1.3120	1.1814	1.0291	0.9340	0.7299	0.6450	0.5518	0.4886
0.3600	0.7828	1.2660	1.1400	0.9930	0.9012	0.7043	0.6224	0.5324	0.4715
0.4000	0.7668	1.2402	1.1167	0.9728	0.8828	0.6900	0.6097	0.5216	0.4619
0.4600	0.7907	1.2789	1.1515	1.0031	0.9103	0.7115	0.6287	0.5378	0.4763
0.5000	0.8053	1.3025	1.1728	1.0216	0.9271	0.7246	0.6403	0.5477	0.4851
0.6000	0.7823	1.2652	1.1392	0.9924	0.9006	0.7039	0.6220	0.5321	0.4712
0.7500	0.7550	1.2210	1.0994	0.9577	0.8692	0.6793	0.6003	0.5135	0.4548
0.8500	0.7413	1.1953	1.0768	0.9390	0.8527	0.6674	0.5902	0.5055	0.4480
1.0000	0.7238	1.1614	1.0474	0.9147	0.8315	0.6525	0.5778	0.4955	0.4398
1.5000	0.5512	0.8677	0.7860	0.6900	0.6296	0.4988	0.4439	0.3831	0.3415
2.0000	0.2693	0.4159	0.3783	0.3339	0.3059	0.2448	0.2189	0.1901	0.1703
3.0000	0.1507	0.2244	0.2058	0.1836	0.1694	0.1382	0.1247	0.1096	0.0991
4.0000	0.1233	0.1776	0.1640	0.1477	0.1372	0.1138	0.1036	0.0920	0.0839
5.0000	0.1055	0.1475	0.1371	0.1246	0.1164	0.0980	0.0899	0.0807	0.0741
10.0000	0.0211	0.0295	0.0274	0.0249	0.0233	0.0196	0.0180	0.0161	0.0148

Table 16b
CMRR and TA-55 Envelope Horizontal DRS SDC-4 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278
0.0200	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278	0.6278
0.0300	0.6278	0.6892	0.6753	0.6575	0.6452	0.6150	0.6005	0.5825	0.5690
0.0400	0.7085	0.8375	0.8075	0.7697	0.7441	0.6830	0.6542	0.6196	0.5939
0.0500	0.7782	0.9709	0.9251	0.8682	0.8303	0.7413	0.7004	0.6518	0.6163
0.0600	0.8471	1.1046	1.0424	0.9659	0.9156	0.7991	0.7464	0.6848	0.6403
0.0750	0.9524	1.3107	1.2224	1.1154	1.0459	0.8879	0.8180	0.7374	0.6802
0.0900	1.0619	1.5267	1.4104	1.2709	1.1811	0.9806	0.8932	0.7938	0.7243
0.1000	1.1349	1.6737	1.5376	1.3754	1.2717	1.0421	0.9430	0.8312	0.7535
0.1200	1.2144	1.8718	1.7032	1.5043	1.3785	1.1043	0.9880	0.8584	0.7695
0.1500	1.3192	2.0931	1.8926	1.6577	1.5104	1.1920	1.0587	0.9112	0.8109
0.1700	1.2688	2.0521	1.8477	1.6096	1.4608	1.1416	1.0089	0.8630	0.7643
0.2000	1.2062	1.9508	1.7565	1.5301	1.3887	1.0853	0.9591	0.8204	0.7265
0.2400	1.2120	1.9602	1.7650	1.5375	1.3953	1.0905	0.9637	0.8243	0.7300
0.3000	1.2191	1.9717	1.7754	1.5465	1.4035	1.0969	0.9694	0.8292	0.7343
0.3600	1.1831	1.9136	1.7230	1.5009	1.3622	1.0646	0.9408	0.8047	0.7127
0.4000	1.1628	1.8808	1.6935	1.4752	1.3388	1.0463	0.9247	0.7909	0.7005
0.4600	1.2117	1.9598	1.7647	1.5372	1.3951	1.0903	0.9635	0.8242	0.7299
0.5000	1.2419	2.0086	1.8086	1.5755	1.4298	1.1174	0.9875	0.8447	0.7481
0.6000	1.2257	1.9824	1.7850	1.5549	1.4112	1.1029	0.9746	0.8337	0.7383
0.7500	1.2062	1.9508	1.7565	1.5301	1.3887	1.0853	0.9591	0.8204	0.7265
0.8500	1.1827	1.9071	1.7181	1.4983	1.3606	1.0648	0.9417	0.8065	0.7148
1.0000	1.1530	1.8500	1.6683	1.4570	1.3245	1.0394	0.9203	0.7892	0.7005
1.5000	0.9835	1.5484	1.4026	1.2312	1.1234	0.8901	0.7921	0.6836	0.6094
2.0000	0.5190	0.8016	0.7291	0.6436	0.5895	0.4718	0.4219	0.3664	0.3282
3.0000	0.2823	0.4203	0.3853	0.3438	0.3172	0.2587	0.2335	0.2052	0.1856
4.0000	0.2318	0.3339	0.3084	0.2777	0.2579	0.2139	0.1948	0.1730	0.1578
5.0000	0.1989	0.2781	0.2585	0.2348	0.2194	0.1848	0.1696	0.1521	0.1397
10.0000	0.0413	0.0578	0.0537	0.0488	0.0456	0.0384	0.0352	0.0316	0.0290

Table 16c
CMRR and TA-55 Envelope Horizontal DRS SDC-5 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	1.0333	1.0333	1.0333	1.0333	1.0333	1.0333	1.0333	1.0333	1.0333
0.0200	1.0333	1.0333	1.0333	1.0333	1.0333	1.0333	1.0333	1.0333	1.0333
0.0300	1.0333	1.1344	1.1115	1.0822	1.0619	1.0123	0.9883	0.9588	0.9366
0.0400	1.1798	1.3946	1.3446	1.2816	1.2390	1.1372	1.0893	1.0317	0.9890
0.0500	1.3075	1.6312	1.5543	1.4587	1.3950	1.2455	1.1767	1.0951	1.0355
0.0600	1.4082	1.8362	1.7329	1.6058	1.5221	1.3284	1.2409	1.1384	1.0645
0.0750	1.5606	2.1476	2.0030	1.8277	1.7137	1.4549	1.3403	1.2082	1.1146
0.0900	1.7220	2.4756	2.2871	2.0608	1.9153	1.5901	1.4484	1.2872	1.1744
0.1000	1.8228	2.6882	2.4696	2.2091	2.0425	1.6737	1.5146	1.3350	1.2102
0.1200	1.9754	3.0448	2.7706	2.4470	2.2424	1.7963	1.6071	1.3963	1.2518
0.1500	2.1796	3.4581	3.1269	2.7388	2.4954	1.9694	1.7492	1.5055	1.3398
0.1700	2.0958	3.3896	3.0521	2.6586	2.4129	1.8857	1.6665	1.4255	1.2624
0.2000	1.9917	3.2213	2.9005	2.5267	2.2931	1.7921	1.5838	1.3547	1.1997
0.2400	2.0232	3.2723	2.9464	2.5666	2.3294	1.8205	1.6088	1.3762	1.2187
0.3000	2.0625	3.3358	3.0036	2.6164	2.3745	1.8558	1.6400	1.4028	1.2423
0.3600	1.9897	3.2181	2.8977	2.5241	2.2908	1.7903	1.5822	1.3534	1.1985
0.4000	1.9489	3.1521	2.8382	2.4723	2.2438	1.7536	1.5497	1.3256	1.1739
0.4600	2.0673	3.3435	3.0106	2.6225	2.3801	1.8601	1.6438	1.4061	1.2452
0.5000	2.1413	3.4633	3.1184	2.7164	2.4653	1.9267	1.7027	1.4565	1.2898
0.6000	2.1601	3.4937	3.1458	2.7403	2.4870	1.9437	1.7177	1.4693	1.3012
0.7500	2.1834	3.5314	3.1797	2.7699	2.5138	1.9646	1.7362	1.4851	1.3152
0.8500	2.1560	3.4765	3.1318	2.7312	2.4802	1.9411	1.7166	1.4702	1.3030
1.0000	2.1209	3.4030	3.0688	2.6801	2.4364	1.9120	1.6928	1.4518	1.2886
1.5000	1.9940	3.1394	2.8438	2.4962	2.2777	1.8046	1.6060	1.3859	1.2356
2.0000	1.1274	1.7411	1.5837	1.3981	1.2805	1.0249	0.9165	0.7958	0.7129
3.0000	0.6367	0.9479	0.8690	0.7753	0.7154	0.5835	0.5267	0.4628	0.4185
4.0000	0.5314	0.7654	0.7069	0.6366	0.5913	0.4904	0.4465	0.3965	0.3617
5.0000	0.4618	0.6456	0.6001	0.5451	0.5094	0.4290	0.3936	0.3531	0.3244
10.0000	0.1045	0.1462	0.1359	0.1234	0.1153	0.0971	0.0891	0.0799	0.0734

Table 17a
CMRR and TA-55 Envelope Vertical DRS SDC-3 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731
0.0200	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731	0.4731
0.0300	0.6554	0.8421	0.7971	0.7413	0.7047	0.6217	0.5851	0.5427	0.5123
0.0400	0.8259	1.2018	1.1071	0.9931	0.9206	0.7632	0.6969	0.6227	0.5712
0.0500	0.9882	1.5063	1.3735	1.2157	1.1164	0.9042	0.8164	0.7194	0.6529
0.0600	1.1405	1.8094	1.6354	1.4309	1.3034	1.0349	0.9254	0.8057	0.7246
0.0750	1.2656	2.0997	1.8794	1.6232	1.4652	1.1376	1.0064	0.8646	0.7695
0.0900	1.1961	2.0671	1.8337	1.5651	1.4012	1.0658	0.9337	0.7923	0.6986
0.1000	1.0988	1.9492	1.7193	1.4565	1.2970	0.9738	0.8477	0.7136	0.6255
0.1200	1.0393	1.8712	1.6452	1.3876	1.2320	0.9182	0.7964	0.6675	0.5831
0.1500	0.9709	1.7628	1.5469	1.3016	1.1538	0.8562	0.7411	0.6196	0.5402
0.1700	0.8950	1.6178	1.4210	1.1973	1.0622	0.7901	0.6846	0.5731	0.5002
0.2000	0.8053	1.4348	1.2643	1.0696	0.9517	0.7130	0.6200	0.5213	0.4564
0.2400	0.6942	1.2210	1.0790	0.9163	0.8174	0.6163	0.5375	0.4537	0.3985
0.3000	0.5789	1.0081	0.8928	0.7603	0.6796	0.5150	0.4503	0.3812	0.3355
0.3600	0.5292	0.9217	0.8163	0.6952	0.6214	0.4709	0.4117	0.3485	0.3068
0.4000	0.5025	0.8752	0.7751	0.6601	0.5900	0.4471	0.3909	0.3310	0.2913
0.4600	0.5130	0.8933	0.7911	0.6738	0.6023	0.4564	0.3990	0.3378	0.2973
0.5000	0.5193	0.9043	0.8009	0.6821	0.6097	0.4620	0.4039	0.3420	0.3010
0.6000	0.4804	0.8367	0.7410	0.6310	0.5640	0.4274	0.3737	0.3164	0.2785
0.7500	0.4368	0.7607	0.6737	0.5737	0.5128	0.3886	0.3398	0.2877	0.2532
0.8500	0.4257	0.7385	0.6546	0.5581	0.4992	0.3790	0.3317	0.2812	0.2476
1.0000	0.4116	0.7099	0.6299	0.5379	0.4820	0.3669	0.3216	0.2731	0.2409
1.5000	0.3116	0.5251	0.4683	0.4027	0.3624	0.2792	0.2460	0.2104	0.1866
2.0000	0.1548	0.2546	0.2283	0.1977	0.1787	0.1394	0.1235	0.1064	0.0949
3.0000	0.0876	0.1377	0.1247	0.1094	0.0998	0.0796	0.0714	0.0623	0.0562
4.0000	0.0717	0.1082	0.0989	0.0878	0.0808	0.0658	0.0596	0.0527	0.0479
5.0000	0.0615	0.0893	0.0822	0.0738	0.0685	0.0568	0.0519	0.0464	0.0426
10.0000	0.0123	0.0179	0.0164	0.0148	0.0137	0.0114	0.0104	0.0093	0.0085

Table 17b
CMRR and TA-55 Envelope Vertical DRS SDC-4 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.7383	0.7383	0.7383	0.7383	0.7383	0.7383	0.7383	0.7383	0.7383
0.0200	0.7383	0.7383	0.7383	0.7383	0.7383	0.7383	0.7383	0.7383	0.7383
0.0300	1.0287	1.3218	1.2512	1.1636	1.1061	0.9758	0.9183	0.8518	0.8041
0.0400	1.3017	1.8941	1.7448	1.5653	1.4509	1.2028	1.0984	0.9814	0.9003
0.0500	1.5624	2.3817	2.1717	1.9221	1.7651	1.4296	1.2909	1.1375	1.0323
0.0600	1.8030	2.8603	2.5853	2.2620	2.0605	1.6360	1.4629	1.2737	1.1455
0.0750	1.9956	3.3107	2.9635	2.5594	2.3102	1.7937	1.5869	1.3632	1.2133
0.0900	1.8875	3.2621	2.8938	2.4699	2.2113	1.6820	1.4734	1.2503	1.1024
0.1000	1.7594	3.1211	2.7530	2.3321	2.0767	1.5592	1.3573	1.1427	1.0016
0.1200	1.6621	2.9924	2.6310	2.2190	1.9703	1.4684	1.2736	1.0676	0.9325
0.1500	1.5502	2.8149	2.4700	2.0784	1.8423	1.3671	1.1833	0.9894	0.8626
0.1700	1.4318	2.5882	2.2733	1.9154	1.6994	1.2640	1.0952	0.9169	0.8002
0.2000	1.2915	2.3011	2.0276	1.7154	1.5263	1.1435	0.9943	0.8361	0.7320
0.2400	1.1164	1.9637	1.7354	1.4737	1.3146	0.9912	0.8645	0.7297	0.6409
0.3000	0.9342	1.6270	1.4408	1.2271	1.0968	0.8311	0.7267	0.6152	0.5415
0.3600	0.8515	1.4829	1.3133	1.1184	0.9997	0.7575	0.6623	0.5608	0.4936
0.4000	0.8071	1.4056	1.2448	1.0601	0.9476	0.7180	0.6278	0.5315	0.4678
0.4600	0.8222	1.4319	1.2680	1.0799	0.9653	0.7314	0.6395	0.5414	0.4766
0.5000	0.8313	1.4478	1.2821	1.0919	0.9760	0.7396	0.6466	0.5474	0.4819
0.6000	0.7696	1.3403	1.1870	1.0109	0.9036	0.6847	0.5987	0.5068	0.4461
0.7500	0.7003	1.2197	1.0801	0.9199	0.8222	0.6231	0.5448	0.4612	0.4060
0.8500	0.6766	1.1740	1.0406	0.8872	0.7935	0.6025	0.5273	0.4469	0.3936
1.0000	0.6471	1.1160	0.9903	0.8457	0.7577	0.5769	0.5056	0.4293	0.3787
1.5000	0.5479	0.9232	0.8234	0.7081	0.6372	0.4908	0.4326	0.3699	0.3280
2.0000	0.2965	0.4878	0.4375	0.3787	0.3424	0.2670	0.2367	0.2039	0.1818
3.0000	0.1626	0.2556	0.2315	0.2031	0.1854	0.1478	0.1325	0.1157	0.1043
4.0000	0.1339	0.2019	0.1845	0.1638	0.1508	0.1228	0.1111	0.0983	0.0894
5.0000	0.1151	0.1673	0.1541	0.1383	0.1283	0.1064	0.0972	0.0869	0.0798
10.0000	0.0238	0.0346	0.0319	0.0286	0.0265	0.0220	0.0201	0.0180	0.0165

Table 17c
CMRR and TA-55 Envelope Vertical DRS SDC-5 Spectra for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	1.2903	1.2903	1.2903	1.2903	1.2903	1.2903	1.2903	1.2903	1.2903
0.0200	1.2903	1.2903	1.2903	1.2903	1.2903	1.2903	1.2903	1.2903	1.2903
0.0300	1.8187	2.3368	2.2120	2.0571	1.9554	1.7251	1.6235	1.5059	1.4215
0.0400	2.3201	3.3761	3.1100	2.7899	2.5860	2.1439	1.9578	1.7493	1.6047
0.0500	2.8025	4.2721	3.8955	3.4477	3.1661	2.5644	2.3155	2.0403	1.8517
0.0600	3.2242	5.1150	4.6231	4.0450	3.6847	2.9255	2.6161	2.2777	2.0484
0.0750	3.5622	5.9096	5.2898	4.5685	4.1238	3.2017	2.8325	2.4334	2.1658
0.0900	3.2710	5.6531	5.0149	4.2802	3.8321	2.9148	2.5533	2.1667	1.9104
0.1000	2.9851	5.2954	4.6708	3.9568	3.5234	2.6454	2.3028	1.9387	1.6993
0.1200	2.8312	5.0972	4.4816	3.7798	3.3561	2.5012	2.1695	1.8184	1.5883
0.1500	2.6535	4.8181	4.2278	3.5575	3.1534	2.3400	2.0254	1.6935	1.4765
0.1700	2.4749	4.4736	3.9294	3.3108	2.9373	2.1847	1.8930	1.5848	1.3832
0.2000	2.2608	4.0281	3.5495	3.0030	2.6719	2.0017	1.7405	1.4636	1.2815
0.2400	1.9662	3.4584	3.0563	2.5953	2.3152	1.7456	1.5226	1.2852	1.1286
0.3000	1.6574	2.8865	2.5563	2.1770	1.9459	1.4745	1.2892	1.0915	0.9607
0.3600	1.5137	2.6363	2.3347	1.9883	1.7773	1.3467	1.1775	0.9969	0.8775
0.4000	1.4364	2.5017	2.2155	1.8868	1.6865	1.2780	1.1174	0.9460	0.8327
0.4600	1.4434	2.5139	2.2263	1.8960	1.6947	1.2842	1.1228	0.9506	0.8367
0.5000	1.4476	2.5212	2.2327	1.9015	1.6996	1.2879	1.1261	0.9533	0.8391
0.6000	1.3450	2.3424	2.0744	1.7667	1.5792	1.1966	1.0462	0.8858	0.7797
0.7500	1.2293	2.1409	1.8959	1.6146	1.4433	1.0936	0.9562	0.8095	0.7126
0.8500	1.1874	2.0602	1.8261	1.5570	1.3925	1.0574	0.9253	0.7843	0.6907
1.0000	1.1352	1.9579	1.7373	1.4836	1.3292	1.0120	0.8869	0.7532	0.6644
1.5000	1.0322	1.7394	1.5515	1.3342	1.2005	0.9248	0.8151	0.6969	0.6181
2.0000	0.6272	1.0319	0.9254	0.8010	0.7243	0.5647	0.5006	0.4312	0.3845
3.0000	0.3533	0.5552	0.5029	0.4411	0.4027	0.3211	0.2878	0.2513	0.2265
4.0000	0.2982	0.4498	0.4111	0.3650	0.3359	0.2736	0.2476	0.2189	0.1992
5.0000	0.2615	0.3800	0.3501	0.3143	0.2914	0.2417	0.2209	0.1974	0.1812
10.0000	0.0604	0.0877	0.0808	0.0726	0.0673	0.0558	0.0510	0.0456	0.0418

Table 18a
Dacite Horizontal DRS SDC-3 Spectra Including Topographic Amplification for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.2582	0.2582	0.2582	0.2582	0.2582	0.2582	0.2582	0.2582	0.2582
0.0200	0.2582	0.2582	0.2582	0.2582	0.2582	0.2582	0.2582	0.2582	0.2582
0.0300	0.2582	0.2834	0.2777	0.2704	0.2653	0.2529	0.2469	0.2396	0.2340
0.0400	0.3405	0.4026	0.3881	0.3699	0.3576	0.3283	0.3144	0.2978	0.2855
0.0500	0.4222	0.5267	0.5018	0.4710	0.4504	0.4021	0.3799	0.3536	0.3343
0.0600	0.4931	0.6429	0.6068	0.5622	0.5330	0.4651	0.4345	0.3986	0.3727
0.0750	0.5754	0.7918	0.7385	0.6738	0.6318	0.5364	0.4941	0.4454	0.4109
0.0900	0.6370	0.9157	0.8460	0.7623	0.7085	0.5882	0.5358	0.4761	0.4344
0.1000	0.6668	0.9834	0.9034	0.8081	0.7472	0.6123	0.5541	0.4884	0.4427
0.1200	0.6956	1.0721	0.9756	0.8616	0.7896	0.6325	0.5659	0.4917	0.4408
0.1500	0.7324	1.1620	1.0507	0.9203	0.8385	0.6618	0.5878	0.5059	0.4502
0.1700	0.7091	1.1468	1.0326	0.8995	0.8163	0.6380	0.5638	0.4823	0.4271
0.2000	0.6798	1.0995	0.9900	0.8624	0.7827	0.6117	0.5406	0.4624	0.4095
0.2400	0.6243	1.0097	0.9092	0.7920	0.7188	0.5617	0.4964	0.4246	0.3760
0.3000	0.5625	0.9097	0.8191	0.7135	0.6476	0.5061	0.4472	0.3826	0.3388
0.3600	0.5149	0.8328	0.7498	0.6532	0.5928	0.4633	0.4094	0.3502	0.3101
0.4000	0.4892	0.7913	0.7125	0.6206	0.5633	0.4402	0.3890	0.3328	0.2947
0.4600	0.4577	0.7403	0.6665	0.5806	0.5269	0.4118	0.3639	0.3113	0.2757
0.5000	0.4398	0.7114	0.6405	0.5580	0.5064	0.3958	0.3497	0.2992	0.2649
0.6000	0.3936	0.6366	0.5732	0.4993	0.4532	0.3542	0.3130	0.2677	0.2371
0.7500	0.3436	0.5557	0.5004	0.4359	0.3956	0.3092	0.2732	0.2337	0.2070
0.8500	0.3110	0.5014	0.4517	0.3939	0.3577	0.2800	0.2476	0.2120	0.1879
1.0000	0.2732	0.4383	0.3953	0.3452	0.3138	0.2463	0.2180	0.1870	0.1660
1.5000	0.1986	0.3126	0.2832	0.2486	0.2268	0.1797	0.1599	0.1380	0.1230
2.0000	0.1529	0.2362	0.2148	0.1897	0.1737	0.1390	0.1243	0.1080	0.0967
3.0000	0.1106	0.1646	0.1509	0.1346	0.1242	0.1013	0.0915	0.0804	0.0727
4.0000	0.0929	0.1338	0.1236	0.1113	0.1034	0.0857	0.0781	0.0693	0.0632
5.0000	0.0812	0.1134	0.1054	0.0958	0.0895	0.0754	0.0692	0.0620	0.0570
10.0000	0.0183	0.0257	0.0238	0.0217	0.0202	0.0170	0.0156	0.0140	0.0129

Table 18b
Dacite Horizontal DRS SDC-4 Spectra Including Topographic Amplification for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.4305	0.4305	0.4305	0.4305	0.4305	0.4305	0.4305	0.4305	0.4305
0.0200	0.4305	0.4305	0.4305	0.4305	0.4305	0.4305	0.4305	0.4305	0.4305
0.0300	0.4305	0.4726	0.4630	0.4508	0.4424	0.4217	0.4117	0.3994	0.3902
0.0400	0.5683	0.6717	0.6477	0.6173	0.5968	0.5478	0.5247	0.4969	0.4764
0.0500	0.7049	0.8794	0.8379	0.7863	0.7520	0.6714	0.6343	0.5903	0.5582
0.0600	0.8291	1.0812	1.0204	0.9455	0.8962	0.7822	0.7306	0.6703	0.6268
0.0750	0.9833	1.3531	1.2620	1.1516	1.0797	0.9167	0.8444	0.7613	0.7022
0.0900	1.1106	1.5967	1.4751	1.3291	1.2353	1.0255	0.9342	0.8302	0.7575
0.1000	1.1833	1.7451	1.6032	1.4341	1.3260	1.0866	0.9833	0.8667	0.7856
0.1200	1.2641	1.9485	1.7730	1.5659	1.4350	1.1495	1.0285	0.8936	0.8011
0.1500	1.3705	2.1745	1.9662	1.7222	1.5691	1.2384	1.0999	0.9467	0.8425
0.1700	1.3361	2.1610	1.9458	1.6950	1.5383	1.2022	1.0624	0.9088	0.8048
0.2000	1.2927	2.0908	1.8825	1.6399	1.4883	1.1631	1.0279	0.8793	0.7787
0.2400	1.1488	1.8580	1.6730	1.4573	1.3226	1.0336	0.9135	0.7814	0.6920
0.3000	0.9942	1.6081	1.4479	1.2613	1.1447	0.8946	0.7906	0.6763	0.5989
0.3600	0.8807	1.4244	1.2825	1.1172	1.0139	0.7924	0.7003	0.5990	0.5305
0.4000	0.8210	1.3279	1.1957	1.0416	0.9453	0.7388	0.6529	0.5585	0.4946
0.4600	0.7655	1.2381	1.1148	0.9711	0.8813	0.6888	0.6087	0.5207	0.4611
0.5000	0.7342	1.1874	1.0691	0.9313	0.8452	0.6606	0.5838	0.4994	0.4422
0.6000	0.6620	1.0706	0.9640	0.8398	0.7621	0.5956	0.5264	0.4503	0.3987
0.7500	0.5832	0.9432	0.8493	0.7398	0.6714	0.5248	0.4637	0.3967	0.3513
0.8500	0.5319	0.8577	0.7726	0.6738	0.6119	0.4789	0.4235	0.3627	0.3215
1.0000	0.4720	0.7573	0.6829	0.5964	0.5422	0.4255	0.3767	0.3231	0.2868
1.5000	0.3556	0.5599	0.5072	0.4452	0.4062	0.3218	0.2864	0.2472	0.2204
2.0000	0.2801	0.4326	0.3935	0.3474	0.3182	0.2547	0.2277	0.1977	0.1771
3.0000	0.2025	0.3016	0.2764	0.2466	0.2276	0.1856	0.1675	0.1472	0.1331
4.0000	0.1738	0.2504	0.2312	0.2082	0.1934	0.1604	0.1461	0.1297	0.1183
5.0000	0.1543	0.2158	0.2006	0.1822	0.1703	0.1434	0.1316	0.1180	0.1084
10.0000	0.0359	0.0501	0.0466	0.0423	0.0396	0.0333	0.0306	0.0274	0.0252

Table 18c
Dacite Horizontal DRS SDC-5 Spectra Including Topographic Amplification for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.7680	0.7680	0.7680	0.7680	0.7680	0.7680	0.7680	0.7680	0.7680
0.0200	0.7680	0.7680	0.7680	0.7680	0.7680	0.7680	0.7680	0.7680	0.7680
0.0300	0.7680	0.8431	0.8261	0.8043	0.7893	0.7524	0.7346	0.7127	0.6961
0.0400	1.0090	1.1928	1.1501	1.0962	1.0597	0.9727	0.9317	0.8824	0.8459
0.0500	1.2470	1.5557	1.4823	1.3911	1.3304	1.1878	1.1222	1.0444	0.9876
0.0600	1.4478	1.8879	1.7817	1.6510	1.5649	1.3658	1.2758	1.1704	1.0945
0.0750	1.7517	2.4106	2.2483	2.0515	1.9235	1.6331	1.5044	1.3562	1.2510
0.0900	1.9818	2.8491	2.6321	2.3717	2.2043	1.8300	1.6670	1.4814	1.3516
0.1000	2.1375	3.1523	2.8960	2.5904	2.3951	1.9627	1.7761	1.5655	1.4191
0.1200	2.3181	3.5732	3.2513	2.8716	2.6315	2.1080	1.8860	1.6386	1.4690
0.1500	2.5601	4.0619	3.6728	3.2170	2.9310	2.3132	2.0545	1.7683	1.5737
0.1700	2.5175	4.0717	3.6662	3.1936	2.8984	2.2652	2.0018	1.7123	1.5164
0.2000	2.4632	3.9839	3.5871	3.1247	2.8359	2.2163	1.9586	1.6754	1.4837
0.2400	2.2391	3.6215	3.2608	2.8405	2.5779	2.0147	1.7805	1.5230	1.3488
0.3000	1.9924	3.2225	2.9016	2.5276	2.2939	1.7928	1.5843	1.3552	1.2002
0.3600	1.7507	2.8315	2.5495	2.2209	2.0156	1.5752	1.3921	1.1908	1.0545
0.4000	1.6246	2.6275	2.3659	2.0609	1.8704	1.4618	1.2918	1.1050	0.9786
0.4600	1.4900	2.4099	2.1699	1.8902	1.7155	1.3407	1.1848	1.0135	0.8975
0.5000	1.4151	2.2888	2.0609	1.7952	1.6293	1.2733	1.1253	0.9625	0.8524
0.6000	1.2694	2.0530	1.8486	1.6103	1.4614	1.1422	1.0094	0.8634	0.7646
0.7500	1.1112	1.7973	1.6183	1.4097	1.2794	0.9999	0.8836	0.7558	0.6694
0.8500	1.0148	1.6364	1.4742	1.2856	1.1674	0.9137	0.8080	0.6920	0.6134
1.0000	0.9020	1.4473	1.3052	1.1399	1.0363	0.8132	0.7200	0.6175	0.5481
1.5000	0.7159	1.1271	1.0210	0.8962	0.8177	0.6479	0.5766	0.4976	0.4436
2.0000	0.5899	0.9110	0.8286	0.7315	0.6700	0.5363	0.4796	0.4164	0.3730
3.0000	0.4477	0.6666	0.6111	0.5452	0.5030	0.4103	0.3704	0.3254	0.2943
4.0000	0.3997	0.5757	0.5317	0.4788	0.4448	0.3689	0.3359	0.2983	0.2720
5.0000	0.3660	0.5117	0.4756	0.4320	0.4037	0.3400	0.3120	0.2798	0.2571
10.0000	0.0932	0.1303	0.1211	0.1100	0.1028	0.0866	0.0794	0.0712	0.0654

Table 19a
Dacite Vertical DRS SDC-3 Spectra Including Topographic Amplification for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.2418	0.2418	0.2418	0.2418	0.2418	0.2418	0.2418	0.2418	0.2418
0.0200	0.2418	0.2418	0.2418	0.2418	0.2418	0.2418	0.2418	0.2418	0.2418
0.0300	0.3548	0.4559	0.4316	0.4013	0.3815	0.3366	0.3167	0.2938	0.2773
0.0400	0.4658	0.6778	0.6244	0.5601	0.5192	0.4304	0.3930	0.3512	0.3221
0.0500	0.5752	0.8769	0.7996	0.7077	0.6499	0.5264	0.4753	0.4188	0.3801
0.0600	0.6831	1.0837	0.9795	0.8570	0.7807	0.6198	0.5543	0.4826	0.4340
0.0750	0.7738	1.2838	1.1491	0.9924	0.8958	0.6955	0.6153	0.5286	0.4705
0.0900	0.8540	1.4760	1.3094	1.1175	1.0005	0.7610	0.6667	0.5657	0.4988
0.1000	0.7757	1.3760	1.2137	1.0282	0.9156	0.6874	0.5984	0.5038	0.4416
0.1200	0.7044	1.2682	1.1151	0.9405	0.8350	0.6223	0.5398	0.4524	0.3952
0.1500	0.6260	1.1367	0.9974	0.8393	0.7439	0.5521	0.4778	0.3995	0.3483
0.1700	0.5594	1.0111	0.8881	0.7483	0.6639	0.4938	0.4279	0.3582	0.3126
0.2000	0.4833	0.8612	0.7588	0.6420	0.5712	0.4279	0.3721	0.3129	0.2740
0.2400	0.4200	0.7387	0.6528	0.5543	0.4945	0.3729	0.3252	0.2745	0.2411
0.3000	0.3536	0.6159	0.5454	0.4645	0.4152	0.3146	0.2751	0.2329	0.2050
0.3600	0.3127	0.5446	0.4823	0.4108	0.3672	0.2782	0.2433	0.2060	0.1813
0.4000	0.2913	0.5073	0.4493	0.3826	0.3420	0.2592	0.2266	0.1918	0.1689
0.4600	0.2682	0.4671	0.4137	0.3523	0.3149	0.2386	0.2086	0.1766	0.1555
0.5000	0.2553	0.4447	0.3938	0.3354	0.2998	0.2272	0.1986	0.1682	0.1480
0.6000	0.2286	0.3982	0.3527	0.3003	0.2685	0.2034	0.1779	0.1506	0.1325
0.7500	0.1998	0.3479	0.3081	0.2624	0.2345	0.1777	0.1554	0.1315	0.1158
0.8500	0.1807	0.3136	0.2779	0.2370	0.2120	0.1609	0.1408	0.1194	0.1051
1.0000	0.1587	0.2737	0.2429	0.2074	0.1858	0.1415	0.1240	0.1053	0.0929
1.5000	0.1154	0.1944	0.1734	0.1491	0.1342	0.1034	0.0911	0.0779	0.0691
2.0000	0.0929	0.1528	0.1370	0.1186	0.1073	0.0836	0.0741	0.0639	0.0569
3.0000	0.0644	0.1011	0.0916	0.0804	0.0734	0.0585	0.0524	0.0458	0.0413
4.0000	0.0540	0.0815	0.0745	0.0661	0.0609	0.0496	0.0449	0.0397	0.0361
5.0000	0.0472	0.0686	0.0632	0.0567	0.0526	0.0436	0.0399	0.0356	0.0327
10.0000	0.0107	0.0155	0.0143	0.0128	0.0119	0.0099	0.0090	0.0081	0.0074

Table 19b
Dacite Vertical DRS SDC-4 Spectra Including Topographic Amplification for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.4064	0.4064	0.4064	0.4064	0.4064	0.4064	0.4064	0.4064	0.4064
0.0200	0.4064	0.4064	0.4064	0.4064	0.4064	0.4064	0.4064	0.4064	0.4064
0.0300	0.6009	0.7721	0.7309	0.6797	0.6461	0.5700	0.5364	0.4976	0.4697
0.0400	0.7931	1.1540	1.0631	0.9537	0.8840	0.7328	0.6692	0.5980	0.5485
0.0500	0.9835	1.4993	1.3671	1.2100	1.1112	0.9000	0.8126	0.7161	0.6499
0.0600	1.1847	1.8794	1.6987	1.4863	1.3539	1.0749	0.9612	0.8369	0.7527
0.0750	1.3658	2.2658	2.0281	1.7516	1.5811	1.2275	1.0860	0.9330	0.8304
0.0900	1.5624	2.7002	2.3953	2.0444	1.8304	1.3922	1.2196	1.0349	0.9125
0.1000	1.4638	2.5967	2.2905	1.9403	1.7278	1.2973	1.1292	0.9507	0.8333
0.1200	1.3391	2.4109	2.1198	1.7879	1.5874	1.1831	1.0262	0.8601	0.7513
0.1500	1.2009	2.1805	1.9133	1.6100	1.4271	1.0590	0.9166	0.7664	0.6682
0.1700	1.0575	1.9116	1.6790	1.4147	1.2551	0.9335	0.8089	0.6772	0.5910
0.2000	0.8966	1.5975	1.4077	1.1909	1.0596	0.7938	0.6903	0.5804	0.5082
0.2400	0.7598	1.3364	1.1810	1.0029	0.8947	0.6745	0.5884	0.4966	0.4361
0.3000	0.6205	1.0806	0.9569	0.8150	0.7285	0.5520	0.4826	0.4086	0.3597
0.3600	0.5375	0.9361	0.8290	0.7060	0.6311	0.4782	0.4181	0.3540	0.3116
0.4000	0.4947	0.8616	0.7631	0.6498	0.5809	0.4402	0.3848	0.3258	0.2868
0.4600	0.4510	0.7854	0.6956	0.5924	0.5295	0.4012	0.3508	0.2970	0.2614
0.5000	0.4268	0.7432	0.6582	0.5606	0.5011	0.3797	0.3320	0.2810	0.2474
0.6000	0.3853	0.6710	0.5942	0.5061	0.4523	0.3428	0.2997	0.2537	0.2233
0.7500	0.3399	0.5920	0.5243	0.4465	0.3991	0.3024	0.2644	0.2239	0.1970
0.8500	0.3098	0.5375	0.4765	0.4062	0.3633	0.2759	0.2414	0.2046	0.1802
1.0000	0.2746	0.4737	0.4203	0.3589	0.3216	0.2448	0.2146	0.1822	0.1608
1.5000	0.2071	0.3490	0.3113	0.2677	0.2409	0.1855	0.1635	0.1398	0.1240
2.0000	0.1755	0.2887	0.2589	0.2241	0.2026	0.1580	0.1401	0.1207	0.1076
3.0000	0.1179	0.1854	0.1679	0.1473	0.1344	0.1072	0.0961	0.0839	0.0756
4.0000	0.1010	0.1523	0.1392	0.1236	0.1137	0.0926	0.0838	0.0741	0.0674
5.0000	0.0895	0.1301	0.1198	0.1076	0.0998	0.0827	0.0756	0.0676	0.0620
10.0000	0.0208	0.0302	0.0279	0.0250	0.0232	0.0192	0.0176	0.0157	0.0144

Table 19c
Dacite Vertical DRS SDC-5 Spectra Including Topographic Amplification for Multiple Damping Levels

PERIOD (SEC)	SA(5%)	SA(0.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.7407	0.7407	0.7407	0.7407	0.7407	0.7407	0.7407	0.7407	0.7407
0.0200	0.7407	0.7407	0.7407	0.7407	0.7407	0.7407	0.7407	0.7407	0.7407
0.0300	1.1047	1.4194	1.3436	1.2495	1.1878	1.0479	0.9862	0.9147	0.8634
0.0400	1.4669	2.1345	1.9663	1.7639	1.6350	1.3555	1.2378	1.1060	1.0146
0.0500	1.8278	2.7863	2.5407	2.2486	2.0650	1.6725	1.5102	1.3307	1.2077
0.0600	2.2100	3.5060	3.1689	2.7726	2.5256	2.0053	1.7932	1.5612	1.4041
0.0750	2.5823	4.2839	3.8346	3.3117	2.9894	2.3209	2.0533	1.7640	1.5700
0.0900	2.9370	5.0759	4.5028	3.8432	3.4408	2.6172	2.2926	1.9455	1.7153
0.1000	2.7270	4.8375	4.2670	3.6147	3.2188	2.4167	2.1037	1.7711	1.5524
0.1200	2.4905	4.4839	3.9424	3.3251	2.9523	2.2003	1.9085	1.5997	1.3972
0.1500	2.2288	4.0470	3.5512	2.9882	2.6487	1.9656	1.7013	1.4225	1.2402
0.1700	1.9874	3.5924	3.1554	2.6586	2.3587	1.7544	1.5202	1.2727	1.1107
0.2000	1.7124	3.0512	2.6886	2.2746	2.0239	1.5162	1.3184	1.1086	0.9707
0.2400	1.4670	2.5803	2.2803	1.9364	1.7274	1.3024	1.1360	0.9589	0.8421
0.3000	1.2139	2.1142	1.8723	1.5945	1.4253	1.0800	0.9443	0.7995	0.7037
0.3600	1.0500	1.8286	1.6194	1.3792	1.2328	0.9341	0.8167	0.6915	0.6086
0.4000	0.9655	1.6816	1.4892	1.2682	1.1336	0.8590	0.7511	0.6359	0.5597
0.4600	0.8717	1.5181	1.3444	1.1450	1.0234	0.7755	0.6781	0.5741	0.5053
0.5000	0.8201	1.4283	1.2649	1.0772	0.9629	0.7296	0.6379	0.5401	0.4754
0.6000	0.7371	1.2838	1.1369	0.9682	0.8655	0.6558	0.5734	0.4855	0.4273
0.7500	0.6469	1.1267	0.9978	0.8498	0.7596	0.5756	0.5032	0.4260	0.3750
0.8500	0.5907	1.0249	0.9084	0.7746	0.6928	0.5260	0.4603	0.3902	0.3436
1.0000	0.5249	0.9054	0.8034	0.6860	0.6146	0.4680	0.4101	0.3483	0.3073
1.5000	0.4182	0.7047	0.6286	0.5405	0.4864	0.3747	0.3302	0.2824	0.2504
2.0000	0.3766	0.6197	0.5557	0.4810	0.4349	0.3391	0.3007	0.2590	0.2309
3.0000	0.2581	0.4056	0.3674	0.3223	0.2942	0.2346	0.2103	0.1836	0.1655
4.0000	0.2297	0.3464	0.3166	0.2811	0.2587	0.2107	0.1907	0.1686	0.1534
5.0000	0.2098	0.3048	0.2808	0.2521	0.2338	0.1939	0.1772	0.1584	0.1453
10.0000	0.0542	0.0787	0.0725	0.0651	0.0604	0.0501	0.0458	0.0409	0.0375

Table 20a
Dacite Horizontal DRS SDC-3 Spectra for Multiple Damping Levels

PERIOD	SA(5%)	SA(.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.2377	0.2377	0.2377	0.2377	0.2377	0.2377	0.2377	0.2377	0.2377
0.0200	0.2377	0.2377	0.2377	0.2377	0.2377	0.2377	0.2377	0.2377	0.2377
0.0300	0.2377	0.2610	0.2557	0.2490	0.2443	0.2329	0.2274	0.2206	0.2155
0.0400	0.3133	0.3703	0.3570	0.3403	0.3290	0.3020	0.2892	0.2740	0.2626
0.0500	0.3880	0.4841	0.4613	0.4329	0.4140	0.3696	0.3492	0.3250	0.3073
0.0600	0.4544	0.5926	0.5592	0.5182	0.4912	0.4287	0.4004	0.3674	0.3435
0.0750	0.5303	0.7298	0.6806	0.6211	0.5823	0.4944	0.4554	0.4106	0.3787
0.0900	0.5875	0.8447	0.7804	0.7031	0.6535	0.5425	0.4942	0.4392	0.4007
0.1000	0.6150	0.9070	0.8333	0.7454	0.6892	0.5648	0.5111	0.4505	0.4083
0.1200	0.6428	0.9909	0.9016	0.7963	0.7297	0.5846	0.5230	0.4544	0.4074
0.1500	0.6786	1.0766	0.9735	0.8527	0.7769	0.6131	0.5446	0.4687	0.4171
0.1700	0.6581	1.0643	0.9583	0.8348	0.7576	0.5921	0.5233	0.4476	0.3964
0.2000	0.6323	1.0227	0.9209	0.8022	0.7280	0.5690	0.5028	0.4301	0.3809
0.2400	0.5787	0.9360	0.8428	0.7341	0.6663	0.5207	0.4602	0.3936	0.3486
0.3000	0.5192	0.8397	0.7561	0.6586	0.5978	0.4672	0.4129	0.3531	0.3127
0.3600	0.4753	0.7687	0.6921	0.6029	0.5472	0.4276	0.3779	0.3233	0.2863
0.4000	0.4516	0.7304	0.6577	0.5729	0.5199	0.4063	0.3591	0.3072	0.2720
0.4600	0.4227	0.6837	0.6156	0.5363	0.4867	0.3804	0.3361	0.2875	0.2546
0.5000	0.4064	0.6573	0.5919	0.5156	0.4679	0.3657	0.3232	0.2764	0.2448
0.6000	0.3635	0.5880	0.5294	0.4612	0.4185	0.3271	0.2891	0.2473	0.2190
0.7500	0.3172	0.5130	0.4619	0.4024	0.3652	0.2854	0.2522	0.2157	0.1911
0.8500	0.2872	0.4631	0.4172	0.3638	0.3304	0.2586	0.2287	0.1958	0.1736
1.0000	0.2524	0.4051	0.3653	0.3190	0.2900	0.2276	0.2015	0.1728	0.1534
1.5000	0.1845	0.2904	0.2631	0.2309	0.2107	0.1669	0.1486	0.1282	0.1143
2.0000	0.1425	0.2200	0.2001	0.1767	0.1618	0.1295	0.1158	0.1006	0.0901
3.0000	0.1031	0.1534	0.1407	0.1255	0.1158	0.0944	0.0853	0.0749	0.0678
4.0000	0.0867	0.1249	0.1153	0.1039	0.0965	0.0800	0.0729	0.0647	0.0590
5.0000	0.0758	0.1060	0.0985	0.0895	0.0836	0.0704	0.0646	0.0580	0.0533
10.0000	0.0172	0.0241	0.0224	0.0203	0.0190	0.0160	0.0147	0.0132	0.0121

Table 20b
Dacite Horizontal DRS SDC-4 Spectra for Multiple Damping Levels

PERIOD	SA(5%)	SA(.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.3883	0.3883	0.3883	0.3883	0.3883	0.3883	0.3883	0.3883	0.3883
0.0200	0.3883	0.3883	0.3883	0.3883	0.3883	0.3883	0.3883	0.3883	0.3883
0.0300	0.3883	0.4263	0.4177	0.4067	0.3990	0.3804	0.3714	0.3603	0.3519
0.0400	0.5114	0.6045	0.5829	0.5556	0.5371	0.4930	0.4722	0.4472	0.4287
0.0500	0.6332	0.7900	0.7527	0.7064	0.6756	0.6032	0.5698	0.5303	0.5015
0.0600	0.7448	0.9712	0.9165	0.8493	0.8051	0.7026	0.6563	0.6021	0.5630
0.0750	0.8862	1.2196	1.1375	1.0379	0.9732	0.8262	0.7611	0.6861	0.6329
0.0900	1.0000	1.4377	1.3282	1.1968	1.1123	0.9234	0.8412	0.7475	0.6820
0.1000	1.0647	1.5702	1.4426	1.2904	1.1931	0.9777	0.8847	0.7798	0.7069
0.1200	1.1428	1.7615	1.6028	1.4156	1.2973	1.0392	0.9298	0.8078	0.7242
0.1500	1.2462	1.9772	1.7878	1.5659	1.4267	1.1260	1.0001	0.8608	0.7660
0.1700	1.2208	1.9744	1.7778	1.5486	1.4055	1.0984	0.9707	0.8303	0.7353
0.2000	1.1885	1.9223	1.7309	1.5078	1.3684	1.0694	0.9451	0.8084	0.7159
0.2400	1.0558	1.7076	1.5375	1.3393	1.2155	0.9500	0.8395	0.7181	0.6360
0.3000	0.9133	1.4771	1.3300	1.1586	1.0515	0.8218	0.7262	0.6212	0.5501
0.3600	0.8074	1.3058	1.1758	1.0242	0.9295	0.7265	0.6420	0.5492	0.4863
0.4000	0.7519	1.2160	1.0949	0.9538	0.8656	0.6765	0.5978	0.5114	0.4529
0.4600	0.7008	1.1335	1.0206	0.8891	0.8069	0.6306	0.5573	0.4767	0.4222
0.5000	0.6721	1.0870	0.9787	0.8526	0.7737	0.6047	0.5344	0.4571	0.4048
0.6000	0.6038	0.9766	0.8794	0.7660	0.6952	0.5433	0.4802	0.4107	0.3637
0.7500	0.5297	0.8567	0.7714	0.6720	0.6098	0.4766	0.4212	0.3603	0.3191
0.8500	0.4830	0.7789	0.7017	0.6119	0.5557	0.4349	0.3846	0.3294	0.2919
1.0000	0.4285	0.6876	0.6200	0.5415	0.4923	0.3863	0.3420	0.2933	0.2604
1.5000	0.3251	0.5118	0.4636	0.4070	0.3714	0.2942	0.2618	0.2260	0.2014
2.0000	0.2573	0.3974	0.3615	0.3191	0.2923	0.2339	0.2092	0.1816	0.1627
3.0000	0.1862	0.2773	0.2542	0.2268	0.2093	0.1707	0.1541	0.1354	0.1224
4.0000	0.1602	0.2307	0.2131	0.1919	0.1782	0.1478	0.1346	0.1195	0.1090
5.0000	0.1425	0.1992	0.1851	0.1682	0.1572	0.1324	0.1215	0.1089	0.1001
10.0000	0.0334	0.0467	0.0435	0.0395	0.0369	0.0311	0.0285	0.0256	0.0235

Table 20c
Dacite Horizontal DRS SDC-5 Spectra for Multiple Damping Levels

PERIOD	SA(5%)	SA(.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.6663	0.6663	0.6663	0.6663	0.6663	0.6663	0.6663	0.6663	0.6663
0.0200	0.6663	0.6663	0.6663	0.6663	0.6663	0.6663	0.6663	0.6663	0.6663
0.0300	0.6663	0.7314	0.7167	0.6978	0.6847	0.6528	0.6373	0.6183	0.6039
0.0400	0.8705	1.0291	0.9922	0.9457	0.9142	0.8392	0.8038	0.7613	0.7298
0.0500	1.0712	1.3364	1.2734	1.1950	1.1429	1.0204	0.9640	0.8971	0.8484
0.0600	1.2471	1.6261	1.5346	1.4220	1.3480	1.1764	1.0989	1.0081	0.9427
0.0750	1.5168	2.0873	1.9468	1.7764	1.6656	1.4141	1.3026	1.1743	1.0833
0.0900	1.7164	2.4676	2.2797	2.0541	1.9091	1.5849	1.4437	1.2830	1.1706
0.1000	1.8501	2.7285	2.5066	2.2422	2.0731	1.6988	1.5373	1.3551	1.2283
0.1200	2.0125	3.1022	2.8227	2.4930	2.2846	1.8301	1.6374	1.4226	1.2753
0.1500	2.2309	3.5395	3.2005	2.8033	2.5541	2.0158	1.7903	1.5409	1.3714
0.1700	2.1952	3.5505	3.1969	2.7848	2.5274	1.9752	1.7456	1.4931	1.3223
0.2000	2.1497	3.4769	3.1307	2.7271	2.4750	1.9343	1.7094	1.4622	1.2949
0.2400	1.9730	3.1911	2.8733	2.5029	2.2716	1.7753	1.5689	1.3420	1.1885
0.3000	1.7764	2.8731	2.5869	2.2535	2.0452	1.5984	1.4125	1.2083	1.0700
0.3600	1.5651	2.5313	2.2792	1.9854	1.8019	1.4082	1.2445	1.0645	0.9427
0.4000	1.4546	2.3526	2.1184	1.8453	1.6747	1.3088	1.1567	0.9894	0.8762
0.4600	1.3350	2.1592	1.9442	1.6936	1.5370	1.2012	1.0616	0.9080	0.8042
0.5000	1.2684	2.0515	1.8472	1.6091	1.4603	1.1413	1.0086	0.8627	0.7640
0.6000	1.1349	1.8355	1.6527	1.4397	1.3066	1.0211	0.9024	0.7719	0.6836
0.7500	0.9904	1.6019	1.4424	1.2565	1.1403	0.8912	0.7876	0.6737	0.5966
0.8500	0.9033	1.4566	1.3122	1.1444	1.0392	0.8133	0.7192	0.6160	0.5460
1.0000	0.8016	1.2861	1.1598	1.0129	0.9208	0.7226	0.6398	0.5487	0.4870
1.5000	0.6434	1.0129	0.9175	0.8054	0.7349	0.5823	0.5182	0.4471	0.3986
2.0000	0.5341	0.8249	0.7503	0.6623	0.6067	0.4855	0.4342	0.3770	0.3378
3.0000	0.4084	0.6081	0.5574	0.4973	0.4589	0.3743	0.3379	0.2969	0.2685
4.0000	0.3666	0.5281	0.4877	0.4392	0.4080	0.3384	0.3081	0.2736	0.2495
5.0000	0.3372	0.4714	0.4381	0.3980	0.3720	0.3132	0.2874	0.2578	0.2368
10.0000	0.0868	0.1214	0.1128	0.1025	0.0958	0.0807	0.0740	0.0664	0.0610

Table 21a
Dacite Vertical DRS SDC-3 Spectra for Multiple Damping Levels

PERIOD	SA(5%)	SA(.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.2030	0.2030	0.2030	0.2030	0.2030	0.2030	0.2030	0.2030	0.2030
0.0200	0.2030	0.2030	0.2030	0.2030	0.2030	0.2030	0.2030	0.2030	0.2030
0.0300	0.2977	0.3825	0.3621	0.3367	0.3201	0.2824	0.2657	0.2465	0.2327
0.0400	0.3906	0.5684	0.5236	0.4697	0.4354	0.3609	0.3296	0.2945	0.2702
0.0500	0.4822	0.7351	0.6703	0.5933	0.5448	0.4413	0.3984	0.3511	0.3186
0.0600	0.5731	0.9092	0.8218	0.7190	0.6550	0.5200	0.4650	0.4049	0.3641
0.0750	0.6513	1.0805	0.9672	0.8353	0.7540	0.5854	0.5179	0.4449	0.3960
0.0900	0.6689	1.1560	1.0255	0.8753	0.7836	0.5961	0.5221	0.4431	0.3907
0.1000	0.6539	1.1600	1.0232	0.8668	0.7719	0.5795	0.5045	0.4247	0.3723
0.1200	0.5921	1.0659	0.9372	0.7904	0.7018	0.5231	0.4537	0.3803	0.3322
0.1500	0.5242	0.9519	0.8352	0.7028	0.6230	0.4623	0.4001	0.3346	0.2917
0.1700	0.4695	0.8487	0.7455	0.6281	0.5573	0.4145	0.3591	0.3007	0.2624
0.2000	0.4069	0.7251	0.6389	0.5405	0.4810	0.3603	0.3133	0.2635	0.2307
0.2400	0.3537	0.6222	0.5499	0.4669	0.4165	0.3141	0.2739	0.2312	0.2031
0.3000	0.2980	0.5190	0.4596	0.3915	0.3499	0.2651	0.2318	0.1963	0.1728
0.3600	0.2630	0.4580	0.4056	0.3454	0.3087	0.2339	0.2045	0.1732	0.1524
0.4000	0.2446	0.4260	0.3773	0.3213	0.2872	0.2176	0.1903	0.1611	0.1418
0.4600	0.2253	0.3924	0.3475	0.2959	0.2645	0.2004	0.1753	0.1484	0.1306
0.5000	0.2145	0.3736	0.3308	0.2818	0.2519	0.1908	0.1669	0.1413	0.1243
0.6000	0.1923	0.3349	0.2966	0.2526	0.2258	0.1711	0.1496	0.1266	0.1115
0.7500	0.1682	0.2929	0.2594	0.2209	0.1975	0.1496	0.1308	0.1108	0.0975
0.8500	0.1522	0.2641	0.2341	0.1996	0.1785	0.1355	0.1186	0.1005	0.0885
1.0000	0.1337	0.2305	0.2045	0.1747	0.1565	0.1191	0.1044	0.0887	0.0782
1.5000	0.0976	0.1645	0.1467	0.1261	0.1135	0.0874	0.0771	0.0659	0.0584
2.0000	0.0790	0.1299	0.1165	0.1009	0.0912	0.0711	0.0630	0.0543	0.0484
3.0000	0.0548	0.0861	0.0780	0.0684	0.0624	0.0498	0.0446	0.0390	0.0351
4.0000	0.0461	0.0695	0.0635	0.0564	0.0519	0.0423	0.0383	0.0338	0.0308
5.0000	0.0403	0.0586	0.0540	0.0485	0.0449	0.0373	0.0341	0.0304	0.0279
10.0000	0.0092	0.0133	0.0122	0.0110	0.0102	0.0085	0.0077	0.0069	0.0063

Table 21b
Dacite Vertical DRS SDC-4 Spectra for Multiple Damping Levels

PERIOD	SA(5%)	SA(.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.3357	0.3357	0.3357	0.3357	0.3357	0.3357	0.3357	0.3357	0.3357
0.0200	0.3357	0.3357	0.3357	0.3357	0.3357	0.3357	0.3357	0.3357	0.3357
0.0300	0.4952	0.6363	0.6023	0.5602	0.5325	0.4698	0.4421	0.4101	0.3871
0.0400	0.6526	0.9496	0.8748	0.7847	0.7274	0.6030	0.5507	0.4920	0.4514
0.0500	0.8083	1.2322	1.1236	0.9944	0.9132	0.7397	0.6679	0.5885	0.5341
0.0600	0.9738	1.5449	1.3963	1.2217	1.1129	0.8836	0.7901	0.6880	0.6187
0.0750	1.1261	1.8681	1.6722	1.4442	1.3036	1.0121	0.8954	0.7692	0.6846
0.0900	1.1898	2.0563	1.8242	1.5569	1.3939	1.0603	0.9288	0.7881	0.6949
0.1000	1.2083	2.1434	1.8906	1.6016	1.4262	1.0708	0.9321	0.7847	0.6878
0.1200	1.1003	1.9809	1.7417	1.4690	1.3043	0.9721	0.8431	0.7067	0.6173
0.1500	0.9811	1.7815	1.5632	1.3154	1.1660	0.8652	0.7489	0.6262	0.5459
0.1700	0.8703	1.5732	1.3819	1.1643	1.0330	0.7683	0.6657	0.5573	0.4864
0.2000	0.7449	1.3273	1.1696	0.9895	0.8804	0.6596	0.5735	0.4823	0.4223
0.2400	0.6339	1.1150	0.9853	0.8367	0.7464	0.5628	0.4909	0.4143	0.3639
0.3000	0.5202	0.9060	0.8024	0.6833	0.6108	0.4628	0.4047	0.3426	0.3016
0.3600	0.4487	0.7815	0.6921	0.5894	0.5268	0.3992	0.3490	0.2955	0.2601
0.4000	0.4120	0.7174	0.6354	0.5411	0.4837	0.3665	0.3204	0.2713	0.2388
0.4600	0.3752	0.6535	0.5787	0.4929	0.4406	0.3338	0.2919	0.2471	0.2175
0.5000	0.3549	0.6181	0.5474	0.4662	0.4167	0.3157	0.2761	0.2337	0.2057
0.6000	0.3203	0.5579	0.4941	0.4208	0.3761	0.2850	0.2492	0.2110	0.1857
0.7500	0.2826	0.4922	0.4358	0.3712	0.3318	0.2514	0.2198	0.1861	0.1638
0.8500	0.2573	0.4465	0.3957	0.3374	0.3018	0.2291	0.2005	0.1700	0.1497
1.0000	0.2279	0.3930	0.3487	0.2978	0.2668	0.2032	0.1780	0.1512	0.1334
1.5000	0.1728	0.2912	0.2597	0.2233	0.2010	0.1548	0.1365	0.1167	0.1035
2.0000	0.1475	0.2427	0.2177	0.1884	0.1704	0.1328	0.1178	0.1014	0.0904
3.0000	0.0993	0.1561	0.1414	0.1240	0.1132	0.0903	0.0809	0.0707	0.0637
4.0000	0.0853	0.1287	0.1176	0.1044	0.0961	0.0783	0.0709	0.0626	0.0570
5.0000	0.0759	0.1102	0.1016	0.0912	0.0845	0.0701	0.0641	0.0573	0.0526
10.0000	0.0178	0.0258	0.0238	0.0214	0.0198	0.0164	0.0150	0.0134	0.0123

Table 21c
Dacite Vertical DRS SDC-5 Spectra for Multiple Damping Levels

PERIOD	SA(5%)	SA(.5%)	SA(1%)	SA(2%)	SA(3%)	SA(7%)	SA(10%)	SA(15%)	SA(20%)
0.0100	0.5900	0.5900	0.5900	0.5900	0.5900	0.5900	0.5900	0.5900	0.5900
0.0200	0.5900	0.5900	0.5900	0.5900	0.5900	0.5900	0.5900	0.5900	0.5900
0.0300	0.8815	1.1327	1.0722	0.9971	0.9478	0.8362	0.7869	0.7299	0.6890
0.0400	1.1721	1.7056	1.5711	1.4095	1.3064	1.0831	0.9891	0.8837	0.8107
0.0500	1.4620	2.2287	2.0322	1.7986	1.6517	1.3378	1.2079	1.0644	0.9660
0.0600	1.7646	2.7995	2.5303	2.2139	2.0166	1.6012	1.4318	1.2466	1.1211
0.0750	2.0498	3.4006	3.0439	2.6288	2.3730	1.8423	1.6299	1.4002	1.2462
0.0900	2.1265	3.6751	3.2602	2.7826	2.4913	1.8949	1.6600	1.4086	1.2420
0.1000	2.1163	3.7541	3.3113	2.8051	2.4979	1.8755	1.6326	1.3745	1.2047
0.1200	1.9215	3.4595	3.0417	2.5654	2.2778	1.6976	1.4724	1.2342	1.0780
0.1500	1.7074	3.1002	2.7203	2.2891	2.0290	1.5057	1.3032	1.0897	0.9501
0.1700	1.5324	2.7700	2.4330	2.0500	1.8187	1.3528	1.1722	0.9813	0.8565
0.2000	1.3317	2.3728	2.0908	1.7689	1.5739	1.1791	1.0253	0.8621	0.7548
0.2400	1.1562	2.0336	1.7972	1.5261	1.3614	1.0264	0.8953	0.7557	0.6637
0.3000	0.9725	1.6937	1.4999	1.2774	1.1418	0.8652	0.7565	0.6404	0.5637
0.3600	0.8452	1.4721	1.3036	1.1102	0.9924	0.7520	0.6575	0.5566	0.4900
0.4000	0.7795	1.3575	1.2022	1.0238	0.9152	0.6935	0.6063	0.5133	0.4518
0.4600	0.7036	1.2253	1.0851	0.9241	0.8261	0.6259	0.5473	0.4633	0.4078
0.5000	0.6619	1.1527	1.0208	0.8694	0.7771	0.5888	0.5148	0.4359	0.3837
0.6000	0.5962	1.0383	0.9195	0.7831	0.7000	0.5304	0.4638	0.3926	0.3456
0.7500	0.5246	0.9137	0.8091	0.6891	0.6160	0.4667	0.4081	0.3455	0.3041
0.8500	0.4799	0.8326	0.7380	0.6292	0.5628	0.4273	0.3740	0.3170	0.2791
1.0000	0.4274	0.7372	0.6541	0.5586	0.5005	0.3810	0.3339	0.2836	0.2502
1.5000	0.3424	0.5769	0.5146	0.4425	0.3982	0.3067	0.2703	0.2312	0.2050
2.0000	0.3119	0.5132	0.4602	0.3984	0.3602	0.2809	0.2490	0.2145	0.1912
3.0000	0.2150	0.3380	0.3061	0.2685	0.2451	0.1955	0.1752	0.1530	0.1379
4.0000	0.1922	0.2899	0.2649	0.2352	0.2165	0.1763	0.1596	0.1411	0.1284
5.0000	0.1762	0.2560	0.2359	0.2117	0.1963	0.1629	0.1488	0.1330	0.1221
10.0000	0.0459	0.0666	0.0614	0.0551	0.0511	0.0424	0.0387	0.0346	0.0318

Appendix A

Steering Committee's Peer Reviews of 5 June 2009 and 31 August 2009 and Response to Comments

Via e-mail

Memorandum

To: Michael W. Salmon
SAFER Project Engineer, D-5
Los Alamos National Laboratory, MS K575

From: Confirmatory Studies Steering Committee:
Walter J. Arabasz
Carl J. Costantino
Michael N. Machette

Subject: Peer Review of *Update of the Seismic Design Ground Motions for the CMRR Facility, Los Alamos National Laboratory*

Date: June 5, 2009

Background[1]

In 2007, URS Corp completed an updated site-specific PSHA for LANL.[2] In 2009, LANS initiated the Confirmatory Studies project to revisit some of the results of the 2007 UPSHA report, notably to determine whether the resulting design-basis ground motions might be overly conservative. For continuity, Michael W. Salmon, LANL project leader for the current Confirmatory Studies project (and also the project leader for the 2007 UPSHA project), reconstituted the same Steering Committee from the 2004–2007 UPSHA project to provide guidance to him for the current project. For other background information, see the Committee's report on Confirmatory Studies Workshop #1.[3]

Work Product Reviewed

The work product reviewed and commented on here consists of the subject report, dated May 22, 2009, authored by Ivan Wong of URS Corp and Walter Silva of Pacific Engineering and Analysis. The report is identified as a "draft" report (see Attachment for a reproduction of the cover page and table of contents).

Methodology Used

This review falls under DOE technical and procedural guidance aimed at ensuring an independent review focusing on "the arguments and logic used to develop the hazard results" (DOE-STD-1023-95, Sec. 3.1.2.3). The comments provided here result from a "participatory peer review," that is, an ongoing review in which the reviewers have had full and frequent access to the project and have had ongoing interactions with the study team—consistent with recommendations of the Senior Seismic Hazard Analysis Committee (SSHAC, NUREG/CR-6372).

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[1] Acronyms and abbreviations are explained in the Appendix.

[2] Wong, I. (and multiple authors), 2007. *Update of the Probabilistic Seismic Hazard Analysis and Development of Seismic Design Ground Motions at the Los Alamos National Laboratory*. Oakland, CA, URS Corporation.

[3] Arabasz, W. J., Costantino, C. J., and Machette, M. N., 2009. *Committee Report on Confirmatory Studies Workshop #1*. Memorandum to M. W. Salmon, dated April 6, 2009.

The methodology primarily relied on for this review was the standard one of careful scrutiny of assumptions, data, interpretations, and conclusions vis-à-vis the reviewers' (1) technical knowledge of the content, both site-specific and general, (2) familiarity with the relevant technical literature, and (3) understanding of valid PSHA procedures

Disclosure

In early 2009, LANL managers did not envision that the Confirmatory Studies would be carried out as a continuation of the 2007 UPSHA in terms of a SSHAC process. One of the present Committee members (CJC) participated in a subcontract under URS Corp to prepare a report to LANL entitled, *Re-examination of the Vertical Probabilistic Hazard at Los Alamos National Laboratory* by Ivan Wong, Walter Silva, and Carl J. Costantino and dated March 16, 2009. (See the Committee's report on Workshop #1 for comment on Carl's role as proponent, evaluator, and reviewer in the current project.[4])

The present work product being reviewed does not contain analyses, conclusions, or interpretations, in which Dr. Costantino had any direct material involvement.

In reviewing the present work product, the Committee relied heavily on Dr. Costantino's expertise in critically examining details of the heart of the report—namely, the updating of horizontal and vertical design motions with consistent strain-compatible properties. The value of his unique expertise is well recognized and is emphasized by the circumstance, noted in the report, of "the difficulty and lack of industry consensus on developing (modeling) site-specific vertical motions" (p. 3-6).

Terminology

We were asked by Michael Salmon, project leader, to use the same comment-and-finding format for this review as previously used for the 2004–2007 UPSHA project. Accordingly, we use the following definitions given to the peer review committee in a memorandum from Michael Salmon dated May 19, 2005:

<u>Concern</u>: "A <u>concern</u> is defined as a point of concern in the process that, if not corrected, has a direct impact on the conclusions in the final work product (the design basis ground motion for LANL)."

<u>Finding</u>: "For the purpose of this peer review a <u>finding</u> is defined as a point of concern in the process of that has no impact on the overall validity of the final result."

As in the 2004–20007 project, we also use the classification of "Other Comments" to include remarks that do not rise to the level of either a finding or concern, including observations relating to clarity of documentation.

[4] Arabasz,, Costantino, and Machette, op. cit. p. 4.

List of Concerns

From its review of the subject report, the Committee has no comments that rise to the level of a *Concern*.

List of Findings

F-1. Weighting of Empirical vs. Stochastic V/H Ratios. In Section 3.1.1 (page 3-4, paragraph 3), it is stated that the stochastically computed V/H ratios are conservative and this conservatism is appropriate to use for engineering design. Figure 11 appears to indicate that the amount of conservatism between stochastic and empirical is very large, particularly at mid-frequency ranges between 1 and 10 Hz. Since the vertical motions are so important from a structural design perspective, particularly for the CMRR facility with its large open bays, the issue of whether this conservatism is excessive should be considered. Whether the weighting of 0.5 of empirical to stochastic is appropriate is not discussed anywhere. [It should be noted that the Nuclear Regulatory Commission has accepted empirical V/H ratios for new facility designs.] The report (and resulting vertical spectra) should address this sensitivity to weighting between empirical and stochastic approaches.

F-2. Non-Use of Idriss NGA Model. At Workshop #1 the Committee agreed that recomputing hazard at LANL using the NGA models was justified and desirable. In the subject report, Wong and Silva used only four of the five published NGA models, excluding that of Idriss (2008).[5] No mention is made of why the latter model was not used—despite the Committee's recommendation after reading the March 2009 draft report[6] that justification for excluding the Idriss model should be documented.[7]

The SSHAC guidelines require the proper representation of "the center, body, and *range*" (emphasis added) of technical interpretations among the informed technical community. Excluding the Idriss model may be justifiable if the other four NGA models adequately represent the center, body, and range of the distribution—but not, however, if the authors simply favor the other models.

F-3. Approach Used to Select Value of Epistemic Uncertainty for NGA Models. The Committee wrote the following in its report on Workshop #1:

> In order to resolve what value or values should be used for sigma in recomputing hazard at LANL, the following approach was agreed upon at the workshop: Ivan Wong, as TI, will consult with Walt Silva, Bob Youngs, Norm Abrahamson, and Ken Campbell—all knowledgeable experts on the matter—and report the outcome to the project team and the Committee.[8]

Section 2.2 on *Epistemic Uncertainty Added to NGA Models* is well-described and contains details on how a USGS review panel approached the same problem, together with a well-reasoned approach recommended by Bob Youngs. In the subject report (p. 2-3), Wong and Silva chose to add epistemic uncertainty of 0.25 (ln) to the NGA models, and they note that "sensitivity analyses show that the mean hazard up to a return period of 100,000 years is not very sensitive to the amount of additional epistemic uncertainty." For this review, we accept the latter claim and expect that the authors will be prepared to substantiate it at the next

[5] Idriss, I. M., 2008, An NGA empirical model for estimating the horizontal spectral values generated by shallow crustal earthquakes: Earthquake Spectra, v. 24, p. 217–242.

[6] Wong, I., Silva, W., and Costantino, C. J., 2009, Re-examination of the vertical probabilistic hazard at Los Alamos National Laboratory: technical report prepared for LANL, March 16, 2009.

[7] Arabasz, Costantino, and Machette, op. cit. p. 5.

[8] Ibid.

Confirmatory Studies workshop. We also note that the approach taken to select the appropriate value or values for epistemic uncertainty for use with the NGA models was not what was agreed to at Workshop #1 (see above).

Other Comments

O-1. In Section 3.1 (page 3-2, first paragraph), the report indicates that multiple base-case models (profiles, modulus reduction and damping, equivalent-linear versus nonlinear models, and so on) were used in these calculations. Of these parameters, only the base-case shear-wave velocity profiles (Base Case A and B) are indicated in the report. We can find no description of different base-case modulus reduction and damping or linear-versus-nonlinear models that were used in the calculations.

O-2. Also in Section 3.1 (page 3-2, first paragraph), the statement is made that weights were assigned to each hazard curve "which reflected judgment regarding the relative appropriateness of *in-situ* conditions." It is unclear what this statement means.

O-3. Section 3.1.1.1 indicates that laboratory modulus degradation and damping curves were adjusted for field-versus-laboratory to try to account for potential sample disturbance effects, and so on. The curves should be plotted in this report, indication should be made of which soil layers were included in this characterization, and the potential impact of this adjustment on the computed response should be provided. By comparing Figures 9a and 9c, for example, it appears that this adjustment has negligible effects on computed response. If so, this should be stated.

O-4. On page 3-5 (first paragraph), a short description of layer correlations used in the randomization process is provided. It appears that this model is the same as the one developed from the deep soil site at the Savannah River Site. If so, its appropriateness for application to the LANL site needs to be provided.

O-5. Figures 19a–19h indicate that the strain iteration was artificially cut off at 500 ft and that material damping below was assumed to be zero. The soil-structure interaction calculations require iterated profile data (P- and S-wave velocity and damping) to depths of 700 ft (or top of dacite). Recommendations for profile data below 500 ft should be provided.

Please contact us if you wish to discuss any of our comments or observations.

For the Committee,

Walter J. Arabasz, Chair
Tel: 801-581-7410
arabasz@seis.utah.edu

Copy:
Carl J. Costantino
Michael N. Machette

Attachment (cover and Table of Contents of subject report)

APPENDIX

Acronyms and Abbreviations

CMRR	Chemistry and Metallurgical Research Replacement [Facility]
Confirmatory Studies	Confirmatory Studies of the 2007 Update of the Los Alamos National Laboratory Probabilistic Seismic Hazard Assessment
DOE	Department of Energy
LANL	Los Alamos National Laboratory
LANS	Los Alamos National Security, LLC
NGA	Next Generation Attenuation [Relationships]
PSHA	Probabilistic Seismic Hazard Assessment
SSHAC	Senior Seismic Hazard Analysis Committee
UPSHA	Update to Probabilistic Seismic Hazard Assessment
URS Corp	URS Corporation
USGS	U.S. Geological Survey

DRAFT

UPDATE OF THE SEISMIC DESIGN GROUND MOTIONS FOR THE CMRR FACILITY LOS ALAMOS NATIONAL LABORATORY

Prepared for

LOS ALAMOS NATIONAL LABORATORY

Prepared by

Ivan Wong
URS Corporation
Seismic Hazards Group
1333 Broadway, Suite 800
Oakland, CA 94612

Walter Silva
Pacific Engineering and Analysis
856 Seaview Drive
El Cerrito, CA 94530

22 May 2009

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RESPONSES TO COMMENTS

Confirmatory Studies Steering Committee

Review Dated 5 June 2009

Prepared by
Walter Silva and Ivan Wong

17 June 2009

Comment

F-1. Weighting of Empirical vs. Stochastic V/H Ratios. In Section 3.1.1 (page 3-4, paragraph 3), it is stated that the stochastically computed V/H ratios are conservative and this conservatism is appropriate to use for engineering design. Figure 11 appears to indicate that the amount of conservatism between stochastic and empirical is very large, particularly at mid-frequency ranges between 1 and 10 Hz. Since the vertical motions are so important from a structural design perspective, particularly for the CMRR facility with its large open bays, the issue of whether this conservatism is excessive should be considered. Whether the weighting of 0.5 of empirical to stochastic is appropriate is not discussed anywhere. [It should be noted that the Nuclear Regulatory Commission has accepted empirical V/H ratios for new facility designs.] The report (and resulting vertical spectra) should address this sensitivity to weighting between empirical and stochastic approaches.

Response

In Section 3.1.1 (page 3-4, paragraph 3), with regard to conservatism in the site-specific V/H ratios, the statement reads "*An indirect validation was also performed by comparing V/H ratios from Western North America (WNA) empirical attenuation relations with model predictions over a wide range in loading conditions (Silva, 1997). The results showed a favorable comparison with the model exceeding the empirical V/H ratios at high-frequency, particularly at soil sites and at high loading levels. For engineering design applications, this reflects a conservative and therefore acceptable bias.*" The conservatism referred to is at "high-frequency" and was intended to refer to about 10 Hz and above, based on Figure 55 in the referenced document (Silva, 1997).

At intermediate frequency, say 5 Hz, Figure 55 shows the model exceeding the empirical (Abrahamson and Silva [1997] herein referred to as AS) V/H ratio by about 15% at the two closest distances. This is within the epistemic variability of empirical deep firm soil V/H ratios between Campbell and Bozorgnia (2003) and Abrahamson and Silva (1997) shown in Figure 54a and 54b. As such, the modeling approach to computing V/H ratios does not at all appear to be excessively conservative at intermediate frequencies. Even at high-frequency, Figure 55 (Silva, 1997) shows the model V/H ratios exceed the empirical AS by about 20% to 25% which, in the context of strong ground motions and in particular at high loading levels, is generally considered an acceptable model.

Considering Figure 11 (now Figure 55) and the "very large" conservatism at frequencies between 1 Hz and 10 Hz. It is important to recall the largest site-specific V/H ratio, which exceeds the empirical V/H ratio in Figure 55 by more than about a factor of 2 and is about equal to the empirical V/H AS ratio near 10 Hz, reflects the initial conservative selection of V/H ratios used in the 2007 analyses (Wong *et al*., 2007) as is discussed on page 3-7. Additionally, this

V/H ratio is used only at AEF 10^{5} and below (page 3-7), where the horizontal peak acceleration is over 2g. At higher AEF, the lower site-specific V/H ratio was used in the 2007 analyses, which exceeds the empirical AS by about 25% from about 1 Hz to about 5 Hz and is below the empirical from about 6 Hz to about 20 Hz, the critical frequency range for the vertical response of the CMRR facility.

The conservatism in the selection of the magnitudes and distances in both the site-specific and empirical V/H ratios in the 2007 hazard analyses (Wong *et al*., 2007) was purposeful. It reflected a reasonable approach to accommodating the large uncertainty that exists in developing vertical site-specific design motions at close distances and high loading levels. Figure 57 illustrates this uncertainty in showing the difference in the two available empirical V/H ratios at large magnitude and close distances. At frequencies between about 1 Hz and 30 Hz the medians differ by about 30% with the Campbell and Bozorgnia (2003) V/H ratio significantly below AS, both of which were based on data available around 1997. It is important to reiterate there were virtually no recordings on the hanging wall of normal faults for magnitudes greater than about **M** 6 at distances within 10 km. As a result, for this source and site location, the epistemic uncertainty of V/H ratios for deep firm soil is likely quite large. While the site-specific V/H ratios exceed the empirical generic deep firm soil V/H ratios, there is no compelling reason to consider the site-specific V/H ratios as overly conservative. Indeed the differences in the profiles between CMRR and WNA generic deep firm soil (Figure 50) suggests that at intermediate- and high-frequency the site-specific V/H ratio should exceed the empirical generic soil V/H ratios due to greater nonlinear effects in the CMRR horizontal component, resulting in a larger V/H ratio, conditional on linearity in both the empirical and site-specific vertical motions.

Regarding the comment of the NRC acceptance of empirical V/H ratios for new facilities, I am not aware of any NRC licensing activity with hazard similar to Los Alamos, with the site located on the hanging wall and within 5 km of an active **M** 6.5+ source and with 10^{4} horizontal peak acceleration of about 1g. This far exceeds the maximum horizontal peak acceleration of about 0.5g in the empirical V/H ratios. I suspect (hopeful) the NRC would closely examine empirical V/H ratio at 0.5g applied at 1.0g and above (recall for the DRS at 10^{4} the UHRS is required at 10^{5} which is at about 2g for CMRR). Also as far as I am aware the NRC has also accepted inclusion of site-specific V/H ratios with a 50% weight.

Regarding the sensitivity of the vertical hazard to the empirical and site-specific V/H ratios, this was addressed in the 16 March 2009 report "Re-examination of the Vertical Probabilistic Hazard at the Los Alamos National Laboratory" (Wong *et al*., 2009). In this report, Figure 2-5 show the vertical UHS computed with the combined empirical and site-specific V/H ratios, the site-specific V/H ratios, the empirical AS V/H ratios, and the empirical Campbell and Bozorgnia (2004) V/H ratios with all comparisons at AEF 10^{3}, 4×10^{4}, 10^{4}, 4×10^{5}, and 10^{5} for the 2007 hazard analyses (Wong *et al*., 2007). The comparisons illustrate that for frequencies beyond about 7 Hz, the vertical UHS computed with the site-specific V/H ratios is lower than the empirical V/H ratios. Between about 1 Hz and 7 Hz the vertical UHS computed using the site-specific V/H ratios exceeds the empirical by about 30% to as much as about 50%. It is not known what the corresponding differences are for the hazard update, which reduced the purposeful conservatism in the 2007 hazard analyses (Wong *et al*., 2007) with a much denser selection and implementation of magnitudes and distances in the V/H ratios (Figures 58 and 59, Table 6). This comparison could be implemented in the current report.

Comment

F-2. Non-Use of Idriss NGA Model. At Workshop #1 the Committee agreed that recomputing hazard at LANL using the NGA models was justified and desirable. In the subject report, Wong and Silva used only four of the five published NGA models, excluding that of Idriss (2008). No mention is made of why the latter model was not used—despite the Committee's recommendation after reading the March 2009 draft report that justification for excluding the Idriss model should be documented.

The SSHAC guidelines require the proper representation of "the center, body, and range" (emphasis added) of technical interpretations among the informed technical community. Excluding the Idriss model may be justifiable if the other four NGA models adequately represent the center, body, and range of the distribution—but not, however, if the authors simply favor the other models.

Response

An explanation of why the Idriss (2008) model was not used has been inserted into the report.

Comment

F-3. Approach Used to Select Value of Epistemic Uncertainty for NGA Models. The Committee wrote the following in its report on Workshop #1:

> *In order to resolve what value or values should be used for sigma in recomputing hazard at LANL, the following approach was agreed upon at the workshop: Ivan Wong, as TI, will consult with Walt Silva, Bob Youngs, Norm Abrahamson, and Ken Campbell—all knowledgeable experts on the matter—and report the outcome to the project team and the Committee.*

Section 2.2 on Epistemic Uncertainty Added to NGA Models is well-described and contains details on how a USGS review panel approached the same problem, together with a well-reasoned approach recommended by Bob Youngs. In the subject report (p. 2-3), Wong and Silva chose to add epistemic uncertainty of 0.25 (ln) to the NGA models, and they note that "sensitivity analyses show that the mean hazard up to a return period of 100,000 years is not very sensitive to the amount of additional epistemic uncertainty." For this review, we accept the latter claim and expect that the authors will be prepared to substantiate it at the next Peer Review of Update of the Seismic Design Ground Motions for the CMRR Facility June 5, 2009.

Confirmatory Studies workshop. We also note that the approach taken to select the appropriate value or values for epistemic uncertainty for use with the NGA models was not what was agreed to at Workshop #1 (see above).

Response

A reference to Wong *et al*. (2009), which shows the hazard sensitivity to additional epistemic uncertainty, has been added to the report. In selecting the amount of the additional epistemic uncertainty, the TI consulted with Walt Silva, Norm Abrahamson, and Bob Youngs. The TI is aware of Ken Campbell's position based on communications on another project.

Comment

O-1. In Section 3.1 (page 3-2, first paragraph), the report indicates that multiple base-case models (profiles, modulus reduction and damping, equivalent-linear versus nonlinear models, and so on) were used in these calculations. Of these parameters, only the base-case shear-wave velocity profiles (Base Case A and B) are indicated in the report. We can find no description of different base-case modulus reduction and damping or linear-versus-nonlinear models that were used in the calculations.

Response

We were originally instructed to refer to the 2007 report (Wong *et al*., 2007) for redundant material. Whether or not this report should be a stand-alone report needs to be resolved.

Comment

O-2. Also in Section 3.1 (page 3-2, first paragraph), the statement is made that weights were assigned to each hazard curve "which reflected judgment regarding the relative appropriateness of in-situ conditions." It is unclear what this statement means.

Response

The text in quotation can be replaced by "The relative weights reflect our judgment of how well each model reflects in-situ material behavior."

Comment

O-3. Section 3.1.1.1 indicates that laboratory modulus degradation and damping curves were adjusted for field-versus-laboratory to try to account for potential sample disturbance effects, and so on. The curves should be plotted in this report, indication should be made of which soil layers were included in this characterization, and the potential impact of this adjustment on the computed response should be provided. By comparing Figures 9a and 9c, for example, it appears that this adjustment has negligible effects on computed response. If so, this should be stated.

Response

Same as O-1.

Comment

O-4. On page 3-5 (first paragraph), a short description of layer correlations used in the randomization process is provided. It appears that this model is the same as the one developed from the deep soil site at the Savannah River Site. If so, its appropriateness for application to the LANL site needs to be provided.

Response

The correlation model developed from velocity data acquired at the proposed NPR facility at the Savannah River Site (SRS) was assumed to be appropriate for application to LANL. With only six velocity surveys at CMRR, four to a depth of about 150 ft and only two beyond about 500 ft deep across the CMRR site preclude any meaningful statistical analysis of velocity variability and corresponding demonstration of statistical equivalence in soil variability between CMRR and the Savannah River NPR site. For example, to compare the CMRR shear-wave velocity COV with that of the NPR requires the estimate of the standard deviation based on only six samples. At the 90% confidence limit, the estimate is accurate to within only 45% of its true value. To get within 20% of its true value requires about 30 velocity surveys, at the 90% confidence limit. Data limitations unfortunately result in assumptions. However, the use of a firm soil correlation model from the SRS likely underestimates the variability over the stiffer (e.g., $V_S \geq 2{,}000$ ft/sec) portions of CMRR as velocity variability increases with overall profile stiffness (Chiou *et al*., 2008). The potentially lower variability used at CMRR is somewhat conservative as it results in less wave scattering and larger high-frequency motions than would be present with random profiles generated with larger intrinsic variability. Additionally, to accommodate the deterministic change in character over the top 150 ft across the CMRR site,

two base-case profiles, A and B (Figure 50), were developed. The assumed correlation model was applied to each base-case with the resulting hazard enveloped to produce final design motions. This approach was intended to properly accommodate the deterministic change in the shallow portion of the profile across the CMRR as epistemic variability. The enveloping process was necessitated by the desire for a single design spectrum at the site and conservatively accommodated the possibility that the SRS correlation model resulted in too much variability (too much scattering) in the low velocity regions of the CMRR profile at depths near 150 ft and 250 ft (Figure 50). If the Steering Committee feels such a discussion is warranted, it can be added to the text.

Comment

O-5. Figures 19a–19h indicate that the strain iteration was artificially cut off at 500 ft and that material damping below was assumed to be zero. The soil-structure interaction calculations require iterated profile data (P- and S-wave velocity and damping) to depths of 700 ft (or top of dacite). Recommendations for profile data below 500 ft should be provided.

Response

Appropriate small-strain damping will be added to the profiles and median and ± 1σ estimates computed. Note the profile depth to dacite was randomized between about 600 ft and 900 ft. As a result, strain-compatible properties are available only to the shallowest depth (Figure 71). Because the analysis is linear below 500 ft, the deepest velocities and dampings available may be extended to dacite at a depth of about 750 ft.

Via e-mail

Memorandum

To: Michael W. Salmon
SAFER Project Engineer, D-5
Los Alamos National Laboratory, MS K575

From: Confirmatory Studies Steering Committee:
Walter J. Arabasz
Carl J. Costantino
Michael N. Machette

Subject: Peer Review of *Update of the Seismic Design Ground Motions for the CMRR Facility, Los Alamos National Laboratory (Final Report, 14 August 2009)*

Date: August 31, 2009

Background[1]

On June 5, 2009, the Confirmatory Studies Steering Committee ("the Committee") submitted to LANL a peer review of a draft report (dated May 22, 2009) prepared by Ivan Wong of URS Corp and Walter Silva of PE&A titled, *Update of the Seismic Design Ground Motions for the CMRR Facility, Los Alamos National Laboratory* (hereafter, **"the draft report"**).

On June 17, 2009, Walter Silva and Ivan Wong remitted to LANL a document titled, *Los Alamos Review, Response to Comments* (hereafter, **"the Response to Comments"**) providing responses to review comments made by the Committee in our June 5, 2009, report.

The subject report (hereafter, **"the final report"**) was submitted to LANL on August 14, 2009, and was prepared by Ivan Wong and Mark Dober of URS Corp and by Walter Silva, Bob Darragh, and Nick Gregor of PE&A. The final report incorporates changes stemming from the Response to Comments as well as significant additional information relating to recomputed hazard, an update of horizontal and vertical design motions, and design response spectra.

Work Products Reviewed

The work products reviewed and commented on herein consist of (I) the Response to Comments and (II) the final report for the CMRR seismic design ground motions.

Methodology Used

This review falls under DOE technical and procedural guidance aimed at ensuring an independent review focusing on "the arguments and logic used to develop the hazard results" (DOE-STD-1023-95, Sec. 3.1.2.3). The comments provided here result from a "participatory peer review," that is, an ongoing review in which the reviewers have had full and frequent access to the project and have had ongoing interactions with the study team—consistent with recommendations of the Senior Seismic Hazard Analysis Committee (SSHAC, NUREG/CR-6372).

[1] Acronyms and abbreviations are explained in the Appendix.

The methodology primarily relied on for this review was the standard one of careful scrutiny of assumptions, data, interpretations, and conclusions vis-à-vis the reviewers' (1) technical knowledge of the content, both site-specific and general, (2) familiarity with the relevant technical literature, and (3) understanding of valid PSHA procedures

Terminology

We use the same comment-and-finding format for this review as previously used for the 2004–2007 UPSHA project and in our June 2009 peer review of the draft report. The following definitions were given to the peer review committee in a memorandum from Michael Salmon dated May 19, 2005:

Concern: "A concern is defined as a point of concern in the process that, if not corrected, has a direct impact on the conclusions in the final work product (the design basis ground motion for LANL)."

Finding: "For the purpose of this peer review a finding is defined as a point of concern in the process that has no impact on the overall validity of the final result."

As in the 2004–20007 project, we also use the classification of "Other Comments" to include remarks that do not rise to the level of either a finding or concern; these include observations relating to clarity of documentation.

I. Review of Silva and Wong's Response to Comments

F-1. Weighting of empirical vs. stochastic V/H ratios. In the response to our Comment F-1, a detailed description of the estimated degree of conservatism is provided for the stochastically computed V/H ratios, together with the sensitivities of these values to various structural frequency ranges of interest. From preliminary structural evaluations of the CMRR facility, we now know that the structures are extremely sensitive to vertical motions, particularly at the higher frequencies near and around the peak of the DRS, and that the seismic input motions being used for the design are large compared to values we typically use for facility designs. The description provided in this response presents a clearer understanding of the adequacy of the stochastic modeling and should be presented in this updated report, irrespective of whether the update is intended to be a stand-alone document or not. We recommend that the URS/PE&A comment about the NRC in their response be removed from this description since it does not agree with the current NRC Staff Guidance documents.

F-2. Non-use of Idress NGA model. An explanation of why the Idriss NGA model was not used was inserted into the final report and is satisfactory. Comment closed.

F-3. Approach used to select value of epistemic uncertainty for NGA models. The explanation offered by the TI (Ivan Wong) regarding how a value of epistemic uncertainty (sigma μ) for the NGA models was evaluated, vis-à-vis a SSHAC process, is satisfactory. We note that the process involved the TI consulting with informed experts and then apparently making an independent evaluation. The value of 0.25 (ln) adopted for epistemic uncertainty associated with the NGA models is admitted to be "somewhat conservative" and possibly "too conservative" (final report, p. 2-3). However, the authors of the final report justify this value based on precedence—namely, its use by the USGS for the magnitude and distance bin of interest to the LANL study—and because of larger uncertainty (due to limited data) expected for sites in the hanging wall of normal faults. Further, the argument is made that "sensitivity analyses show that the mean hazard up to a return period of 100,000 years is not very sensitive to the amount of additional epistemic uncertainty (Figures 3-23 to 3-27 in Wong *et al.*, 2009)" (final report, p. 2-3). We accept the validity of the latter argument—at least based on evidence for the relative insensitivity of hazard at the CMRR site for sigma μ = 0.25 vs. 0.40 as presented in the cited document. Comment closed.

O-1. Lack of description of different base-case modulus reduction and damping or linear-versus-nonlinear models used in calculations. The response to our comment stated, "We were originally instructed to refer to the 2007 report (Wong *et al*., 2007) for redundant material. Whether or not this report should be a stand-alone report needs to be resolved." The Committee understands this position. Rather than placing the burden on the reader to go back to the voluminous 2007 report to seek clarification on some issues, we believe that providing small additions to this revised *Update* report—such as recommended in our original Comment O-1—will help the reader better understand the updated procedures and results.

O-2. Unclear statement regarding weighting of hazard curves based on judgment and in-situ conditions. The revised wording is satisfactory. Comment closed.

O-3. Procedure used to adjust laboratory modulus degradation and damping curves for field-versus-laboratory. Silva and Wong's response was, "Same as O-1." See our reply to their O-1 response above.

O-4. Appropriateness of applying Savannah River model to LANL. In Section 3.1.1.1 (first paragraph under the title "Site Aleatory Variability), the same description of the correlation model used in the CMRR site-response calculations is provided as in the draft report. That model was based on extensive CPT velocity data taken at the Savannah River Site. It is our opinion that the final report should clearly indicate what correlation model was used in these current calculations. In addition, it is not obvious that the model, based on data from a site with no significant layer variability and with relatively uniform increase in velocity with depth, is appropriate for application to a site where there are distinct layers of tuffs, formed at different geologic times by different processes, and apparent significant velocity variability. The final report should provide plots of the individual velocity realizations and comparisons made to the base case models to ensure that the profile randomizations are appropriate for the site data available.

O-5. Recommendation that profile data below 500 ft be provided for strain iteration. Silva and Wong's response to this comment is satisfactory. Comment closed.

II. Review of Final Report for the CMRR Seismic Design Ground Motions[2]

List of Concerns

C-1. Assurance that hazard computations and other computations underpinning the seismic design ground motions are error-free. In section 2.3 (p. 2-4, para. 4), the report states that, "The site-specific hazard was recomputed because of an error in the 2007 study where the distance metric for the stochastic models was mistakenly considered to be rupture distance rather than the Joyner-Boore distance." This reported error, which resulted in a "difference in hazard [of] 12% at a return period of 10,000 years" is clearly disconcerting. Further, it is our understanding that the use of NGA models requires a much more difficult calculation for the distance metric than for previous models. We assume that URS/PE&A will provide assurance to LANL that the new algorithms have properly met QA requirements. A statement to that effect should be added in this paragraph in the final report.

List of Findings

F-4. Procedure used to obtain parameter values from randomizations. In Section 3.1.1.1 (third paragraph under the title "Site Aleatory Variability) of the final report, the description provided

[2] The numbering of concerns, findings, and other comments continues the sequence beginning in our peer-review report of June 5, 2009.

indicates that the procedure used to obtain P-wave velocities for the individual vertical profile realizations uses the base-case values of Poisson's ratio together with the individual realizations for S-wave velocities, presumably for each layer in the profile randomizations. This description is the same as provided in the draft report. In reviewing the best-estimate (BE), upper-bound (UB), and lower-bound (LB) profile data provided in the May 2009 calculations (i.e., in the draft report), it was noted that BE, UB, and LB values along with sigma estimates were provided for Poisson's ratio together with the corresponding V_S and V_P data. In addition, the BE, UB, and LB V_P data were not apparently related to the corresponding V_S data; that is, the V_P values could not be directly calculated from the V_S and Poisson's ratio data. Similarly, the data for unit weights provided in the same data file also indicated BE, UB, LB, and sigma values which were significantly different and indicated a range of variability that does not seem to be appropriate for typical geologic materials. The project needs to provide an explanation of these data and how they were developed from the randomizations since their use can impact the deterministic calculations being used for the SSI evaluations.

F-5. DRS for dacite and topographic effects. In Section 3.4, it is noted that the DRS provided for dacite include topographic effects. If this is true, this effect is inappropriate since the purpose of the dacite DRS is for use at other LANL sites where such topographic effects may not be appropriate.

Other Comments

O-6. Misstatement in text. In section 2.3 (p. 2-4, para. 3) the text states, "At a mean return period of 2,500 years, the maximum difference [between pre-NGA and NGA spectra] is nearly 50% at a spectral period of 0.2 sec (Figure 24)." The plotted Uniform Hazard Spectra on Figure 24 for a 2,500-yr return period appear to indicate a difference of 20% at 0.2 sec with a maximum decrease of about 25% at 0.3 sec.

O-7. Recommendation #4 to evaluate the impact of an alternative kappa value of 0.08 sec. This recommendation refers to a kappa value of 0.08 sec "that was established from the LANL seismic data but not used because of time and budget constraints (Wong *et al.*, 2007)." We do not agree that the value of 0.08 sec was convincingly "established" (see Committee report dated April 6, 2009)[3]. However, revisiting the issue to explore epistemic uncertainty in kappa is a logical consideration.

O-8. Clarification of terms. The final report refers to corrected and uncorrected curves as well as adjusted and unadjusted curves, but definitions of these terms are not included in the Update. We assume that the adjusted/unadjusted curves refer to field/laboratory velocity comparisons. It would be helpful in this updated report to explain these terms.

O-9. "Multiple realizations." In Section 3.1.1.1 (first paragraph under the title "Site Aleatory Variability), it is indicated that multiple realizations were used for the dynamic material properties to accommodate random fluctuations in measured data. The report should indicate how many were actually used in the randomization program.

O-10. Subjective statements regarding variability. As in the draft report, statements are made that the "variability is acceptably low for engineering applications" and that "for engineering design applications, this reflects a conservative and therefore acceptable bias." We do not understand how these judgments can be made without discussing the impact of these conservatisms on structural

[3] Arabasz, W. J., Costantino, C. J., and Machette, M. N., 2009. *Committee Report on Confirmatory Studies Workshop #1.* Memorandum to M. W. Salmon, dated April 6, 2009 (see Comment No. 7, p. 5f.).

design, facility costs, etc. These subjective statements are not helpful when trying to determine adequacy of the calculations.

O-11. Missing text for Section 3.5. Section 3.5 (DRS at Multiple Damping Ratios) is blank in the version of the document provided to the Committee. Since this issue is still being evaluated by the DNFSB, along with appropriate selection of seed time histories, it is recommended that such information not be included in this report.

O-12. Procedures used to estimate horizontal and vertical hazard. Section 2.4 describes a sensitivity calculation to perform horizontal (H) and vertical (V) hazard estimates directly from available attenuation models as opposed to generating the verticals through V/H ratios. It would be helpful if a conclusion can be drawn indicating that the results are similar, providing support to the procedures used for the calculations of record.

O-13. Explanation of SDC. For clarity, we suggest that "SDC" (Seismic Design Category) be briefly explained when used for the first time (last paragraph on p. 3-9 in section 3.2).

Please contact us if you wish to discuss any of our comments or observations.

For the Committee,

Walter J. Arabasz, Chair
Tel: 801-581-7410
arabasz@seis.utah.edu

Copy:
Carl J. Costantino
Michael N. Machette

APPENDIX

Acronyms and Abbreviations

CMRR	Chemistry and Metallurgical Research Replacement [Facility]
Confirmatory Studies	Confirmatory Studies of the 2007 Update of the Los Alamos National Laboratory Probabilistic Seismic Hazard Assessment
CPT	Cone Penetration Test
DOE	Department of Energy
DNFSB	Defense Nuclear Facilities Safety Board
DRS	Design Response Spectrum
LANL	Los Alamos National Laboratory
NGA	Next Generation Attenuation [Relationships]
NRC	Nuclear Regulatory Commission
PE&A	Pacific Engineering and Analysis
PSHA	Probabilistic Seismic Hazard Assessment
QA	Quality Assurance
SDC	Seismic Design Category
SSHAC	Senior Seismic Hazard Analysis Committee
SSI	Soil-Structure Interaction
URS Corp	URS Corporation
USGS	U.S. Geological Survey

RESPONSES TO COMMENTS

Confirmatory Studies Steering Committee

Review Dated 31 August 2009

Prepared by
Walter Silva and Ivan Wong

17 September 2009

Comment

F-1. Weighting of empirical vs. stochastic V/H ratios. In the response to our Comment F-1, a detailed description of the estimated degree of conservatism is provided for the stochastically computed V/H ratios, together with the sensitivities of these values to various structural frequency ranges of interest. From preliminary structural evaluations of the CMRR facility, we now know that the structures are extremely sensitive to vertical motions, particularly at the higher frequencies near and around the peak of the DRS, and that the seismic input motions being used for the design are large compared to values we typically use for facility designs. The description provided in this response presents a clearer understanding of the adequacy of the stochastic modeling and should be presented in this updated report, irrespective of whether the update is intended to be a stand-alone document or not. We recommend that the URS/PE&A comment about the NRC in their response be removed from this description since it does not agree with the current NRC Staff Guidance documents.

Response

The last sentence of the fifth paragraph of the original review responses dated June 16, 2009 which referenced the NRC has been revised and a statement regarding current NRC guidance regarding V/H ratios added. The original review comment (*F-1*) and updated response is reproduced here.

In addition we agree with the review statement that the "seismic input motions being used for the design are large compared to values we typically use for facility design". We do believe however this is due to the hazard environment, proximity to an active source, and to a minor extent the inclusion of topographic effects rather than conservatism explicitly incorporated in the updated analysis. The purposeful explicit conservatism incorporated in developing the 2007 vertical analyses has been removed and it is believed the current vertical design motions appropriately reflect the very large uncertainty in developing vertical design motions at very close rupture distances on the hanging wall of large magnitude earthquakes, for which very few recordings exist.

Also we have added some text on p3-7 to further point out the restricted (AEF 10^{5} and below) use of the largest model V/H ratio in the 2007 analysis and therefore its minimal impact on vertical design motions and on p3-4 the "conservatism" at high-frequency in the referred to model validation was quantified by adding the model exceeded the empirical by about "20% to 25%".

Original Comment and Response

F-1. Weighting of Empirical vs. Stochastic V/H Ratios. In Section 3.1.1 (page 3-4, paragraph 3), it is stated that the stochastically computed V/H ratios are conservative and this conservatism is appropriate to use for engineering design. Figure 11 appears to indicate that the amount of conservatism between stochastic and empirical is very large, particularly at mid-frequency ranges between 1 and 10 Hz. Since the vertical motions are so important from a structural design perspective, particularly for the CMRR facility with its large open bays, the issue of whether this conservatism is excessive should be considered. Whether the weighting of 0.5 of empirical to stochastic is appropriate is not discussed anywhere. [It should be noted that the Nuclear Regulatory Commission has accepted empirical V/H ratios for new facility designs.] The report (and resulting vertical spectra) should address this sensitivity to weighting between empirical and stochastic approaches.

Response

In Section 3.1.1 (page 3-4, paragraph 3), with regard to conservatism in the site-specific V/H ratios, the statement reads "*An indirect validation was also performed by comparing V/H ratios from Western North America (WNA) empirical attenuation relations with model predictions over a wide range in loading conditions (Silva, 1997). The results showed a favorable comparison with the model exceeding the empirical V/H ratios at high-frequency, particularly at soil sites and at high loading levels. For engineering design applications, this reflects a conservative and therefore acceptable bias.*" The conservatism referred to is at "high-frequency" and was intended to refer to about 10 Hz and above, based on Figure 55 in the referenced document (Silva, 1997).

At intermediate frequency, say 5 Hz, Figure 55 shows the model exceeding the empirical (Abrahamson and Silva, 1997 herein referred to as AS) V/H ratio by about 15% at the two closest distances. This is within the epistemic variability of empirical deep firm soil V/H ratios between Campbell and Bozorgnia, 2003 and Abrahamson and Silva, 1997 shown in Figure 54a and 54b. As such the modeling approach to computing V/H ratios does not at all appear to be excessively conservative at intermediate frequencies. Even at high-frequency, Figure 55 (Silva, 1997) shows the model V/H ratios exceed the empirical AS by about 20% to 25% which, in the context of strong ground motions and in particular at high loading levels, is generally considered an acceptable model.

Considering Figure 11 (now Figure 55) and the "very large" conservatism at frequencies between 1 Hz and 10 Hz. It is important to recall the largest site-specific V/H ratio, which exceeds the empirical V/H ratio in Figure 55 by more than about a factor of 2 and is about equal to the empirical V/H AS ratio near 10 Hz, reflects the initial conservative selection of V/H ratios used in the 2007 analyses (Wong et al., 2007) and is discussed on page 3-7. Additionally, this V/H ratio is used only at AEF 10^{5} and below (page 3-7), where the horizontal peak acceleration is over 2g. At higher AEF, the lower site-specific V/H ratio was used in the 2007 analyses, which exceeds the empirical AS by about 25% from about 1 Hz to about 5 Hz and is below the empirical from about 6 Hz to about 20 Hz, the critical frequency range for the vertical response of the CMRR facility.

The conservatism in the selection of the magnitudes and distances in both the site-specific and empirical V/H ratios in the 2007 hazard analyses (Wong et al., 2007) was purposeful. It reflected a reasonable approach to accommodating the large uncertainty that exists in developing vertical site-specific design motions at close distances and high loading levels.

Figure 57 illustrates this uncertainty in showing the difference in the two available empirical V/H ratios at large magnitude and close distances. At frequencies between about 1 Hz and 30 Hz the medians differ by about 30% with the Campbell and Bozorgnia (2003) V/H ratio significantly below AS, both of which were based on data available around 1997. It is important to reiterate there were virtually no recordings on the hanging wall of normal faults for magnitudes greater than about **M** 6 at distances within 10 km. As a result, for this source and site location, the epistemic uncertainty of V/H ratios for deep firm soil is likely quite large. While the site-specific V/H ratios exceed the empirical generic deep firm soil V/H ratios, there is no compelling reason to consider the site-specific V/H ratios are overly conservative. Indeed the differences in the profiles between CMRR and WNA generic deep firm soil (Figure 50) suggests that at intermediate- and high-frequency the site-specific V/H ratio should exceed the empirical generic soil V/H ratios due to greater nonlinear effects in the CMRR horizontal component, resulting in a larger V/H ratio, conditional on linearity in both the empirical and site-specific vertical motions.

Regarding the comment of the NRC acceptance of empirical V/H ratios for new facilities, I am not aware of any NRC licensing activity with hazard similar to Los Alamos, with the site located on the hanging wall and within 5 km of an active **M** 6.5+ source and with 10^{4} horizontal peak acceleration of about 1g. This far exceeds the maximum horizontal peak acceleration of about 0.5g in the empirical V/H ratios. I suspect (hopeful) the NRC would closely examine empirical V/H ratio at 0.5g applied at 1.0g and above (recall for the DRS at 10^{4} the UHRS is required at 10^{5} which is at about 2g for CMRR). Also as far as I am aware the NRC has also accepted inclusion of site-specific V/H ratios along with empirical V/H ratios. The NRC staff guidance states that "appropriate" V/H ratios should be used in developing vertical design spectra, permitting the use of V/H ratios the applicant considers and demonstrates most effectively captures the potential effects of site-specific dynamic material properties, the hazard environment (proximity and magnitude of dominant sources), and the uncertainty in developing vertical hazard. It may also be worth noting that the hard rock V/H ratios developed in NUREG/CR-6728 for CENA were largely model driven and accepted by the NRC provided the applicant demonstrates the site reflects hard rock conditions.

Regarding the sensitivity of the vertical hazard to the empirical and site-specific V/H ratios, this was addressed in the 16 January 2009 report "Development of Vertical UHRS For the CMRR Site at The Los Alamos National Laboratory". In this report Figure 2-5 shows the vertical UHS computed with the combined empirical and site-specific V/H ratios, the site-specific V/H ratios, the empirical AS V/H ratios, and the empirical Campbell and Bozorgnia (2004) V/H ratios with all comparisons at AEF 10^{3}, 4×10^{4}, 10^{4}, 4×10^{5}, and 10^{5} for the 2007 hazard analyses (Wong et al., 2007). The comparisons illustrate that for frequencies beyond about 7 Hz, the vertical UHS computed with the site-specific V/H ratios is lower than the empirical V/H ratios. Between about 1 Hz and 7 Hz the vertical UHS computed using the site-specific V/H ratios exceeds the empirical by about 30% to as much as about 50%. It is not known what the corresponding differences are for the hazard update, which reduced the purposeful conservatism in the 2007 hazard analyses (Wong et al., 2007) with a much denser selection and implementation of magnitudes and distances in the V/H ratios (Figures 58 and 59, Table 6). This comparison could be implemented in the current report.

Comments

O-1. Lack of description of different base-case modulus reduction and damping or linear-versus nonlinear models used in calculations. The response to our comment stated, "We were originally

instructed to refer to the 2007 report (Wong et al., 2007) for redundant material. Whether or not this report should be a stand-alone report needs to be resolved." The Committee understands this position. Rather than placing the burden on the reader to go back to the voluminous 2007 report to seek clarification on some issues, we believe that providing small additions to this revised Update report— such as recommended in our original Comment O-1—will help the reader better understand the updated procedures and results.

O-3. Procedure used to adjust laboratory modulus degradation and damping curves for field- versus laboratory. Silva and Wong's response was, "Same as O-1." See our reply to their O-1 response above.

Response

At this time the Los Alamos project management does not wish to have the Update Report of August 14, 2009 as a stand-alone document. Under consideration is an appropriate expansion of the Update Report to include all relevant material as recommended or including the update as an Appendix in the original 2007 report.

Comment

O-4. Appropriateness of applying Savannah River model to LANL. In Section 3.1.1.1 (first paragraph under the title "Site Aleatory Variability), the same description of the correlation model used in the CMRR site-response calculations is provided as in the draft report. That model was based on extensive CPT velocity data taken at the Savannah River Site. It is our opinion that the final report should clearly indicate what correlation model was used in these current calculations. In addition, it is not obvious that the model, based on data from a site with no significant layer variability and with relatively uniform increase in velocity with depth, is appropriate for application to a site where there are distinct layers of tuffs, formed at different geologic times by different processes, and apparent significant velocity variability. The final report should provide plots of the individual velocity realizations and comparisons made to the base case models to ensure that the profile randomizations are appropriate for the site data available.

Response

In Section 3.1.1.1, the end of the second paragraph which states "..borings over a typical large footprint" was amended to "..borings over a large footprint (H Area at the DOE Savannah River Site, Silva et al., 1997)". Plots of median and ± 1σ profiles as well as all 30 individual profile realizations compared to the base-case have been added for CMRR profiles A and B. In reference to the added plots, the following paragraph was placed after the first paragraph in Section 3.1.1.1 following Site Aleatory Variability:

For the CMRR base cases A and B, Figure 51 and Figure 52 show the suits of 30 random profiles respectively. Figures 51 and 52 each begin with the median and ± 1σ profiles as well as the respective base-cases. Following each plot of the statistics are the random profiles with five realizations displayed per plot.

Comment

C-1. Assurance that hazard computations and other computations underpinning the seismic design ground motions are error-free. In section 2.3 (p. 2-4, para. 4), the report states that, "The site-specific hazard was recomputed because of an error in the 2007 study where the distance metric for the stochastic models was mistakenly considered to be rupture distance rather than the Joyner-Boore distance." This reported error, which resulted in a "difference in hazard [of] 12% at a return period of 10,000 years" is clearly disconcerting. Further, it is our understanding that the

use of NGA models requires a much more difficult calculation for the distance metric than for previous models. We assume that URS/PE&A will provide assurance to LANL that the new algorithms have properly met QA requirements. A statement to that effect should be added in this paragraph in the final report.

Response

Statements added to report.

Comment

F-4. Procedure used to obtain parameter values from randomizations. In Section 3.1.1.1 (third paragraph under the title "Site Aleatory Variability) of the final report, the description provided indicates that the procedure used to obtain P-wave velocities for the individual vertical profile realizations uses the base-case values of Poisson's ratio together with the individual realizations for S-wave velocities, presumably for each layer in the profile randomizations. This description is the same as provided in the draft report. In reviewing the best-estimate (BE), upper-bound (UB), and lower-bound (LB) profile data provided in the May 2009 calculations (i.e., in the draft report), it was noted that BE, UB, and LB values along with sigma estimates were provided for Poisson's ratio together with the corresponding VS and VP data. In addition, the BE, UB, and LB VP data were not apparently related to the corresponding VS data; that is, the VP values could not be directly calculated from the VS and Poisson's ratio data. Similarly, the data for unit weights provided in the same data file also indicated BE, UB, LB, and sigma values which were significantly different and indicated a range of variability that does not seem to be appropriate for typical geologic materials. The project needs to provide an explanation of these data and how they were developed from the randomizations since their use can impact the deterministic calculations being used for the SSI evaluations.

Response

In one of the codes used to develop hazard-consistent strain-compatible properties, an incorrect column of data was used to develop statistics of some of the properties. This error had not occurred previously and we have revised procedures to eliminate the possibility of the error to reoccur.

Comment

F-5. DRS for dacite and topographic effects. In Section 3.4, it is noted that the DRS provided for dacite include topographic effects. If this is true, this effect is inappropriate since the purpose of the dacite DRS is for use at other LANL sites where such topographic effects may not be appropriate.

Response

DRS and time histories for dacite without topographic effects have been added.

Comment

O-6. Misstatement in text. In section 2.3 (p. 2-4, para. 3) the text states, "At a mean return period of 2,500 years, the maximum difference [between pre-NGA and NGA spectra] is nearly 50% at a spectral period of 0.2 sec (Figure 24)." The plotted Uniform Hazard Spectra on Figure 24 for a 2,500-yr return period appear to indicate a difference of 20% at 0.2 sec with a maximum decrease of about 25% at 0.3 sec.

Response

Statement corrected in report.

Comment

O-7. Recommendation #4 to evaluate the impact of an alternative kappa value of 0.08 sec. This recommendation refers to a kappa value of 0.08 sec "that was established from the LANL seismic data but not used because of time and budget constraints (Wong et al., 2007)." We do not agree that the value of 0.08 sec was convincingly "established" (see Committee report dated April 6, 2009). However, revisiting the issue to explore epistemic uncertainty in kappa is a logical consideration.

Response

Statement corrected in report.

Comment

O-8. Clarification of terms. The final report refers to corrected and uncorrected curves as well as adjusted and unadjusted curves, but definitions of these terms are not included in the Update. We assume that the adjusted/unadjusted curves refer to field/laboratory velocity comparisons. It would be helpful in this updated report to explain these terms.

Response

The 2nd paragraph in Section 3.1.1.1 states "Additionally, in the RVT equivalent-linear analysis for the CMRR site, epistemic variability in G/Gmax and hysteretic damping curves, intended to approximately account for sample disturbance, was accommodated with two sets of curves (Wong et al., 2007). In this approach, the ratio of the small-strain laboratory VS computed at the approximate in-situ confining stress to that measured in the field was used to adjust the curves derived from the RCTS (resonant column torsional shear) laboratory tests. The curve adjustment or correction involved applying the velocity ratio to the reference strain which, for ratios less than 1, results in a set of more linear modulus reduction and lower damping curves (Wong et al., 2007)."

In the text the word "adjustment" was amended to "adjustment or correction".

Comment

O-9. "Multiple realizations." In Section 3.1.1.1 (first paragraph under the title "Site Aleatory Variability), it is indicated that multiple realizations were used for the dynamic material properties to accommodate random fluctuations in measured data. The report should indicate how many were actually used in the randomization program.

Response

In the first paragraph under Site Aleatory Variability "*multiple realizations*" was amended to "*multiple (30) realizations*".

Comment

O-10. Subjective statements regarding variability. As in the draft report, statements are made that the "variability is acceptably low for engineering applications" and that "for engineering design applications, this reflects a conservative and therefore acceptable bias." We do not understand how these judgments can be made without discussing the impact of these conservatisms on structural design, facility costs, etc. These 'subjective' statements are not helpful when trying to determine adequacy of the calculations.

Response

The statement "conservative and therefore acceptable bias" was amended to "conservative bias, likely resulting from the assumed linearity in the vertical analyses".

Comment

> *O-11. Missing text for Section 3.5. Section 3.5 (DRS at Multiple Damping Ratios) is blank in the version of the document provided to the Committee. Since this issue is still being evaluated by the DNFSB, along with appropriate selection of seed time histories, it is recommended that such information not be included in this report.*

Response

Section 3.5 text added.

Comment

> *O-12. Procedures used to estimate horizontal and vertical hazard. Section 2.4 describes a sensitivity calculation to perform horizontal (H) and vertical (V) hazard estimates directly from available attenuation models as opposed to generating the verticals through V/H ratios. It would be helpful if a conclusion can be drawn indicating that the results are similar, providing support to the procedures used for the calculations of record.*

Response

Paragraph added to text.

Comment

> *O-13. Explanation of SDC. For clarity, we suggest that "SDC" (Seismic Design Category) be briefly explained when used for the first time (last paragraph on p. 3-9 in section 3.2).*

Response

"SDC" defined in report.

Appendix B

Board's Staff Evaluation of CMRR Seismic Design Ground Motion and Response to Comments

Board's Staff Evaluation of CMRR Seismic Design Ground Motion
June 23, 2009

The Board's staff has completed its review of the Update of the Seismic Design Ground Motions for the CMRR Facility. The Board's staff has identified no significant issue regarding the development of the updated ground motions. One significant issue regarding the use of these updated ground motions to establish revised seismic Design Response Spectra (DRS) for CMRR is identified.

Significant Issue with revising CMRR seismic DRS:

- The ratio of vertical to horizontal (V/H) seismic DRS should include a lower bound floor. Currently the seismic DRS V/H ratio falls below .67 for frequencies less than about 2 Hertz, reaching values less than 0.4 for frequencies below 1 Hertz. LANL and the CMRR Project should establish a lower bound floor for the V/H ratio with respect to revising the seismic design response spectra for CMRR. While this issue does not need to be resolved prior to CMRR Certification, it needs to be addressed prior to proceeding with updated soil-structure interaction analysis.

RESPONSE: A lower bound of 0.5 was adopted. See page 3-4 of report.

The CMRR Project has advised the Board's staff that they are proceeding with assessing the feasibility of ground improvement for the non-welded Bandelier tuff unit immediately below the CMRR foundation ($Qbt3_L$ or 3-Lower). While the Board's staff appreciates the potential benefits of ground improvement, the impact on soil-structure interaction analysis has yet to be analyzed. The project is requested to provide the Board's staff with the following:

- Schedule and list of deliverables associated with assessing the feasibility of ground improvement for the 3-Lower.

- Schedule and list of deliverables associated with assessing the impact of ground improvement on seismic design ground motions. Generation of in-layer motions at the CMRR foundation elevation consistent with the revised DRS should be given high priority.

- Schedule and list of deliverables associated with assessing design basis analyses including revised slope stability, building sliding, and foundation settlements calculations.

Other ground motion topics and issues:

- The response to the Peer Review Panel (Comment O-4) discusses the soil layer-to-layer correlation model used in the Probabilistic Seismic Hazard Analysis (PSHA). While the PSHA has included two base case profiles, in part to address layer-to-layer correlation uncertainty, LANL is encouraged to improve their approach to layer-to-layer correlation. Actions to improve this correlation should be included in the LANL Long Term Seismic Program Plan.

- LANL is requested to provide a schedule for developing the LANL Long Term Seismic Program Plan.

Appendix C

At-Depth CMRR DRS and UHRS

APPENDIX C

EXPLANATION

In the tables that follow the at-depth motions were defined as:

65* ft Outcrop: outcrop motion computed at a depth in the profile of 65 ft (overlying material present) and taken as twice the upgoing waves at a depth of 65 ft within the profile.

65* ft Total: within or in-layer motion computed at a depth in the profile of 65 ft (overlying material present) and taken as the sum of the upgoing and downgoing waves at a depth of 65 ft within the profile.

65* Removed: outcrop motion computed at the surface of the CMRR column with 65 ft of material removed, sometimes referred to as a geologic outcrop.

*The same definitions apply to depths of 69 ft and 75 ft

Table C-1
CMRR Design Spectra: 65 ft Outcrop

	SDC-3		SDC-4		SDC-5	
Period (sec)	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**
0.010	0.43052	0.45249	0.69046	0.74757	1.24144	1.38432
0.020	0.43052	0.45249	0.69046	0.74757	1.24144	1.38432
0.030	0.43052	0.64126	0.69046	1.06961	1.24144	1.97891
0.050	0.56721	0.99496	0.91433	1.67968	1.58005	3.10415
0.060	0.62473	1.13926	1.00344	1.92245	1.72139	3.50245
0.075	0.71550	1.25828	1.14492	2.11851	1.90883	3.75658
0.085	0.77623	1.15252	1.24180	1.93160	2.03734	3.44542
0.100	0.85201	1.19087	1.35636	2.05283	2.21804	3.53903
0.150	0.88616	0.99821	1.42786	1.71622	2.37101	3.01332
0.200	0.77038	0.79609	1.28016	1.38699	2.23076	2.57841
0.300	0.85181	0.63530	1.40932	1.07680	2.51906	1.97535
0.400	0.78775	0.54197	1.29674	0.91039	2.42280	1.66846
0.500	0.86260	0.52548	1.44744	0.88999	2.68230	1.60668
0.750	0.79178	0.45122	1.32912	0.74466	2.50929	1.35176
1.000	0.73818	0.41688	1.21970	0.67652	2.30306	1.21715
1.500	0.54929	0.31051	0.97045	0.54191	2.01222	1.04743
2.000	0.28175	0.16220	0.54118	0.30988	1.15073	0.65119
3.000	0.15493	0.09031	0.28940	0.16854	0.63646	0.36566
5.000	0.10891	0.06330	0.20465	0.11919	0.46816	0.27283
10.000	0.02176	0.01265	0.04281	0.02464	0.10920	0.06303

Table C-2
CMRR UHRS Spectra: 65 ft Outcrop

	1,000 Yr RP		2,500 Yr RP		10,000 Yr RP		50,000 Yr RP		100,000 Yr RP	
Period (sec)	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.25396	0.25479	0.44739	0.45648	0.94266	1.01360	1.45740	1.60150	2.51840	2.83390
0.020	0.25396	0.25479	0.44739	0.45648	0.94266	1.01360	1.45740	1.60150	2.51840	2.83390
0.030	0.25396	0.35681	0.44739	0.64076	0.94266	1.45289	1.45740	2.30235	2.51840	4.04839
0.050	0.33094	0.54536	0.58645	0.98228	1.25680	2.28680	1.93480	3.63730	3.16830	6.34500
0.060	0.36428	0.62102	0.64825	1.12520	1.39990	2.62910	2.11950	4.16210	3.43270	7.12560
0.075	0.41240	0.67419	0.74524	1.24560	1.60820	2.94830	2.41390	4.58150	3.77300	7.55800
0.085	0.44849	0.61695	0.80869	1.14610	1.75840	2.70920	2.61780	4.16780	4.00280	6.92870
0.100	0.50119	0.63016	0.89198	1.15140	1.95080	2.88970	2.85230	4.49200	4.33730	7.05020
0.150	0.51471	0.53268	0.91661	0.96767	2.02550	2.42230	3.02080	3.75050	4.67040	6.02640
0.200	0.43157	0.41779	0.77268	0.76155	1.73490	1.85840	2.75030	3.05130	4.49850	5.29930
0.300	0.48166	0.34602	0.85807	0.62470	1.87880	1.44280	3.02130	2.33640	5.13320	4.04630
0.400	0.44506	0.29818	0.79757	0.53775	1.73220	1.22210	2.77290	1.96650	4.98950	3.41530
0.500	0.47642	0.28633	0.85677	0.51710	1.93860	1.21330	3.12490	1.93040	5.50900	3.26380
0.750	0.44811	0.25791	0.78612	0.45570	1.74920	1.00160	2.87010	1.59440	5.20050	2.75910
1.000	0.39710	0.22893	0.74459	0.42815	1.63390	0.92535	2.61310	1.43630	4.75210	2.46840
1.500	0.24112	0.13929	0.51818	0.29654	1.31260	0.74093	2.14990	1.19310	4.24010	2.16280
2.000	0.10950	0.06323	0.24448	0.14150	0.72811	0.41587	1.25000	0.71387	2.44330	1.37950
3.000	0.06255	0.03647	0.13823	0.08066	0.38295	0.22150	0.65922	0.38374	1.36850	0.78491
5.000	0.04255	0.02487	0.09659	0.05602	0.26767	0.15530	0.46757	0.27259	1.01950	0.59482
10.000	0.00888	0.00513	0.01844	0.01083	0.05239	0.03031	0.10006	0.05731	0.24848	0.14332

Table C-3
CMRR Design Spectra: 65 ft Total

	SDC-3		SDC-4		SDC-5	
Period (sec)	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**
0.010	0.39547	0.41027	0.63429	0.67688	1.13796	1.25162
0.020	0.39547	0.41027	0.63429	0.67688	1.13796	1.25162
0.030	0.39547	0.55578	0.63429	0.92316	1.13796	1.69555
0.050	0.51140	0.81468	0.82822	1.36476	1.44512	2.48545
0.060	0.55808	0.95427	0.90826	1.61682	1.54966	2.90459
0.075	0.61902	1.08297	1.01480	1.85958	1.70399	3.31553
0.085	0.65768	1.01451	1.08295	1.73830	1.81330	3.12659
0.100	0.70466	1.02271	1.17001	1.82244	1.95072	3.22399
0.150	0.73586	0.87947	1.22220	1.55731	2.02646	2.79460
0.200	0.67286	0.73265	1.11624	1.28082	1.92206	2.43220
0.300	0.77807	0.60472	1.25903	1.02015	2.17781	1.87227
0.400	0.74570	0.52887	1.20341	0.88408	2.15249	1.61390
0.500	0.82661	0.51739	1.36679	0.87711	2.42941	1.58466
0.750	0.77424	0.44563	1.28942	0.73542	2.39219	1.33863
1.000	0.72691	0.41203	1.19501	0.66755	2.23274	1.20190
1.500	0.54281	0.30775	0.95555	0.53612	1.96218	1.03562
2.000	0.27951	0.16109	0.53554	0.30727	1.13069	0.64273
3.000	0.15425	0.08992	0.28766	0.16760	0.63073	0.36303
5.000	0.10842	0.06301	0.20339	0.11849	0.46383	0.27055
10.000	0.02169	0.01260	0.04261	0.02452	0.10840	0.06258

Table C-4
CMRR UHRS Spectra: 65 ft Total Motion

	1,000 Yr RP		2,500 Yr RP		10,000 Yr RP		50,000 Yr RP		100,000 Yr RP	
Period (sec)	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.23151	0.22999	0.41095	0.41445	0.86628	0.92095	1.33880	1.44900	2.30700	2.55910
0.020	0.23151	0.22999	0.41095	0.41445	0.86628	0.92095	1.33880	1.44900	2.30700	2.55910
0.030	0.23151	0.30675	0.41095	0.55766	0.86628	1.26207	1.33880	1.98291	2.30700	3.45678
0.050	0.29196	0.44093	0.52630	0.81053	1.14700	1.87710	1.75660	2.94400	2.89940	5.04880
0.060	0.31293	0.50358	0.57152	0.93869	1.25790	2.22070	1.93110	3.50750	3.09170	5.88230
0.075	0.33174	0.54628	0.62932	1.05110	1.42490	2.58270	2.16560	4.06130	3.37440	6.68320
0.085	0.34878	0.51108	0.66568	0.98685	1.54030	2.43390	2.31610	3.79230	3.57680	6.30340
0.100	0.37850	0.50210	0.70731	0.95654	1.66790	2.61390	2.51270	4.05470	3.84160	6.43400
0.150	0.40939	0.44843	0.73841	0.82778	1.71670	2.16850	2.62520	3.45390	4.00000	5.63860
0.200	0.38607	0.38943	0.67599	0.69847	1.48920	1.68350	2.39620	2.82250	3.87950	5.04960
0.300	0.45404	0.33380	0.80140	0.59744	1.69730	1.36120	2.66930	2.20840	4.38930	3.83960
0.400	0.43152	0.29300	0.77012	0.52729	1.63530	1.19220	2.54790	1.90510	4.36610	3.29660
0.500	0.46453	0.28170	0.83320	0.50866	1.86510	1.19630	2.92920	1.90340	4.91490	3.21940
0.750	0.44240	0.25490	0.77483	0.45004	1.71070	0.98844	2.77330	1.57460	4.92620	2.73460
1.000	0.39377	0.22692	0.73694	0.42386	1.60720	0.91445	2.55370	1.41620	4.59030	2.43700
1.500	0.23957	0.13846	0.51391	0.29444	1.29720	0.73388	2.11310	1.17930	4.12080	2.13750
2.000	0.10901	0.06296	0.24313	0.14076	0.72300	0.41277	1.23550	0.70729	2.39440	1.35960
3.000	0.06237	0.03637	0.13786	0.08040	0.38118	0.22043	0.65471	0.38137	1.35470	0.77878
5.000	0.04243	0.02480	0.09633	0.05584	0.26652	0.15451	0.46430	0.27080	1.00890	0.58937
10.000	0.00885	0.00512	0.01840	0.01080	0.05217	0.03018	0.09954	0.05699	0.24645	0.14222

Table C-5
CMRR Design Spectra: 65 ft Removed

	SDC-3		SDC-4		SDC-5	
Period (sec)	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**
0.010	0.55235	0.53782	0.91173	0.89937	1.65666	1.64272
0.020	0.55235	0.53782	0.91173	0.89937	1.65666	1.64272
0.030	0.55235	0.75481	0.91173	1.27047	1.65666	2.32519
0.050	0.75545	1.15688	1.24043	1.96324	2.16624	3.60215
0.060	0.84211	1.34525	1.38121	2.28679	2.38178	4.17407
0.075	0.97282	1.58533	1.59451	2.71207	2.69759	4.87390
0.085	1.06071	1.52100	1.74406	2.61003	2.92594	4.69622
0.100	1.13733	1.58976	1.91144	2.87049	3.22967	5.11194
0.150	1.23033	1.29410	2.02553	2.27694	3.41584	4.00736
0.200	1.26630	1.06580	2.07128	1.81029	3.60563	3.23540
0.300	1.28878	0.79559	2.22205	1.37767	4.18337	2.56218
0.400	1.24412	0.72720	2.06691	1.21444	3.99105	2.26602
0.500	1.17931	0.67547	2.12370	1.21779	4.25169	2.35311
0.750	0.97707	0.54693	1.78957	0.98167	3.81480	1.97554
1.000	0.89450	0.50197	1.68171	0.92757	3.61959	1.90249
1.500	0.50441	0.28393	1.00360	0.55463	2.58058	1.31955
2.000	0.21410	0.12377	0.40765	0.23547	0.97033	0.54602
3.000	0.13956	0.08156	0.25282	0.14774	0.52565	0.30913
5.000	0.10238	0.05940	0.19078	0.11086	0.42089	0.24717
10.000	0.02079	0.01214	0.04066	0.02364	0.10503	0.06070

Table C-6
CMRR UHRS Spectra: 65 ft Removed Motion

	1,000 Yr RP		2,500 Yr RP		10,000 Yr RP		50,000 Yr RP		100,000 Yr RP	
Period (sec)	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.29755	0.28202	0.55772	0.53603	1.25050	1.24080	1.95220	1.93840	3.36570	3.33690
0.020	0.29755	0.28202	0.55772	0.53603	1.25050	1.24080	1.95220	1.93840	3.36570	3.33690
0.030	0.29755	0.38970	0.55772	0.74742	1.25050	1.75354	1.95220	2.74713	3.36570	4.72506
0.050	0.40170	0.58569	0.76682	1.13620	1.72260	2.71120	2.64910	4.26250	4.34410	7.32360
0.060	0.44448	0.67399	0.85571	1.31890	1.93220	3.17470	2.94820	4.96920	4.75250	8.46420
0.075	0.51214	0.78466	0.98924	1.54450	2.25270	3.80070	3.40230	5.91210	5.34390	9.82160
0.085	0.55343	0.74965	1.07520	1.47730	2.49630	3.65410	3.72730	5.69840	5.76530	9.46880
0.100	0.57793	0.74076	1.12790	1.46740	2.71730	4.04700	4.12990	6.42860	6.38590	10.26300
0.150	0.65471	0.63594	1.24550	1.22580	2.86880	3.21120	4.33160	5.03370	6.75710	8.02080
0.200	0.72322	0.57579	1.29030	1.04580	2.82560	2.47840	4.41510	3.93220	7.25710	6.54900
0.300	0.66031	0.40495	1.24580	0.76575	2.94990	1.85180	4.86280	3.02150	8.64510	5.26220
0.400	0.67140	0.38931	1.24810	0.72573	2.76400	1.64420	4.44020	2.61570	8.28490	4.64940
0.500	0.53775	0.30799	1.09150	0.62444	2.79320	1.62370	4.74980	2.72520	8.94300	4.88920
0.750	0.43317	0.24856	0.88910	0.50787	2.33460	1.30300	4.03650	2.19190	8.16770	4.15130
1.000	0.37872	0.21724	0.79297	0.45275	2.19470	1.22680	3.84310	2.10150	7.76770	4.02050
1.500	0.20274	0.11642	0.42253	0.24226	1.23050	0.69247	2.35940	1.29190	5.88090	2.93590
2.000	0.08818	0.05076	0.18742	0.10843	0.51906	0.29962	0.93749	0.54130	2.14860	1.20140
3.000	0.05922	0.03449	0.12839	0.07504	0.33661	0.19636	0.56715	0.33141	1.11280	0.65574
5.000	0.04037	0.02361	0.09157	0.05304	0.25105	0.14579	0.43406	0.25242	0.90697	0.53410
10.000	0.00854	0.00491	0.01772	0.01040	0.04980	0.02867	0.09477	0.05497	0.23968	0.13866

Table C-7
CMRR Design Spectra: 69 ft Outcrop

	SDC-3		SDC-4		SDC-5	
Period (sec)	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**
0.010	0.42983	0.45571	0.67163	0.73610	1.17219	1.32433
0.020	0.42983	0.45571	0.67163	0.73610	1.17219	1.32433
0.030	0.42983	0.64546	0.67163	1.05186	1.17219	1.90099
0.050	0.55537	1.00076	0.86723	1.64915	1.47173	2.99748
0.060	0.60835	1.13215	0.94744	1.86274	1.59182	3.36297
0.075	0.68914	1.24224	1.06499	2.03313	1.76508	3.60955
0.085	0.74696	1.14636	1.15051	1.87183	1.87565	3.32393
0.100	0.81579	1.13792	1.25959	1.89327	2.03596	3.24714
0.150	0.85618	0.97256	1.32809	1.62164	2.15635	2.78620
0.200	0.77921	0.79894	1.23728	1.34132	2.06240	2.41420
0.300	0.82167	0.62190	1.31742	1.03511	2.30208	1.87925
0.400	0.78026	0.52319	1.26188	0.86935	2.26785	1.56766
0.500	0.83768	0.51867	1.36307	0.86348	2.43772	1.54899
0.750	0.80532	0.46320	1.33104	0.76174	2.38791	1.36044
1.000	0.73377	0.41635	1.22868	0.68651	2.28254	1.23482
1.500	0.57035	0.32460	1.00841	0.56813	2.00637	1.07790
2.000	0.28227	0.16250	0.54939	0.31434	1.17477	0.66736
3.000	0.15542	0.09060	0.28959	0.16872	0.63493	0.36532
5.000	0.10887	0.06327	0.20425	0.11898	0.46684	0.27236
10.000	0.02181	0.01267	0.04284	0.02463	0.10914	0.06303

Table C-8
CMRR UHRS Spectra: 69 ft Outcrop

	1,000 Yr RP		2,500 Yr RP		10,000 Yr RP		50,000 Yr RP		100,000 Yr RP	
Period (sec)	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.26045	0.26327	0.45847	0.47021	0.93741	1.01510	1.39920	1.55920	2.34730	2.68030
0.020	0.26045	0.26327	0.45847	0.47021	0.93741	1.01510	1.39920	1.55920	2.34730	2.68030
0.030	0.26045	0.37027	0.45847	0.66014	0.93741	1.44320	1.39920	2.23794	2.34730	3.85663
0.050	0.33766	0.56901	0.59276	1.01220	1.21120	2.24830	1.80620	3.52840	2.92610	6.09950
0.060	0.37304	0.64512	0.65103	1.14680	1.33080	2.56760	1.97060	3.98220	3.15250	6.81290
0.075	0.42758	0.71157	0.74322	1.26500	1.50160	2.83230	2.20650	4.33510	3.48040	7.26260
0.085	0.46878	0.65394	0.80827	1.17010	1.62400	2.61680	2.37980	3.98640	3.68220	6.68240
0.100	0.50874	0.64030	0.88060	1.13990	1.79880	2.69140	2.60860	4.07020	3.97670	6.44460
0.150	0.54030	0.55681	0.91992	0.97216	1.89370	2.27020	2.75680	3.49000	4.21830	5.55340
0.200	0.46650	0.44314	0.81788	0.79313	1.72330	1.82530	2.59850	2.89660	4.08490	4.90280
0.300	0.49124	0.35352	0.85413	0.62273	1.78400	1.39000	2.78020	2.22570	4.64640	3.83740
0.400	0.44710	0.28964	0.80410	0.52476	1.73610	1.18960	2.67460	1.86770	4.59130	3.18070
0.500	0.49253	0.29505	0.85800	0.51926	1.85080	1.17620	2.89790	1.85690	4.94540	3.14240
0.750	0.44014	0.25387	0.81208	0.46943	1.81160	1.04840	2.85200	1.62810	4.84520	2.74960
1.000	0.38947	0.22464	0.73035	0.42085	1.65340	0.93808	2.64990	1.46920	4.68530	2.50470
1.500	0.25110	0.14515	0.53764	0.30909	1.38390	0.78308	2.23480	1.25270	4.16920	2.21090
2.000	0.10870	0.06276	0.24171	0.14001	0.72849	0.41695	1.27750	0.72865	2.50700	1.42150
3.000	0.06295	0.03671	0.13903	0.08108	0.38413	0.22213	0.65880	0.38373	1.36330	0.78343
5.000	0.04259	0.02490	0.09671	0.05607	0.26781	0.15525	0.46627	0.27195	1.01580	0.59360
10.000	0.00890	0.00514	0.01851	0.01086	0.05247	0.03036	0.10008	0.05726	0.24820	0.14327

Table C-9
CMRR Design Spectra: 69 ft Total

	SDC-3		SDC-4		SDC-5	
Period (sec)	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**
0.010	0.40832	0.42740	0.64278	0.69325	1.12119	1.25263
0.020	0.40832	0.42740	0.64278	0.69325	1.12119	1.25263
0.030	0.40832	0.58803	0.64278	0.96321	1.12119	1.74201
0.050	0.51663	0.87897	0.81924	1.45770	1.41110	2.63936
0.060	0.56147	1.02237	0.89395	1.70901	1.51375	3.09173
0.075	0.62559	1.14436	0.99698	1.92685	1.66542	3.44650
0.085	0.67500	1.06062	1.07012	1.78228	1.77325	3.19693
0.100	0.73576	1.05534	1.17093	1.81109	1.91913	3.14649
0.150	0.78602	0.91765	1.24685	1.55272	2.01280	2.71478
0.200	0.72647	0.76470	1.16330	1.29745	1.93452	2.36820
0.300	0.78816	0.60640	1.25964	1.01051	2.15470	1.83344
0.400	0.75553	0.51349	1.21310	0.85160	2.14991	1.53712
0.500	0.81574	0.51113	1.31540	0.85021	2.32796	1.52228
0.750	0.79266	0.45850	1.30149	0.75239	2.32042	1.34248
1.000	0.72556	0.41277	1.20864	0.67857	2.23428	1.22094
1.500	0.56595	0.32272	0.99749	0.56395	1.97391	1.06843
2.000	0.28082	0.16180	0.54554	0.31262	1.16383	0.66254
3.000	0.15498	0.09034	0.28848	0.16812	0.63172	0.36384
5.000	0.10858	0.06310	0.20353	0.11858	0.46434	0.27115
10.000	0.02176	0.01264	0.04272	0.02456	0.10873	0.06279

Table C-10
CMRR UHRS Spectra: 69 ft Total

	1,000 Yr RP		2,500 Yr RP		10,000 Yr RP		50,000 Yr RP		100,000 Yr RP	
Period (sec)	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.24358	0.24421	0.43230	0.43916	0.89252	0.95903	1.34410	1.47150	2.24780	2.53590
0.020	0.24358	0.24421	0.43230	0.43916	0.89252	0.95903	1.34410	1.47150	2.24780	2.53590
0.030	0.24358	0.32998	0.43230	0.59832	0.89252	1.32981	1.34410	2.05460	2.24780	3.52921
0.050	0.30062	0.48216	0.54299	0.88336	1.14680	2.00740	1.71940	3.12870	2.81440	5.35210
0.060	0.32251	0.55272	0.58774	1.01930	1.24810	2.35650	1.88000	3.68260	3.00830	6.26610
0.075	0.35822	0.61138	0.65425	1.13270	1.40510	2.67130	2.09770	4.16710	3.29070	6.95590
0.085	0.39226	0.56626	0.70961	1.05200	1.51600	2.49360	2.24570	3.85070	3.49220	6.44200
0.100	0.42756	0.55770	0.77054	1.02490	1.66660	2.58010	2.46190	3.95420	3.76470	6.26160
0.150	0.47976	0.51047	0.82586	0.90388	1.75580	2.16910	2.61730	3.36630	3.94400	5.43760
0.200	0.43409	0.42203	0.75612	0.75117	1.60570	1.74690	2.45340	2.81670	3.83810	4.83910
0.300	0.47419	0.34563	0.82192	0.60650	1.69830	1.35050	2.65410	2.17410	4.33050	3.74780
0.400	0.43863	0.28617	0.78425	0.51603	1.66580	1.16090	2.56190	1.82780	4.33940	3.12240
0.500	0.48464	0.29123	0.84313	0.51213	1.80330	1.15700	2.78390	1.82750	4.69910	3.08740
0.750	0.43680	0.25206	0.80459	0.46567	1.78040	1.03490	2.77950	1.60640	4.69500	2.71320
1.000	0.38723	0.22345	0.72594	0.41847	1.63090	0.92905	2.59990	1.45010	4.57740	2.47550
1.500	0.25010	0.14462	0.53517	0.30780	1.37360	0.77813	2.20710	1.24260	4.09270	2.19020
2.000	0.10841	0.06260	0.24093	0.13958	0.72512	0.41494	1.26730	0.72423	2.48070	1.41040
3.000	0.06284	0.03665	0.13877	0.08092	0.38289	0.22142	0.65598	0.38223	1.35580	0.78008
5.000	0.04252	0.02485	0.09654	0.05596	0.26692	0.15475	0.46443	0.27093	1.00990	0.59075
10.000	0.00889	0.00514	0.01847	0.01084	0.05233	0.03027	0.09977	0.05707	0.24720	0.14270

Table C-11
CMRR Design Spectra: 69 ft Removed

	SDC-3		SDC-4		SDC-5	
Period (sec)	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**
0.010	0.56763	0.54905	0.93745	0.91564	1.72079	1.67014
0.020	0.56763	0.54905	0.93745	0.91564	1.72079	1.67014
0.030	0.56763	0.77147	0.93745	1.30110	1.72079	2.39314
0.050	0.76577	1.18415	1.26780	2.02557	2.24791	3.76509
0.060	0.85339	1.37438	1.41240	2.35437	2.48122	4.35125
0.075	0.98839	1.57271	1.63507	2.70961	2.81569	4.94973
0.085	1.07223	1.53627	1.79463	2.65592	3.07761	4.85125
0.100	1.16798	1.63750	1.97183	2.97518	3.38461	5.36973
0.150	1.23495	1.32713	2.06096	2.35938	3.55456	4.24151
0.200	1.21686	1.07424	2.01016	1.84773	3.56634	3.38261
0.300	1.33517	0.81316	2.26918	1.37332	4.32205	2.54175
0.400	1.34233	0.77345	2.20580	1.26291	4.22684	2.30804
0.500	1.24245	0.69631	2.26046	1.24692	4.56996	2.38775
0.750	1.00755	0.56062	1.86735	1.01278	4.06246	2.03837
1.000	0.90670	0.50564	1.73184	0.94461	3.80875	1.95705
1.500	0.49450	0.27977	0.98909	0.54863	2.59738	1.31437
2.000	0.20571	0.11941	0.38964	0.22691	0.92738	0.52794
3.000	0.13897	0.08114	0.25110	0.14686	0.52414	0.30760
5.000	0.10160	0.05927	0.19004	0.11066	0.42117	0.24676
10.000	0.02082	0.01214	0.04083	0.02367	0.10529	0.06083

Table C-12
CMRR UHRS Spectra: 69 ft Removed

	1,000 Yr RP		2,500 Yr RP		10,000 Yr RP		50,000 Yr RP		100,000 Yr RP	
Period (sec)	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.30486	0.28852	0.57284	0.54872	1.28100	1.26540	2.00790	1.97070	3.50820	3.38990
0.020	0.30486	0.28852	0.57284	0.54872	1.28100	1.26540	2.00790	1.97070	3.50820	3.38990
0.030	0.30486	0.39693	0.57284	0.76240	1.28100	1.79226	2.00790	2.81613	3.50820	4.87154
0.050	0.40172	0.59328	0.77090	1.15380	1.74650	2.77880	2.71870	4.41540	4.53410	7.69250
0.060	0.44604	0.68376	0.85939	1.33720	1.95330	3.24300	3.02840	5.13580	4.98820	8.86830
0.075	0.51337	0.76813	0.99577	1.52140	2.28600	3.76200	3.50500	5.92770	5.61720	10.03900
0.085	0.54699	0.74879	1.06770	1.48110	2.51810	3.68930	3.86960	5.82020	6.12790	9.83770
0.100	0.59530	0.76421	1.15310	1.50210	2.75120	4.12200	4.27000	6.68380	6.75020	10.86400
0.150	0.64329	0.64049	1.23330	1.24420	2.87450	3.29100	4.43740	5.24310	7.09820	8.55810
0.200	0.68290	0.57228	1.22770	1.04090	2.71010	2.49530	4.30600	4.03880	7.23340	6.91180
0.300	0.69835	0.42749	1.30930	0.80247	3.00900	1.84690	4.93050	2.97450	8.96020	5.21330
0.400	0.73238	0.42422	1.36140	0.78948	2.98490	1.73310	4.71260	2.68960	8.73170	4.69530
0.500	0.55885	0.31966	1.13820	0.64806	2.95110	1.66240	5.08160	2.78100	9.65390	4.95010
0.750	0.44216	0.25350	0.90606	0.51721	2.43660	1.35030	4.23700	2.26880	8.74180	4.27860
1.000	0.37482	0.21487	0.79116	0.45110	2.22910	1.24040	3.98920	2.15180	8.24620	4.15360
1.500	0.19756	0.11405	0.41204	0.23778	1.20580	0.68221	2.33140	1.28040	5.95880	2.93240
2.000	0.08566	0.04921	0.18102	0.10473	0.49588	0.28776	0.89373	0.52132	2.05370	1.16360
3.000	0.05897	0.03436	0.12818	0.07471	0.33463	0.19509	0.56256	0.32932	1.11040	0.65274
5.000	0.04023	0.02352	0.09053	0.05291	0.25071	0.14544	0.43319	0.25201	0.90801	0.53332
10.000	0.00853	0.00490	0.01770	0.01038	0.04983	0.02868	0.09530	0.05508	0.24039	0.13901

Table C-13
CMRR Design Spectra: 75 ft Outcrop

	SDC-3		SDC-4		SDC-5	
Period (sec)	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**
0.010	0.42215	0.44593	0.66082	0.72045	1.15469	1.29923
0.020	0.42215	0.44593	0.66082	0.72045	1.15469	1.29923
0.030	0.42215	0.62883	0.66082	1.02447	1.15469	1.85063
0.050	0.54664	0.96957	0.85330	1.59635	1.45415	2.88986
0.060	0.60073	1.09541	0.93687	1.79789	1.57035	3.23502
0.075	0.68058	1.20972	1.05252	1.97749	1.74318	3.49925
0.085	0.73788	1.12269	1.13653	1.83179	1.85919	3.25425
0.100	0.80236	1.11578	1.24925	1.86927	2.01558	3.21286
0.150	0.83020	0.95092	1.30653	1.60430	2.13189	2.78103
0.200	0.75762	0.78357	1.21813	1.33026	2.04015	2.42045
0.300	0.80315	0.61231	1.29237	1.02374	2.27857	1.86950
0.400	0.76264	0.51500	1.23315	0.85651	2.22655	1.54980
0.500	0.82336	0.51211	1.33718	0.85408	2.39149	1.53413
0.750	0.79464	0.45860	1.30602	0.75220	2.33827	1.34314
1.000	0.72612	0.41264	1.20813	0.67714	2.23950	1.21877
1.500	0.56665	0.32287	0.99873	0.56391	1.98245	1.06848
2.000	0.28107	0.16190	0.54595	0.31271	1.16662	0.66311
3.000	0.15510	0.09041	0.28878	0.16827	0.63300	0.36434
5.000	0.10866	0.06315	0.20376	0.11872	0.46571	0.27169
10.000	0.02177	0.01265	0.04276	0.02459	0.10897	0.06293

Table C-14
CMRR UHRS Spectra: 75 ft Outcrop

	1,000 Yr RP		2,500 Yr RP		10,000 Yr RP		50,000 Yr RP		100,000 Yr RP	
Period (sec)	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.25467	0.25682	0.44946	0.46002	0.92060	0.99477	1.37800	1.52620	2.31400	2.63020
0.020	0.25467	0.25682	0.44946	0.46002	0.92060	0.99477	1.37800	1.52620	2.31400	2.63020
0.030	0.25467	0.35969	0.44946	0.64329	0.92060	1.40707	1.37800	2.17936	2.31400	3.75307
0.050	0.33086	0.54985	0.58365	0.98147	1.19260	2.17790	1.77680	3.41390	2.89370	5.87360
0.060	0.36621	0.62317	0.64199	1.11230	1.31030	2.48670	1.95000	3.83890	3.11150	6.54260
0.075	0.42076	0.68968	0.73345	1.23340	1.48670	2.75720	2.18150	4.21380	3.43500	7.03340
0.085	0.45913	0.63732	0.79843	1.14680	1.60800	2.56640	2.35090	3.89970	3.65080	6.53950
0.100	0.48797	0.61613	0.85888	1.11000	1.77660	2.66410	2.59800	4.03250	3.93920	6.37590
0.150	0.50849	0.53019	0.87920	0.93942	1.86220	2.24320	2.73170	3.47300	4.17600	5.55710
0.200	0.44748	0.42991	0.78535	0.76925	1.67700	1.79620	2.57430	2.88880	4.05750	4.93850
0.300	0.47689	0.34584	0.83188	0.61037	1.74400	1.36900	2.73230	2.20620	4.61320	3.82710
0.400	0.43966	0.28625	0.78608	0.51609	1.69170	1.16740	2.61340	1.84100	4.51610	3.15030
0.500	0.48550	0.29100	0.84496	0.51178	1.81950	1.16100	2.84010	1.83830	4.84900	3.11480
0.750	0.43757	0.25242	0.80582	0.46599	1.77930	1.03310	2.79050	1.60560	4.74090	2.71600
1.000	0.38794	0.22380	0.72736	0.41909	1.62900	0.92724	2.59730	1.44570	4.59220	2.47130
1.500	0.25042	0.14478	0.53582	0.30811	1.37470	0.77826	2.20980	1.24210	4.11400	2.19020
2.000	0.10850	0.06264	0.24118	0.13971	0.72547	0.41508	1.26810	0.72432	2.48780	1.41180
3.000	0.06287	0.03667	0.13884	0.08097	0.38316	0.22158	0.65674	0.38259	1.35900	0.78130
5.000	0.04254	0.02487	0.09657	0.05599	0.26717	0.15488	0.46506	0.27128	1.01330	0.59210
10.000	0.00889	0.00514	0.01847	0.01084	0.05237	0.03030	0.09989	0.05715	0.24784	0.14306

Table C-15
CMRR Design Spectra: 75 ft Total

	SDC-3		SDC-4		SDC-5	
Period (sec)	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**
0.010	0.39904	0.41560	0.62690	0.67449	1.09574	1.21952
0.020	0.39904	0.41560	0.62690	0.67449	1.09574	1.21952
0.030	0.39904	0.56335	0.62690	0.91998	1.09574	1.66093
0.050	0.50797	0.82644	0.80355	1.36021	1.38396	2.45120
0.060	0.55732	0.94679	0.87965	1.56201	1.48762	2.77412
0.075	0.62474	1.07549	0.98961	1.78432	1.63197	3.15002
0.085	0.66842	1.02215	1.05599	1.69701	1.73330	2.99928
0.100	0.71488	1.02468	1.14205	1.76501	1.87388	3.05730
0.150	0.74380	0.89440	1.19621	1.53666	1.96070	2.73180
0.200	0.68371	0.74096	1.11083	1.27475	1.87972	2.37227
0.300	0.75710	0.59081	1.20985	0.98803	2.07663	1.80039
0.400	0.73115	0.50242	1.17431	0.83406	2.06887	1.51058
0.500	0.79744	0.50338	1.28551	0.84004	2.26886	1.50434
0.750	0.78027	0.45331	1.27666	0.74379	2.27390	1.32872
1.000	0.71668	0.40842	1.18769	0.66889	2.18689	1.20478
1.500	0.56180	0.32085	0.98778	0.56004	1.94730	1.06005
2.000	0.27947	0.16113	0.54210	0.31106	1.15588	0.65876
3.000	0.15462	0.09013	0.28766	0.16765	0.62960	0.36276
5.000	0.10833	0.06296	0.20301	0.11828	0.46283	0.27036
10.000	0.02171	0.01261	0.04263	0.02451	0.10848	0.06265

Table C-16
CMRR UHRS Spectra:75 ft Total

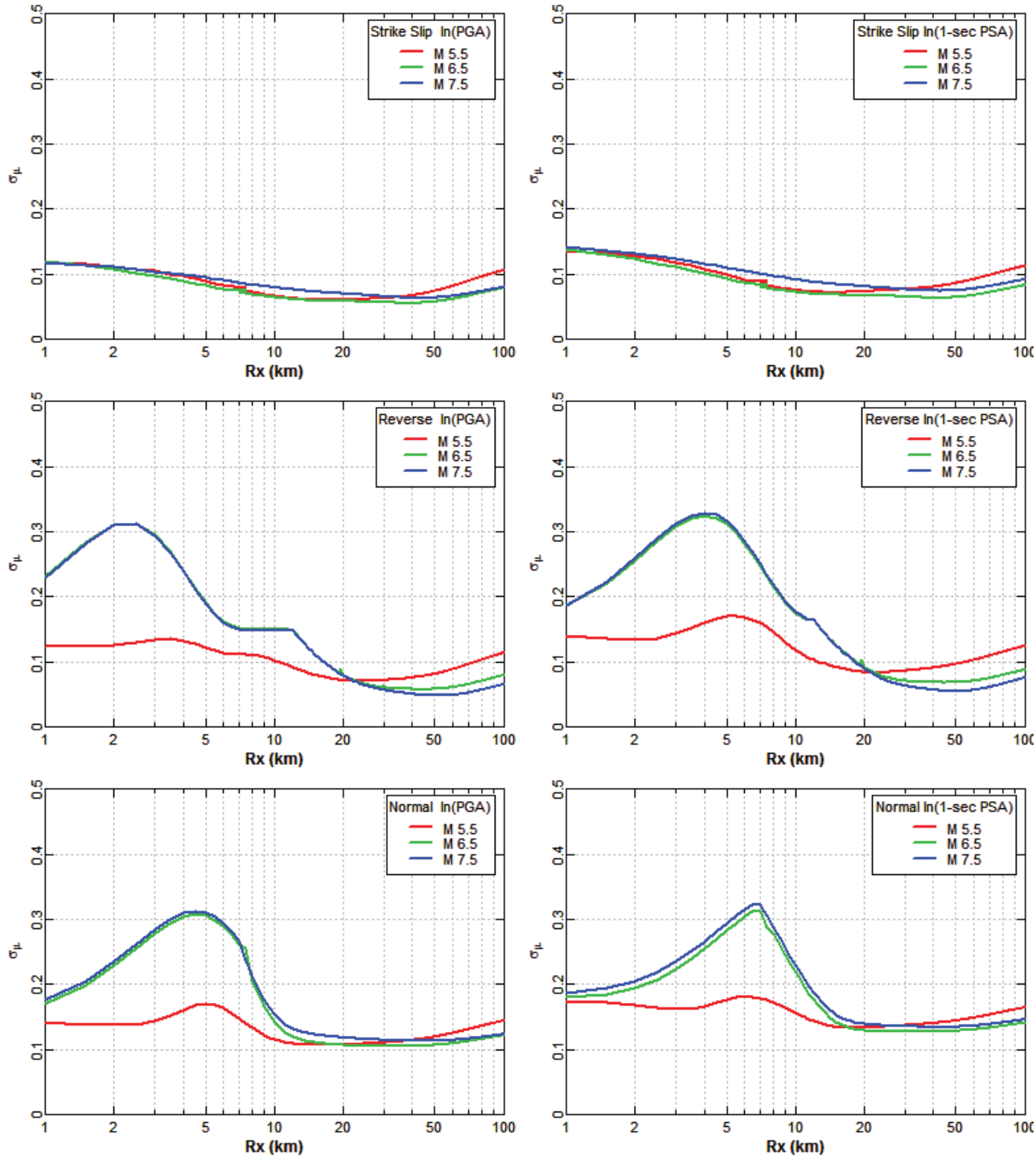
	1,000 Yr RP		2,500 Yr RP		10,000 Yr RP		50,000 Yr RP		100,000 Yr RP	
Period (sec)	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**
0.010	0.23714	0.23650	0.42334	0.42680	0.87283	0.93219	1.30960	1.43220	2.19640	2.46990
0.020	0.23714	0.23650	0.42334	0.42680	0.87283	0.93219	1.30960	1.43220	2.19640	2.46990
0.030	0.23714	0.31656	0.42334	0.57495	0.87283	1.27356	1.30960	1.95948	2.19640	3.36125
0.050	0.29721	0.45707	0.53519	0.83687	1.12930	1.88690	1.68450	2.90840	2.75750	4.95560
0.060	0.32597	0.51974	0.58851	0.95650	1.23350	2.16680	1.84190	3.34390	2.95220	5.58810
0.075	0.36056	0.58175	0.65734	1.08040	1.39020	2.49870	2.07580	3.83050	3.21680	6.32080
0.085	0.38707	0.55141	0.70517	1.02610	1.50120	2.37570	2.21210	3.64440	3.40250	6.02050
0.100	0.40302	0.52645	0.74581	0.99148	1.63460	2.51370	2.40580	3.86070	3.67190	6.08000
0.150	0.43430	0.47580	0.77081	0.86764	1.68860	2.14720	2.52840	3.35700	3.85420	5.49420
0.200	0.40230	0.40115	0.70135	0.71781	1.52610	1.70020	2.35980	2.78670	3.75000	4.88250
0.300	0.45254	0.33429	0.78963	0.58881	1.63380	1.31680	2.54900	2.12950	4.17550	3.68670
0.400	0.42652	0.28100	0.75871	0.50442	1.61210	1.13430	2.48040	1.79100	4.17000	3.07300
0.500	0.47424	0.28603	0.82447	0.50273	1.76430	1.14150	2.72030	1.80870	4.57530	3.05230
0.750	0.43292	0.24983	0.79481	0.46045	1.74250	1.02000	2.72170	1.58790	4.60240	2.68810
1.000	0.38476	0.22216	0.72077	0.41563	1.60410	0.91684	2.54820	1.42670	4.47490	2.44270
1.500	0.24903	0.14404	0.53254	0.30636	1.36360	0.77303	2.18300	1.23320	4.03110	2.17230
2.000	0.10808	0.06243	0.24013	0.13911	0.72177	0.41289	1.25830	0.72031	2.46240	1.40200
3.000	0.06272	0.03658	0.13851	0.08076	0.38186	0.22083	0.65394	0.38108	1.35110	0.77771
5.000	0.04244	0.02481	0.09634	0.05585	0.26620	0.15435	0.46317	0.27022	1.00640	0.58899
10.000	0.00887	0.00513	0.01843	0.01082	0.05222	0.03021	0.09956	0.05695	0.24663	0.14237

Table C-17
CMRR Design Spectra: 75 ft Removed

	SDC-3		SDC-4		SDC-5	
Period (sec)	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.58074	0.55264	0.96058	0.92069	1.77729	1.67623
0.020	0.58074	0.55264	0.96058	0.92069	1.77729	1.67623
0.030	0.58074	0.78115	0.96058	1.31097	1.77729	2.41234
0.050	0.80490	1.20803	1.32217	2.04621	2.35430	3.81616
0.060	0.90610	1.41542	1.48676	2.40099	2.60916	4.43801
0.075	1.04538	1.66824	1.72410	2.86169	2.98653	5.24846
0.085	1.13021	1.60333	1.87478	2.75800	3.23183	5.08462
0.100	1.22530	1.66666	2.05049	3.00683	3.53329	5.42228
0.150	1.29565	1.33286	2.14793	2.35399	3.72992	4.21614
0.200	1.33575	1.10050	2.20432	1.87225	3.97821	3.41083
0.300	1.38872	0.83640	2.34881	1.39329	4.54093	2.55996
0.400	1.31641	0.75638	2.20868	1.26030	4.32288	2.31024
0.500	1.21795	0.68633	2.20929	1.23195	4.55233	2.38178
0.750	0.96083	0.53153	1.84460	0.98922	4.14212	2.03789
1.000	0.85845	0.47774	1.65906	0.90031	3.79721	1.90076
1.500	0.48738	0.27627	0.96209	0.53551	2.52331	1.29063
2.000	0.20807	0.12078	0.39089	0.22759	0.92309	0.52708
3.000	0.13819	0.08070	0.24904	0.14561	0.51677	0.30413
5.000	0.10171	0.05907	0.18954	0.11018	0.41791	0.24540
10.000	0.02075	0.01209	0.04071	0.02359	0.10490	0.06062

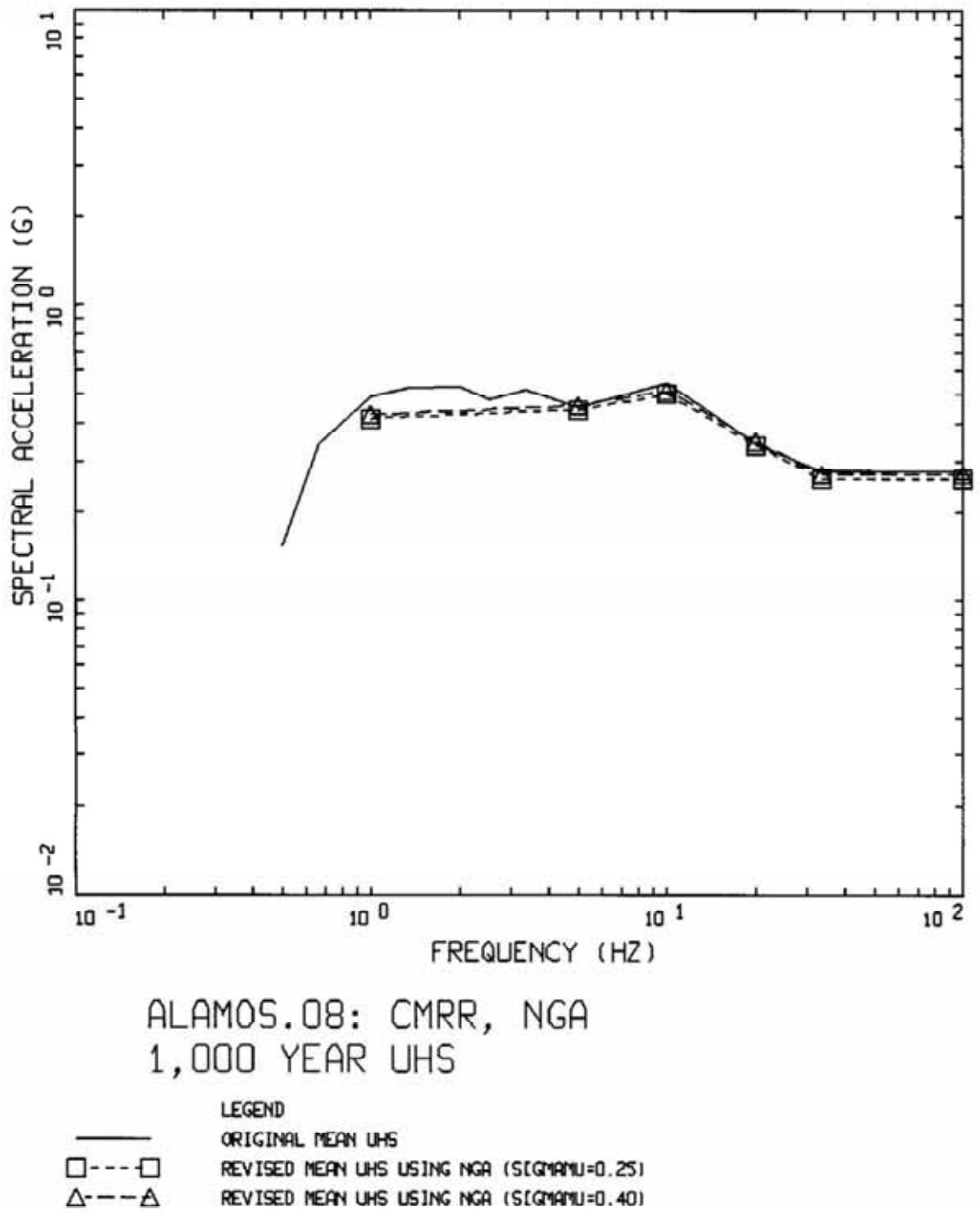
Table C-18
CMRR UHRS Spectra: 75 Removed

	1,000 Yr RP		2,500 Yr RP		10,000 Yr RP		50,000 Yr RP		100,000 Yr RP	
Period (sec)	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.010	0.30999	0.28899	0.58517	0.55287	1.31420	1.27760	2.05900	1.98060	3.62950	3.39720
0.020	0.30999	0.28899	0.58517	0.55287	1.31420	1.27760	2.05900	1.98060	3.62950	3.39720
0.030	0.30999	0.40270	0.58517	0.77577	1.31420	1.80923	2.05900	2.83054	3.62950	4.90885
0.050	0.42813	0.61169	0.81666	1.18870	1.81780	2.80450	2.82430	4.43850	4.75610	7.80510
0.060	0.47924	0.70833	0.92037	1.39070	2.05220	3.30180	3.17410	5.21180	5.24670	9.04920
0.075	0.54663	0.81955	1.05640	1.62080	2.39250	3.95570	3.69030	6.24680	5.97800	10.66700
0.085	0.58660	0.78449	1.13560	1.55340	2.59650	3.80920	4.02430	6.02880	6.46440	10.34900
0.100	0.63172	0.78264	1.22040	1.53970	2.86290	4.15920	4.42090	6.73110	7.05240	10.97200
0.150	0.68689	0.65406	1.30260	1.25780	2.96230	3.26060	4.60930	5.21390	7.48220	8.51390
0.200	0.74685	0.58752	1.34910	1.07810	2.98850	2.55930	4.71950	4.07010	8.09200	6.94000
0.300	0.73176	0.44664	1.36840	0.83682	3.11130	1.88190	5.09120	2.99710	9.45160	5.23540
0.400	0.68026	0.39414	1.30770	0.75657	2.99590	1.73240	4.76820	2.71140	8.97210	4.70130
0.500	0.53152	0.30476	1.11910	0.63727	2.89820	1.65150	4.95930	2.75090	9.65090	4.94270
0.750	0.40699	0.23310	0.83414	0.47600	2.34710	1.29330	4.25970	2.24920	9.04090	4.32370
1.000	0.35408	0.20295	0.74032	0.42251	2.10570	1.16970	3.84400	2.05990	8.33290	4.06390
1.500	0.19887	0.11487	0.41150	0.23754	1.17530	0.66644	2.25290	1.24260	5.78400	2.88320
2.000	0.08776	0.05049	0.18458	0.10683	0.49712	0.28855	0.89296	0.52068	2.04060	1.16040
3.000	0.05900	0.03436	0.12780	0.07454	0.33193	0.19366	0.55722	0.32597	1.09310	0.64473
5.000	0.04020	0.02350	0.09097	0.05278	0.24922	0.14484	0.43123	0.25079	0.90060	0.53020
10.000	0.00850	0.00489	0.01764	0.01034	0.04962	0.02856	0.09501	0.05490	0.23954	0.13856

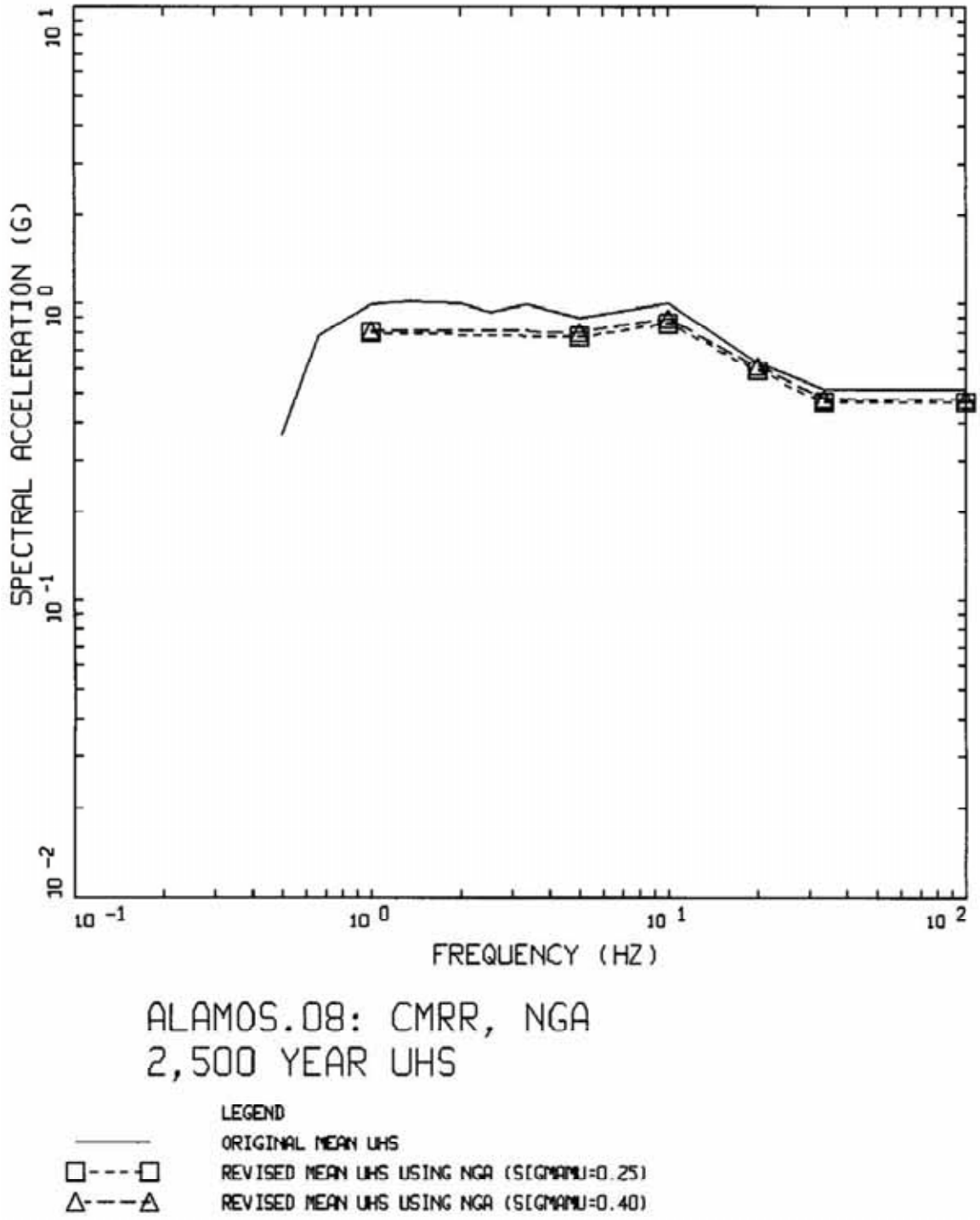


Source: Bob Youngs, AMEC Geomatrix

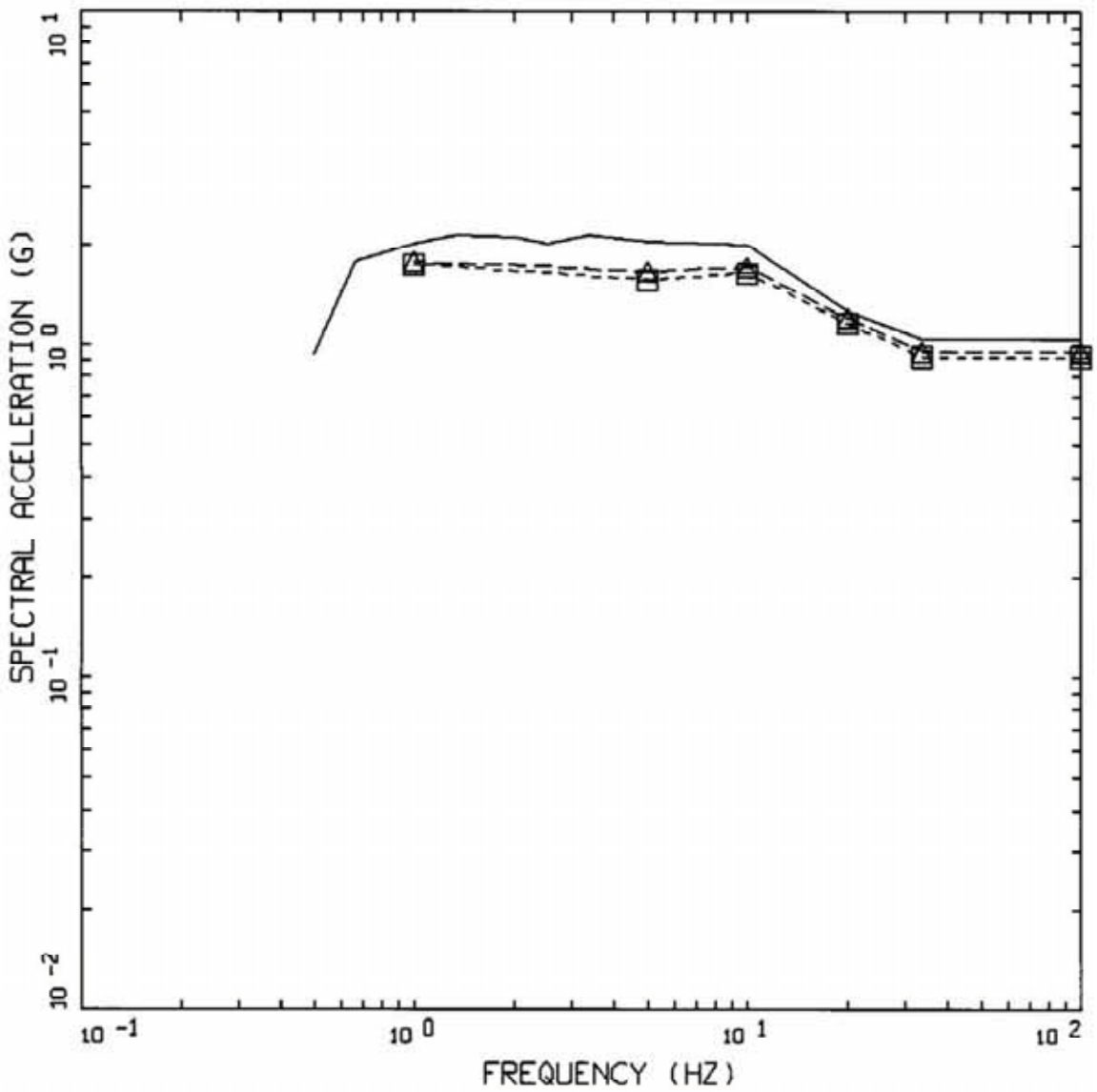
URS	Project No. 26817259 Los Alamos National Lab	UNCERTAINTY IN THE MEDIAN GROUND MOTION ESTIMATES (σ_μ) FOR THE CHIOU AND YOUNGS (2008) GROUND MOTION MODEL DERIVED FROM THE STATISTICAL UNCERTAINTY IN THE MODEL PARAMETERS	Figure 1



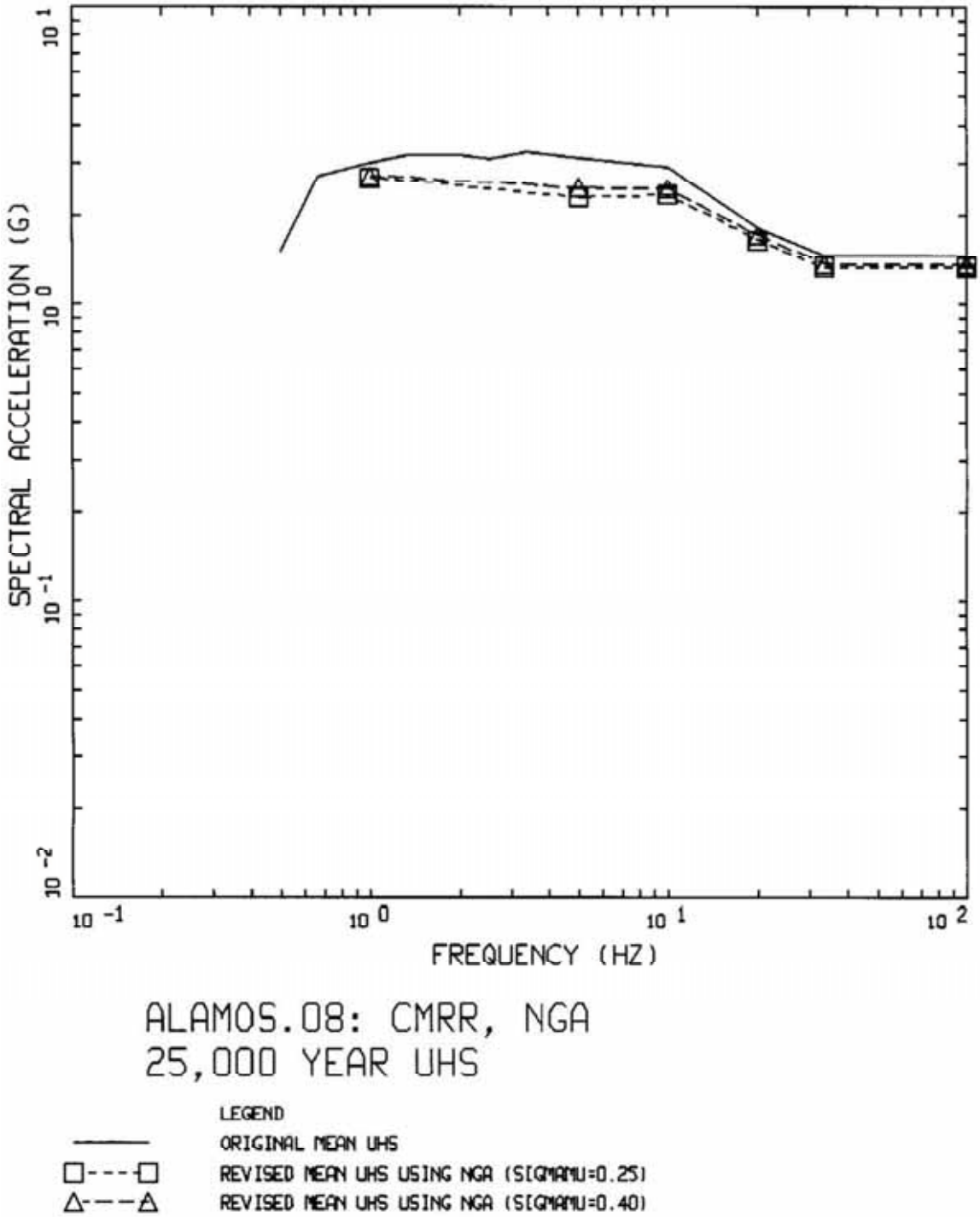
URS	Project No. 26817259	COMPARISON OF NGA 1,000-YEAR RETURN PERIOD UHS WITH 2007 UHS	Figure 2
	Los Alamos National Lab		



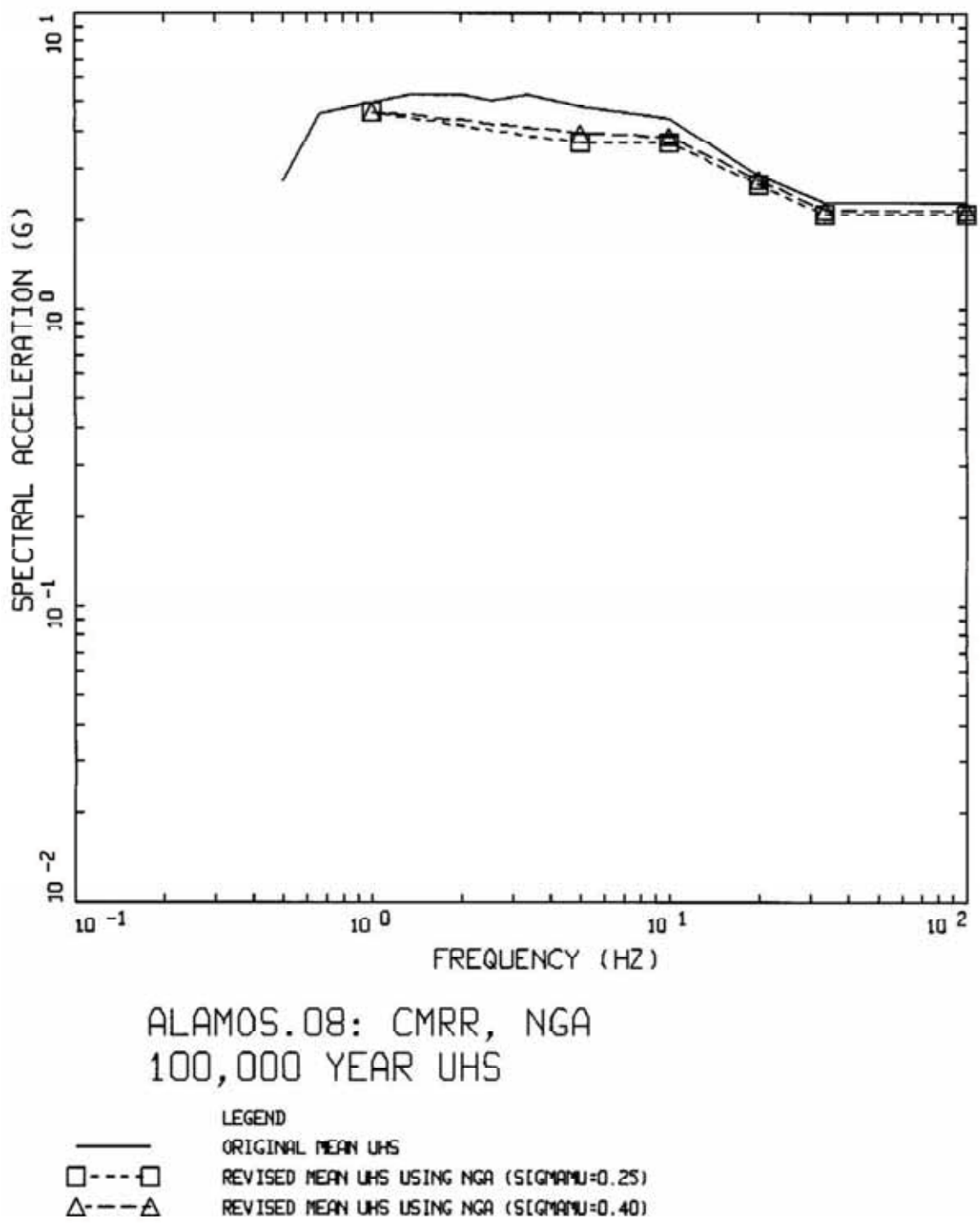
URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF NGA 2,500-YEAR RETURN PERIOD UHS WITH 2007 UHS	Figure 3



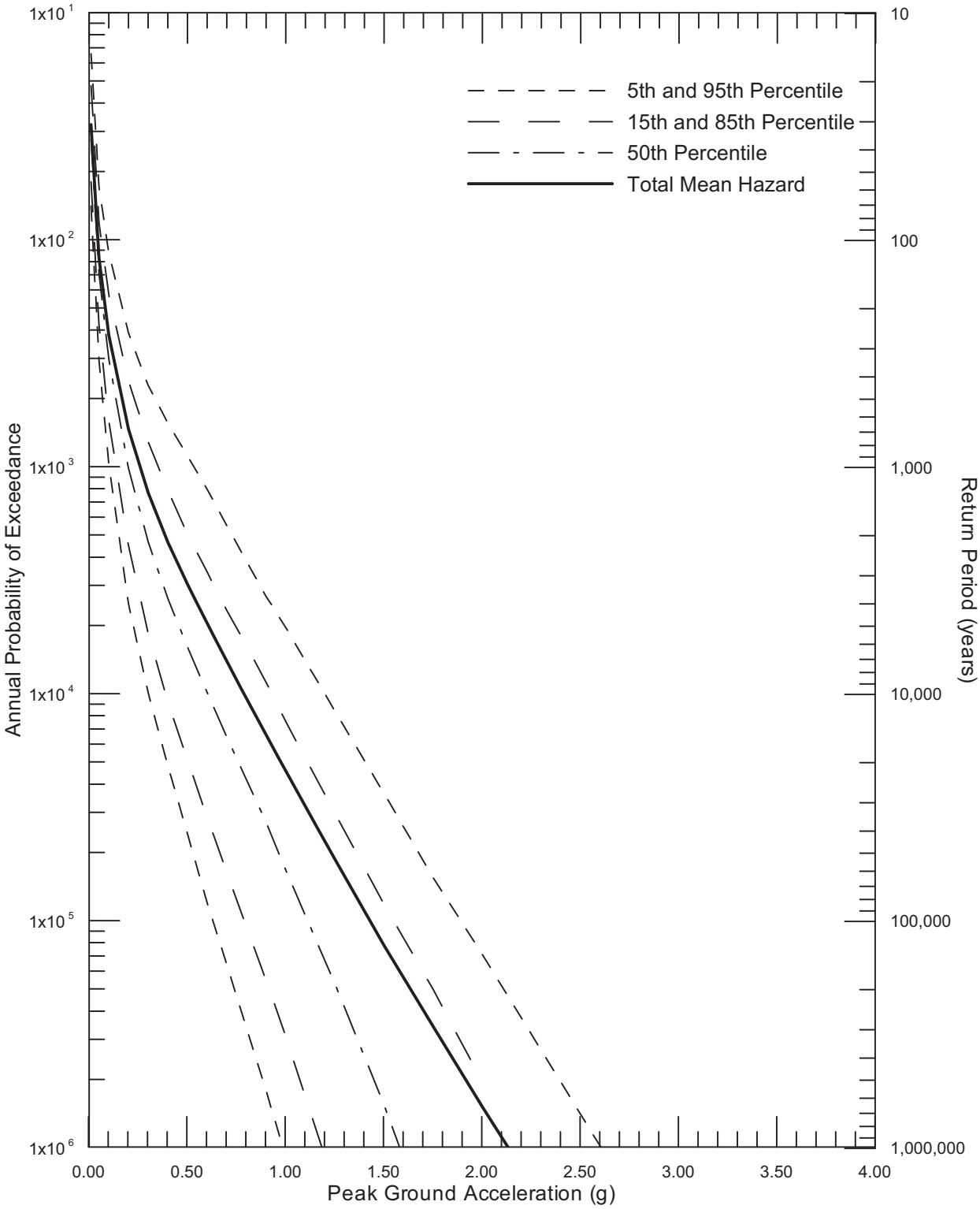
URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF NGA 10,000-YEAR RETURN PERIOD UHS WITH 2007 UHS	Figure 4



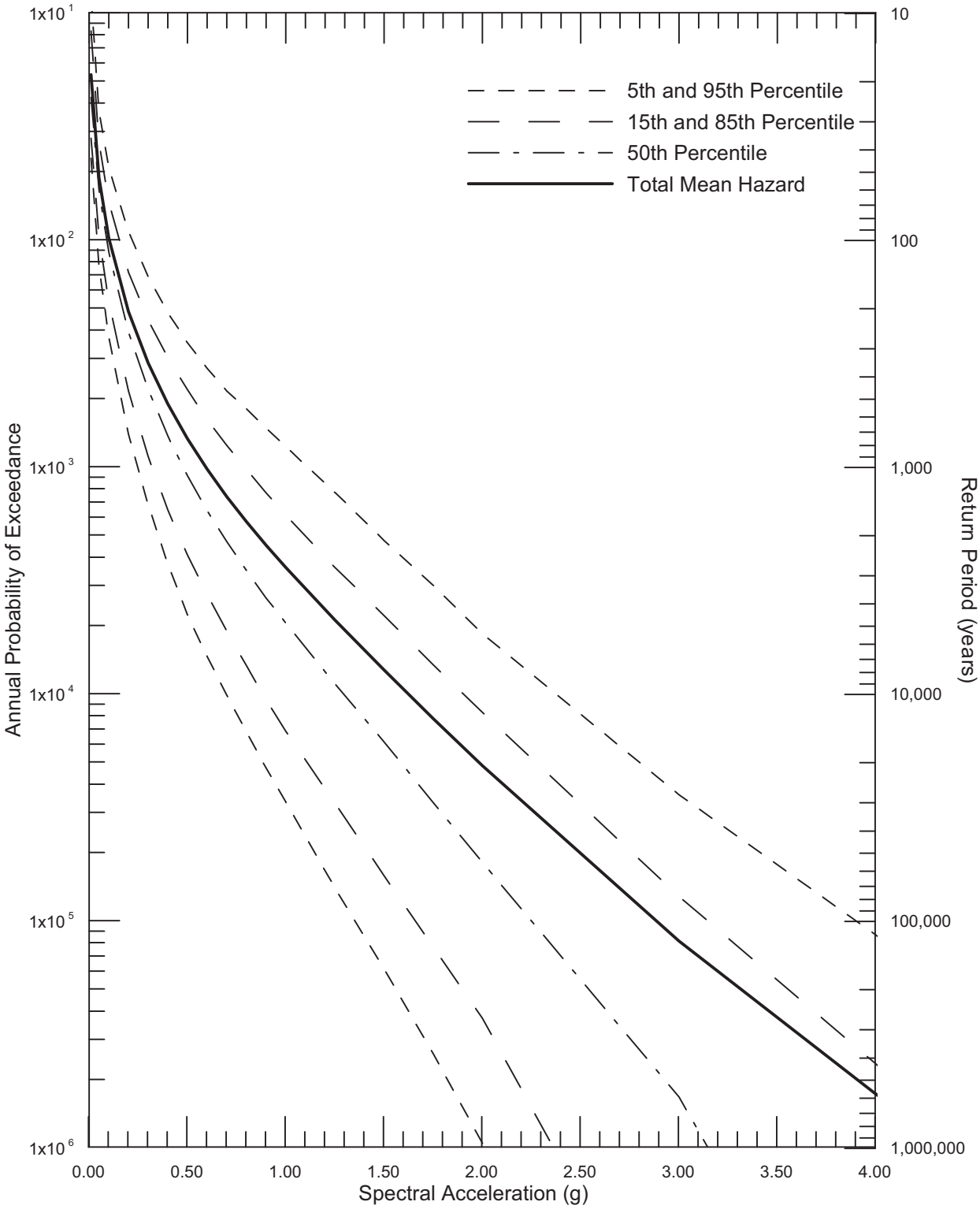
URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF NGA 25,000-YEAR RETURN PERIOD UHS WITH 2007 UHS	Figure 5



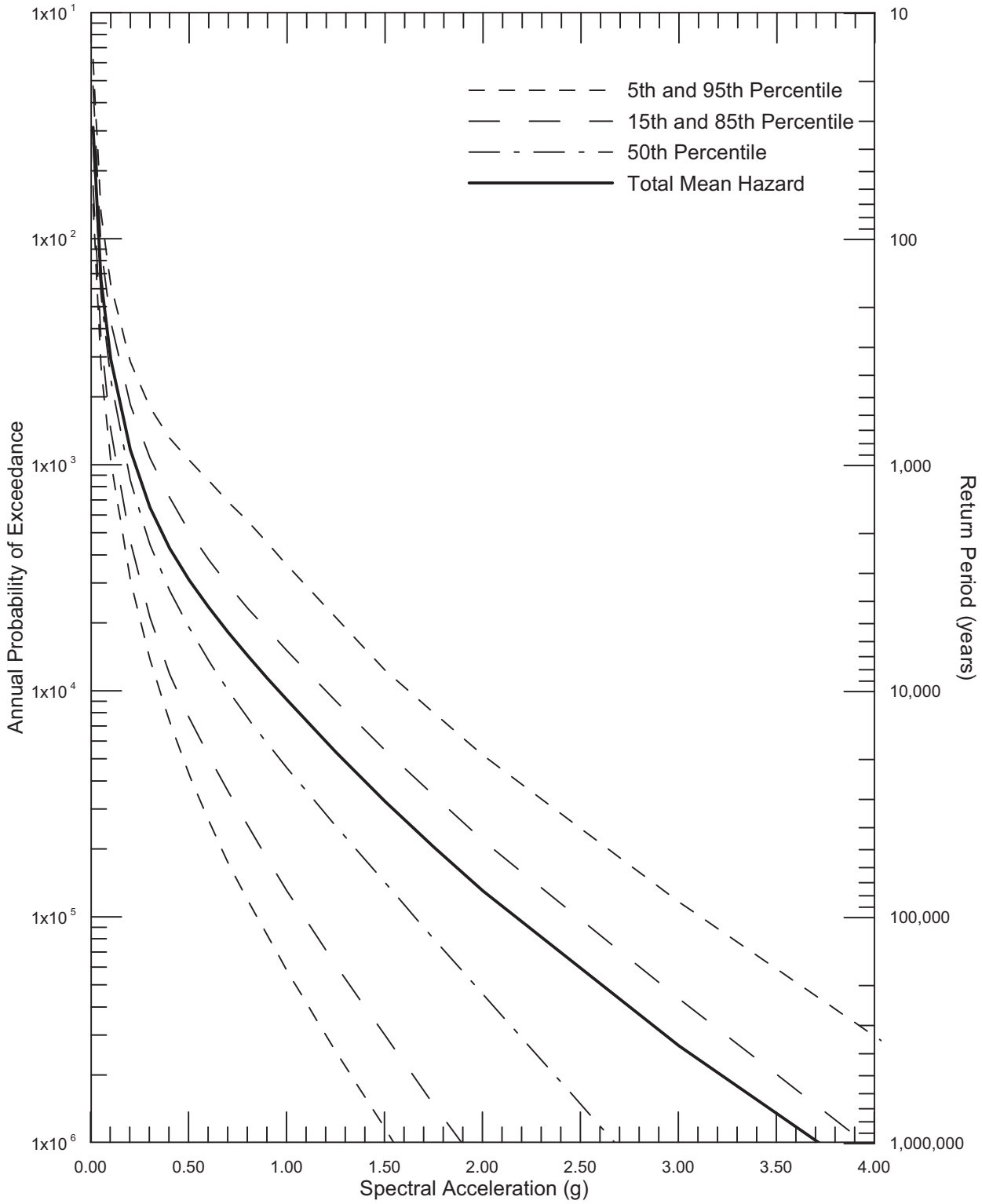
URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF NGA 100,000-YEAR RETURN PERIOD UHS WITH 2007 UHS	Figure 6



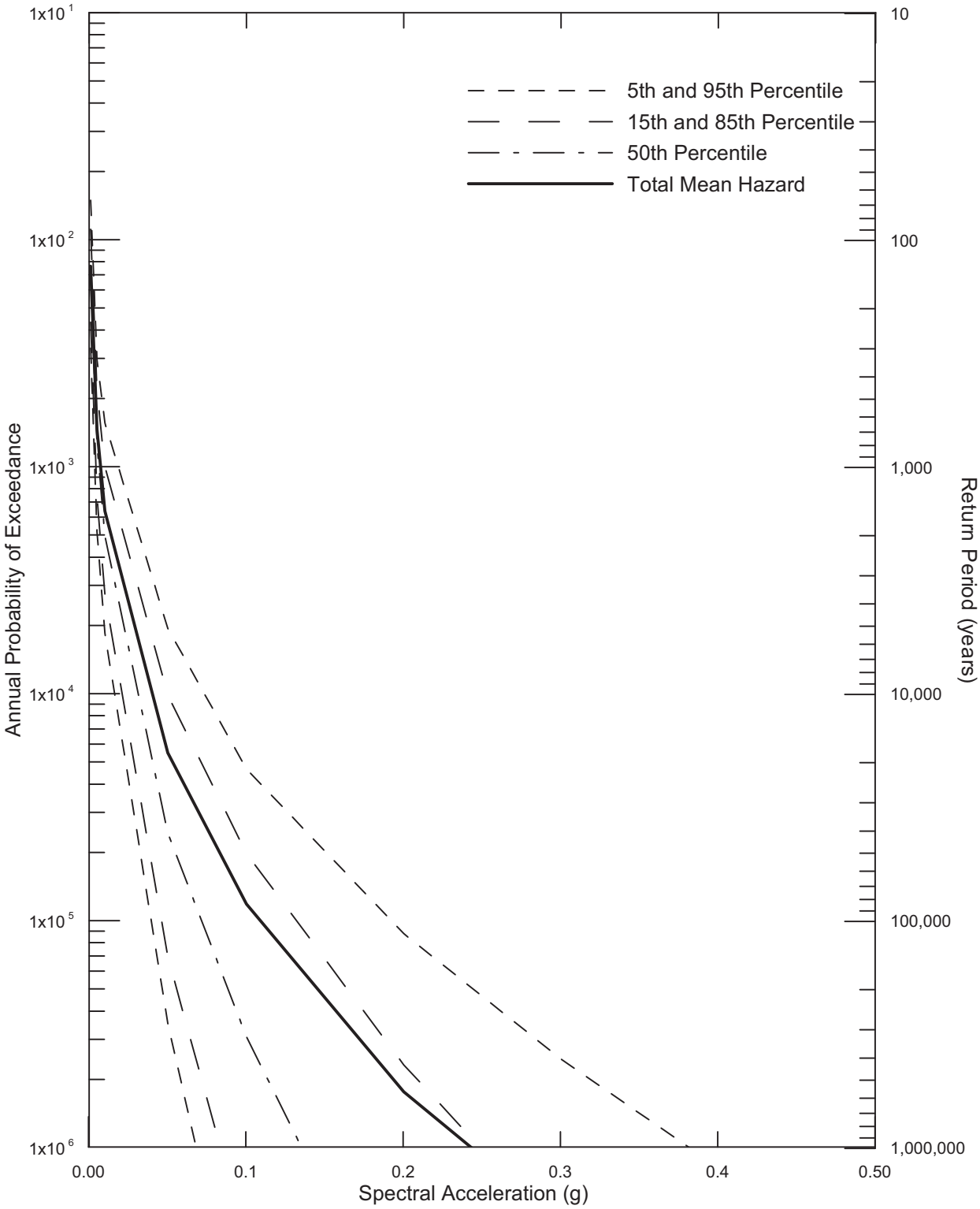
URS	Project No. 26817259	SEISMIC HAZARD CURVES FOR PEAK HORIZONTAL ACCELERATION, CMRR - NGA	Figure 7
	Los Alamos National Lab		



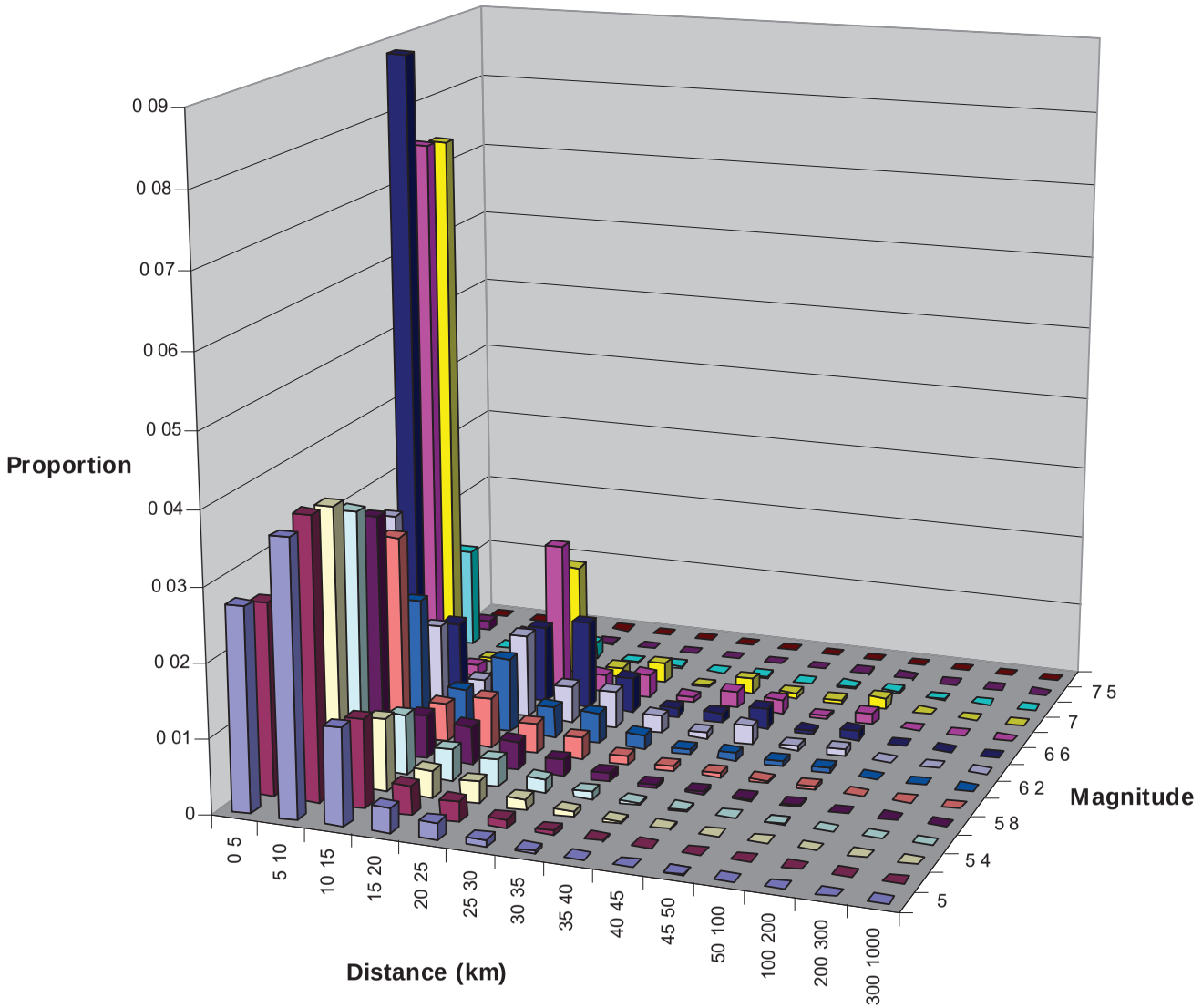
URS	Project No. 26817259 Los Alamos National Lab	SEISMIC HAZARD CURVES FOR 0.2 SEC HORIZONTAL SPECTRAL ACCELERATION, CMRR - NGA	Figure 8



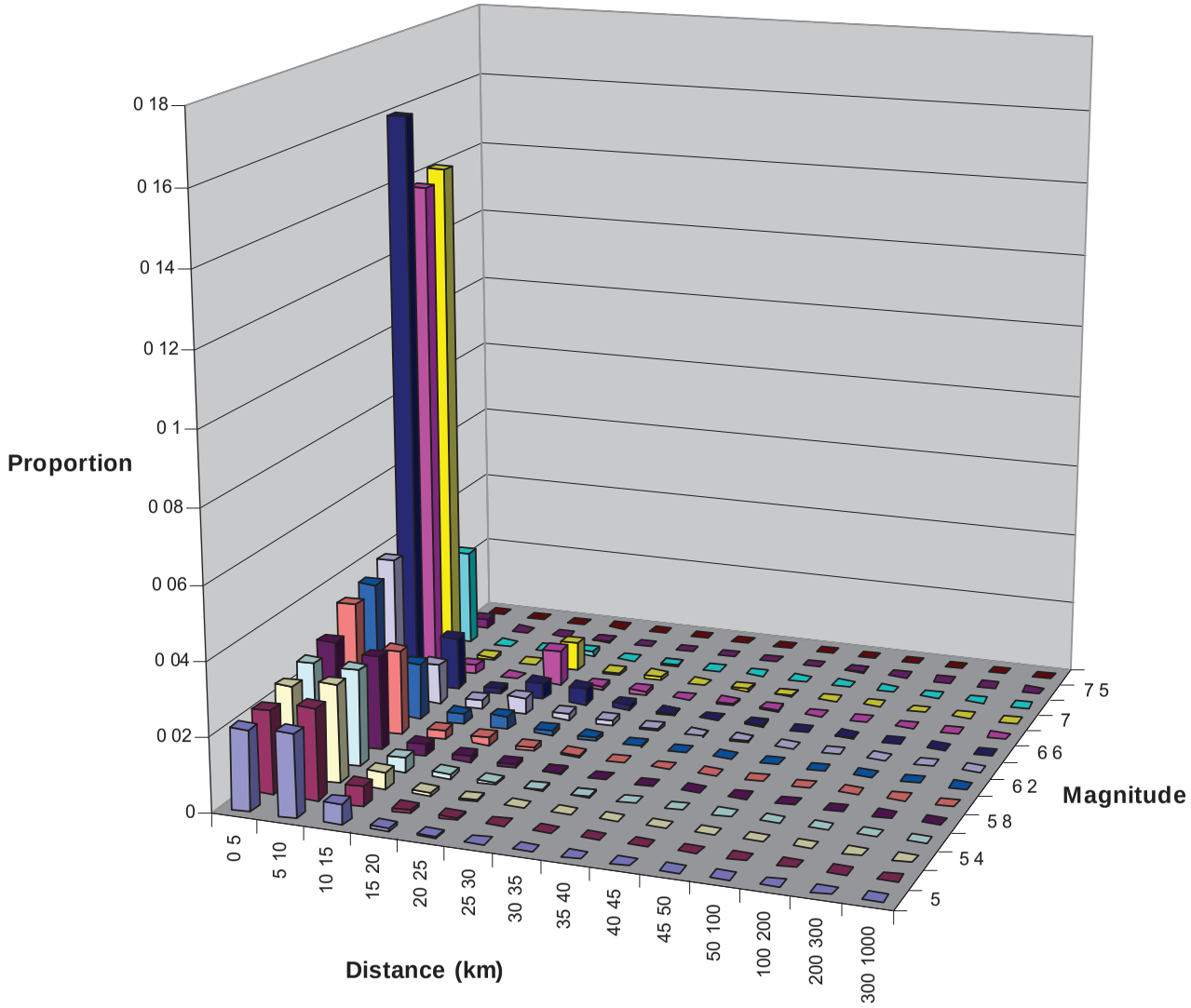
URS	Project No. 26817259 Los Alamos National Lab	SEISMIC HAZARD CURVES FOR 1.0 SEC HORIZONTAL SPECTRAL ACCELERATION, CMRR - NGA	Figure 9



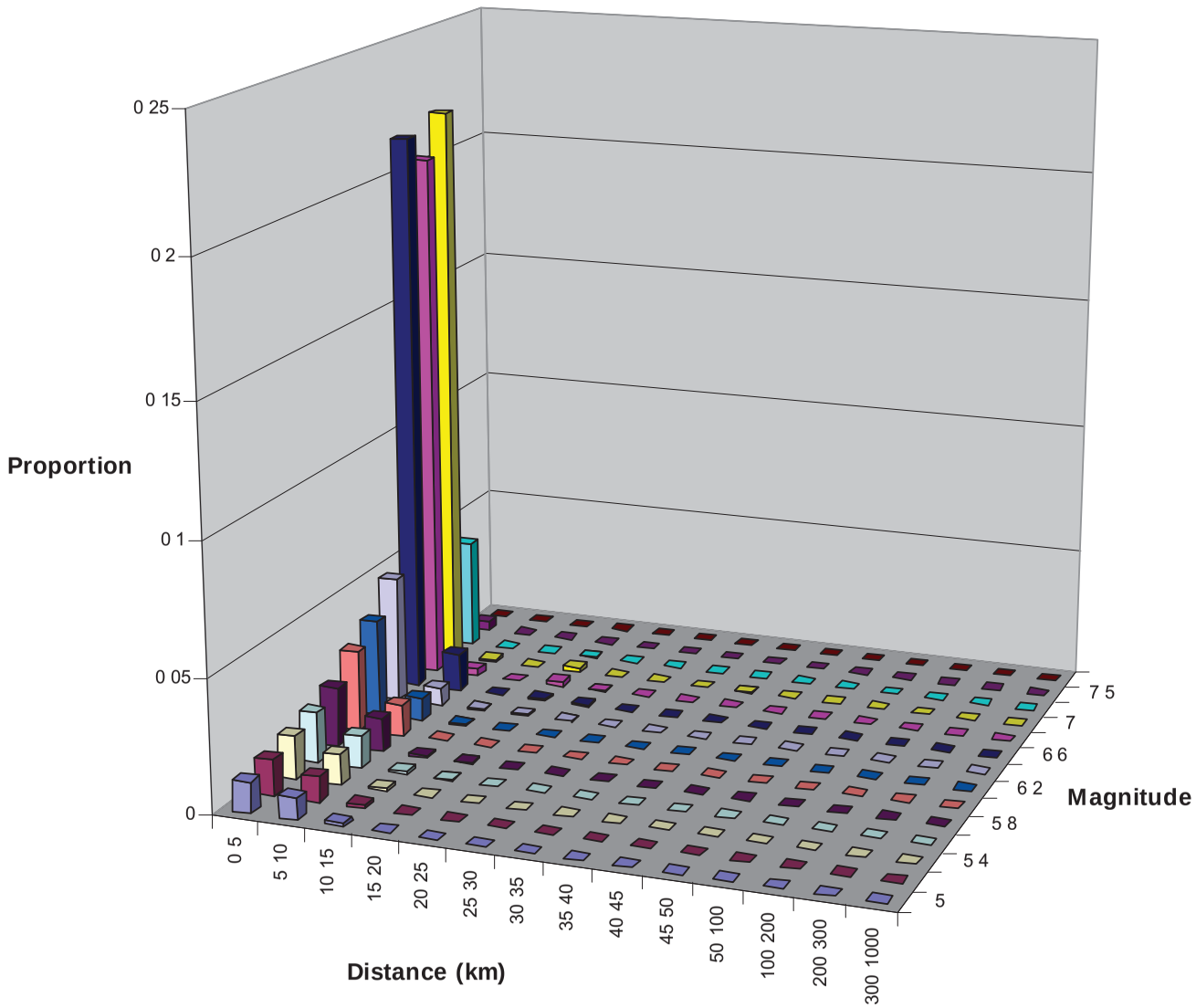
URS	Project No. 26817259 Los Alamos National Lab	SEISMIC HAZARD CURVES FOR 10.0 SEC HORIZONTAL SPECTRAL ACCELERATION, CMRR - NGA	Figure 10



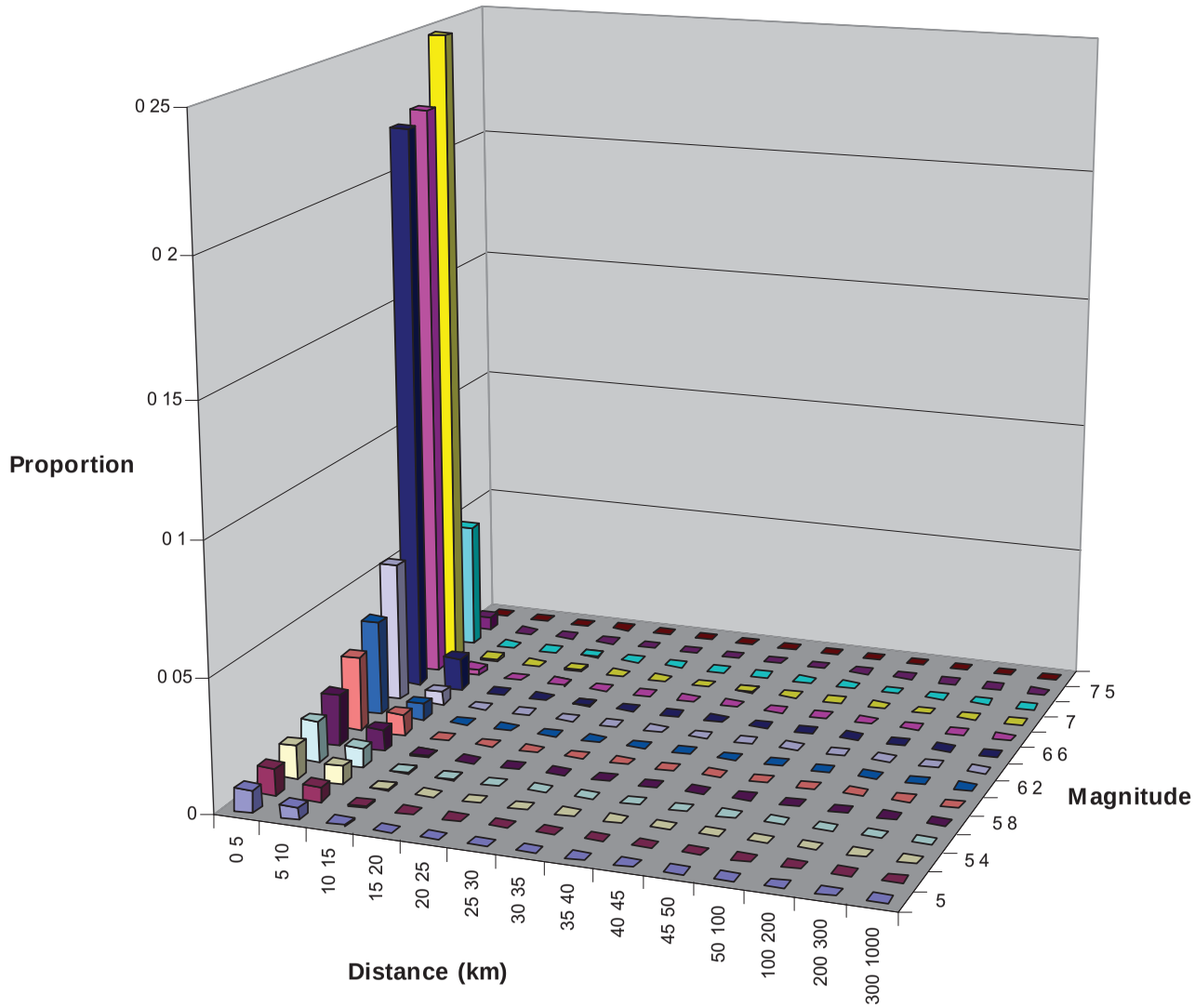
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN PEAK HORIZONTAL ACCELERATION HAZARD AT 1,000-YEAR RETURN PERIOD CMRR - NGA	Figure 11



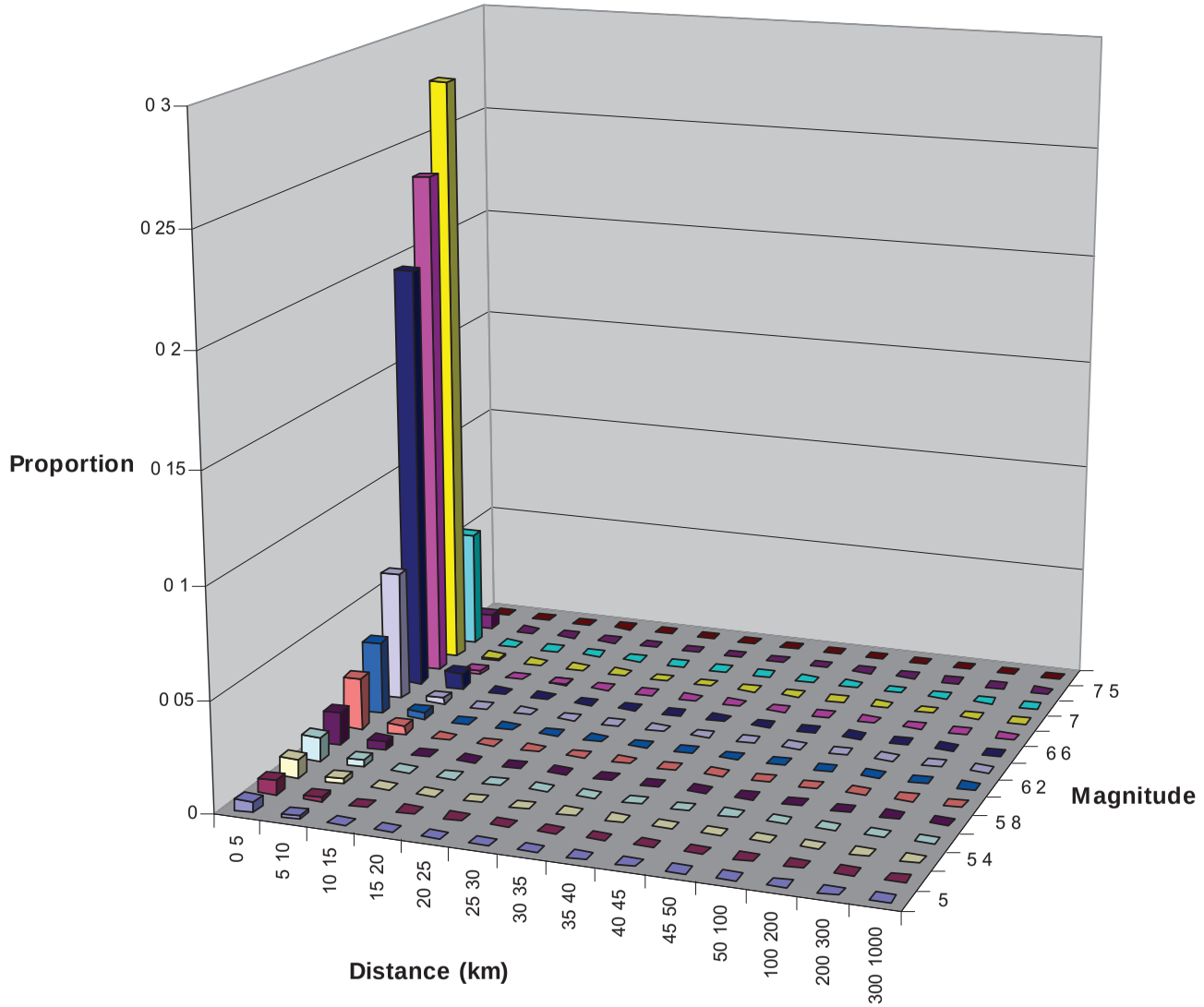
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN PEAK HORIZONTAL ACCELERATION HAZARD AT 2,500-YEAR RETURN PERIOD CMRR - NGA	Figure 12



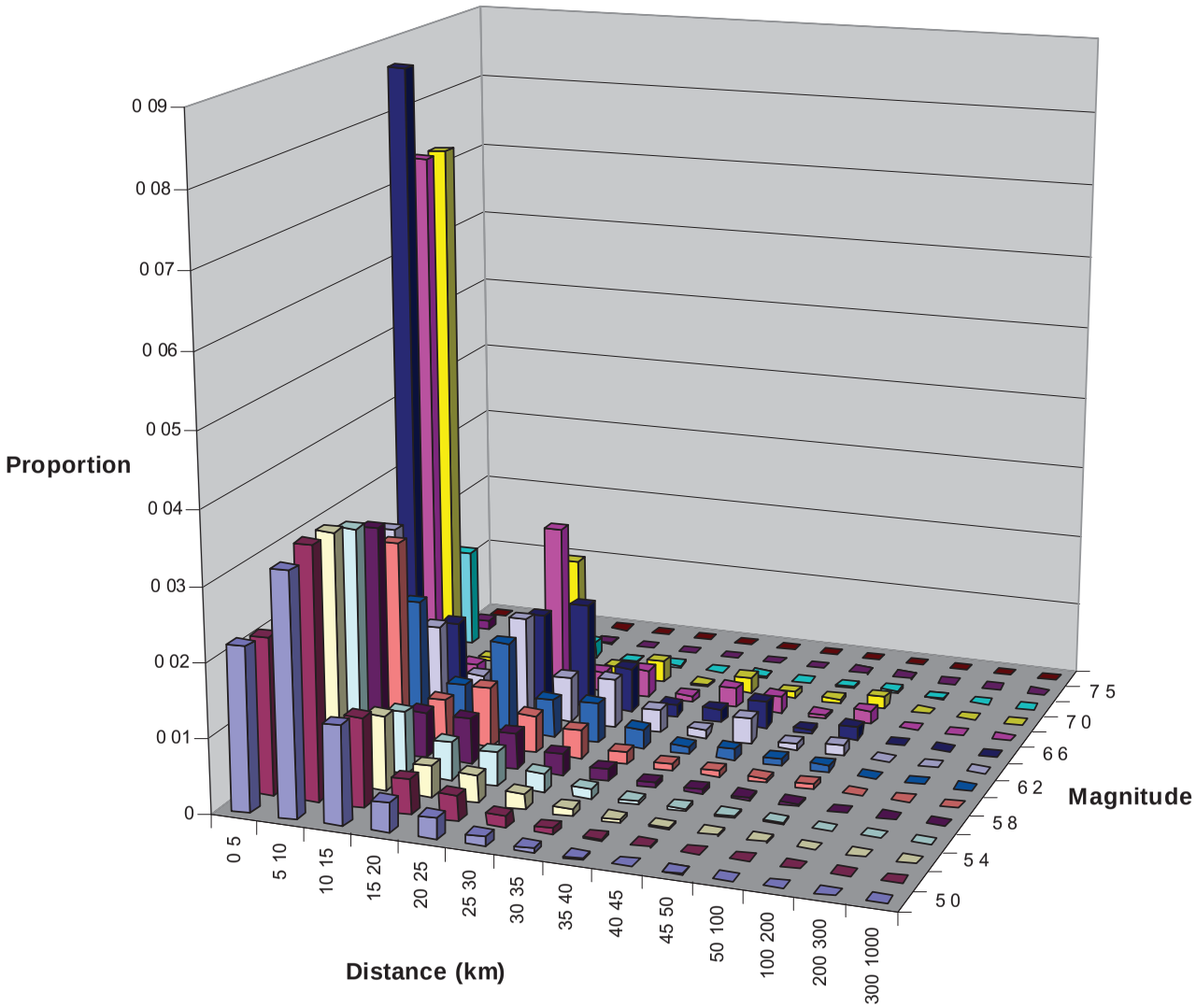
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN PEAK HORIZONTAL ACCELERATION HAZARD AT 10,000-YEAR RETURN PERIOD CMRR - NGA	Figure 13



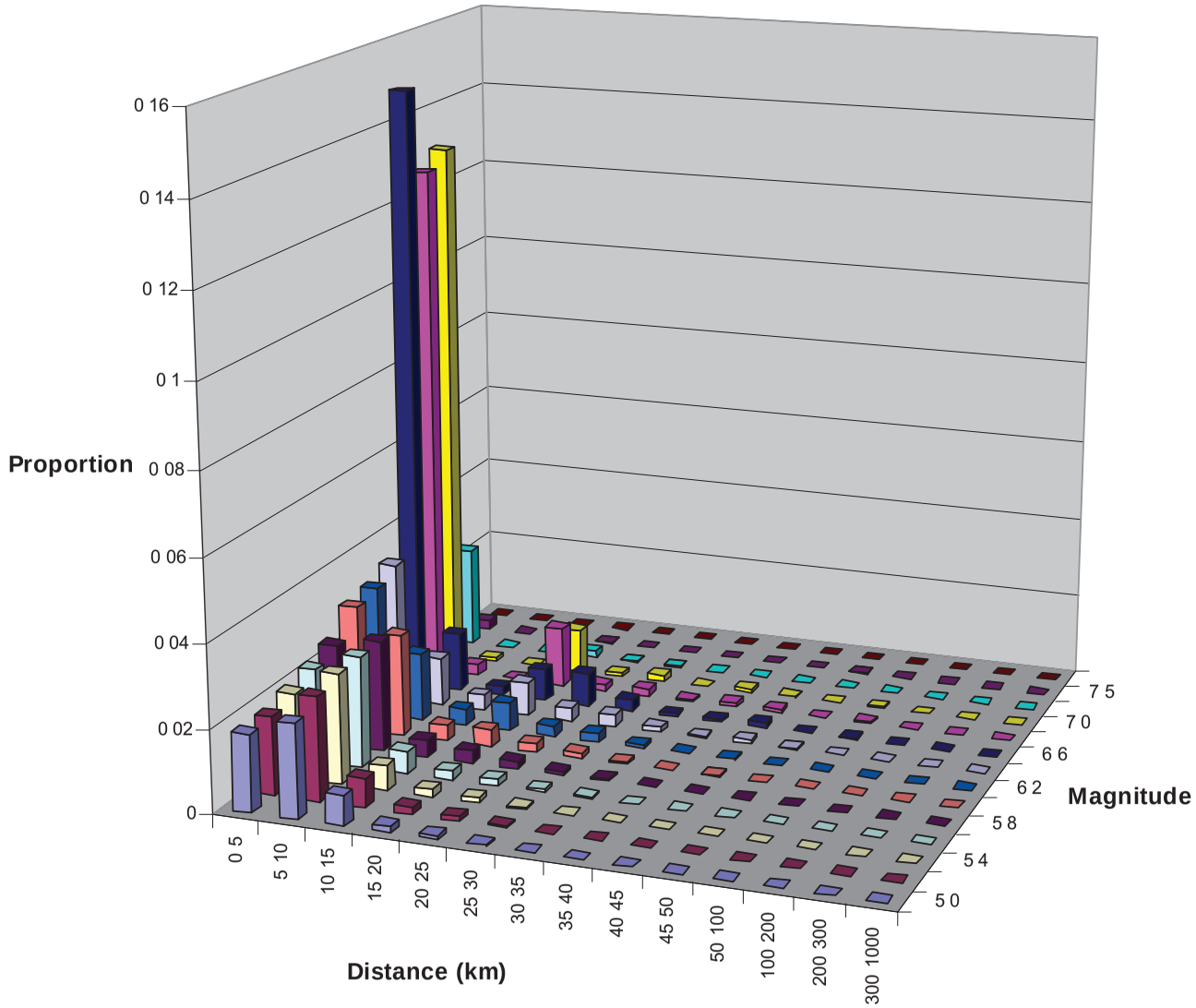
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN PEAK HORIZONTAL ACCELERATION HAZARD AT 25,000-YEAR RETURN PERIOD CMRR - NGA	Figure 14



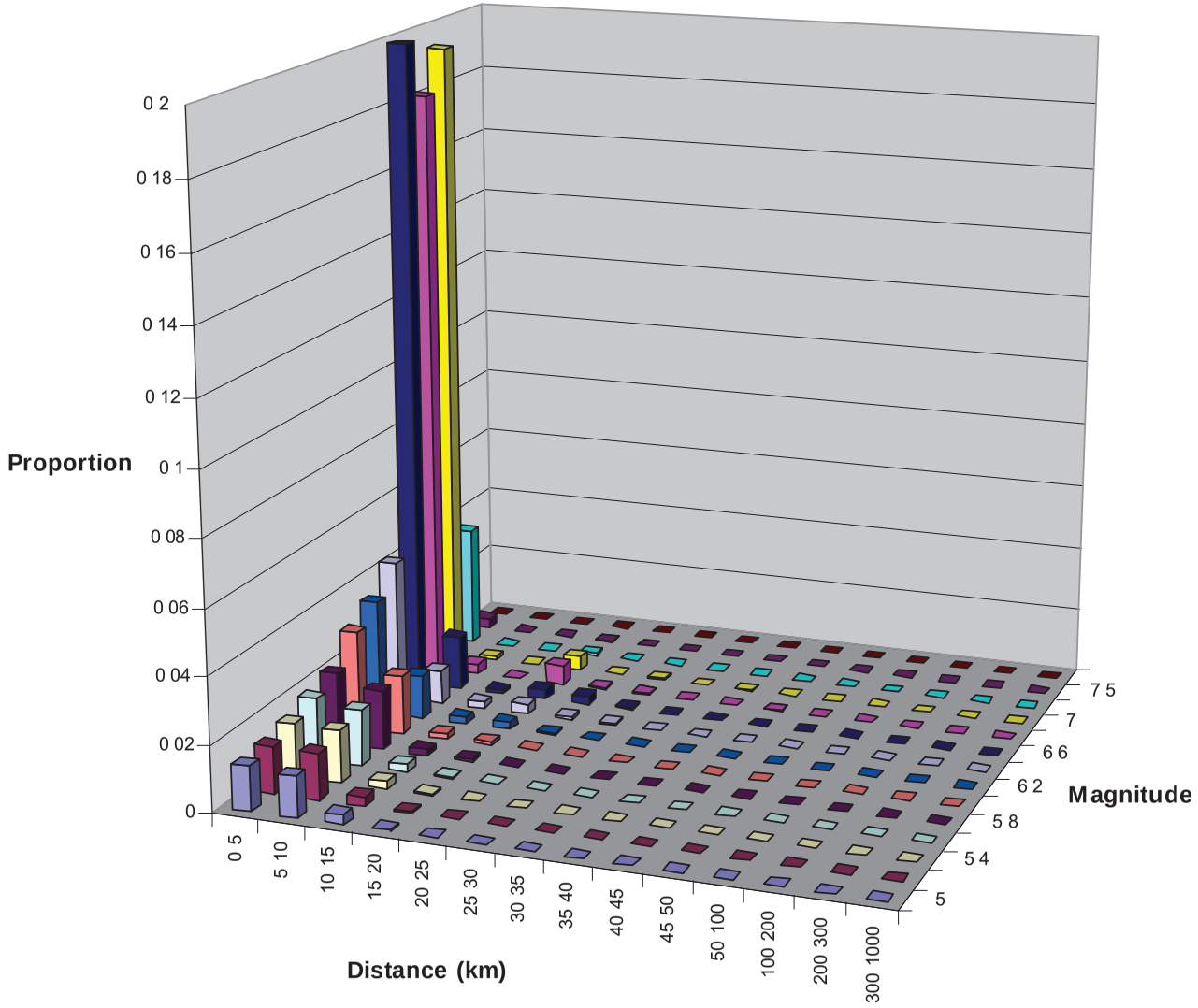
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN PEAK HORIZONTAL ACCELERATION HAZARD AT 100,000-YEAR RETURN PERIOD CMRR - NGA	Figure 15



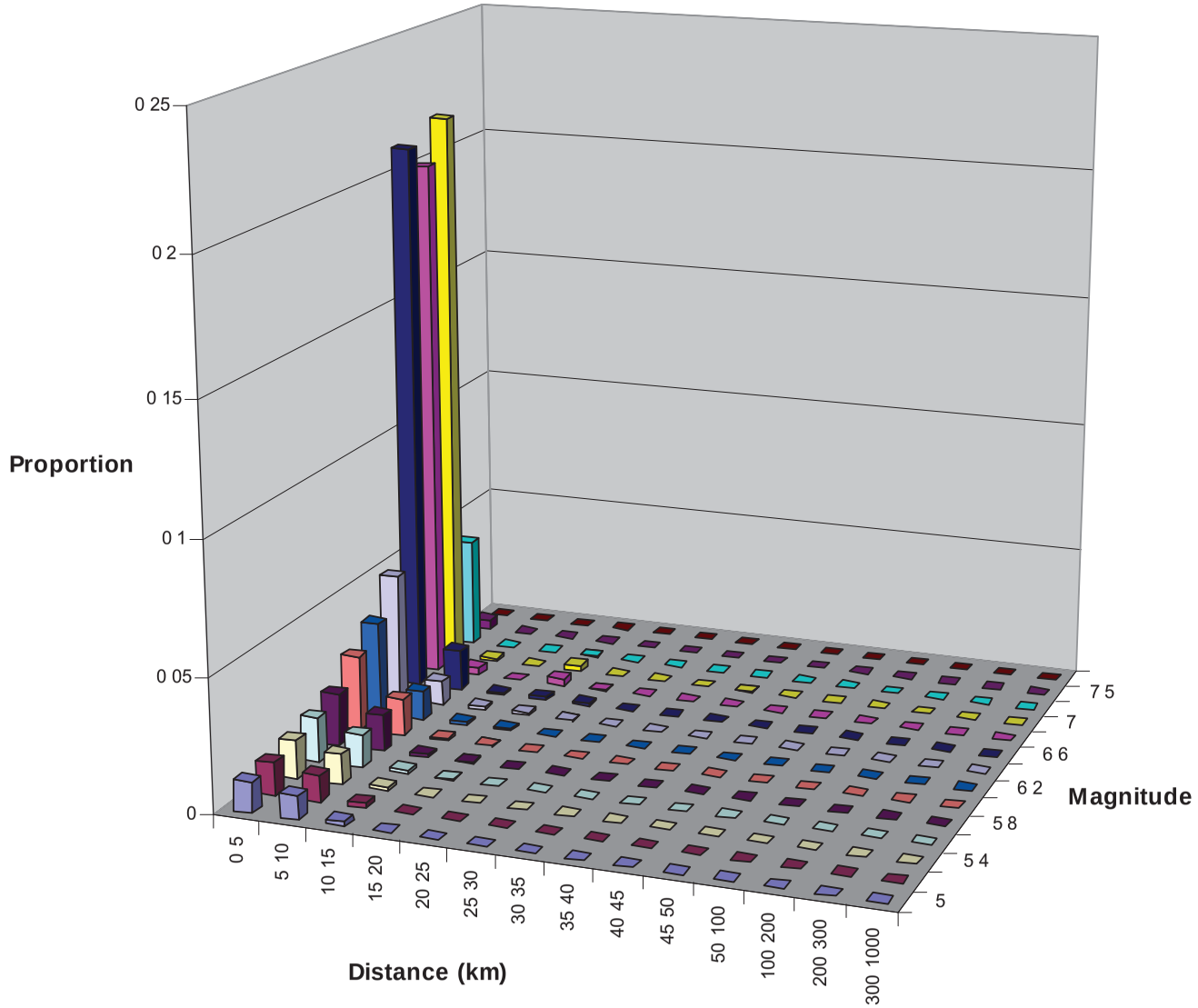
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN 0.2 SEC HORIZONTAL SPECTRAL ACCELERATION HAZARD AT 1,000-YEAR RETURN PERIOD, CMRR - NGA	Figure 16



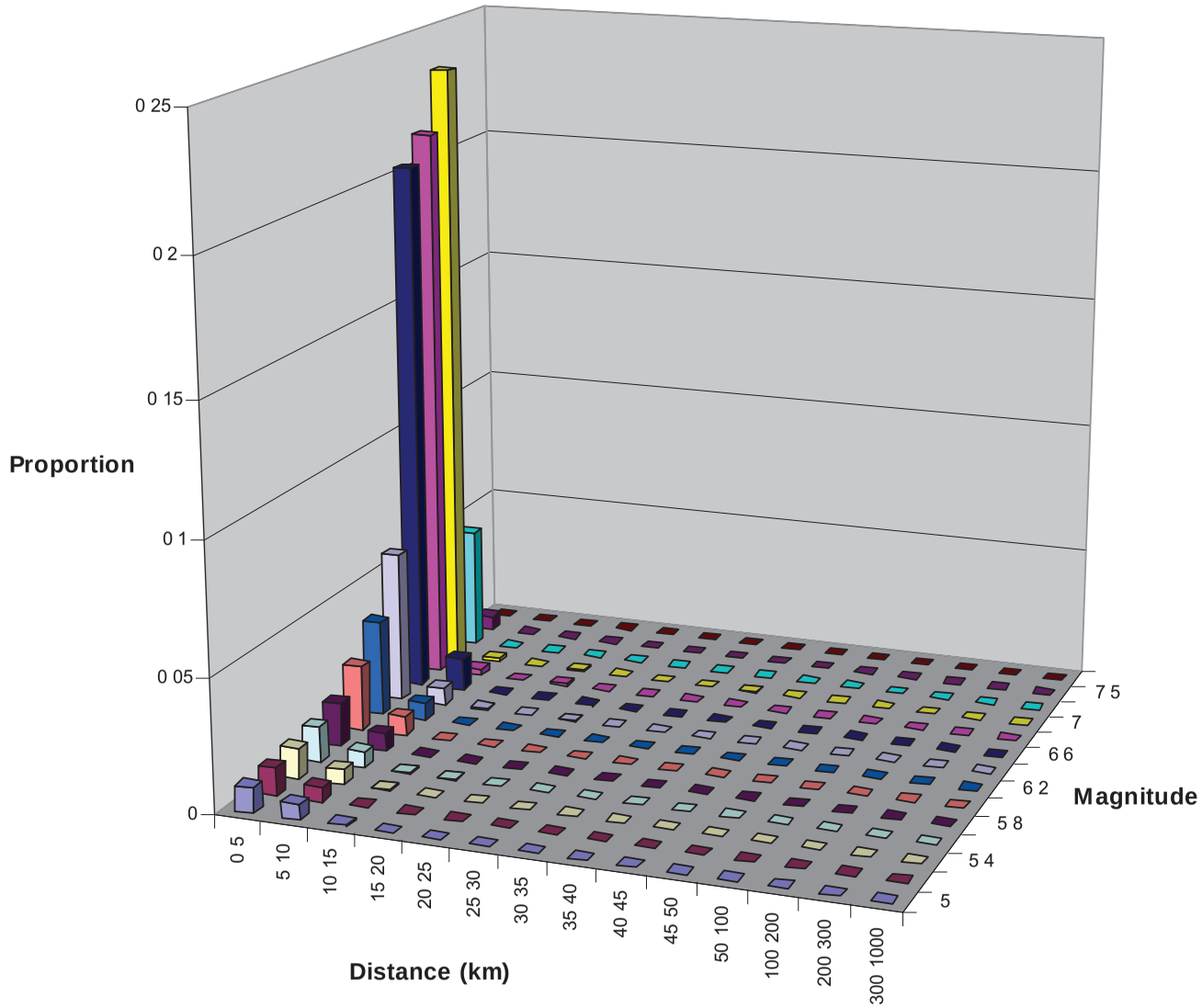
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN 0.2 SEC HORIZONTAL SPECTRAL ACCELERATION HAZARD AT 2,500-YEAR RETURN PERIOD, CMRR - NGA	Figure 17



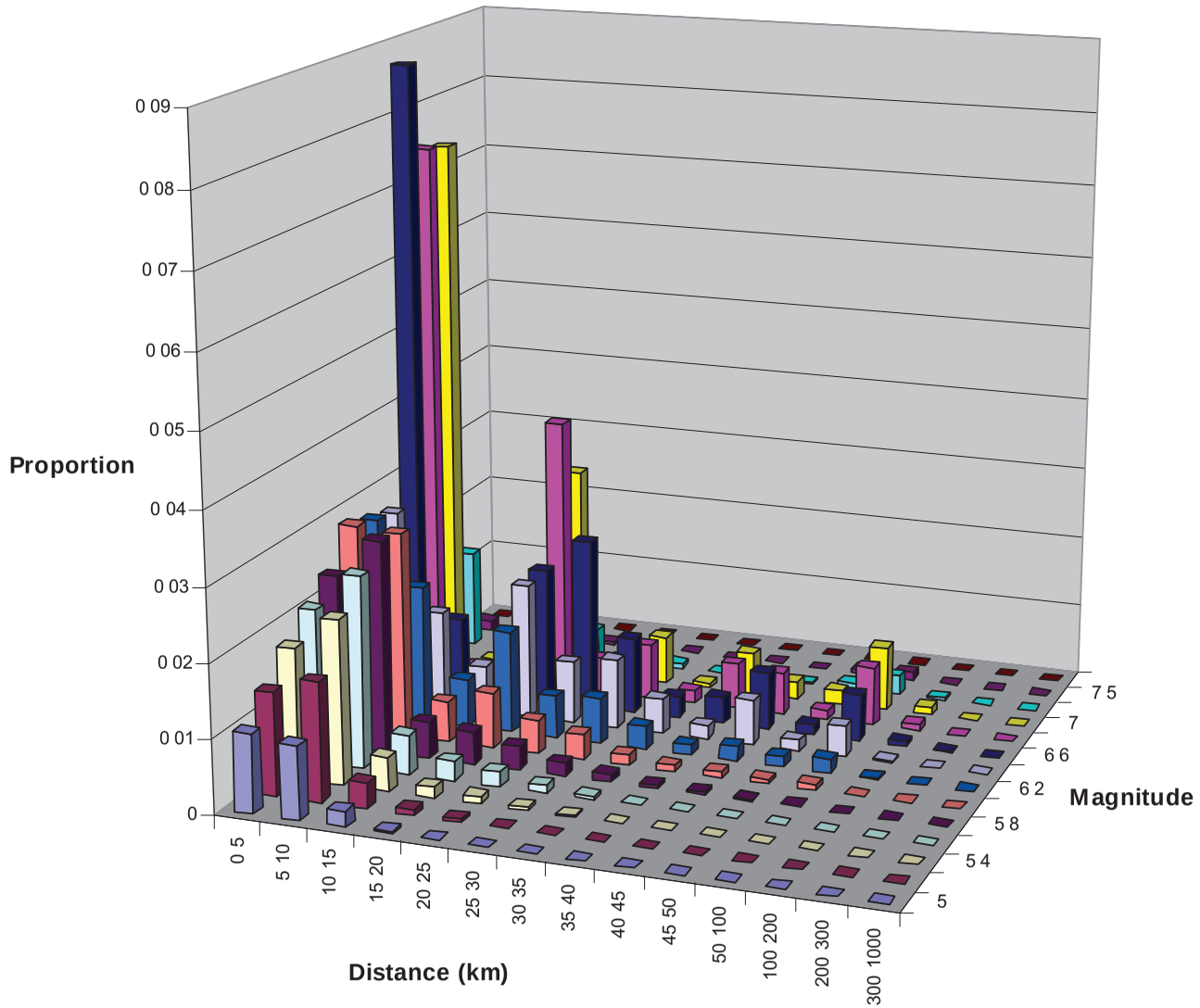
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN 0.2 SEC HORIZONTAL SPECTRAL ACCELERATION HAZARD AT 10,000-YEAR RETURN PERIOD, CMRR - NGA	Figure 18



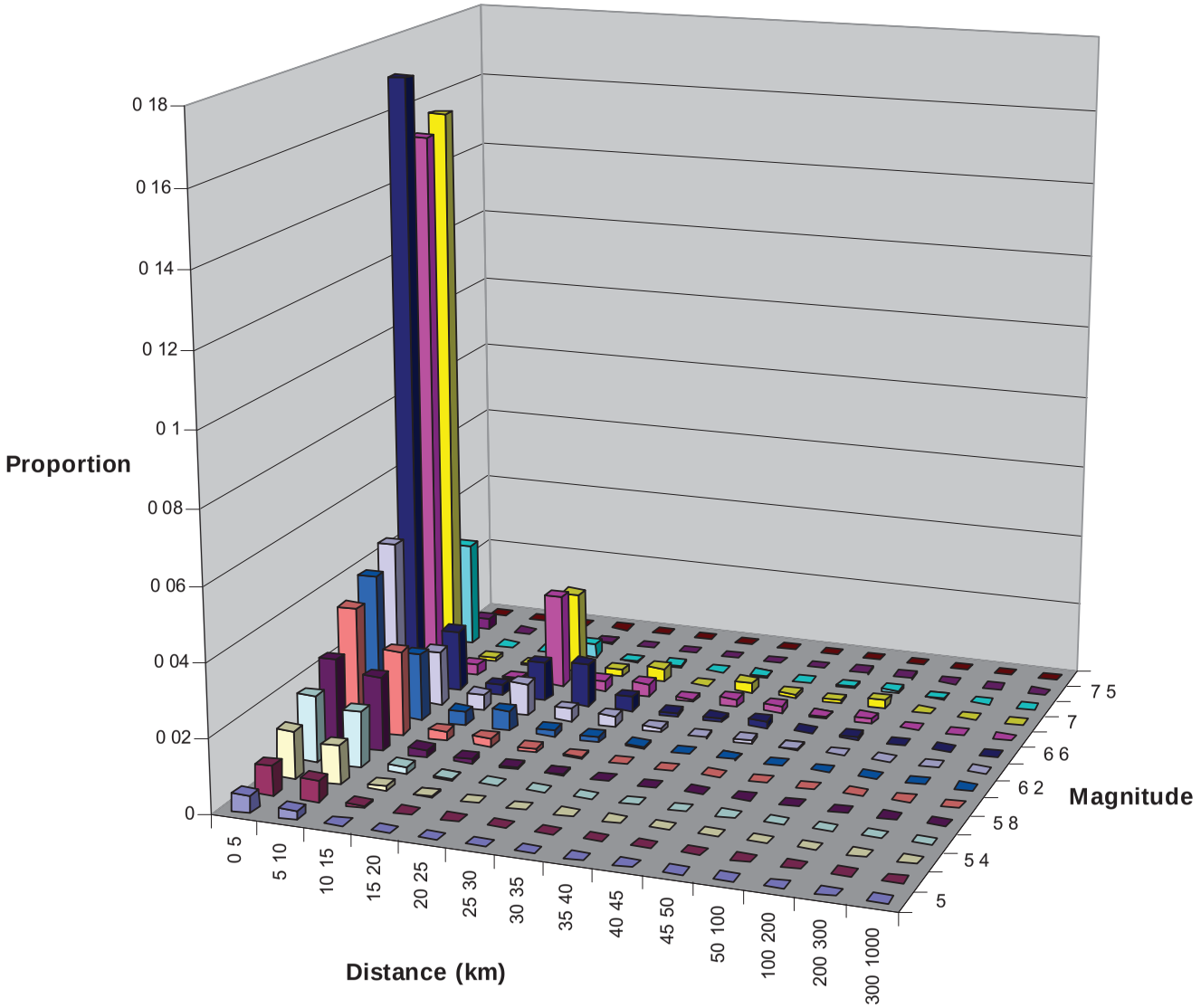
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN 0.2 SEC HORIZONTAL SPECTRAL ACCELERATION HAZARD AT 25,000-YEAR RETURN PERIOD, CMRR - NGA	Figure 19



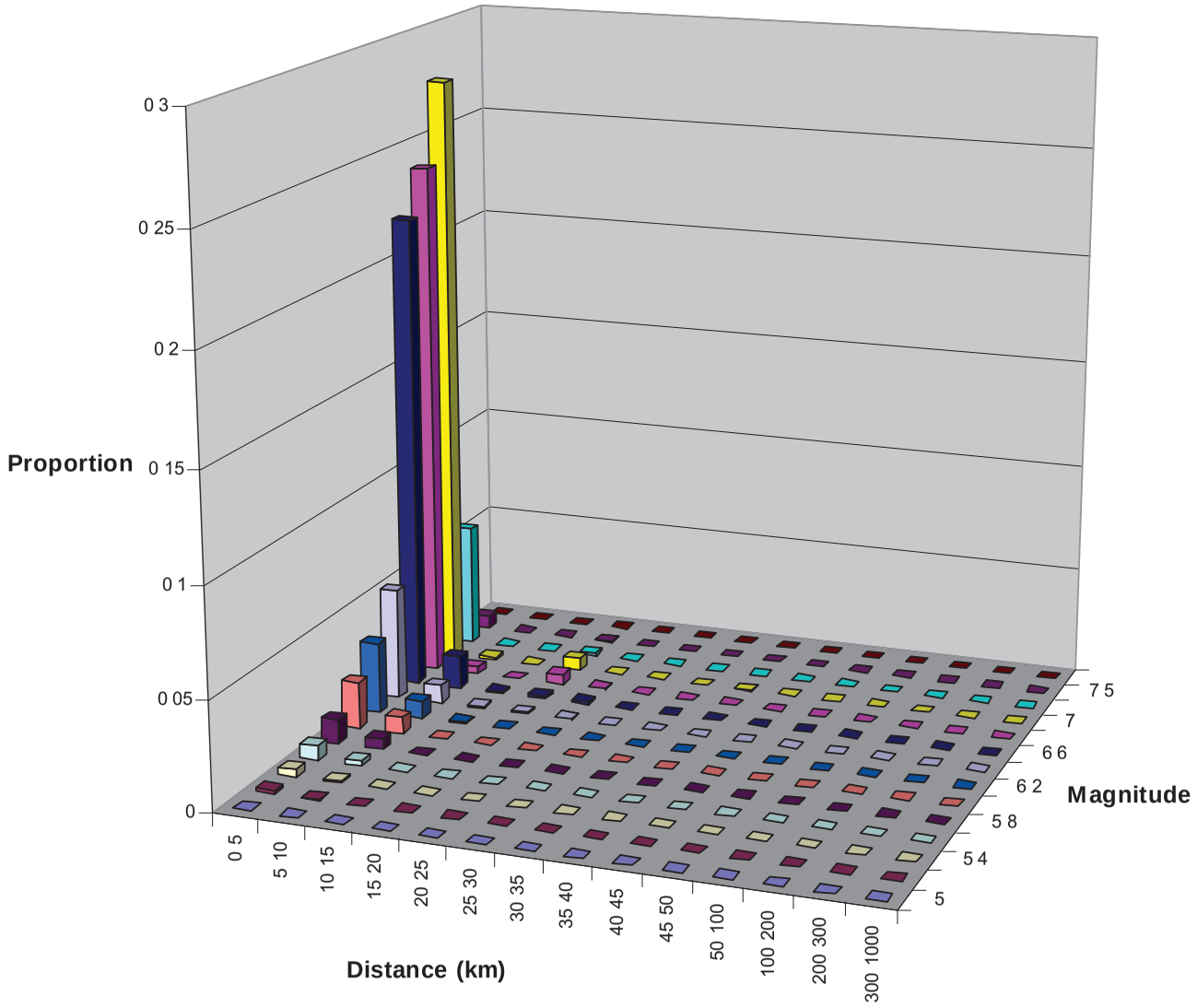
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN 0.2 SEC HORIZONTAL SPECTRAL ACCELERATION HAZARD AT 100,000-YEAR RETURN PERIOD, CMRR - NGA	Figure 20



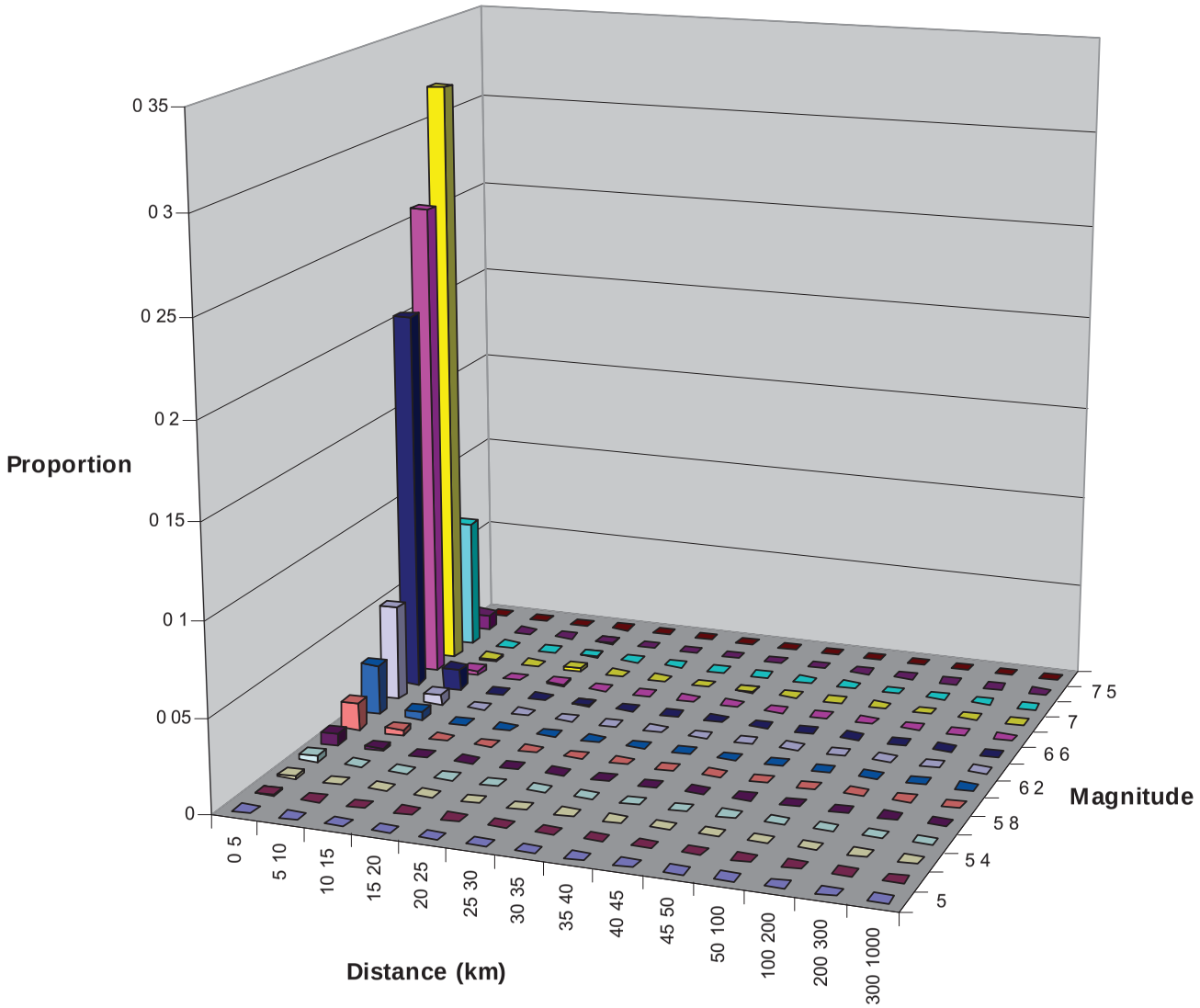
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN 1.0 SEC HORIZONTAL SPECTRAL ACCELERATION HAZARD AT 1,000-YEAR RETURN PERIOD, CMRR - NGA	Figure 21



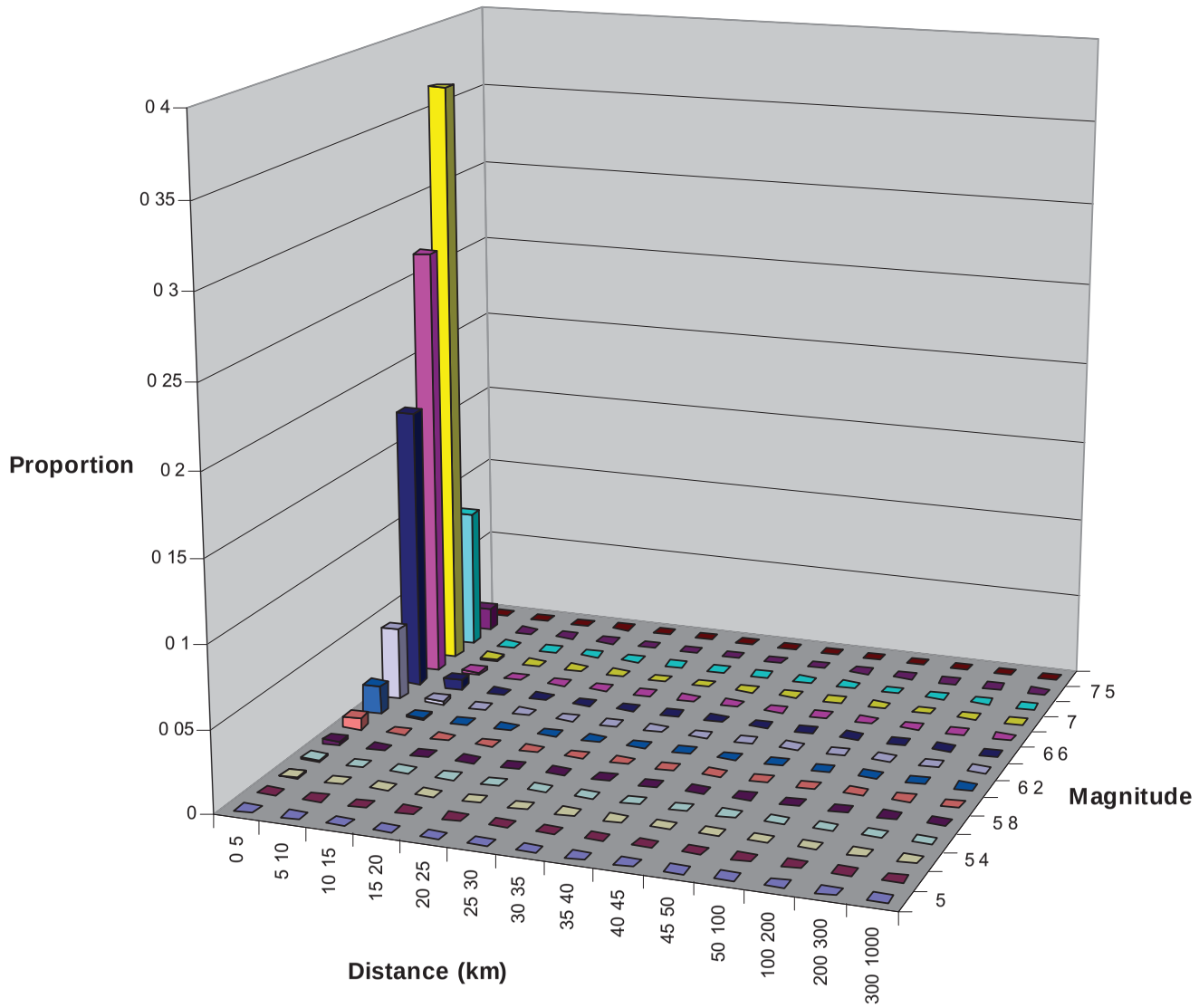
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN 1.0 SEC HORIZONTAL SPECTRAL ACCELERATION HAZARD AT 2,500-YEAR RETURN PERIOD, CMRR - NGA	Figure 22



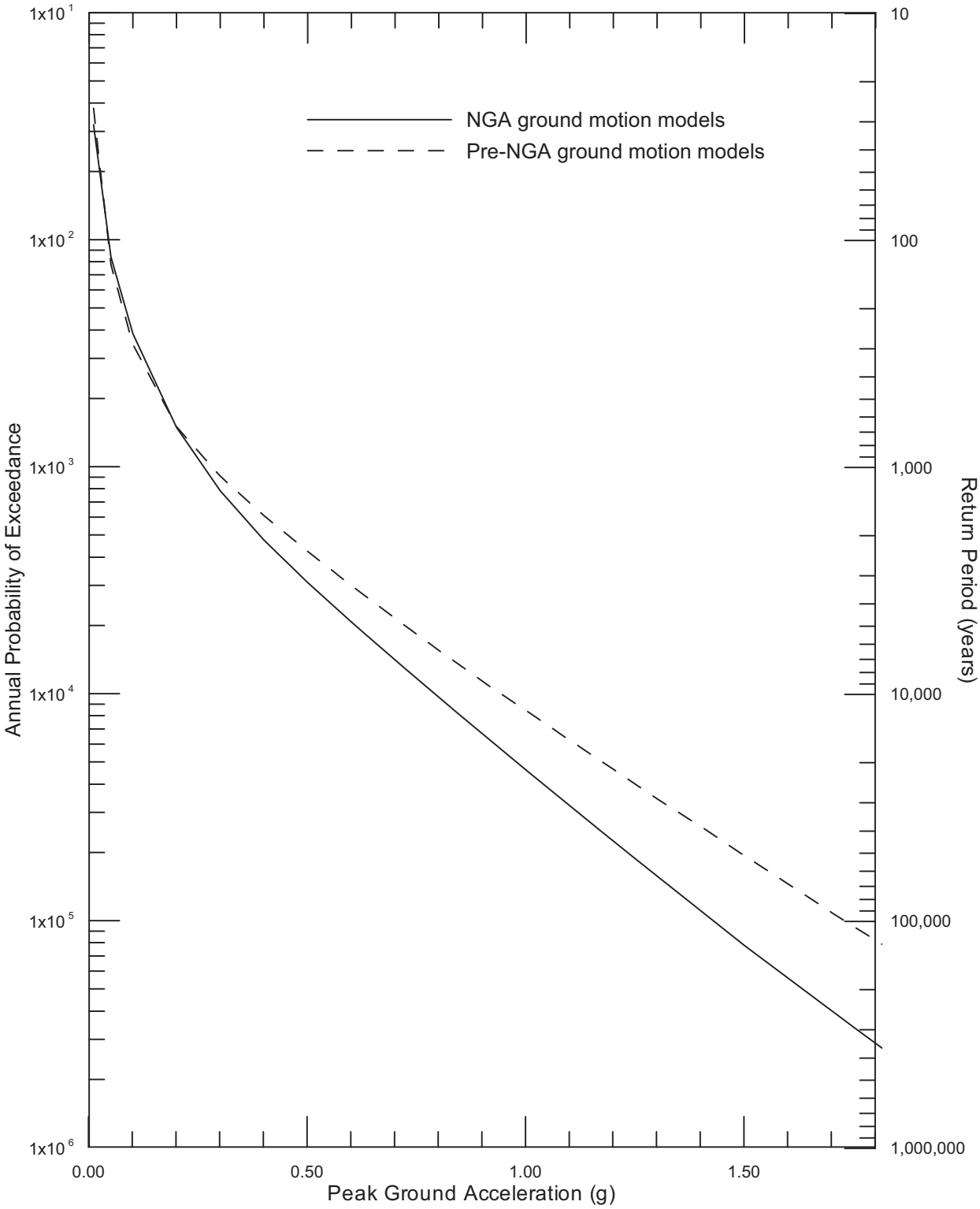
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN 1.0 SEC HORIZONTAL SPECTRAL ACCELERATION HAZARD AT 10,000-YEAR RETURN PERIOD, CMRR - NGA	Figure 23



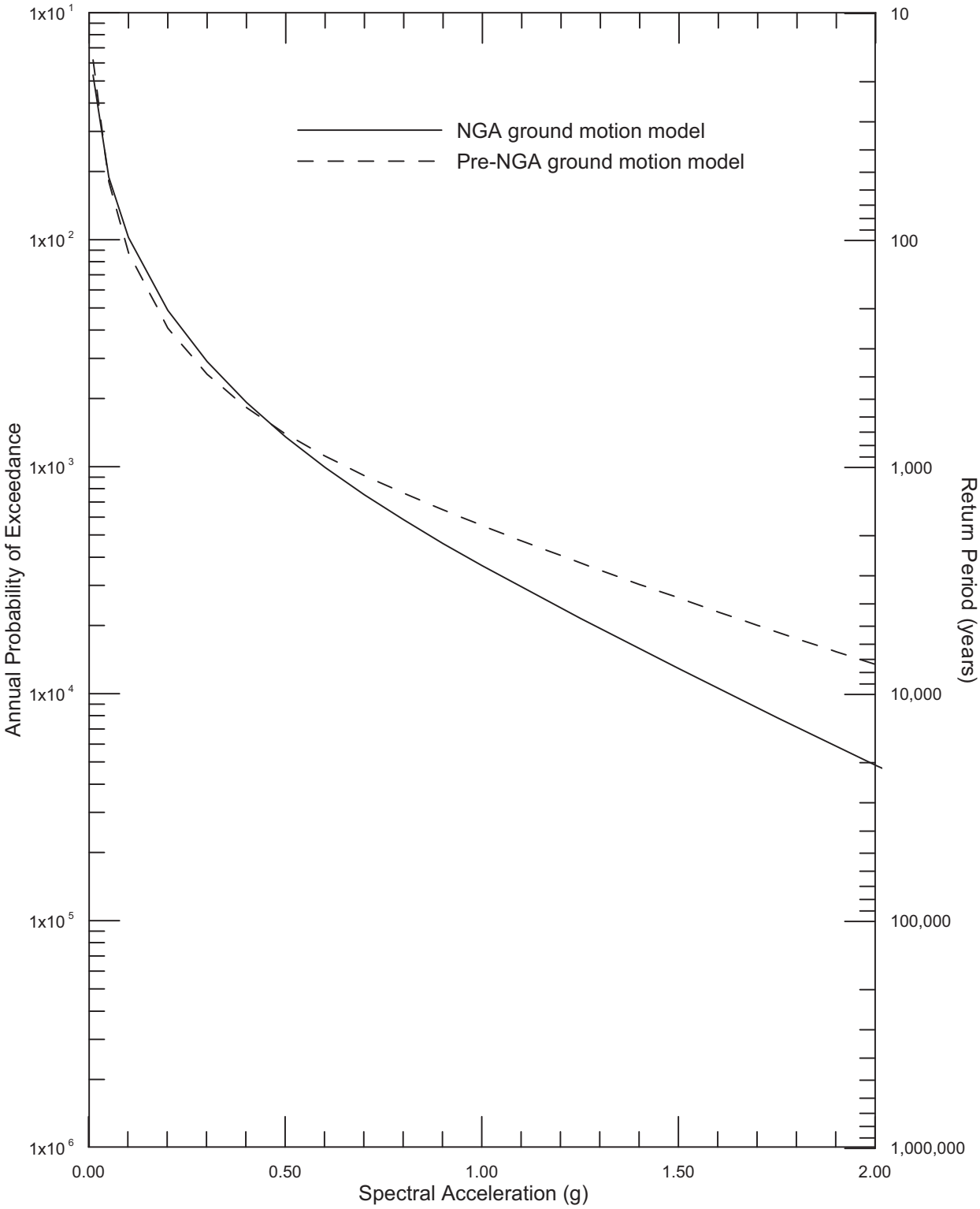
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN 1.0 SEC HORIZONTAL SPECTRAL ACCELERATION HAZARD AT 25,000-YEAR RETURN PERIOD, CMRR - NGA	Figure 24



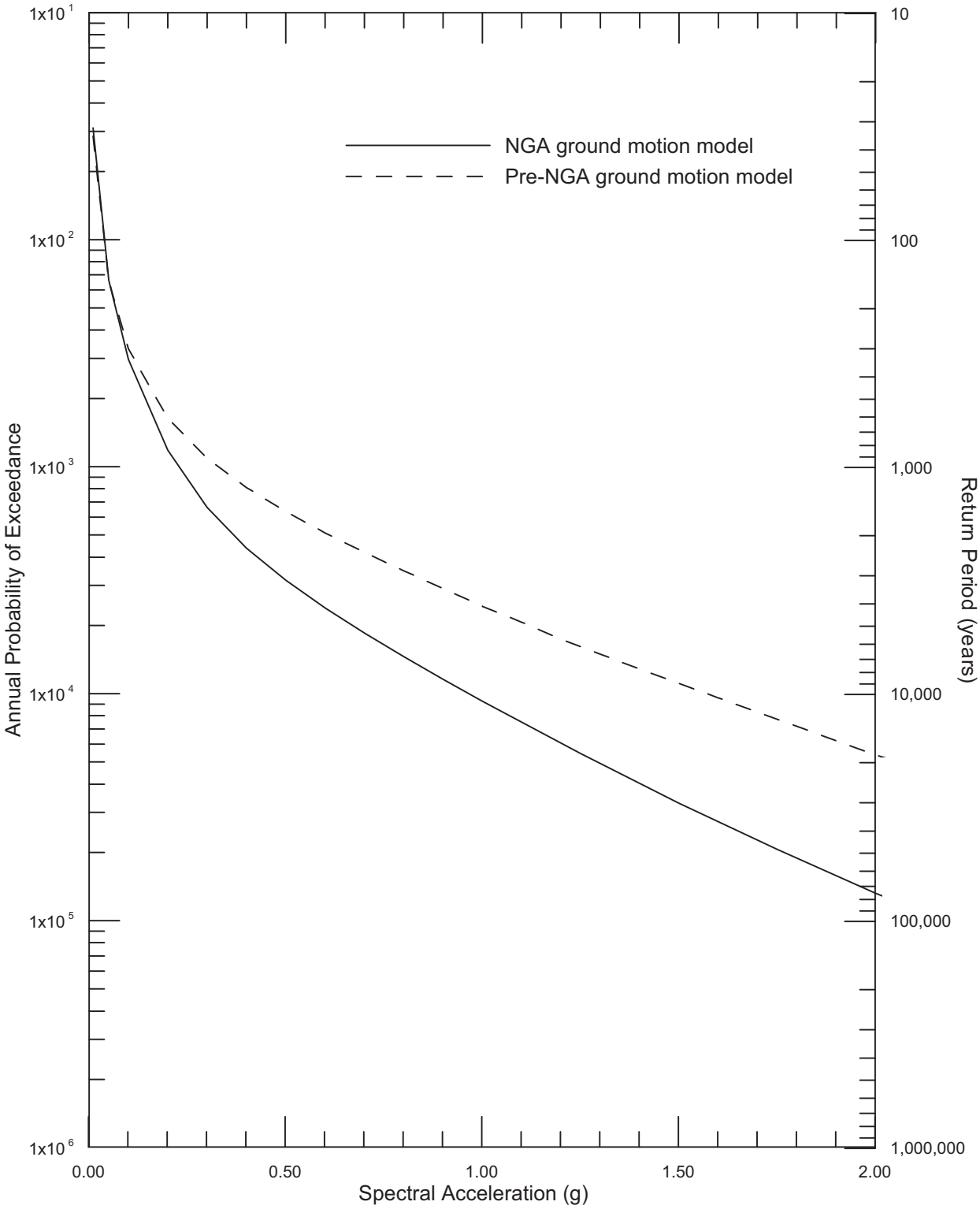
URS	Project No. 26817259 Los Alamos National Lab	MAGNITUDE AND DISTANCE CONTRIBUTIONS TO THE MEAN 1.0 SEC HORIZONTAL SPECTRAL ACCELERATION HAZARD AT 100,000-YEAR RETURN PERIOD, CMRR - NGA	Figure 25



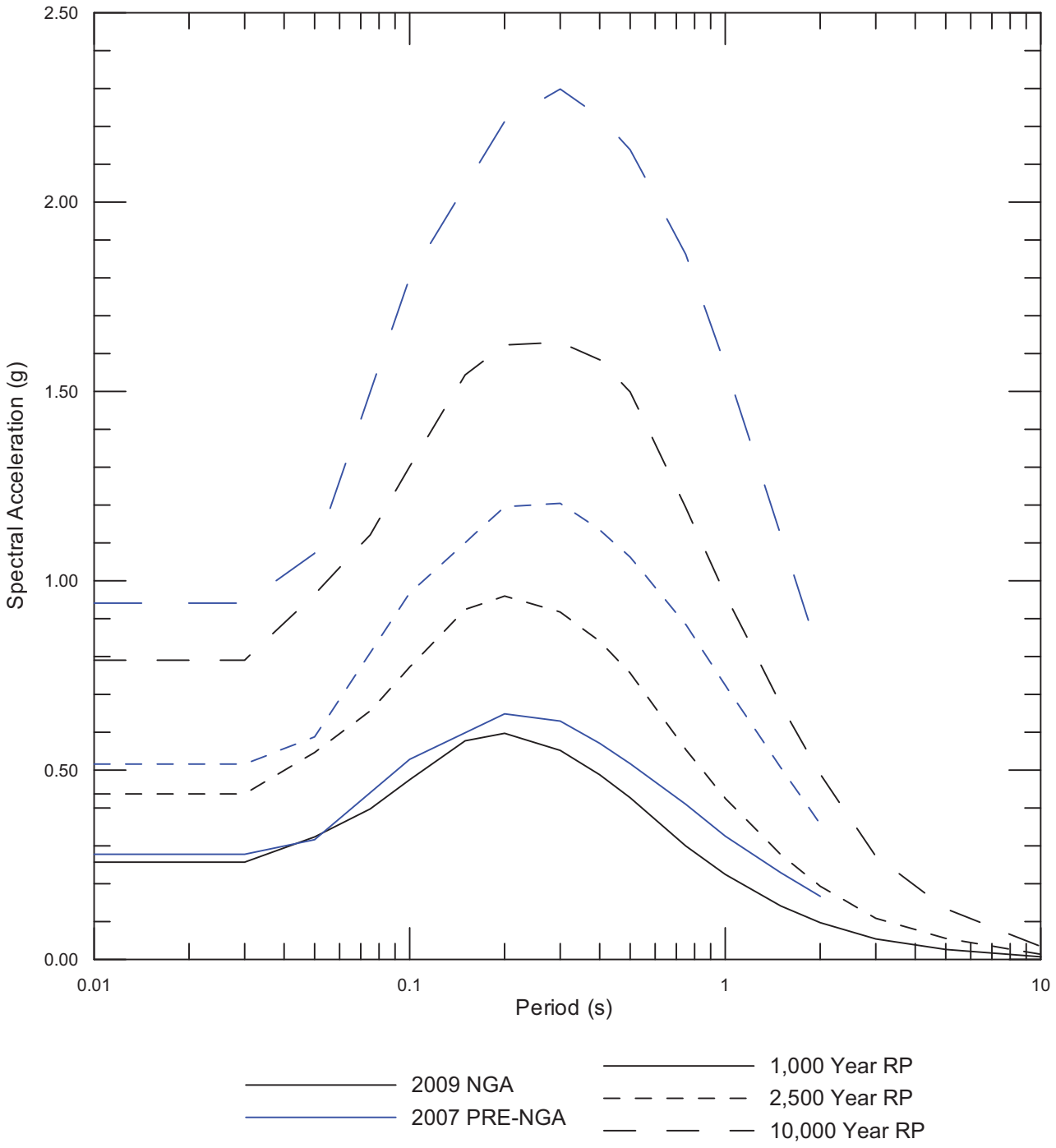
URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF PRE-NGA AND NGA SEISMIC HAZARD CURVES FOR PEAK HORIZONTAL ACCELERATION, CMRR	Figure 26



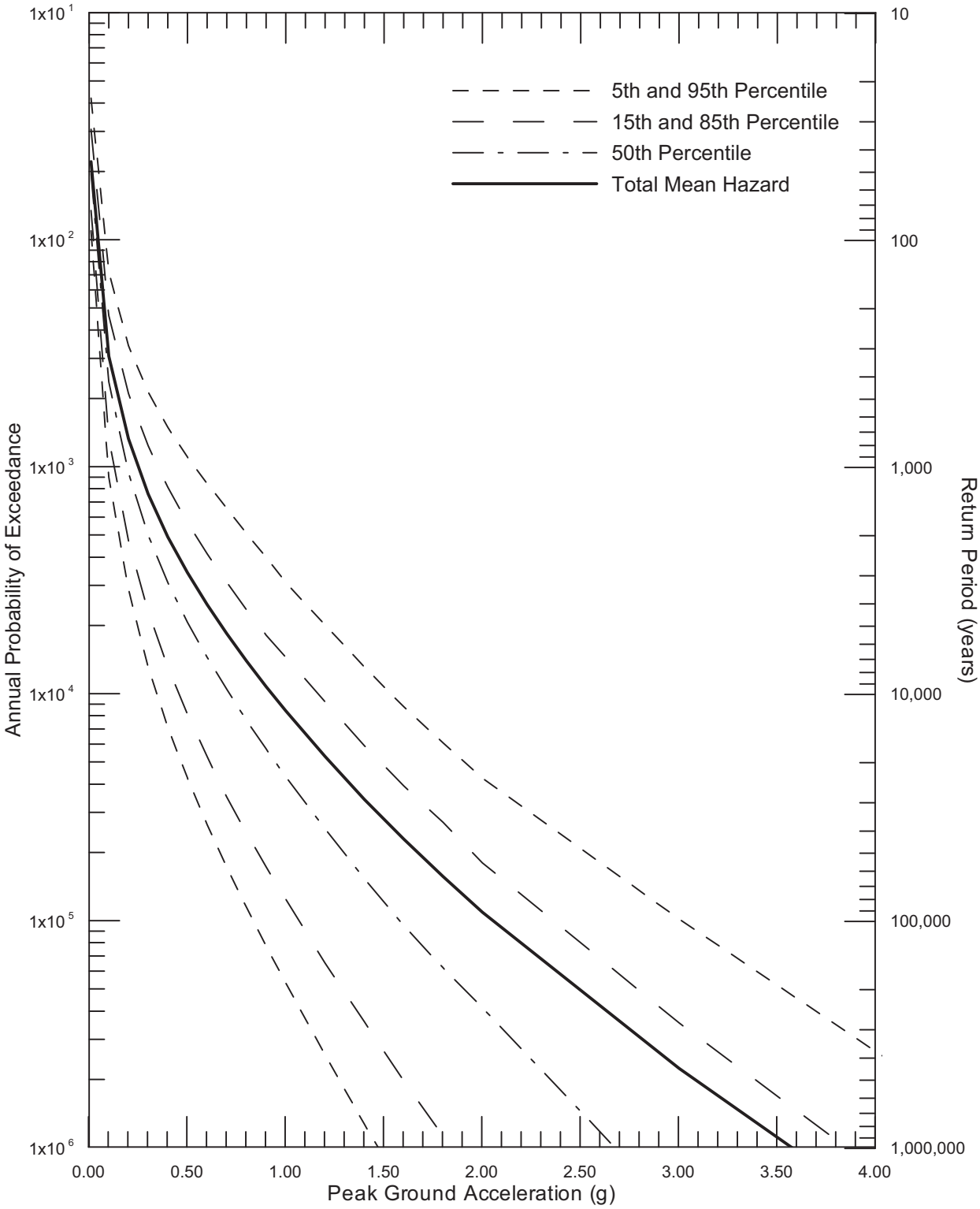
URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF PRE-NGA AND NGA SEISMIC HAZARD CURVES FOR 0.2 SEC HORIZONTAL SPECTRAL ACCELERATION, CMRR	Figure 27



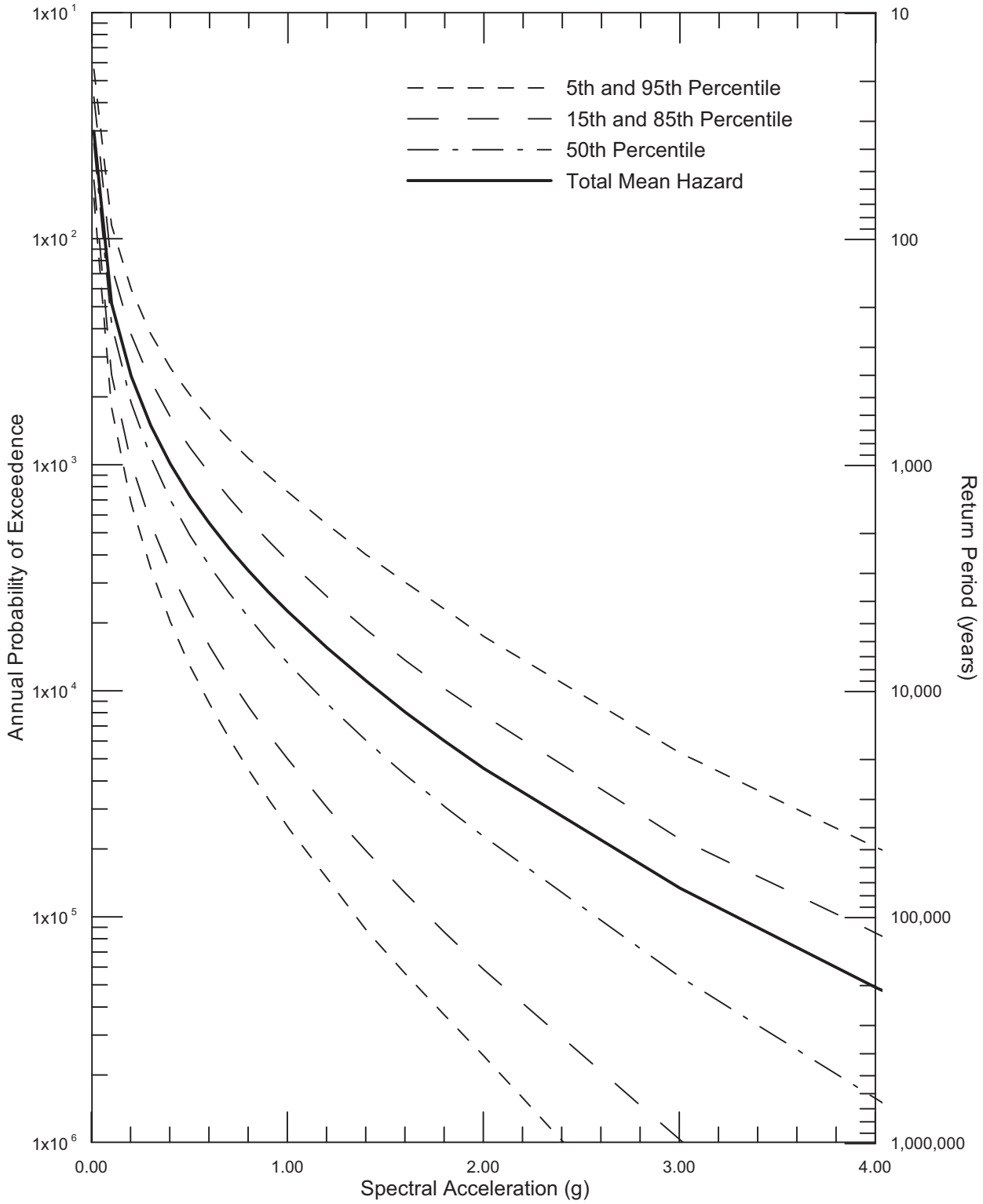
URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF PRE-NGA AND NGA SEISMIC HAZARD CURVES FOR 1.0 SEC HORIZONTAL SPECTRAL ACCELERATION, CMRR	Figure 28



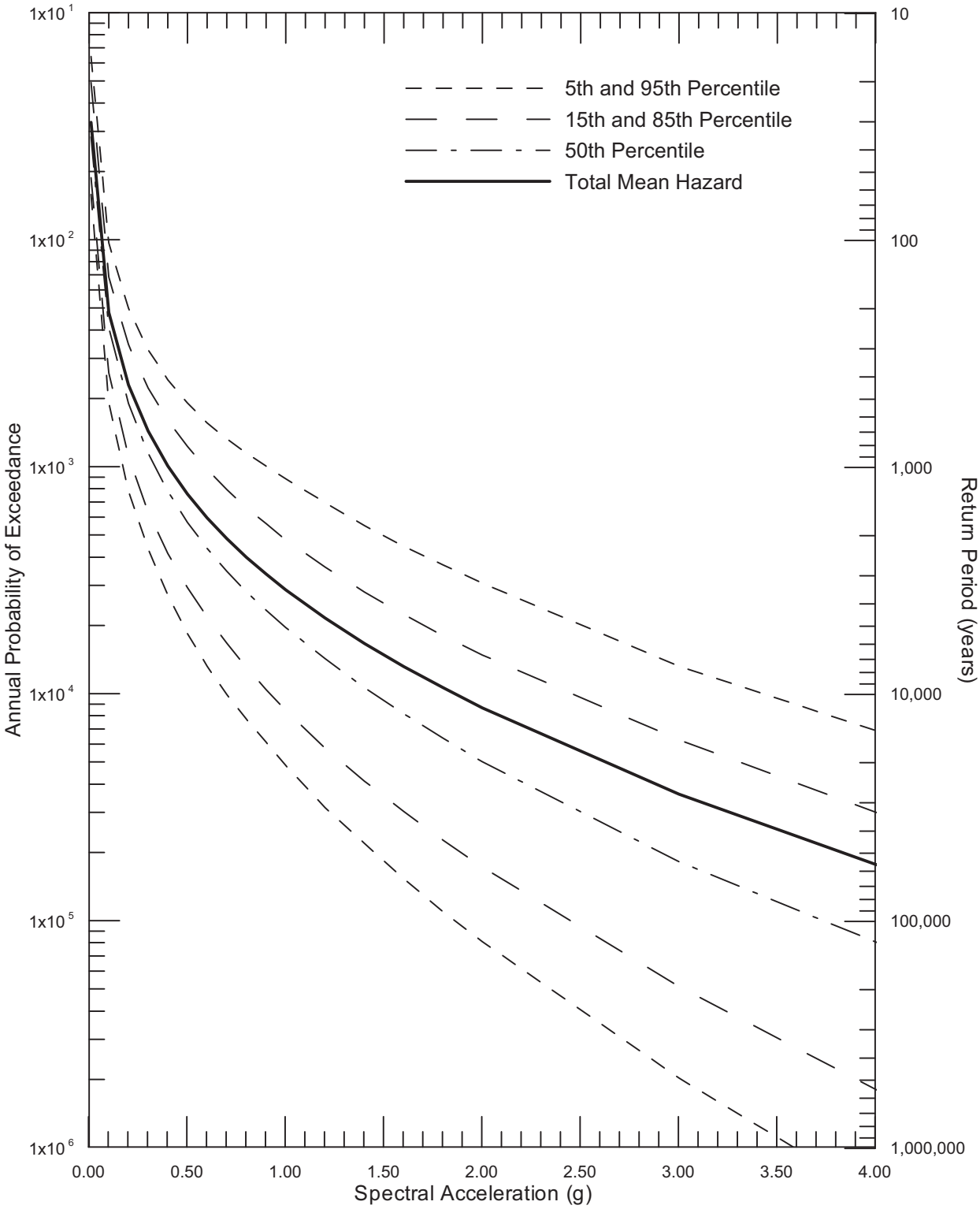
URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF 2007 PRE-NGA AND 2009 NGA UHS	Figure 29



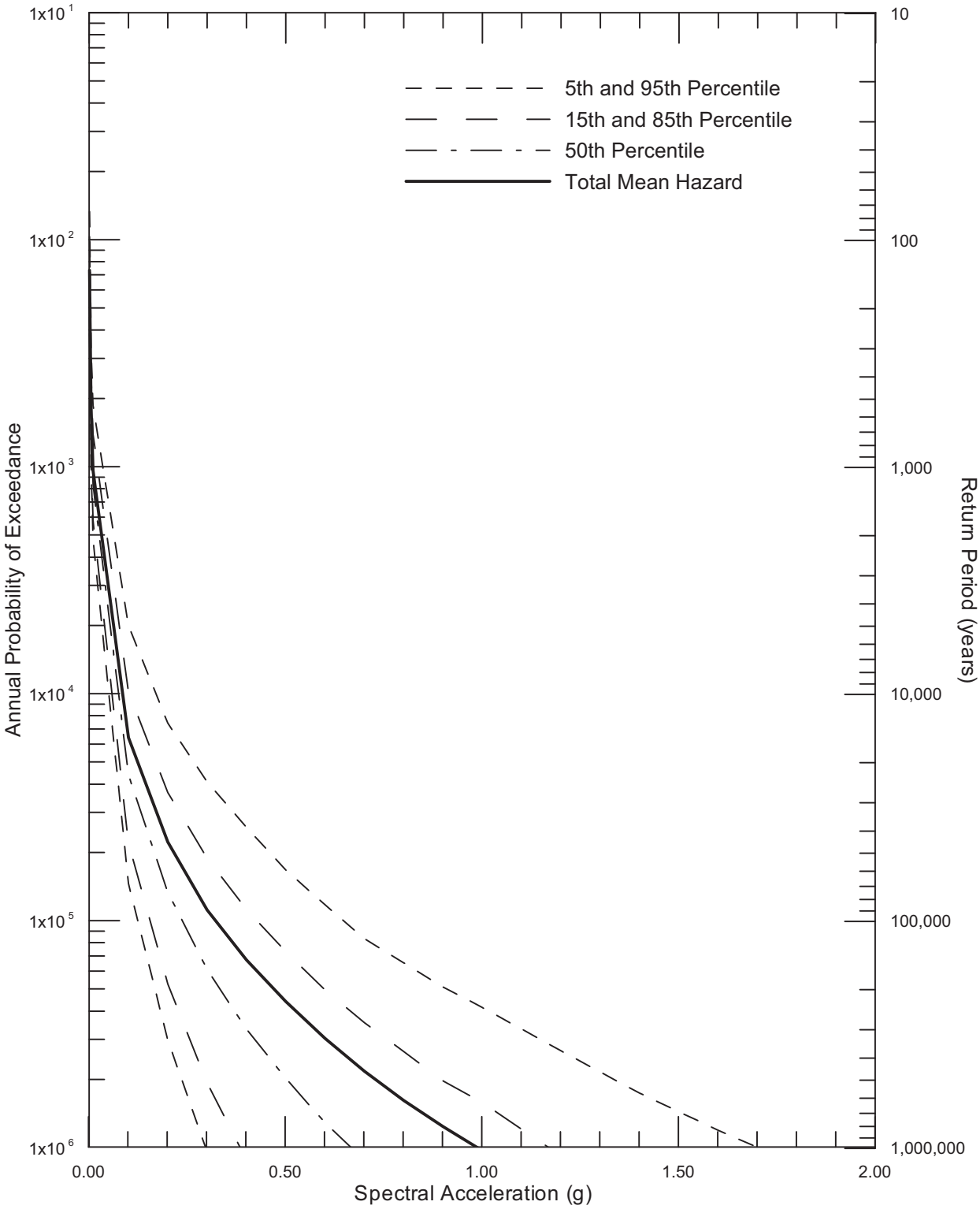
URS	Project No. 26817259 Los Alamos National Lab	SEISMIC HAZARD CURVES FOR PEAK HORIZONTAL ACCELERATION, CMRR - STOCHASTIC	Figure 30



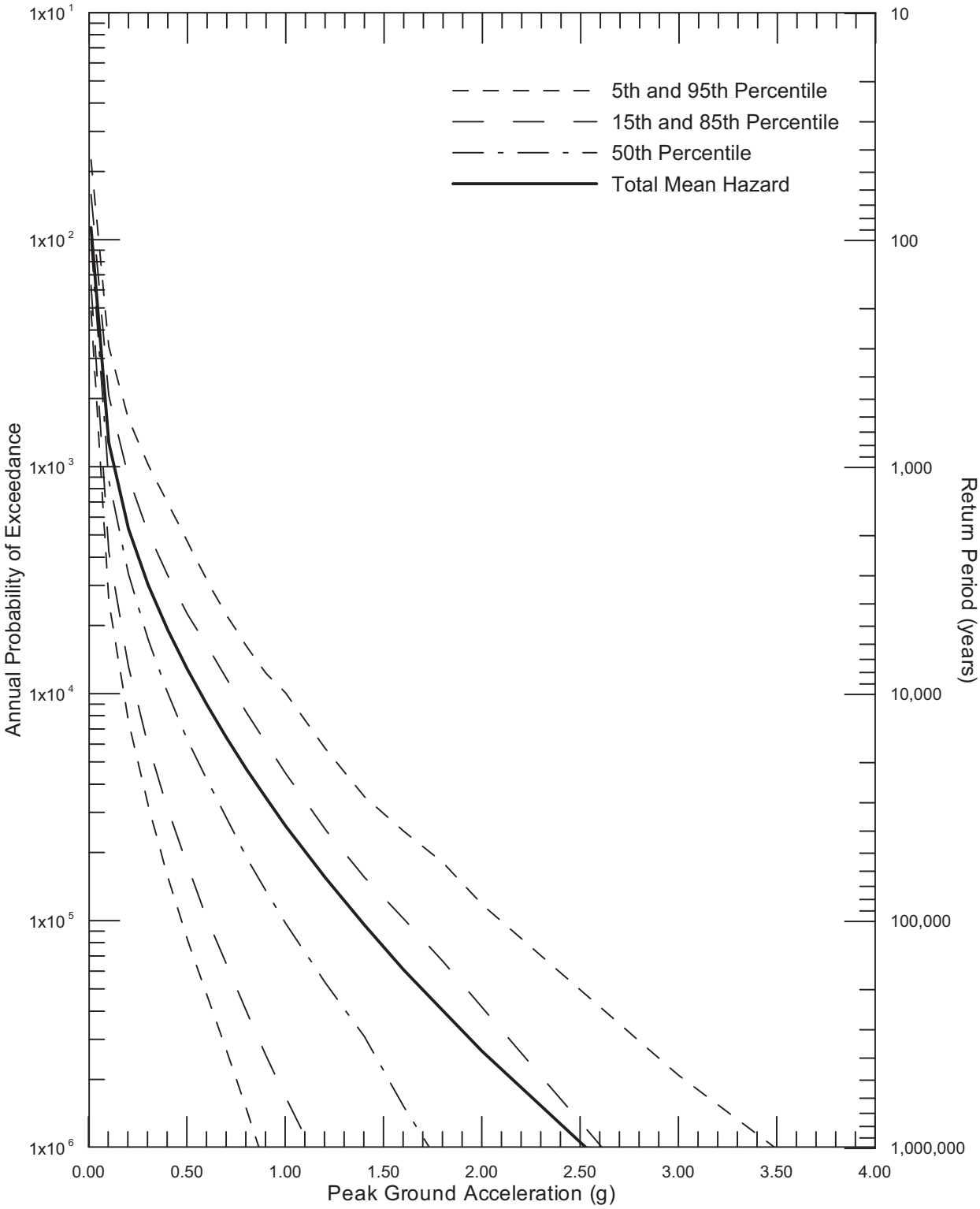
URS	Project No. 26817259 Los Alamos National Lab	SEISMIC HAZARD CURVES FOR 0.2 SEC HORIZONTAL SPECTRAL ACCELERATION, CMRR - STOCHASTIC	Figure 31



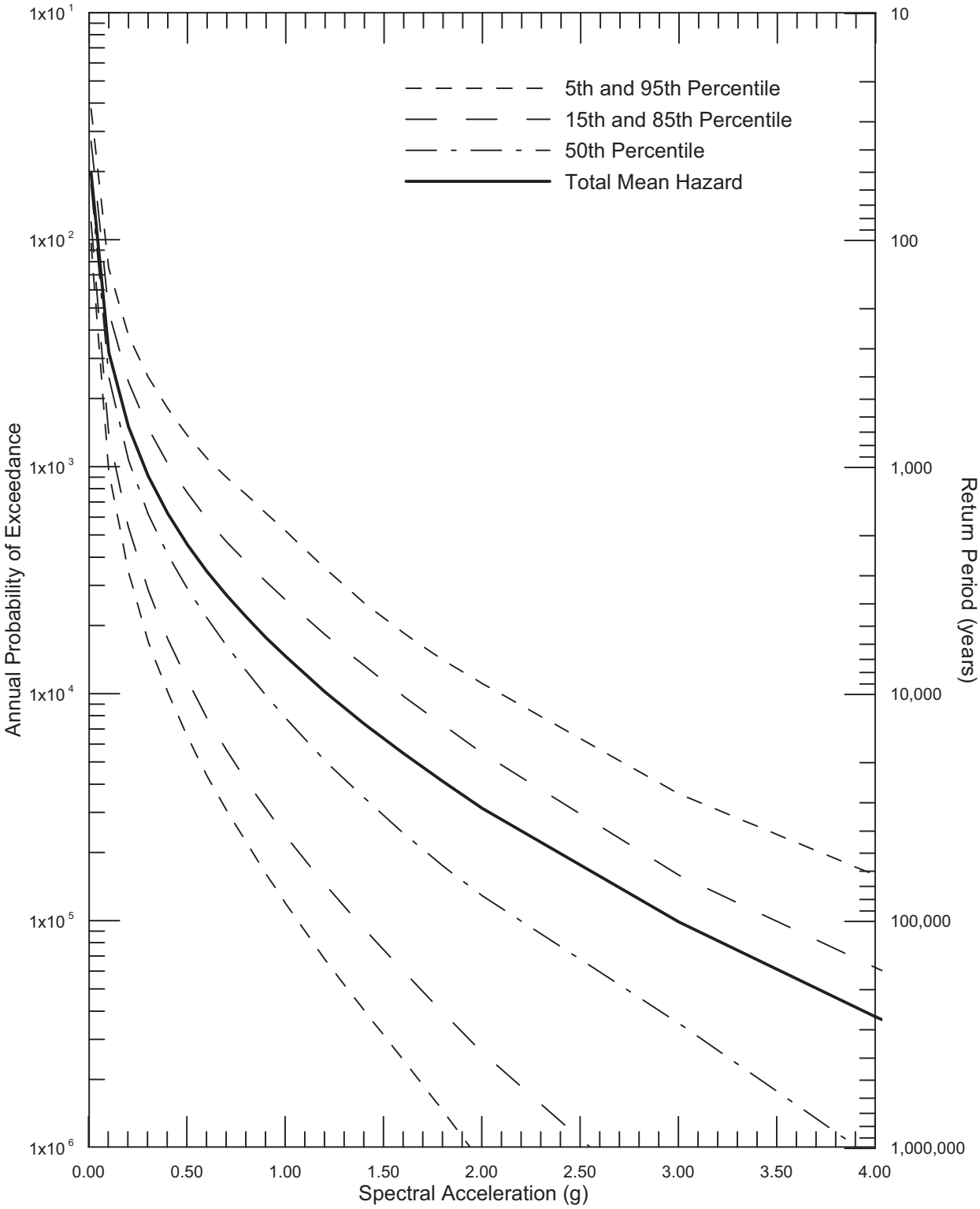
URS	Project No. 26817259 Los Alamos National Lab	SEISMIC HAZARD CURVES FOR 1.0 SEC HORIZONTAL SPECTRAL ACCELERATION, CMRR - STOCHASTIC	Figure 32



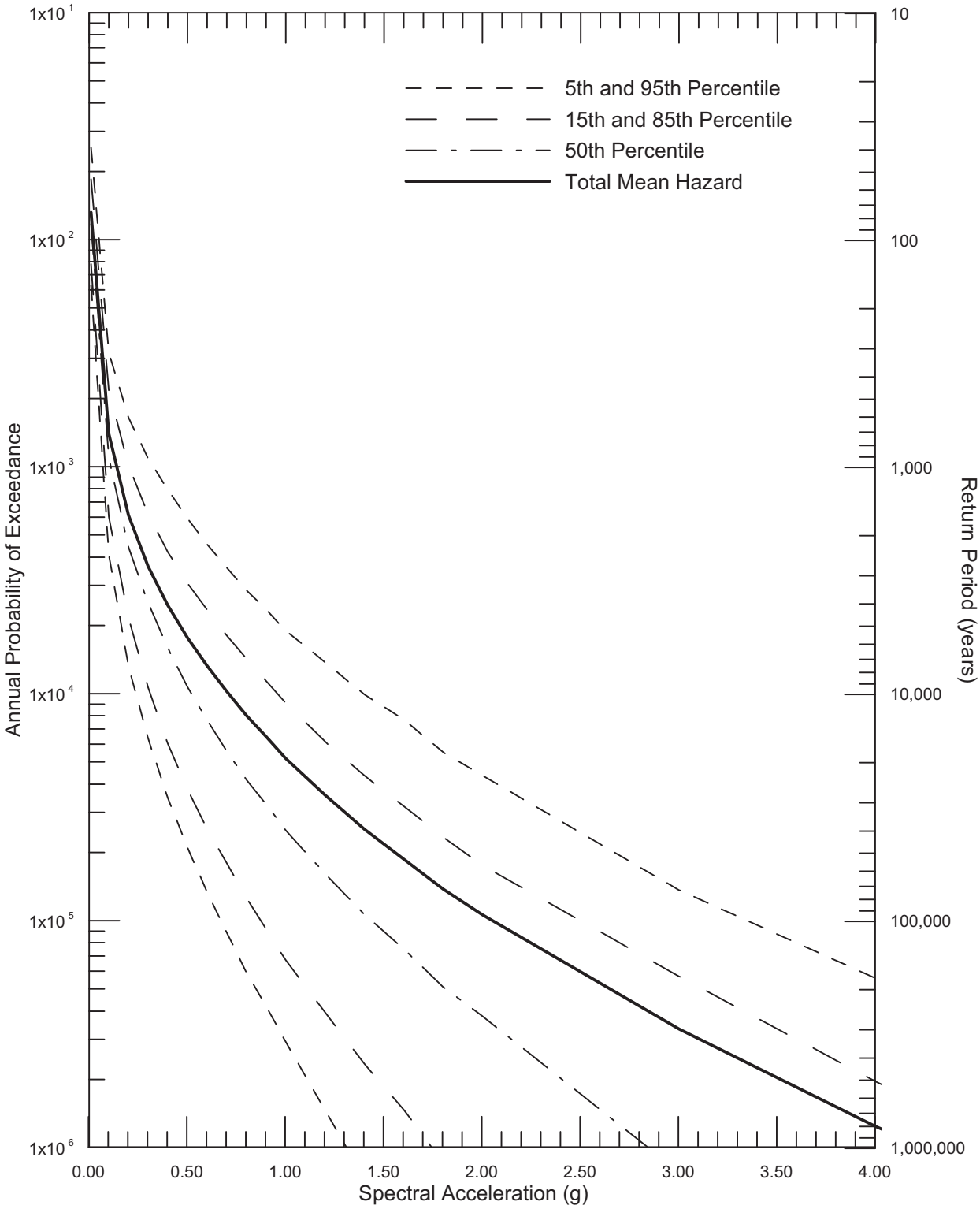
URS	Project No. 26817259 Los Alamos National Lab	SEISMIC HAZARD CURVES FOR 10.0 SEC HORIZONTAL SPECTRAL ACCELERATION, CMRR - STOCHASTIC	Figure 33



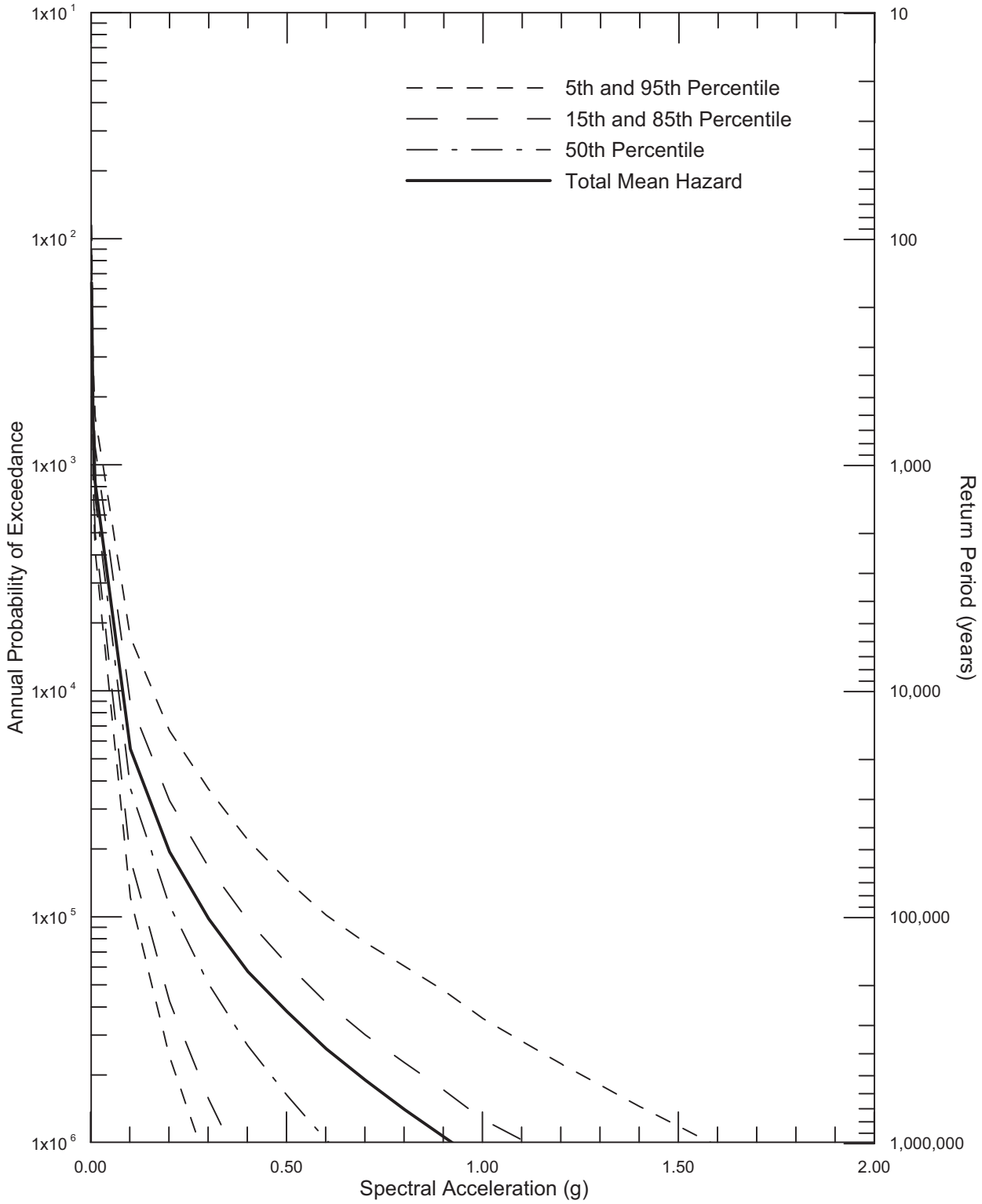
URS	Project No. 26817259	SEISMIC HAZARD CURVES FOR PEAK HORIZONTAL ACCELERATION, CMRR - STOCHASTIC/DACITE	Figure 34
	Los Alamos National Lab		



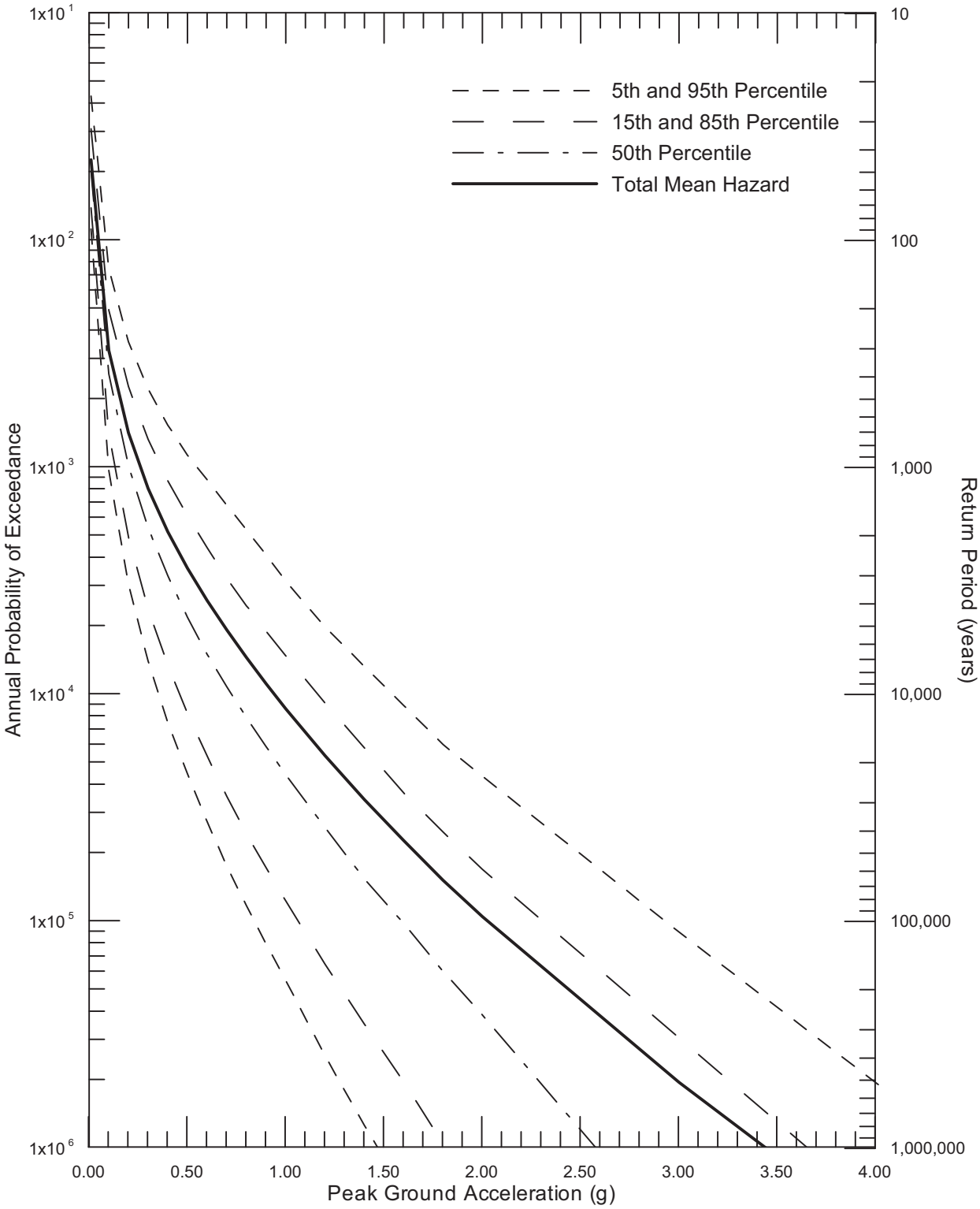
URS	Project No. 26817259 Los Alamos National Lab	SEISMIC HAZARD CURVES FOR 0.2 SEC HORIZONTAL SPECTRAL ACCELERATION, CMRR - STOCHASTIC/DACITE	Figure 35



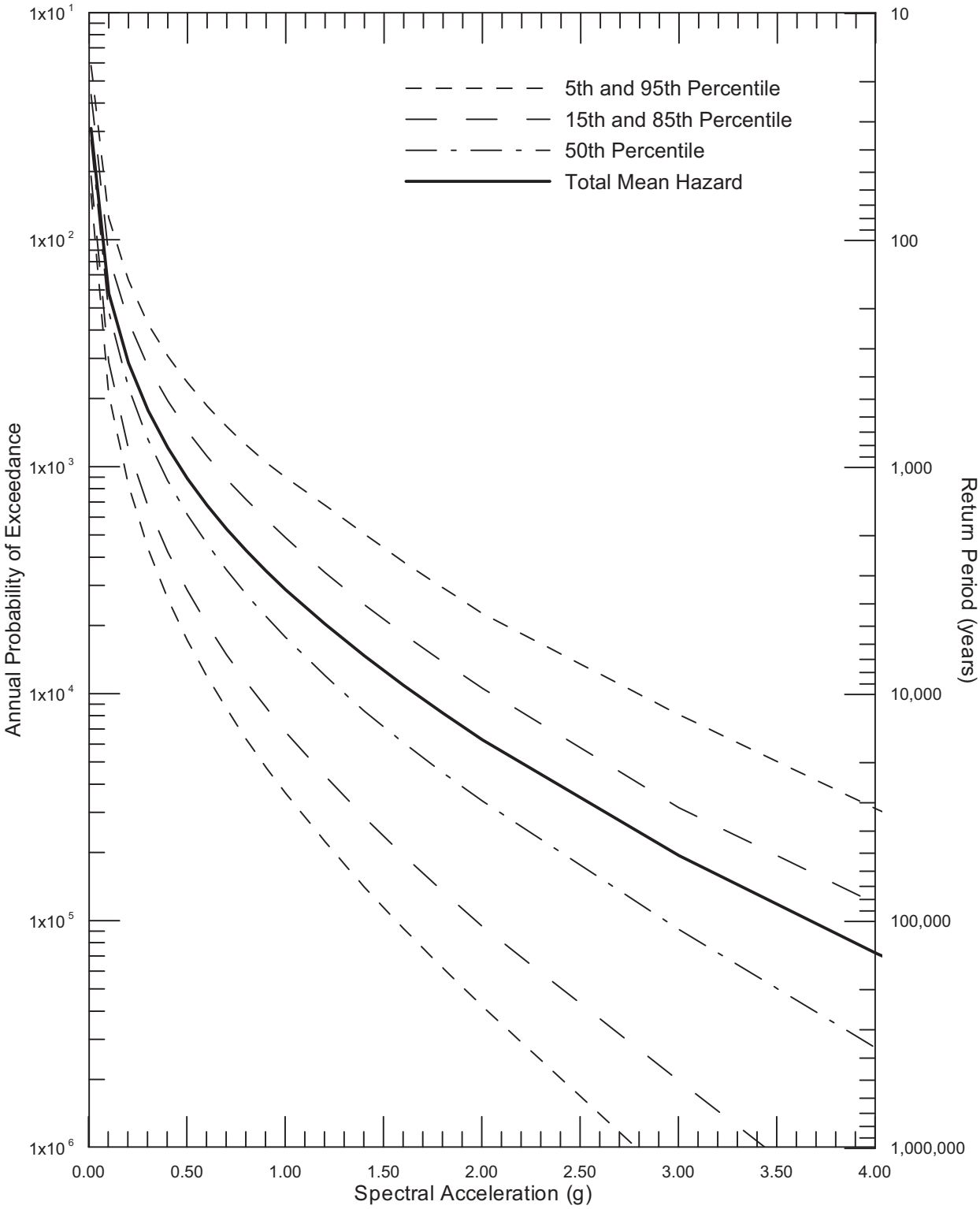
URS	Project No. 26817259 Los Alamos National Lab	SEISMIC HAZARD CURVES FOR 1.0 SEC HORIZONTAL SPECTRAL ACCELERATION, CMRR - STOCHASTIC/DACITE	Figure 36



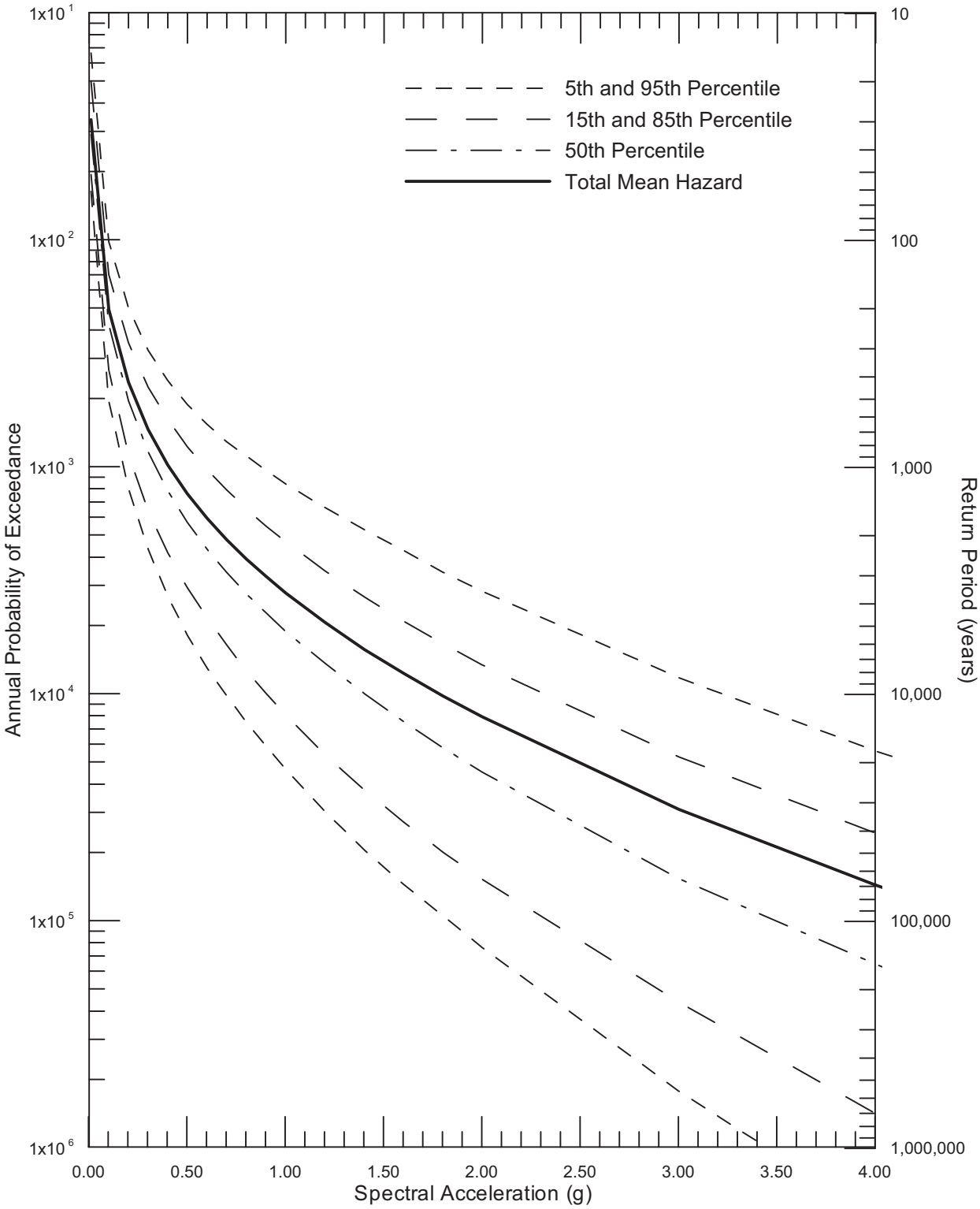
URS	Project No. 26817259 Los Alamos National Lab	SEISMIC HAZARD CURVES FOR 10.0 SEC HORIZONTAL SPECTRAL ACCELERATION, CMRR - STOCHASTIC/DACITE	Figure 37



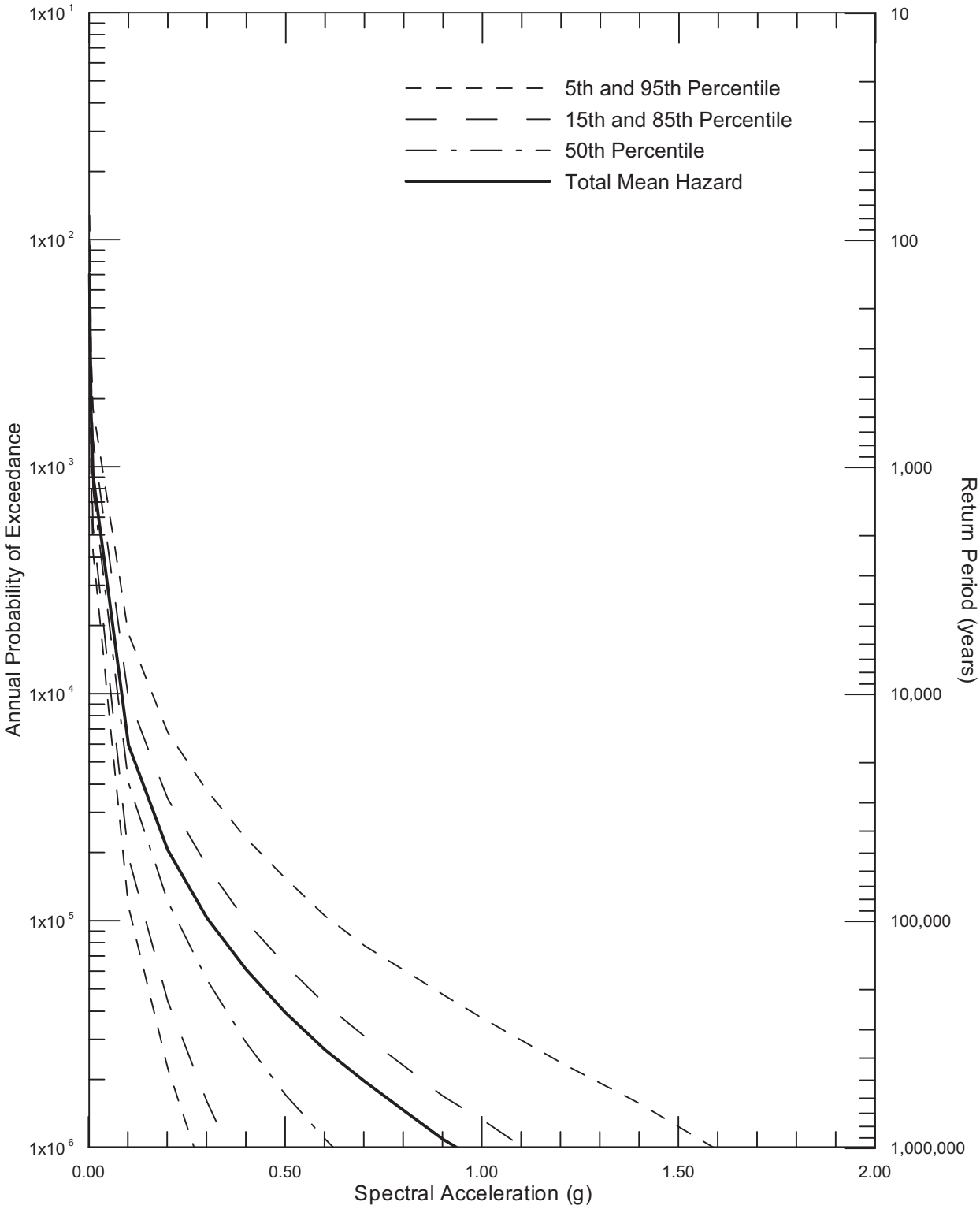
URS	Project No. 26817259	SEISMIC HAZARD CURVES FOR PEAK HORIZONTAL ACCELERATION, TA-55 - STOCHASTIC	Figure 38
	Los Alamos National Lab		



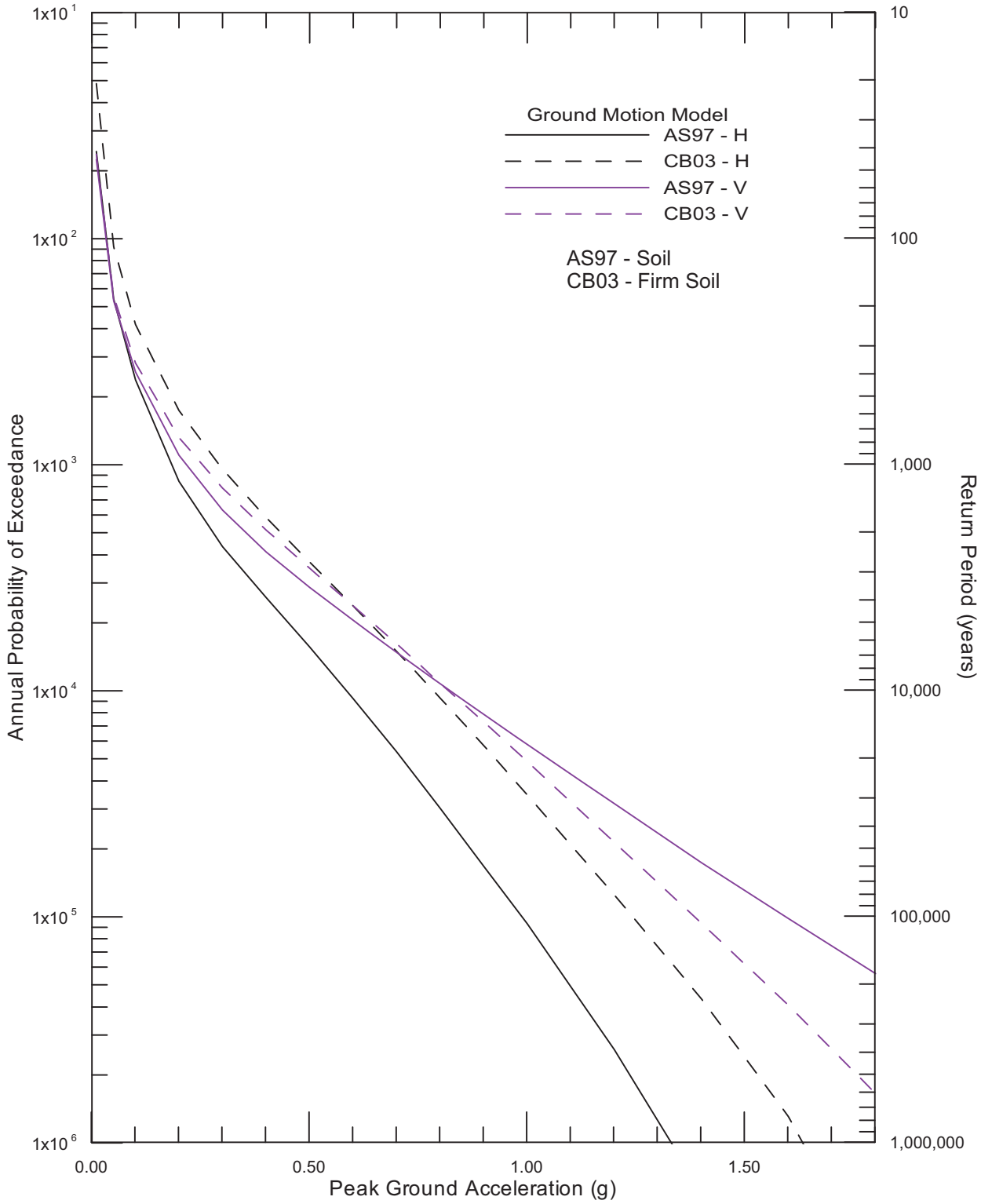
URS	Project No. 26817259 Los Alamos National Lab	SEISMIC HAZARD CURVES FOR 0.2 SEC HORIZONTAL SPECTRAL ACCELERATION, TA-55 - STOCHASTIC	Figure 39



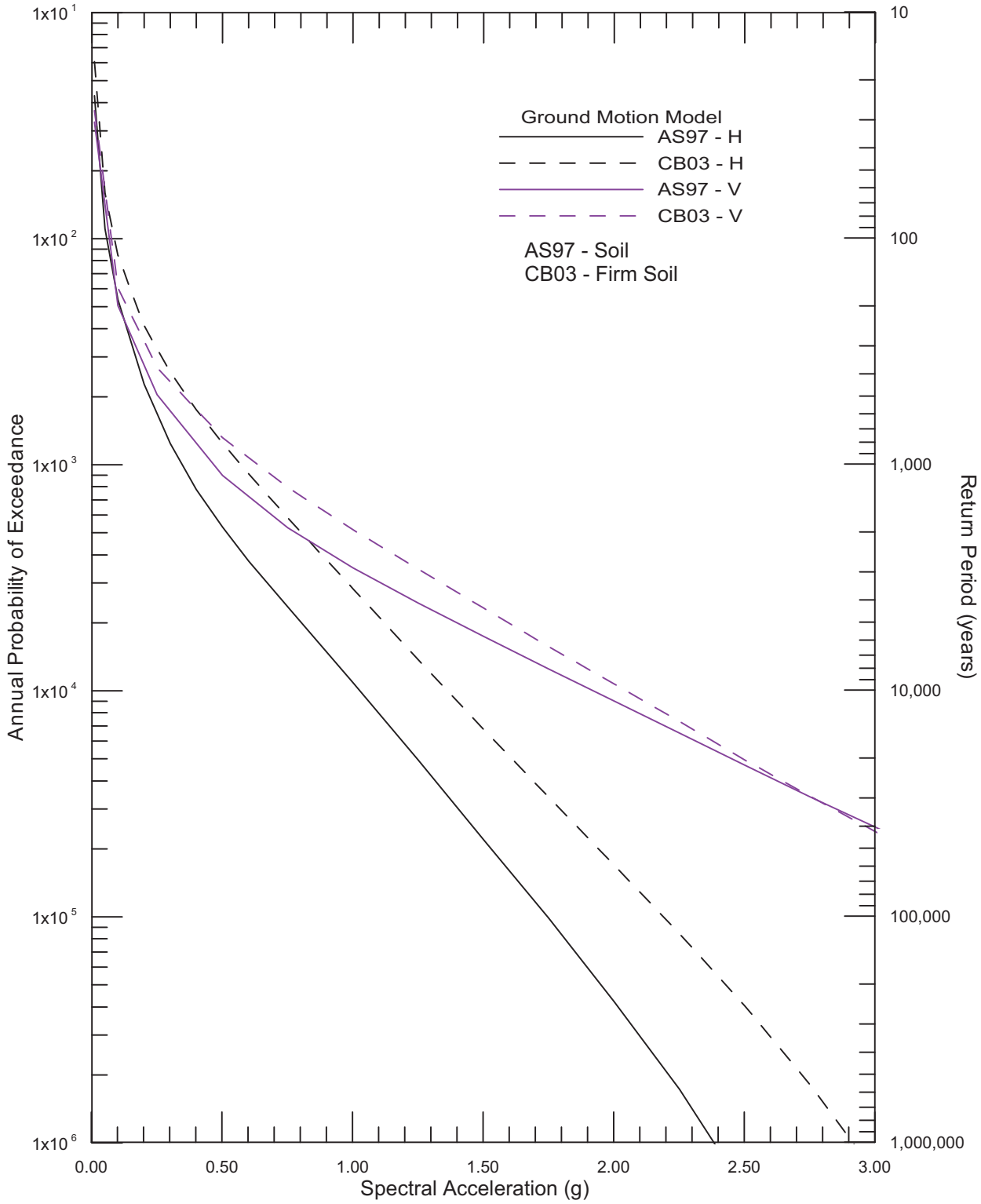
URS	Project No. 26817259 Los Alamos National Lab	SEISMIC HAZARD CURVES FOR 1.0 SEC HORIZONTAL SPECTRAL ACCELERATION, TA-55 - STOCHASTIC	Figure 40



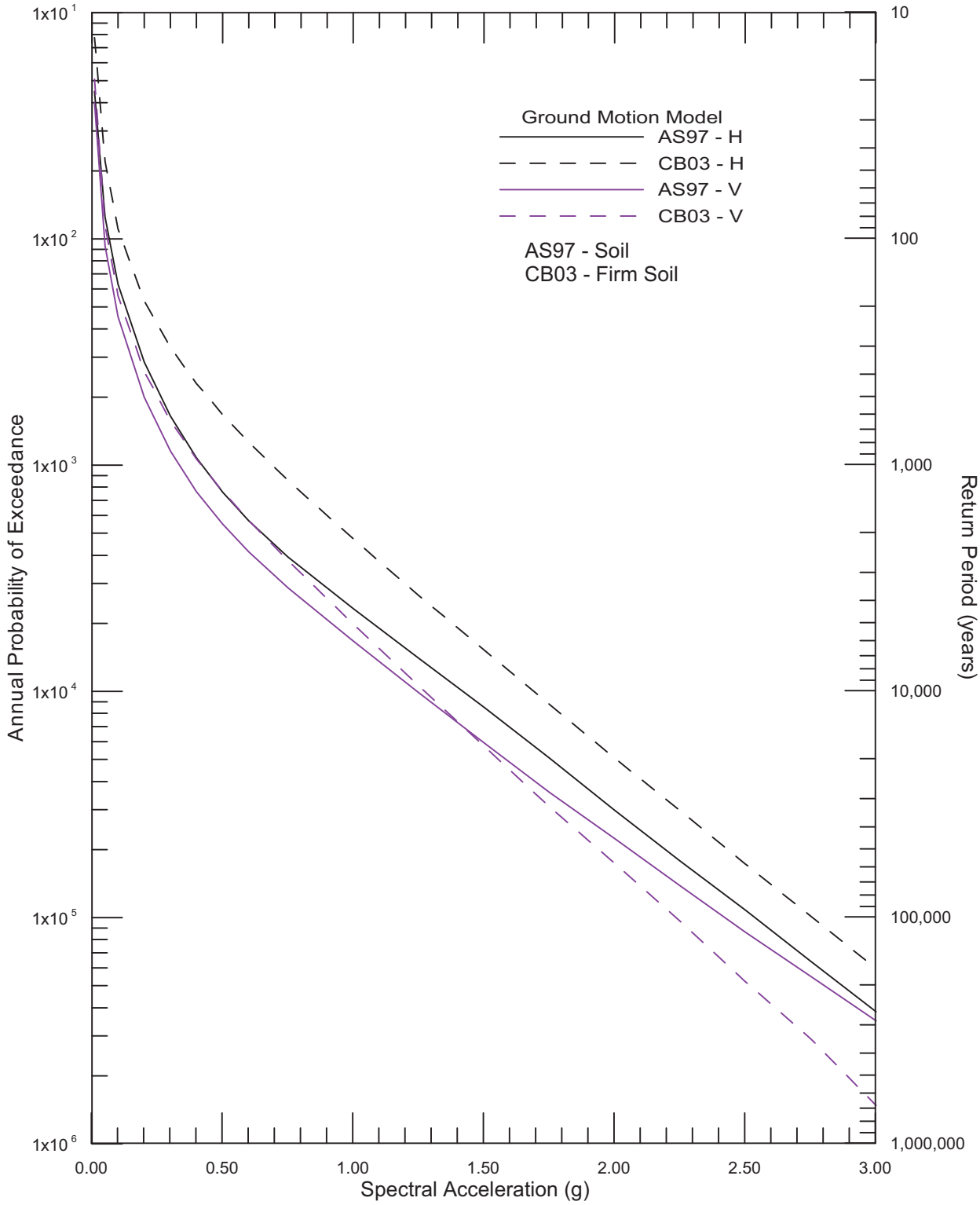
URS	Project No. 26817259 Los Alamos National Lab	SEISMIC HAZARD CURVES FOR 10.0 SEC HORIZONTAL SPECTRAL ACCELERATION, TA-55 - STOCHASTIC	Figure 41



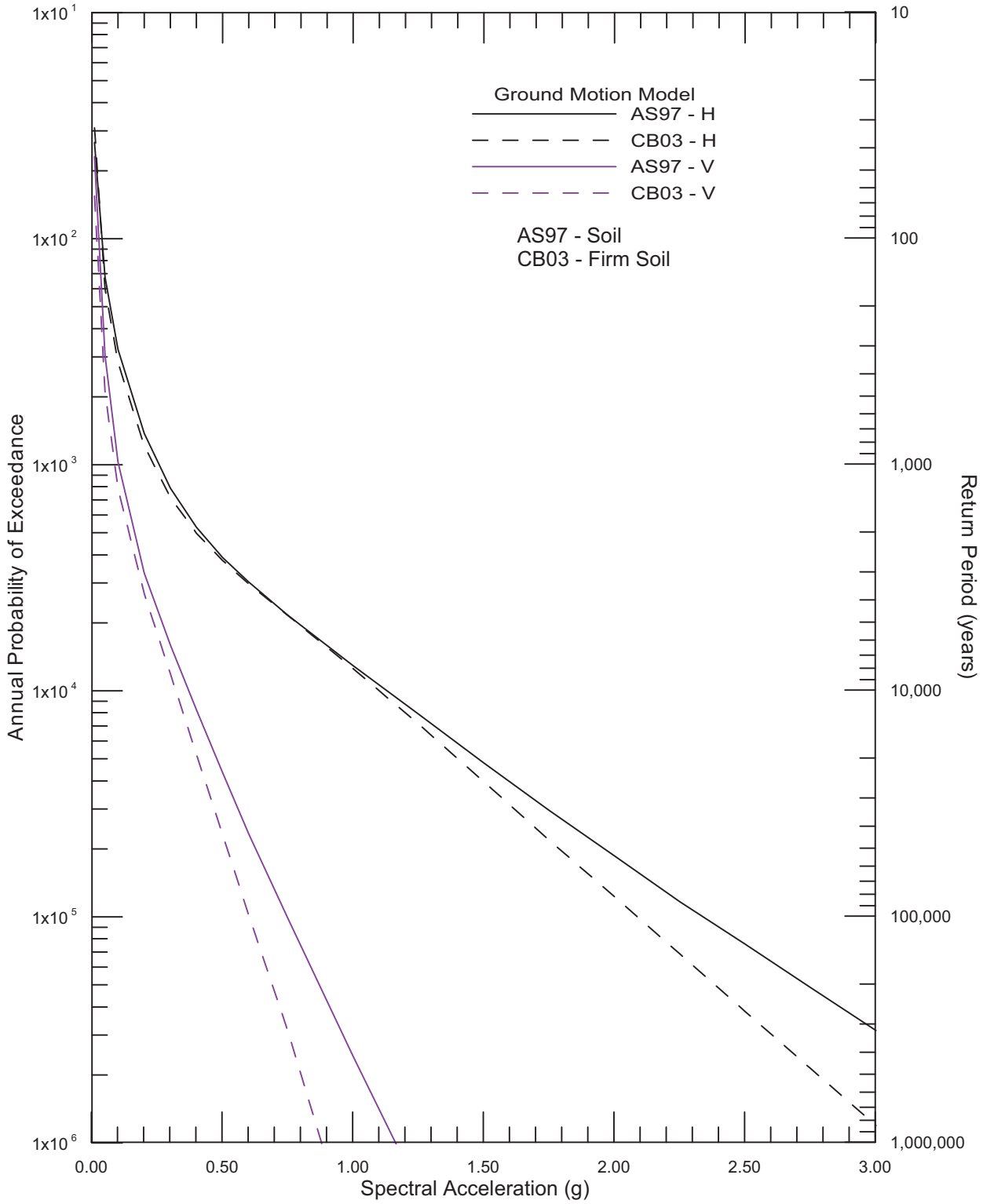
URS	Project No. 26817259 Los Alamos National Lab	MEAN PEAK HORIZONTAL AND VERTICAL HAZARD CURVES USING ABRAHAMSON AND SILVA (1997) AND CAMPBELL AND BOZORGNIA (2003)	Figure 42



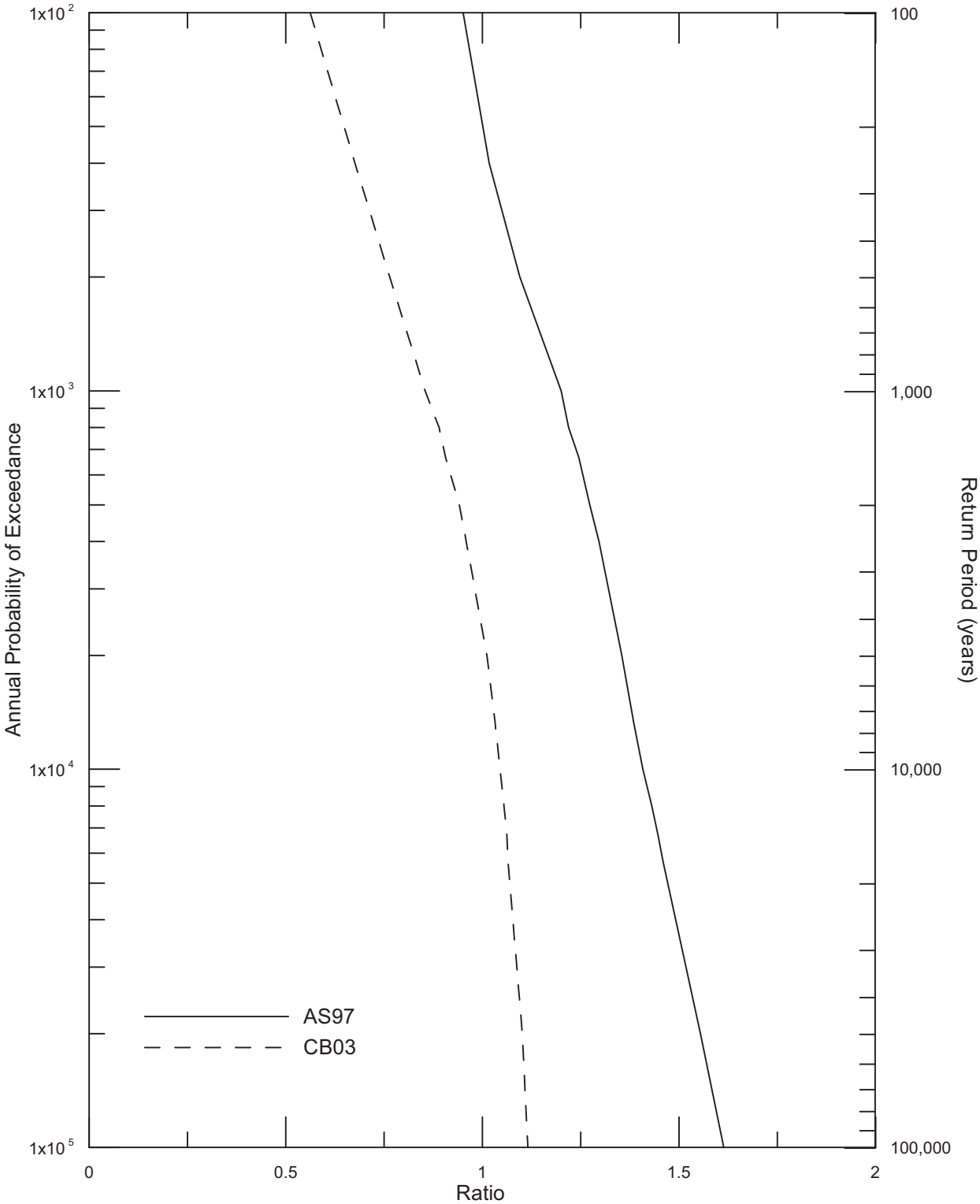
URS	Project No. 26817259 Los Alamos National Lab	MEAN 0.1 SEC HORIZONTAL AND VERTICAL HAZARD CURVES USING ABRAHAMSON AND SILVA (1997) AND CAMPBELL AND BOZORGNIA (2003)	Figure 43



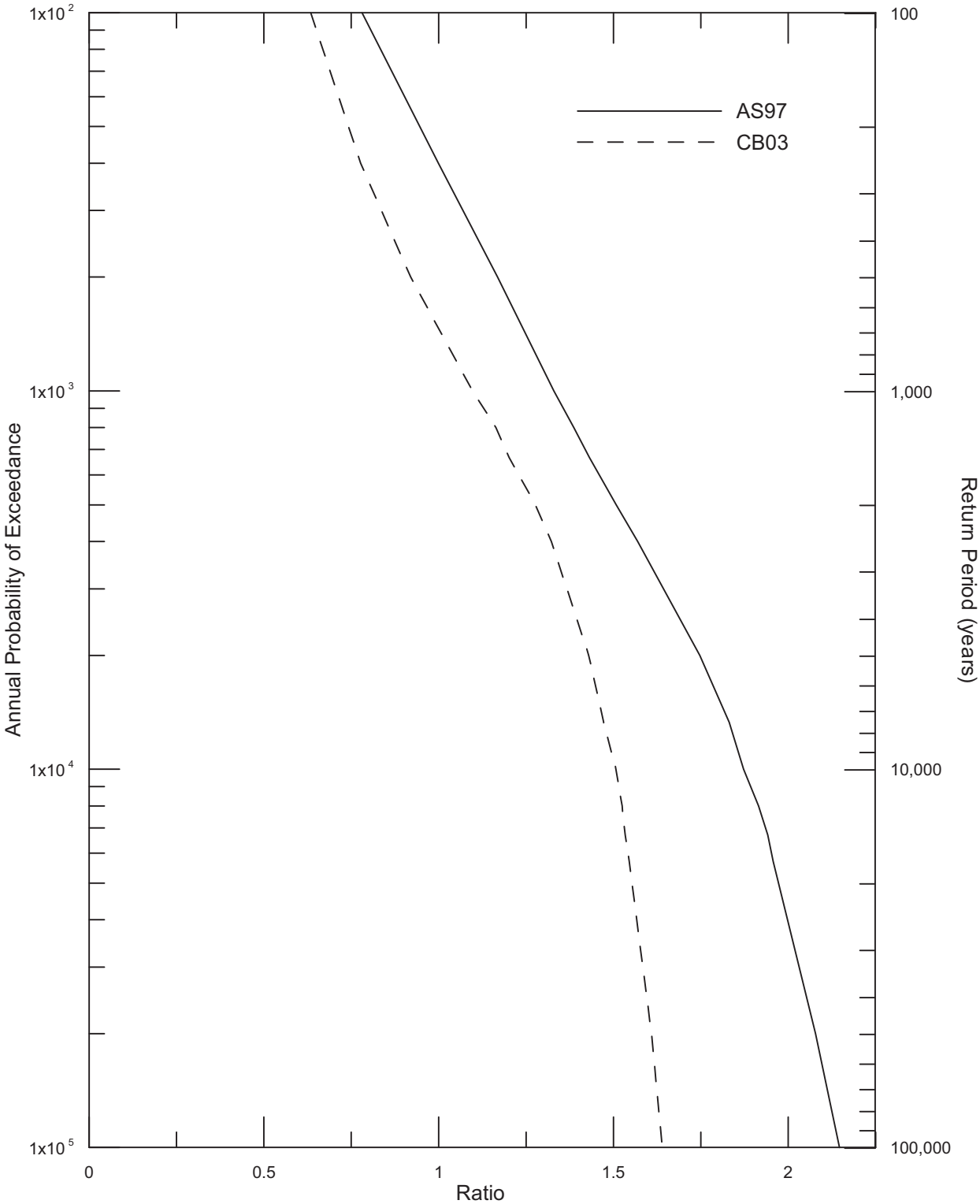
URS	Project No. 26817259 Los Alamos National Lab	MEAN 0.2 SEC HORIZONTAL AND VERTICAL HAZARD CURVES USING ABRAHAMSON AND SILVA (1997) AND CAMPBELL AND BOZORGNIA (2003)	Figure 44



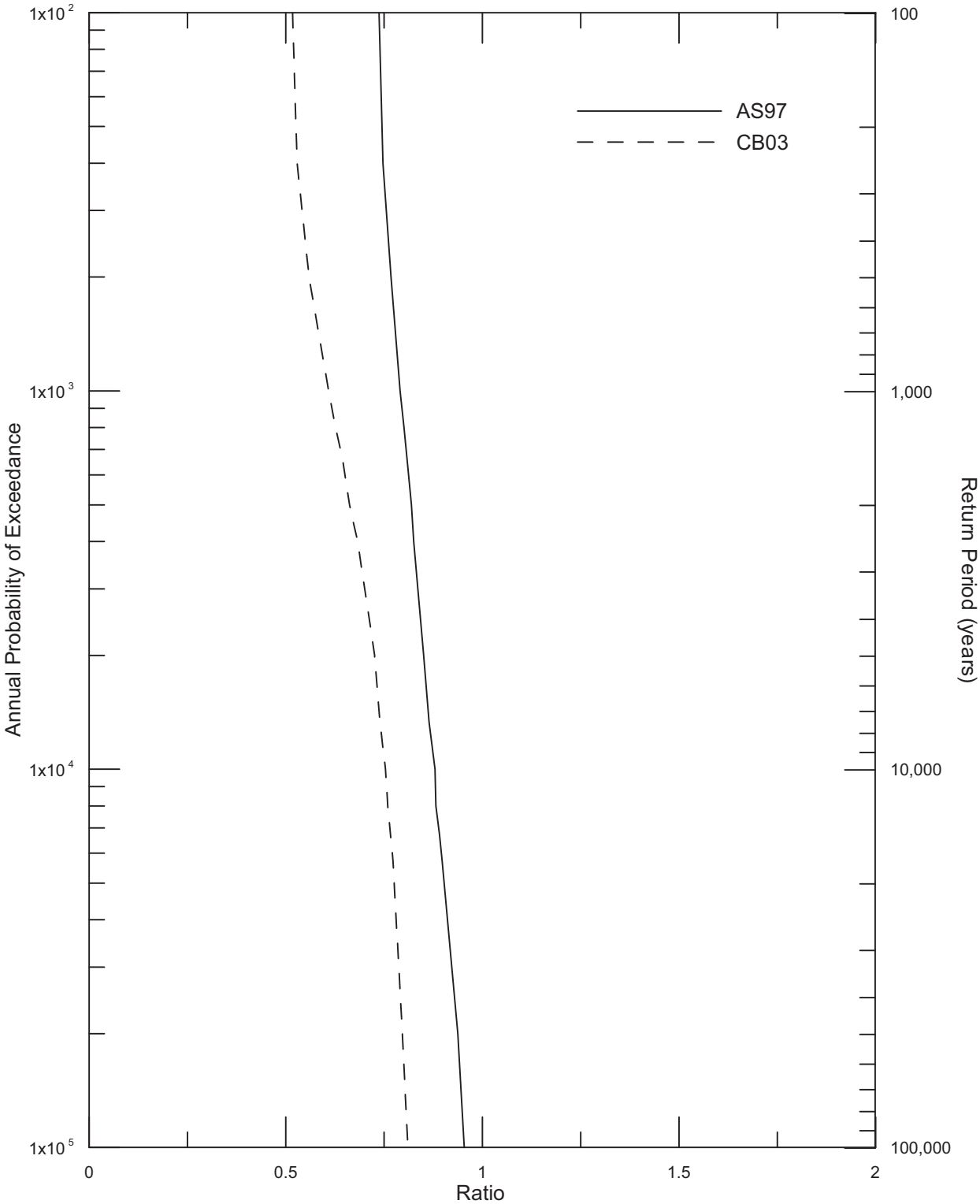
URS	Project No. 26817259 Los Alamos National Lab	MEAN 1.0 SEC HORIZONTAL AND VERTICAL HAZARD CURVES USING ABRAHAMSON AND SILVA (1997) AND CAMPBELL AND BOZORGNIA (2003)	Figure 45



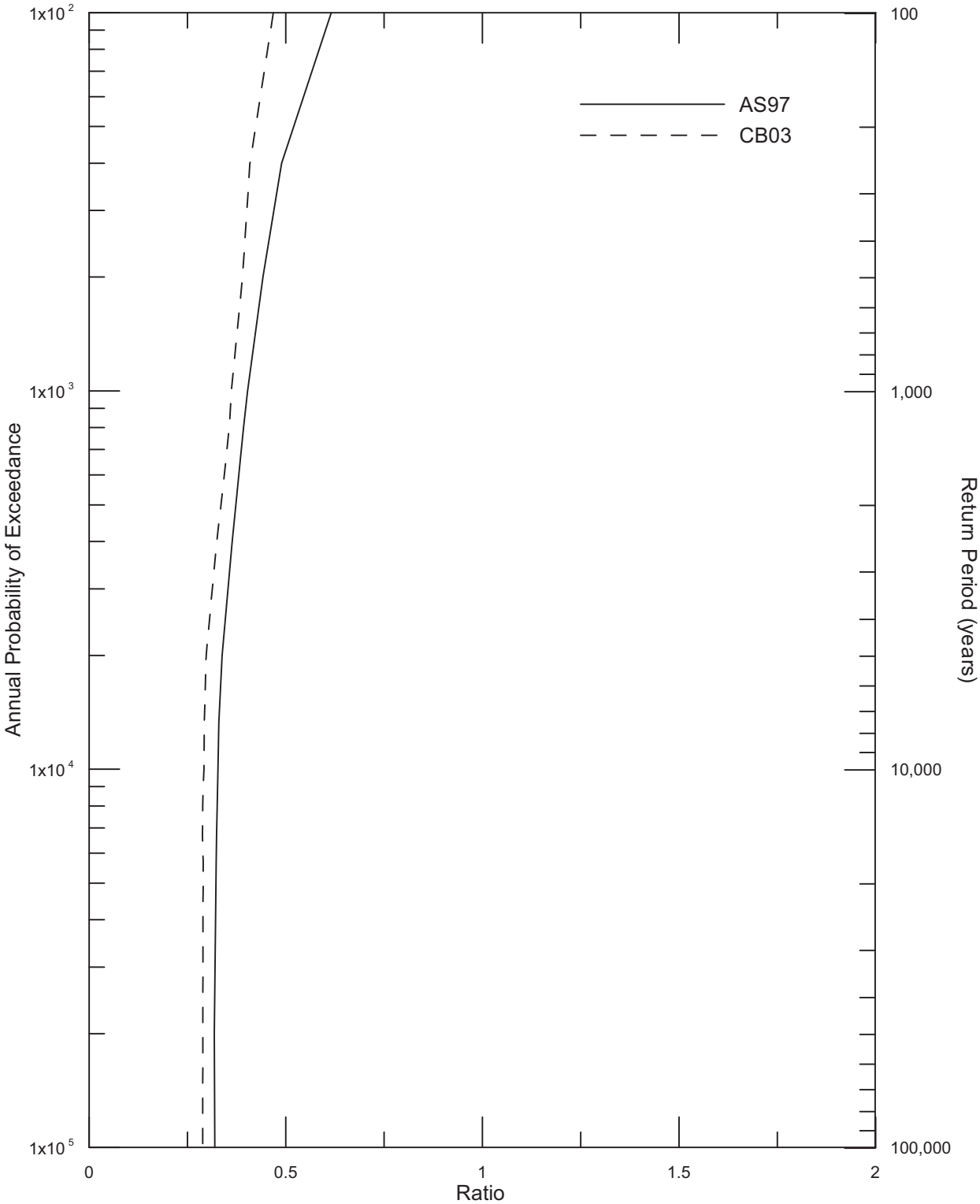
URS	Project No. 26817259 Los Alamos National Lab	MEAN PGA VERTICAL/HORIZONTAL RATIO USING ABRAHAMSON AND SILVA (1997) AND CAMPBELL AND BOZORGNIA (2003)	Figure 46



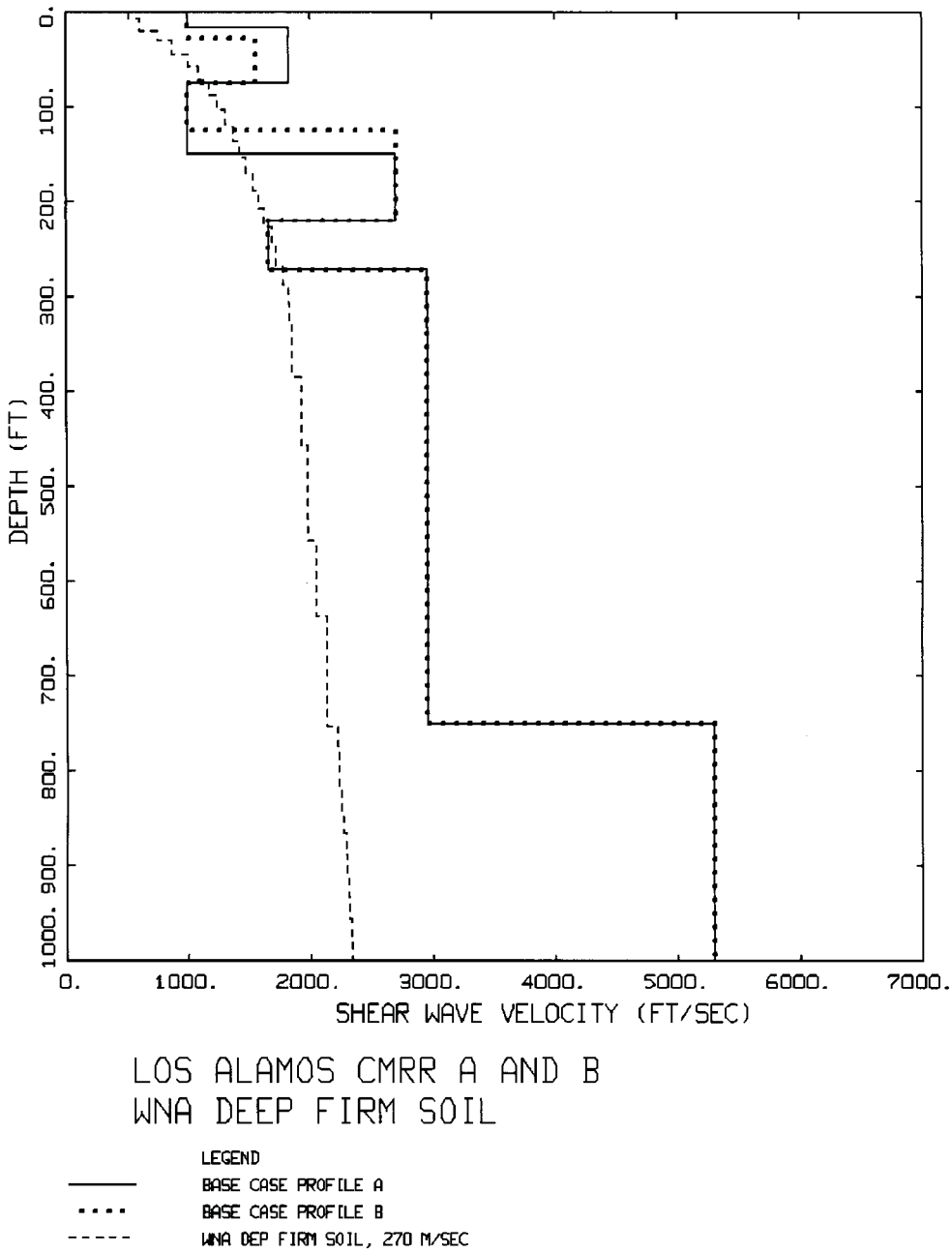
URS	Project No. 26817259 Los Alamos National Lab	MEAN 0.1 SEC VERTICAL/HORIZONTAL RATIO USING ABRAHAMSON AND SILVA (1997) AND CAMPBELL AND BOZORGNIA (2003)	Figure 47



URS	Project No. 26817259 Los Alamos National Lab	MEAN 0.2 SEC VERTICAL/HORIZONTAL RATIO USING ABRAHAMSON AND SILVA (1997) AND CAMPBELL AND BOZORGNIA (2003)	Figure 48

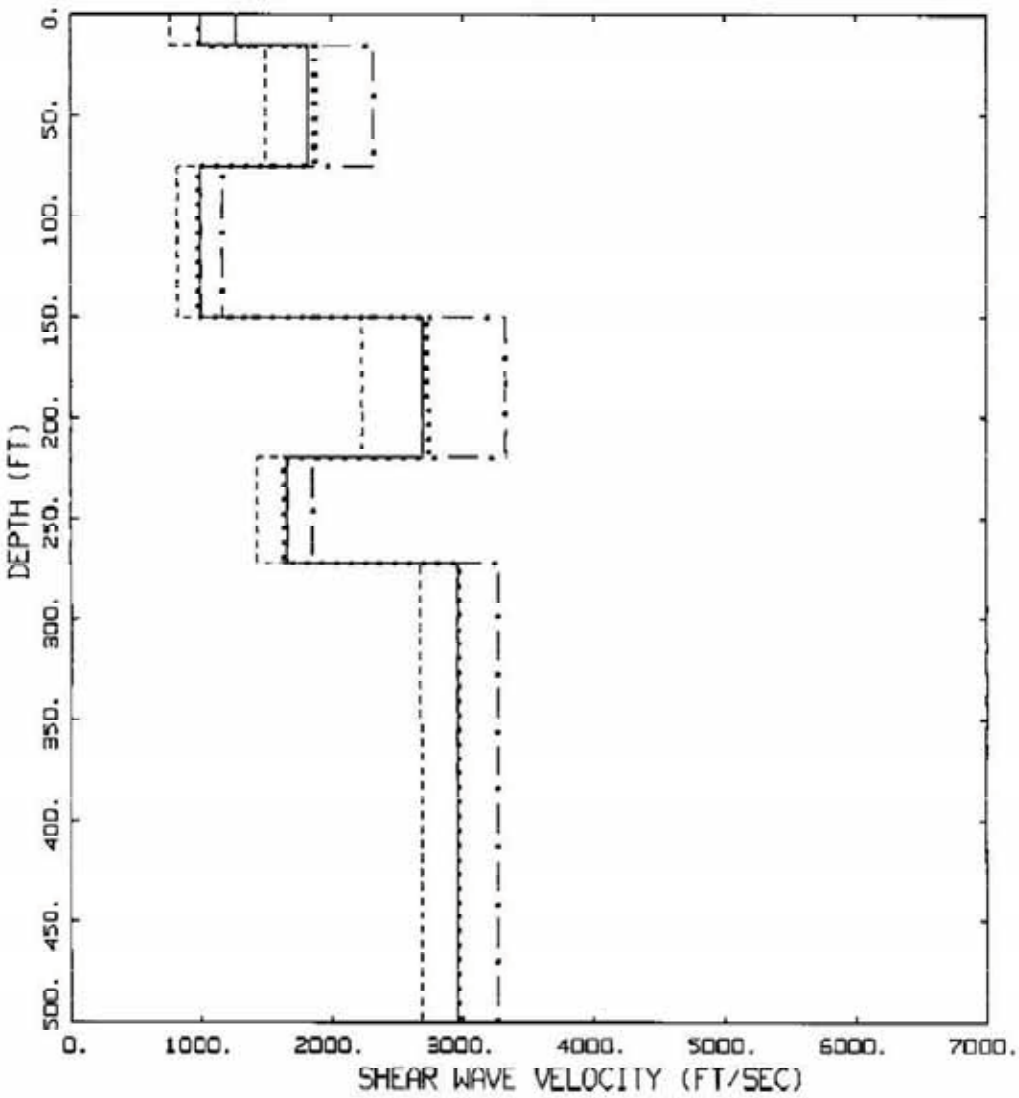


URS	Project No. 26817259 Los Alamos National Lab	MEAN 1.0 SEC VERTICAL/HORIZONTAL RATIO USING ABRAHAMSON AND SILVA (1997) AND CAMPBELL AND BOZORGNIA (2003)	Figure 49



Note: WNA deep firm soil profile is representative of firm soil recording sites in tectonically active regions (Walling et al., 2008).

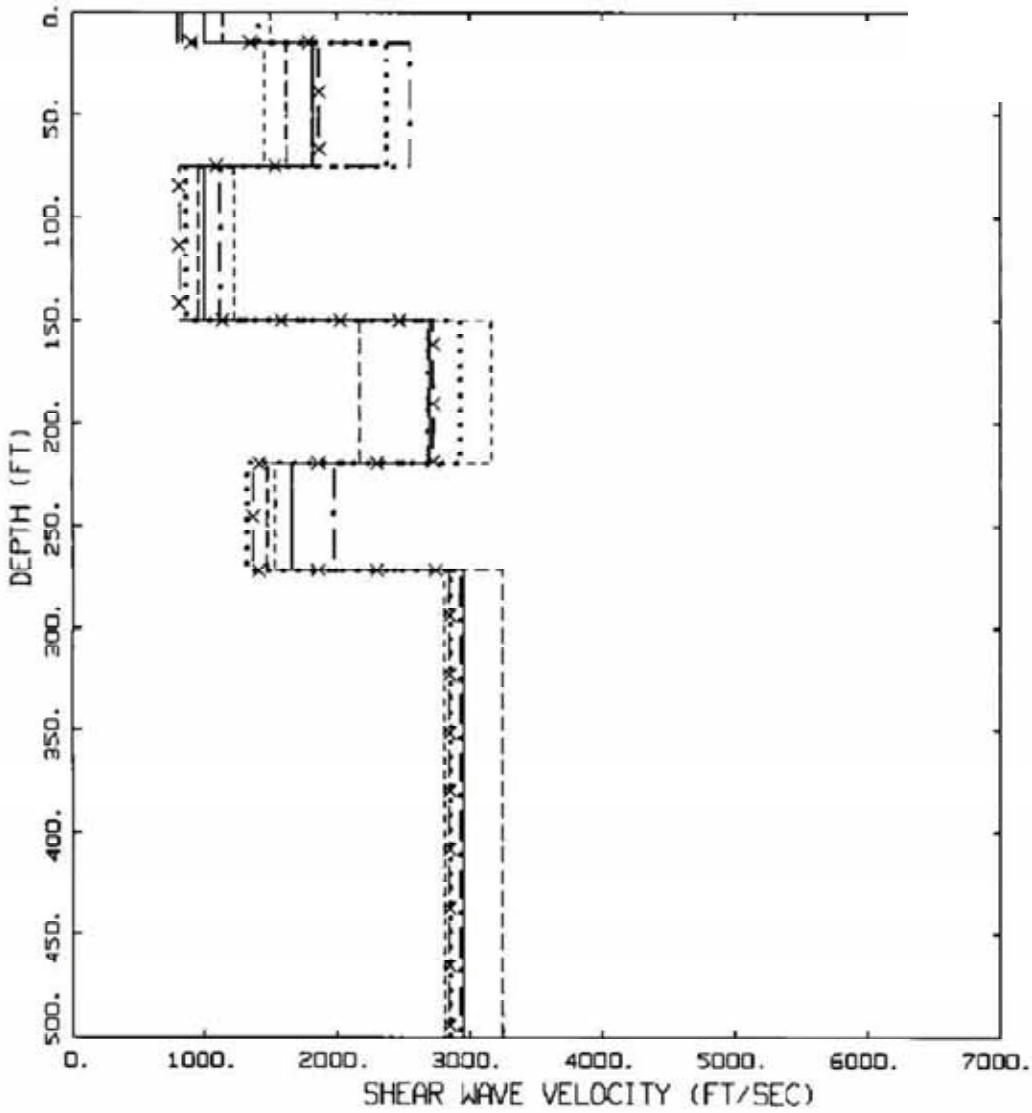
URS	Project No. 26817259 Los Alamos National Lab	CMRR BASE-CASE V_S PROFILES AND REFERENCE WNA, GENERIC DEEP FIRM SOIL (V_S30 270 M/SEC)	Figure 50



CMRR BASE CASE A
MEDIAN, 16TH, AND 84TH

LEGEND
16TH PERCENTILE
50TH PERCENTILE
84TH PERCENTILE
BASE CASE

URS	Project No. 26817259 Los Alamos National Lab	CMRR PROFILE A BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 51a

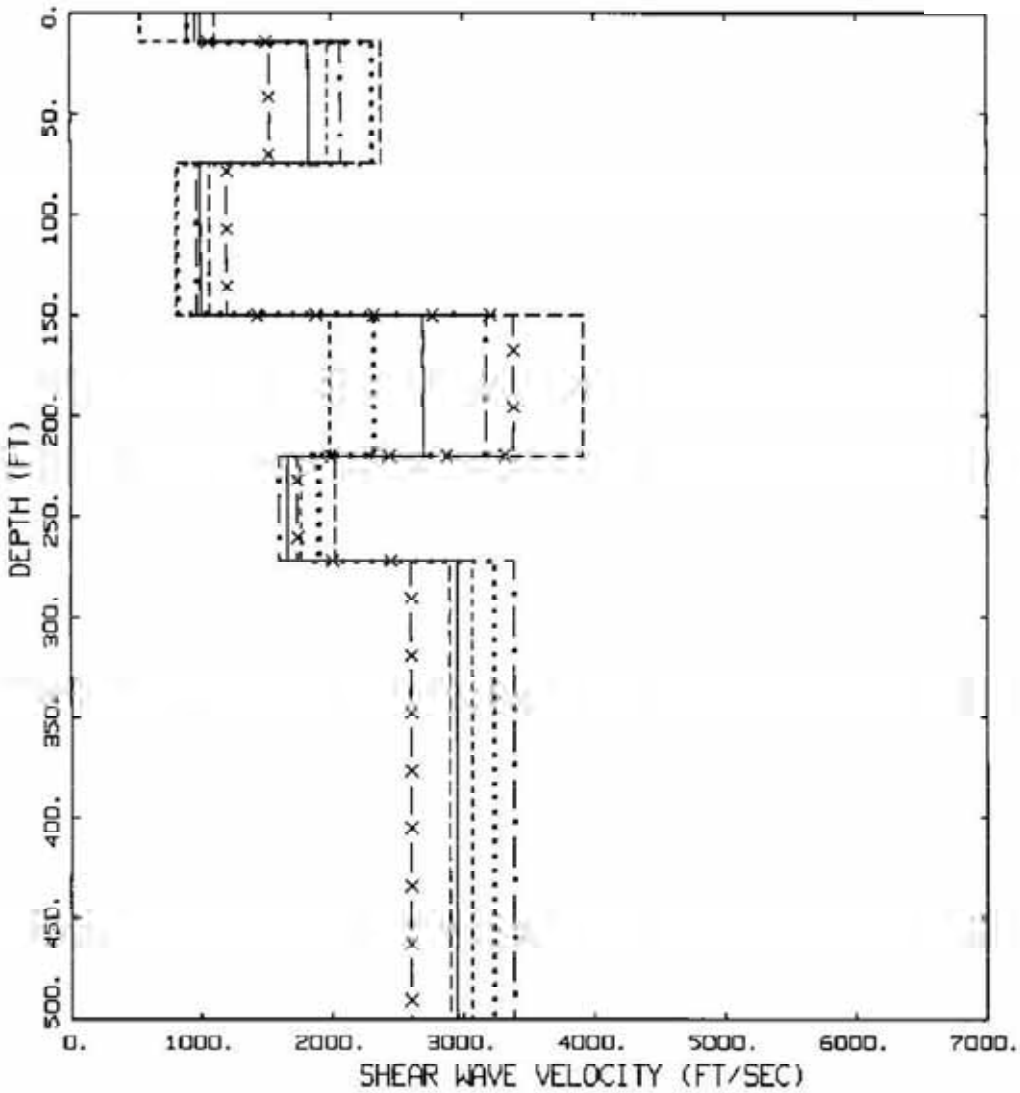


CMRR BASE CASE A
SHEAR-WAVE VELOCITY PROFILES

LEGEND

—×—	REALIZATION 01
••••	REALIZATION 02
-----	REALIZATION 03
– – – –	REALIZATION 04
—•—	REALIZATION 05
———	BASE CASE

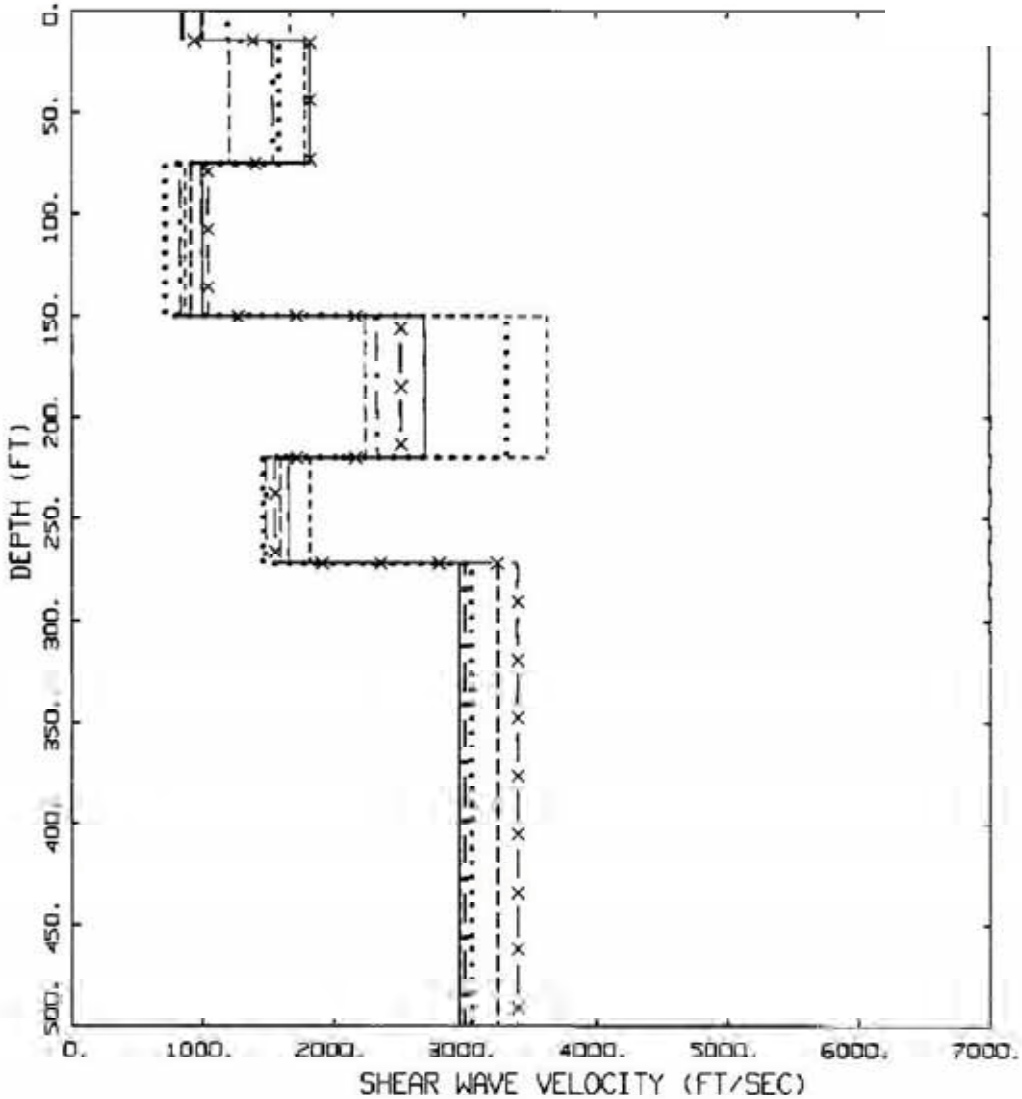
URS	Project No. 26817259	CMRR PROFILE A BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 51b
	Los Alamos National Lab		



CMRR BASE CASE A
SHEAR-WAVE VELOCITY PROFILES

LEGEND
REALIZATION 06
REALIZATION 07
REALIZATION 08
REALIZATION 09
REALIZATION 10
BASE CASE

URS	Project No. 26817259	CMRR PROFILE A BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 51c
	Los Alamos National Lab		

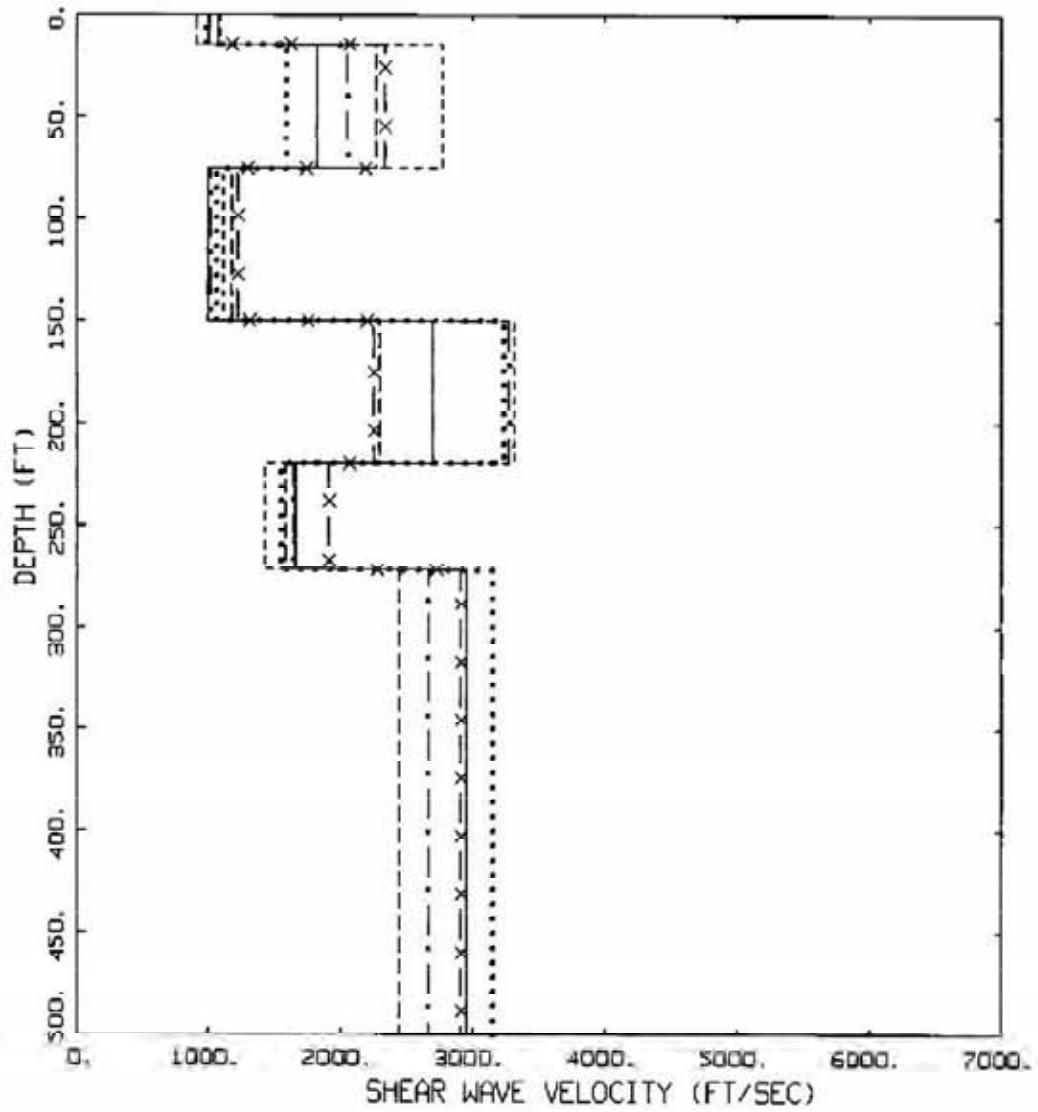


CMRR BASE CASE A
SHEAR-WAVE VELOCITY PROFILES

LEGEND

—×—	REALIZATION 11
••••	REALIZATION 12
-----	REALIZATION 13
— — —	REALIZATION 14
—•—	REALIZATION 15
———	BASE CASE

URS	Project No. 26817259	CMRR PROFILE A BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 51d
	Los Alamos National Lab		

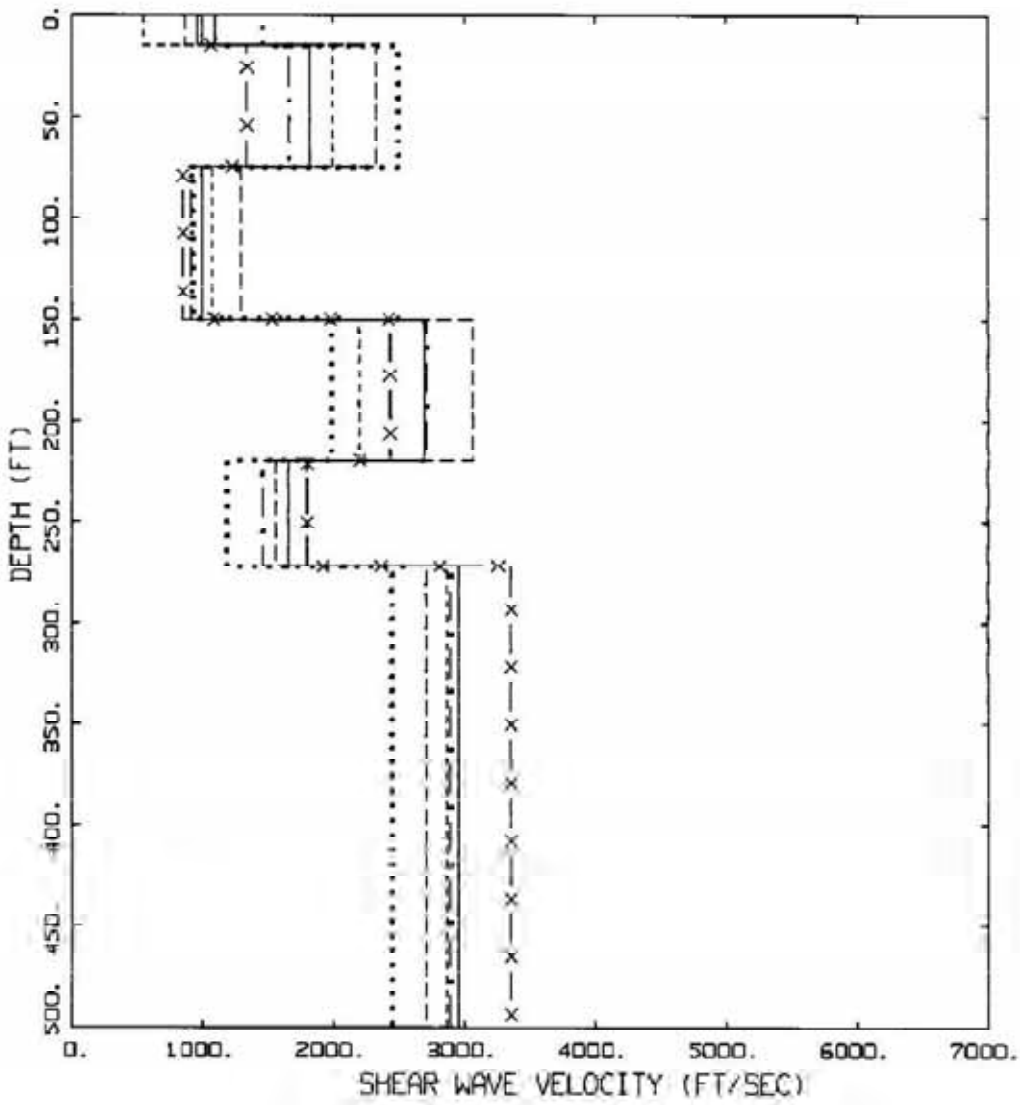


CMRR BASE CASE A
SHEAR-WAVE VELOCITY PROFILES

LEGEND

—x—	REALIZATION 16
....	REALIZATION 17
-----	REALIZATION 18
— — — —	REALIZATION 19
—•—	REALIZATION 20
———	BASE CASE

URS	Project No. 26817259	CMRR PROFILE A BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 51e
	Los Alamos National Lab		

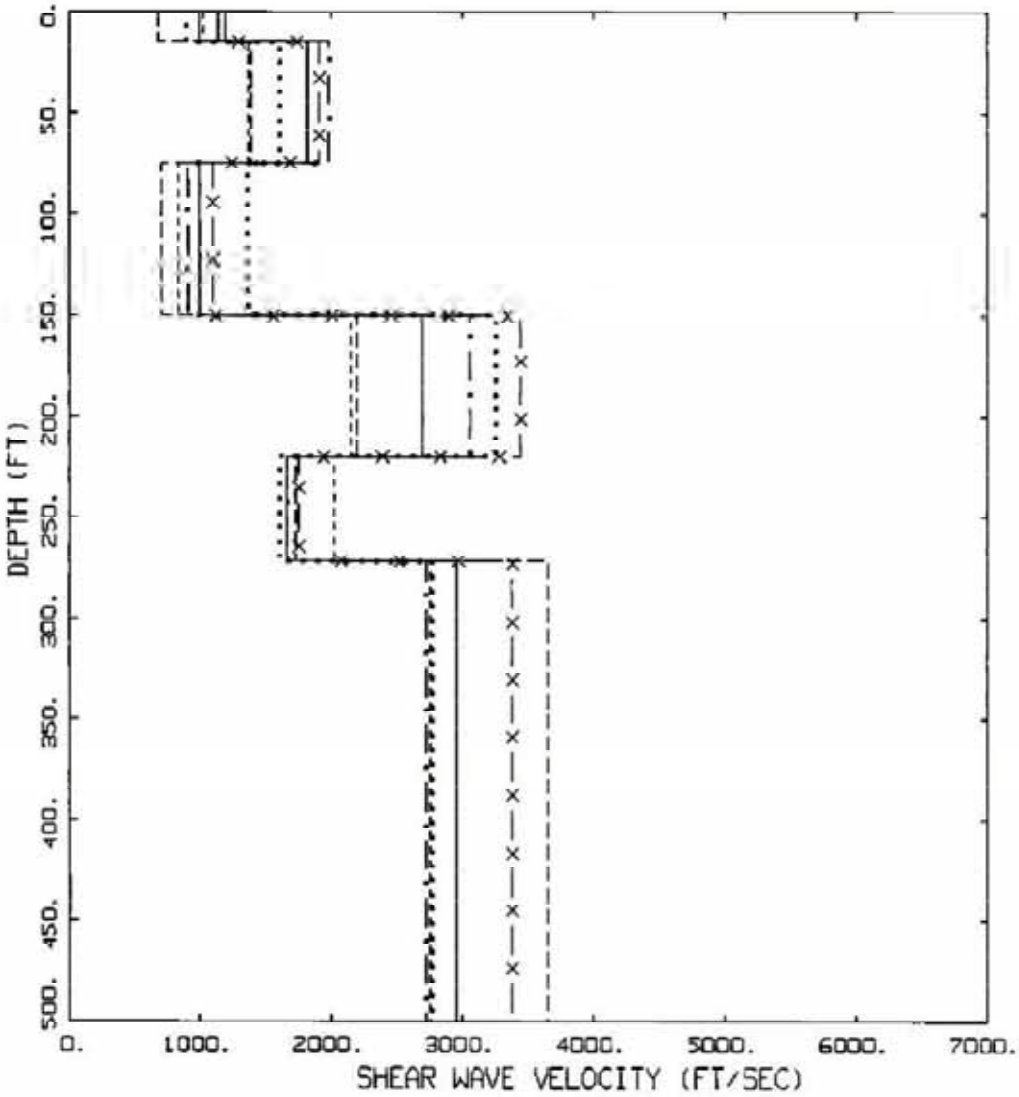


CMRR BASE CASE A
SHEAR-WAVE VELOCITY PROFILES

LEGEND

—×—	REALIZATION 21
••••	REALIZATION 22
-----	REALIZATION 23
— — — —	REALIZATION 24
—·—	REALIZATION 25
———	BASE CASE

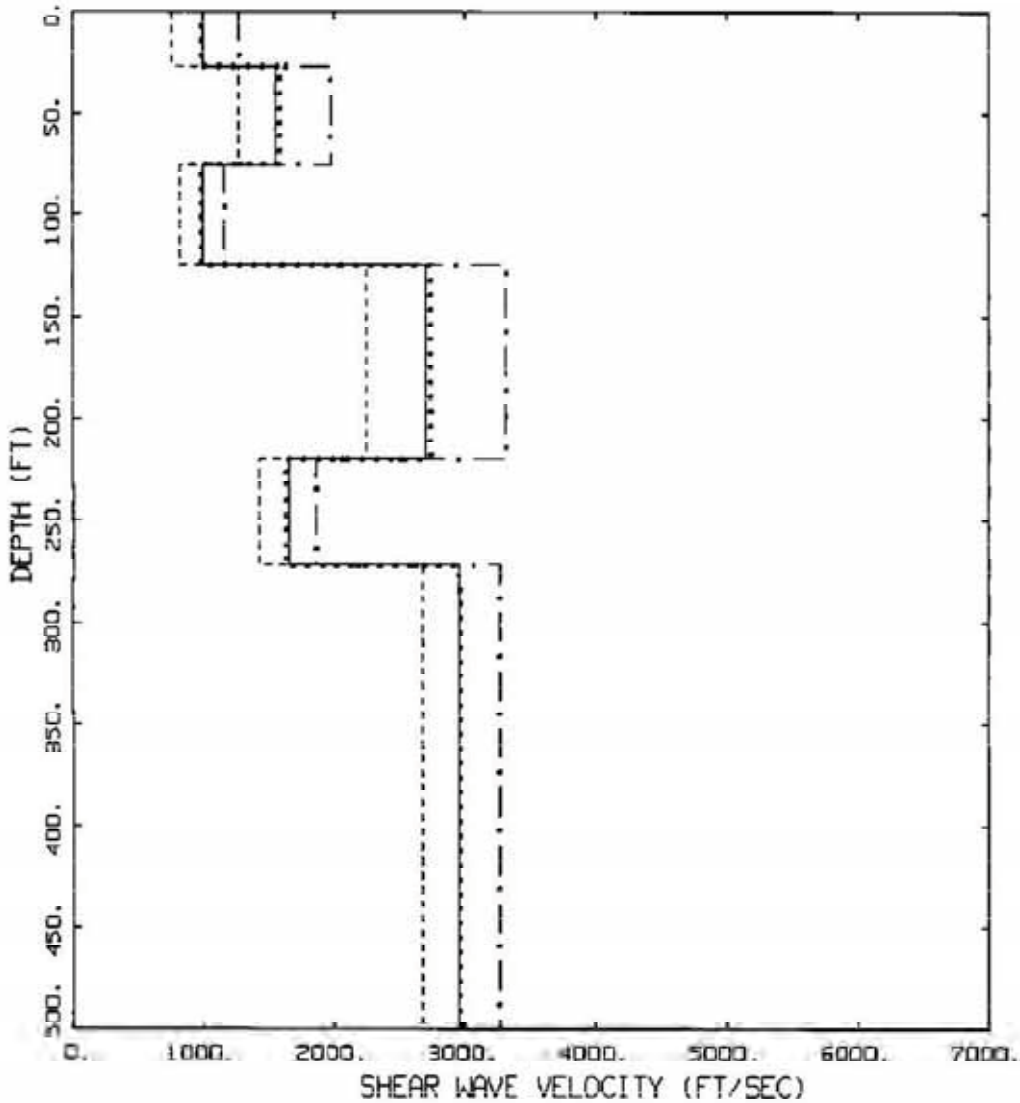
URS	Project No. 26817259	CMRR PROFILE A BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 51f
	Los Alamos National Lab		



CMRR BASE CASE A
SHEAR-WAVE VELOCITY PROFILES

LEGEND
—x— REALIZATION 26
.... REALIZATION 27
----- REALIZATION 28
— — — REALIZATION 29
—·— REALIZATION 30
——— BASE CASE

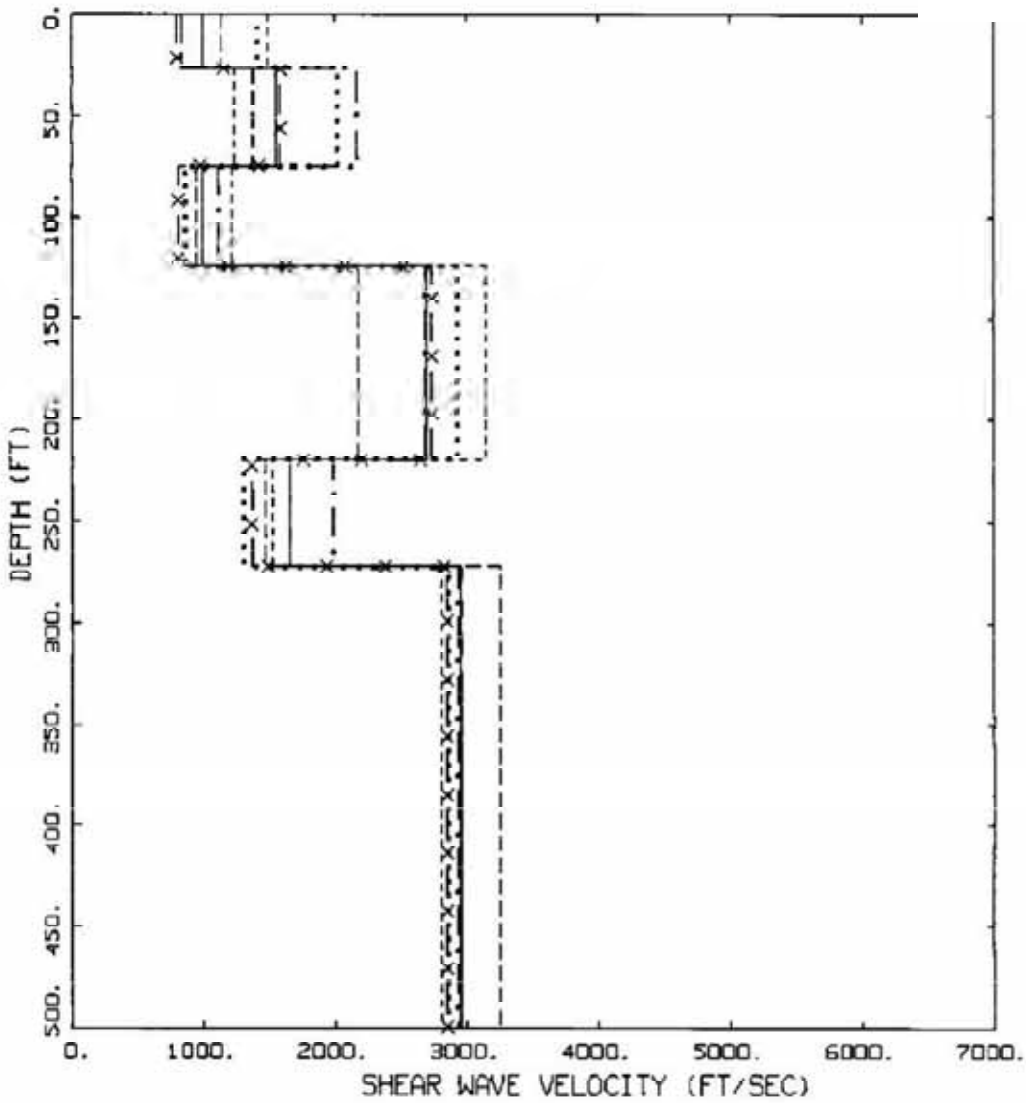
URS	Project No. 26817259 Los Alamos National Lab	CMRR PROFILE A BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 51g



CMRR BASE CASE B
MEDIAN, 16TH, AND 84TH

LEGEND
16TH PERCENTILE
50TH PERCENTILE
84TH PERCENTILE
BASE CASE

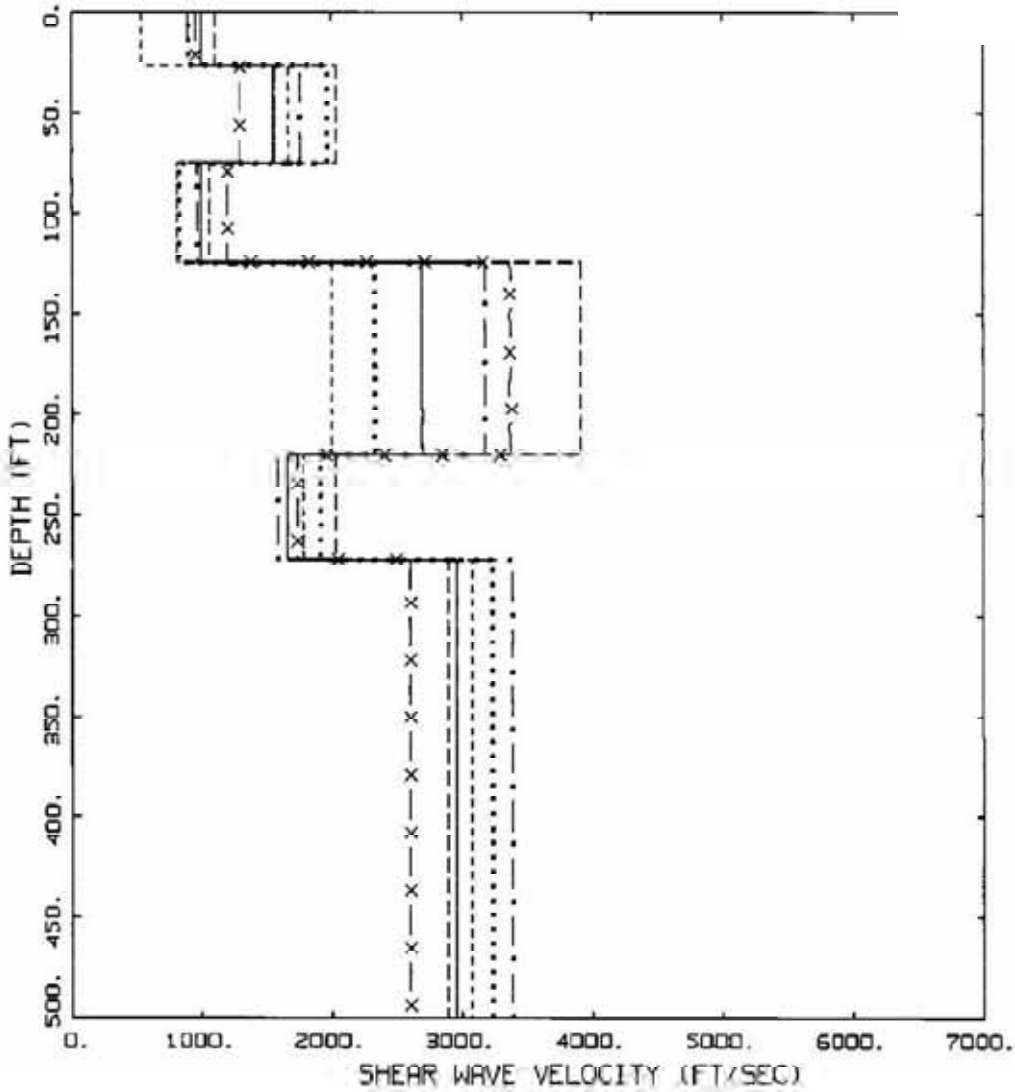
URS	Project No. 26817259 Los Alamos National Lab	CMRR PROFILE B BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 52a



CMRR BASE CASE B
SHEAR-WAVE VELOCITY PROFILES

LEGEND
REALIZATION 01
REALIZATION 02
REALIZATION 03
REALIZATION 04
REALIZATION 05
BASE CASE

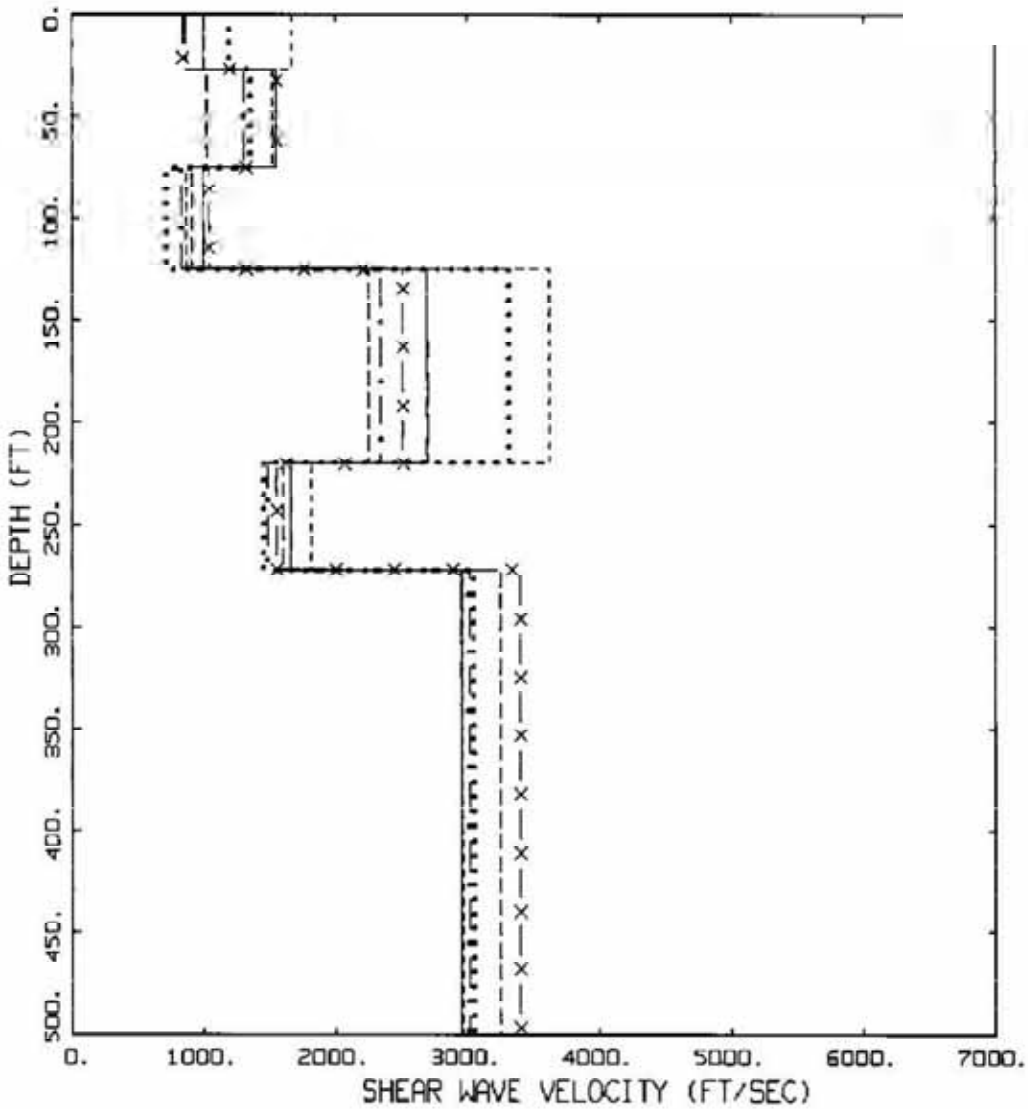
URS	Project No. 26817259	CMRR PROFILE B BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 52b
	Los Alamos National Lab		



CMRR BASE CASE B
SHEAR-WAVE VELOCITY PROFILES

LEGEND
REALIZATION 06
REALIZATION 07
REALIZATION 08
REALIZATION 09
REALIZATION 10
BASE CASE

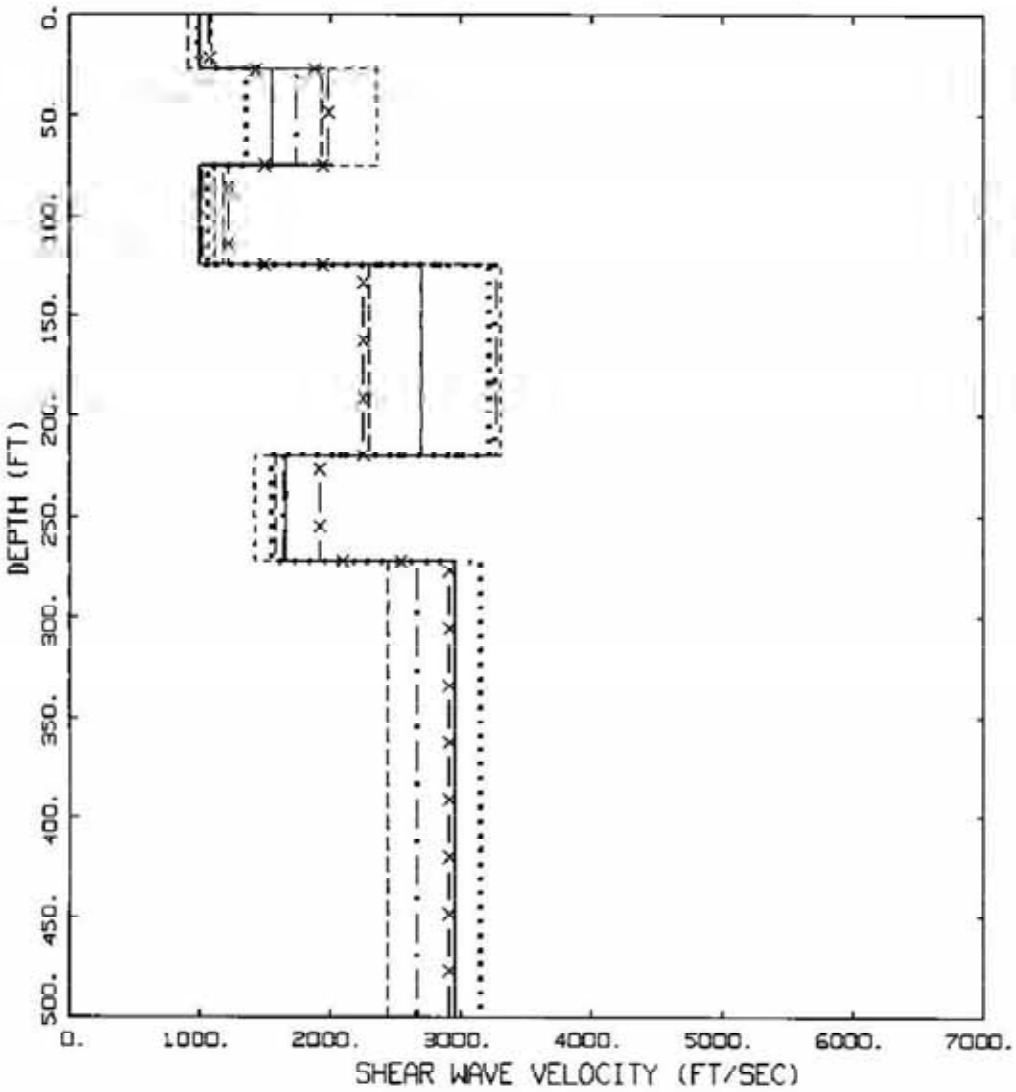
URS	Project No. 26817259	CMRR PROFILE B BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 52c
	Los Alamos National Lab		



CMRR BASE CASE B
SHEAR-WAVE VELOCITY PROFILES

LEGEND
REALIZATION 11
REALIZATION 12
REALIZATION 13
REALIZATION 14
REALIZATION 15
BASE CASE

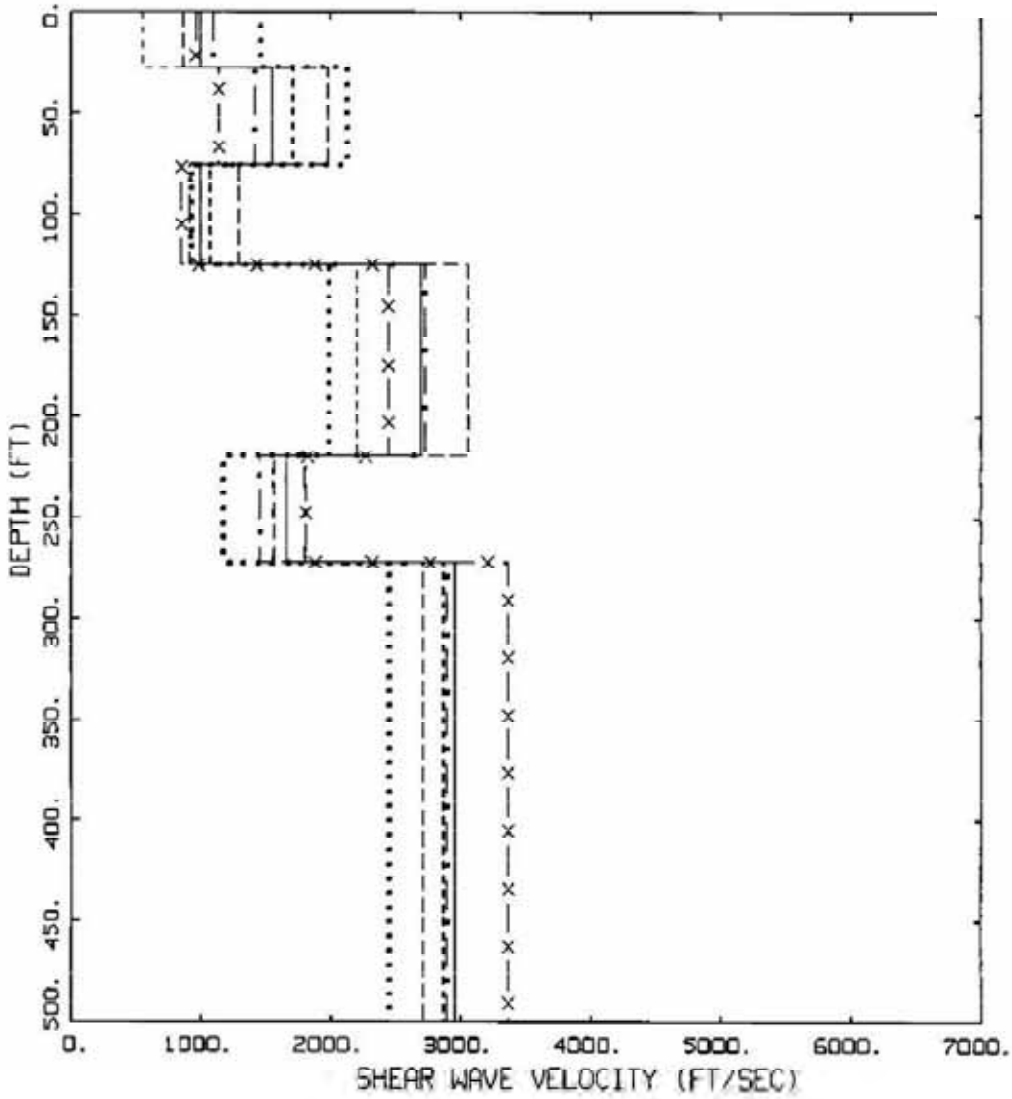
URS	Project No. 26817259 Los Alamos National Lab	CMRR PROFILE B BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 52d



CMRR BASE CASE B
SHEAR-WAVE VELOCITY PROFILES

LEGEND
REALIZATION 16
REALIZATION 17
REALIZATION 18
REALIZATION 19
REALIZATION 20
BASE CASE

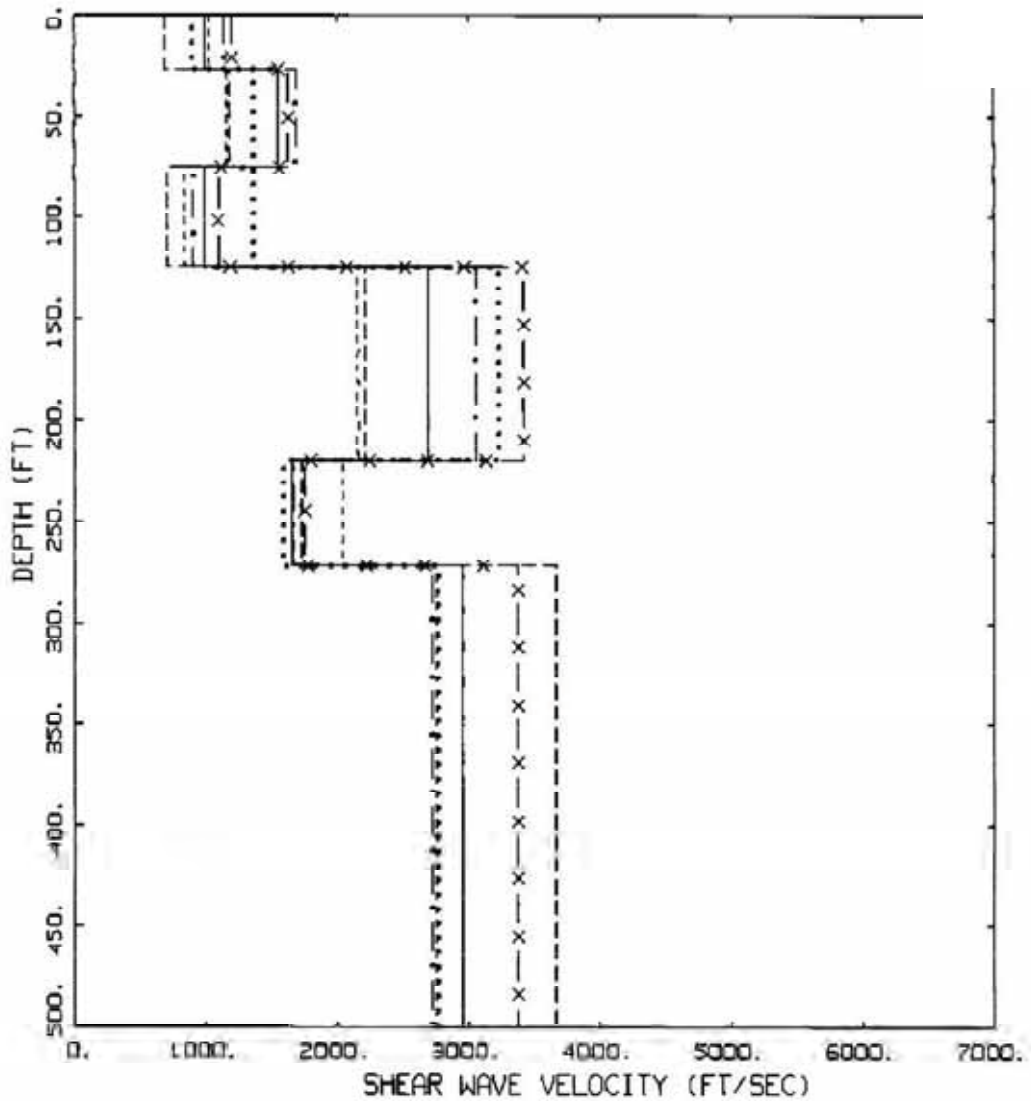
URS	Project No. 26817259 Los Alamos National Lab	CMRR PROFILE B BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 52e



CMRR BASE CASE B
SHEAR-WAVE VELOCITY PROFILES

LEGEND
—x— REALIZATION 21
.... REALIZATION 22
----- REALIZATION 23
– – – – REALIZATION 24
—·— REALIZATION 25
——— BASE CASE

URS	Project No. 26817259 Los Alamos National Lab	CMRR PROFILE B BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 52f

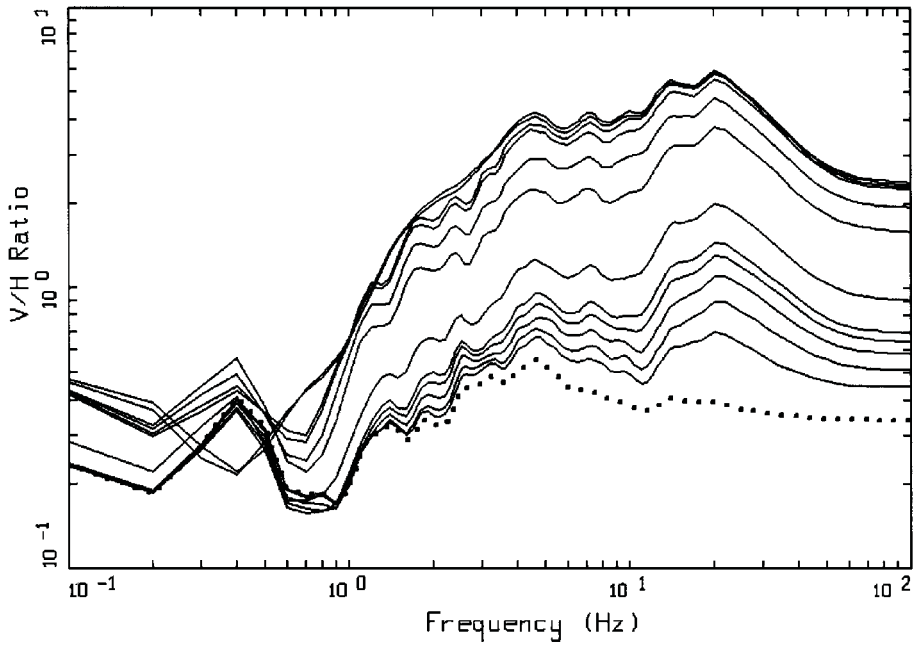


CMRR BASE CASE B
SHEAR-WAVE VELOCITY PROFILES

LEGEND

—×—	REALIZATION 26
- - - -	REALIZATION 27
- - - - -	REALIZATION 28
— — — -	REALIZATION 29
— • —	REALIZATION 30
———	BASE CASE

URS	Project No. 26817259	CMRR PROFILE B BASE CASE, MEDIAN, AND +/- 1σ AND INDIVIDUAL PROFILES	Figure 52g
	Los Alamos National Lab		



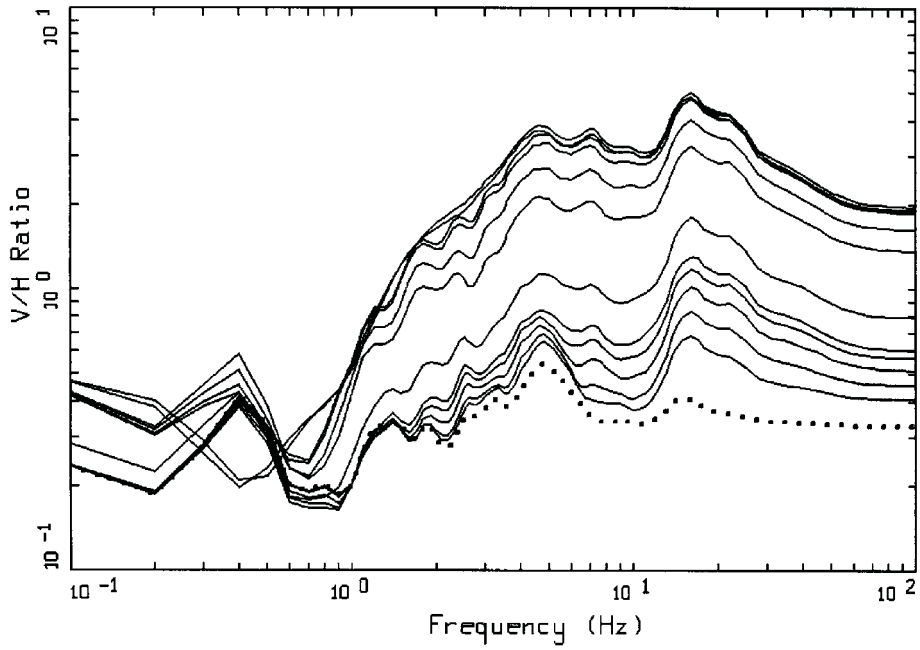
V/H RATIOS, CMRR A
UNADJUSTED CURVES

LEGEND

50TH PERCENTILE, 3.00 g, Distance = 0.0 km
50TH PERCENTILE, 2.00 g, Distance = 0.0 km
50TH PERCENTILE, 1.50 g, Distance = 0.0 km
50TH PERCENTILE, 1.25 g, Distance = 0.0 km
50TH PERCENTILE, 1.00 g, Distance = 0.0 km
50TH PERCENTILE, 0.75 g, Distance = 0.0 km
50TH PERCENTILE, 0.50 g, Distance = 8.0 km
50TH PERCENTILE, 0.40 g, Distance = 14.0 km
50TH PERCENTILE, 0.30 g, Distance = 19.0 km
50TH PERCENTILE, 0.20 g, Distance = 31.0 km
50TH PERCENTILE, 0.10 g, Distance = 60.0 km
50TH PERCENTILE, 0.05 g, Distance = 115.0 km
50TH PERCENTILE, 0.01 g, Distance = 130.0 km

Note: V/H ratios derived from basecase profiles A and B and unadjusted and adjusted modulus reduction and hysteretic damping curves (Wong et al., 2007). Magnitude is M 7.0 and peak accelerations reflect median estimates for generic deep firm soil.

URS	Project No. 26817259	CMRR SITE-SPECIFIC MEDIAN V/H RATIOS	Figure 53a
	Los Alamos National Lab		

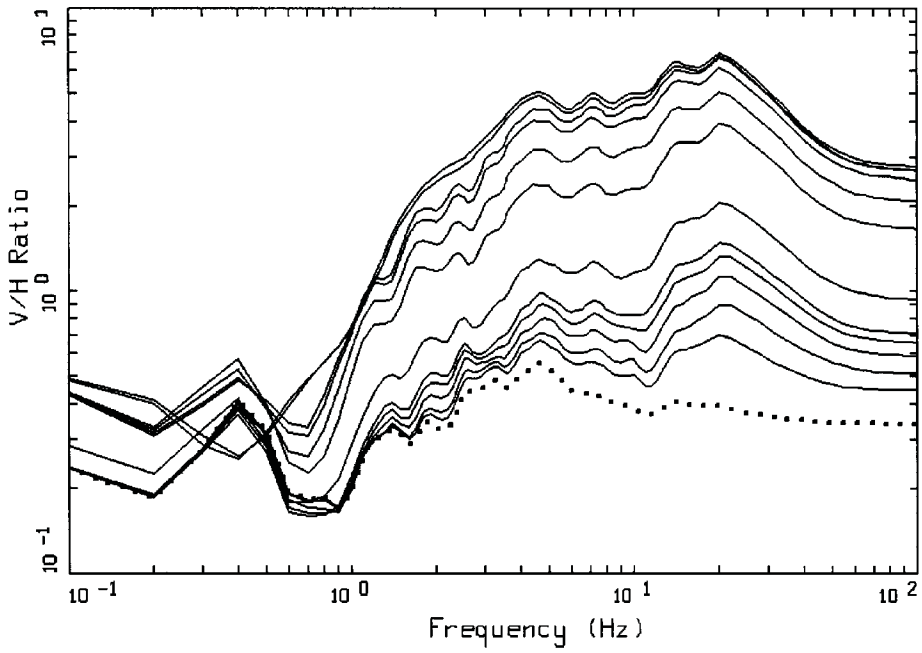


V/H RATIOS, CMRR B
UNADJUSTED CURVES

LEGEND

———	50TH PERCENTILE, 3.00 g, Distance = 0.0 km
———	50TH PERCENTILE, 2.00 g, Distance = 0.0 km
———	50TH PERCENTILE, 1.50 g, Distance = 0.0 km
———	50TH PERCENTILE, 1.25 g, Distance = 0.0 km
———	50TH PERCENTILE, 1.00 g, Distance = 0.0 km
———	50TH PERCENTILE, 0.75 g, Distance = 0.0 km
———	50TH PERCENTILE, 0.50 g, Distance = 8.0 km
———	50TH PERCENTILE, 0.40 g, Distance = 14.0 km
———	50TH PERCENTILE, 0.30 g, Distance = 19.0 km
———	50TH PERCENTILE, 0.20 g, Distance = 31.0 km
———	50TH PERCENTILE, 0.10 g, Distance = 60.0 km
———	50TH PERCENTILE, 0.05 g, Distance = 115.0 km
• • • •	50TH PERCENTILE, 0.01 g, Distance = 130.0 km

Note: V/H ratios derived from basecase profiles A and B and unadjusted and adjusted modulus reduction and hysteretic damping curves (Wong et al., 2007). Magnitude is M 7.0 and peak accelerations reflect median estimates for generic deep firm soil.

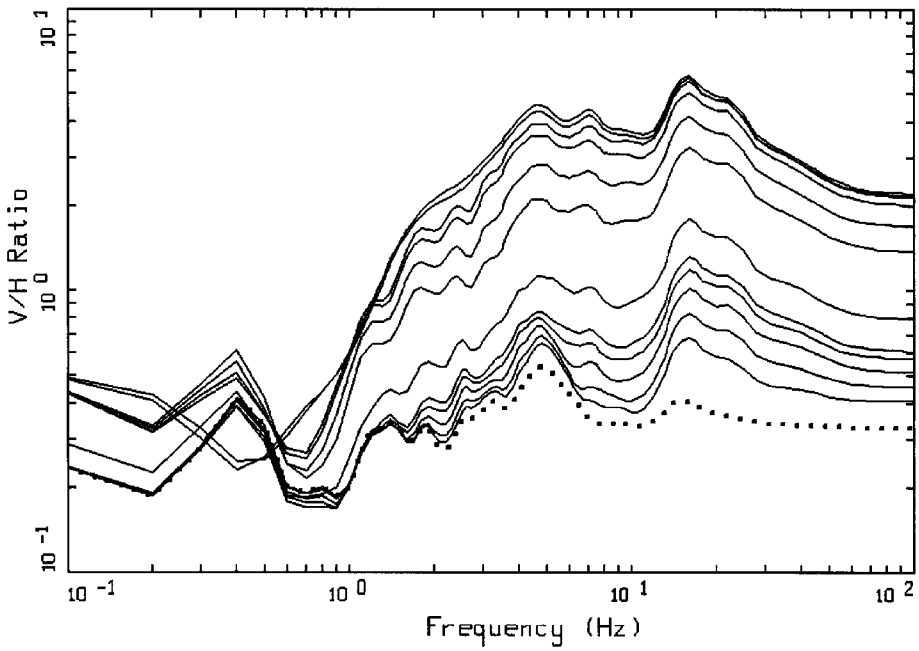


V/H RATIOS, CMRR A
ADJUSTED CURVES

LEGEND

50TH PERCENTILE, 3.00 g, Distance = 0.0 km
50TH PERCENTILE, 2.00 g, Distance = 0.0 km
50TH PERCENTILE, 1.50 g, Distance = 0.0 km
50TH PERCENTILE, 1.25 g, Distance = 0.0 km
50TH PERCENTILE, 1.00 g, Distance = 0.0 km
50TH PERCENTILE, 0.75 g, Distance = 0.0 km
50TH PERCENTILE, 0.50 g, Distance = 8.0 km
50TH PERCENTILE, 0.40 g, Distance = 14.0 km
50TH PERCENTILE, 0.30 g, Distance = 19.0 km
50TH PERCENTILE, 0.20 g, Distance = 31.0 km
50TH PERCENTILE, 0.10 g, Distance = 60.0 km
50TH PERCENTILE, 0.05 g, Distance = 115.0 km
50TH PERCENTILE, 0.01 g, Distance = 130.0 km

Note: V/H ratios derived from basecase profiles A and B and unadjusted and adjusted modulus reduction and hysteretic damping curves (Wong et al., 2007). Magnitude is M 7.0 and peak accelerations reflect median estimates for generic deep firm soil.

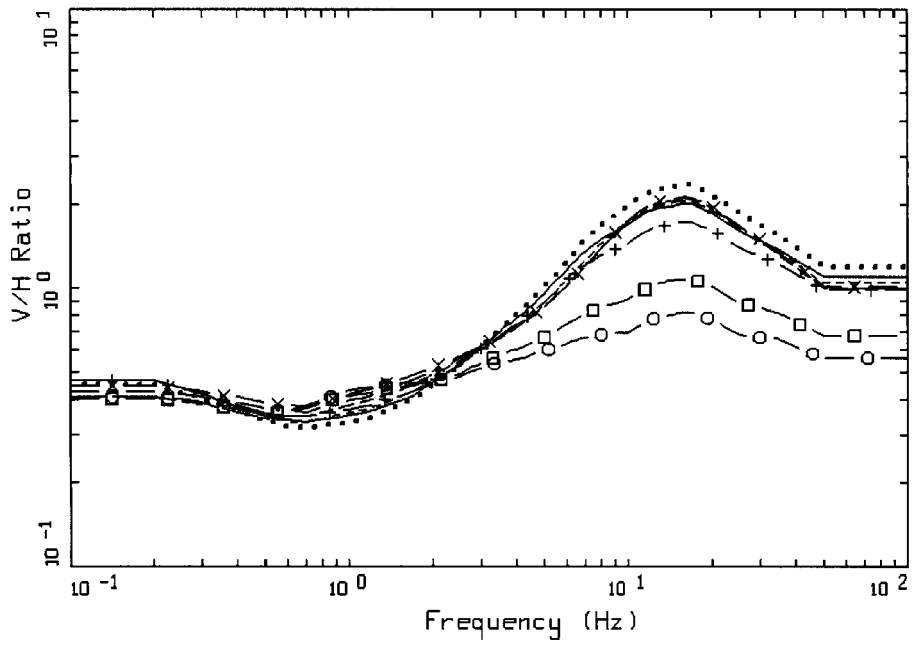


V/H RATIOS, CMRR B
ADJUSTED CURVES

LEGEND

———	50TH PERCENTILE, 3.00 g, Distance = 0.0 km
———	50TH PERCENTILE, 2.00 g, Distance = 0.0 km
———	50TH PERCENTILE, 1.50 g, Distance = 0.0 km
———	50TH PERCENTILE, 1.25 g, Distance = 0.0 km
———	50TH PERCENTILE, 1.00 g, Distance = 0.0 km
———	50TH PERCENTILE, 0.75 g, Distance = 0.0 km
———	50TH PERCENTILE, 0.50 g, Distance = 8.0 km
———	50TH PERCENTILE, 0.40 g, Distance = 14.0 km
———	50TH PERCENTILE, 0.30 g, Distance = 19.0 km
———	50TH PERCENTILE, 0.20 g, Distance = 31.0 km
———	50TH PERCENTILE, 0.10 g, Distance = 60.0 km
———	50TH PERCENTILE, 0.05 g, Distance = 115.0 km
• • • •	50TH PERCENTILE, 0.01 g, Distance = 130.0 km

Note: V/H ratios derived from basecase profiles A and B and unadjusted and adjusted modulus reduction and hysteretic damping curves (Wong et al., 2007). Magnitude is M 7.0 and peak accelerations reflect median estimates for generic deep firm soil.

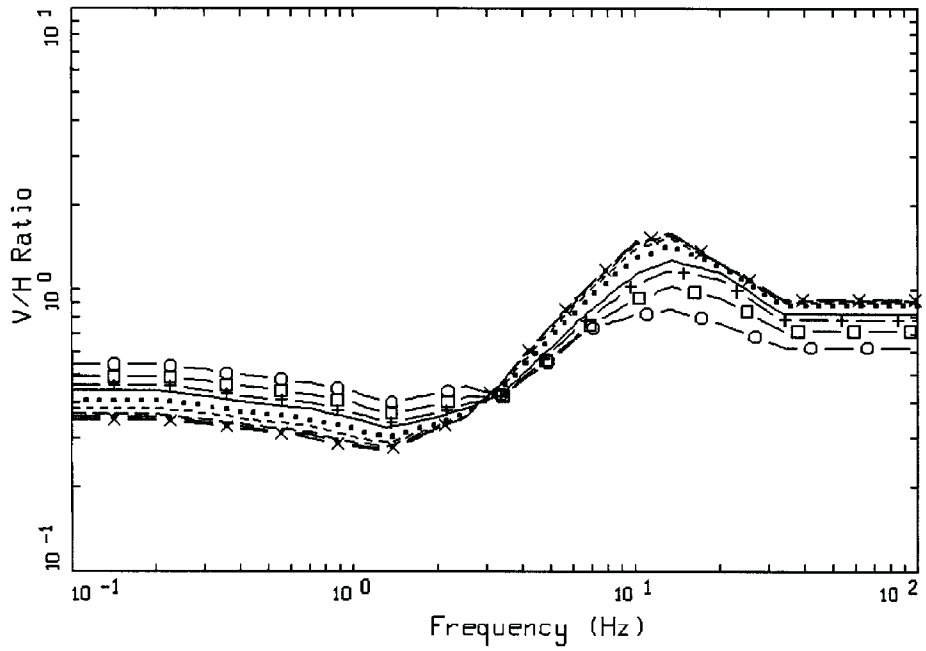


V/H RATIOS, ABRAHAMSON & SILVA
SOIL, NORMAL, HANGING WALL

LEGEND

—×—	0.47 g: DISTANCE = 1 KM
—•—	0.46 g: DISTANCE = 2 KM
— — — -	0.43 g: DISTANCE = 3 KM
- - - - -	0.41 g: DISTANCE = 5 KM
• • • •	0.41 g: DISTANCE = 8 KM
———	0.28 g: DISTANCE = 14 KM
—+—	0.22 g: DISTANCE = 19 KM
—□—	0.11 g: DISTANCE = 31 KM
—○—	0.07 g: DISTANCE = 57 KM

Note: V/H ratios computed for M 7, normal faulting rupture mechanism, and hanging wall site locations at a suite of closest rupture distances (Abrahamson and Silva, 1997; Campbell and Bozorgnia, 2003; as appears in Wong et al., 2007).



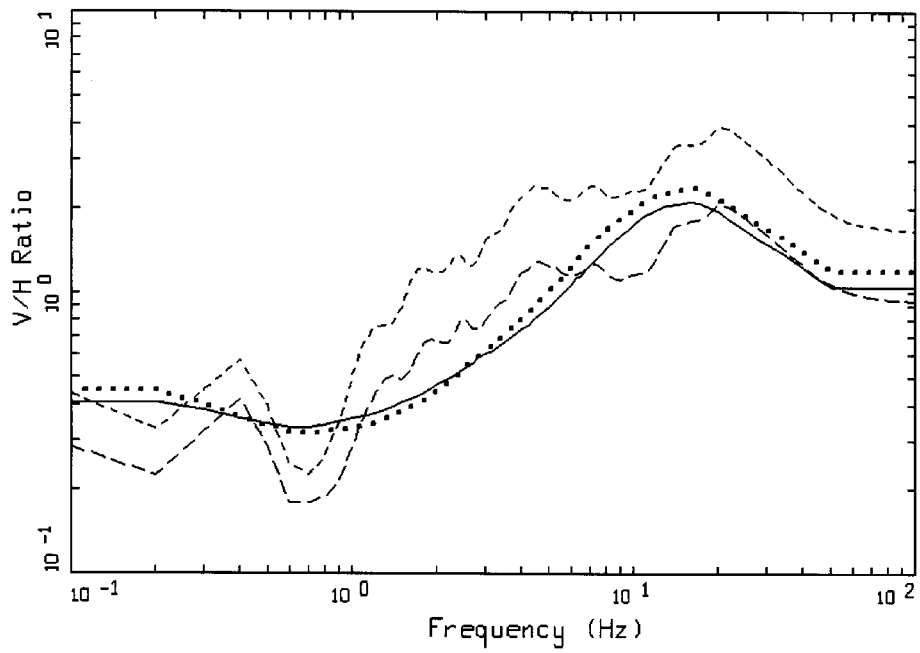
V/H RATIOS, CAMPBELL&BOZORGNIA
SOIL, NORMAL, HANGING WALL

LEGEND

—×—	0.52 g: DISTANCE = 1 KM
—•—	0.51 g: DISTANCE = 2 KM
– – – –	0.50 g: DISTANCE = 3 KM
- - - - -	0.46 g: DISTANCE = 5 KM
• • • •	0.39 g: DISTANCE = 8 KM
———	0.28 g: DISTANCE = 14 KM
—+—	0.22 g: DISTANCE = 19 KM
—□—	0.14 g: DISTANCE = 31 KM
—○—	0.07 g: DISTANCE = 57 KM

Note: V/H ratios computed for M 7, normal faulting rupture mechanism, and hanging wall site locations at a suite of closest rupture distances (Abrahamson and Silva, 1997; Campbell and Bozorgnia, 2003; as appears in Wong et al., 2007).

URS	Project No. 26817259	CMRR EMPIRICAL DEEP FIRM SOIL V/H RATIOS	Figure 54b
	Los Alamos National Lab		



EMPIRICAL AND MODEL V/H RATIOS
LARGEST SETS

LEGEND

ABRAHAMSON AND SILVA, 0.41 g: DISTANCE = 5 KM

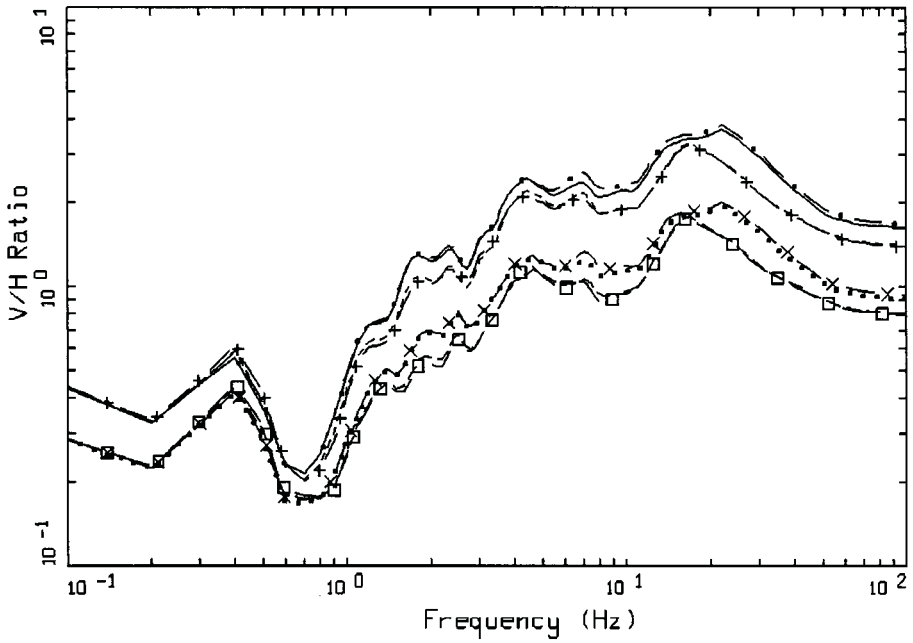
ABRAHAMSON AND SILVA, 0.41 g: DISTANCE = 8 KM

CMRR A, ADJUSTED CURVES, 50TH PERCENTILE, 0.75 g, Distance = 0.0 km

CMRR A, ADJUSTED CURVES, 50TH PERCENTILE, 0.50 g, Distance = 8.0 km

Note: The closest distances reflect the V/H ratios applied at a return period of 100,000 years and longer while the V/H ratios at larger distances were used for shorter return periods.

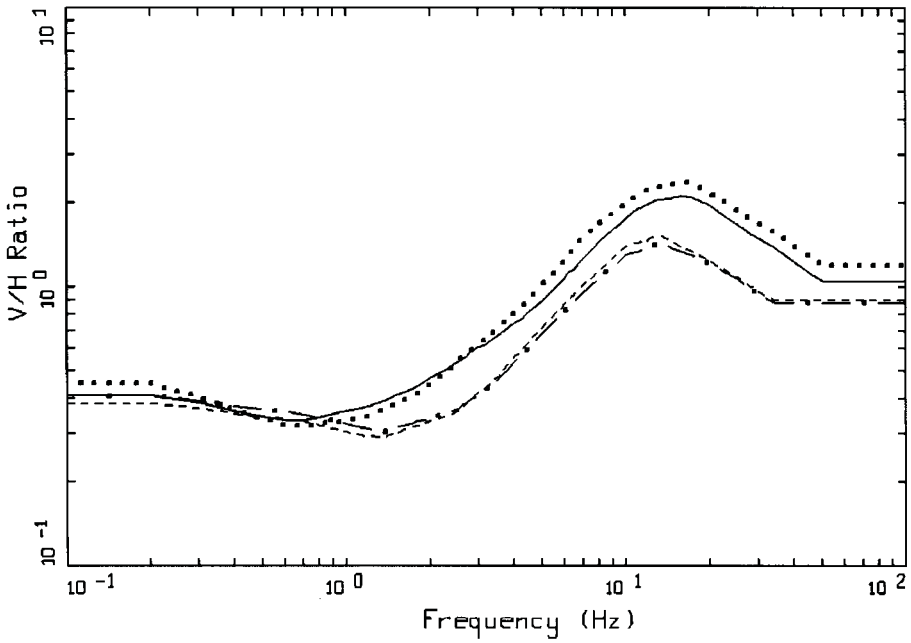
URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF THE LARGEST EMPIRICAL AND SITE-SPECIFIC V/H RATIOS USED IN VERTICAL HAZARD	Figure 55



V/H RATIOS, CMRR
M = 7.0

LEGEND

———	CMRR A, UNADJUSTED CURVES, 50TH PERCENTILE, 0.75 g, DISTANCE = 0.0 KM
• • • •	CMRR A, UNADJUSTED CURVES, 50TH PERCENTILE, 0.50 g, DISTANCE = 8.0 KM
- - - - -	CMRR B, UNADJUSTED CURVES, 50TH PERCENTILE, 0.75 g, DISTANCE = 0.0 KM
— — — -	CMRR B, UNADJUSTED CURVES, 50TH PERCENTILE, 0.50 g, DISTANCE = 8.0 KM
— • —	CMRR A, ADJUSTED CURVES, 50TH PERCENTILE, 0.75 g, DISTANCE = 0.0 KM
— × —	CMRR A, ADJUSTED CURVES, 50TH PERCENTILE, 0.50 g, DISTANCE = 8.0 KM
— + —	CMRR B, ADJUSTED CURVES, 50TH PERCENTILE, 0.75 g, DISTANCE = 0.0 KM
— □ —	CMRR B, ADJUSTED CURVES, 50TH PERCENTILE, 0.50 g, DISTANCE = 8.0 KM

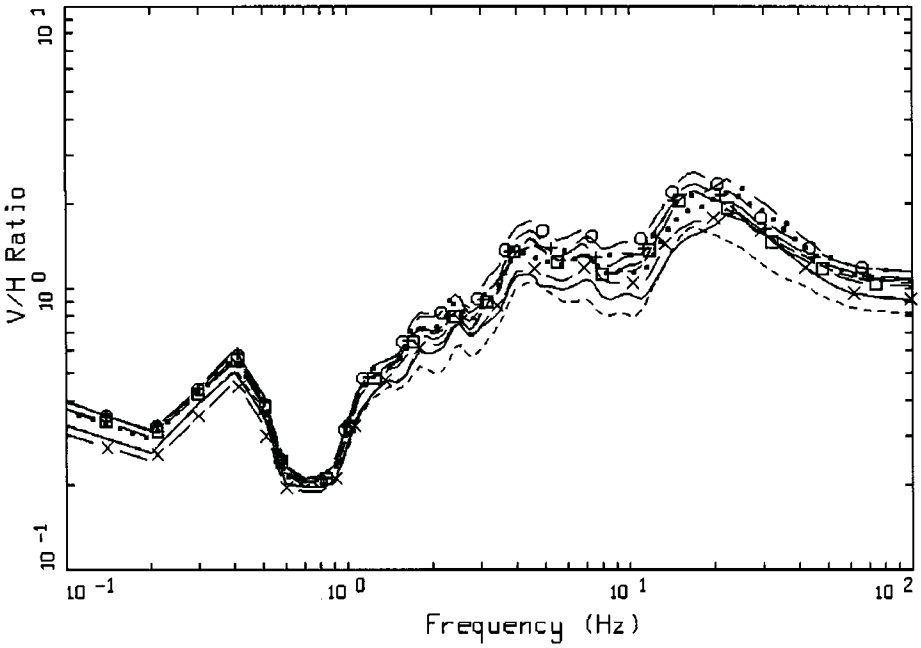


V/H RATIOS, SOIL
M = 7.0

LEGEND

———	ABRAHAMSON AND SILVA, 0.41 g: DISTANCE = 5 KM
• • • •	ABRAHAMSON AND SILVA, 0.41 g: DISTANCE = 8 KM
- - - - -	CAMPBELL AND BOZORGNIA, 0.46 g: DISTANCE = 5 KM
— • —	CAMPBELL AND BOZORGNIA, 0.39 g: DISTANCE = 8 KM

URS	Project No. 26817259 Los Alamos National Lab	SUITE OF GENERIC DEEP FIRM SOIL (EMPIRICAL) MEDIAN V/H RATIOS USED IN THE 2007 VERTICAL HAZARD	Figure 57



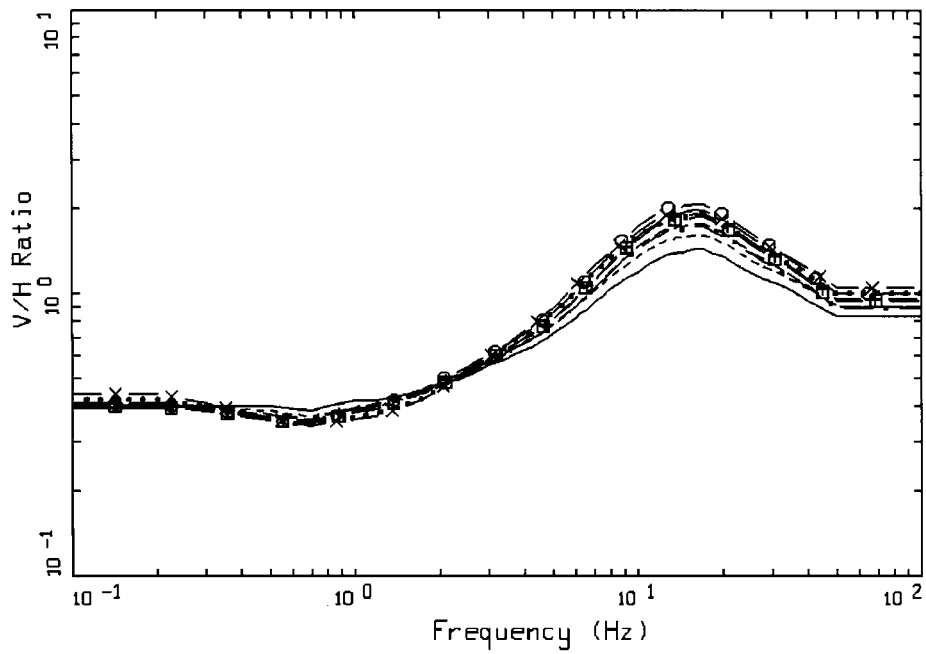
MODEL V/H RATIOS, CMRR
LARGEST SETS

LEGEND

———	CMRR A, ADJUSTED CURVES, 50TH PERCENTILE, M 6.00, DISTANCE = 6.0 KM
• • • •	CMRR A, ADJUSTED CURVES, 50TH PERCENTILE, M 6.20, DISTANCE = 4.0 KM
- - - - -	CMRR A, ADJUSTED CURVES, 50TH PERCENTILE, M 6.20, DISTANCE = 6.0 KM
— — — -	CMRR A, ADJUSTED CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 3.0 KM
— • —	CMRR A, ADJUSTED CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 4.0 KM
— × —	CMRR A, ADJUSTED CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 7.0 KM
— + —	CMRR A, ADJUSTED CURVES, 50TH PERCENTILE, M 6.75, DISTANCE = 3.0 KM
— □ —	CMRR A, ADJUSTED CURVES, 50TH PERCENTILE, M 6.75, DISTANCE = 4.0 KM
— O —	CMRR A, ADJUSTED CURVES, 50TH PERCENTILE, M 7.00, DISTANCE = 3.0 KM

Note: Ratios reflect additional magnitudes and distances used in the update. Profile is CMRR-A, adjusted curves.

URS	Project No. 26817259 Los Alamos National Lab	EXAMPLE SUITE OF LARGEST SITE-SPECIFIC MEDIAN V/H RATIOS USED IN THE VERTICAL HAZARD UPDATE	Figure 58



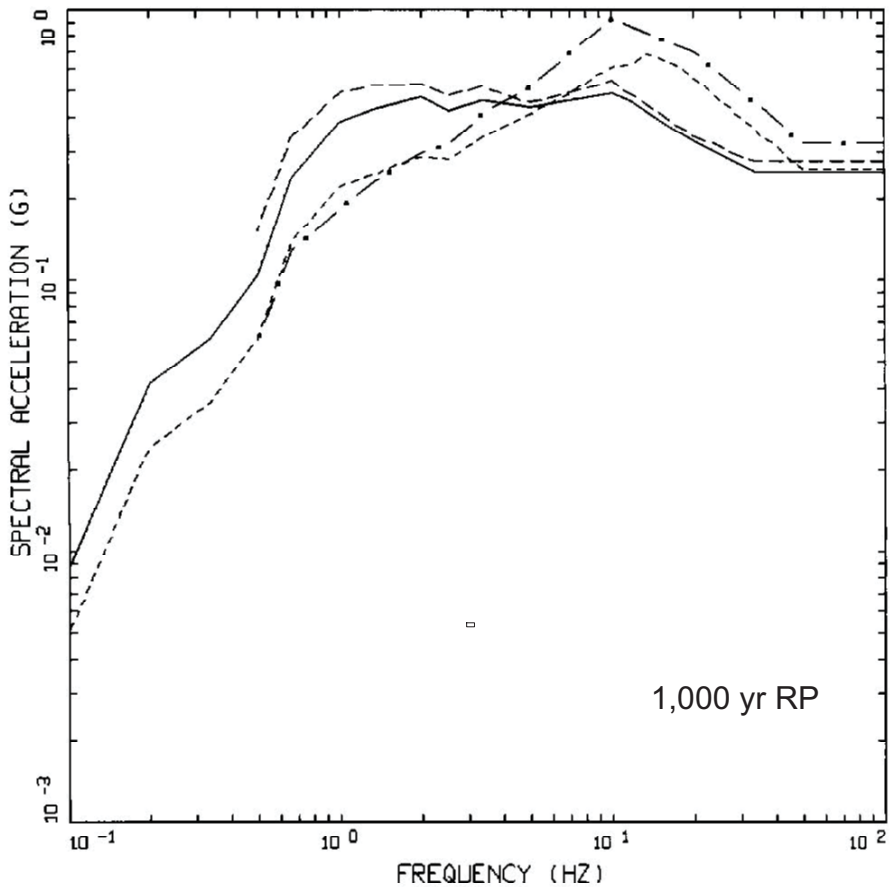
EMPIRICAL V/H RATIOS, SOIL
LARGEST SETS

LEGEND

———	ABRAHAMSON AND SILVA, 50TH PERCENTILE, M 6.00, DISTANCE = 6.0 KM
• • • •	ABRAHAMSON AND SILVA, 50TH PERCENTILE, M 6.20, DISTANCE = 4.0 KM
- - - - -	ABRAHAMSON AND SILVA, 50TH PERCENTILE, M 6.20, DISTANCE = 6.0 KM
— — — -	ABRAHAMSON AND SILVA, 50TH PERCENTILE, M 6.50, DISTANCE = 3.0 KM
— • —	ABRAHAMSON AND SILVA, 50TH PERCENTILE, M 6.50, DISTANCE = 4.0 KM
— × —	ABRAHAMSON AND SILVA, 50TH PERCENTILE, M 6.50, DISTANCE = 7.0 KM
— + —	ABRAHAMSON AND SILVA, 50TH PERCENTILE, M 6.75, DISTANCE = 3.0 KM
— □ —	ABRAHAMSON AND SILVA, 50TH PERCENTILE, M 6.75, DISTANCE = 4.0 KM
— o —	ABRAHAMSON AND SILVA, 50TH PERCENTILE, M 7.00, DISTANCE = 3.0 KM

Note: Ratios reflect additional magnitudes and distances used in the update. Model was Abrahamson and Silva (1997).

URS	Project No. 26817259 Los Alamos National Lab	EXAMPLE SUITE OF LARGEST GENERIC DEEP FIRM SOIL (EMPIRICAL) SITE SPECIFIC MEDIAN V/H RATIOS USED IN THE VERTICAL HAZARD UPDATE	Figure 59



CMRR 1,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

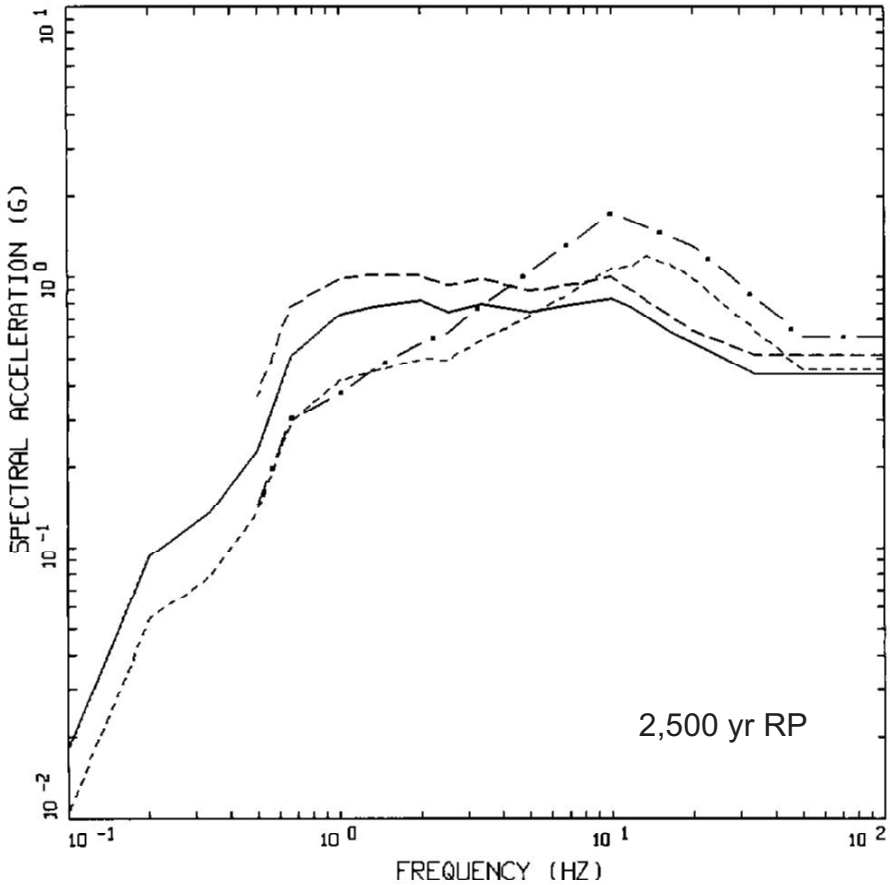
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 0.27g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 0.25g

— • — 2007 REPORT VERTICAL UHS, PGA = 0.32g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 0.26g

URS	Project No. 26817259	2007 AND UPDATED CMRR SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 60a
	Los Alamos National Lab		

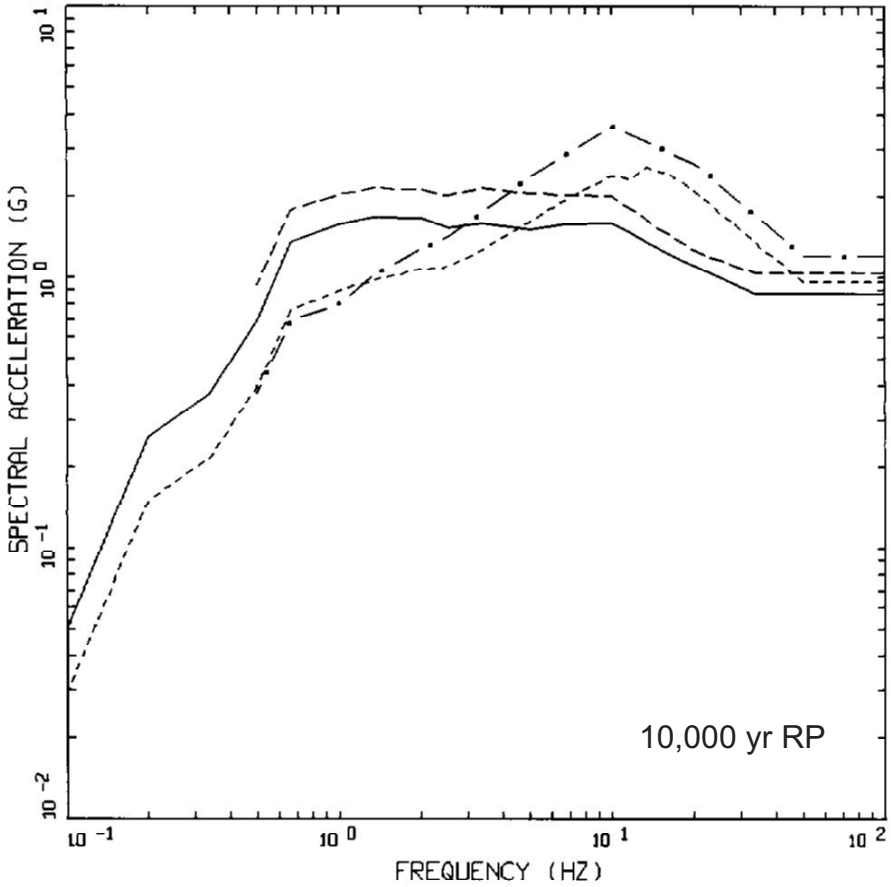


CMRR 2,500 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

- - - - 2007 REPORT HORIZONTAL UHS, PGA = 0.52g
——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 0.44g
— • — 2007 REPORT VERTICAL UHS, PGA = 0.60g
- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 0.46g

URS	Project No. 26817259 Los Alamos National Lab	2007 AND UPDATED CMRR SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 60b



CMRR 10,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

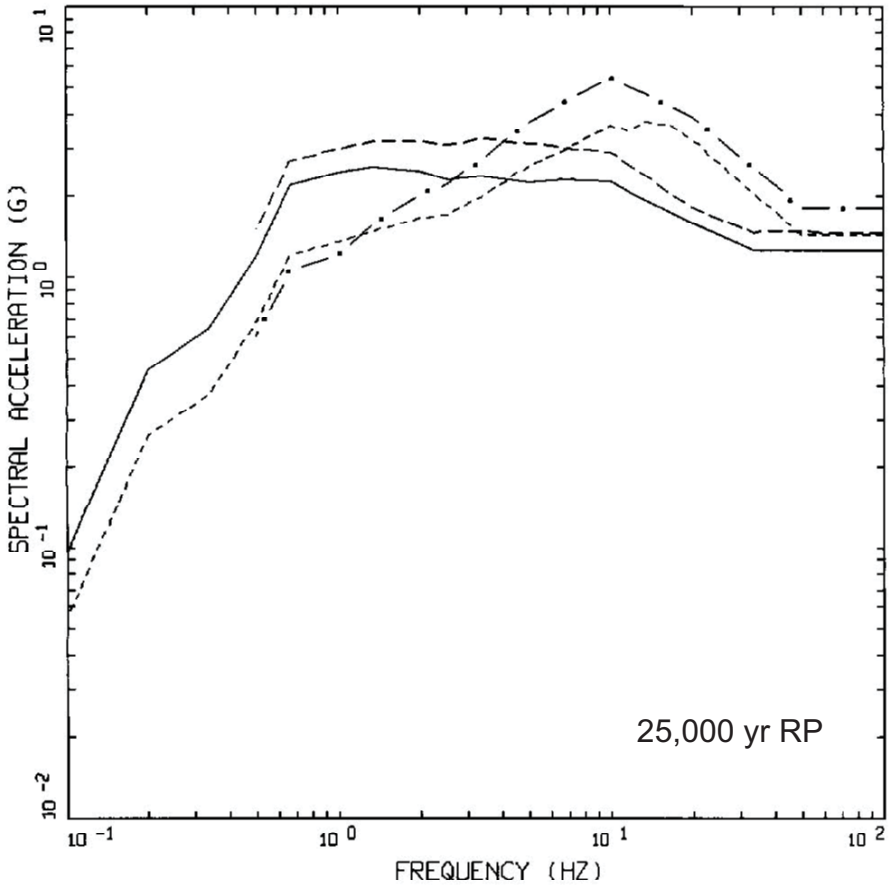
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 1.03g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 0.87g

— • — 2007 REPORT VERTICAL UHS, PGA = 1.21g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 0.96g

URS	Project No. 26817259	2007 AND UPDATED CMRR SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 60c
	Los Alamos National Lab		



CMRR 25,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

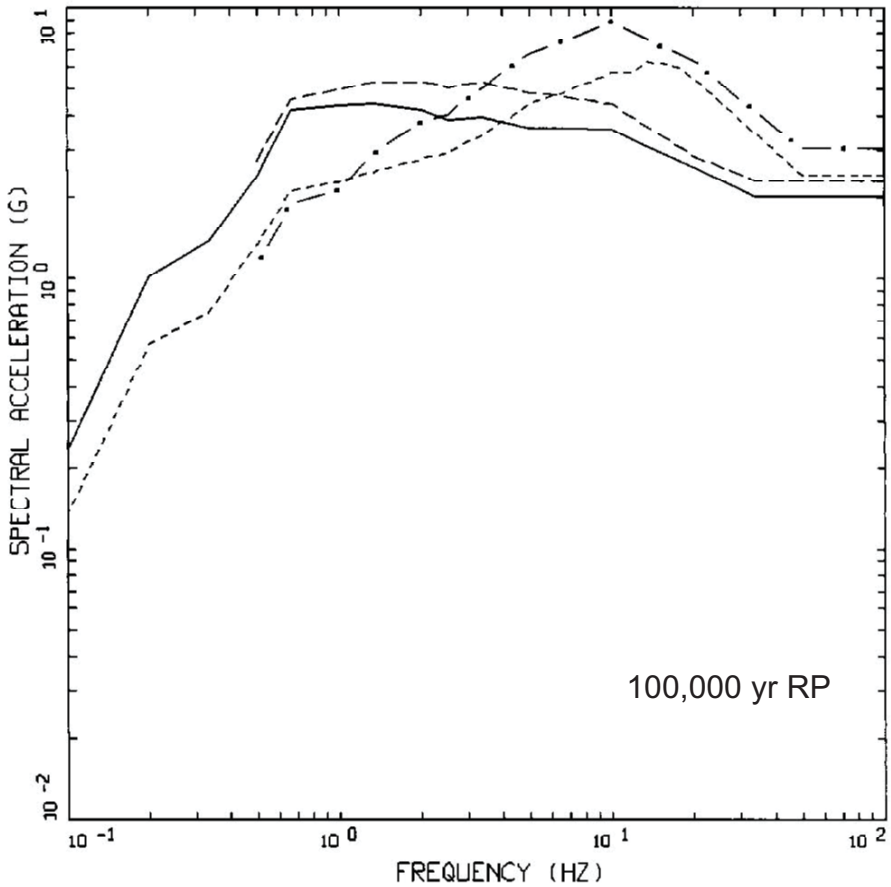
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 1.47g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 1.26g

— • — 2007 REPORT VERTICAL UHS, PGA = 1.79g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 1.43g

URS	Project No. 26817259	2007 AND UPDATED CMRR SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 60d
	Los Alamos National Lab		



CMRR 100,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

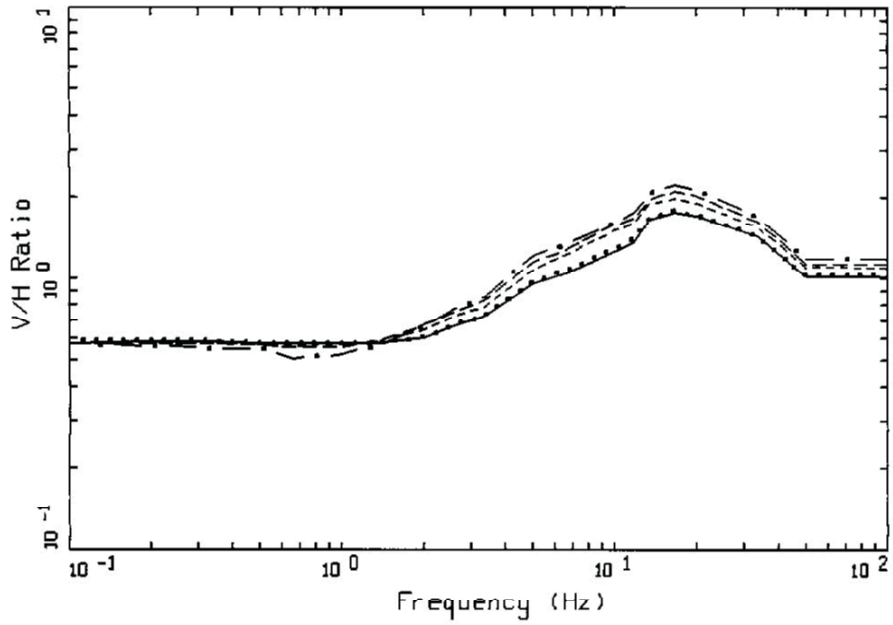
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 2.30g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 2.02g

— · — 2007 REPORT VERTICAL UHS, PGA = 3.01g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 2.39g

URS	Project No. 26817259	2007 AND UPDATED CMRR SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 60e
	Los Alamos National Lab		

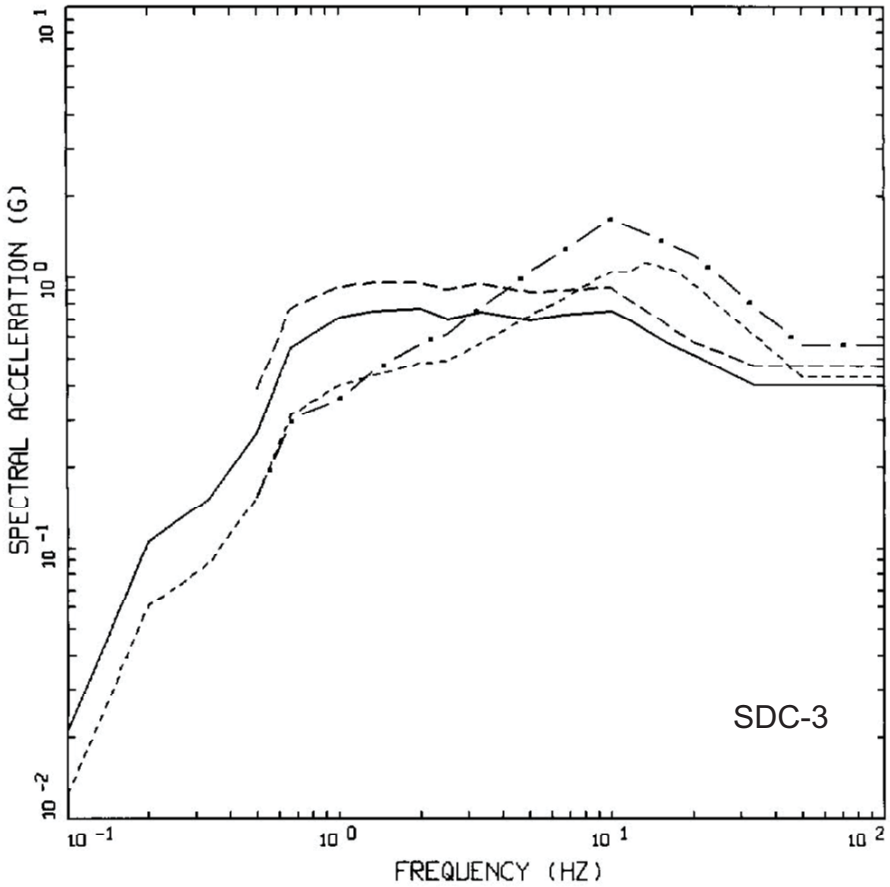


CMRR, MEAN UHRS
IMPLIED V/H RATIO

LEGEND

———	V/H RATIO: 1,000 YEAR (MEAN)
• • • •	V/H RATIO: 2,500 YEAR (MEAN)
- - - - -	V/H RATIO: 10,000 YEAR (MEAN)
— — — -	V/H RATIO: 25,000 YEAR (MEAN)
— • —	V/H RATIO: 100,000 YEAR (MEAN)

URS	Project No. 26817259 Los Alamos National Lab	IMPLIED V/H RATIOS FOR CMRR FROM THE RATIO OF THE VERTICAL AND HORIZONTAL UHRS	Figure 61

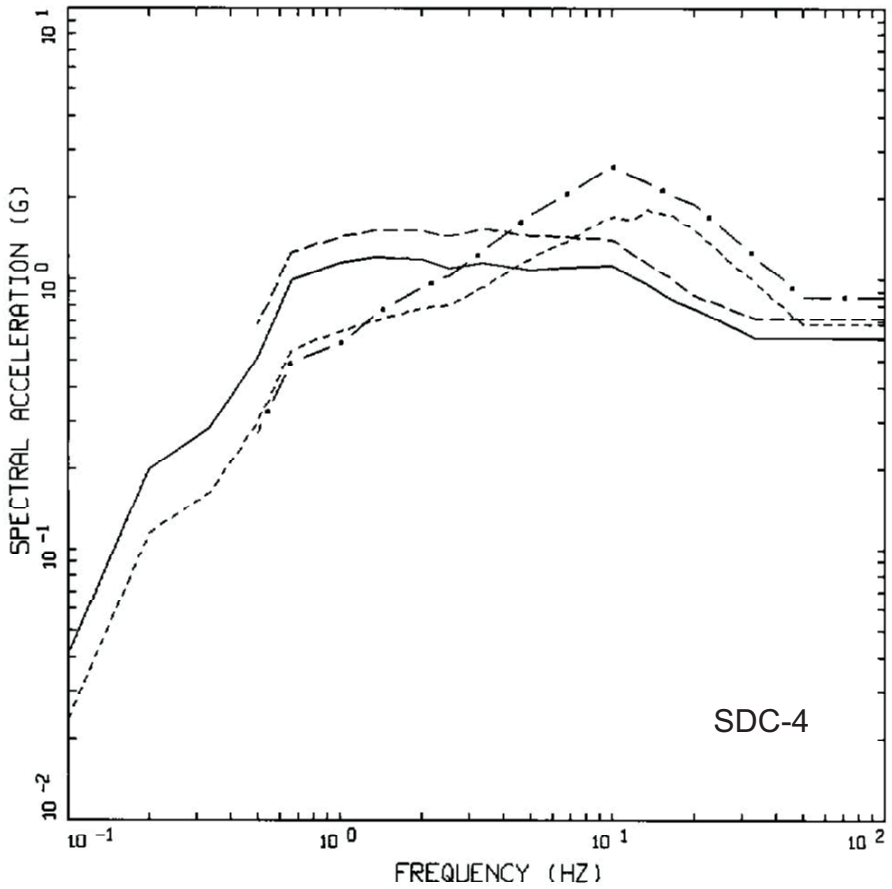


CMRR SDC 3
DRS: HORIZONTAL, VERTICAL

LEGEND

- - - - 2007 REPORT HORIZONTAL: SDC 3 (4x10-4), PGA = 0.47g
——— UPDATED 07/2009 HORIZONTAL: SDC 3 (4x10-4), PGA = 0.40g
— • — 2007 REPORT VERTICAL: SDC 3 (4x10-4), PGA = 0.56g
- - - - - UPDATED 07/2009 VERTICAL: SDC 3 (4x10-4), PGA = 0.43g

URS	Project No. 26817259	2007 AND UPDATED CMRR SITE-SPECIFIC HORIZONTAL DRS	Figure 62a
	Los Alamos National Lab		

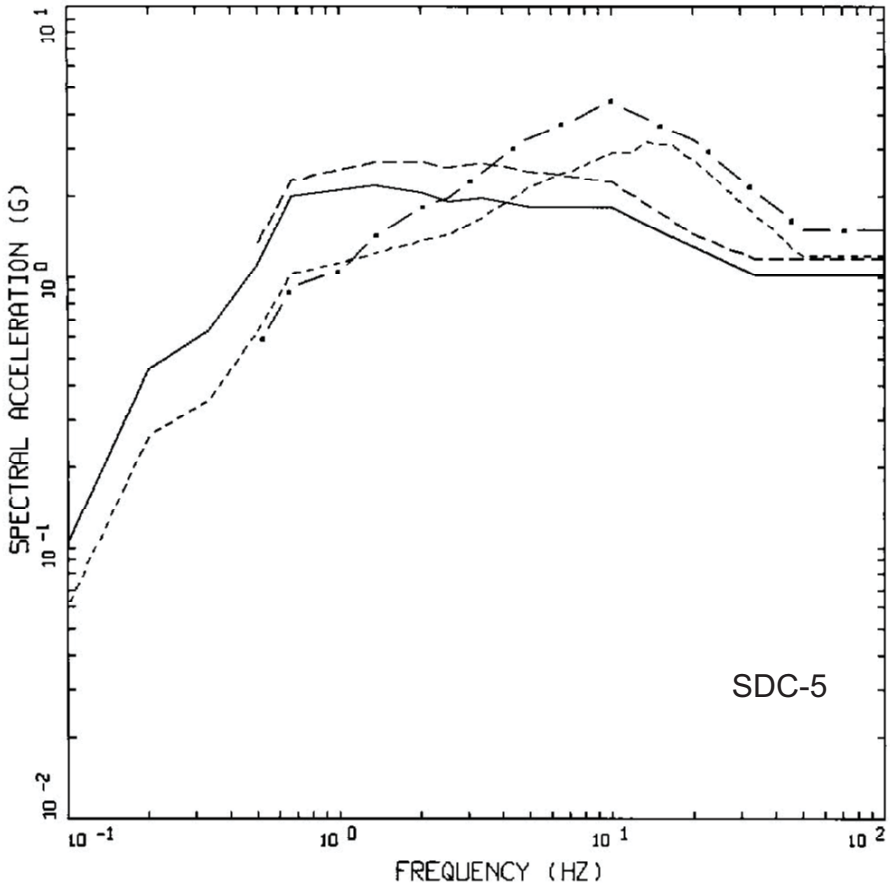


CMRR SDC 4
DRS: HORIZONTAL, VERTICAL

LEGEND

- - - - 2007 REPORT HORIZONTAL: SDC 4 (4x10-4), PGA = 0.72g
——— UPDATED 07/2009 HORIZONTAL: SDC 4 (4x10-4), PGA = 0.61g
— • — 2007 REPORT VERTICAL: SDC 4 (4x10-4), PGA = 0.87g
- - - - - UPDATED 07/2009 VERTICAL: SDC 4 (4x10-4), PGA = 0.68g

URS	Project No. 26817259	2007 AND UPDATED CMRR SITE-SPECIFIC HORIZONTAL DRS	Figure 62b
	Los Alamos National Lab		



CMRR SDC 5
DRS: HORIZONTAL, VERTICAL

LEGEND

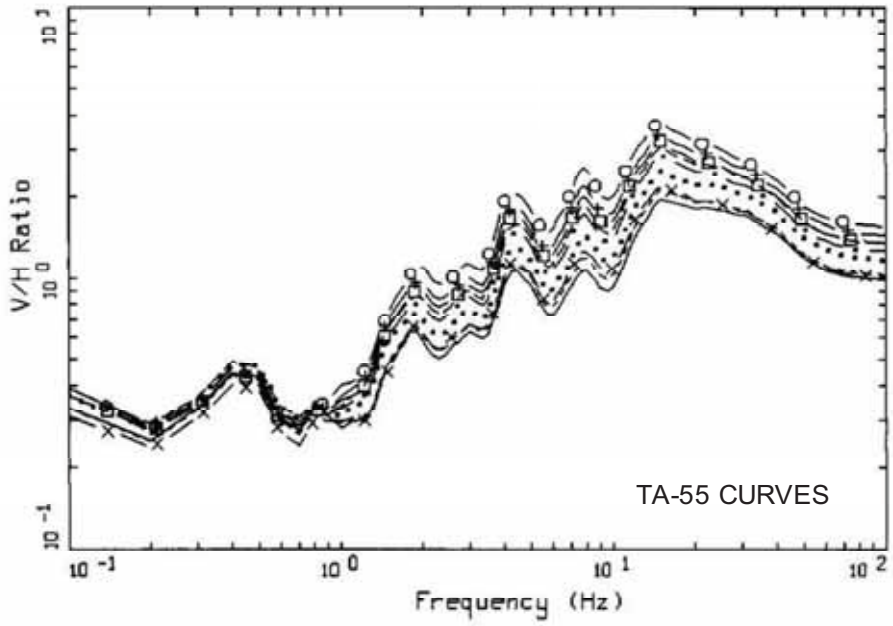
- - - - 2007 REPORT HORIZONTAL: SDC 5 (1x10-4), PGA = 1.17g

——— UPDATED 07/2009 HORIZONTAL: SDC 5 (1x10-4), PGA = 1.03g

— • — 2007 REPORT VERTICAL: SDC 5 (1x10-4), PGA = 1.50g

- - - - - UPDATED 07/2009 VERTICAL: SDC 5 (1x10-4), PGA = 1.20g

URS	Project No. 26817259	2007 AND UPDATED CMRR SITE-SPECIFIC HORIZONTAL DRS	Figure 62c
	Los Alamos National Lab		



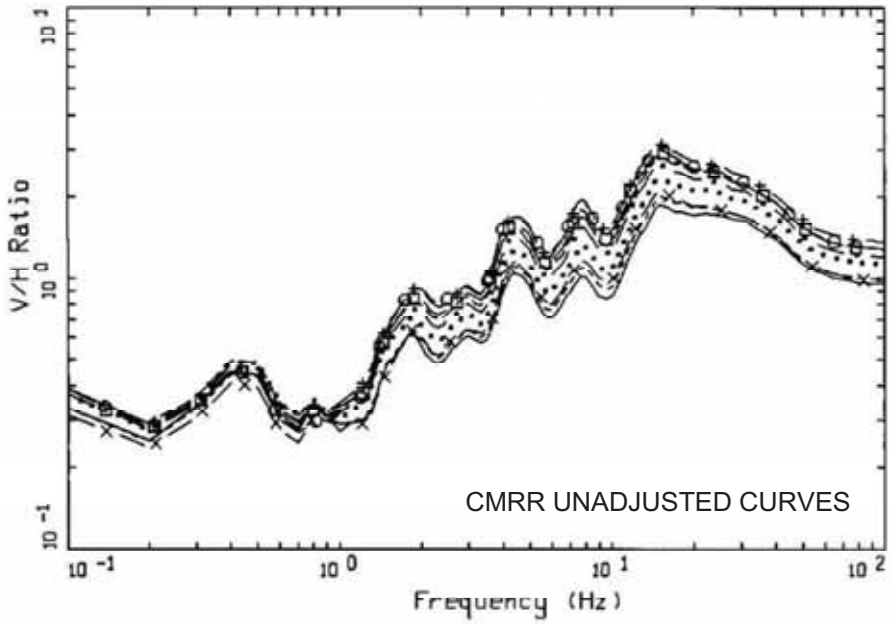
MODEL V/H RATIOS, TA-55
TA-55 CURVES

LEGEND

———	TA-55 CURVES, 50TH PERCENTILE, M 6.00, DISTANCE = 6.0 KM
• • • •	TA-55 CURVES, 50TH PERCENTILE, M 6.20, DISTANCE = 4.0 KM
- - - - -	TA-55 CURVES, 50TH PERCENTILE, M 6.20, DISTANCE = 6.0 KM
— — — -	TA-55 CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 3.0 KM
— • —	TA-55 CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 4.0 KM
— × —	TA-55 CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 7.0 KM
— + —	TA-55 CURVES, 50TH PERCENTILE, M 6.75, DISTANCE = 3.0 KM
— □ —	TA-55 CURVES, 50TH PERCENTILE, M 6.75, DISTANCE = 4.0 KM
— ○ —	TA-55 CURVES, 50TH PERCENTILE, M 7.00, DISTANCE = 3.0 KM

Note: Updated suite of magnitudes and distances using three sets of G/G_{max} and hysteretic damping curves (Wong *et al*., 2007).

URS	Project No. 26817259	SITE-SPECIFIC V/H RATIOS FOR TA-55	Figure 63a
	Los Alamos National Lab		



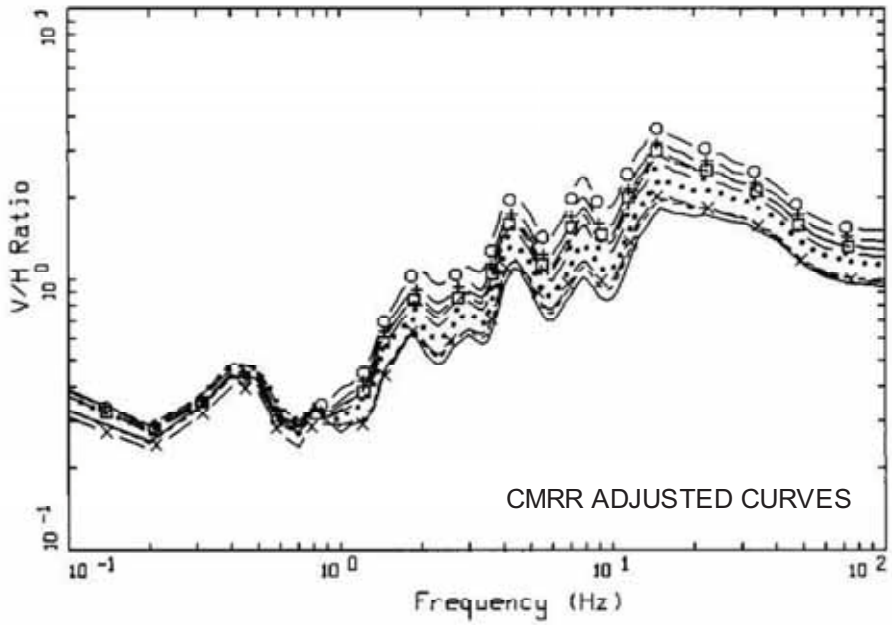
MODEL V/H RATIOS, TA-55
CMRR CURVES

LEGEND

———	CMRR UNADJUSTED CURVES, 50TH PERCENTILE, M 6.00, DISTANCE = 6.0 KM
• • • •	CMRR UNADJUSTED CURVES, 50TH PERCENTILE, M 6.20, DISTANCE = 4.0 KM
- - - - -	CMRR UNADJUSTED CURVES, 50TH PERCENTILE, M 6.20, DISTANCE = 6.0 KM
— — — -	CMRR UNADJUSTED CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 3.0 KM
— • —	CMRR UNADJUSTED CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 4.0 KM
— × —	CMRR UNADJUSTED CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 7.0 KM
— + —	CMRR UNADJUSTED CURVES, 50TH PERCENTILE, M 6.75, DISTANCE = 3.0 KM
— □ —	CMRR UNADJUSTED CURVES, 50TH PERCENTILE, M 6.75, DISTANCE = 4.0 KM
— ○ —	CMRR UNADJUSTED CURVES, 50TH PERCENTILE, M 7.00, DISTANCE = 3.0 KM

Note: Updated suite of magnitudes and distances using three sets of G/G_{max} and hysteretic damping curves (Wong *et al*., 2007).

URS	Project No. 26817259	SITE-SPECIFIC V/H RATIOS FOR TA-55	Figure 63b
	Los Alamos National Lab		



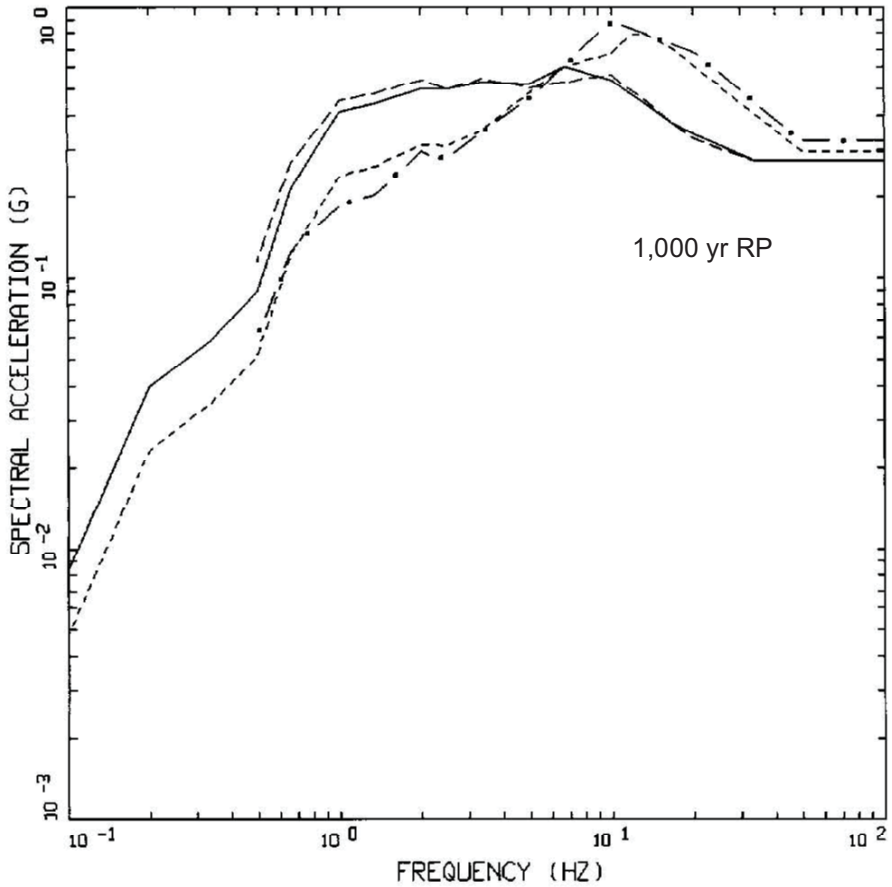
MODEL V/H RATIOS, TA-55
CMRR CURVES

LEGEND

———	CMRR ADJUSTED CURVES, 50TH PERCENTILE, M 6.00, DISTANCE = 6.0 KM
• • • •	CMRR ADJUSTED CURVES, 50TH PERCENTILE, M 6.20, DISTANCE = 4.0 KM
- - - - -	CMRR ADJUSTED CURVES, 50TH PERCENTILE, M 6.20, DISTANCE = 6.0 KM
— — — —	CMRR ADJUSTED CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 3.0 KM
— • —	CMRR ADJUSTED CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 4.0 KM
— × —	CMRR ADJUSTED CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 7.0 KM
— + —	CMRR ADJUSTED CURVES, 50TH PERCENTILE, M 6.75, DISTANCE = 3.0 KM
— □ —	CMRR ADJUSTED CURVES, 50TH PERCENTILE, M 6.75, DISTANCE = 4.0 KM
— ○ —	CMRR ADJUSTED CURVES, 50TH PERCENTILE, M 7.00, DISTANCE = 3.0 KM

Note: updated suite of magnitudes and distances using three sets of G/G_{max} and hysteretic damping curves (Wong *et al*., 2007).

URS	Project No. 26817259 Los Alamos National Lab	SITE-SPECIFIC V/H RATIOS FOR TA-55	Figure 63c

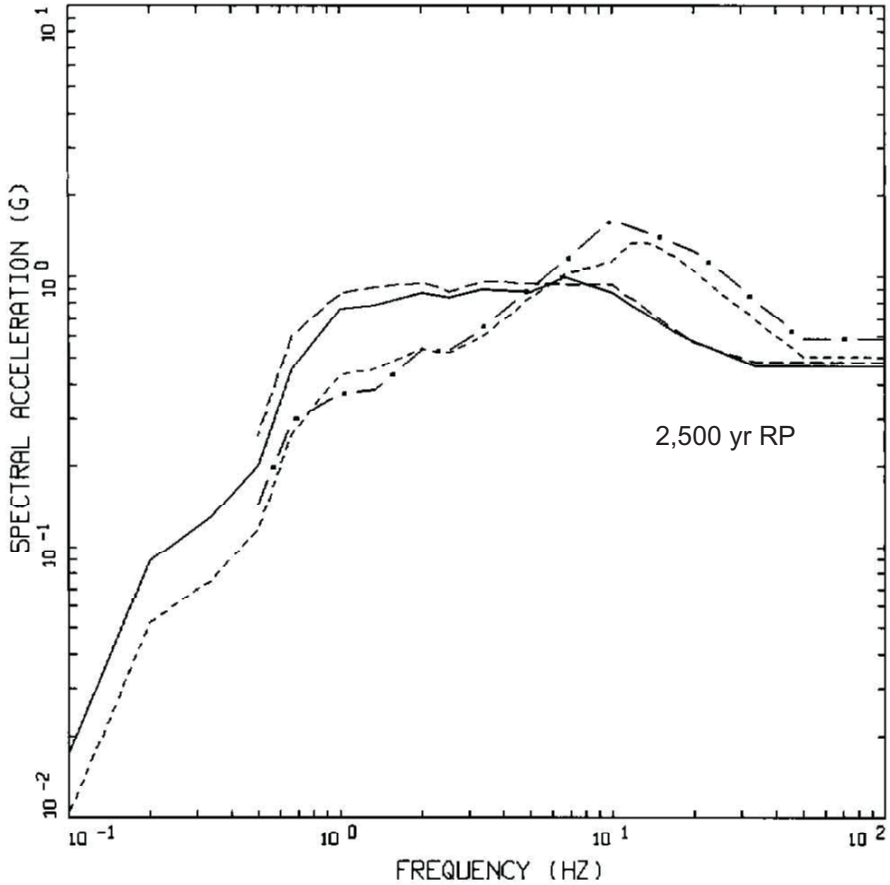


TA55 1,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

- - - - 2007 REPORT HORIZONTAL UHS, PGA = 0.27g
——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 0.27g
— • — 2007 REPORT VERTICAL UHS, PGA = 0.32g
- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 0.29g

URS	Project No. 26817259	TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 64a
	Los Alamos National Lab		

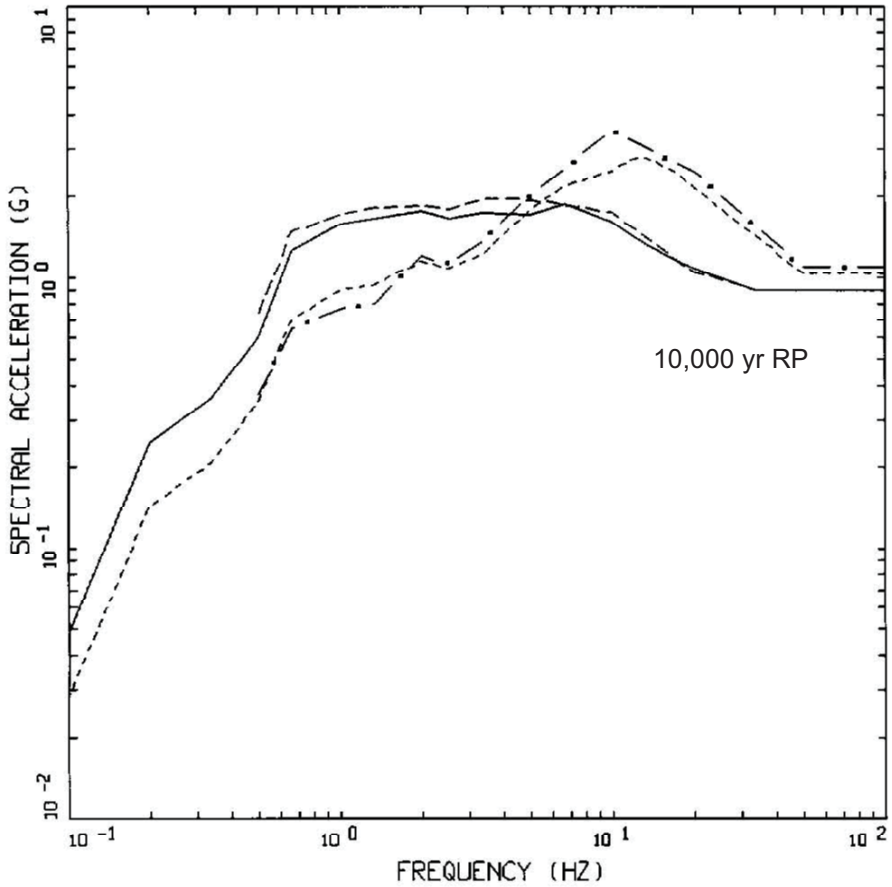


TA55 2,500 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

- - - - 2007 REPORT HORIZONTAL UHS, PGA = 0.48g
——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 0.47g
— • — 2007 REPORT VERTICAL UHS, PGA = 0.59g
- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 0.51g

URS	Project No. 26817259	TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 64b
	Los Alamos National Lab		

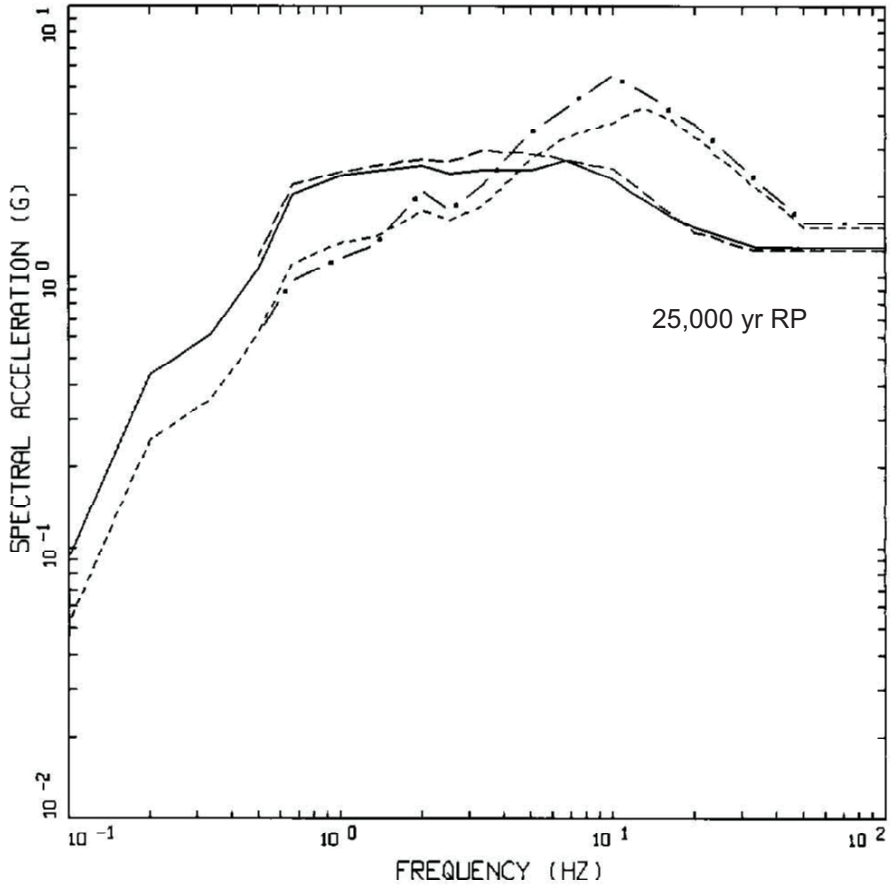


TA55 10,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

- - - - 2007 REPORT HORIZONTAL UHS, PGA = 0.90g
——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 0.90g
— · — 2007 REPORT VERTICAL UHS, PGA = 1.09g
----- UPDATED 07/2009 VERTICAL UHS, PGA = 1.03g

URS	Project No. 26817259	TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 64c
	Los Alamos National Lab		



TA55 25,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

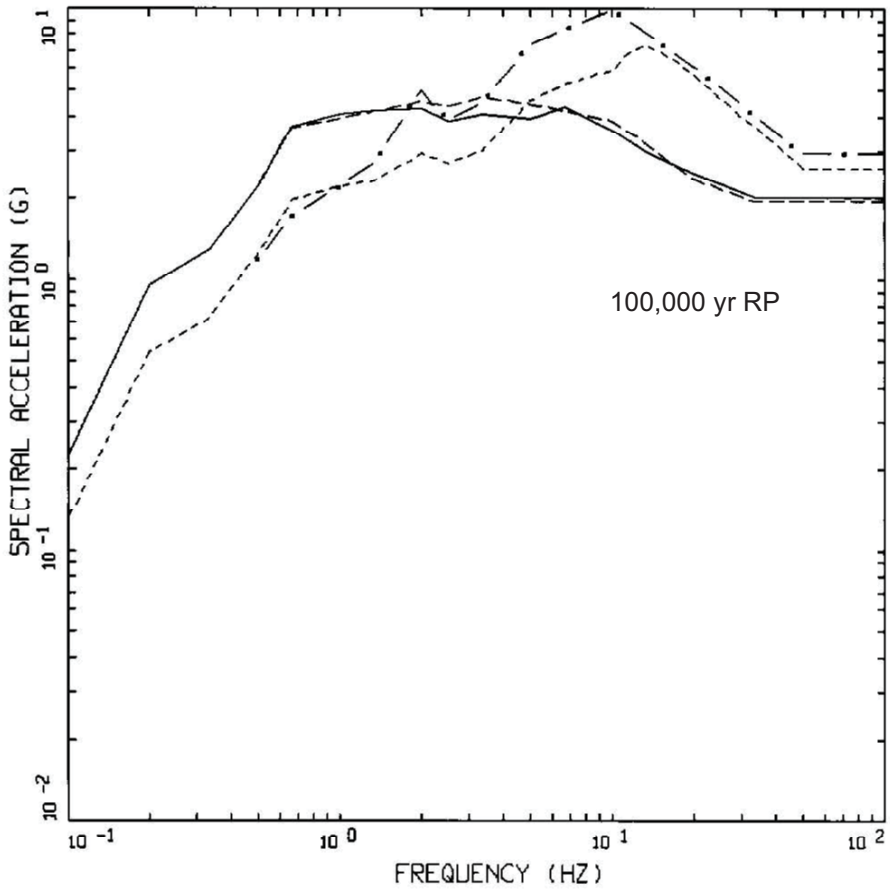
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 1.25g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 1.28g

— • — 2007 REPORT VERTICAL UHS, PGA = 1.59g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 1.54g

URS	Project No. 26817259	TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 64d
	Los Alamos National Lab		



TA55 100,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

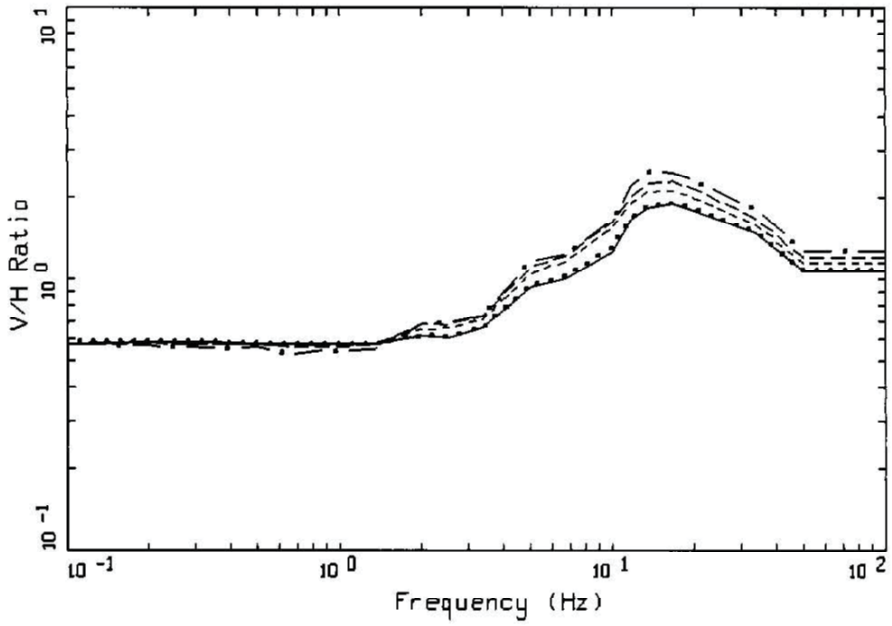
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 1.95g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 2.02g

— • — 2007 REPORT VERTICAL UHS, PGA = 2.91g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 2.58g

URS	Project No. 26817259	TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 64e
	Los Alamos National Lab		

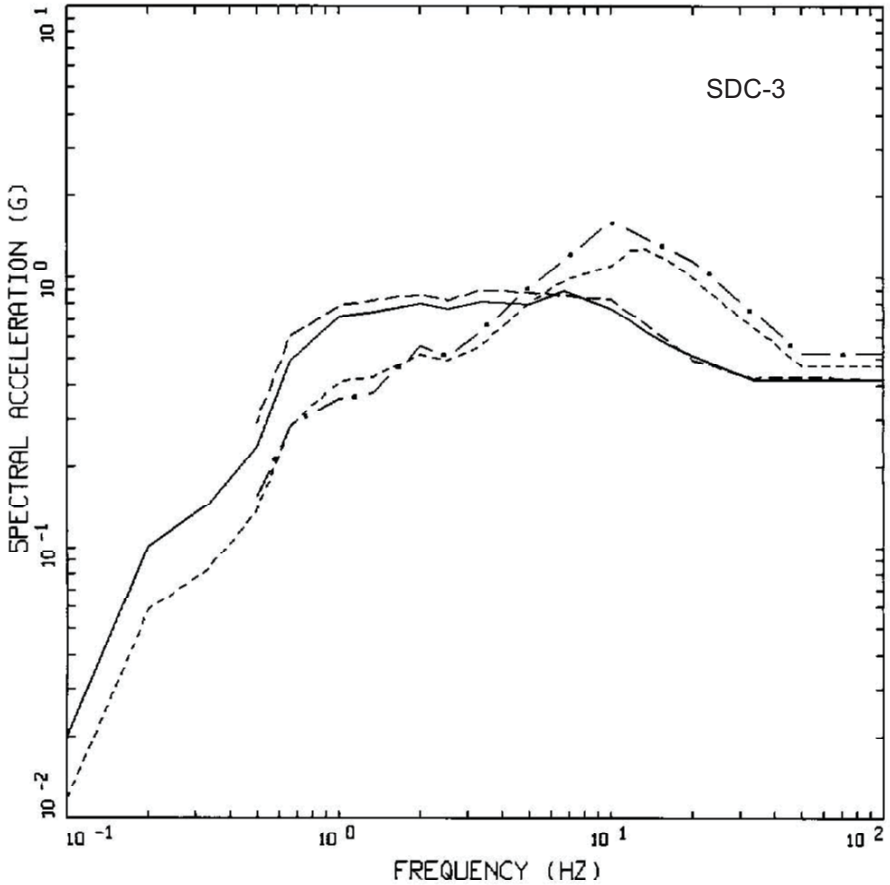


TA55, MEAN UHRS
IMPLIED V/H RATIO

LEGEND

———	V/H RATIO: 1,000 YEAR (MEAN)
• • • •	V/H RATIO: 2,500 YEAR (MEAN)
- - - - -	V/H RATIO: 10,000 YEAR (MEAN)
— — — —	V/H RATIO: 25,000 YEAR (MEAN)
— • —	V/H RATIO: 100,000 YEAR (MEAN)

URS	Project No. 26817259 Los Alamos National Lab	IMPLIED V/H RATIO FOR TA-55 FROM THE RATIO OF THE VERTICAL AND HORIZONTAL UHRS	Figure 65

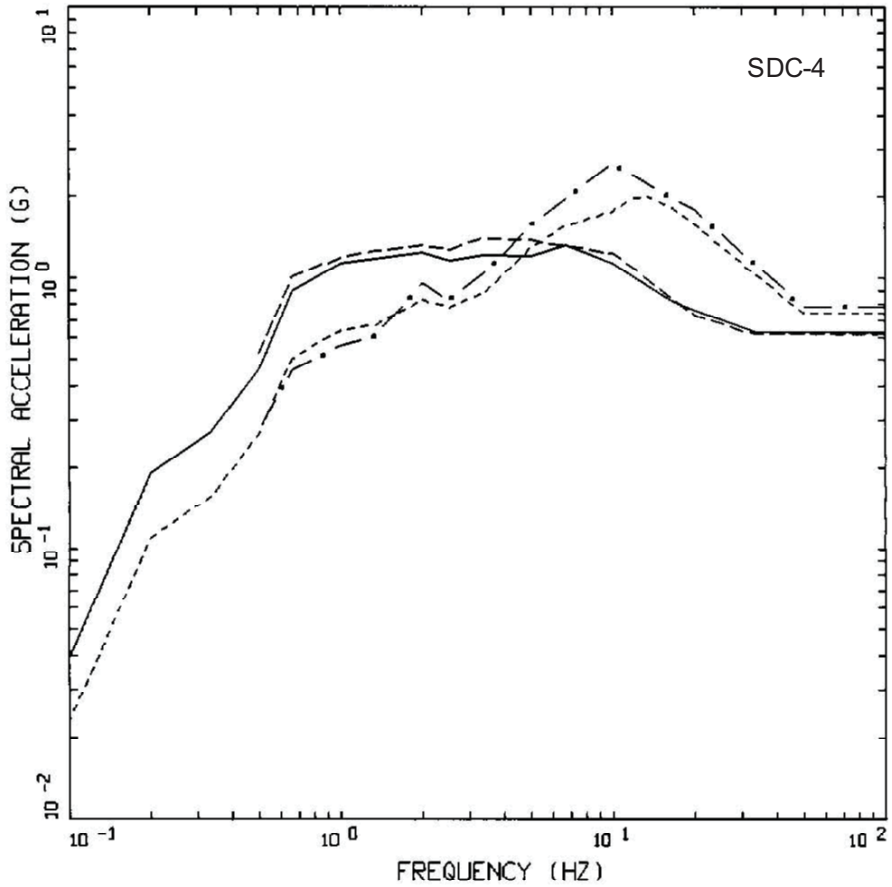


TA55 SDC 3
DRS: HORIZONTAL, VERTICAL

LEGEND

- - - - 2007 REPORT HORIZONTAL: SDC 3 (4x10-4), PGA = 0.42g
——— UPDATED 07/2009 HORIZONTAL: SDC 3 (4x10-4), PGA = 0.42g
— • — 2007 REPORT VERTICAL: SDC 3 (4x10-4), PGA = 0.53g
----- UPDATED 07/2009 VERTICAL: SDC 3 (4x10-4), PGA = 0.47g

URS	Project No. 26817259	TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL DRS	Figure 66a
	Los Alamos National Lab		

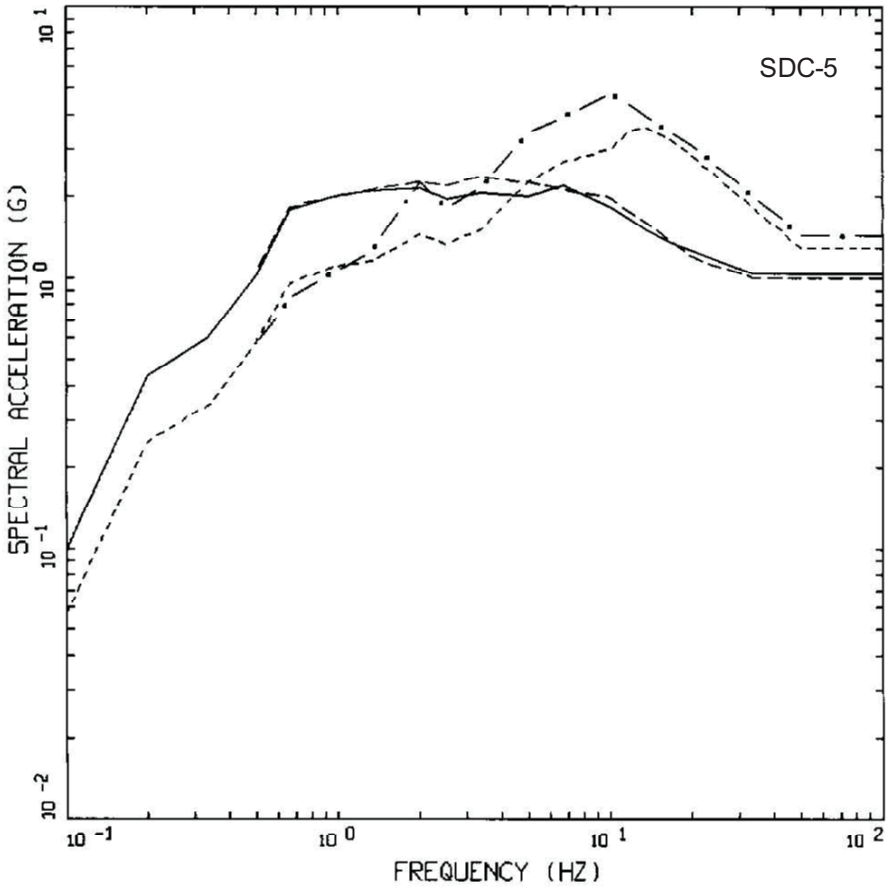


TA55 SDC 4
DRS: HORIZONTAL, VERTICAL

LEGEND

- - - - 2007 REPORT HORIZONTAL: SDC 4 (4x10-4), PGA = 0.62g
——— UPDATED 07/2009 HORIZONTAL: SDC 4 (4x10-4), PGA = 0.63g
— • — 2007 REPORT VERTICAL: SDC 4 (4x10-4), PGA = 0.78g
- - - - - UPDATED 07/2009 VERTICAL: SDC 4 (4x10-4), PGA = 0.74g

URS	Project No. 26817259 Los Alamos National Lab	TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL DRS	Figure 66b



TA55 SDC5
DRS: HORIZONTAL, VERTICAL

LEGEND

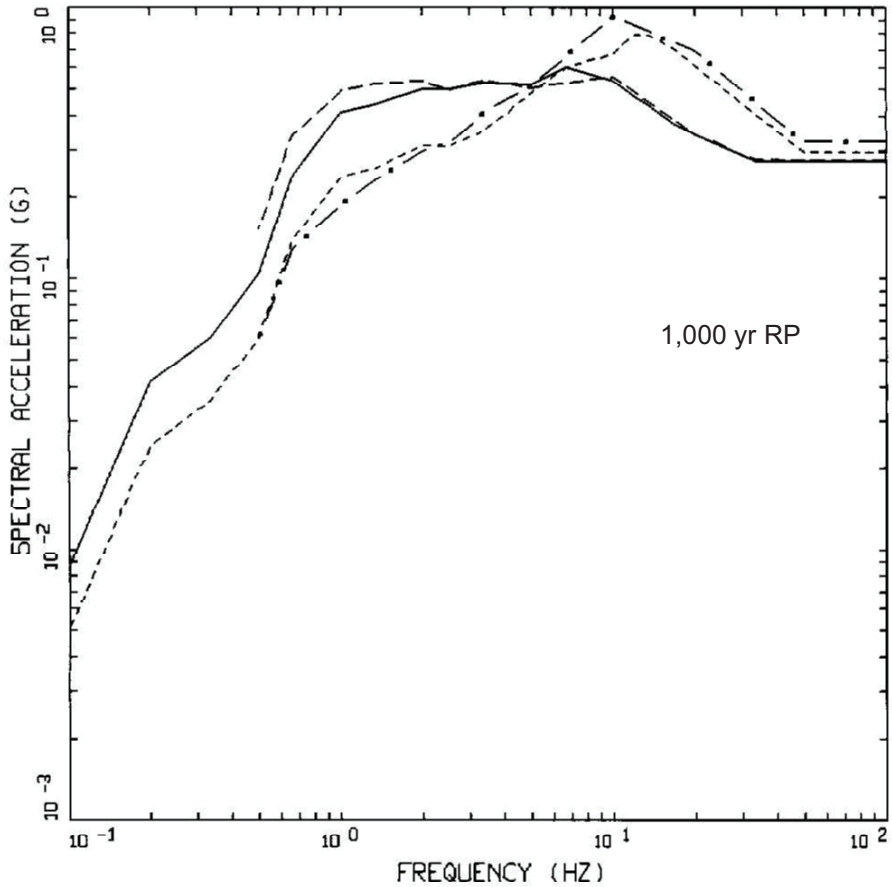
- - - - 2007 REPORT HORIZONTAL: SDC 5 (1x10-4), PGA = 1.00g

——— UPDATED 07/2009 HORIZONTAL: SDC 5 (1x10-4), PGA = 1.03g

— · — 2007 REPORT VERTICAL: SDC 5 (1x10-4), PGA = 1.44g

----- UPDATED 07/2009 VERTICAL: SDC 5 (1x10-4), PGA = 1.29g

URS	Project No. 26817259	TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL DRS	Figure 66c
	Los Alamos National Lab		



CMRR&TA55 1,000 YEAR ENVELOPE
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

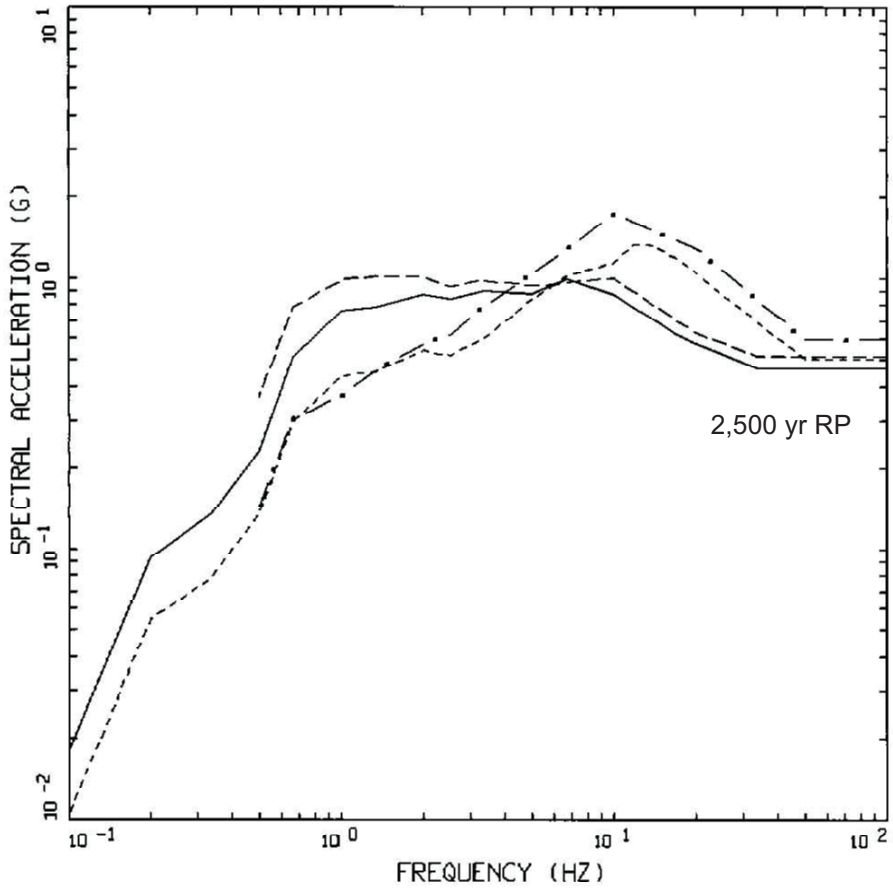
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 0.27g

UPDATED 07/2009 HORIZONTAL UHS, PGA = 0.27g

— • — 2007 REPORT VERTICAL UHS, PGA = 0.32g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 0.29g

URS	Project No. 26817259	ENVELOPE OF CMRR AND TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 67a
	Los Alamos National Lab		



CMRR&TA55 2,500 YEAR ENVELOPE
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

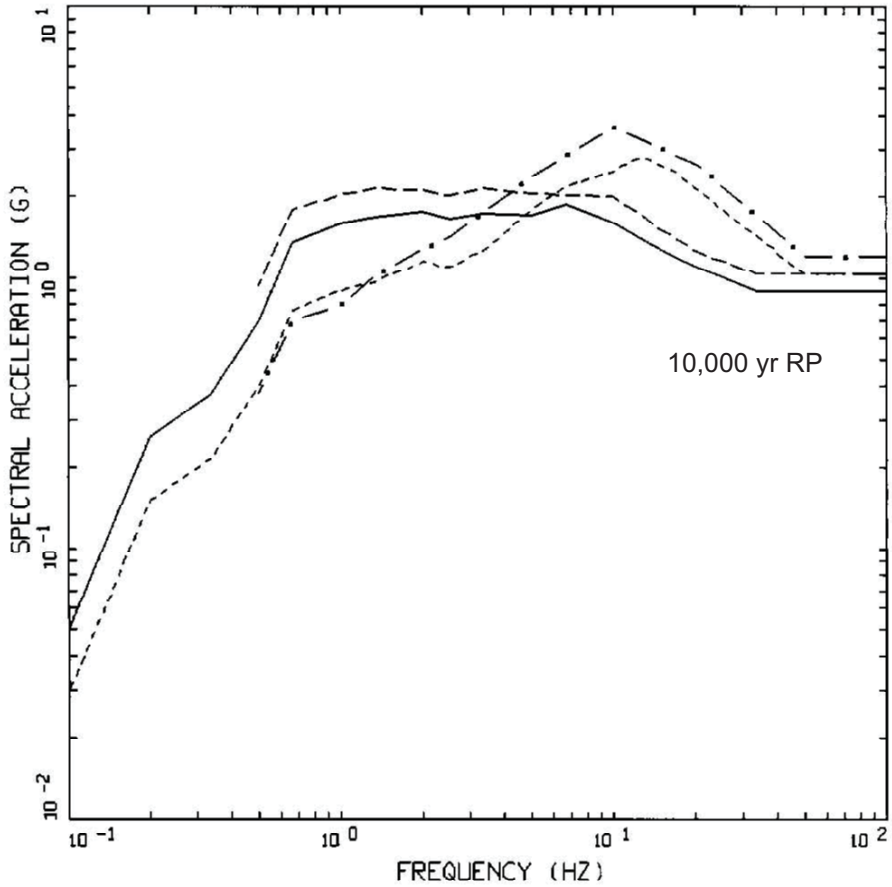
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 0.52g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 0.47g

— · — 2007 REPORT VERTICAL UHS, PGA = 0.60g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 0.51g

URS	Project No. 26817259	ENVELOPE OF CMRR AND TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 67b
	Los Alamos National Lab		



CMRR&TA55 10,000 YEAR ENVELOPE
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

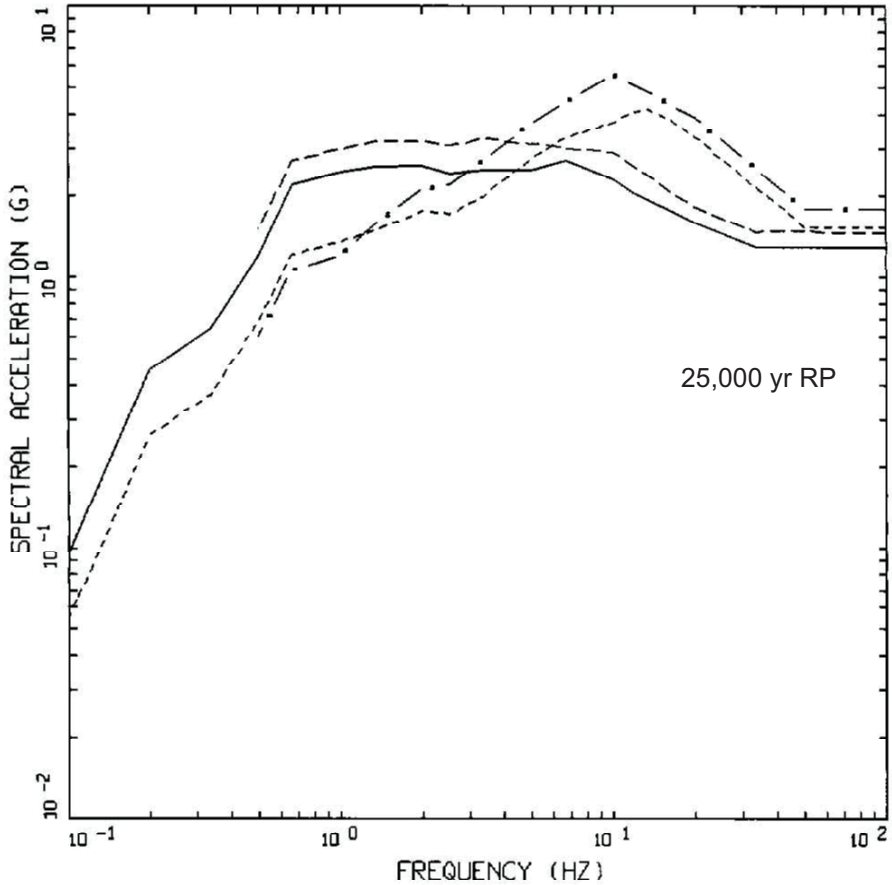
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 1.03g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 0.90g

— • — 2007 REPORT VERTICAL UHS, PGA = 1.21g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 1.03g

URS	Project No. 26817259	ENVELOPE OF CMRR AND TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 67c
	Los Alamos National Lab		



CMRR&TA55 25,000 YEAR ENVELOPE
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

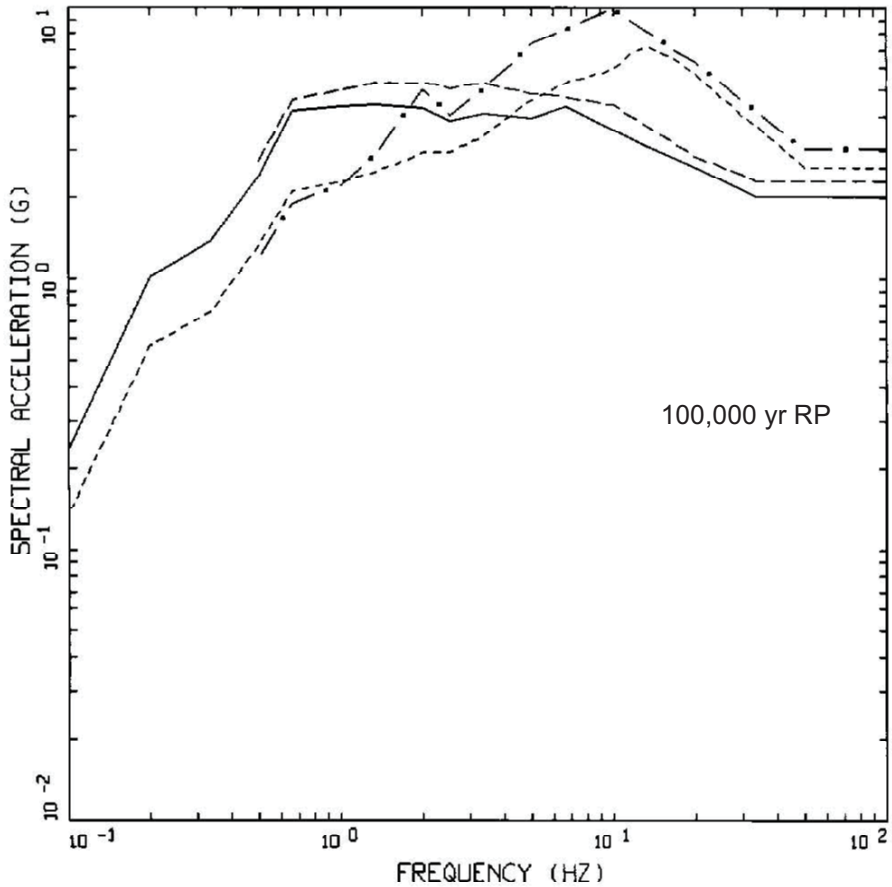
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 1.47g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 1.28g

— · — 2007 REPORT VERTICAL UHS, PGA = 1.79g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 1.54g

URS	Project No. 26817259	ENVELOPE OF CMRR AND TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 67d
	Los Alamos National Lab		



CMRR&TA55 100,000YEAR ENVELOPE
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

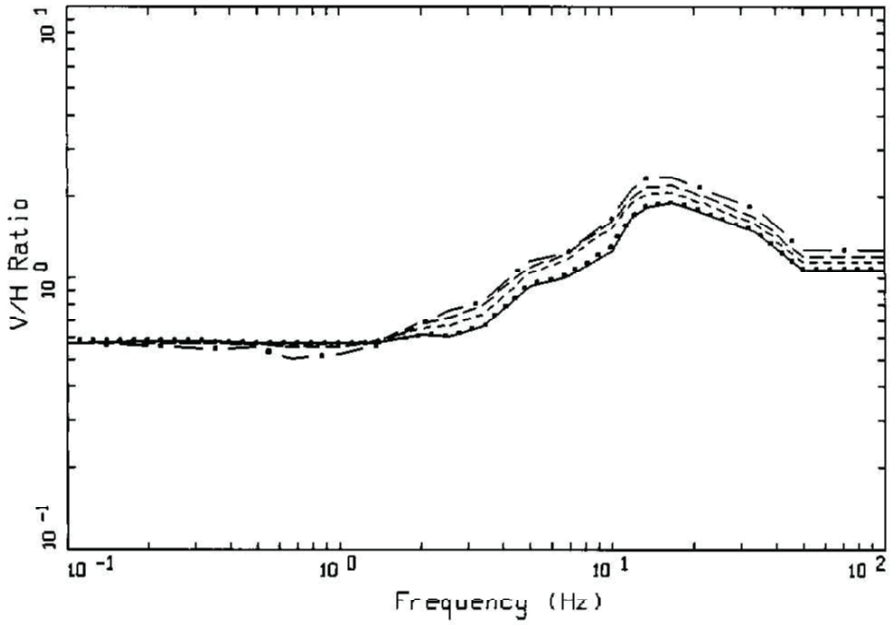
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 2.30g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 2.02g

— • — 2007 REPORT VERTICAL UHS, PGA = 3.01g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 2.58g

URS	Project No. 26817259	ENVELOPE OF CMRR AND TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL UHRS	Figure 67e
	Los Alamos National Lab		

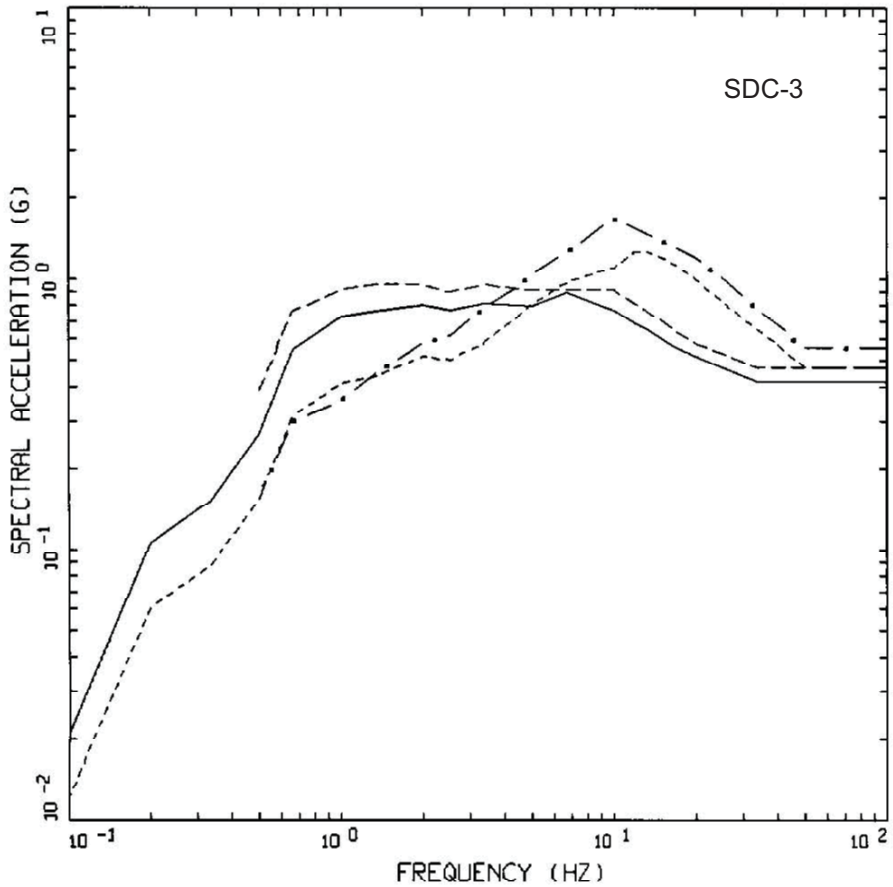


CMRR&TA55 ENVELOPE MEAN UHRS
IMPLIED V/H RATIO

LEGEND

———	V/H RATIO: 1,000 YEAR (MEAN)
• • • •	V/H RATIO: 2,500 YEAR (MEAN)
- - - - -	V/H RATIO: 10,000 YEAR (MEAN)
— — — —	V/H RATIO: 25,000 YEAR (MEAN)
— • —	V/H RATIO: 100,000 YEAR (MEAN)

URS	Project No. 26817259 Los Alamos National Lab	IMPLIED V/H RATIO FOR THE ENVELOPE OF THE CMRR AND TA-55 FROM THE RATIO OF THE VERTICAL AND HORIZONTAL UHRS	Figure 68



CMRR&TA55 ENVELOPE SDC 3
DRS: HORIZONTAL, VERTICAL

LEGEND

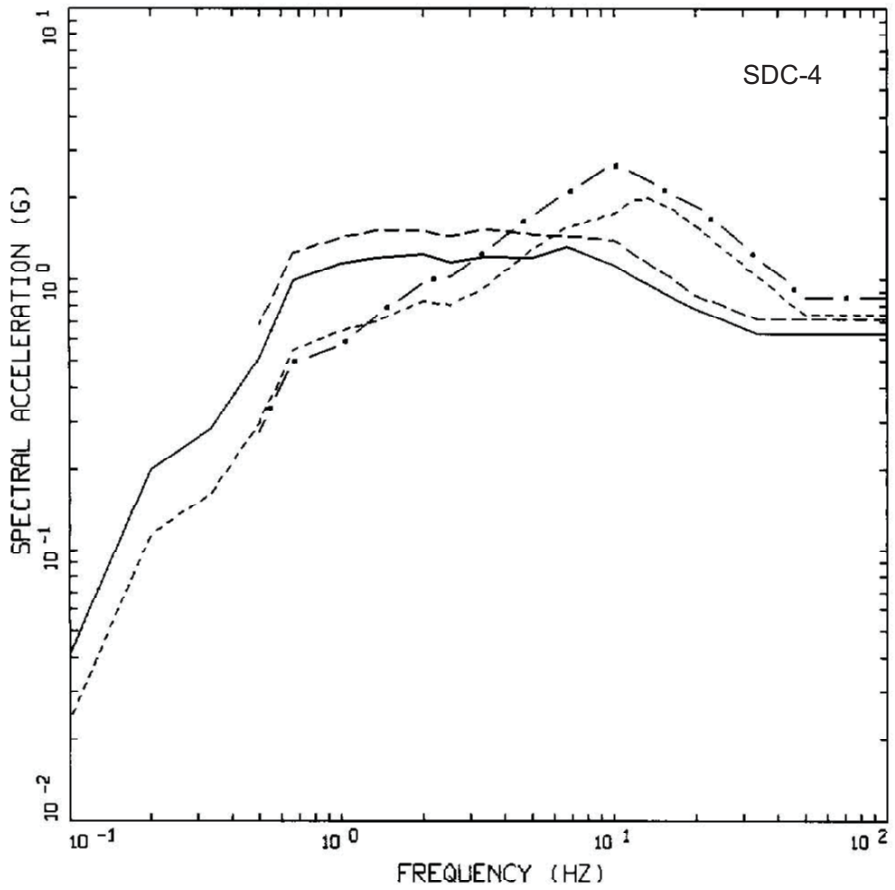
- - - - 2007 REPORT HORIZONTAL: SDC 3 (4x10-4), PGA = 0.47g

——— UPDATED 07/2009 HORIZONTAL: SDC 3 (4x10-4), PGA = 0.42g

— · — 2007 REPORT VERTICAL: SDC 3 (4x10-4), PGA = 0.56g

- - - - - UPDATED 07/2009 VERTICAL: SDC 3 (4x10-4), PGA = 0.47g

URS	Project No. 26817259 Los Alamos National Lab	ENVELOPE OF CMRR AND TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL DRS	Figure 69a



CMRR&TA55 ENVELOPE SDC 4
DRS: HORIZONTAL, VERTICAL

LEGEND

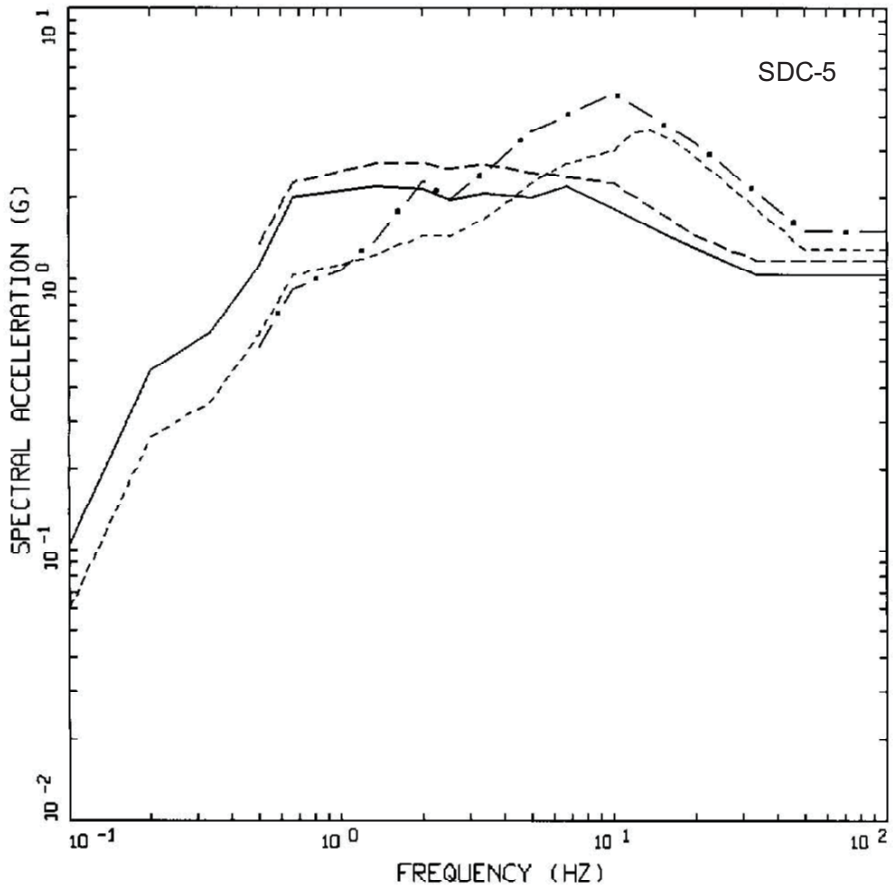
- - - - 2007 REPORT HORIZONTAL: SDC 4 (4x10-4), PGA = 0.72g

——— UPDATED 07/2009 HORIZONTAL: SDC 4 (4x10-4), PGA = 0.63g

— • — 2007 REPORT VERTICAL: SDC 4 (4x10-4), PGA = 0.86g

- - - - - UPDATED 07/2009 VERTICAL: SDC 4 (4x10-4), PGA = 0.74g

URS	Project No. 26817259 Los Alamos National Lab	ENVELOPE OF CMRR AND TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL DRS	Figure 69b



CMRR&TA55 ENVELOPE SDC 5
DRS: HORIZONTAL, VERTICAL

LEGEND

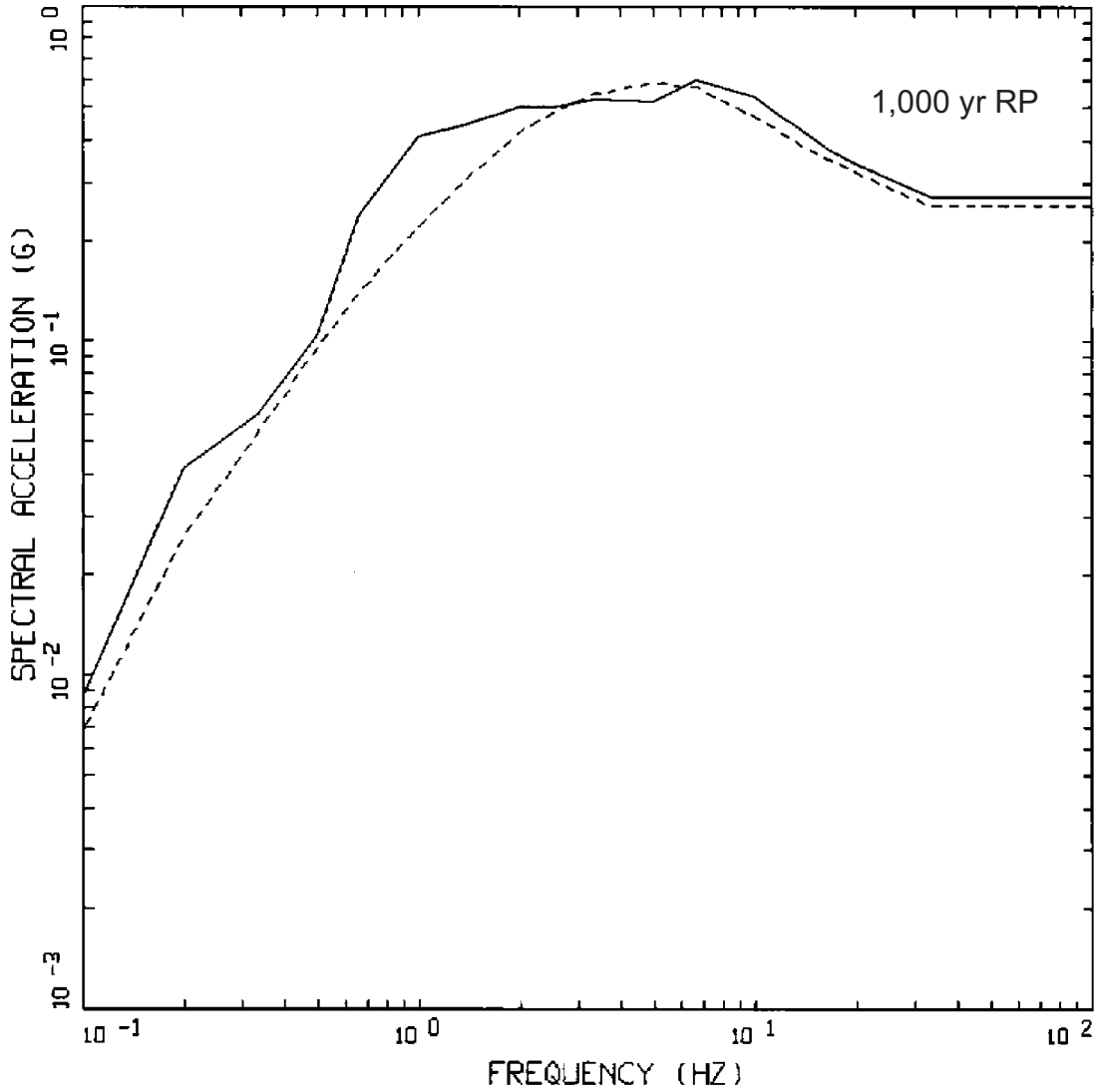
- - - - 2007 REPORT HORIZONTAL: SDC 5 (1x10-4), PGA = 1.17g

——— UPDATED 07/2009 HORIZONTAL: SDC 5 (1x10-4), PGA = 1.03g

— · — 2007 REPORT VERTICAL: SDC 5 (1x10-4), PGA = 1.50g

- - - - - UPDATED 07/2009 VERTICAL: SDC 5 (1x10-4), PGA = 1.29g

URS	Project No. 26817259	ENVELOPE OF CMRR AND TA-55 SITE-SPECIFIC HORIZONTAL AND VERTICAL DRS	Figure 69c
	Los Alamos National Lab		



MEAN UHRS: 1,000 YEAR
HORIZONTAL

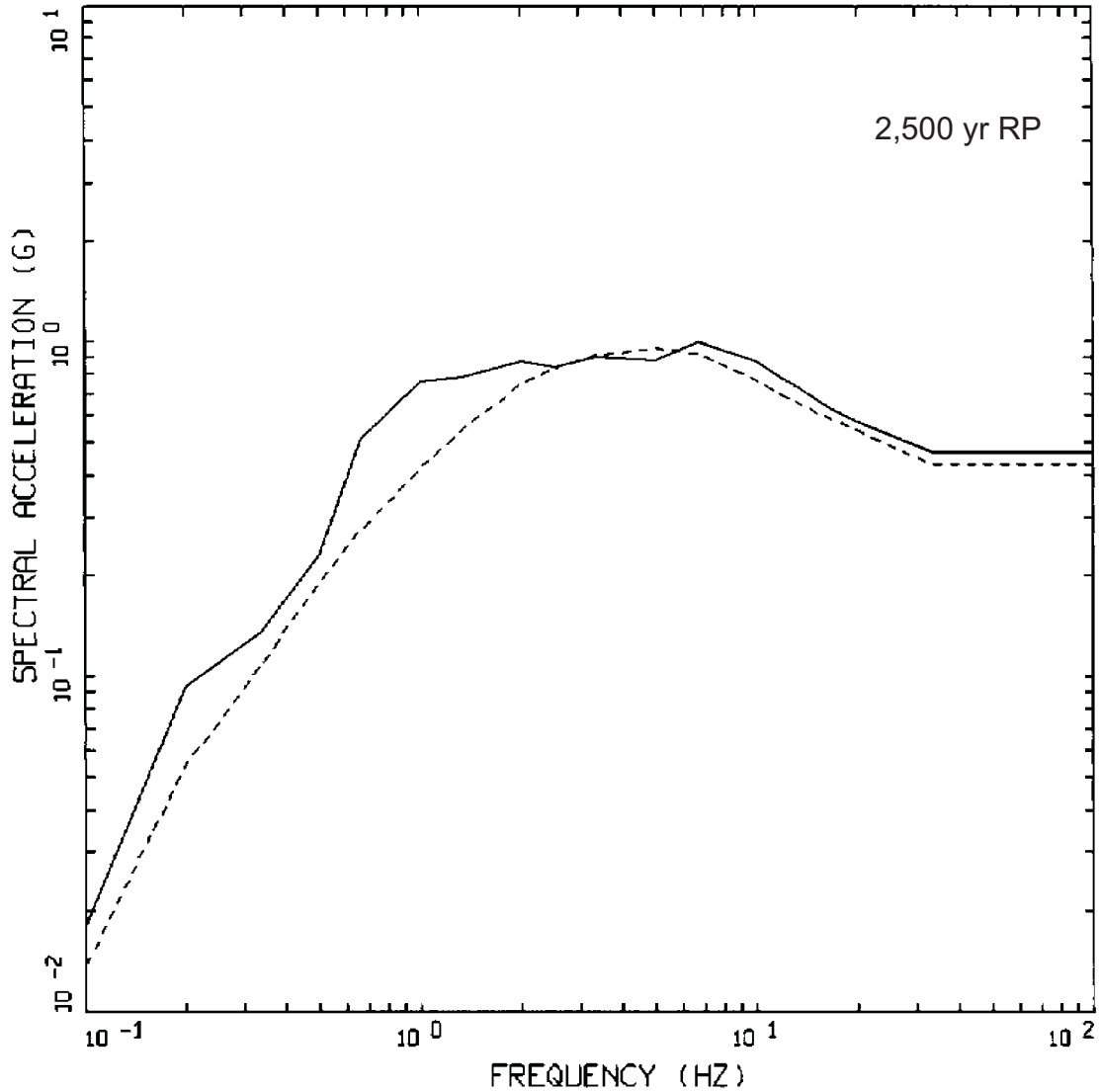
LEGEND

——— UPDATED CMRR&TASS ENVELOPE MEAN UHS, PGA = 0.27g

----- UPDATED NGA GENERRIC SOIL MEAN UHS, PGA = 0.25g

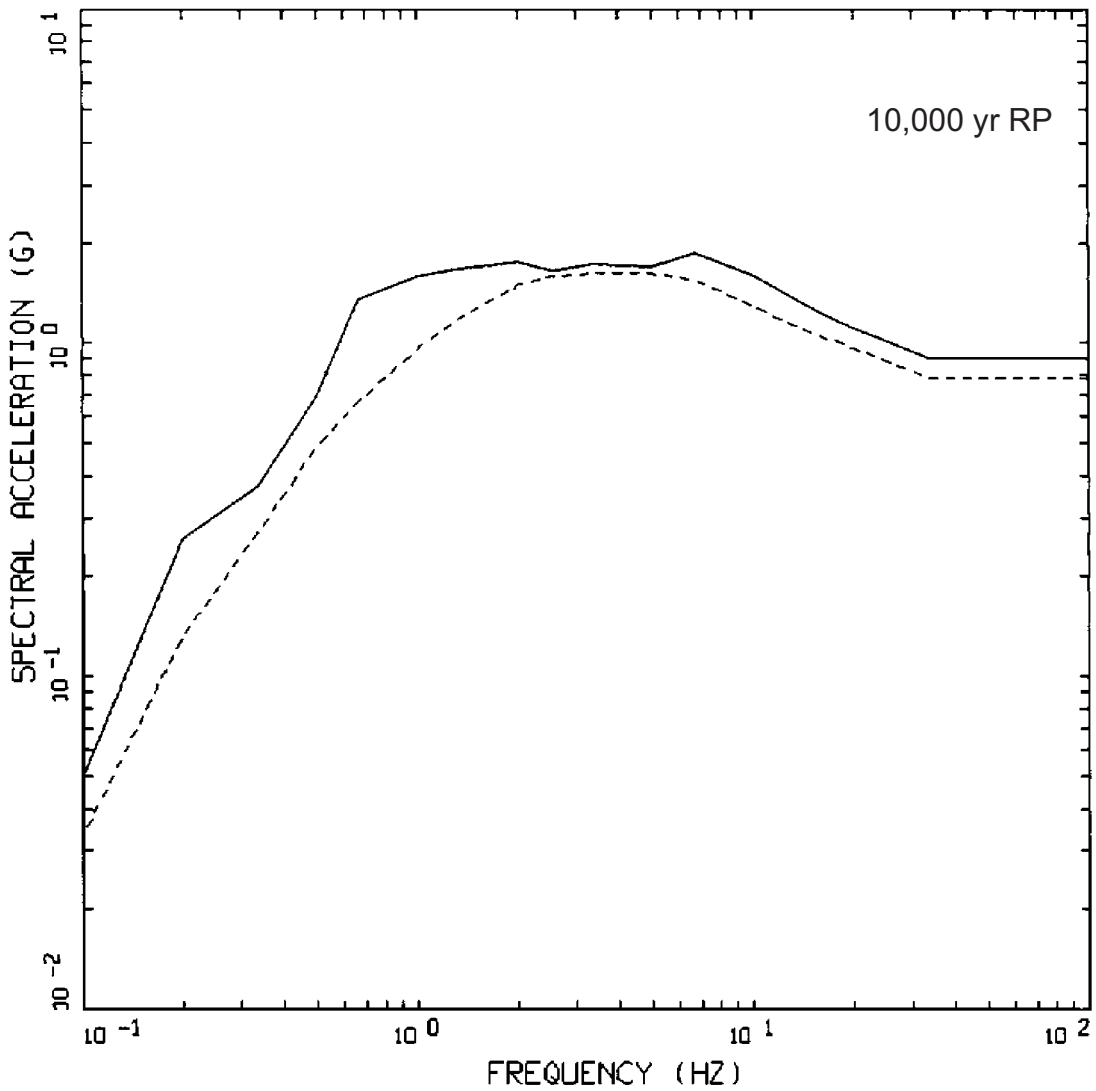
Note: Generic soil spectrum computed using NGA models and Vs_{30} = 270m/sec

URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF CMRR ENVELOPED UHRS AND DEEP GENERIC SOIL UHRS FOR 1,000, 2,500, AND 10,000 YR RETURN PERIODS	Figure 70a



Note: Generic soil spectrum computed using NGA models and Vs_{30} = 270m/sec

URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF CMRR ENVELOPED UHRS AND DEEP GENERIC SOIL UHRS FOR 1,000, 2,500, AND 10,000 YR RETURN PERIODS	Figure 70b



MEAN UHRS: 10,000 YEAR
HORIZONTAL

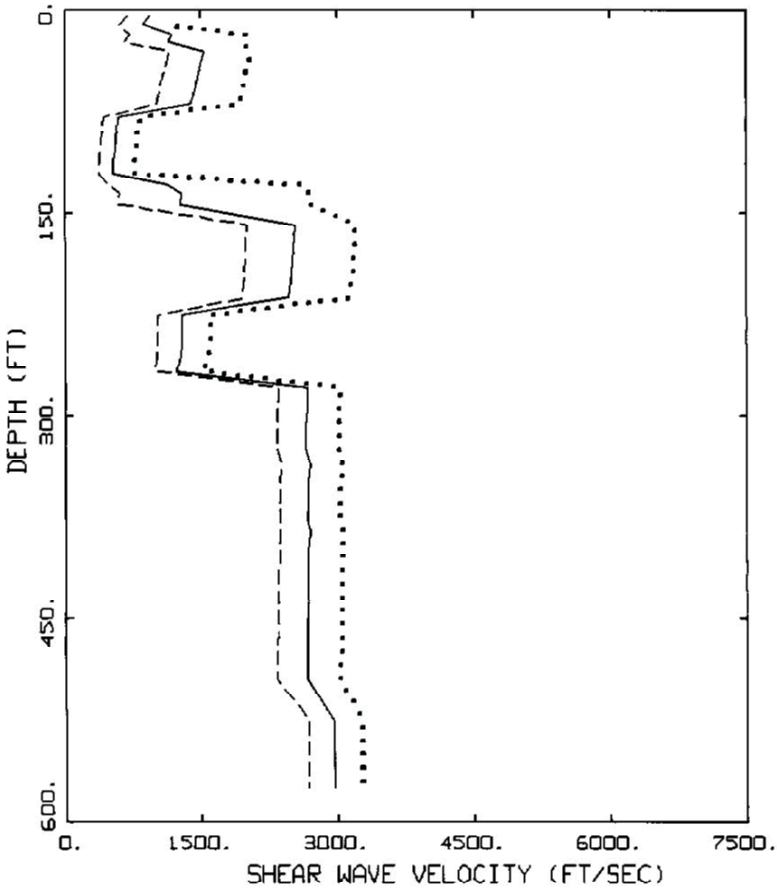
LEGEND

——— UPDATED CMRR&TASS ENVELOPE MEAN UHS, PGA = 0.90g

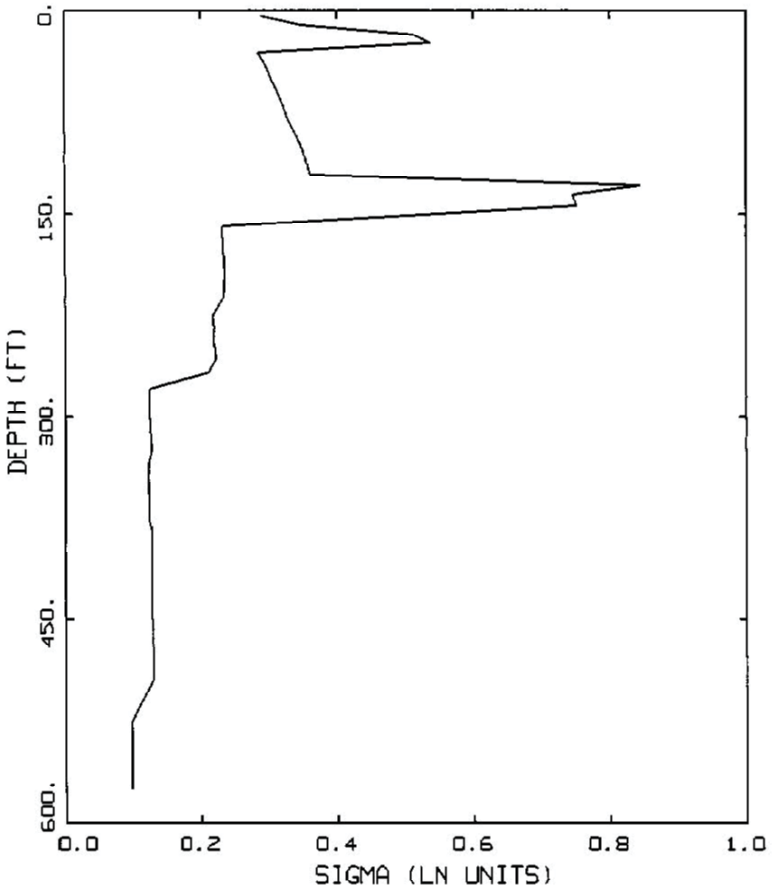
- - - - - UPDATED NGA GENERRIC SOIL MEAN UHS, PGA = 0.79g

Note: Generic soil spectrum computed using NGA models and Vs_{30} = 270m/sec

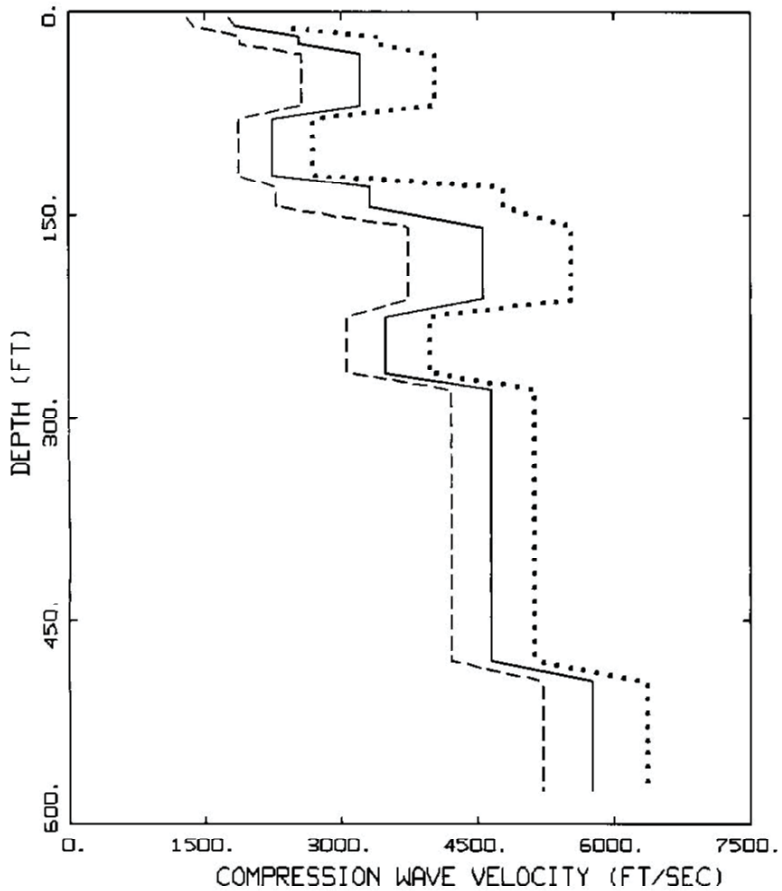
URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF CMRR ENVELOPED UHRS AND DEEP GENERIC SOIL UHRS FOR 1,000, 2,500, AND 10,000 YR RETURN PERIODS	Figure 70c



URS	Project No. 26817259 Los Alamos National Lab	CMRR AND TA-55 MEDIAN AND +/- 1 σ STRAIN-COMPATIBLE PROPERTIES V_s VERSUS DEPTH	Figure 71a



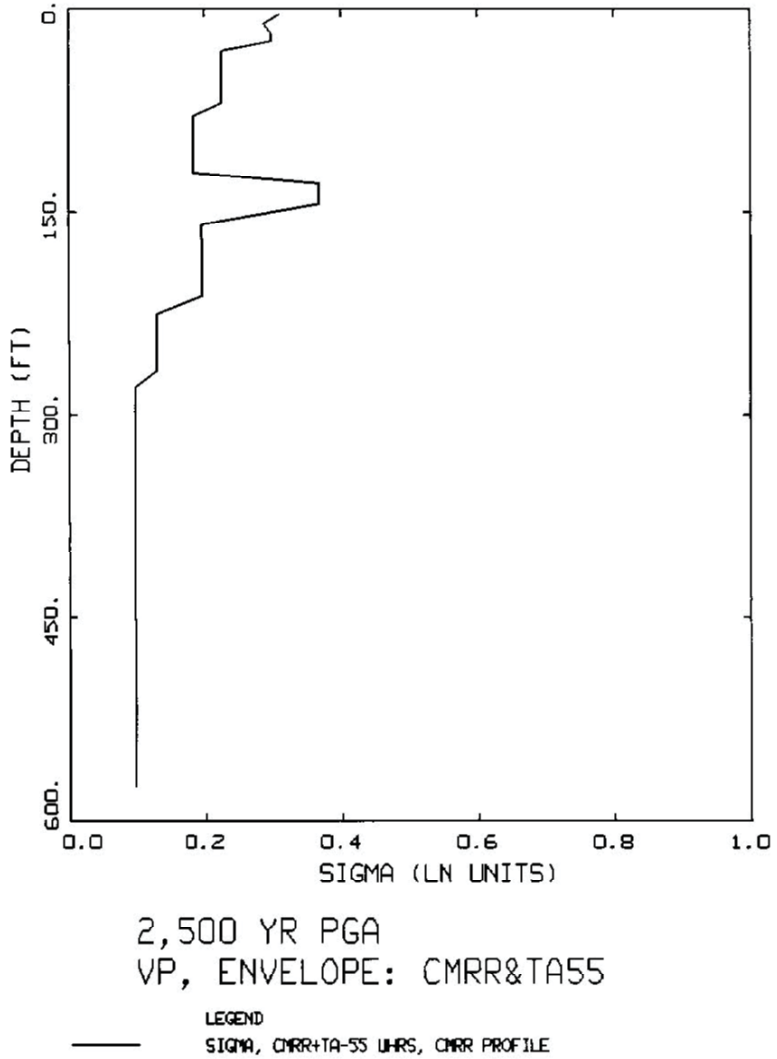
URS	Project No. 26817259 Los Alamos National Lab	CMRR AND TA-55 MEDIAN AND +/- 1 σ STRAIN-COMPATIBLE PROPERTIES V_s SIGMA VERSUS DEPTH	Figure 71b



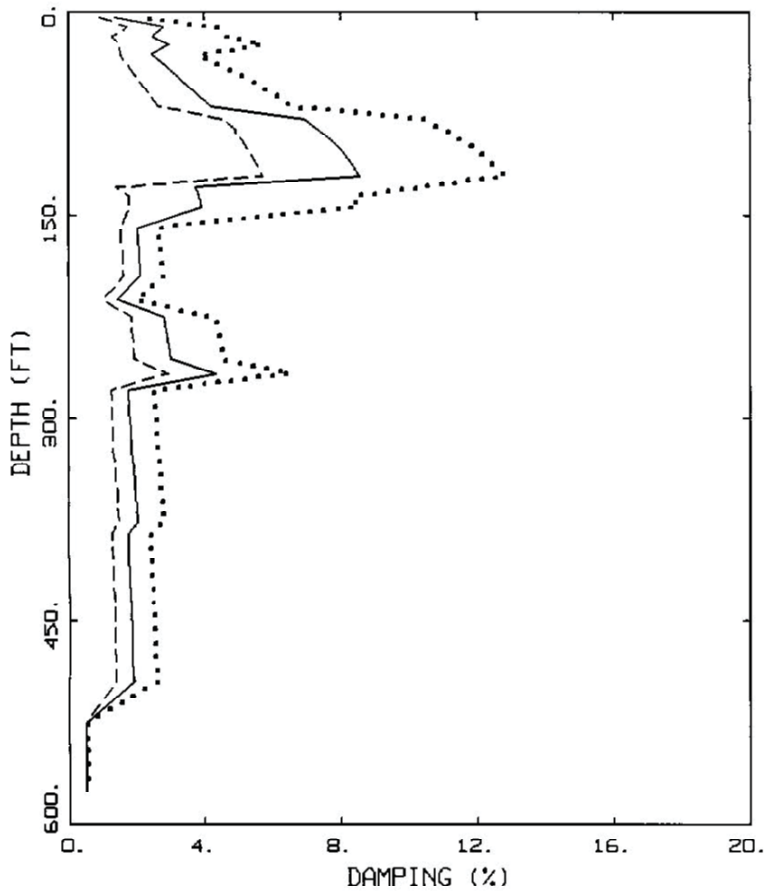
2,500 YR PGA
VP, ENVELOPE: CMRR&TA55

LEGEND
84TH PERCENTILE, CMRR+TA-55 UHRS, CMRR PROFILE
MEDIAN, CMRR CASES
16TH PERCENTILE, CMRR+TA-55 UHRS, CMRR PROFILE

URS	Project No. 26817259	CMRR AND TA-55 MEDIAN AND +/- 1 σ STRAIN-COMPATIBLE PROPERTIES V_p VERSUS DEPTH	Figure 71c
	Los Alamos National Lab		



URS	Project No. 26817259 Los Alamos National Lab	CMRR AND TA-55 MEDIAN AND +/- 1 σ STRAIN-COMPATIBLE PROPERTIES V_p SIGMA VERSUS DEPTH	Figure 71d

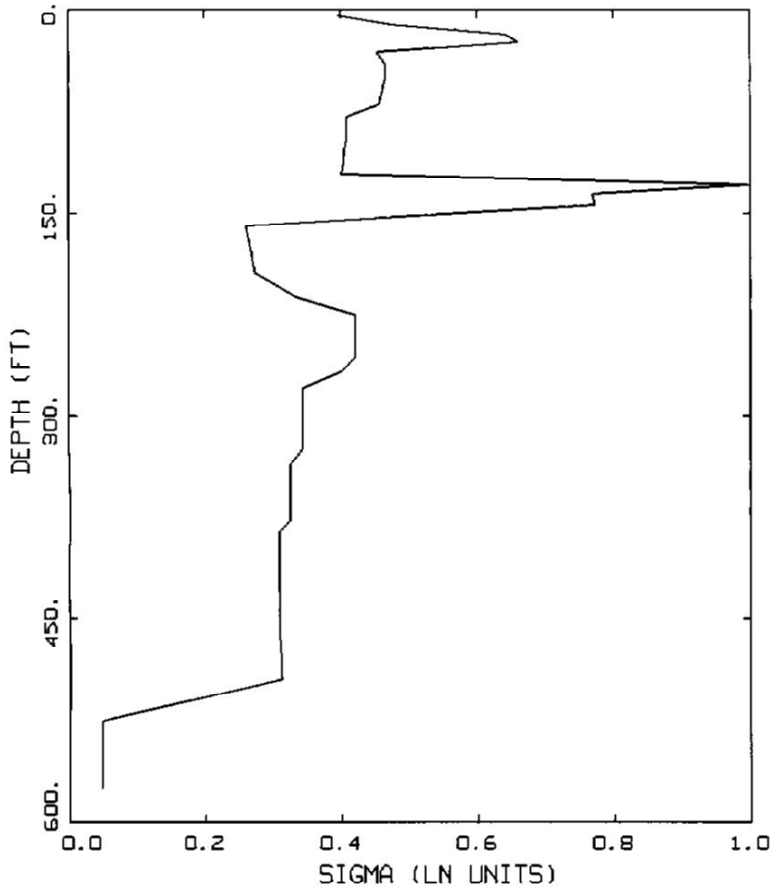


2,500 YR PGA
VS DAMP, ENVELOPE: CMRR&TA55

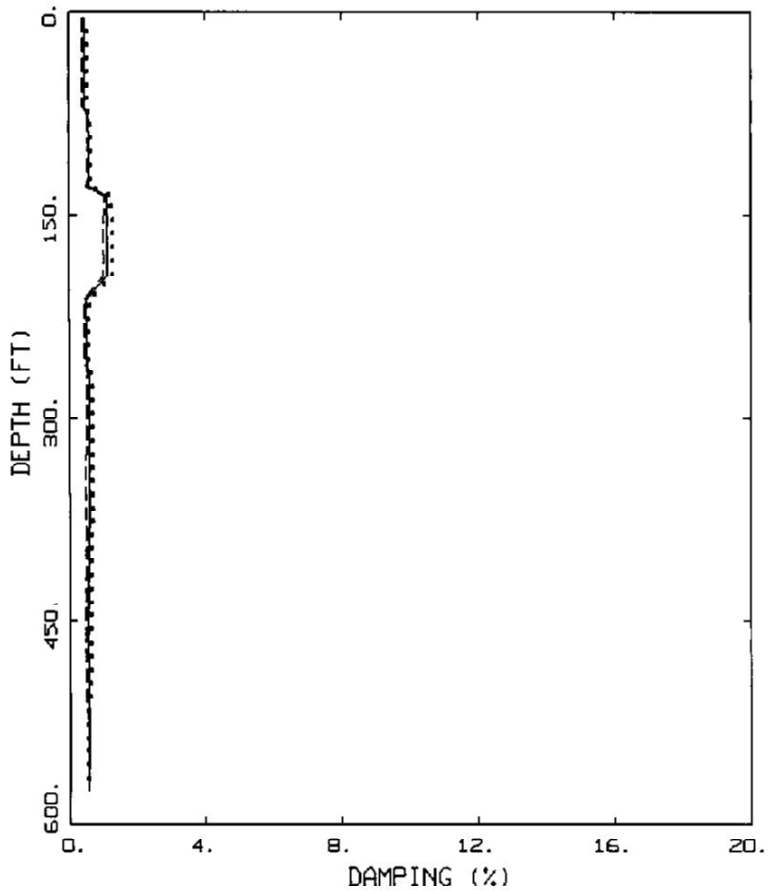
LEGEND

- 84TH PERCENTILE, CMRR+TA-55 UHRS, CMRR PROFILE
- MEDIAN, CMRR CASES
- 16TH PERCENTILE, CMRR+TA-55 UHRS, CMRR PROFILE

URS	Project No. 26817259	CMRR AND TA-55 MEDIAN AND +/- 1 σ STRAIN-COMPATIBLE PROPERTIES V_s DAMPING VERSUS DEPTH	Figure 71e
	Los Alamos National Lab		



URS	Project No. 26817259 Los Alamos National Lab	CMRR AND TA-55 MEDIAN AND +/- 1 σ STRAIN-COMPATIBLE PROPERTIES V_s DAMPING SIGMA VERSUS DEPTH	Figure 71f

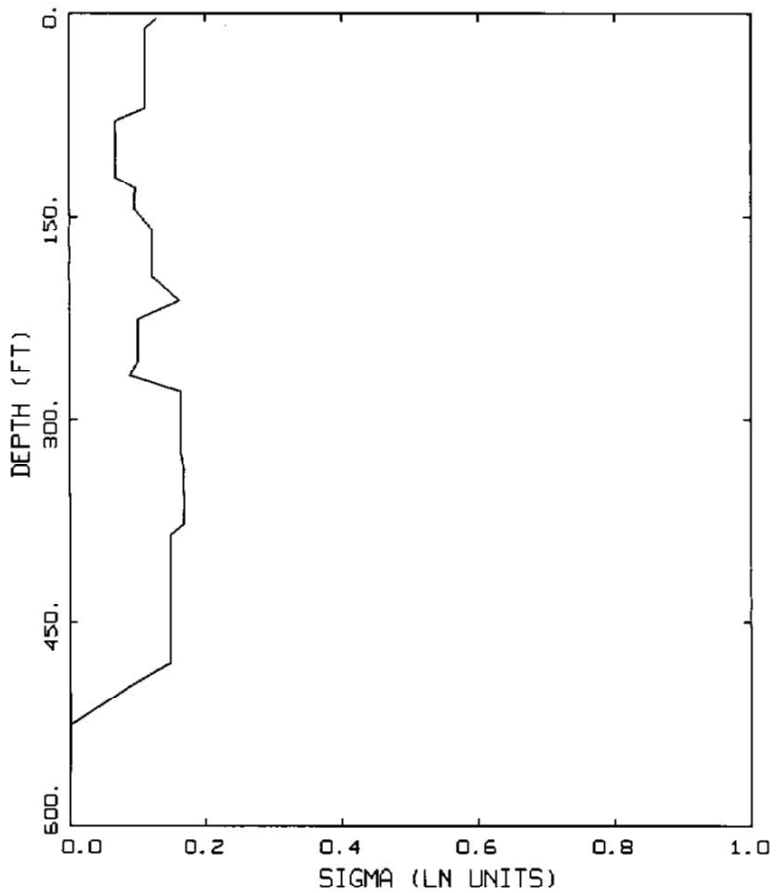


2,500 YR PGA
VP DAMP, ENVELOPE: CMRR&TA55

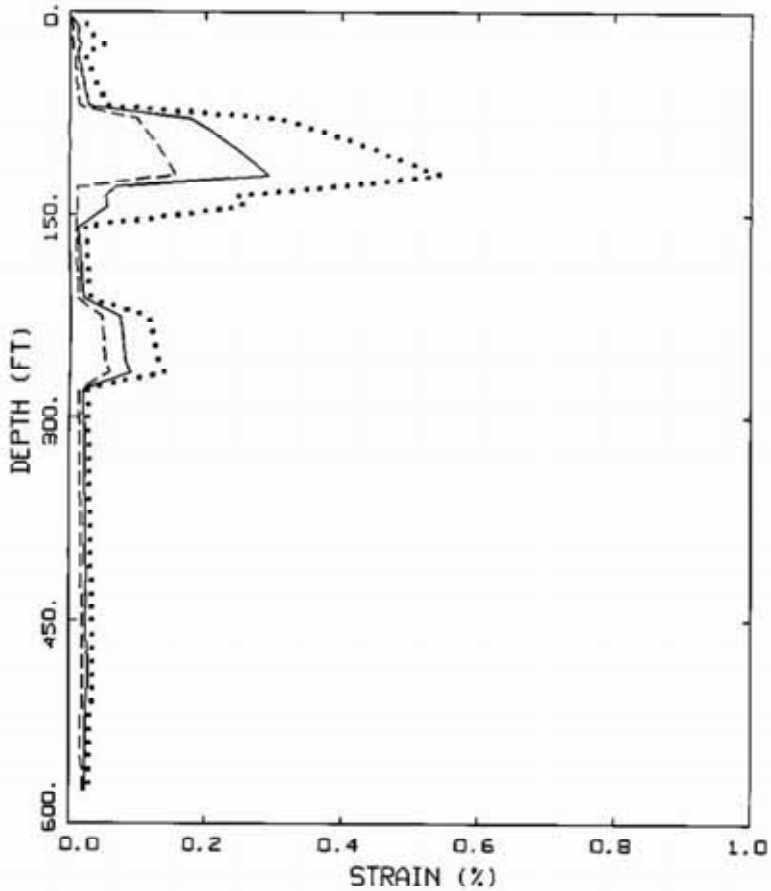
LEGEND

- 84TH PERCENTILE, CMRR+TA-55 UHRS, CMRR PROFILE
- MEDIAN, CMRR CASES
- 16TH PERCENTILE, CMRR+TA-55 UHRS, CMRR PROFILE

URS	Project No. 26817259 Los Alamos National Lab	CMRR AND TA-55 MEDIAN AND +/- 1 σ STRAIN-COMPATIBLE PROPERTIES V_p DAMPING VERSUS DEPTH	Figure 71g



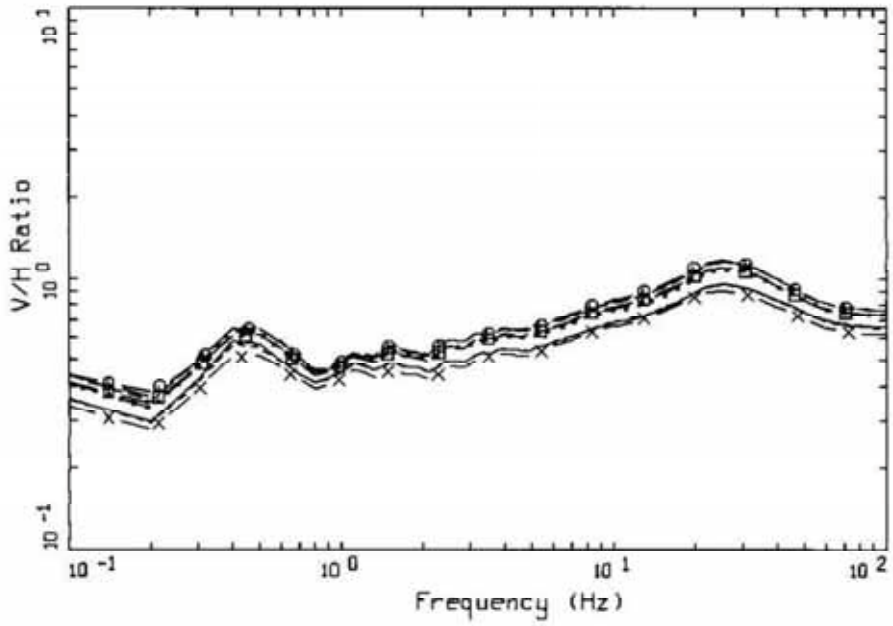
URS	Project No. 26817259 Los Alamos National Lab	CMRR AND TA-55 MEDIAN AND +/- 1 σ STRAIN-COMPATIBLE PROPERTIES V_p DAMPING SIGMA VERSUS DEPTH	Figure 71h



2,500 YR PGA
STRAIN(EYZ),ENVELOPE:CMRR&TA55

LEGEND
84TH PERCENTILE, CMRR+TA-55 UHRS, CMRR PROFILE
MEDIAN, CMRR CASES
16TH PERCENTILE, CMRR+TA-55 UHRS, CMRR PROFILE

URS	Project No. 26817259	MEDIAN and +/- 1σ CMRR AND TA-55 EFFECTIVE CYCLIC SHEAR STRAINS VERSUS DEPTH	Figure 72
	Los Alamos National Lab		



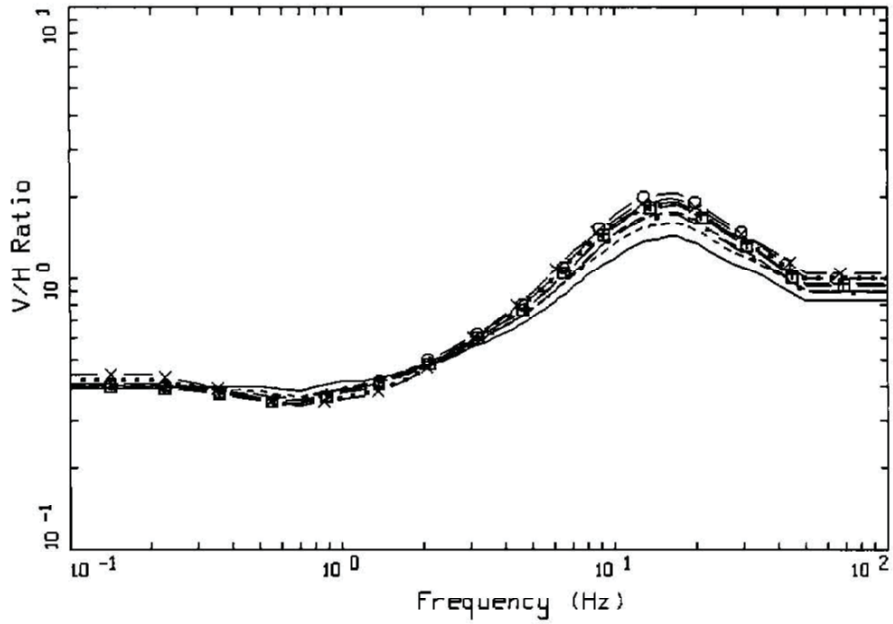
MODEL V/H RATIOS, DACITE
CMRR CURVES

LEGEND

———	DACITE, UNADJUSTED CURVES, 50TH PERCENTILE, M 6.00, DISTANCE = 6.0 KM
• • • •	DACITE, UNADJUSTED CURVES, 50TH PERCENTILE, M 6.20, DISTANCE = 4.0 KM
- - - - -	DACITE, UNADJUSTED CURVES, 50TH PERCENTILE, M 6.20, DISTANCE = 6.0 KM
— — — —	DACITE, UNADJUSTED CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 3.0 KM
— • —	DACITE, UNADJUSTED CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 4.0 KM
— × —	DACITE, UNADJUSTED CURVES, 50TH PERCENTILE, M 6.50, DISTANCE = 7.0 KM
— + —	DACITE, UNADJUSTED CURVES, 50TH PERCENTILE, M 6.75, DISTANCE = 3.0 KM
— □ —	DACITE, UNADJUSTED CURVES, 50TH PERCENTILE, M 6.75, DISTANCE = 4.0 KM
— ○ —	DACITE, UNADJUSTED CURVES, 50TH PERCENTILE, M 7.00, DISTANCE = 3.0 KM

Note: Updated suite of magnitudes and distances using the unadjusted set of G/G_{max} and hysteretic damping curves developed for dacite (Wong *et al.*, 2007).

URS	Project No. 26817259 Los Alamos National Lab	SITE-SPECIFIC V/H RATIOS FOR DACITE OUTCROP	Figure 73

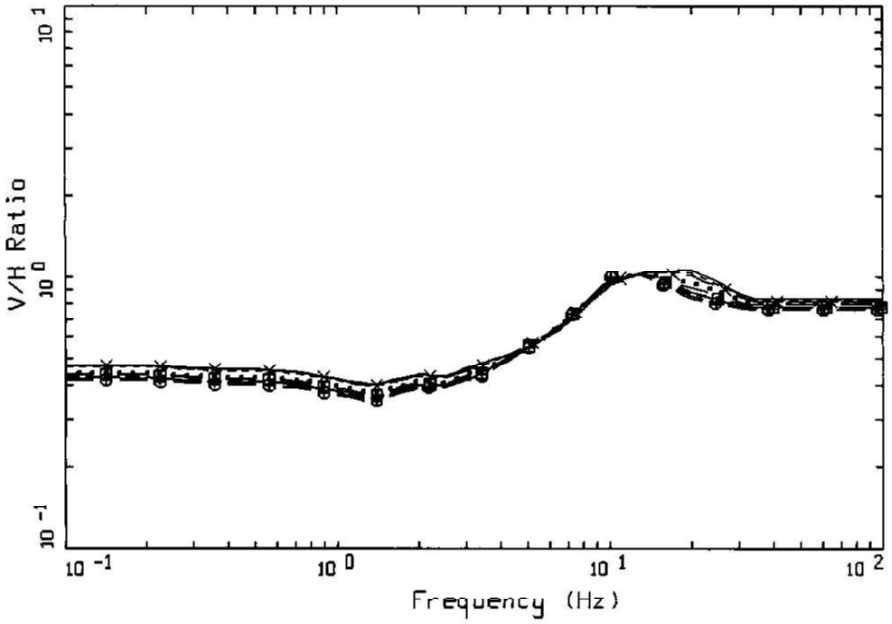


EMPIRICAL V/H RATIOS, SOFT ROCK
ABRAHAMSON AND SILVA

LEGEND

———	50TH PERCENTILE, M 6.00, DISTANCE = 6.0 KM
• • • •	50TH PERCENTILE, M 6.20, DISTANCE = 4.0 KM
- - - - -	50TH PERCENTILE, M 6.20, DISTANCE = 6.0 KM
— — — —	50TH PERCENTILE, M 6.50, DISTANCE = 3.0 KM
— • —	50TH PERCENTILE, M 6.50, DISTANCE = 4.0 KM
— × —	50TH PERCENTILE, M 6.50, DISTANCE = 7.0 KM
— + —	50TH PERCENTILE, M 6.75, DISTANCE = 3.0 KM
— □ —	50TH PERCENTILE, M 6.75, DISTANCE = 4.0 KM
— O —	50TH PERCENTILE, M 7.00, DISTANCE = 3.0 KM

URS	Project No. 26817259 Los Alamos National Lab	EMPIRICAL V/H RATIOS COMPUTED FOR GENERIC SOFT ROCK SITE CONDITIONS ABRAHAMSON AND SILVA, 1997	Figure 74a

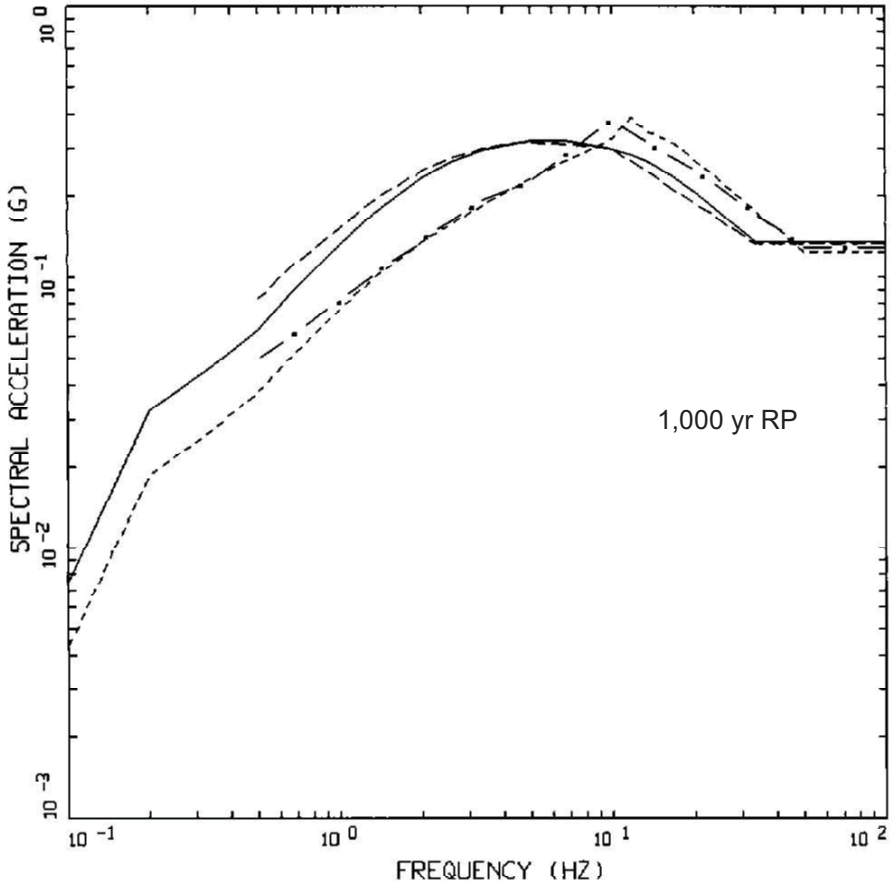


EMPIRICAL V/H RATIOS, SOFT ROCK
CAMPBELL AND BOZORGNIA

LEGEND

———	50TH PERCENTILE, M 6.00, DISTANCE = 6.0 KM
••••	50TH PERCENTILE, M 6.20, DISTANCE = 4.0 KM
-----	50TH PERCENTILE, M 6.20, DISTANCE = 6.0 KM
— — — —	50TH PERCENTILE, M 6.50, DISTANCE = 3.0 KM
— • —	50TH PERCENTILE, M 6.50, DISTANCE = 4.0 KM
— × —	50TH PERCENTILE, M 6.50, DISTANCE = 7.0 KM
— + —	50TH PERCENTILE, M 6.75, DISTANCE = 3.0 KM
— □ —	50TH PERCENTILE, M 6.75, DISTANCE = 4.0 KM
— ○ —	50TH PERCENTILE, M 7.00, DISTANCE = 3.0 KM

URS	Project No. 26817259	EMPIRICAL V/H RATIOS COMPUTED FOR GENERIC SOFT ROCK SITE CONDITIONS CAMPBELL AND BOZORGNIA, 2003	Figure 74b
	Los Alamos National Lab		

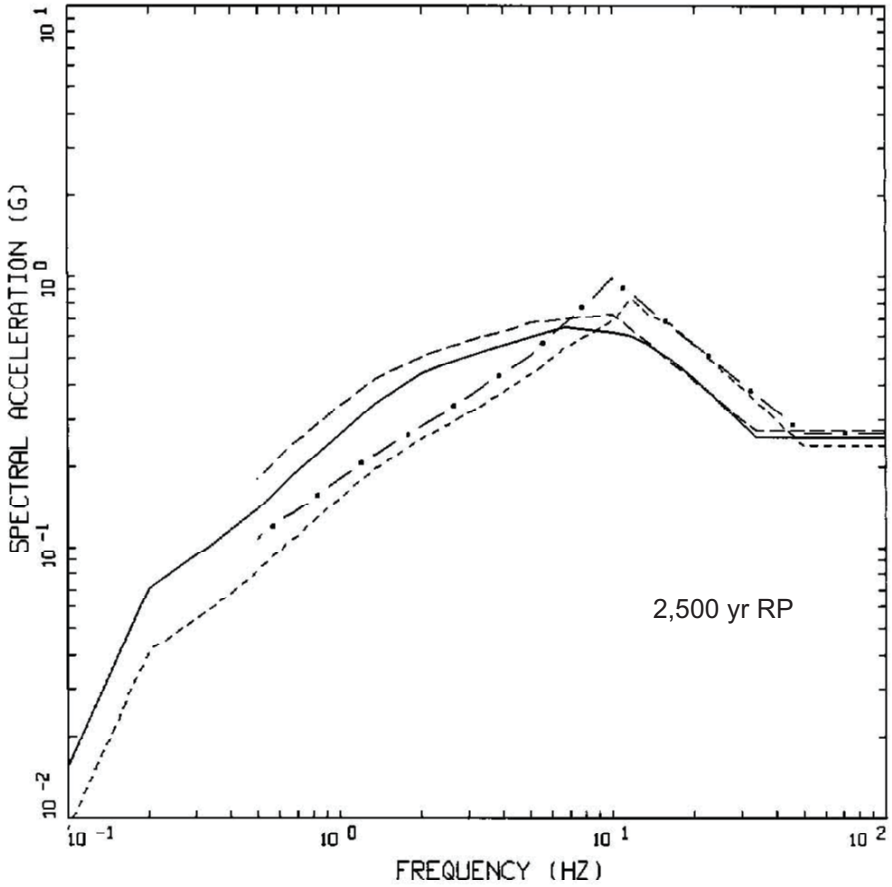


DACITE 1,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

- - - - 2007 REPORT HORIZONTAL UHS, PGA = 0.13g
——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 0.14g
— • — 2007 REPORT VERTICAL UHS, PGA = 0.13g
- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 0.12g

URS	Project No. 26817259 Los Alamos National Lab	DACITE SITE-SPECIFIC OUTCROP HORIZONTAL AND VERTICAL UHRS	Figure 75a



DACITE 2,500 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

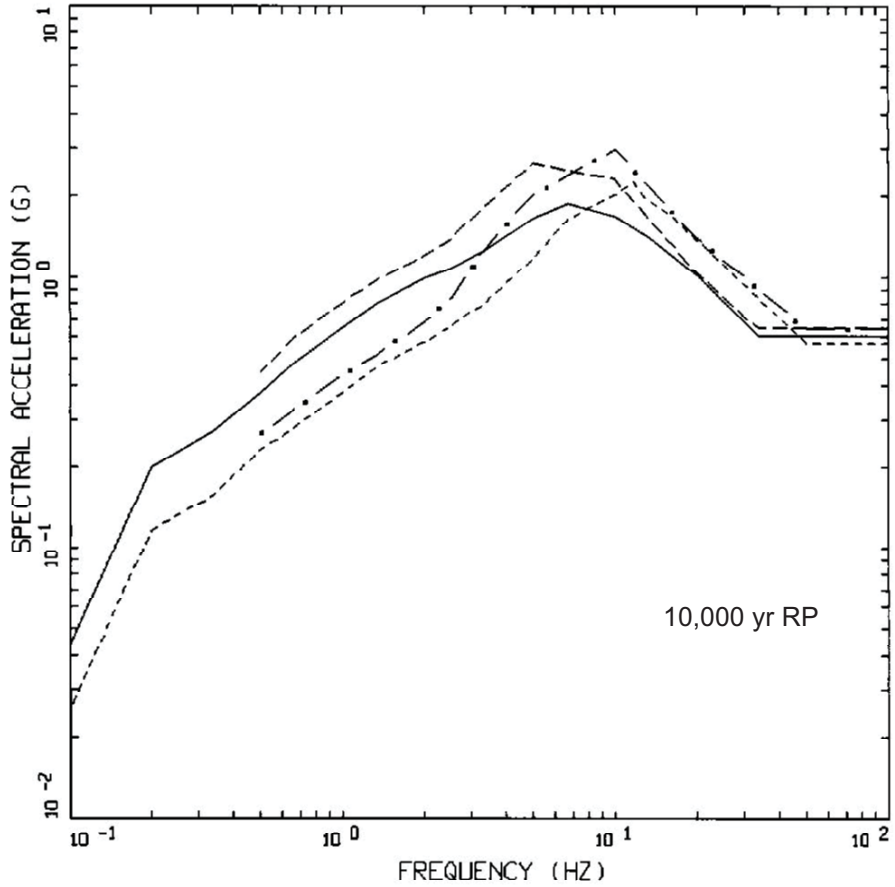
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 0.27g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 0.26g

— • — 2007 REPORT VERTICAL UHS, PGA = 0.27g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 0.24g

URS	Project No. 26817259 Los Alamos National Lab	DACITE SITE-SPECIFIC OUTCROP HORIZONTAL AND VERTICAL UHRS	Figure 75b



DACITE 10,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

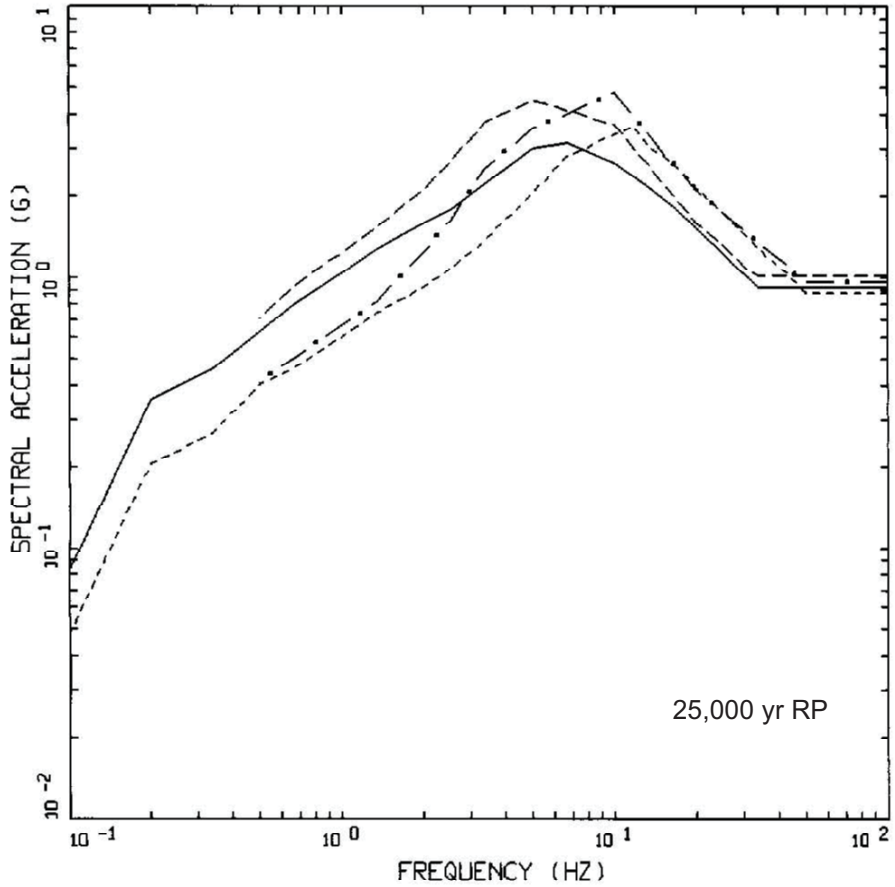
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 0.65g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 0.61g

— · — 2007 REPORT VERTICAL UHS, PGA = 0.65g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 0.57g

URS	Project No. 26817259 Los Alamos National Lab	DACITE SITE-SPECIFIC OUTCROP HORIZONTAL AND VERTICAL UHRS	Figure 75c



DACITE 25,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

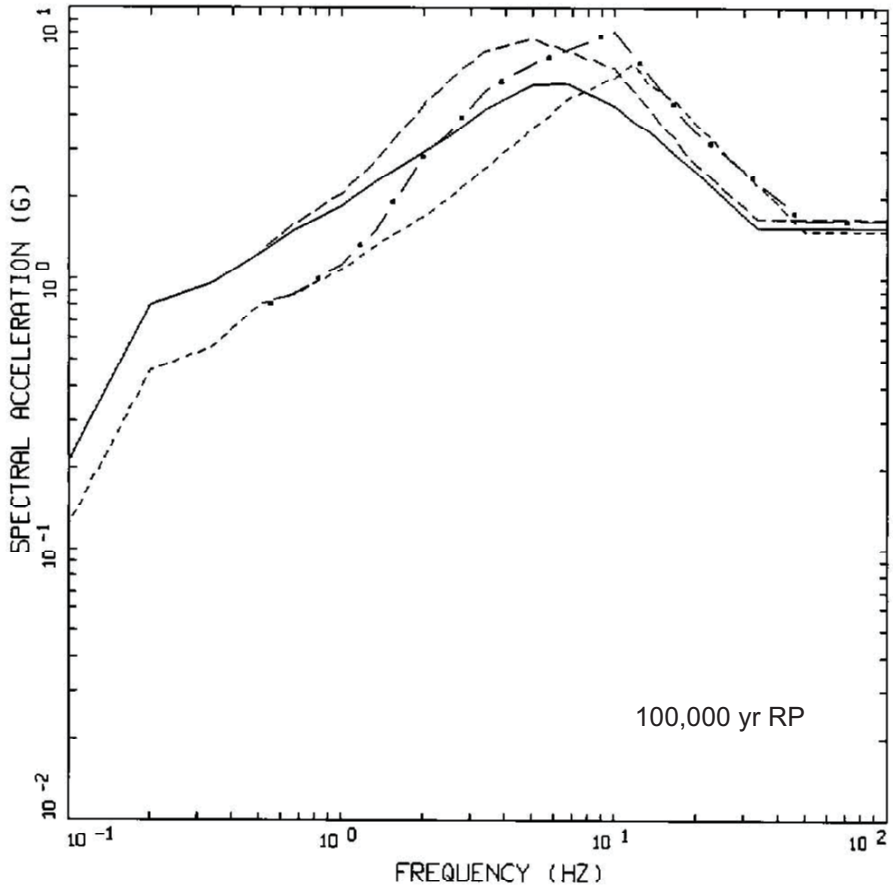
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 1.01g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 0.93g

— • — 2007 REPORT VERTICAL UHS, PGA = 0.97g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 0.88g

URS	Project No. 26817259 Los Alamos National Lab	DACITE SITE-SPECIFIC OUTCROP HORIZONTAL AND VERTICAL UHRS	Figure 75d



DACITE 100,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

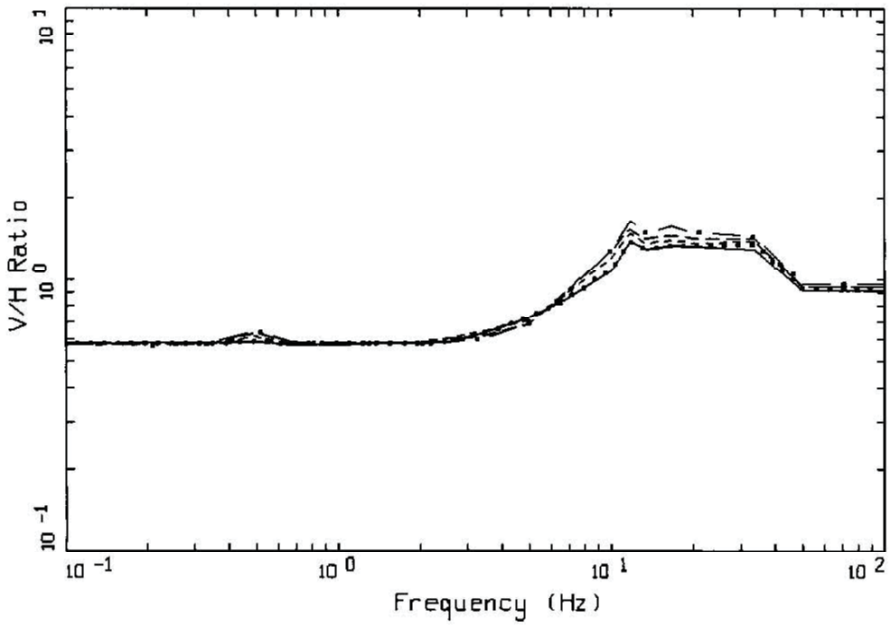
- - - - 2007 REPORT HORIZONTAL UHS, PGA = 1.69g

——— UPDATED 07/2009 HORIZONTAL UHS, PGA = 1.54g

— • — 2007 REPORT VERTICAL UHS, PGA = 1.65g

- - - - - UPDATED 07/2009 VERTICAL UHS, PGA = 1.50g

URS	Project No. 26817259 Los Alamos National Lab	DACITE SITE-SPECIFIC OUTCROP HORIZONTAL AND VERTICAL UHRS	Figure 75e

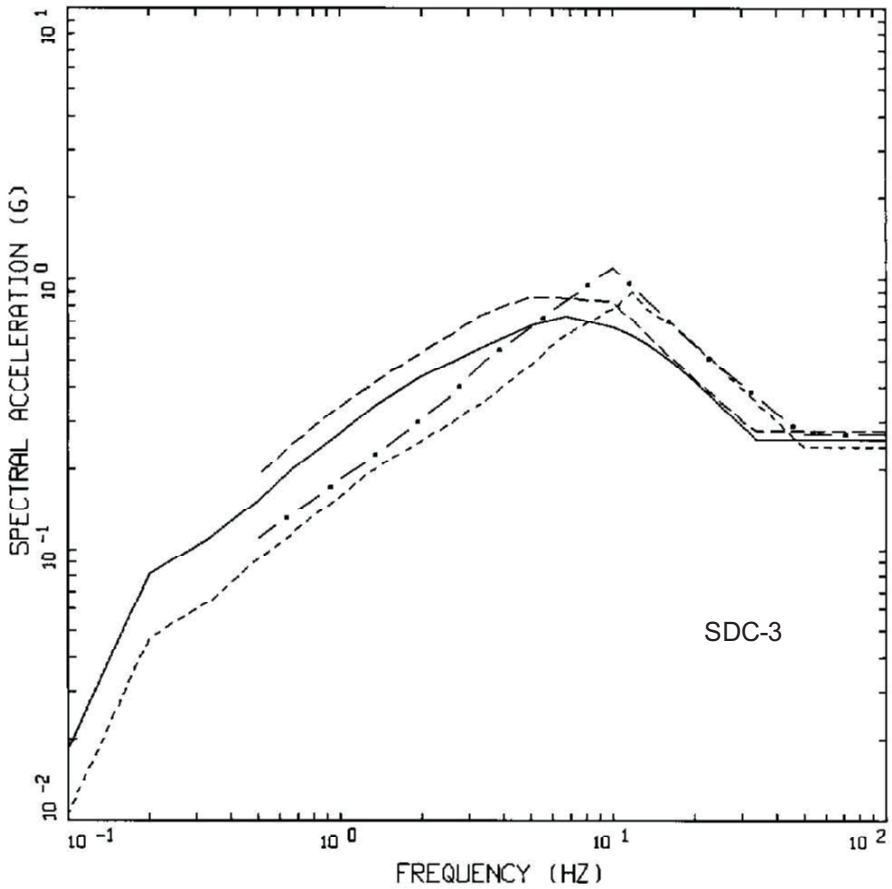


DACITE MEAN UHRS
IMPLIED V/H RATIO

LEGEND

———	V/H RATIO: 1,000 YEAR (MEAN)
• • • •	V/H RATIO: 2,500 YEAR (MEAN)
- - - - -	V/H RATIO: 10,000 YEAR (MEAN)
— — — -	V/H RATIO: 25,000 YEAR (MEAN)
— • —	V/H RATIO: 100,000 YEAR (MEAN)

URS	Project No. 26817259 Los Alamos National Lab	IMPLIED V/H RATIO FOR DACITE OUTCROP AS THE RATIO OF THE VERTICAL AND HORIZONTAL UHRS	Figure 76

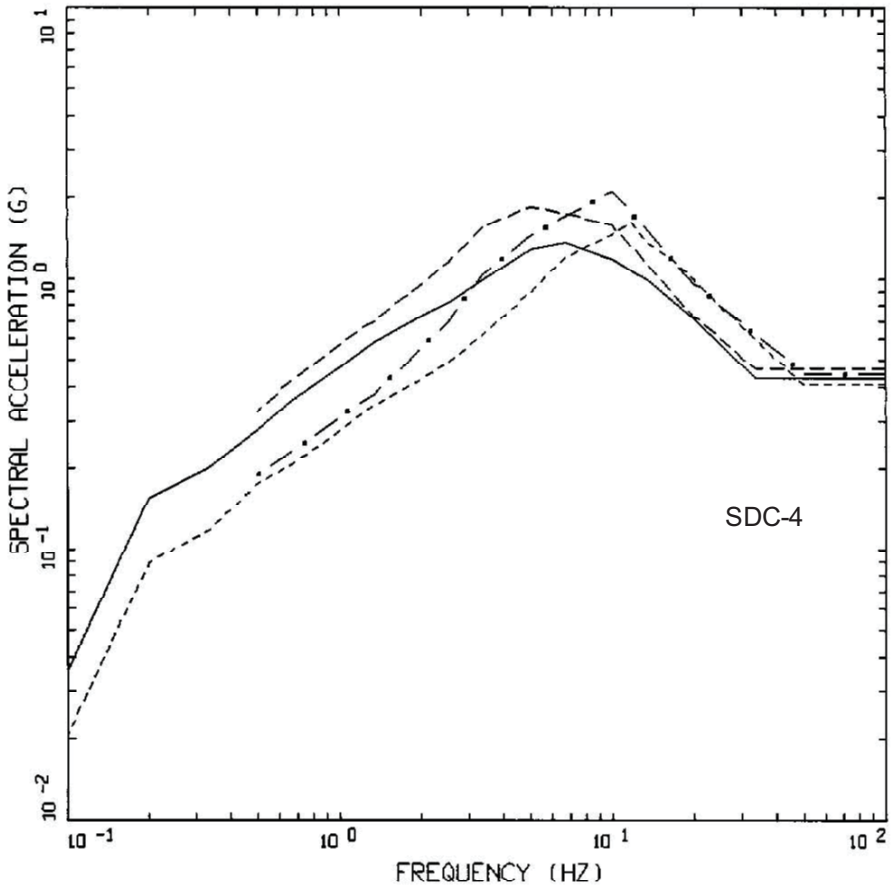


DACITE SDC 3
DRS: HORIZONTAL, VERTICAL

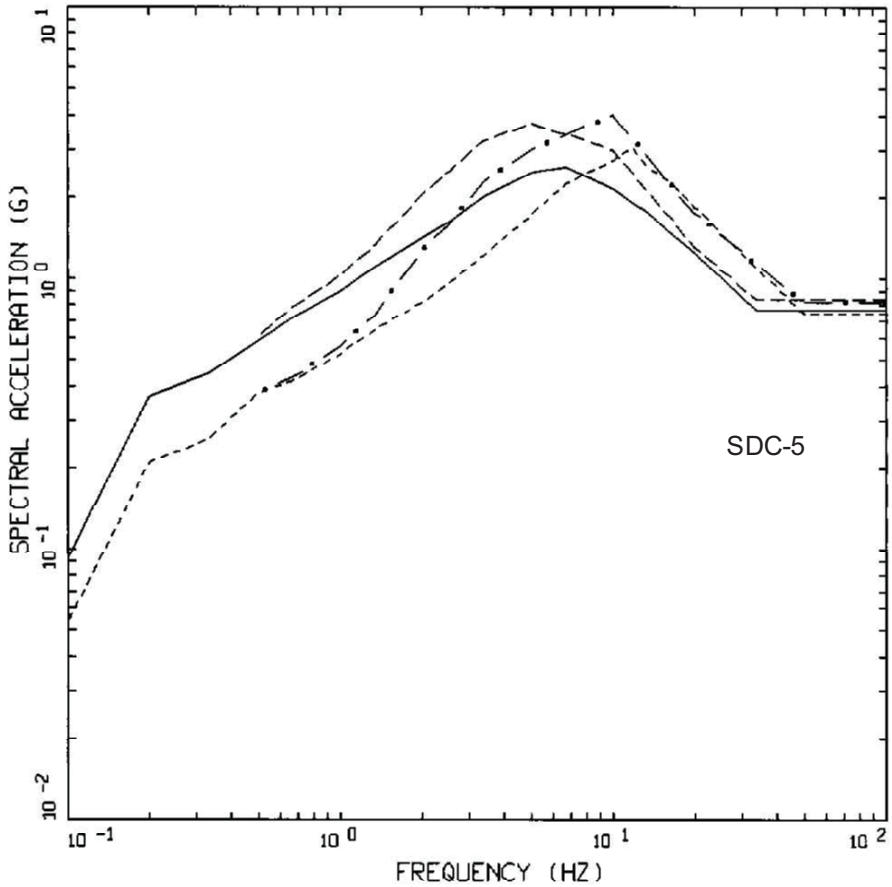
LEGEND

- - - - 2007 REPORT HORIZONTAL: SDC 3 (4x10-4), PGA = 0.28g
——— UPDATED 07/2009 HORIZONTAL: SDC 3 (4x10-4), PGA = 0.26g
— · — 2007 REPORT VERTICAL: SDC 3 (4x10-4), PGA = 0.27g
- - - - - UPDATED 07/2009 VERTICAL: SDC 3 (4x10-4), PGA = 0.24g

URS	Project No. 26817259 Los Alamos National Lab	DACITE SITE-SPECIFIC OUTCROP HORIZONTAL AND VERTICAL DRS	Figure 77a



URS	Project No. 26817259 Los Alamos National Lab	DACITE SITE-SPECIFIC OUTCROP HORIZONTAL AND VERTICAL DRS	Figure 77b

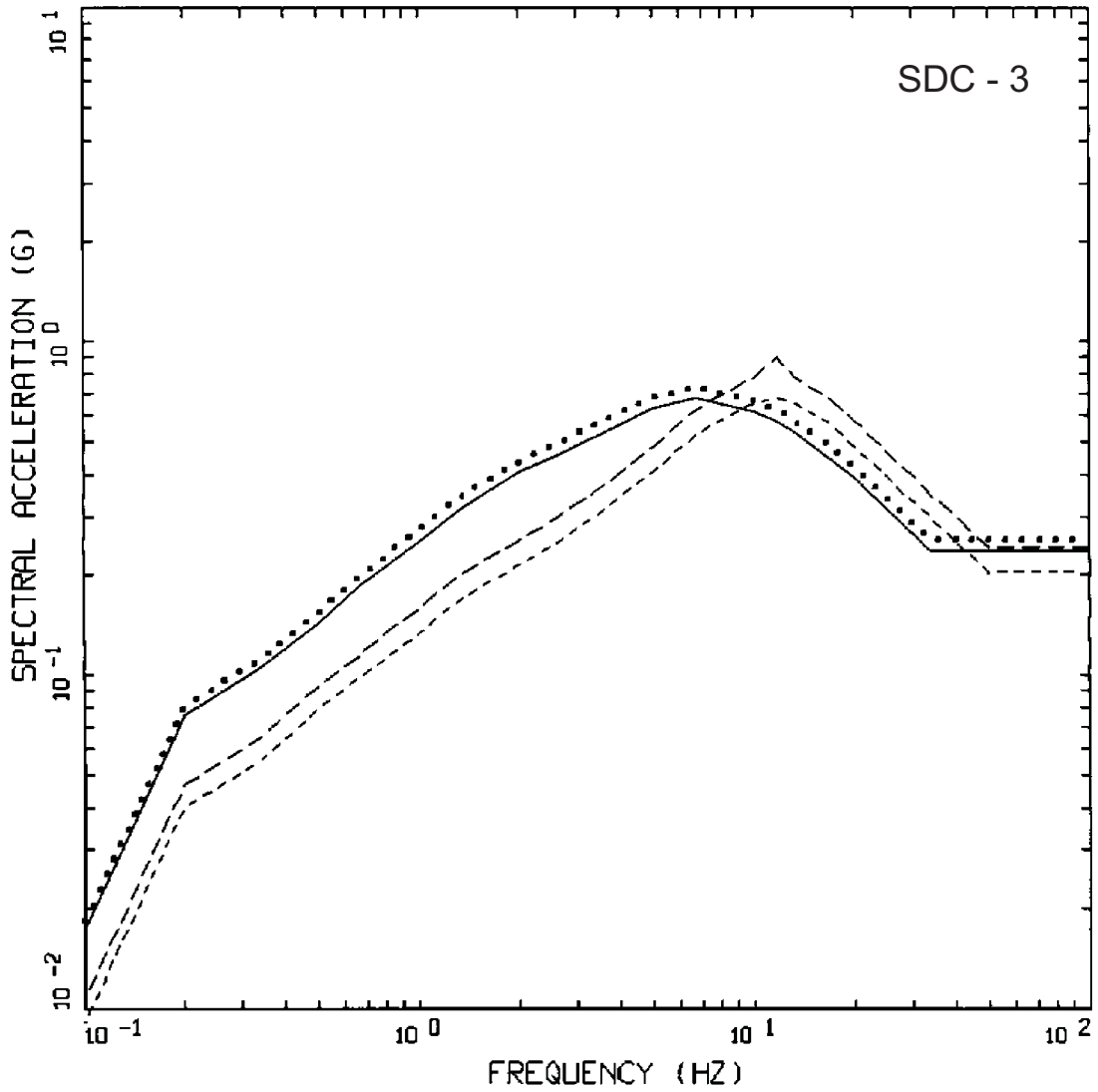


DACITE SDC 5
DRS: HORIZONTAL, VERTICAL

LEGEND

- - - - 2007 REPORT HORIZONTAL: SDC 5 (1x10-4), PGA = 0.84g
——— UPDATED 07/2009 HORIZONTAL: SDC 5 (1x10-4), PGA = 0.77g
— • — 2007 REPORT VERTICAL: SDC 5 (1x10-4), PGA = 0.82g
----- UPDATED 07/2009 VERTICAL: SDC 5 (1x10-4), PGA = 0.74g

URS	Project No. 26817259 Los Alamos National Lab	DACITE SITE-SPECIFIC OUTCROP HORIZONTAL AND VERTICAL DRS	Figure 77c

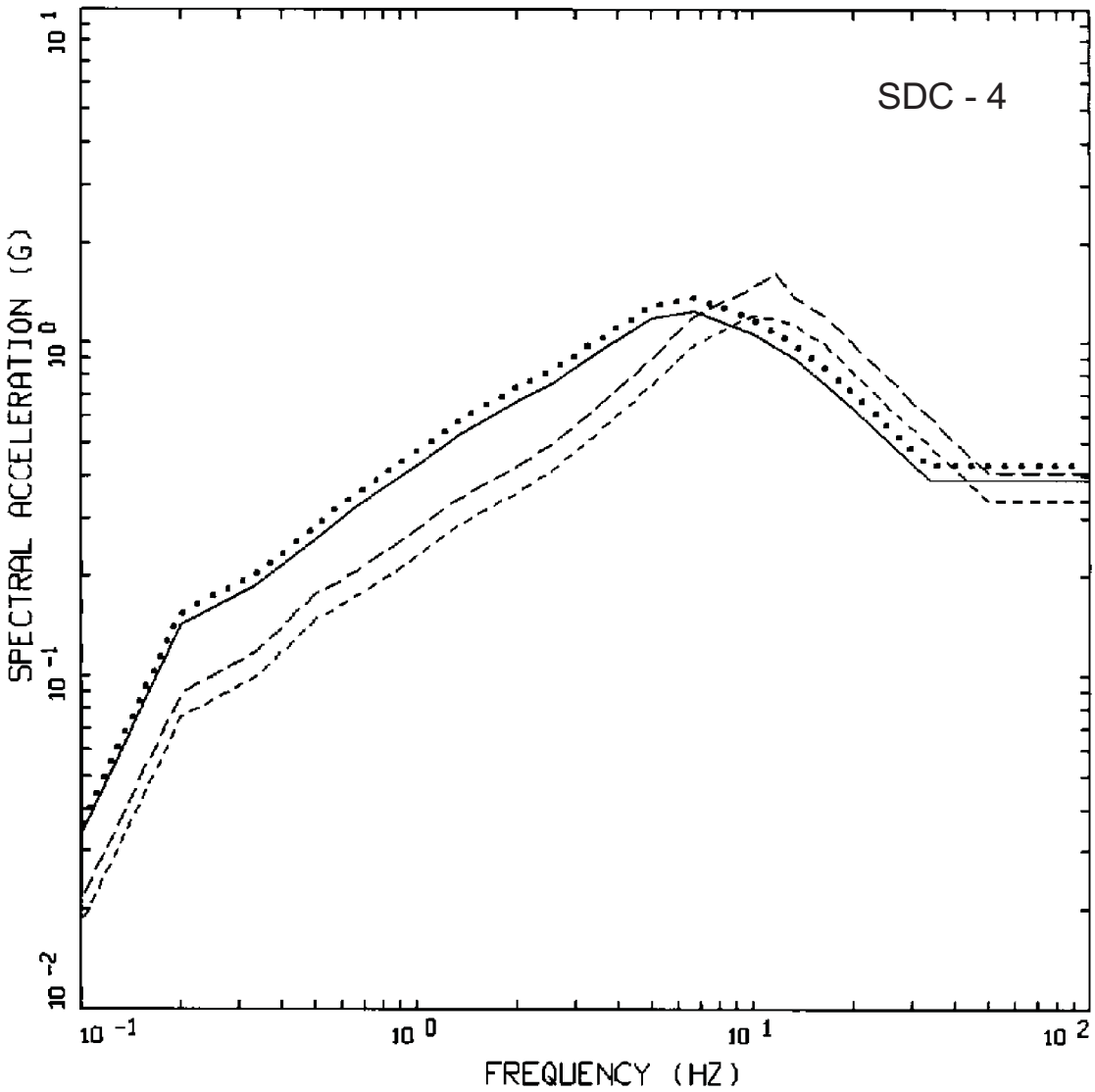


DACITE SDC 3
DRS: HORIZONTAL, VERTICAL

LEGEND

———	UPDATED HORIZONTAL (NO TOPO): SDC 3 (4x10-4), PGA = 0.24g
- - - -	UPDATED HORIZONTAL (WITH TOPO): SDC 3 (4x10-4), PGA = 0.26g
-----	UPDATED VERTICAL (NO TOPO): SDC 3 (4x10-4), PGA = 0.20g
— — — -	UPDATED VERTICAL (WITH TOPO): SDC 3 (4x10-4), PGA = 0.24g

URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF DACITE DRS WITH AND WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 78a

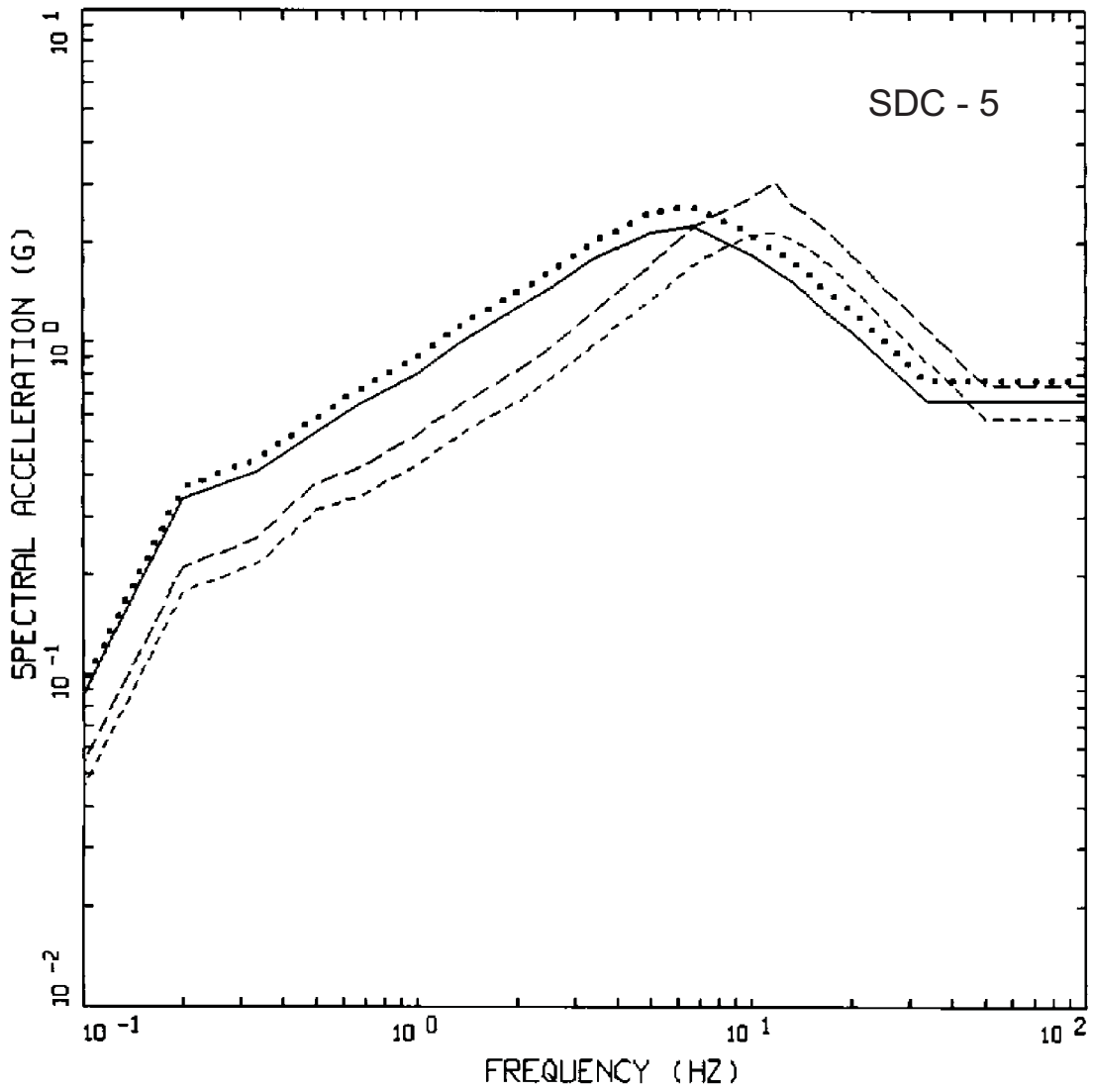


DACITE SDC 4
DRS: HORIZONTAL, VERTICAL

LEGEND

———	UPDATED HORIZONTAL (NO TOPO): SDC 4 (4x10-4), PGA = 0.39g
· · · ·	UPDATED HORIZONTAL (WITH TOPO): SDC 4 (4x10-4), PGA = 0.43g
- - - - -	UPDATED VERTICAL (NO TOPO): SDC 4 (4x10-4), PGA = 0.34g
— — — -	UPDATED VERTICAL (WITH TOPO): SDC 4 (4x10-4), PGA = 0.41g

URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF DACITE DRS WITH AND WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 78b

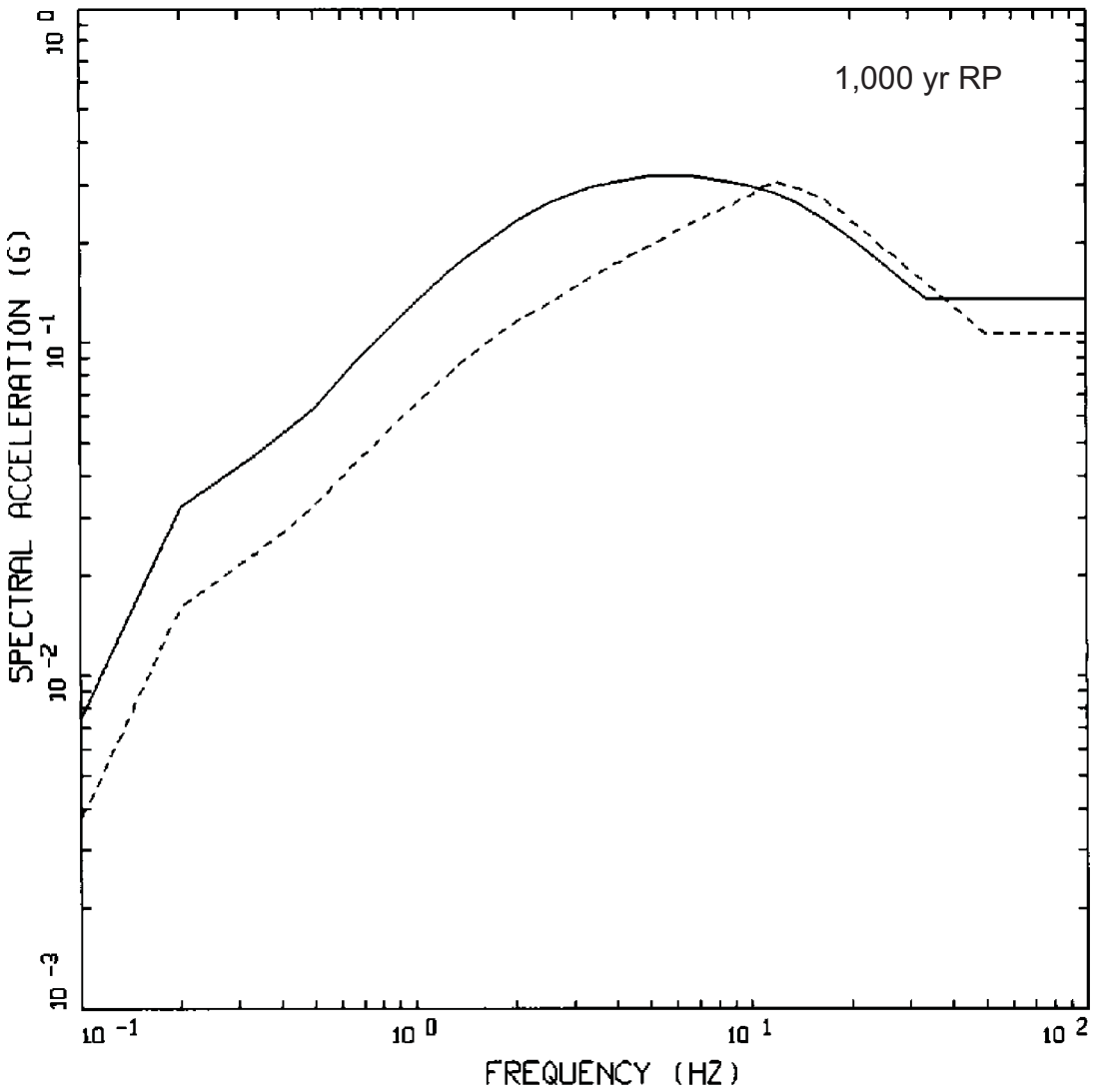


DACITE SDC 5
DRS: HORIZONTAL, VERTICAL

LEGEND

———	UPDATED HORIZONTAL (NO TOPO): SDC 5 (1x10-4), PGA = 0.67g
• • • •	UPDATED HORIZONTAL (WITH TOPO): SDC 5 (1x10-4), PGA = 0.77g
- - - - -	UPDATED VERTICAL (NO TOPO): SDC 5 (1x10-4), PGA = 0.59g
— — — -	UPDATED VERTICAL (WITH TOPO): SDC 5 (1x10-4), PGA = 0.74g

URS	Project No. 26817259 Los Alamos National Lab	COMPARISON OF DACITE DRS WITH AND WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 78c



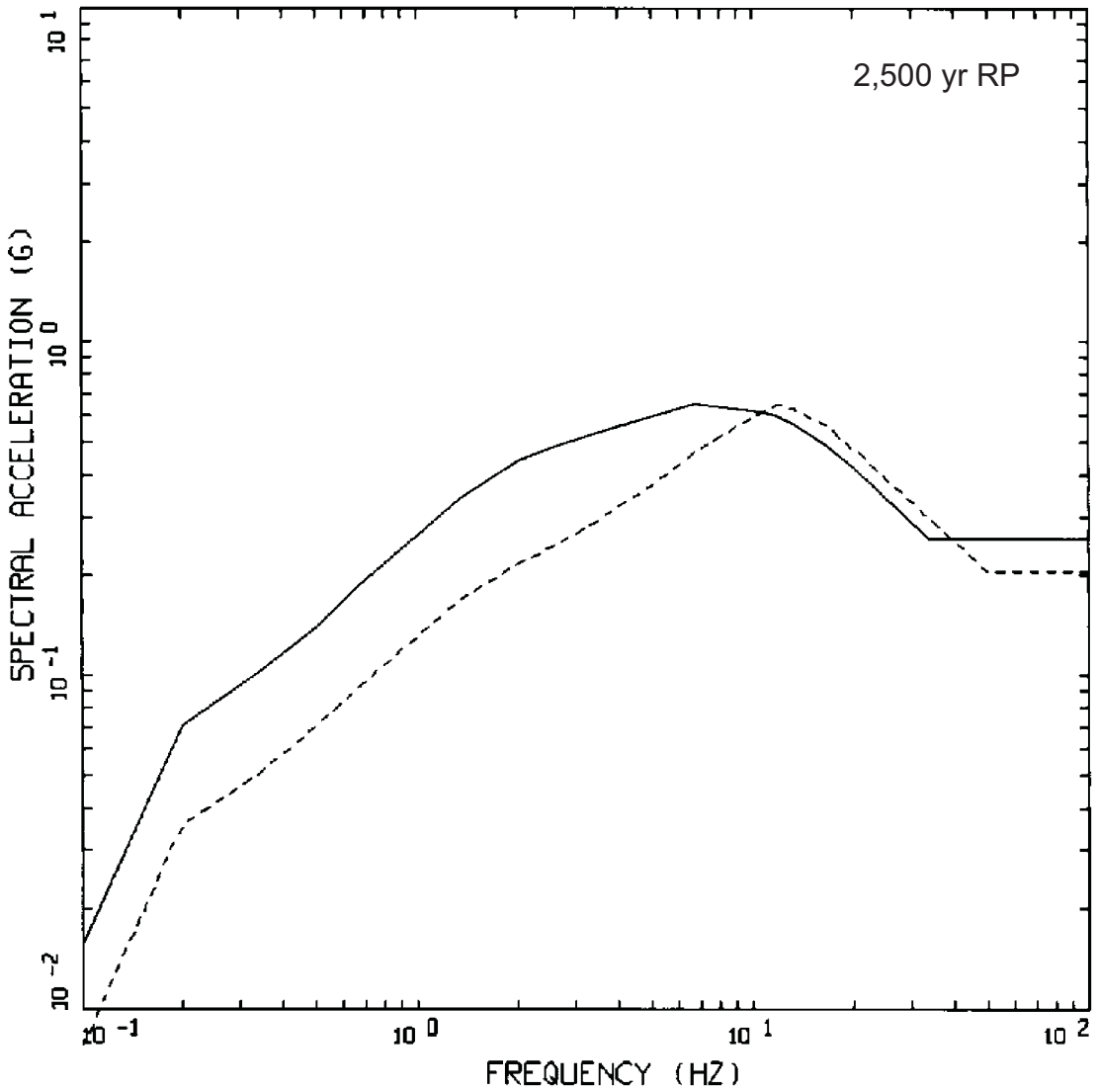
DACITE 1,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

——— UPDATED HORIZONTAL UHS (NO TOPO), PGA = 0.13g

- - - - - UPDATED VERTICAL UHS (NO TOPO), PGA = 0.11g

URS	Project No. 26817259 Los Alamos National Lab	DACITE UHRS WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 79a



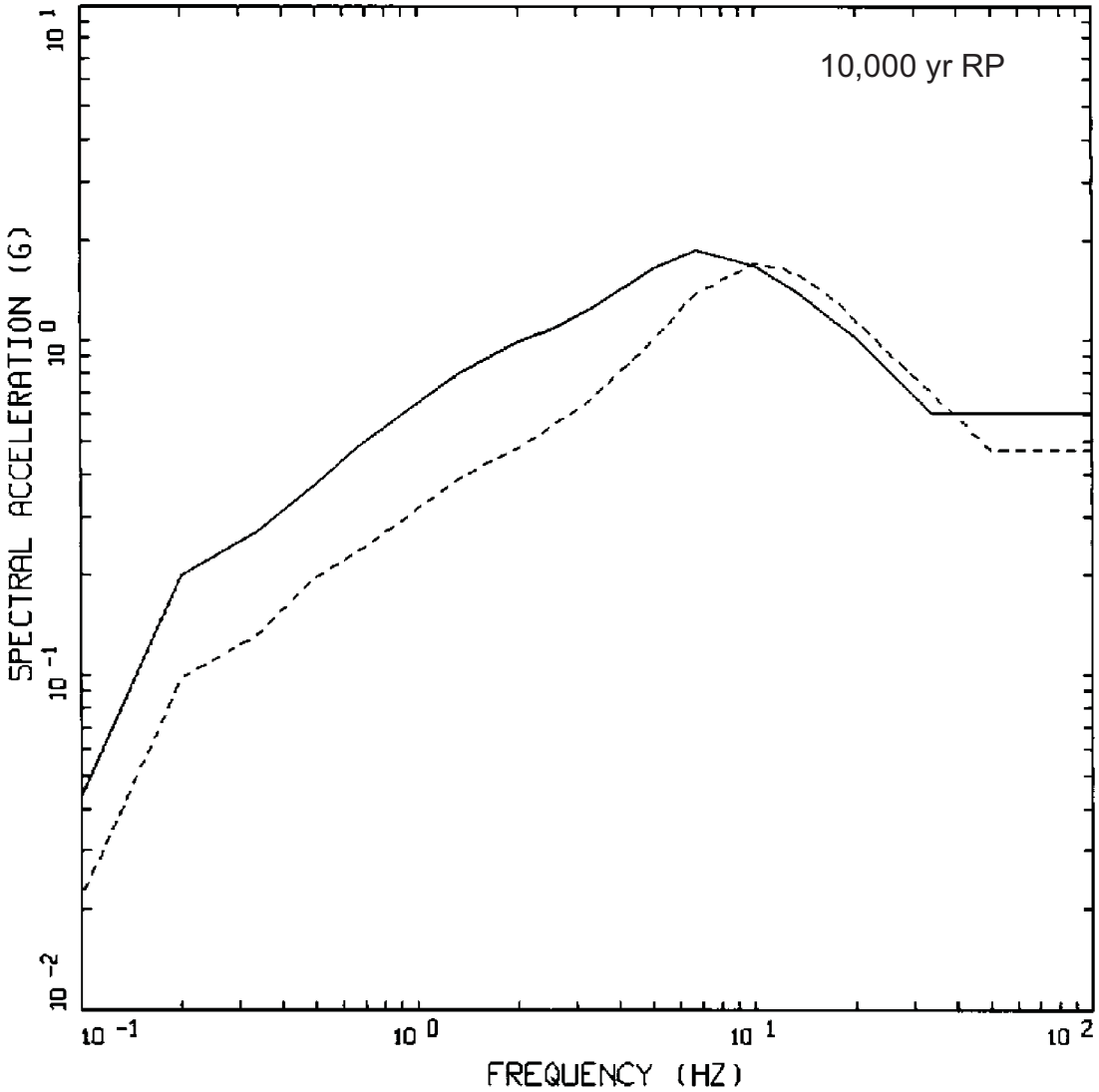
DACITE 2,500 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

——— UPDATED HORIZONTAL UHS (NO TOPO), PGA = 0.24g

- - - - - UPDATED VERTICAL UHS (NO TOPO), PGA = 0.20g

URS	Project No. 26817259 Los Alamos National Lab	DACITE UHRS WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 79b



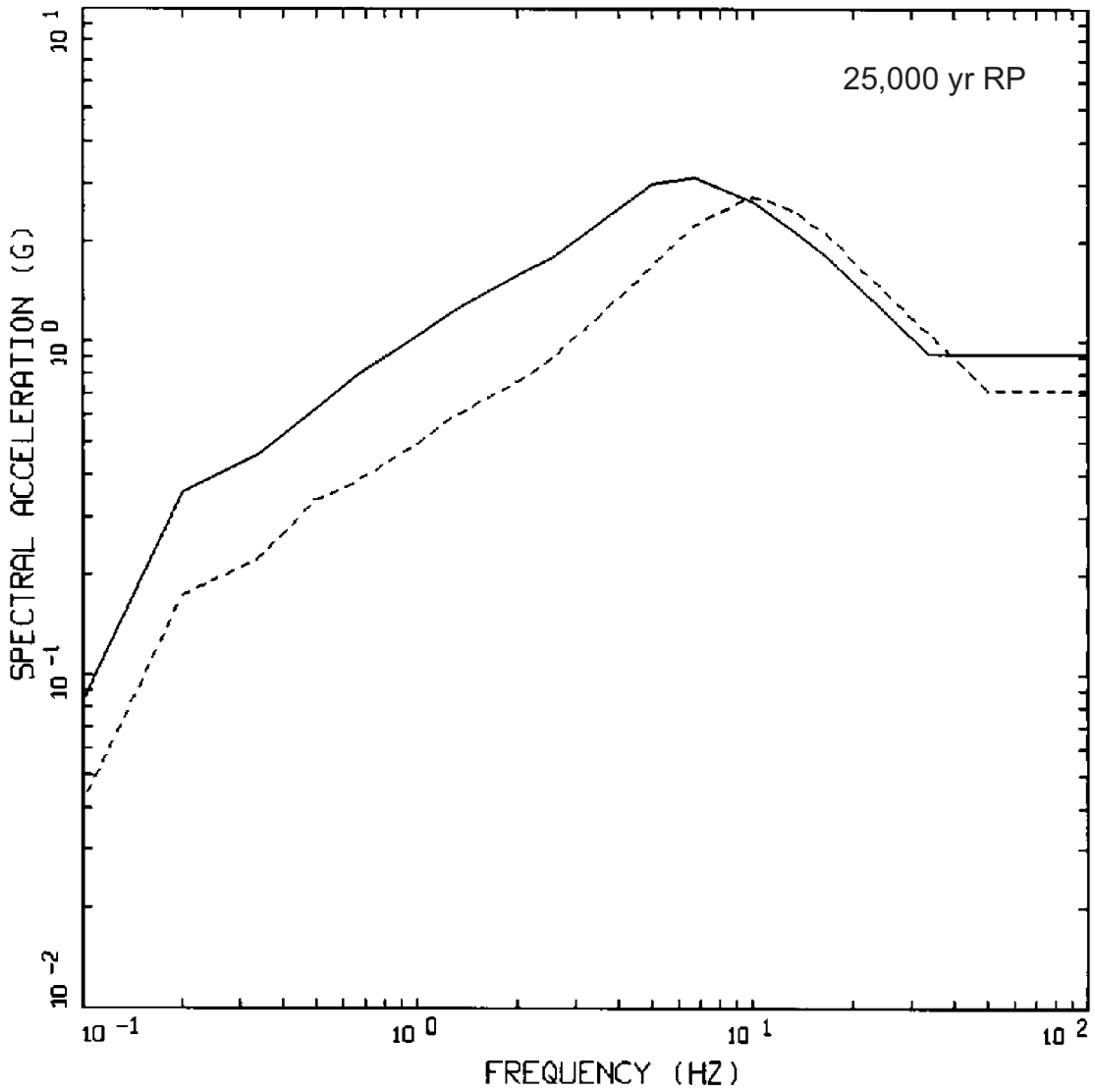
DACITE 10,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

——— UPDATED HORIZONTAL UHS (NO TOPO), PGA = 0.56g

----- UPDATED VERTICAL UHS (NO TOPO), PGA = 0.47g

URS	Project No. 26817259 Los Alamos National Lab	DACITE UHRS WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 79c



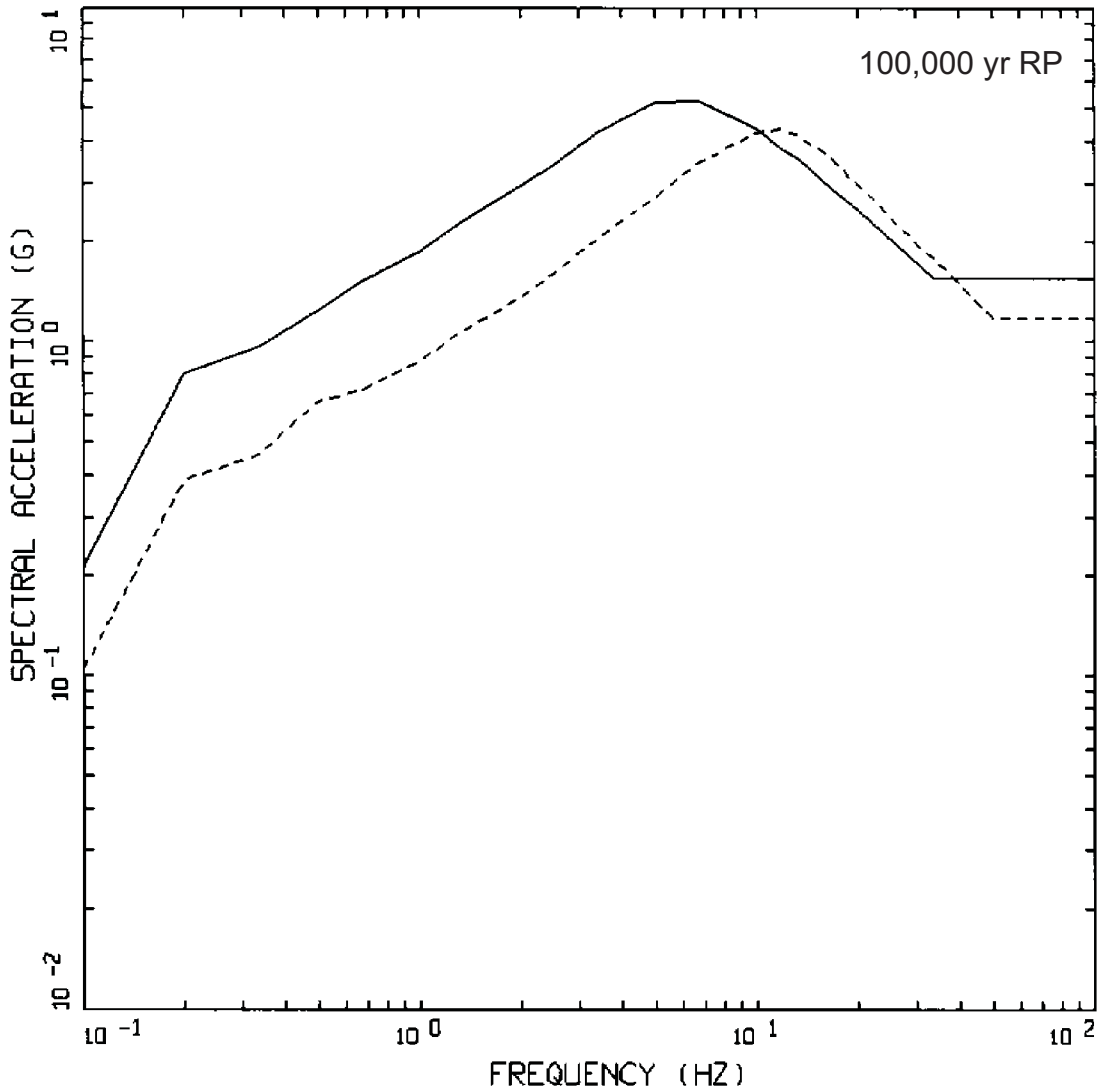
DACITE 25,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

LEGEND

——— UPDATED HORIZONTAL UHS (NO TOPO), PGA = 0.83g

- - - - - UPDATED VERTICAL UHS (NO TOPO), PGA = 0.72g

URS	Project No. 26817259 Los Alamos National Lab	DACITE UHRS WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 79d



DACITE 100,000 YEAR
MEAN UHRS:HORIZONTAL, VERTICAL

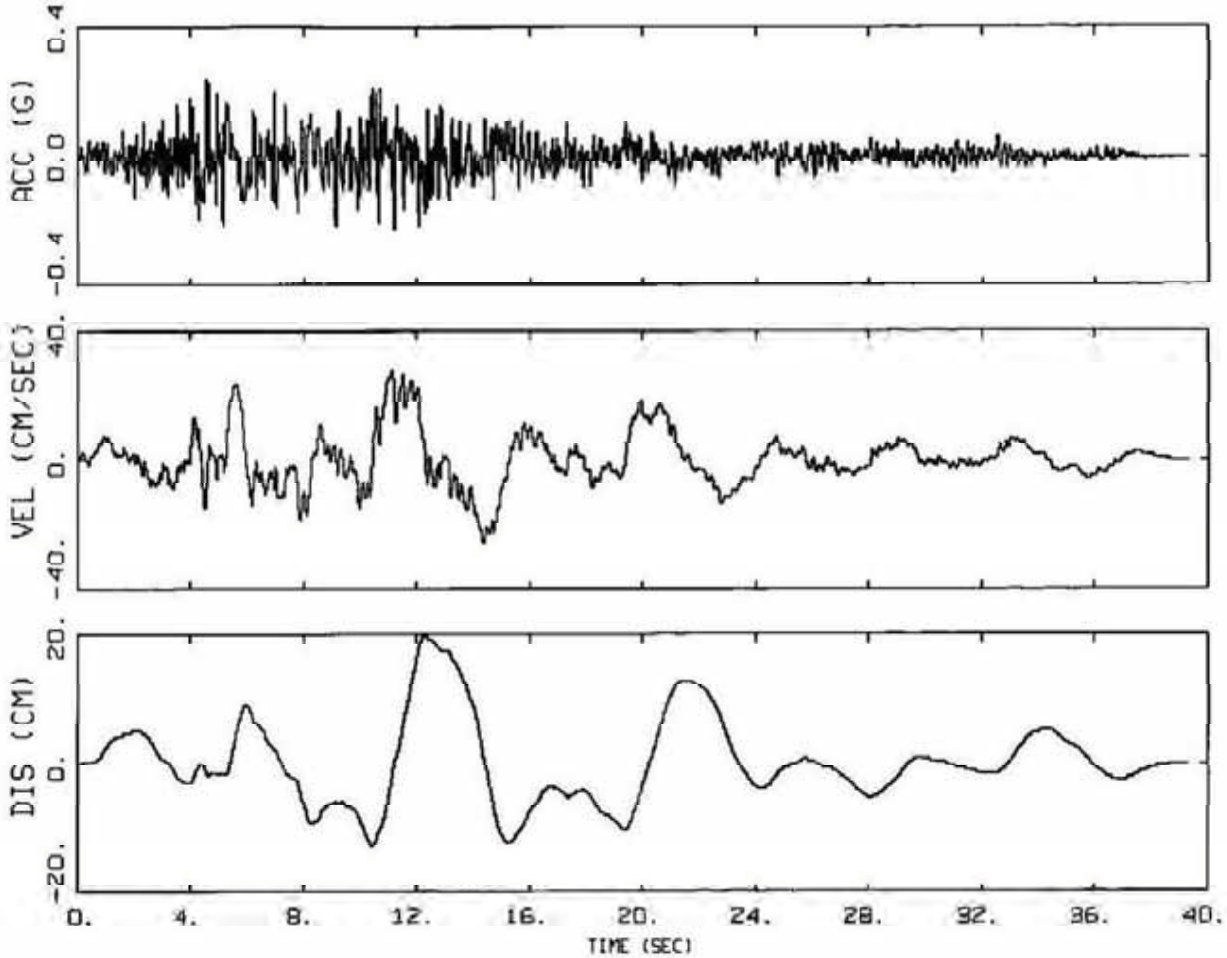
LEGEND

——— UPDATED HORIZONTAL UHS (NO TOPO), PGA = 1.32g

- - - - - UPDATED VERTICAL UHS (NO TOPO), PGA = 1.18g

URS	Project No. 26817259 Los Alamos National Lab	DACITE UHRS WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 79e

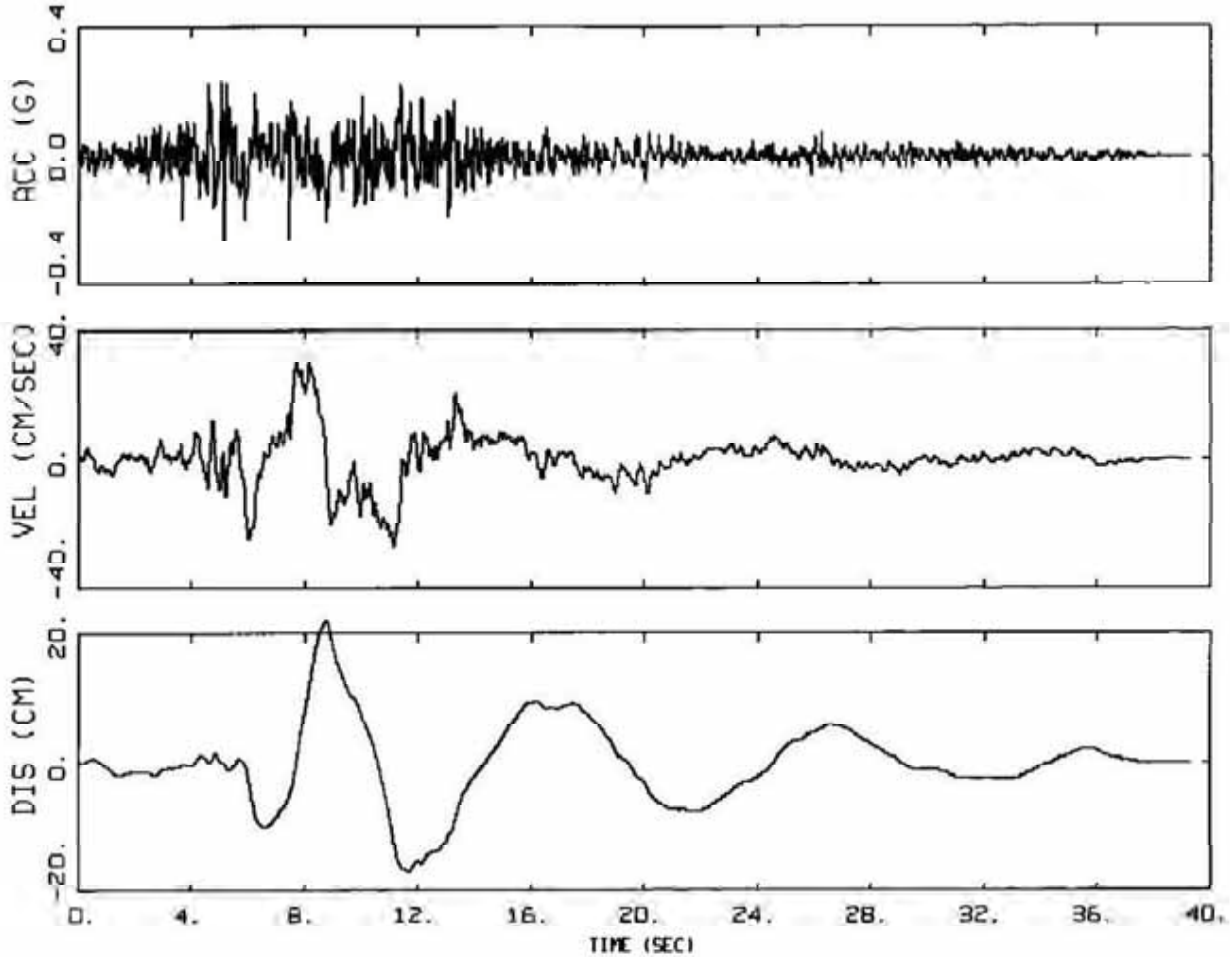
HORIZONTAL 1



DACITE, SDC 3, 2% 50 YR, HORIZONTAL 1
BASELINE CORRECTED

URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-3 DACITE OUTCROP TIME HISTORIES WITH TOPOGRAPHIC AMPLIFICATION	Figure 80a

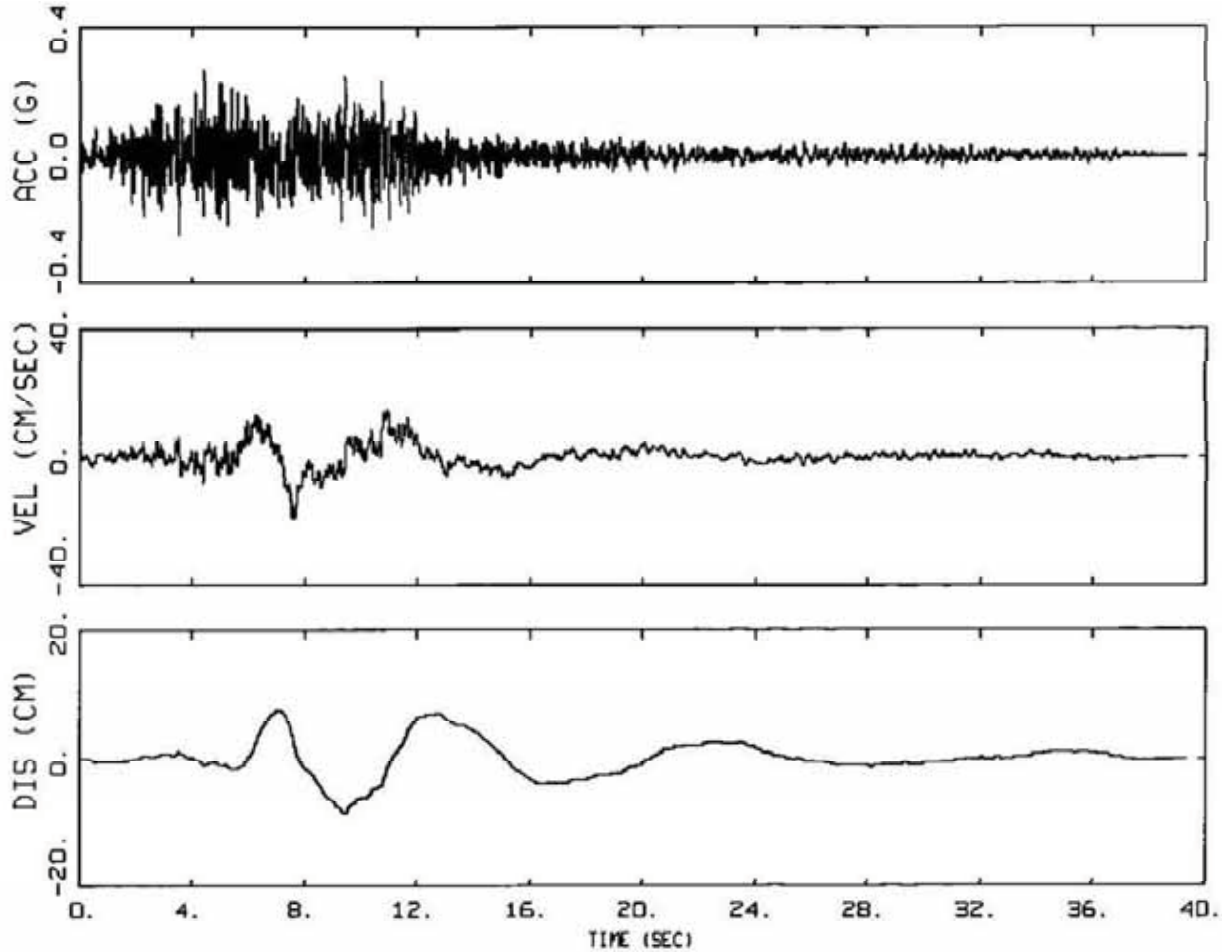
HORIZONTAL 2



DACITE, SDC 3, 2% 50 YR, HORIZONTAL 2
BASELINE CORRECTED

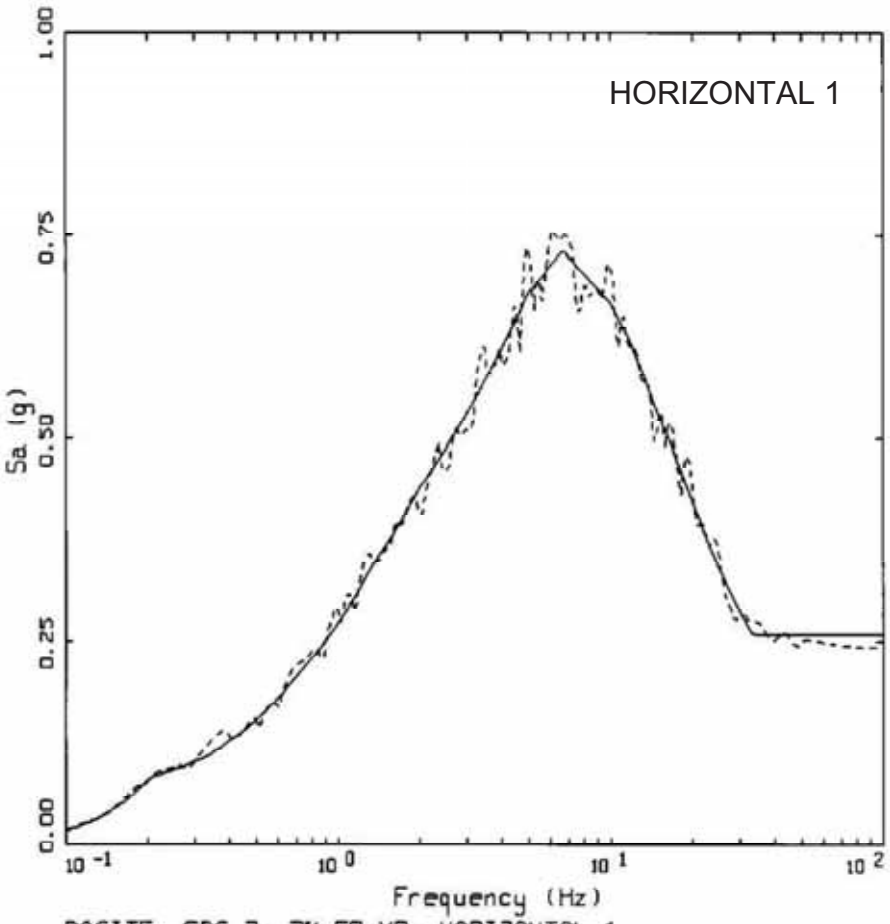
URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-3 DACITE OUTCROP TIME HISTORIES WITH TOPOGRAPHIC AMPLIFICATION	Figure 80b

VERTICAL



DACITE, SDC 3, 2% 50 YR, VERTICAL
BASELINE CORRECTED

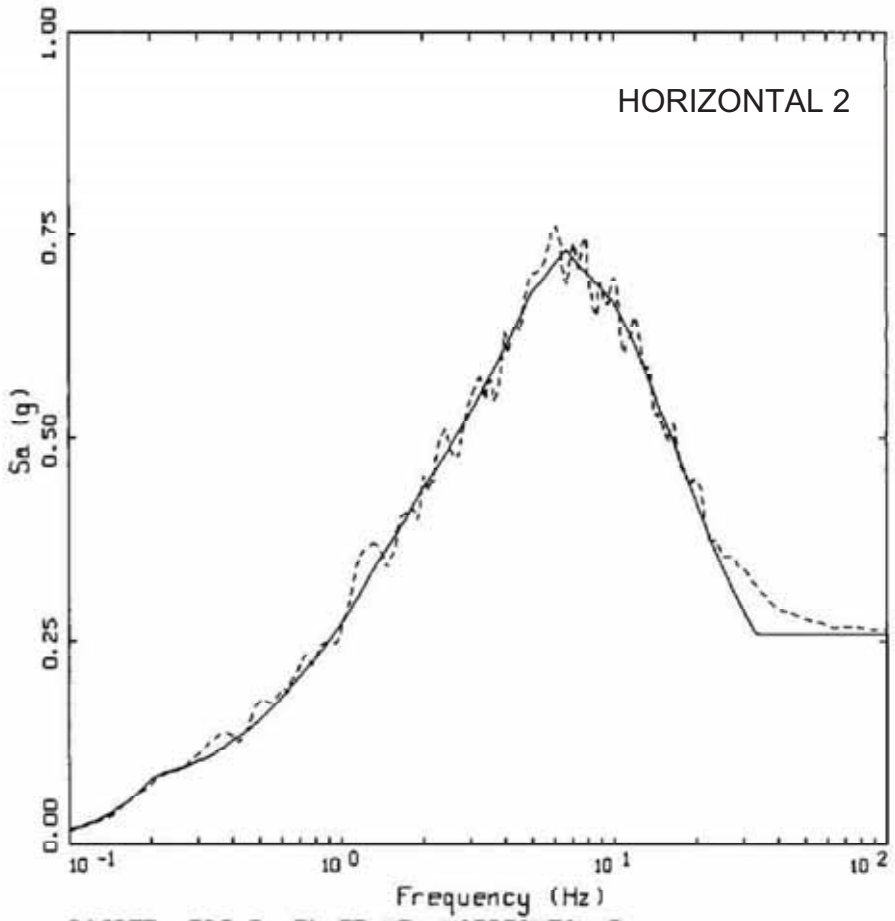
URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-3 DACITE OUTCROP TIME HISTORIES WITH TOPOGRAPHIC AMPLIFICATION	Figure 80c



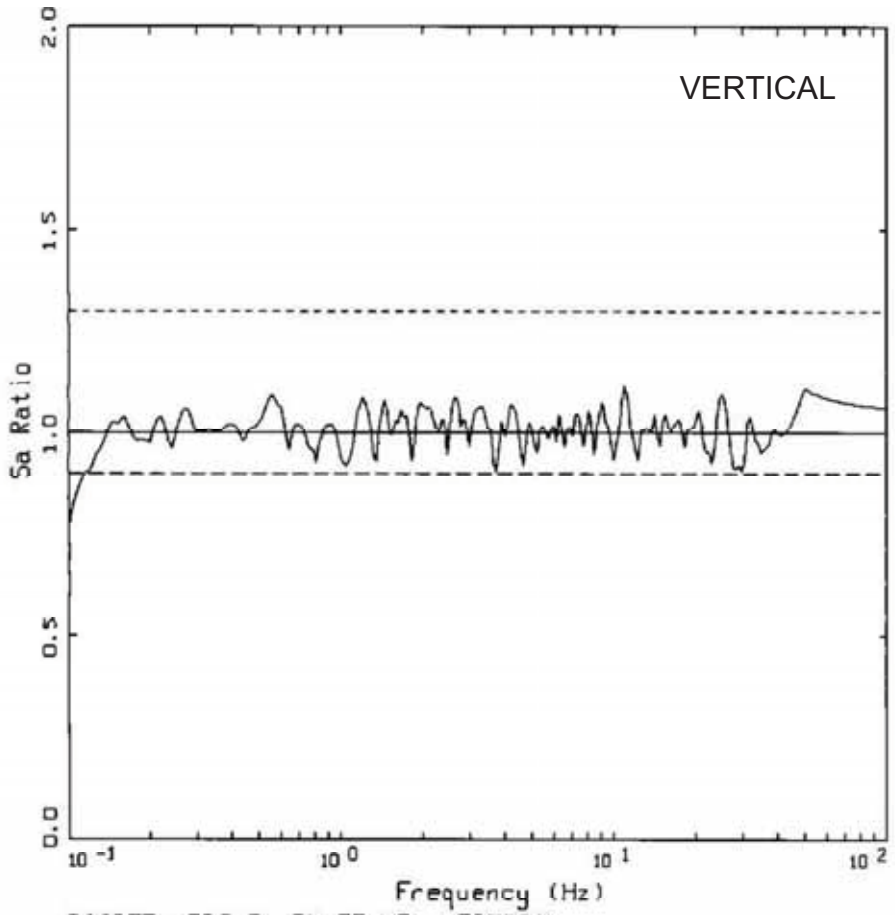
DACITE, SDC 3, 2% 50 YR, HORIZONTAL 1
BASELINE CORRECTED

LEGEND
——— TARGET; PGA = 0.26 g
----- 5 %, SPECTRAL MATCH; PGA = 0.24 g

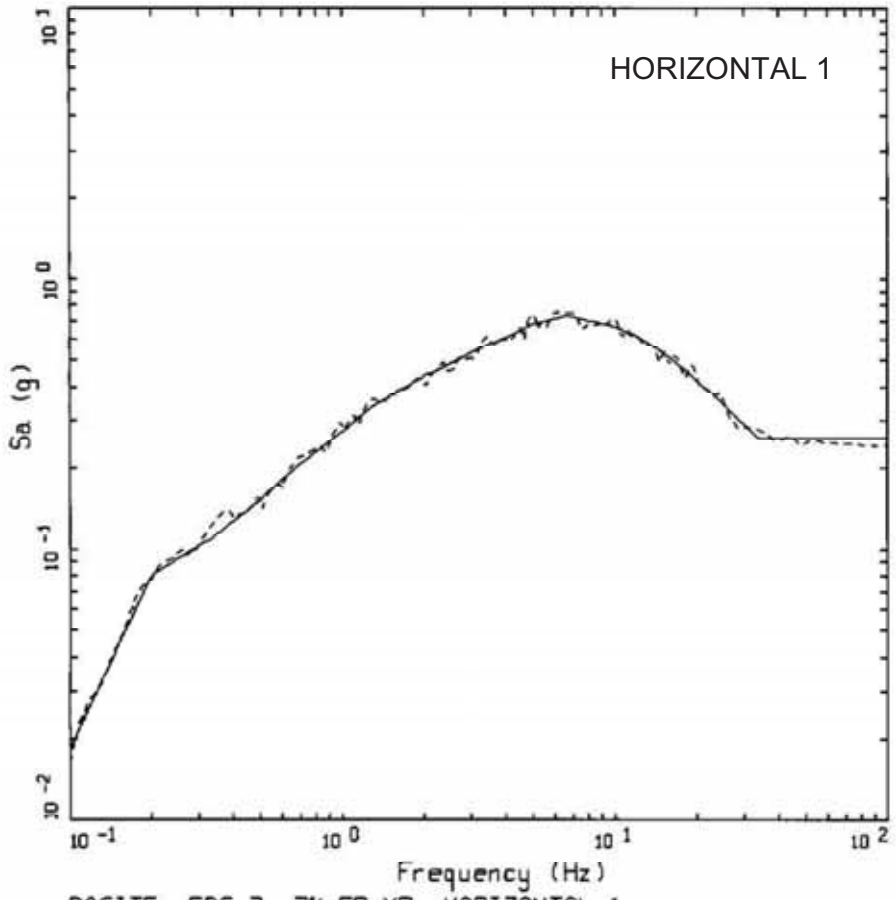
URS	Project No. 26817259 Los Alamos National Lab	SDC-3 DACITE OUTCROP SPECTRAL MATCH LINEAR WITH TOPOGRAPHIC AMPLIFICATION	Figure 80d



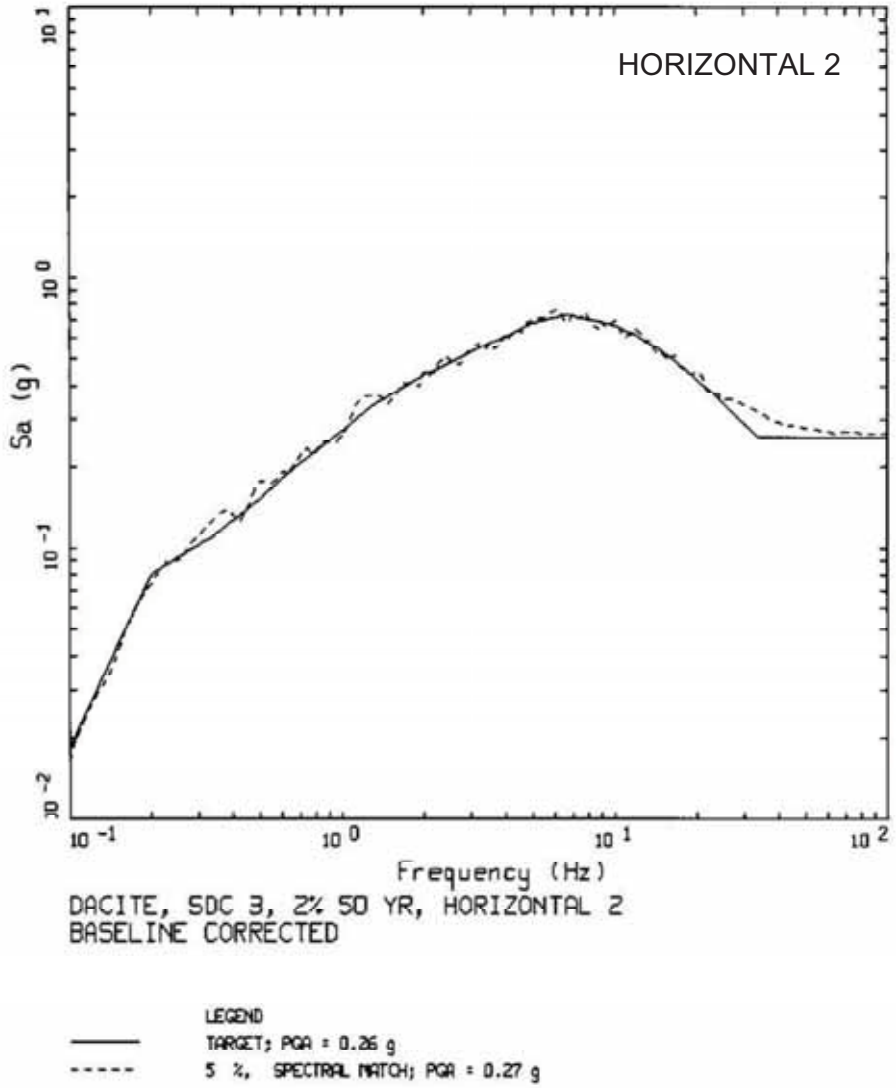
URS	Project No. 26817259	SDC-3 DACITE OUTCROP SPECTRAL MATCH LINEAR WITH TOPOGRAPHIC AMPLIFICATION	Figure 80e
	Los Alamos National Lab		



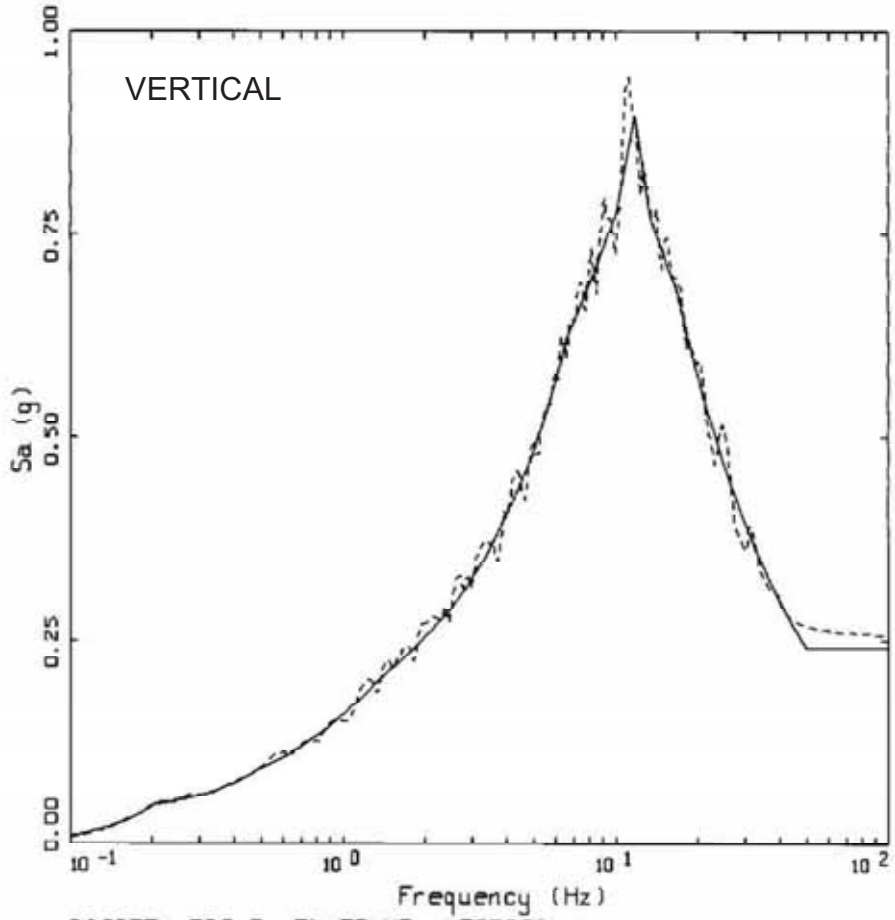
URS	Project No. 26817259 Los Alamos National Lab	SDC-3 DACITE OUTCROP SPECTRAL MATCH LINEAR WITH TOPOGRAPHIC AMPLIFICATION	Figure 80f



URS	Project No. 26817259 Los Alamos National Lab	SDC-3 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITH TOPOGRAPHIC AMPLIFICATION	Figure 80g



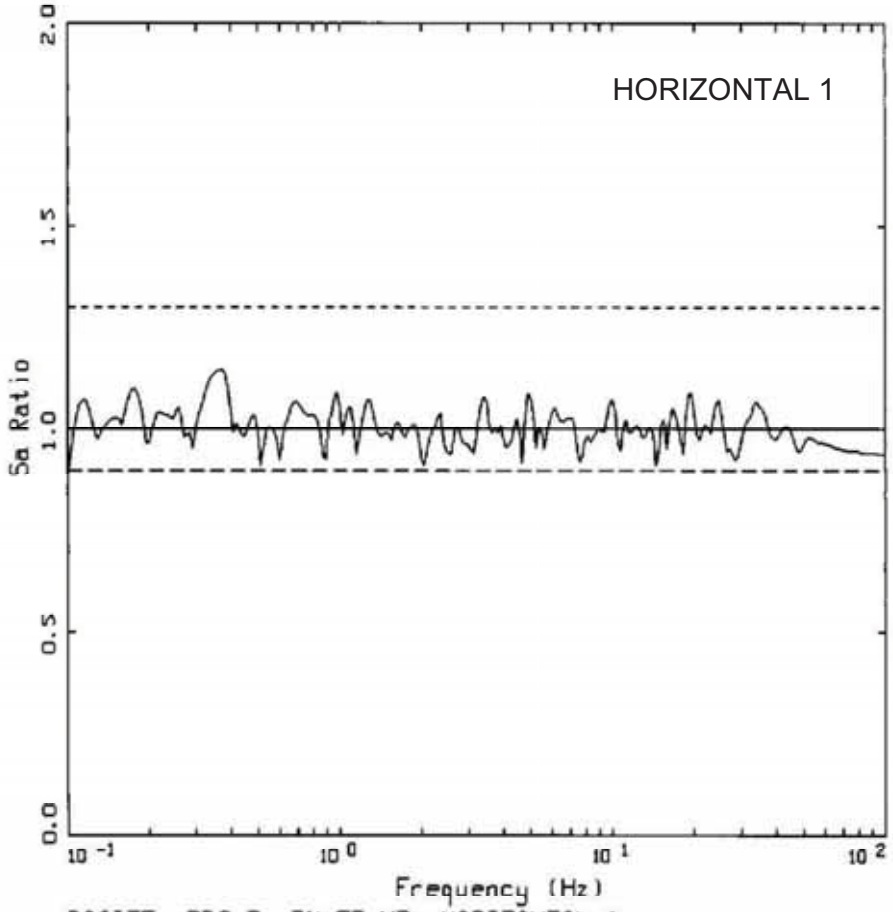
URS	Project No. 26817259 Los Alamos National Lab	SDC-3 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITH TOPOGRAPHIC AMPLIFICATION	Figure 80h



DACITE, SDC 3, 2% 50 YR, VERTICAL
BASELINE CORRECTED

LEGEND
——— TARGET; PGA = 0.24 g
----- 5 %, SPECTRAL MATCH; PGA = 0.26 g

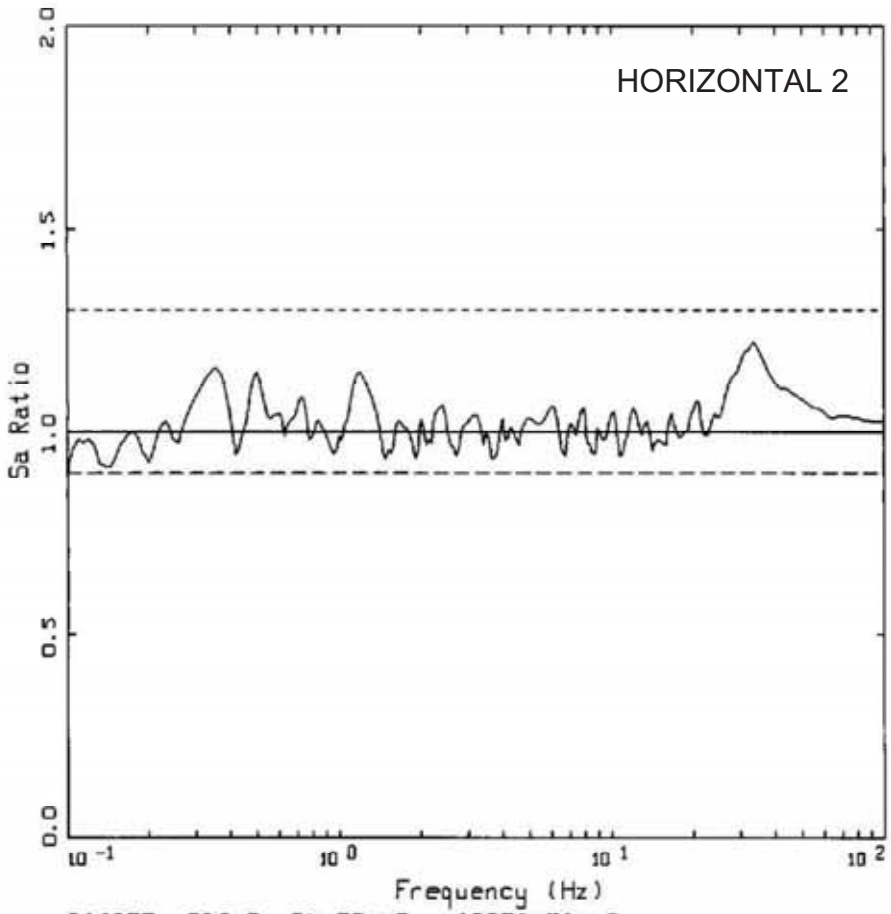
URS	Project No. 26817259	SDC-3 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITH TOPOGRAPHIC AMPLIFICATION	Figure 80i
	Los Alamos National Lab		



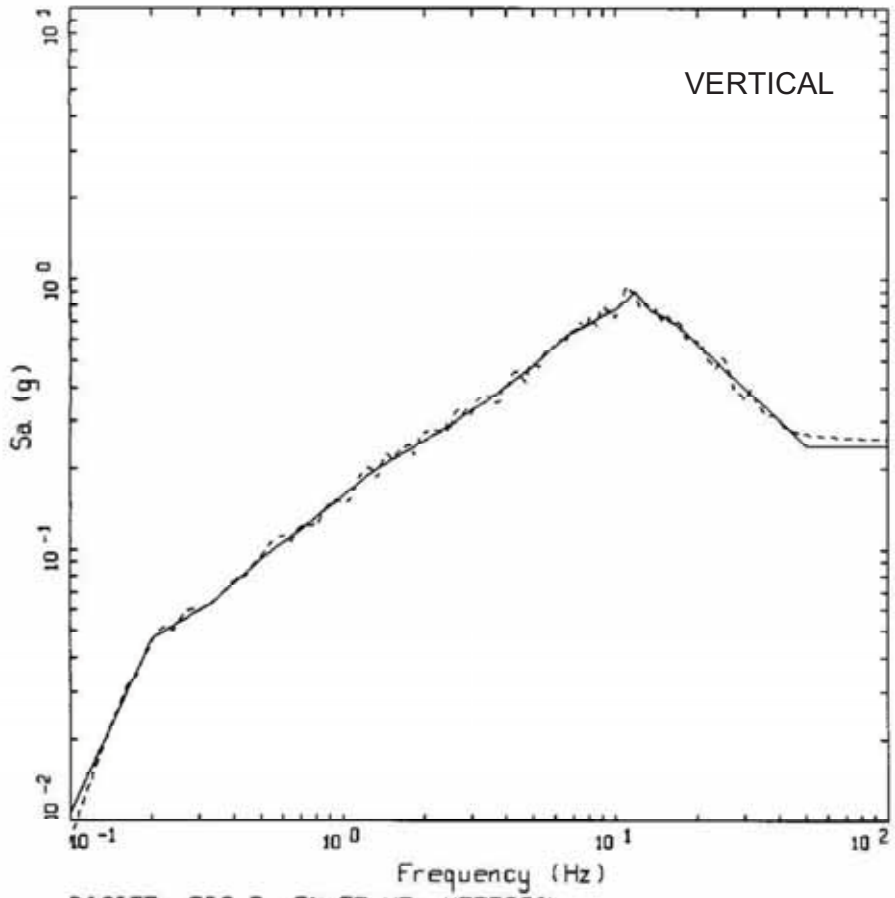
LEGEND

———	SA RATIO: MATCH/TARGET
———	UNITY
- - - - -	UNITY * 1.3
– – – –	UNITY / 1.111

URS	Project No. 26817259 Los Alamos National Lab	SDC-3 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITH TOPOGRAPHIC AMPLIFICATION	Figure 80j

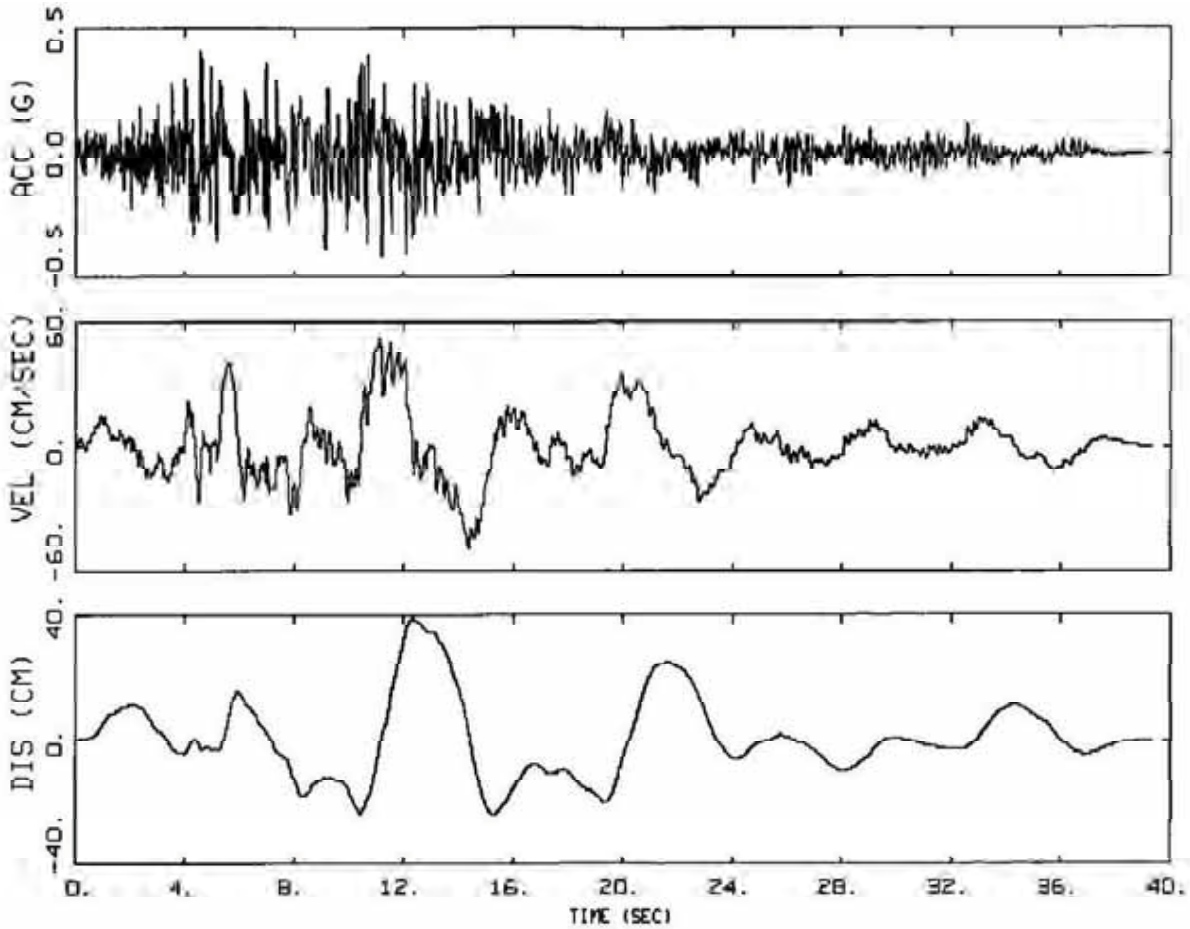


URS	Project No. 26817259 Los Alamos National Lab	SDC-3 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITH TOPOGRAPHIC AMPLIFICATION	Figure 80k



URS	Project No. 26817259 Los Alamos National Lab	SDC-3 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITH TOPOGRAPHIC AMPLIFICATION	Figure 80l

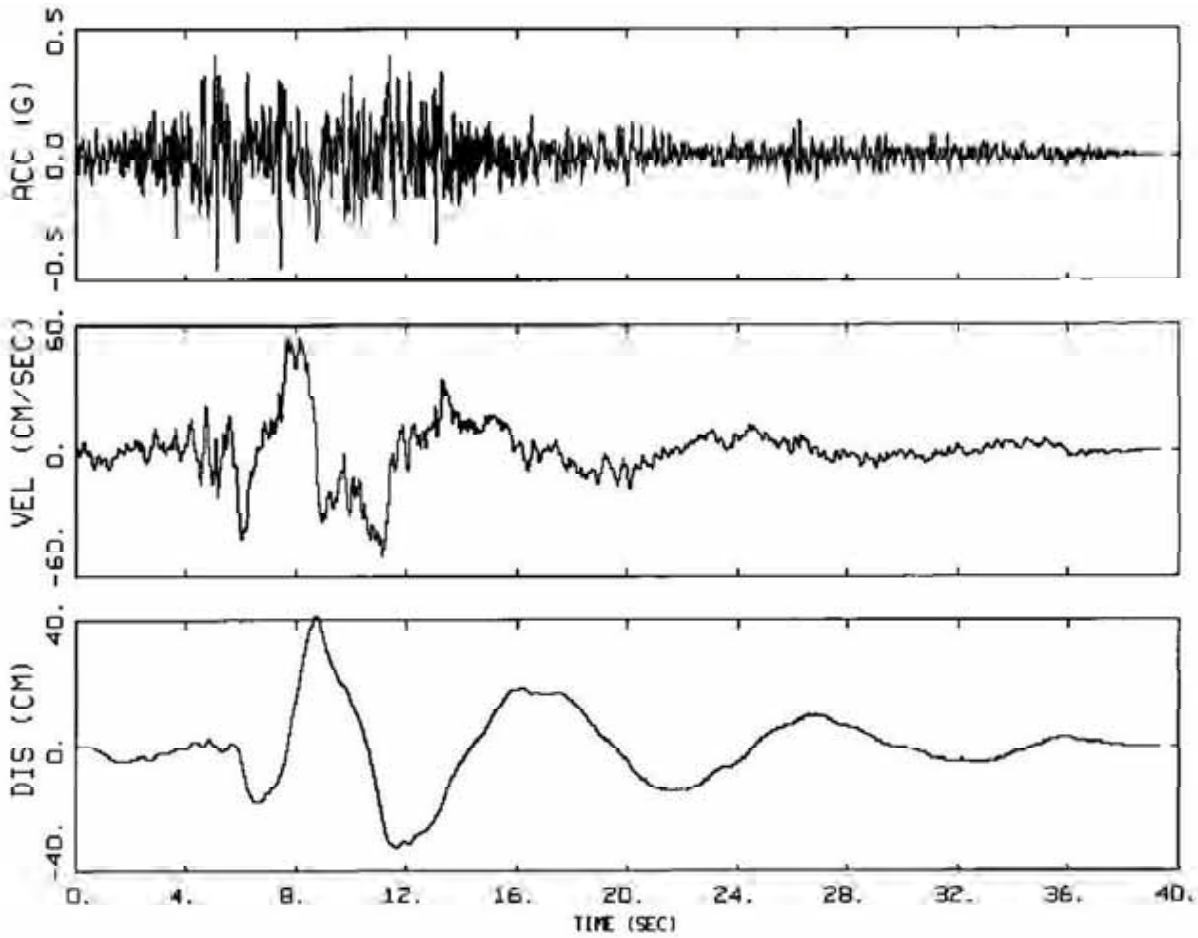
HORIZONTAL 1



DACITE, SDC 4, 2% 50 YR, HORIZONTAL 1
BASELINE CORRECTED

URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-4 DACITE OUTCROP TIME HISTORIES WITH TOPOGRAPHIC AMPLIFICATION	Figure 81a

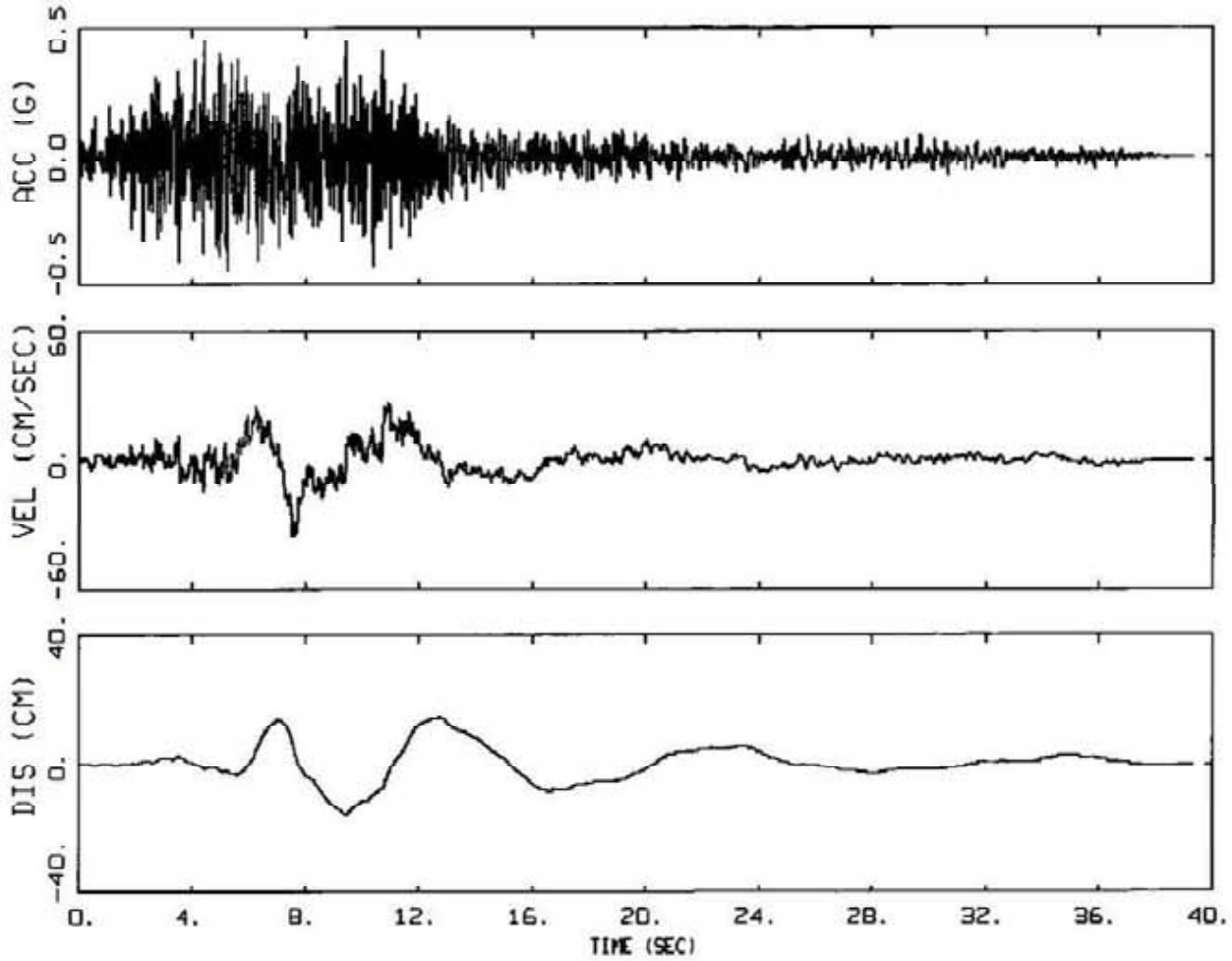
HORIZONTAL 2



DACITE, SDC 4, 2% 50 YR, HORIZONTAL 2
BASELINE CORRECTED

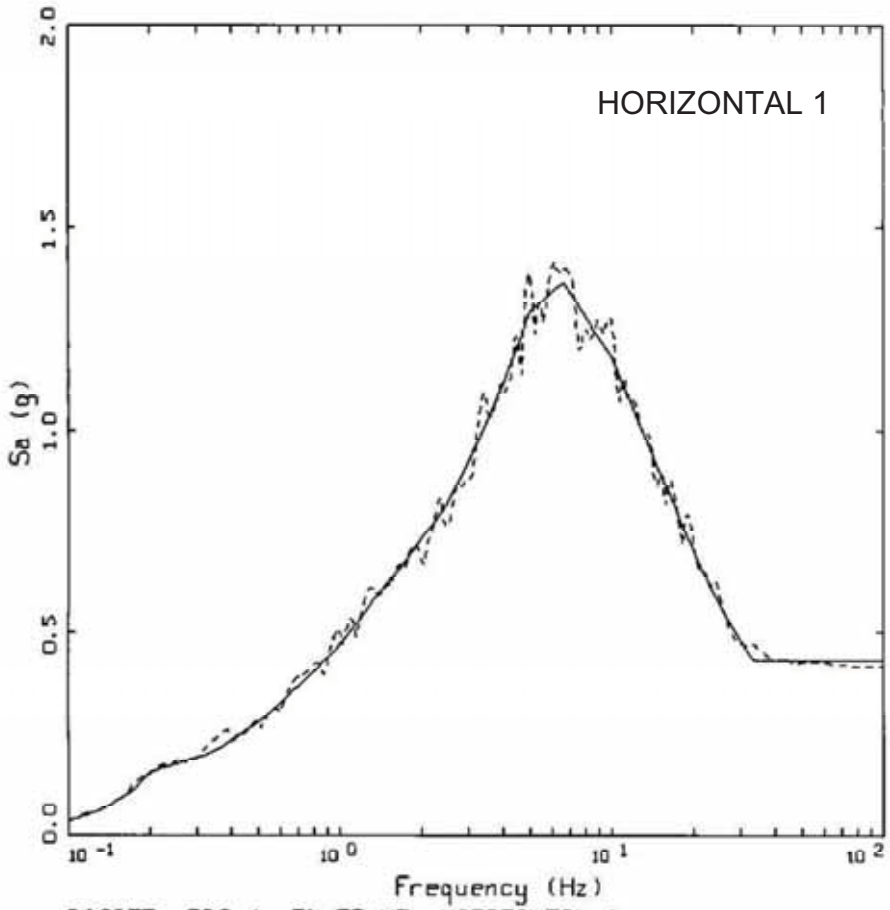
URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-4 DACITE OUTCROP TIME HISTORIES WITH TOPOGRAPHIC AMPLIFICATION	Figure 81b

VERTICAL



DACITE, SDC 4, 2% 50 YR, VERTICAL
BASELINE CORRECTED

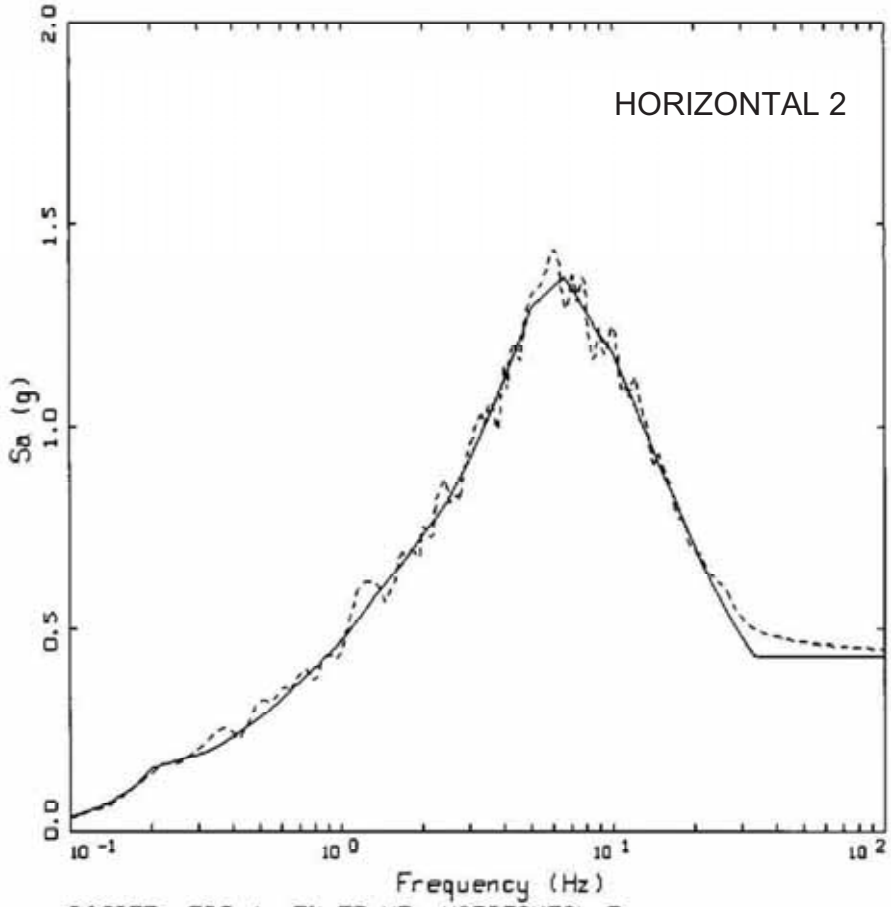
URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-4 DACITE OUTCROP TIME HISTORIES WITH TOPOGRAPHIC AMPLIFICATION	Figure 81c



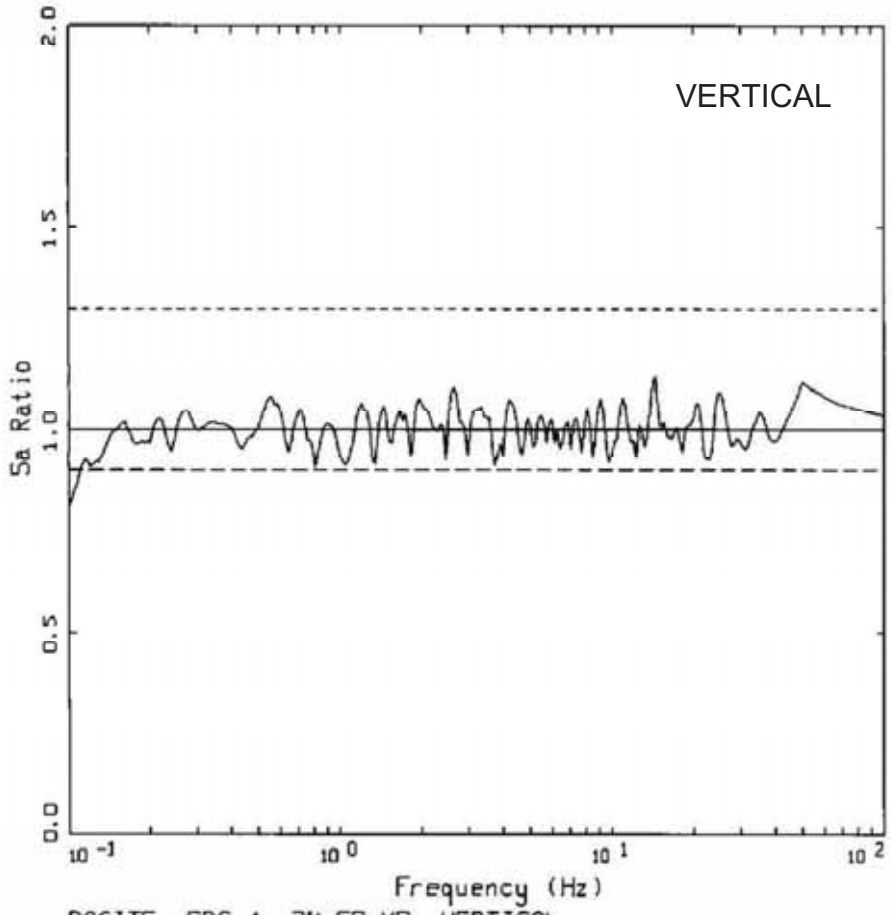
DACITE, SDC 4, 2% 50 YR, HORIZONTAL 1
BASELINE CORRECTED

LEGEND
——— TARGET; PGA = 0.43 g
----- 5 %, SPECTRAL MATCH; PGA = 0.42 g

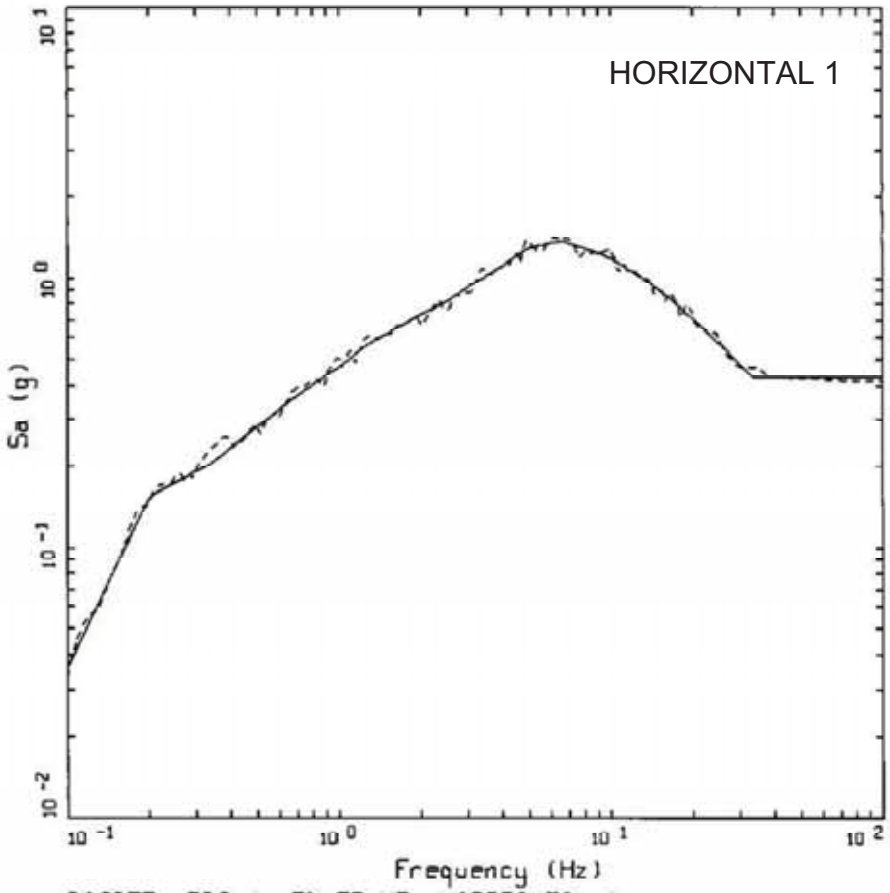
URS	Project No. 26817259 Los Alamos National Lab	SDC-4 DACITE OUTCROP SPECTRAL MATCH LINEAR WITH TOPOGRAPHIC AMPLIFICATION	Figure 81d



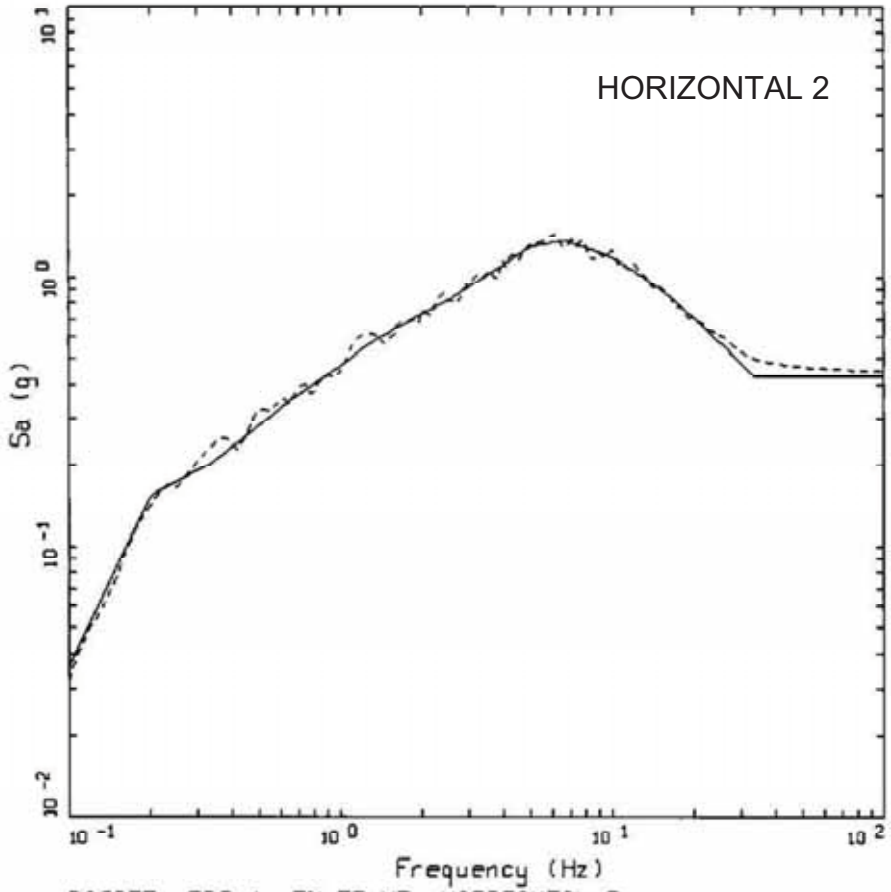
URS	Project No. 26817259 Los Alamos National Lab	SDC-4 DACITE OUTCROP SPECTRAL MATCH LINEAR WITH TOPOGRAPHIC AMPLIFICATION	Figure 81e



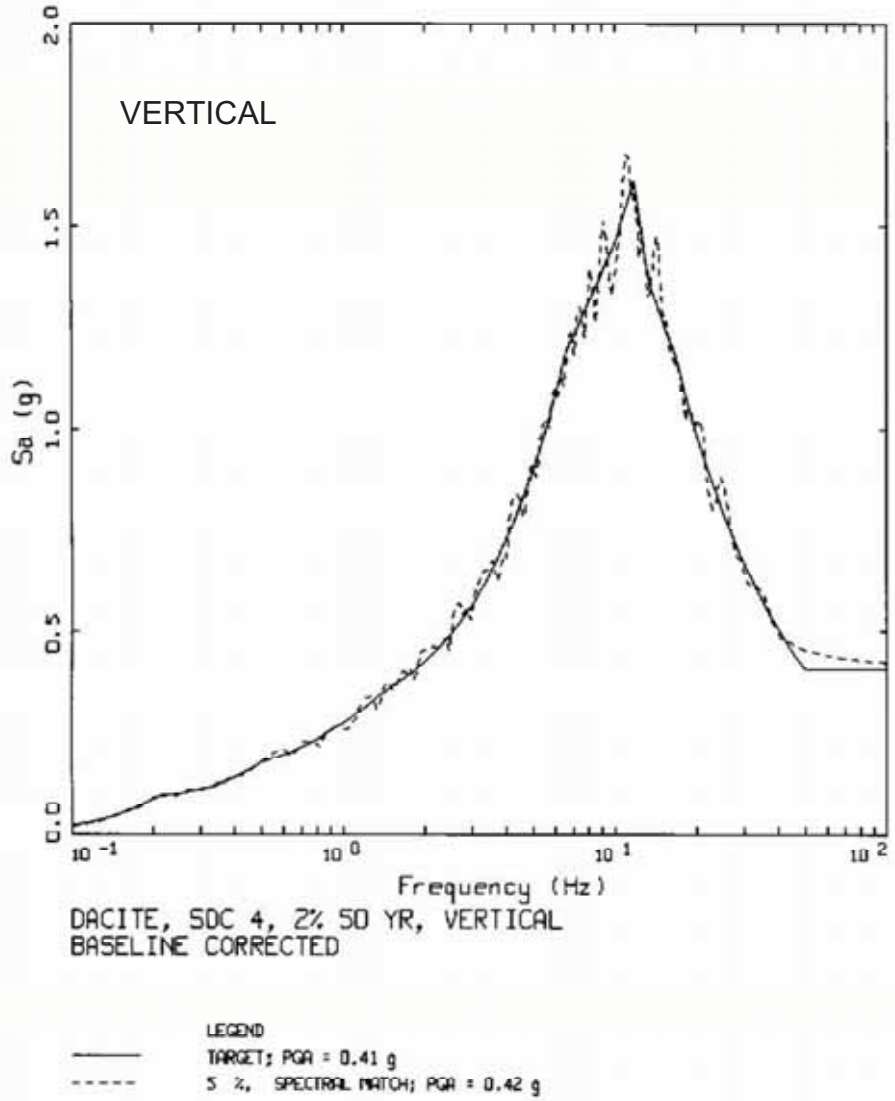
URS	Project No. 26817259 Los Alamos National Lab	SDC-4 DACITE OUTCROP SPECTRAL MATCH LINEAR WITH TOPOGRAPHIC AMPLIFICATION	Figure 81f



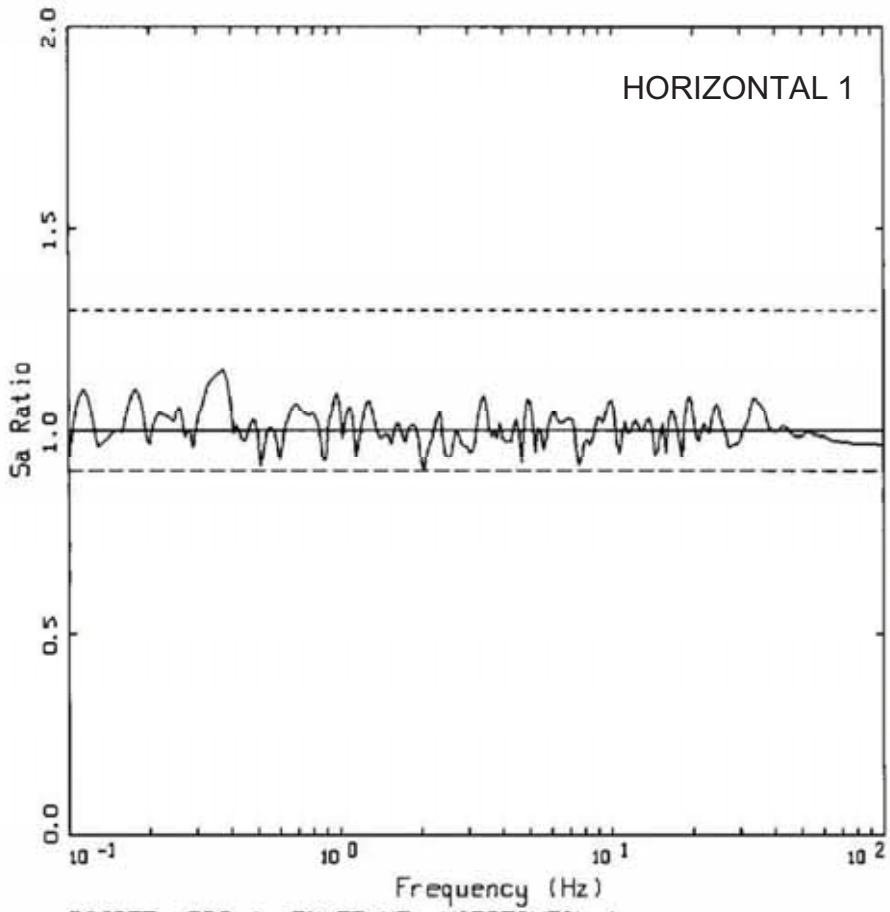
URS	Project No. 26817259 Los Alamos National Lab	SDC-4 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITH TOPOGRAPHIC AMPLIFICATION	Figure 81g



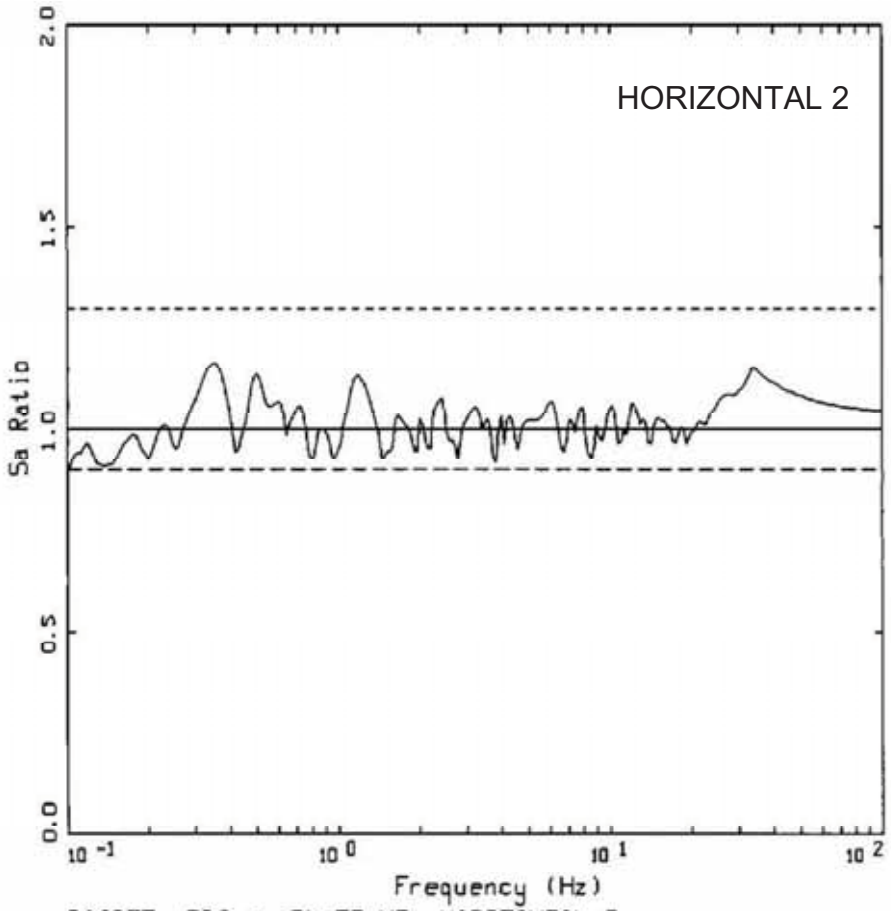
URS	Project No. 26817259 Los Alamos National Lab	SDC-4 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITH TOPOGRAPHIC AMPLIFICATION	Figure 81h



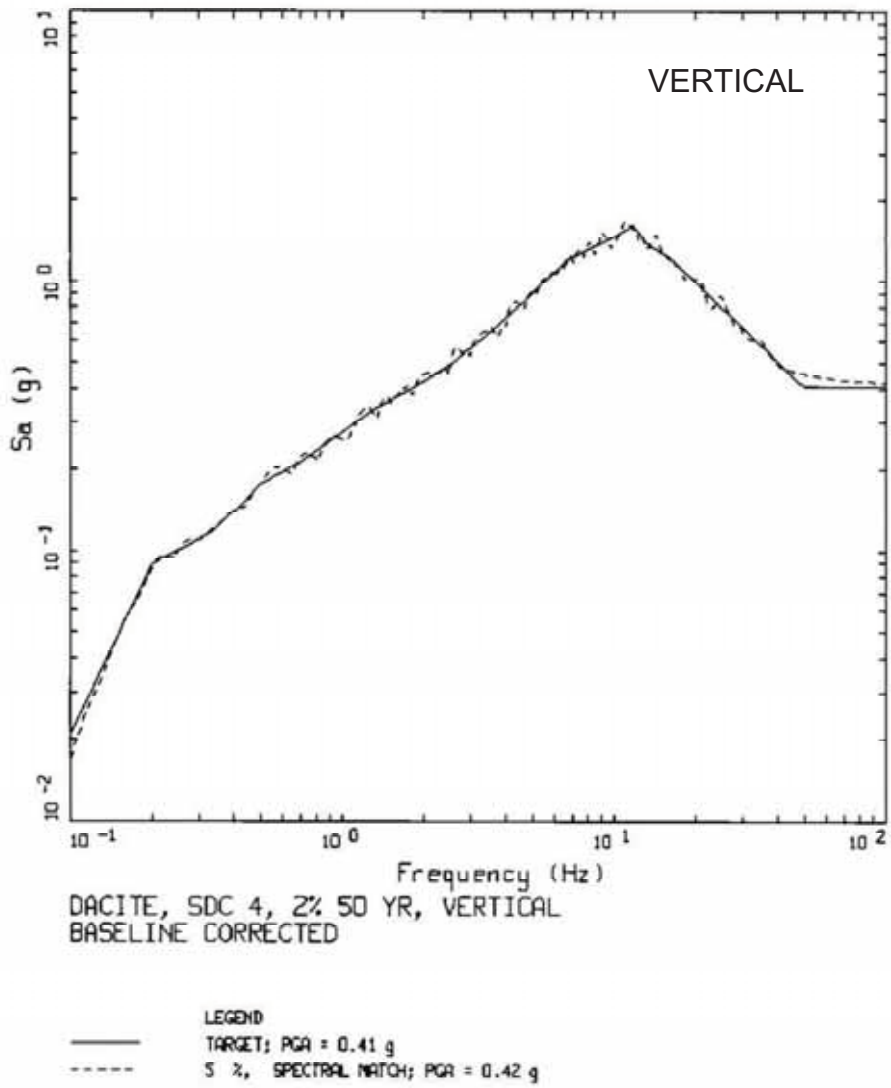
URS	Project No. 26817259 Los Alamos National Lab	SDC-4 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITH TOPOGRAPHIC AMPLIFICATION	Figure 81i



URS	Project No. 26817259 Los Alamos National Lab	SDC-4 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITH TOPOGRAPHIC AMPLIFICATION	Figure 81j

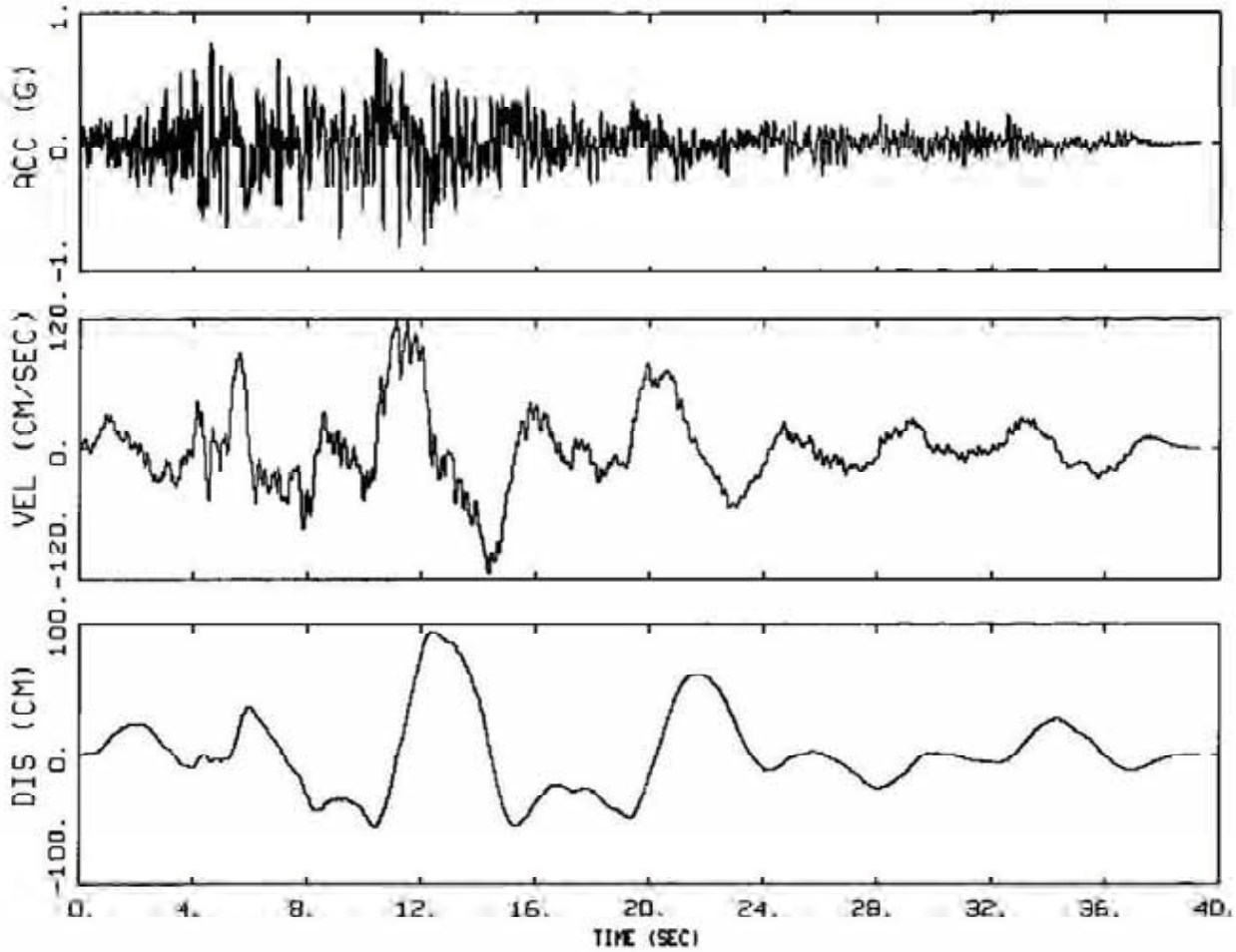


URS	Project No. 26817259 Los Alamos National Lab	SDC-4 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITH TOPOGRAPHIC AMPLIFICATION	Figure 81k



URS	Project No. 26817259 Los Alamos National Lab	SDC-4 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA VERTICAL WITH TOPOGRAPHIC AMPLIFICATION	Figure 81I

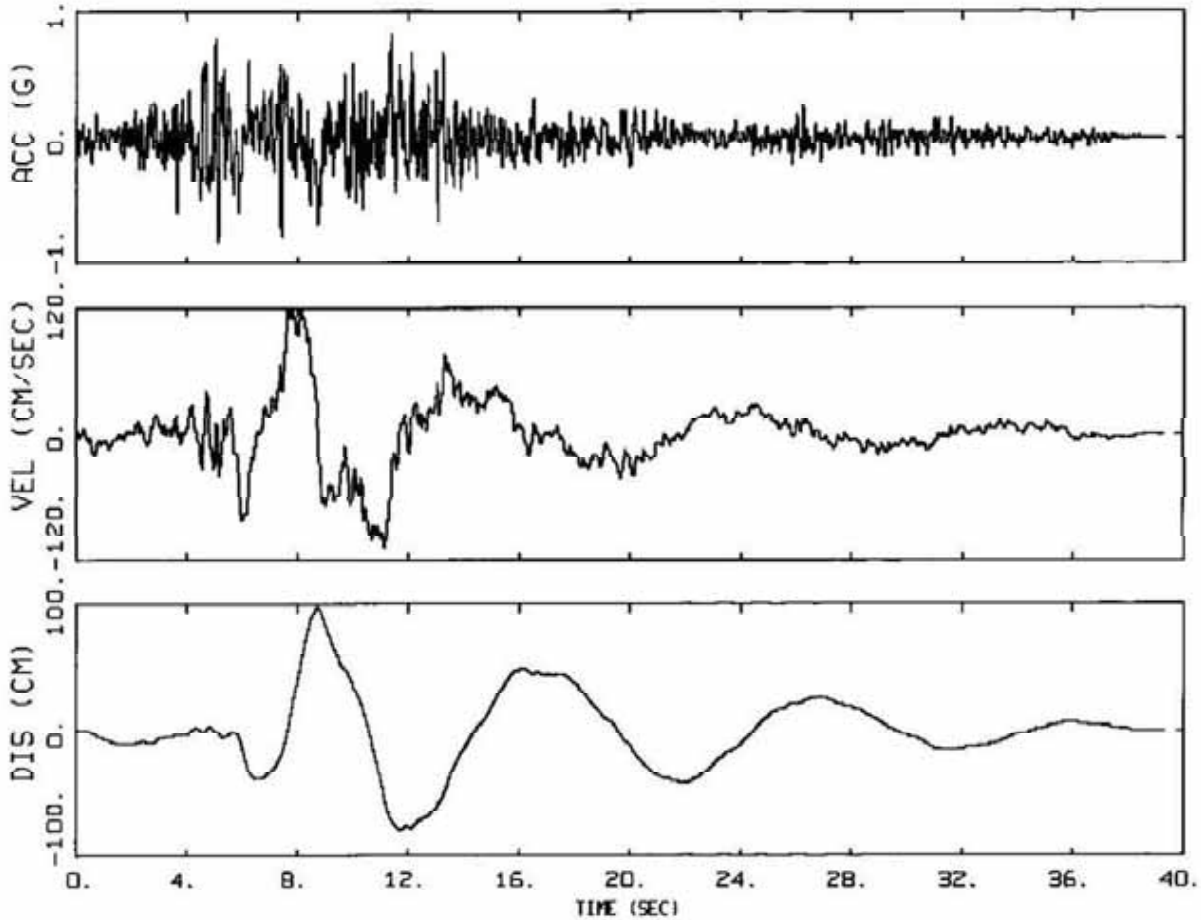
HORIZONTAL 1



DACITE, SDC 5, 5% 500 YR, HORIZONTAL 1
BASELINE CORRECTED

URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-5 DACITE OUTCROP TIME HISTORIES WITH TOPOGRAPHIC AMPLIFICATION	Figure 82a

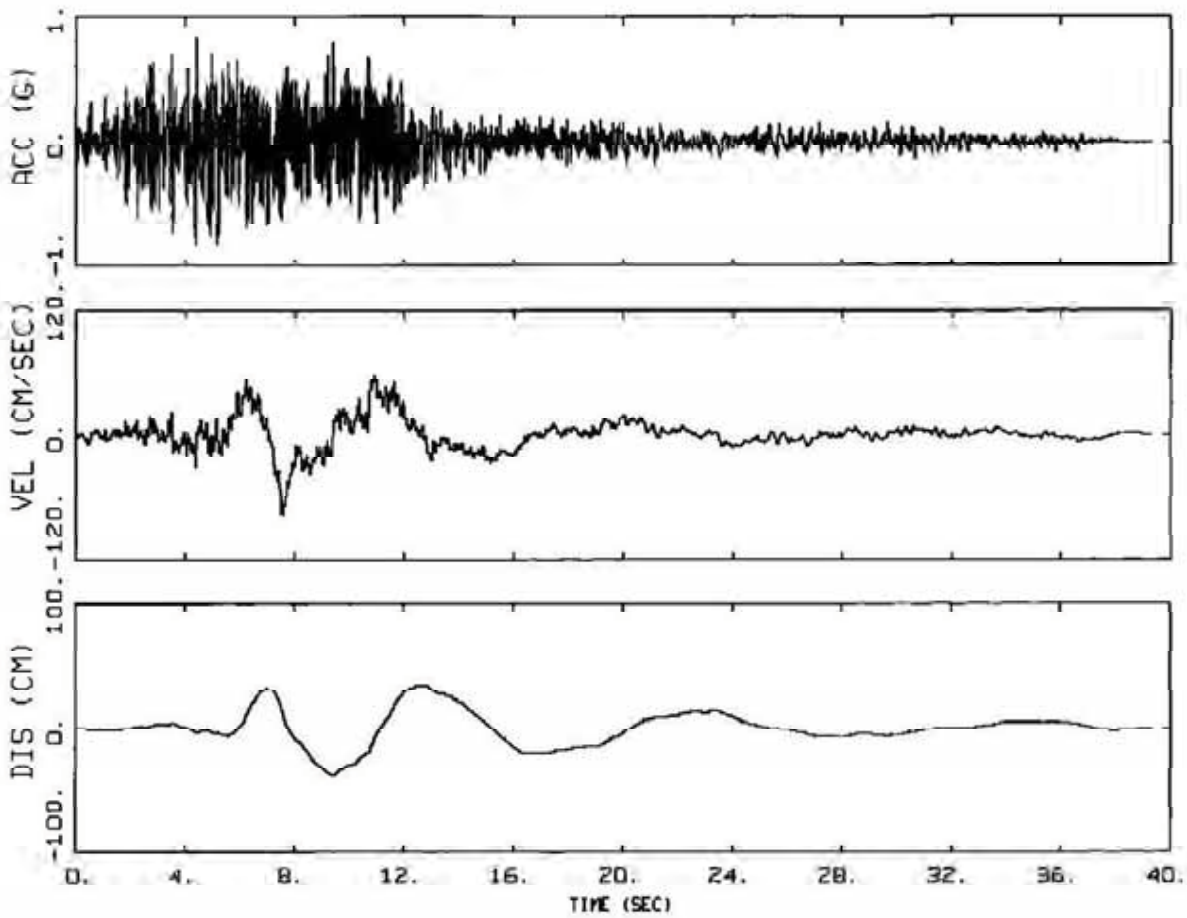
HORIZONTAL 2



DACITE, SDC 5, 5% 500 YR, HORIZONTAL 2
BASELINE CORRECTED

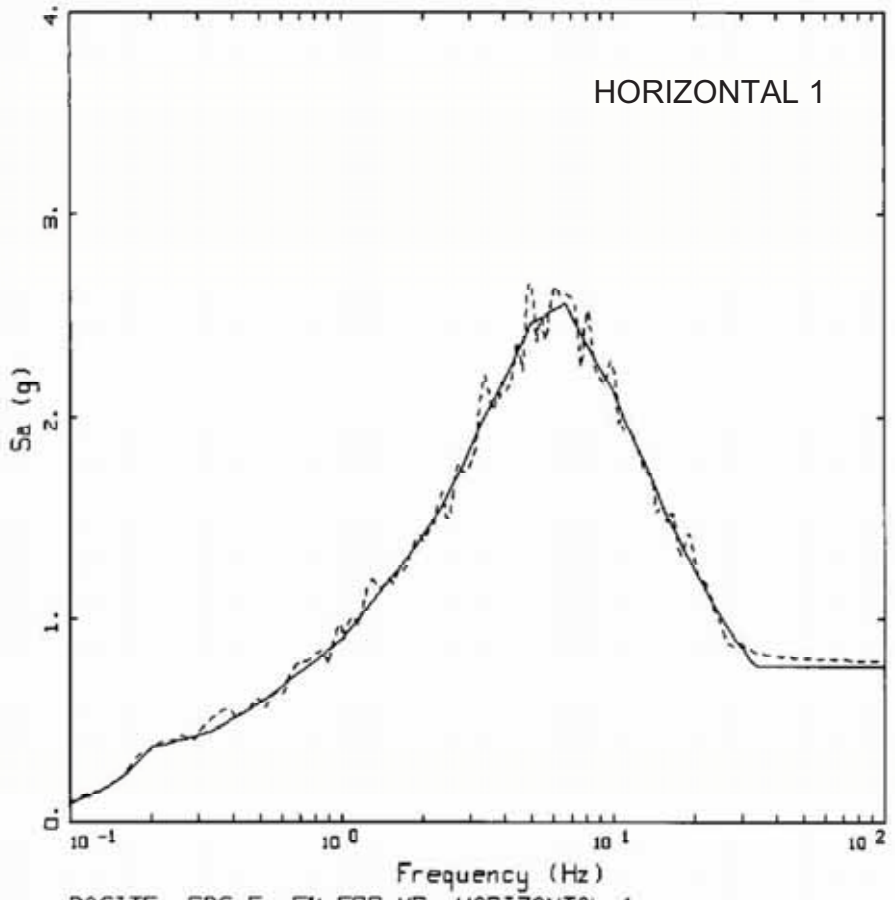
URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-5 DACITE OUTCROP TIME HISTORIES WITH TOPOGRAPHIC AMPLIFICATION	Figure 82b

VERTICAL



DACITE, SDC 5, 5% 500 YR, VERTICAL
BASELINE CORRECTED

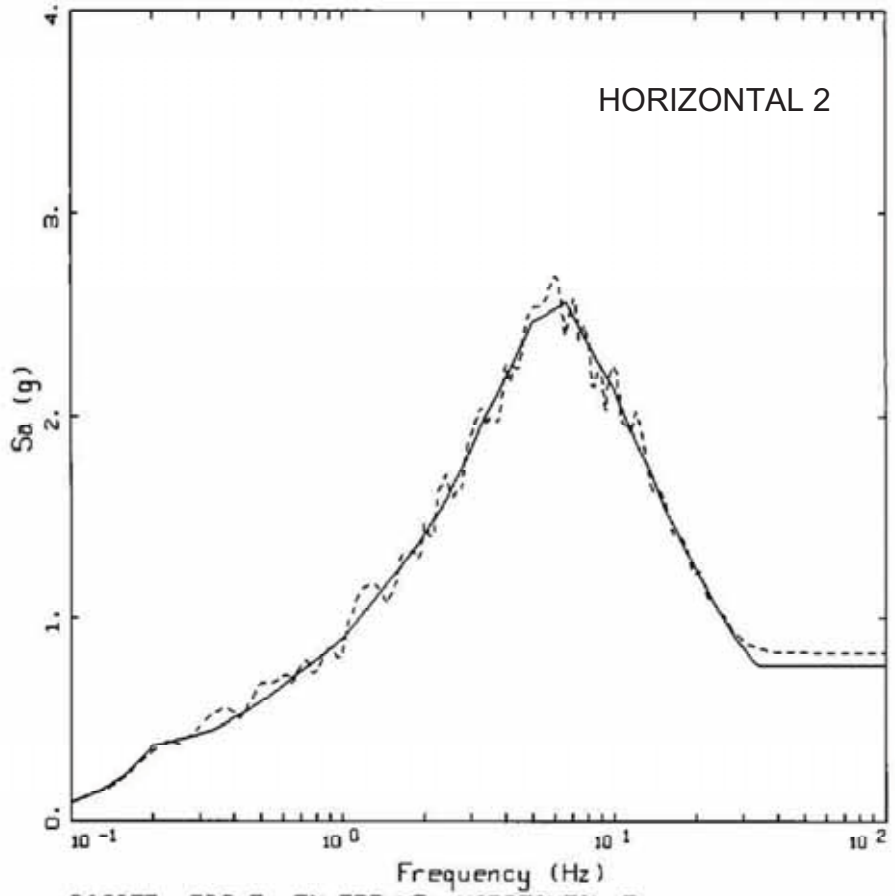
URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-5 DACITE OUTCROP TIME HISTORIES WITH TOPOGRAPHIC AMPLIFICATION	Figure 82c



DACITE, SDC 5, 5% 500 YR, HORIZONTAL 1
BASELINE CORRECTED

LEGEND
——— TARGET; PGA = 0.77 g
----- 5 %, SPECTRAL MATCH; PGA = 0.79 g

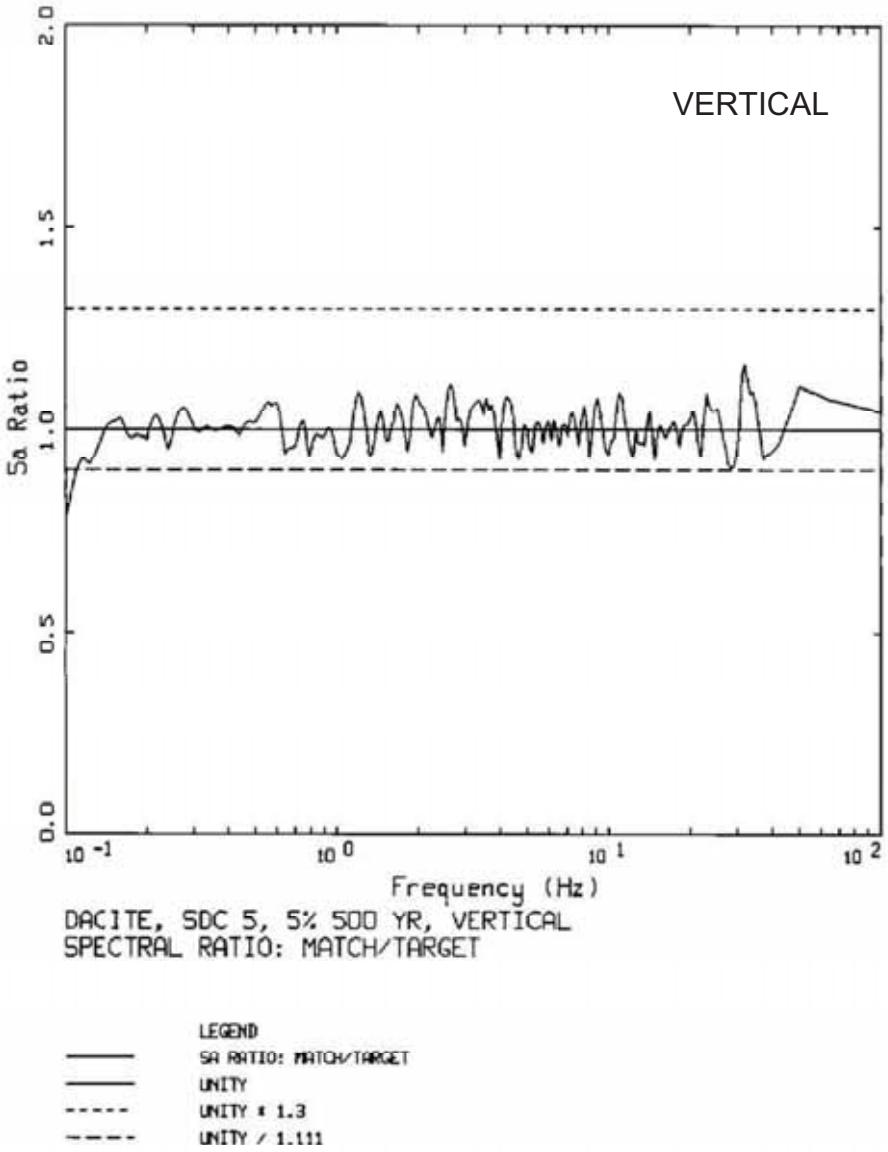
URS	Project No. 26817259 Los Alamos National Lab	SDC-5 DACITE OUTCROP SPECTRAL MATCH LINEAR WITH TOPOGRAPHIC AMPLIFICATION	Figure 82d



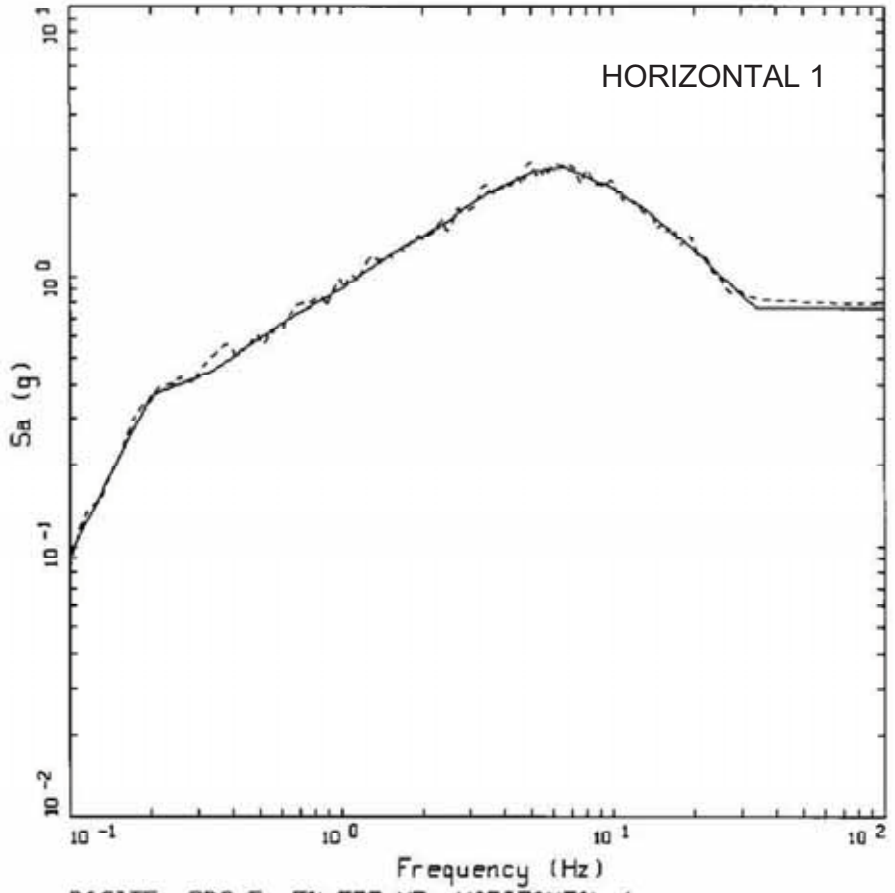
DACITE, SDC 5, 5% 500 YR, HORIZONTAL 2
BASELINE CORRECTED

LEGEND
——— TARGET: PGA = 0.77 g
----- 5 %, SPECTRAL MATCH: PGA = 0.83 g

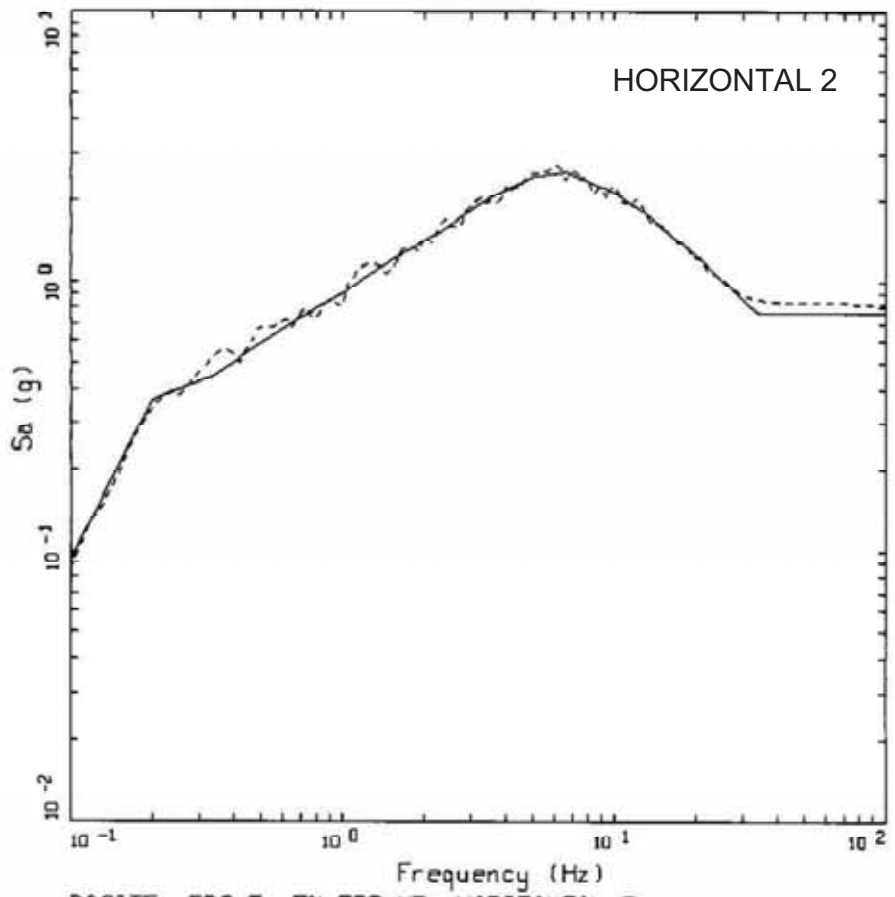
URS	Project No. 26817259	SDC-5 DACITE OUTCROP SPECTRAL MATCH LINEAR WITH TOPOGRAPHIC AMPLIFICATION	Figure 82e
	Los Alamos National Lab		



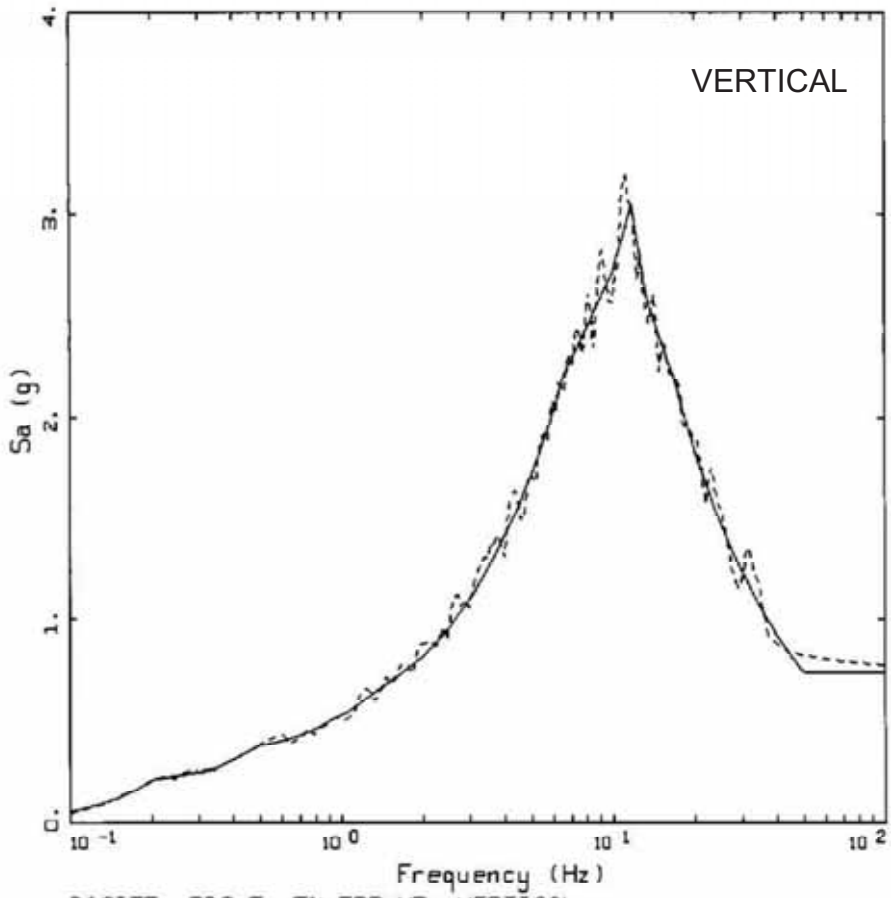
URS	Project No. 26817259 Los Alamos National Lab	SDC-5 DACITE OUTCROP SPECTRAL MATCH LINEAR WITH TOPOGRAPHIC AMPLIFICATION	Figure 82f



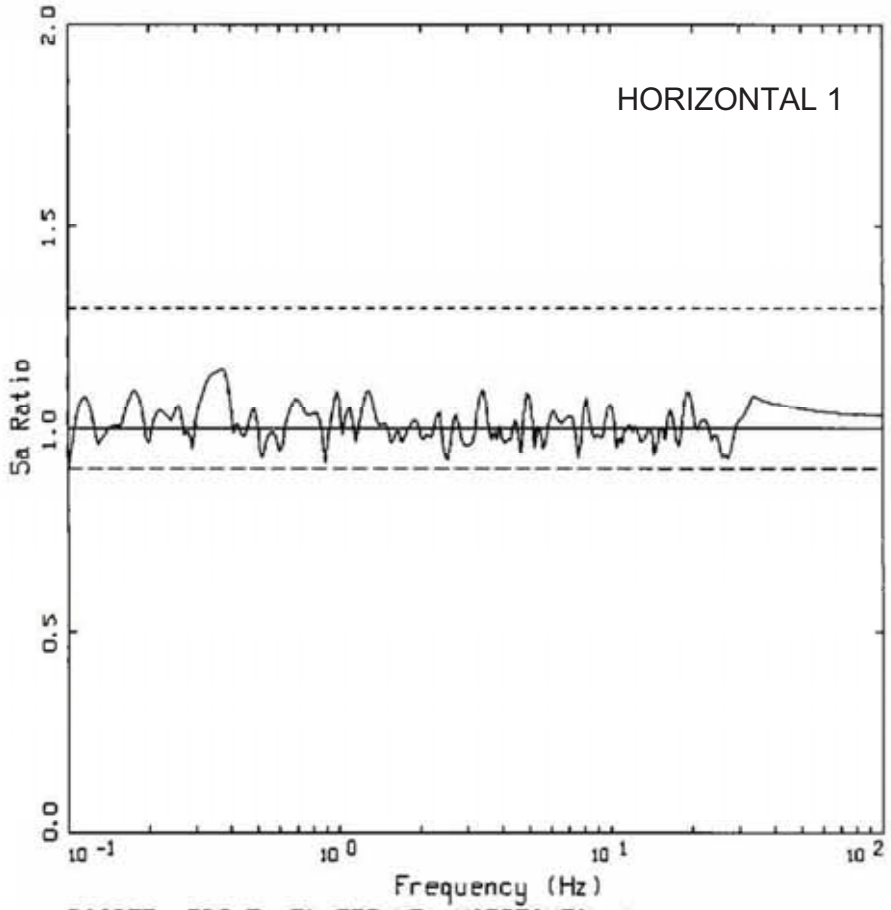
URS	Project No. 26817259 Los Alamos National Lab	SDC-5 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITH TOPOGRAPHIC AMPLIFICATION	Figure 82g



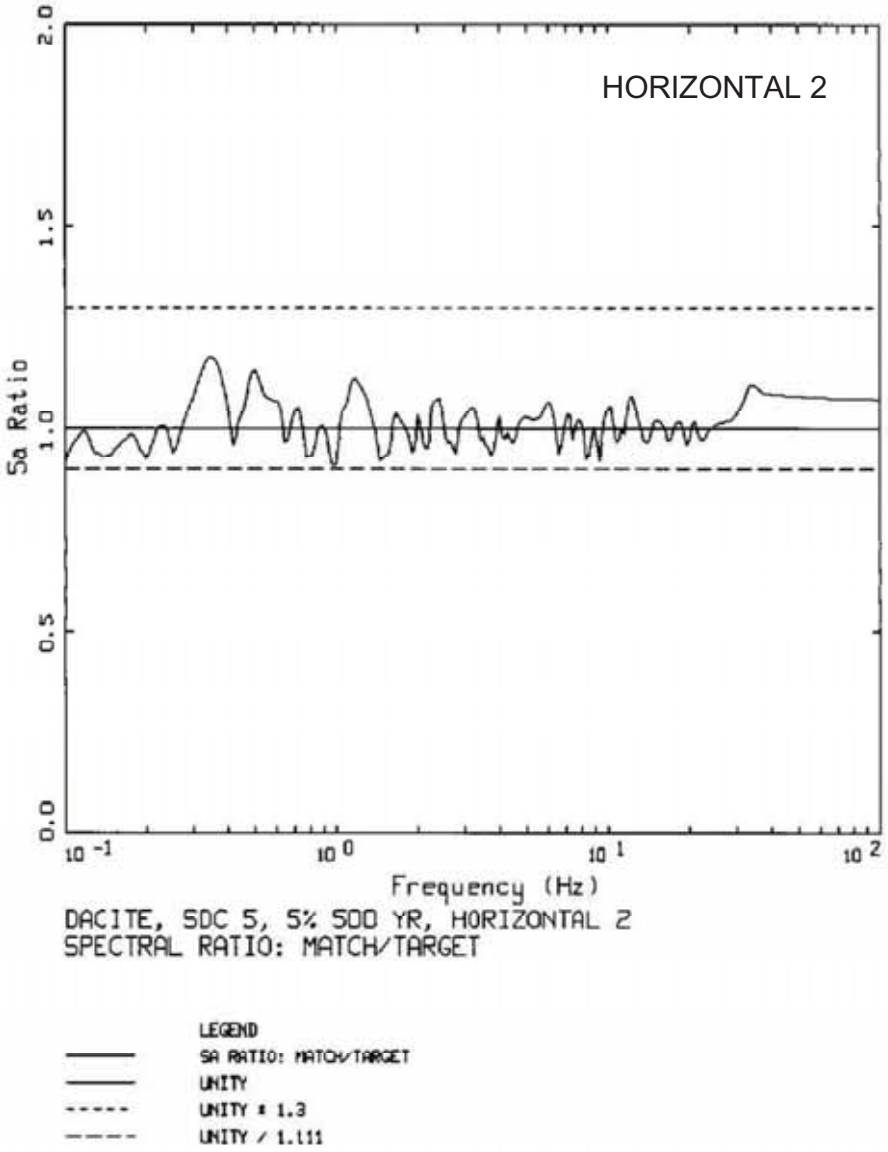
URS	Project No. 26817259 Los Alamos National Lab	SDC-5 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITH TOPOGRAPHIC AMPLIFICATION	Figure 82h



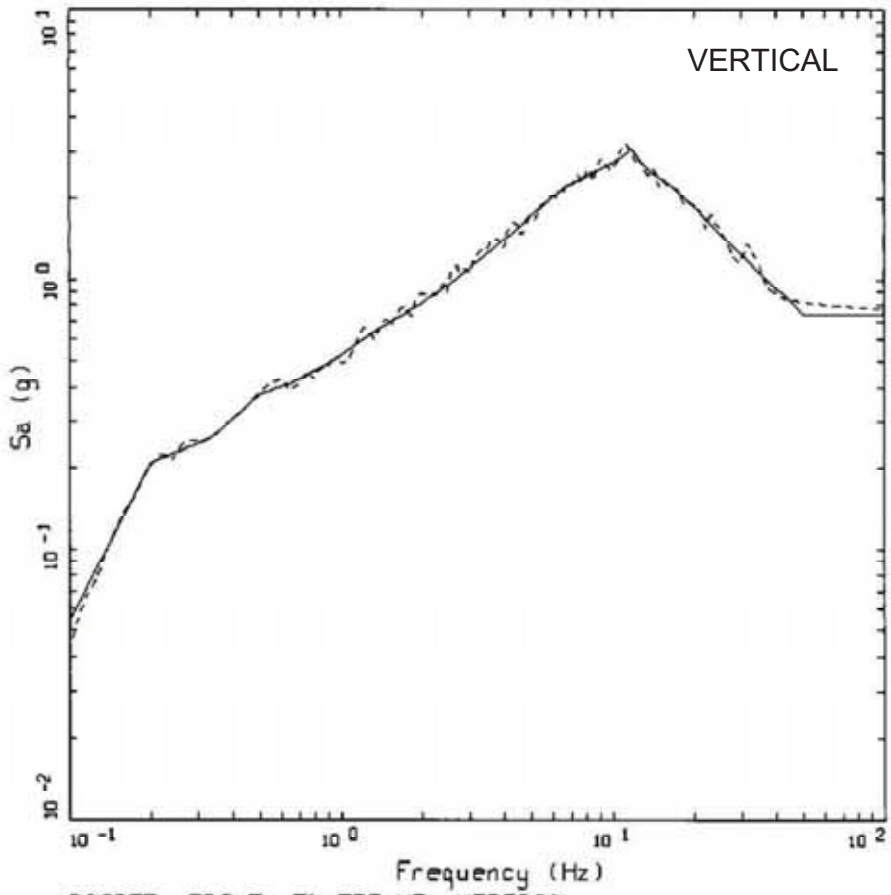
URS	Project No. 26817259	SDC-5 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITH TOPOGRAPHIC AMPLIFICATION	Figure 82i
	Los Alamos National Lab		



URS	Project No. 26817259 Los Alamos National Lab	SDC-5 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITH TOPOGRAPHIC AMPLIFICATION	Figure 82j

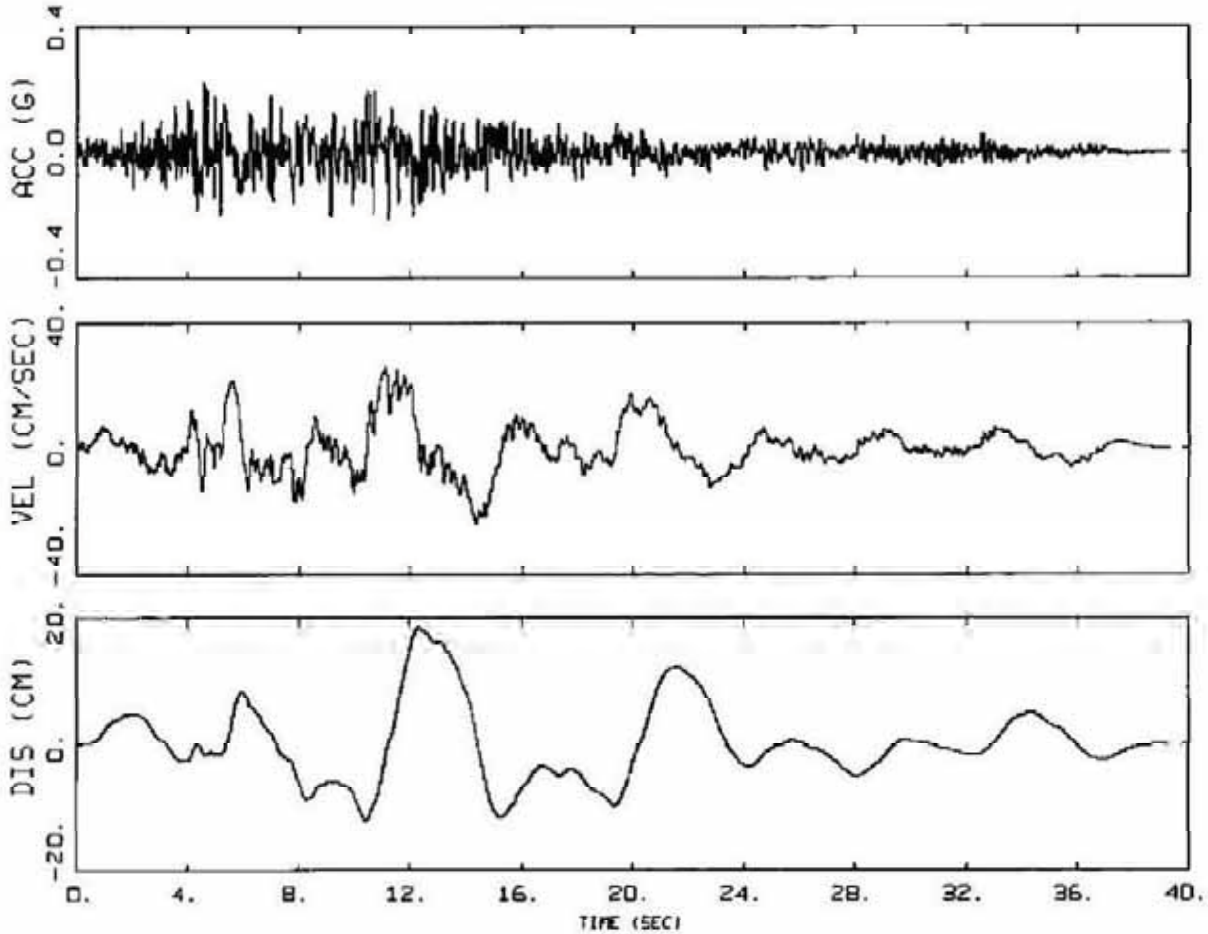


URS	Project No. 26817259 Los Alamos National Lab	SDC-5 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITH TOPOGRAPHIC AMPLIFICATION	Figure 82k



URS	Project No. 26817259 Los Alamos National Lab	SDC-5 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITH TOPOGRAPHIC AMPLIFICATION	Figure 82l

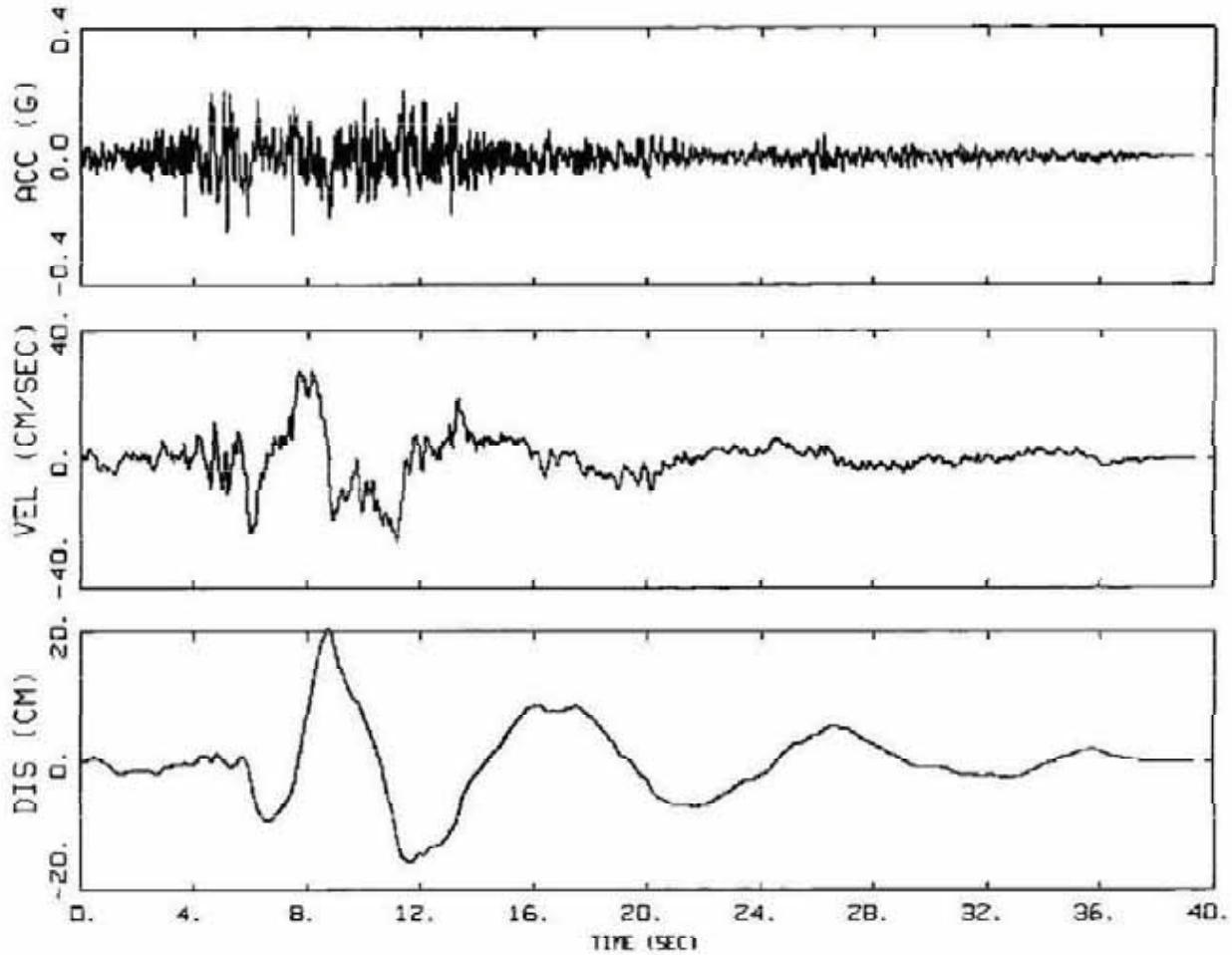
HORIZONTAL 1



DACITE, SDC 3, 2% 50 YR, HORIZONTAL 1 (NO TOPO)
BASELINE CORRECTED

URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-3 DACITE OUTCROP TIME HISTORIES WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 83a

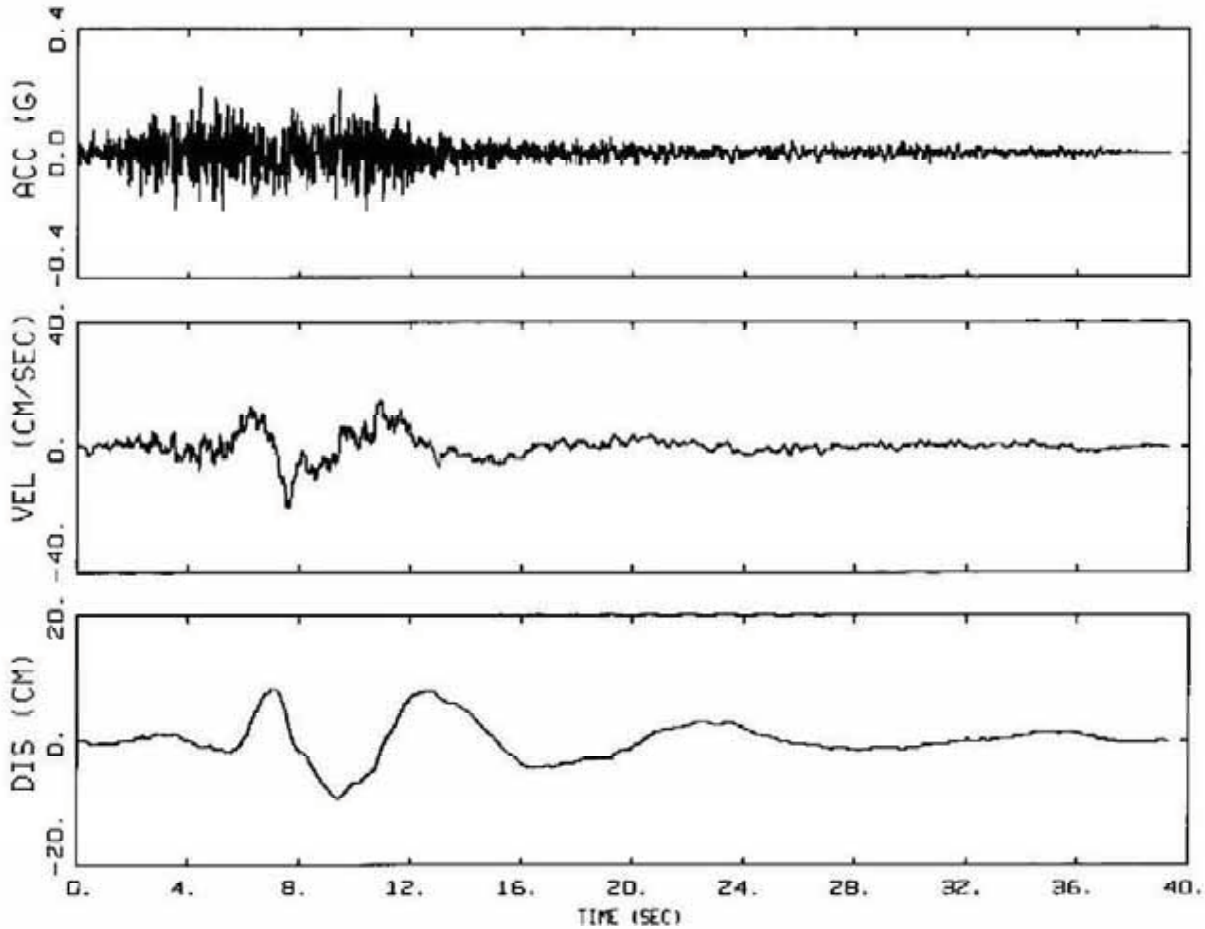
HORIZONTAL 2



DACITE, SDC 3, 2% 50 YR, HORIZONTAL 2 (NO TOPO)
BASELINE CORRECTED

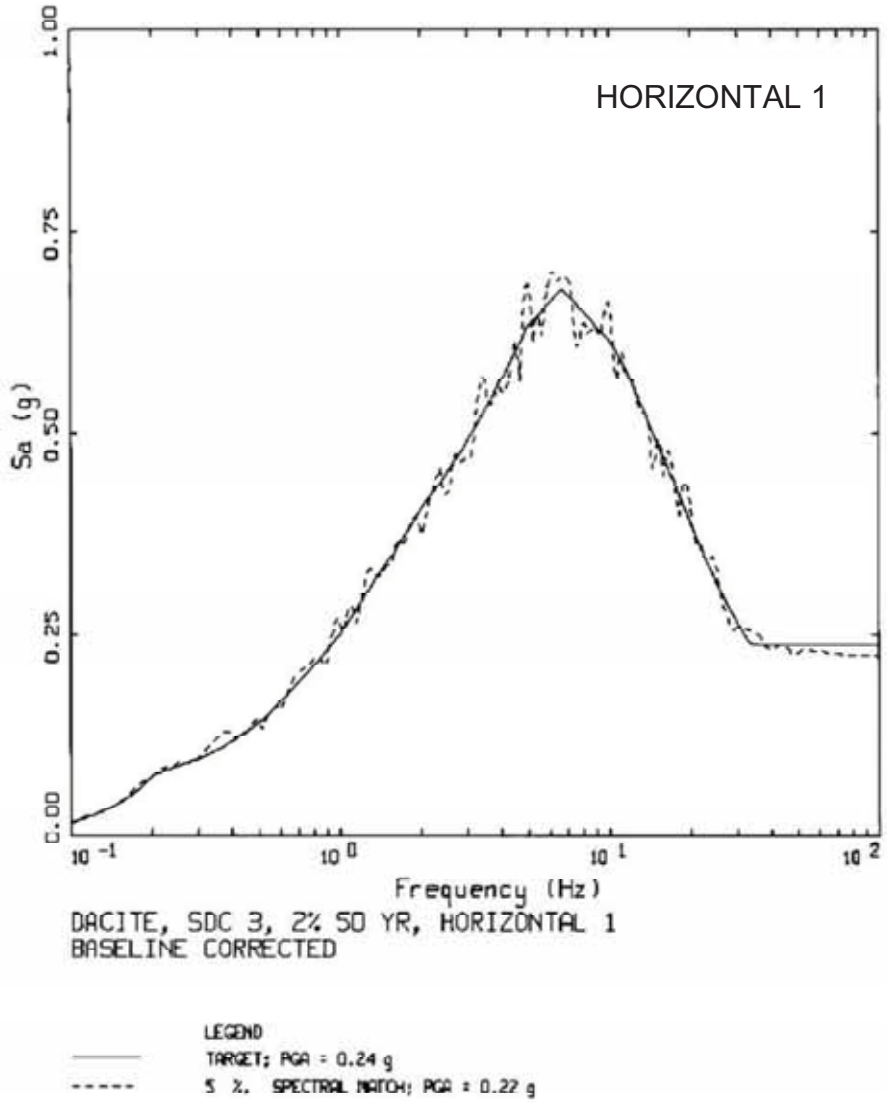
URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-3 DACITE OUTCROP TIME HISTORIES WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 83b

VERTICAL

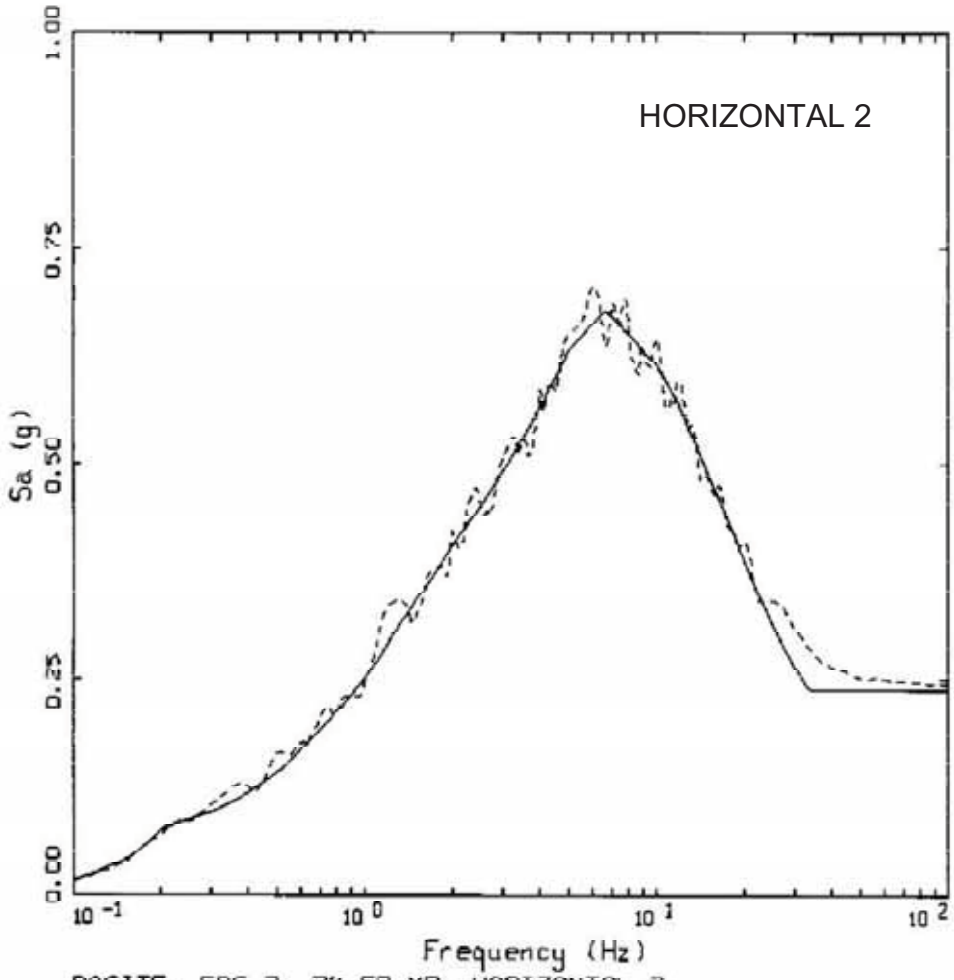


DACITE, SDC 3, 2% 50 YR, VERTICAL (NO TOPO)
BASELINE CORRECTED

URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-3 DACITE OUTCROP TIME HISTORIES WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 83c



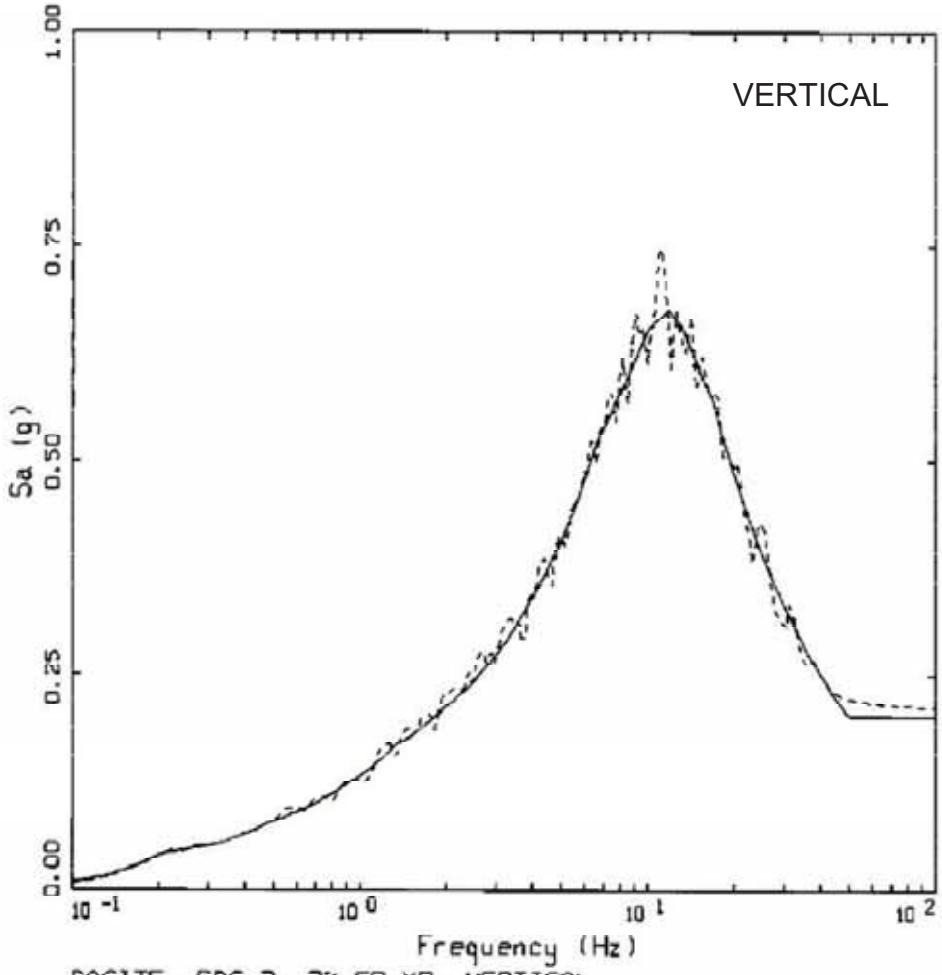
URS	Project No. 26817259	SDC-3 DACITE OUTCROP SPECTRAL MATCH LINEAR WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 83d
	Los Alamos National Lab		



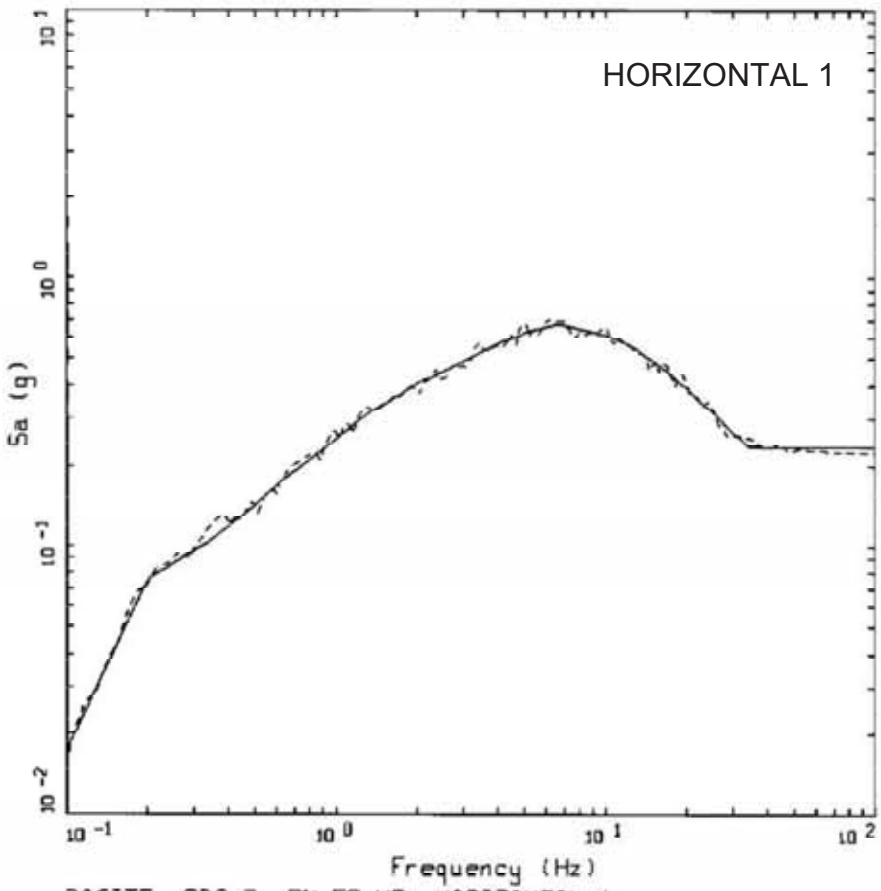
DACITE, SDC 3, 2% 50 YR, HORIZONTAL 2
BASELINE CORRECTED

LEGEND
——— TARGET; PGA = 0.24 g
- - - - - 5 %, SPECTRAL MATCH; PGA = 0.24 g

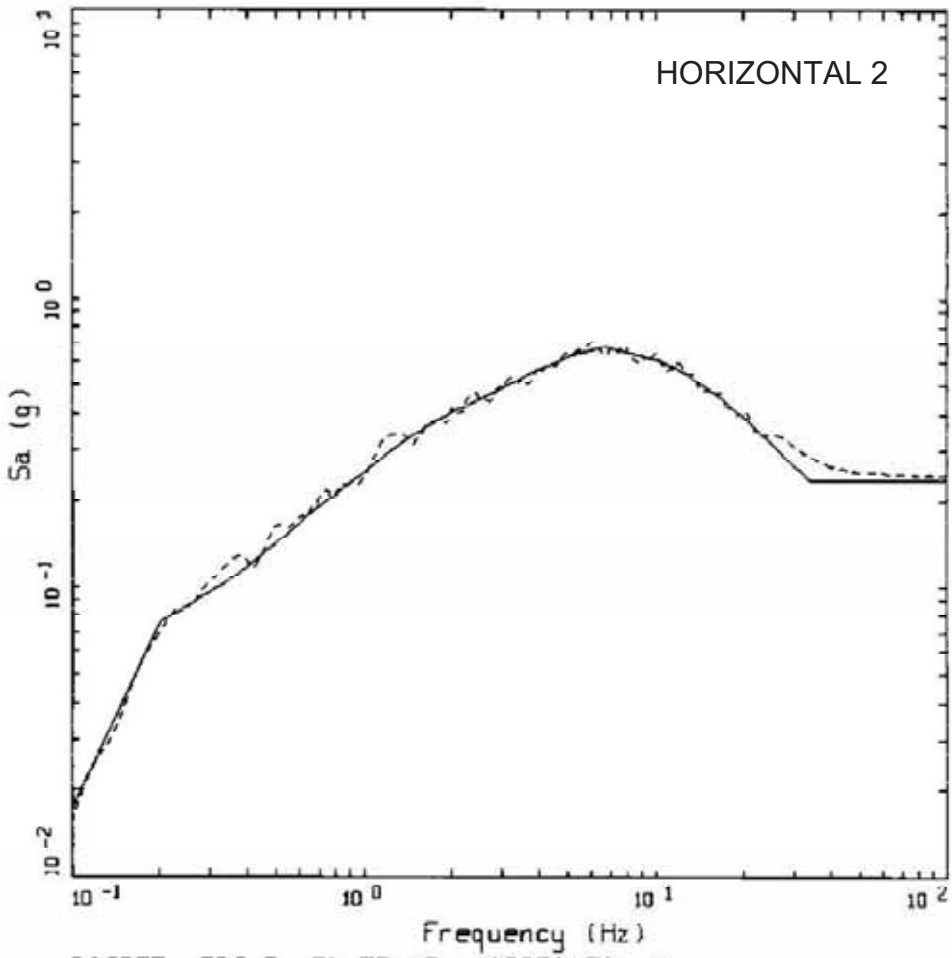
URS	Project No. 26817259 Los Alamos National Lab	SDC-3 DACITE OUTCROP SPECTRAL MATCH LINEAR WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 83e



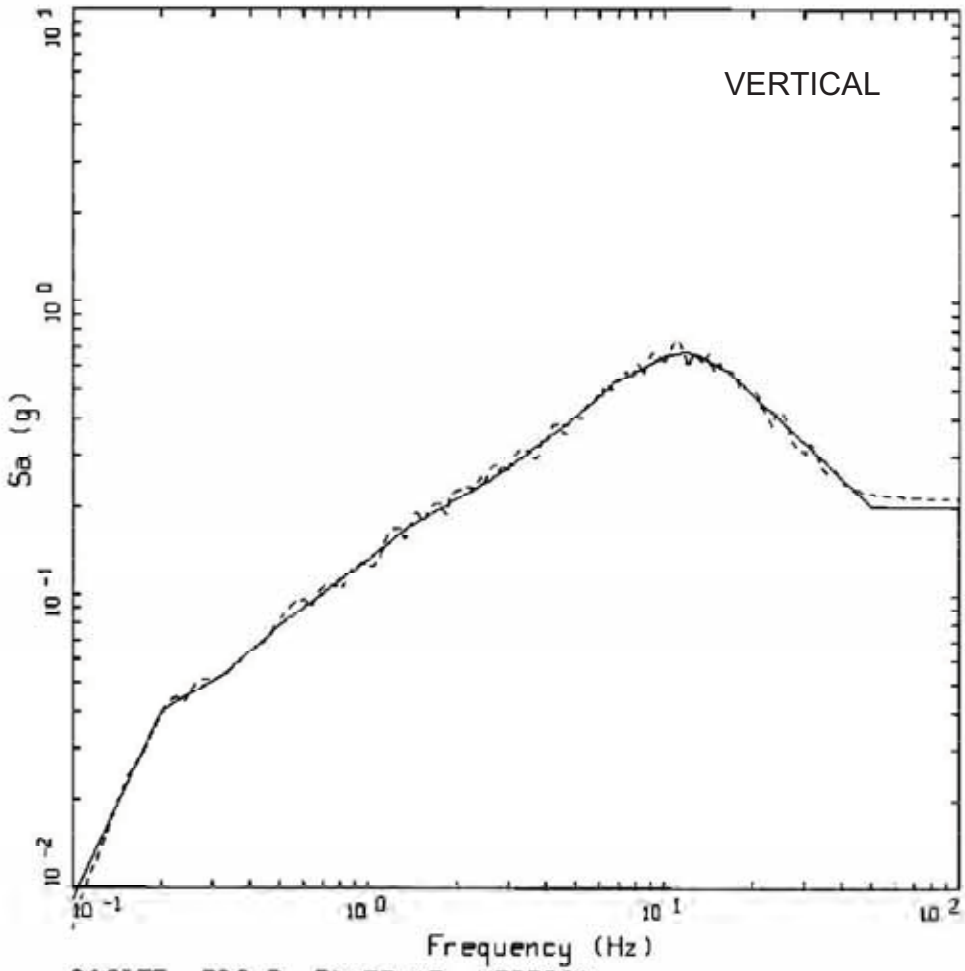
URS	Project No. 26817259 Los Alamos National Lab	SDC-3 DACITE OUTCROP SPECTRAL MATCH LINEAR WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 83f



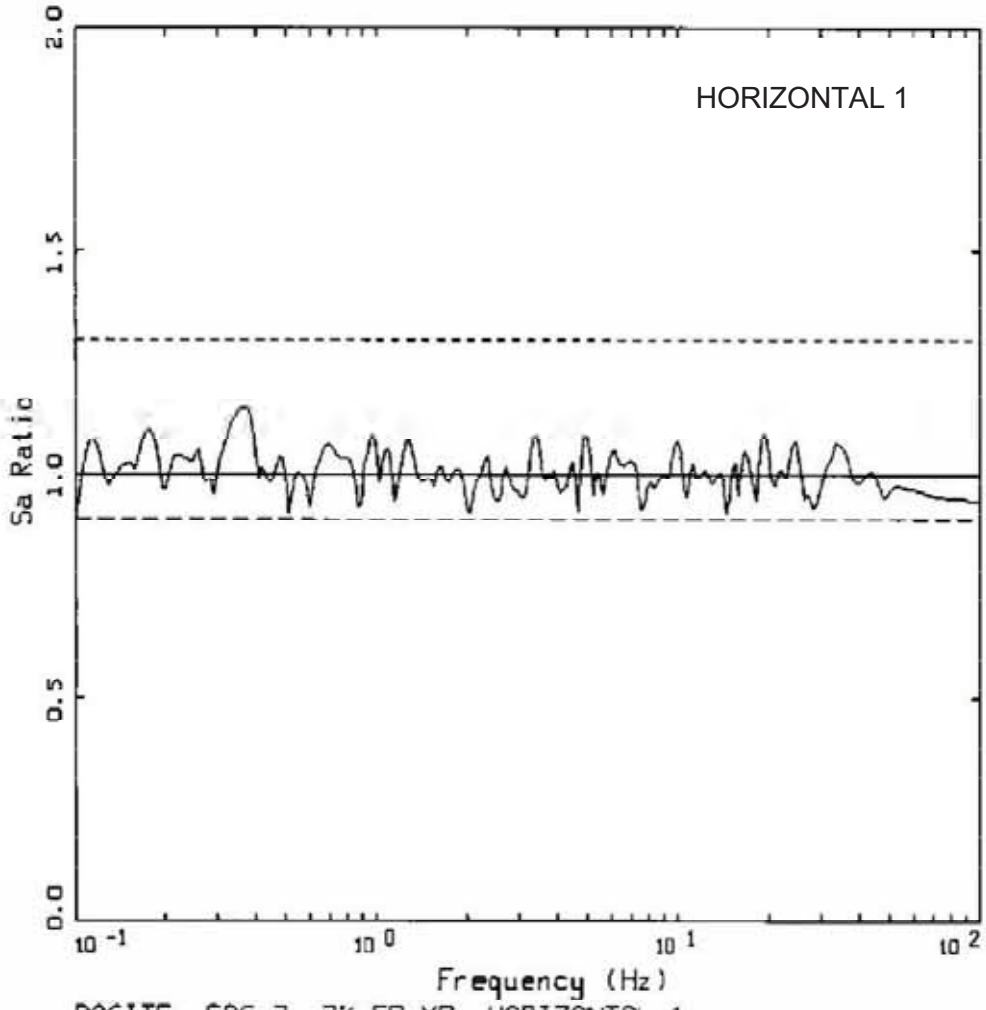
URS	Project No. 26817259	SDC - 3 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 83g
	Los Alamos National Lab		



URS	Project No. 26817259 Los Alamos National Lab	SDC - 3 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 83h



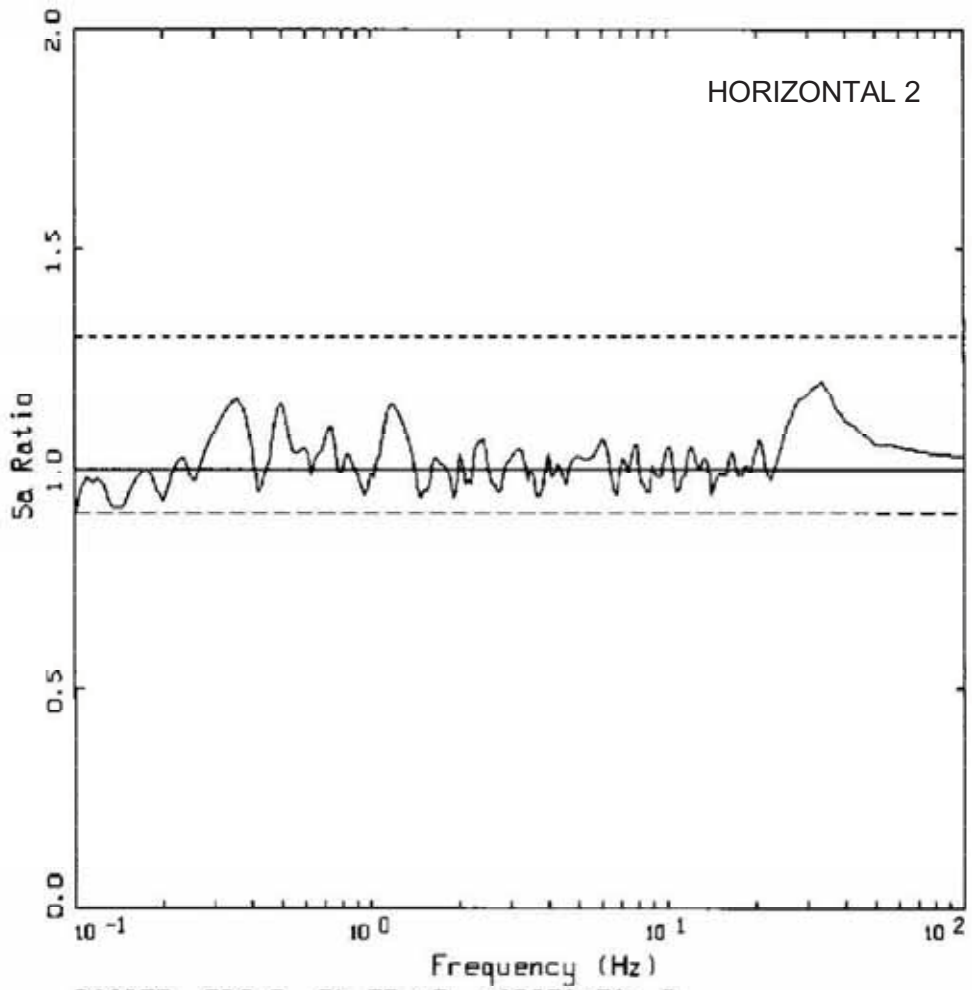
URS	Project No. 26817259 Los Alamos National Lab	SDC - 3 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 83i



DACITE, SDC 3, 2% 50 YR, HORIZONTAL 1
SPECTRAL RATIO: MATCH/TARGET

LEGEND
SA RATIO: MATCH/TARGET
UNITY
UNITY * 1.3
UNITY / 1.111

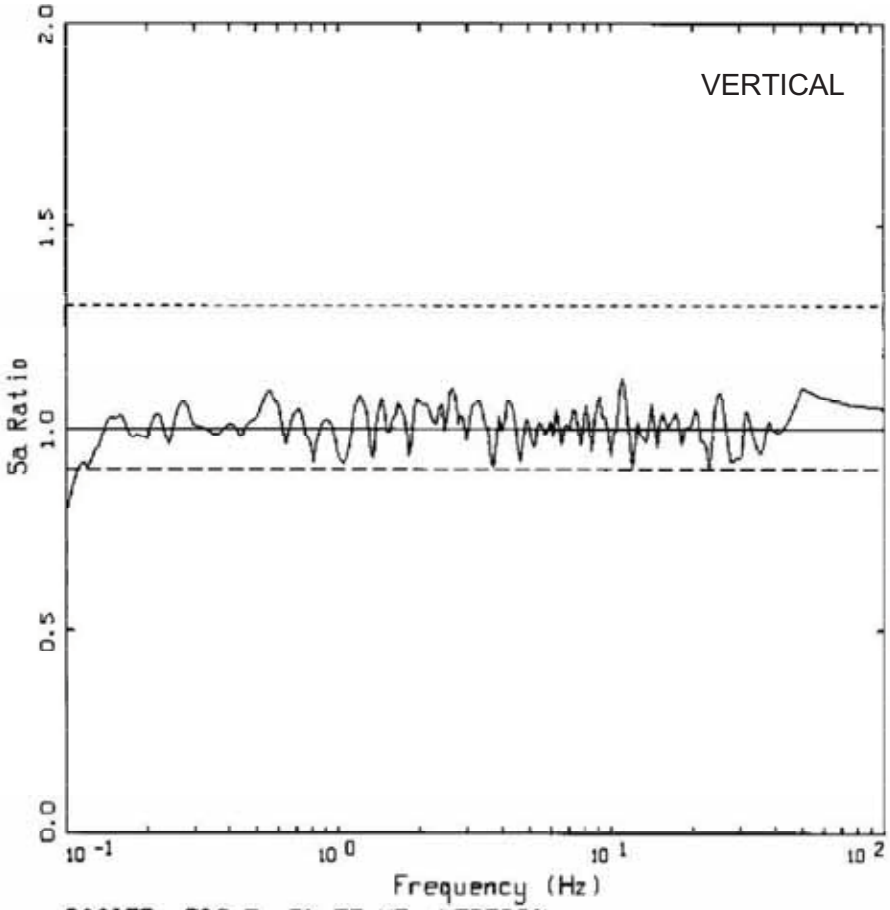
URS	Project No. 26817259 Los Alamos National Lab	SDC - 3 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 83j



DACITE, SDC 3, 2% 50 YR, HORIZONTAL 2
SPECTRAL RATIO: MATCH/TARGET

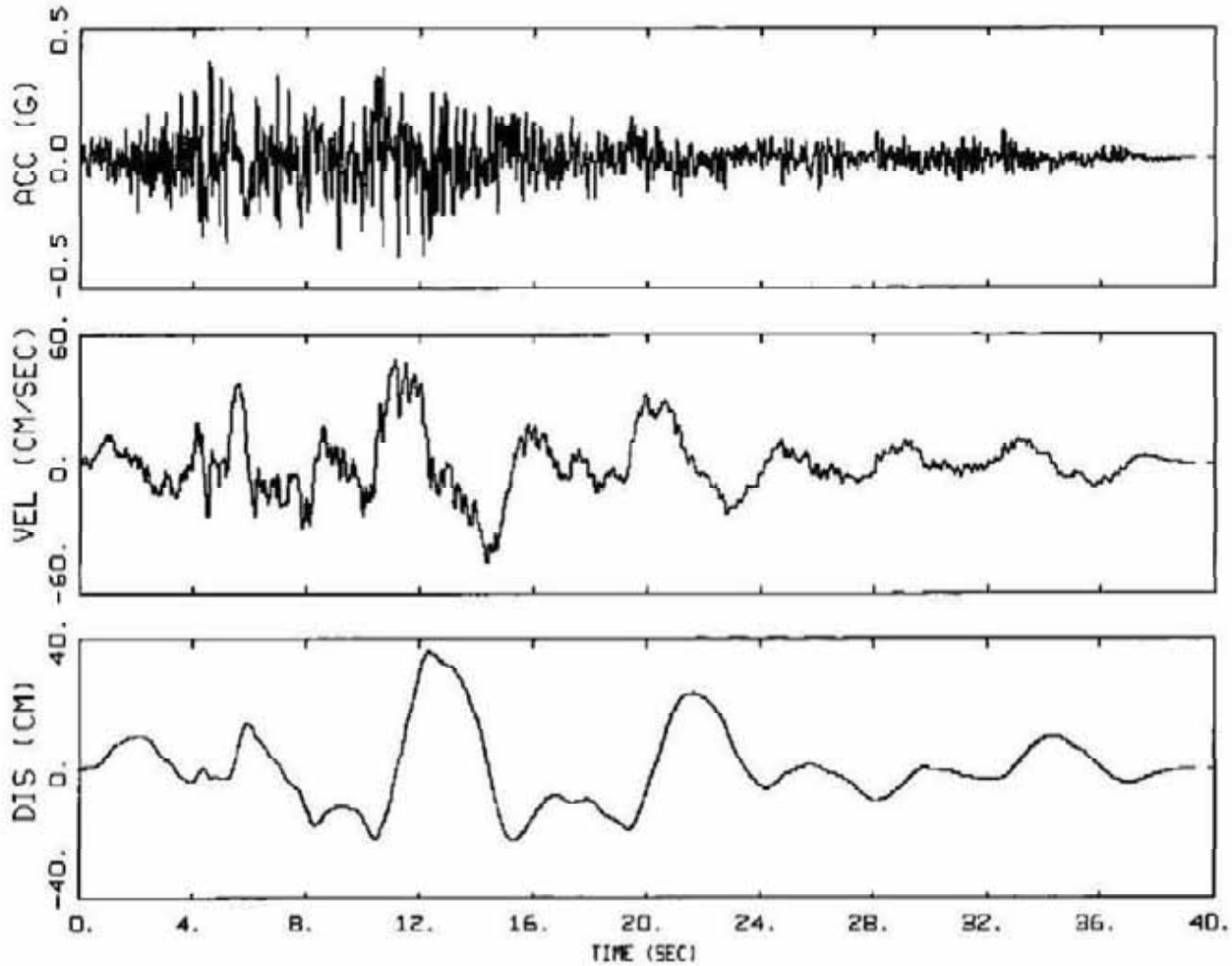
LEGEND
SA RATIO: MATCH/TARGET
UNITY
UNITY * 1.3
UNITY / 1.111

URS	Project No. 26817259 Los Alamos National Lab	SDC - 3 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 83k



URS	Project No. 26817259 Los Alamos National Lab	SDC - 3 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 83I

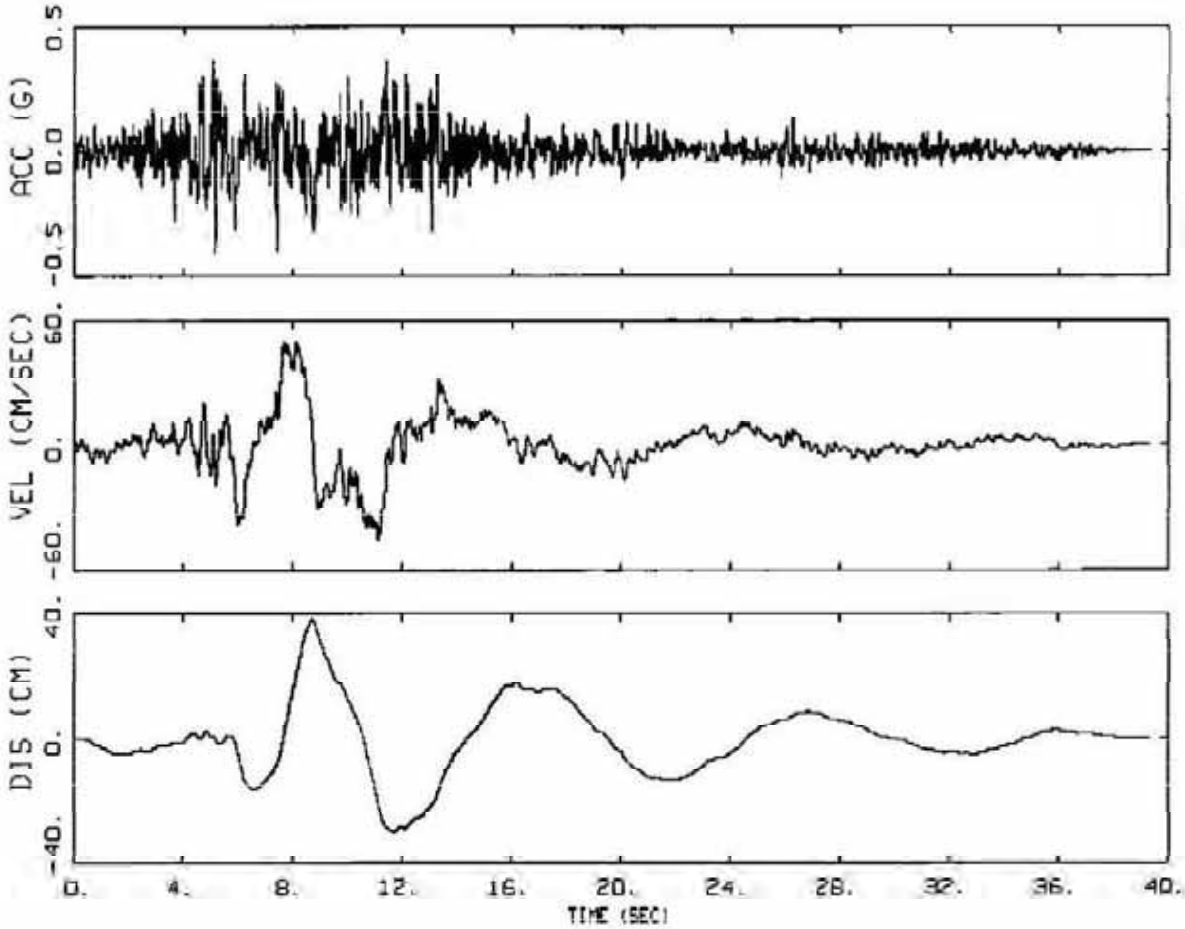
HORIZONTAL 1



DACITE, SDC 4, 2% 50 YR, HORIZONTAL 1 (NO TOPO)
BASELINE CORRECTED

URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-4 DACITE OUTCROP TIME HISTORIES WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 84a

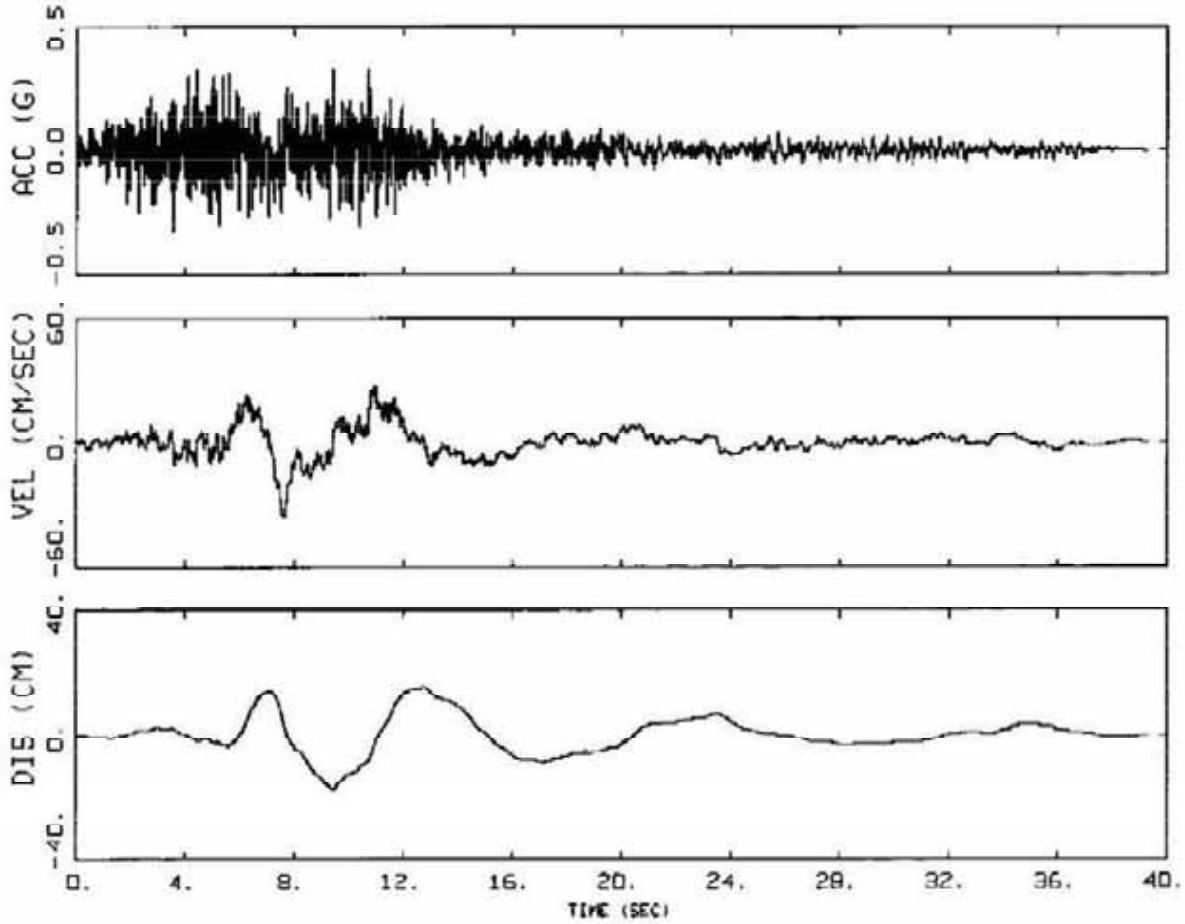
HORIZONTAL 2



DACITE, SDC 4, 2% 50 YR, HORIZONTAL 2 (NO TOPO)
BASELINE CORRECTED

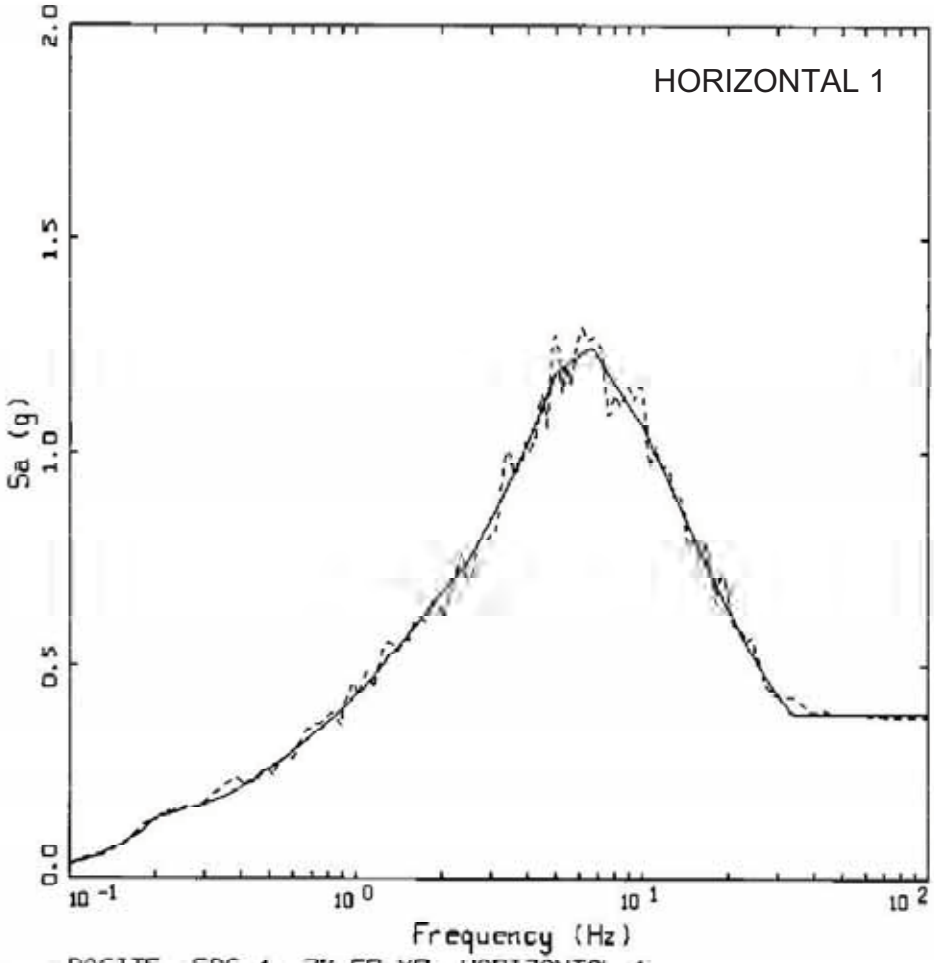
URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-4 DACITE OUTCROP TIME HISTORIES WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 84b

VERTICAL

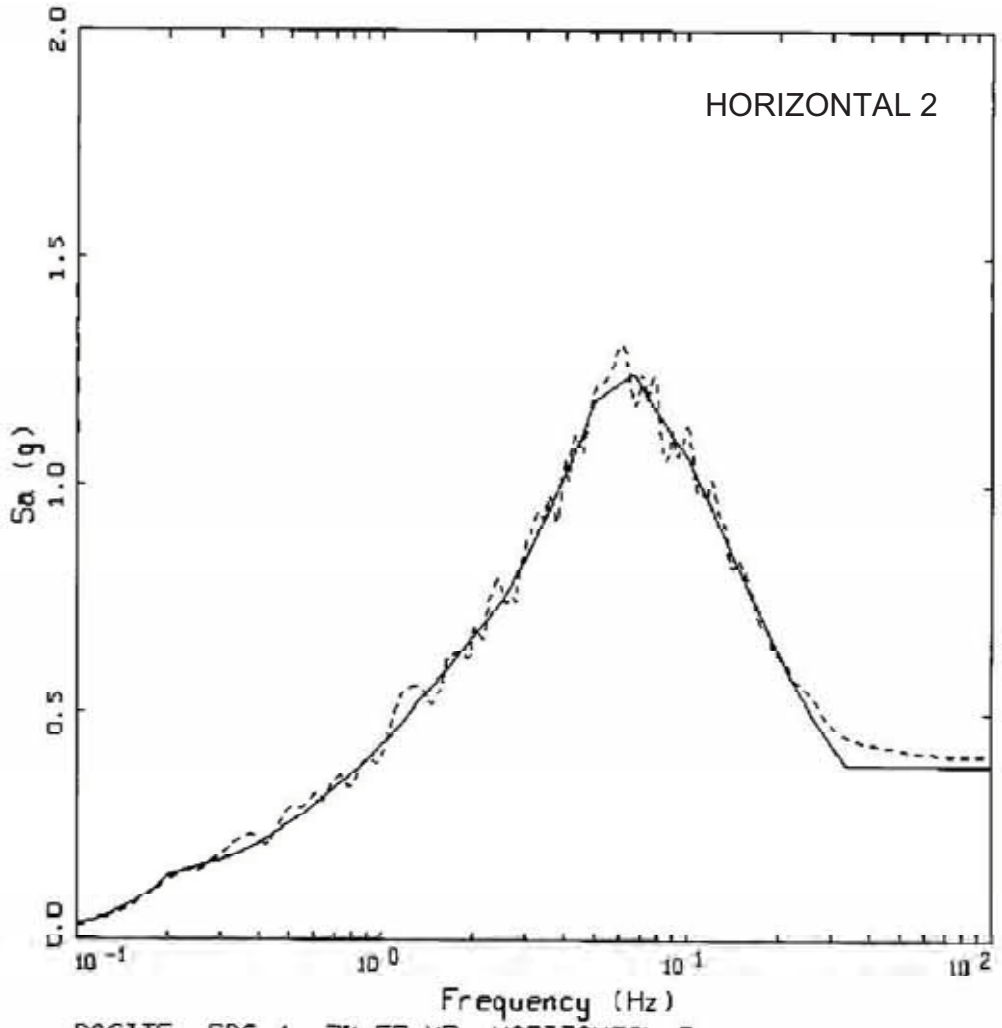


DACITE, SDC 4, 2% 50 YR, VERTICAL (NO TOPO)
BASELINE CORRECTED

URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-4 DACITE OUTCROP TIME HISTORIES WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 84c



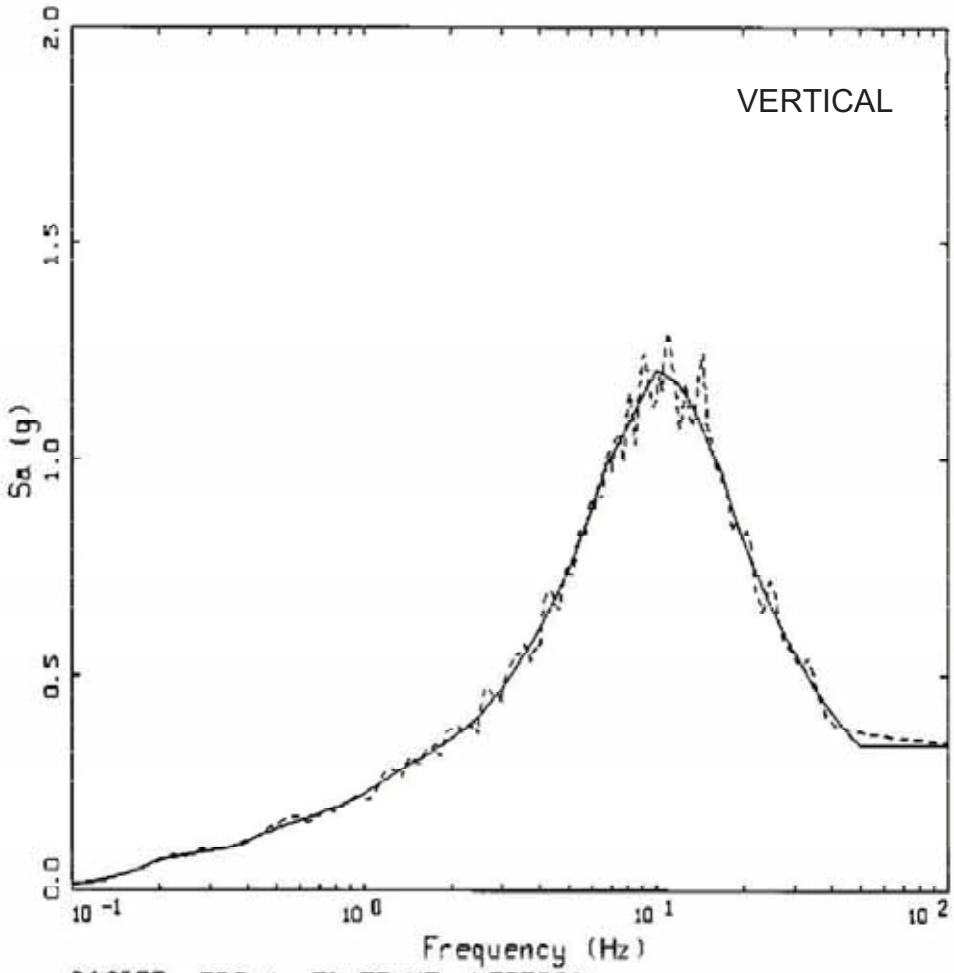
URS	Project No. 26817259 Los Alamos National Lab	SDC - 4 DACITE OUTCROP SPECTRAL MATCH LINEAR WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 84d



DACITE, SDC 4, 2% 50 YR, HORIZONTAL 2
BASELINE CORRECTED

LEGEND
TARGET; PGA = 0.39 g
5 %, SPECTRAL MATCH; PGA = 0.41 g

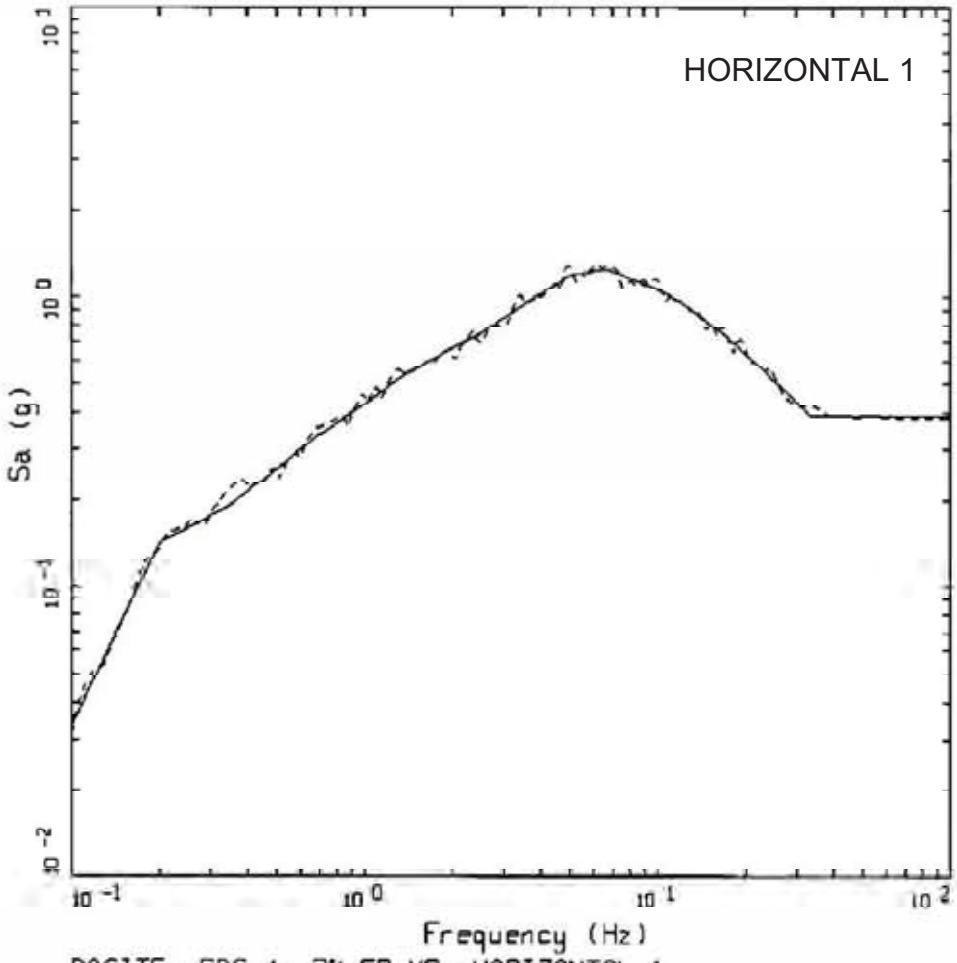
URS	Project No. 26817259 Los Alamos National Lab	SDC - 4 DACITE OUTCROP SPECTRAL MATCH LINEAR WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 84e



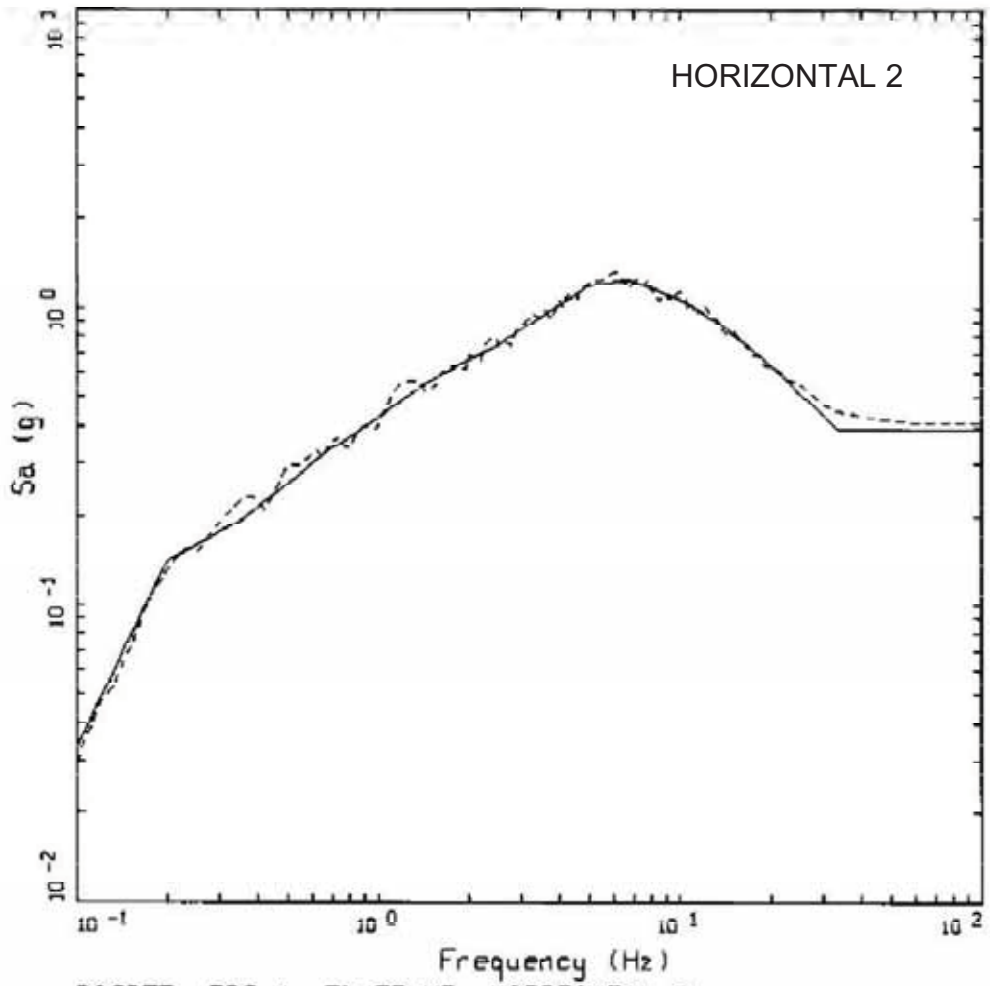
DACITE, SDC 4, 2% 50 YR, VERTICAL
BASELINE CORRECTED

LEGEND
TARGET; PGA = 0.34 g
5 %, SPECTRAL MATCH; PGA = 0.34 g

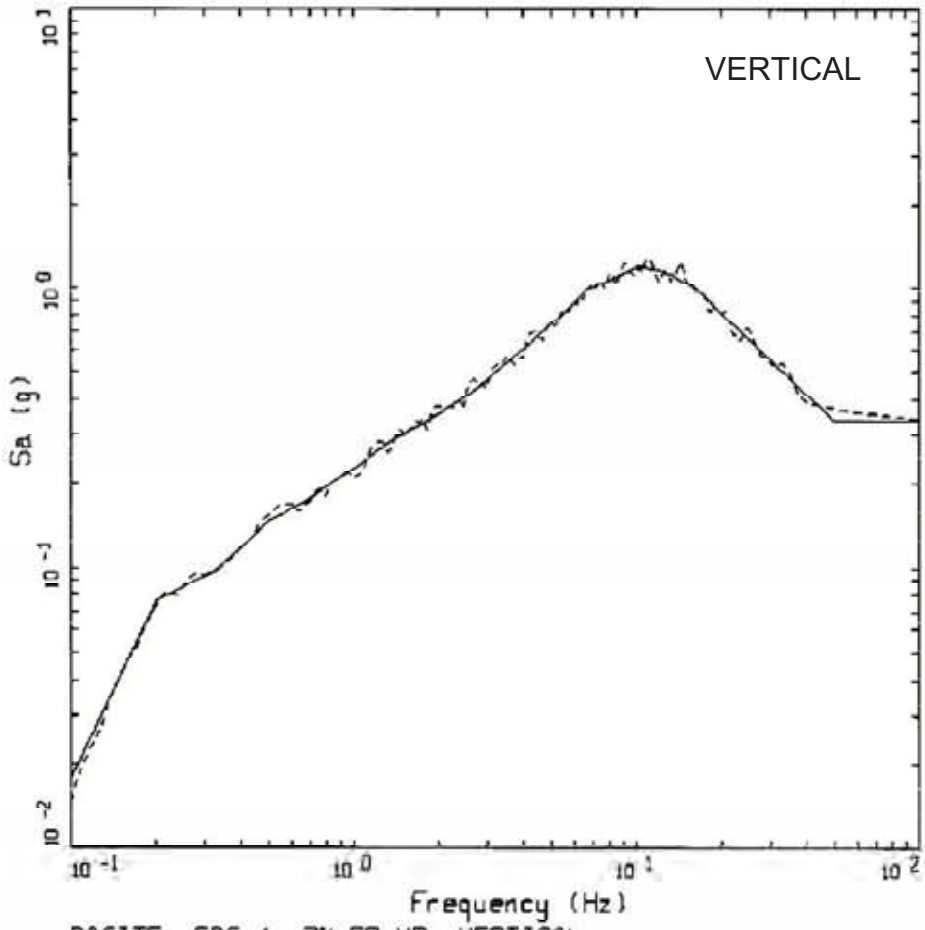
URS	Project No. 26817259 Los Alamos National Lab	SDC - 4 DACITE OUTCROP SPECTRAL MATCH LINEAR WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 84f



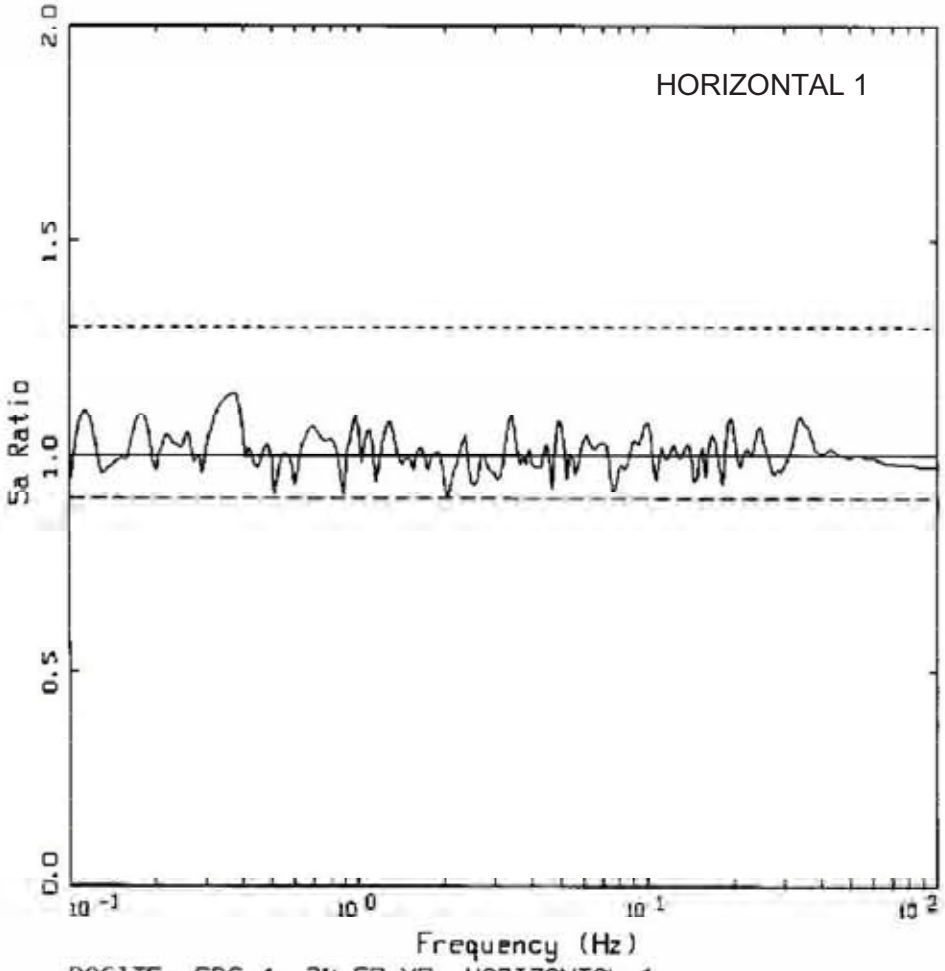
URS	Project No. 26817259 Los Alamos National Lab	SDC - 4 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 84g



URS	Project No. 26817259 Los Alamos National Lab	SDC - 4 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 84h



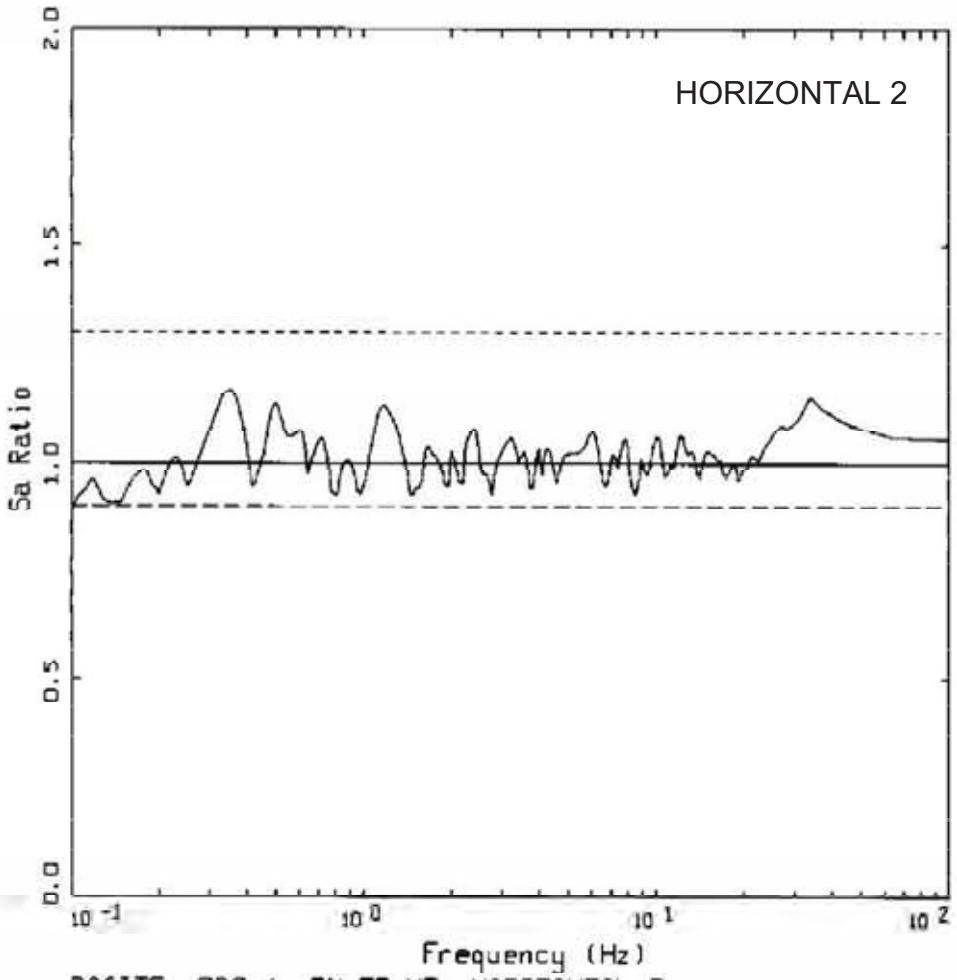
URS	Project No. 26817259 Los Alamos National Lab	SDC - 4 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 84i



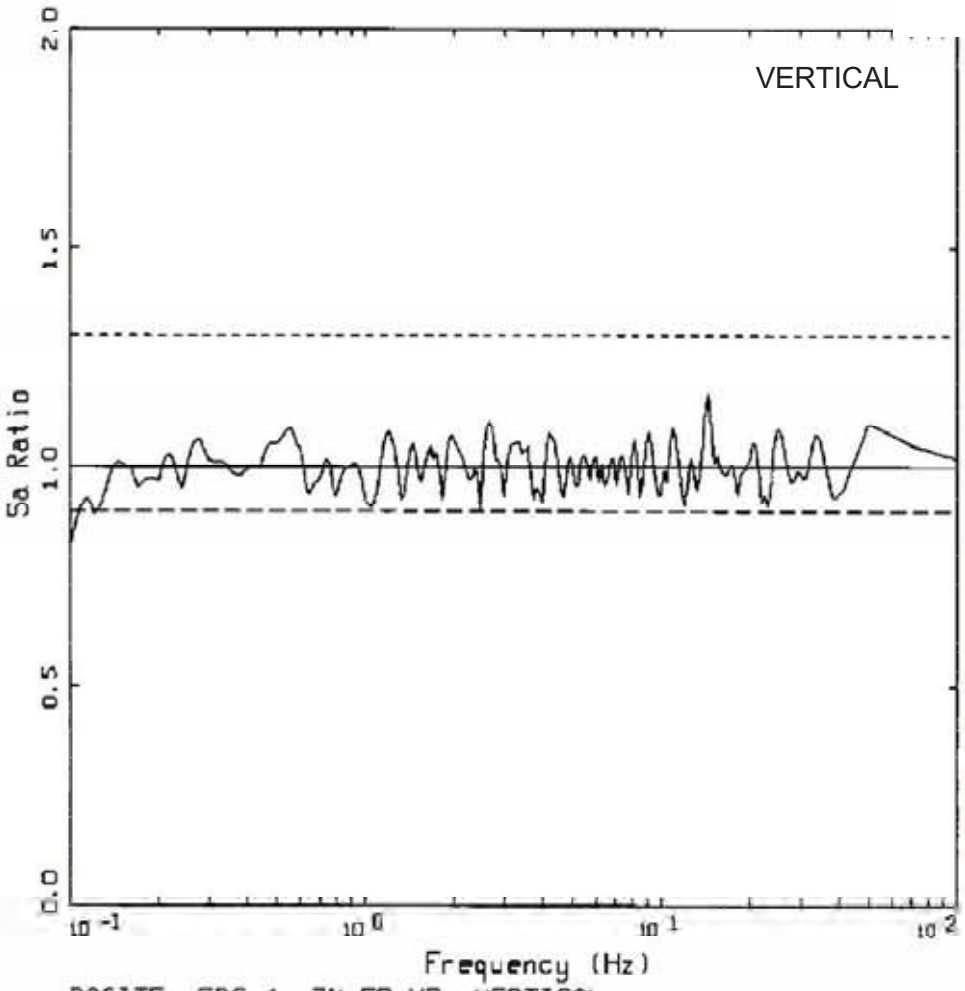
DACITE, SDC 4, 2% 50 YR, HORIZONTAL 1
SPECTRAL RATIO: MATCH/TARGET

LEGEND
SA RATIO: MATCH/TARGET
UNITY
UNITY * 1.3
UNITY / 1.111

URS	Project No. 26817259 Los Alamos National Lab	SDC - 4 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 84j

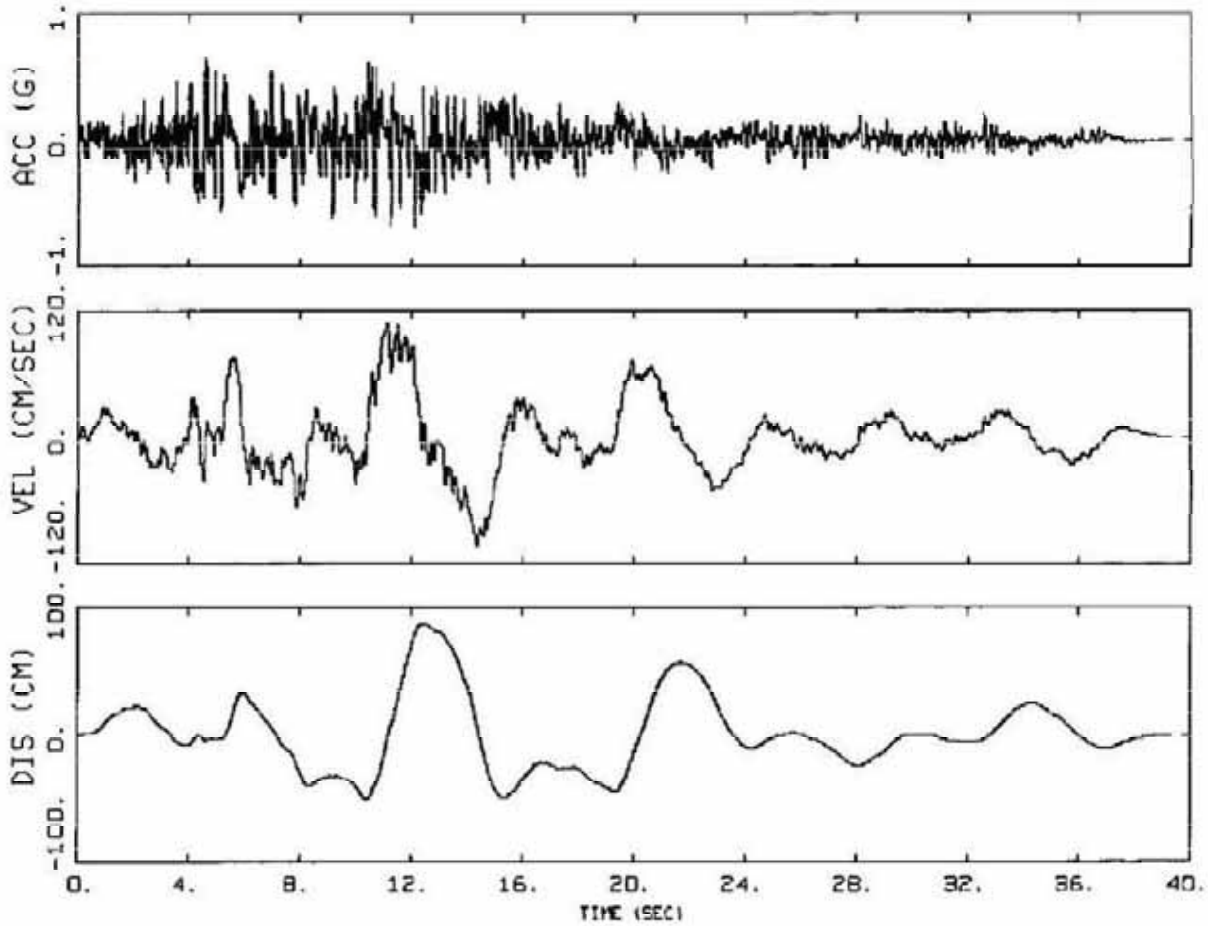


URS	Project No. 26817259 Los Alamos National Lab	SDC - 4 DACITE OUTCROP OF MATCH TO TARGET SPECTRA WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 84k



URS	Project No. 26817259 Los Alamos National Lab	SDC - 4 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 84I

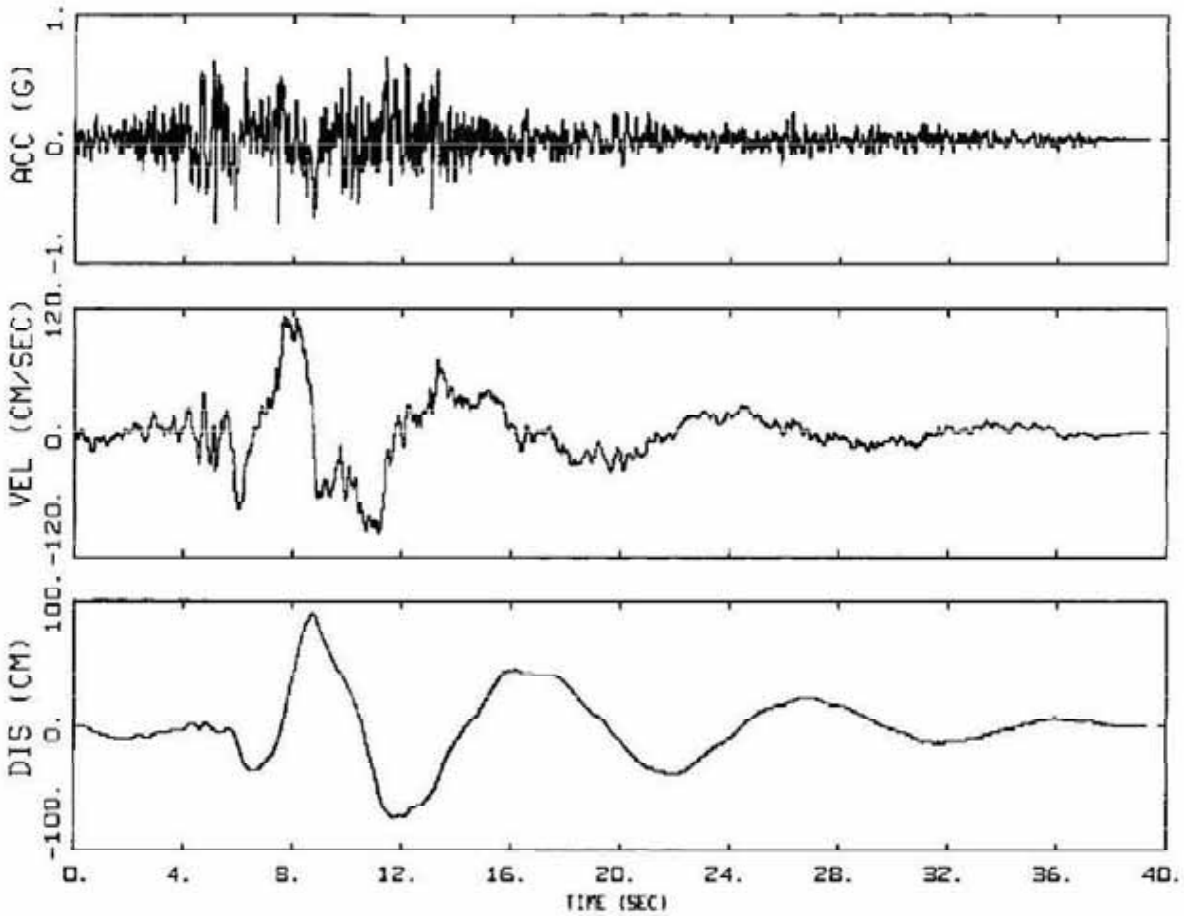
HORIZONTAL 1



DACITE, SDC 5, 5% 500 YR, HORIZONTAL 1 (NO TOPO)
BASELINE CORRECTED

URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-5 DACITE OUTCROP TIME HISTORIES WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 85a

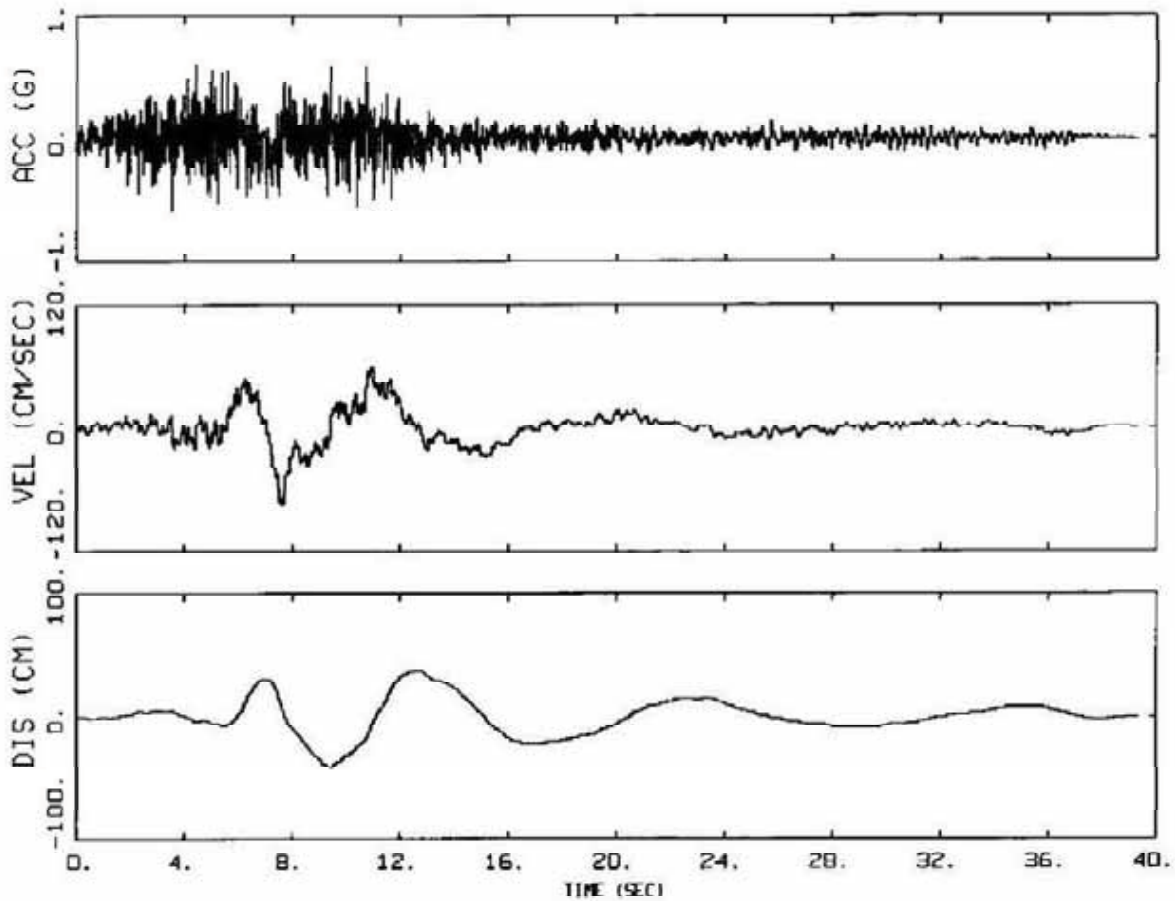
HORIZONTAL 2



DACITE, SDC 5, 5% 500 YR, HORIZONTAL 2 (NO TOPO)
BASELINE CORRECTED

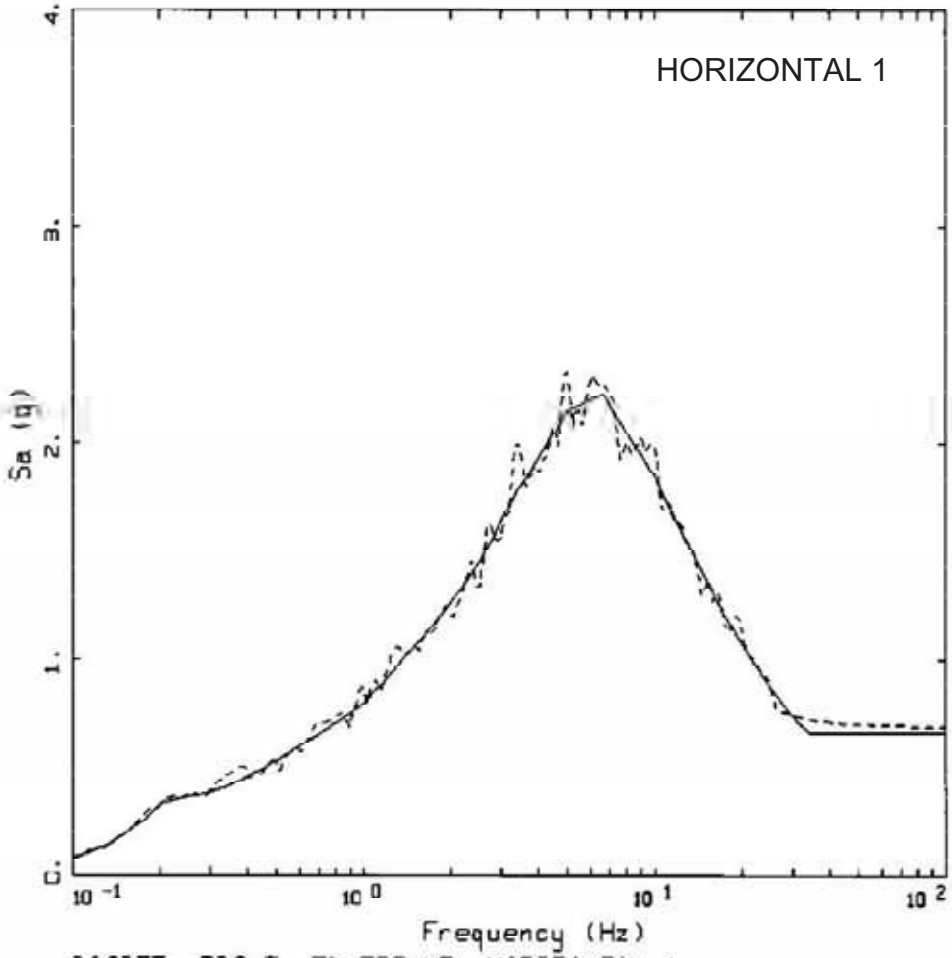
URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-5 DACITE OUTCROP TIME HISTORIES WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 85b

VERTICAL

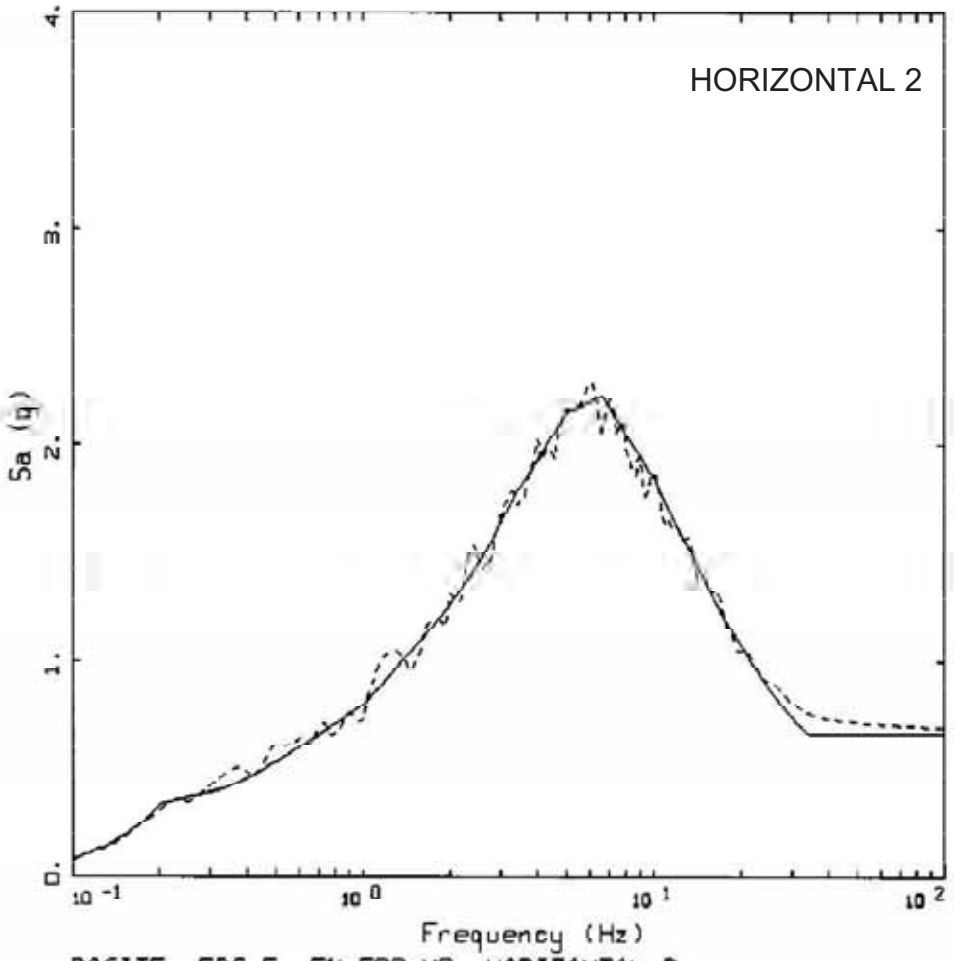


DACITE, SDC 5, 5% 500 YR, VERTICAL (NO TOPO)
BASELINE CORRECTED

URS	Project No. 26817259 Los A amos Nat ona Lab	SDC-5 DACITE OUTCROP TIME HISTORIES WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 85c



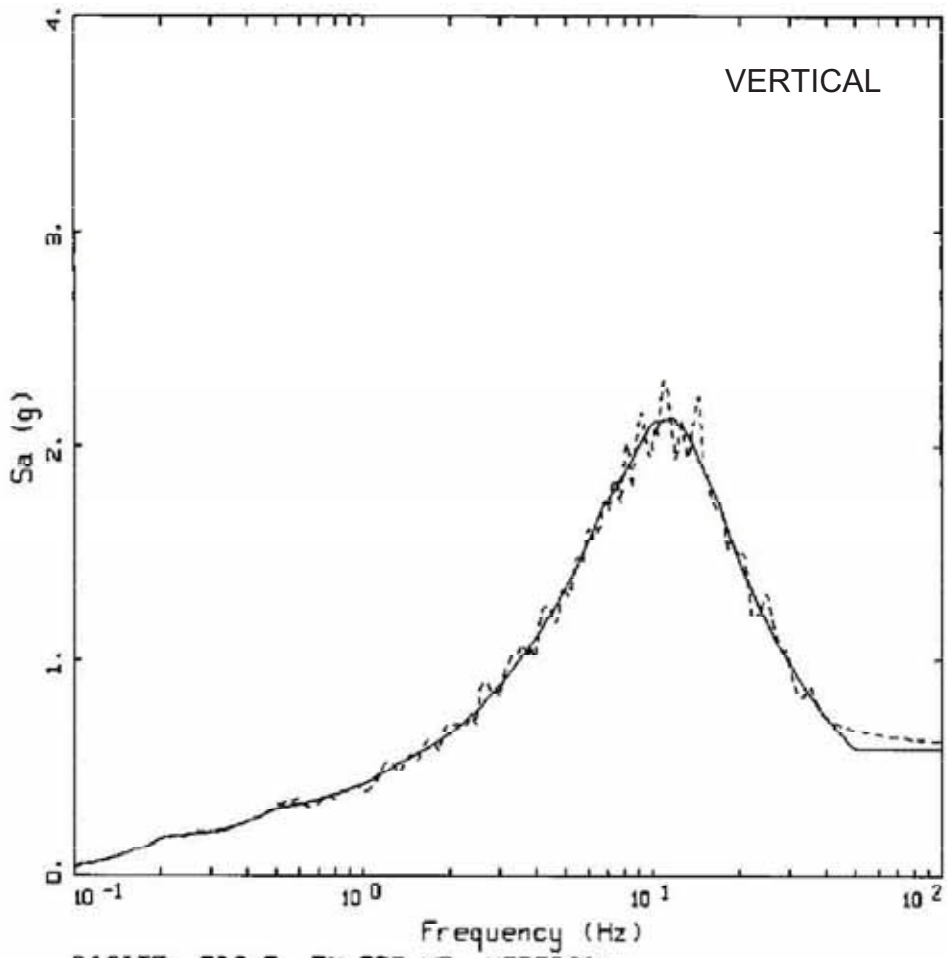
URS	Project No. 26817259 Los Alamos National Lab	SDC - 5 DACITE OUTCROP SPECTRAL MATCH LINEAR WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 85d



DACITE, SDC 5, 5% 500 YR, HORIZONTAL 2
BASELINE CORRECTED

LEGEND
TARGET: PGA = 0.67 g
5 %, SPECTRAL MATCH: PGA = 0.69 g

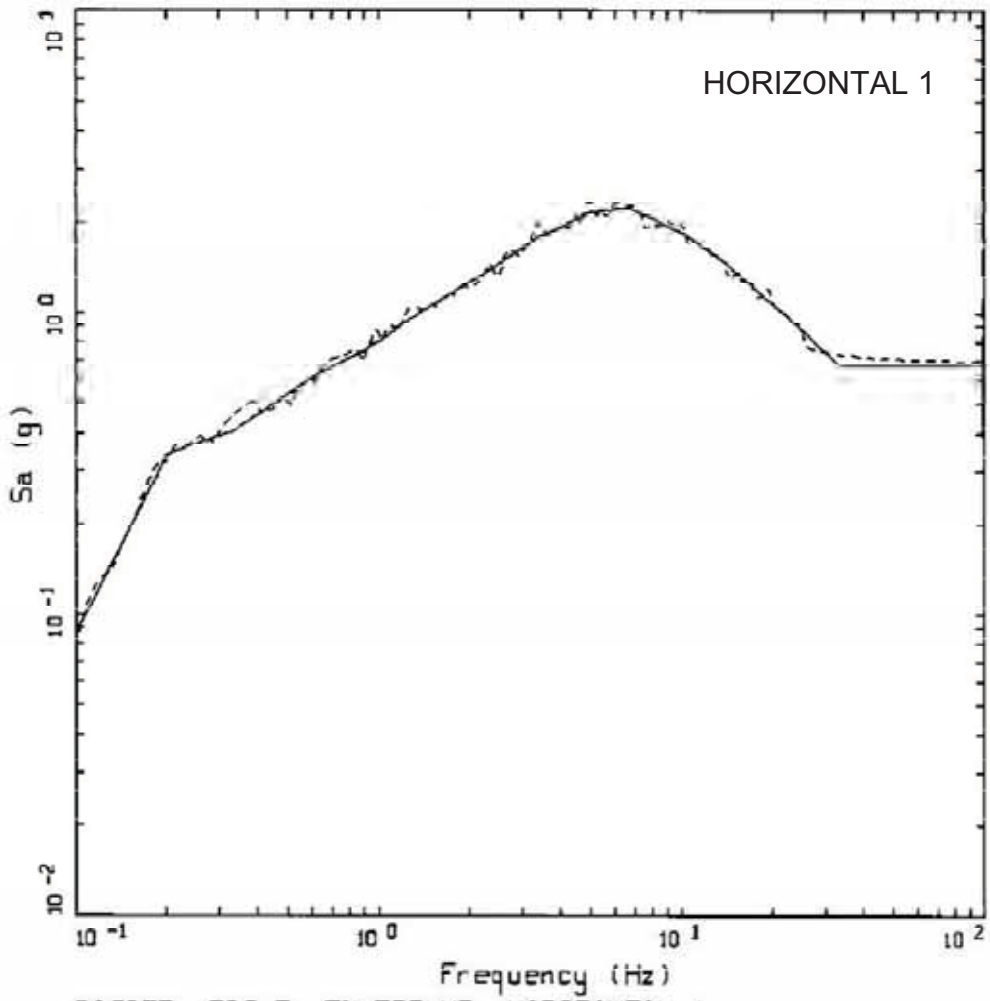
URS	Project No. 26817259 Los Alamos National Lab	SDC - 5 DACITE OUTCROP SPECTRAL MATCH LINEAR WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 85e



DACITE, SDC 5, 5% 500 YR, VERTICAL
BASELINE CORRECTED

LEGEND
TARGET; PGA = 0.59 g
5 %, SPECTRAL MATCH; PGA = 0.62 g

URS	Project No. 26817259 Los Alamos National Lab	SDC - 5 DACITE OUTCROP SPECTRAL MATCH LINEAR WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 85f

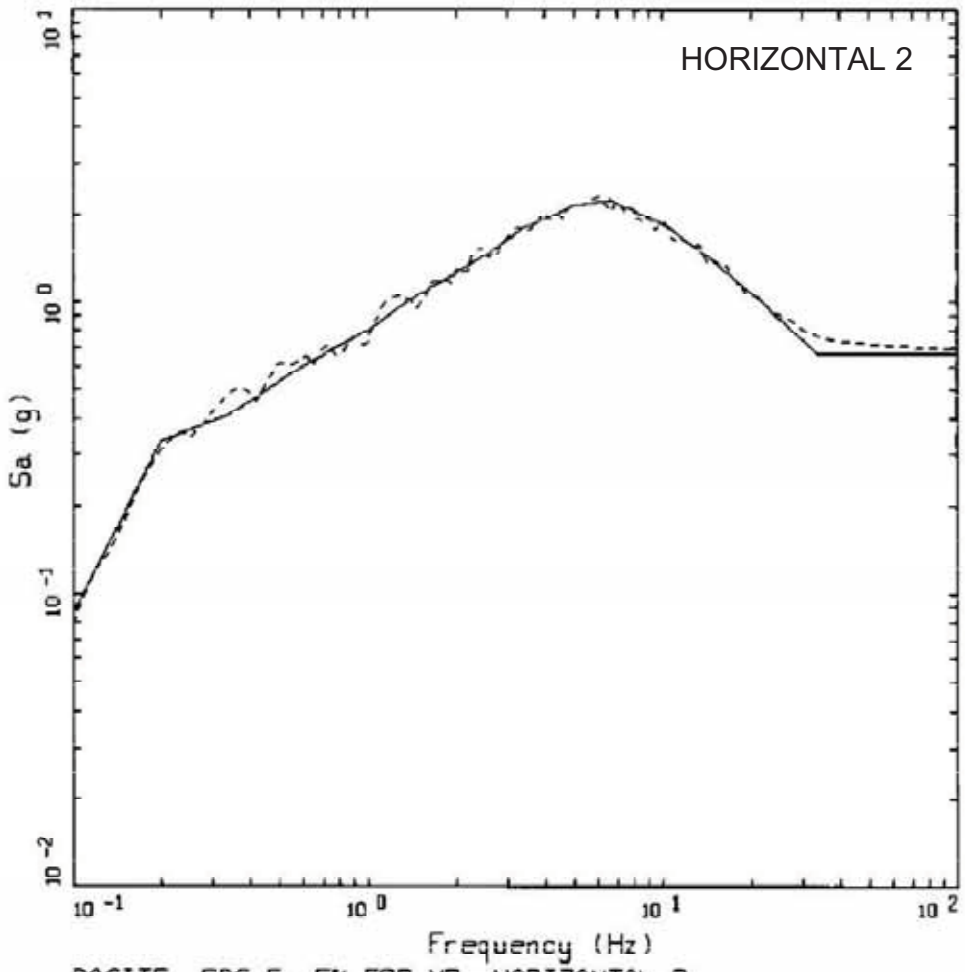


LEGEND

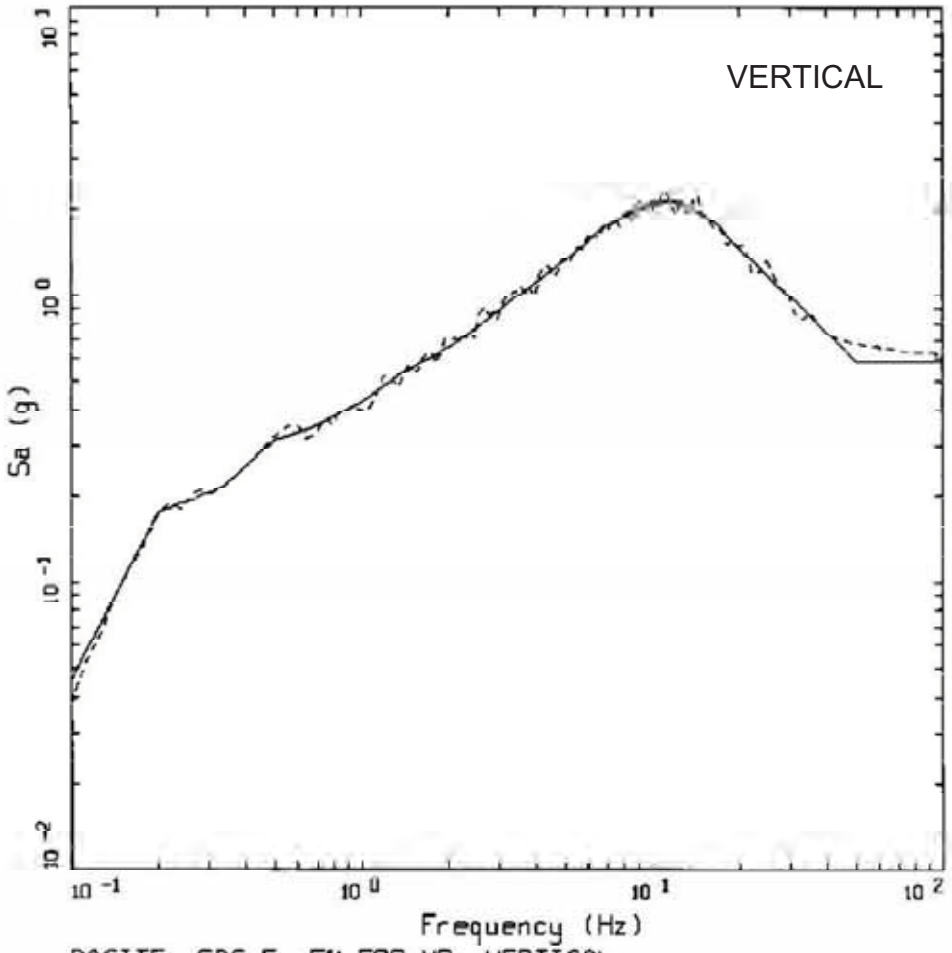
——— TARGET; PGA = 0.67 g

----- 5 %, SPECTRAL MATCH; PGA = 0.69 g

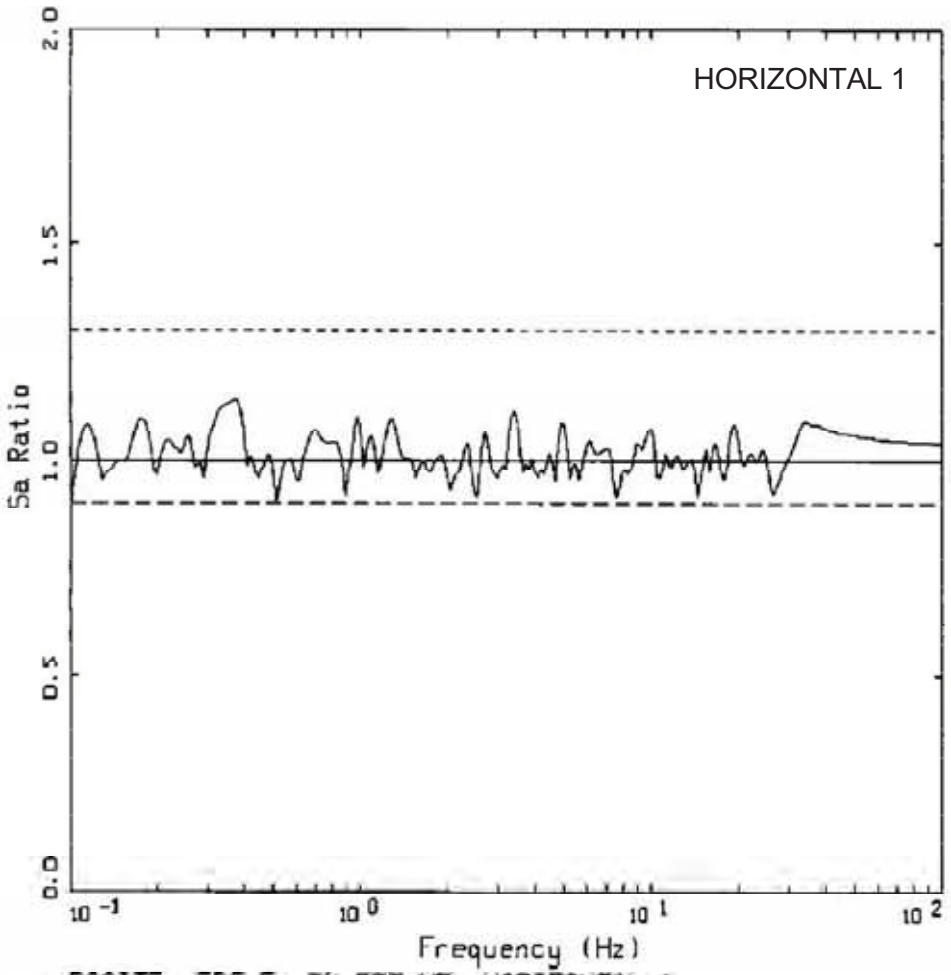
URS	Project No. 26817259 Los Alamos National Lab	SDC - 5 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 85g



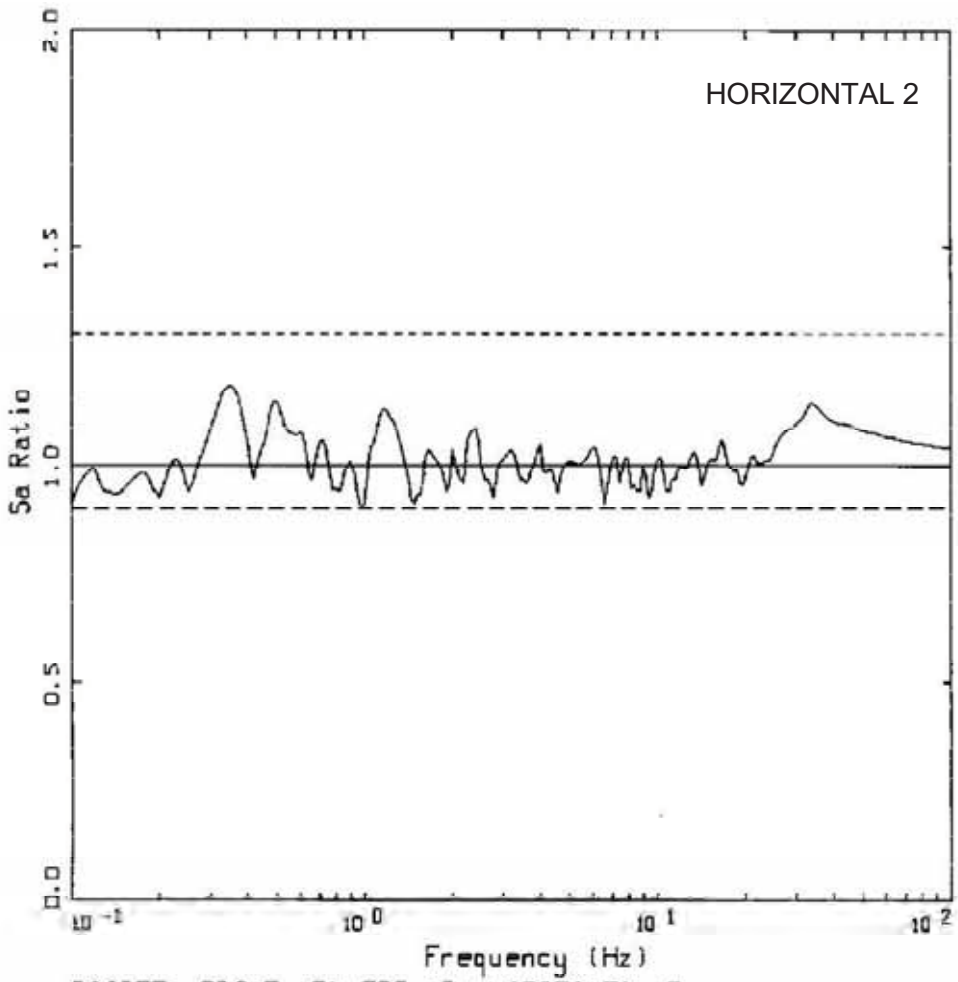
URS	Project No. 26817259 Los Alamos National Lab	SDC - 5 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 85h



URS	Project No. 26817259 Los Alamos National Lab	SDC - 5 DACITE OUTCROP SPECTRAL MATCH LOGARITHMIC WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 85i



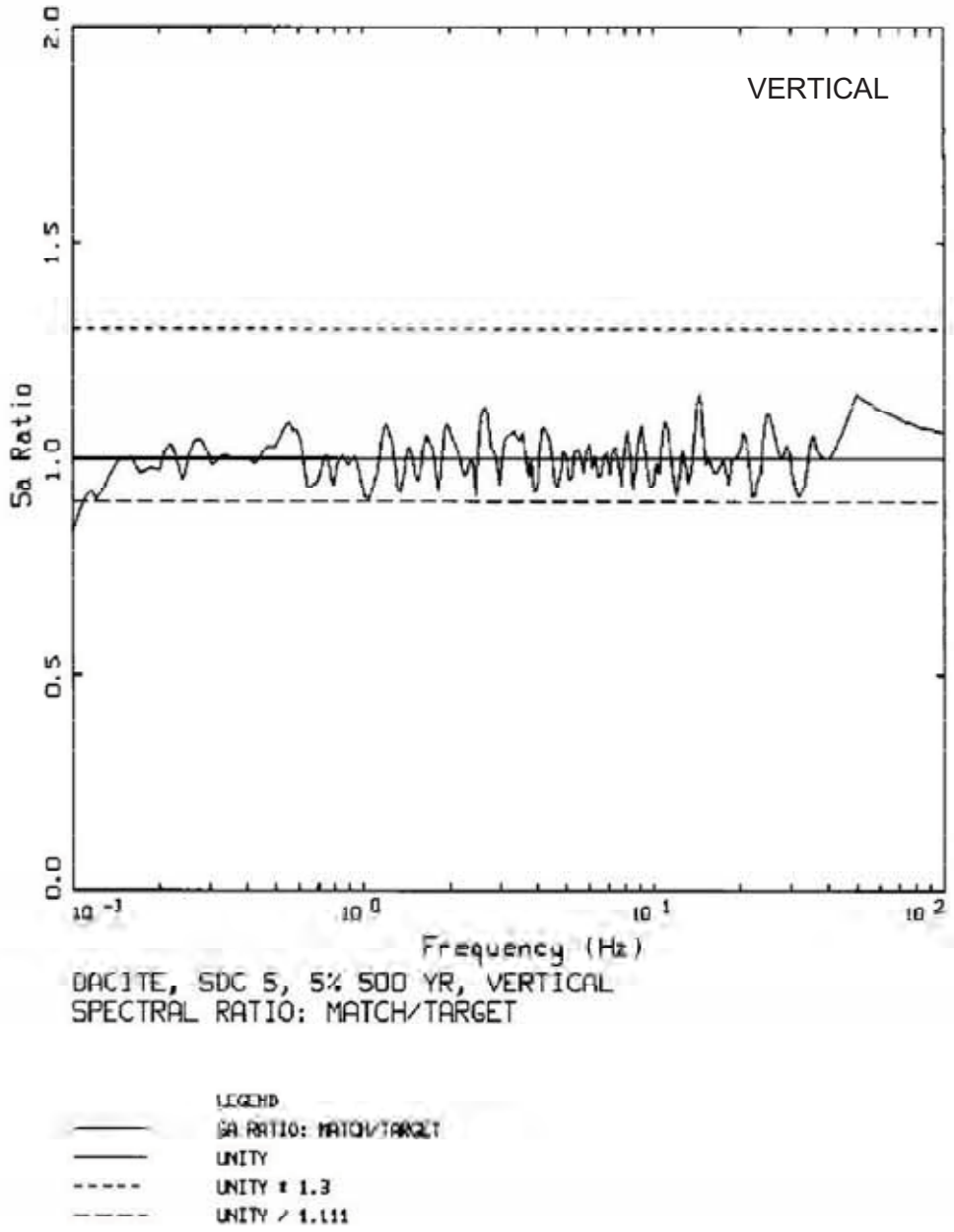
URS	Project No. 26817259 Los Alamos National Lab	SDC - 5 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 85j



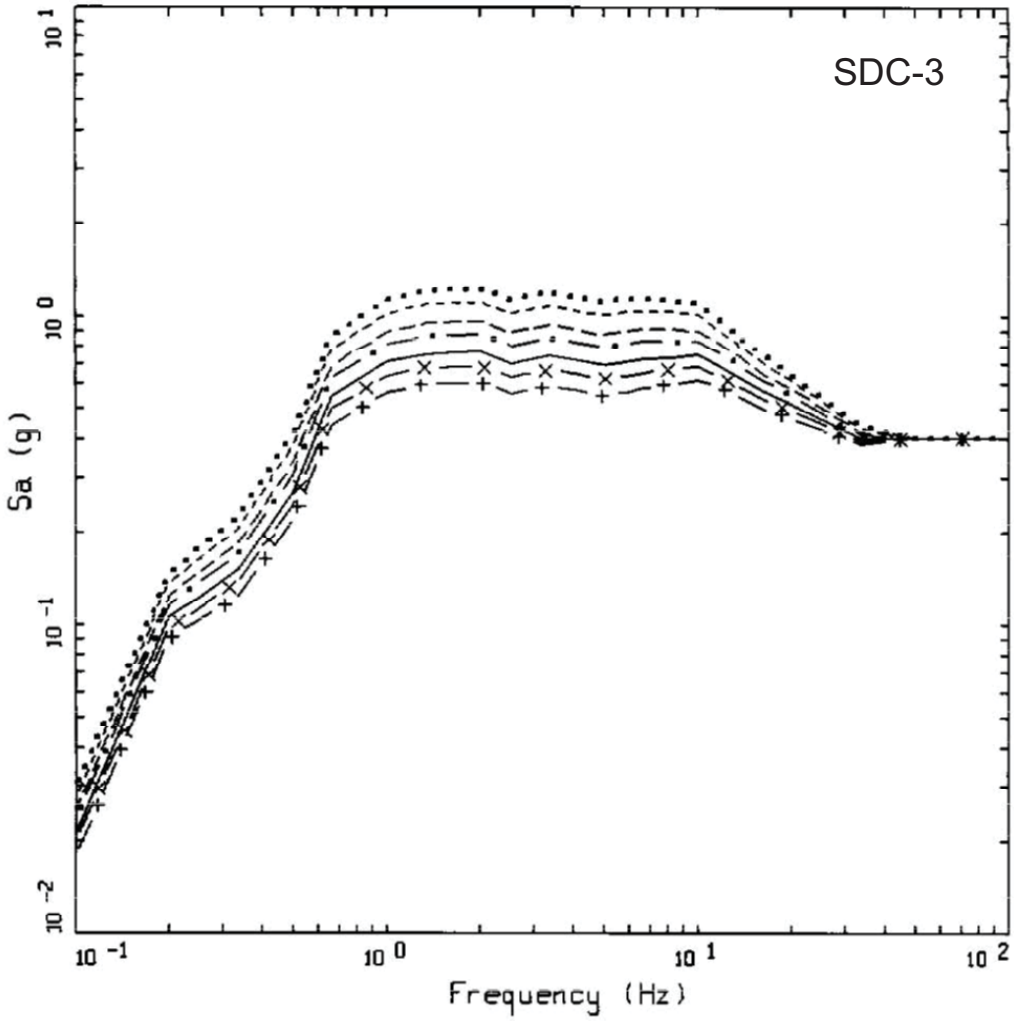
DACITE, SDC 5, 5% 500 YR, HORIZONTAL 2
SPECTRAL RATIO: MATCH/TARGET

LEGEND
SA RATIO: MATCH/TARGET
UNITY
UNITY * 1.3
UNITY / 1.111

URS	Project No. 26817259 Los Alamos National Lab	SDC - 5 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 85k



URS	Project No. 26817259 Los Alamos National Lab	SDC - 5 DACITE OUTCROP RATIO OF MATCH TO TARGET SPECTRA WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 85l

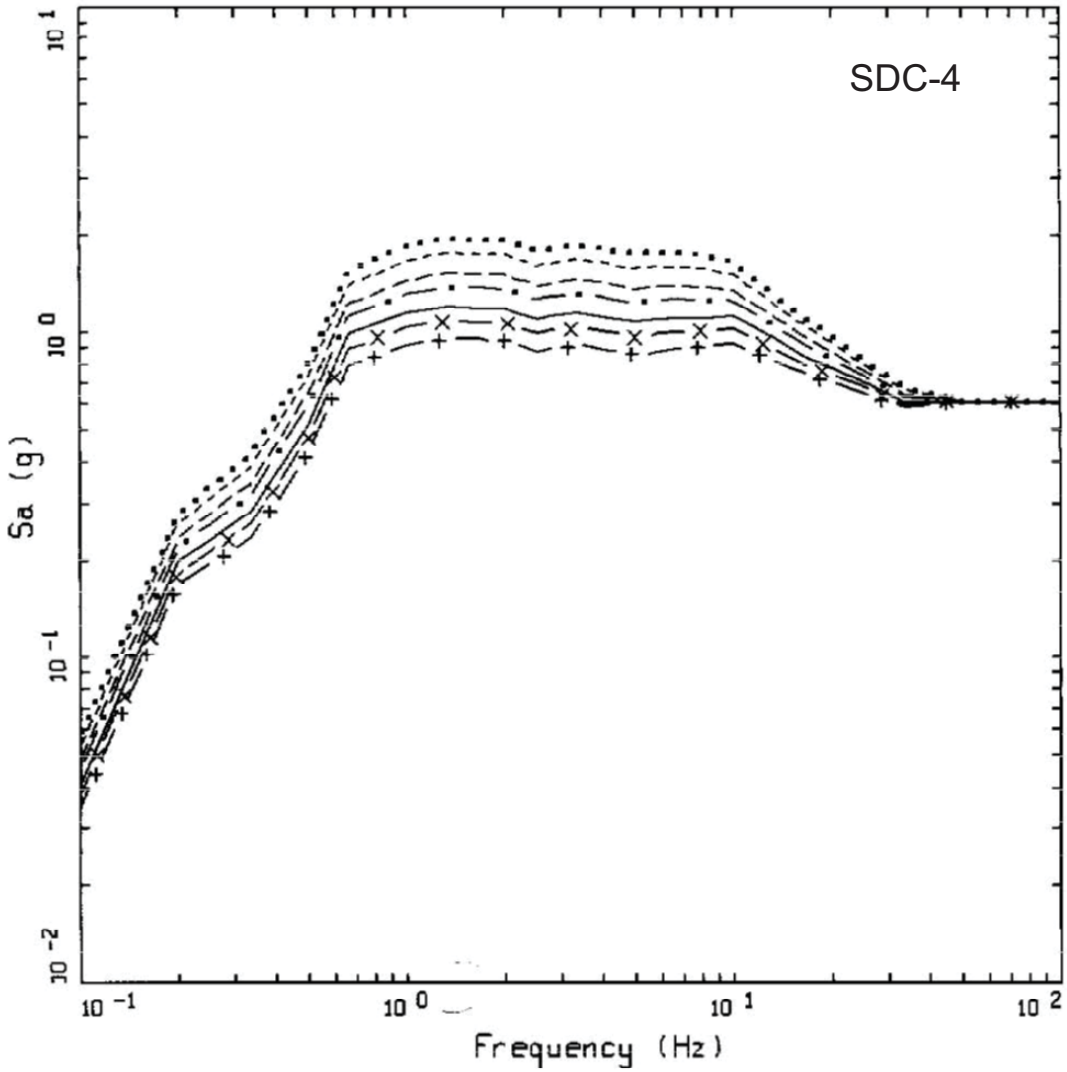


CMRR DRS SPECTRA, HORIZONTAL
SDC 3 (4X10-4), (M6.75)

LEGEND

••••	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— · —	3.0 % DAMPING
———	5.0 % DAMPING
— × —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	HORIZONTAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - CMRR	Figure 86a

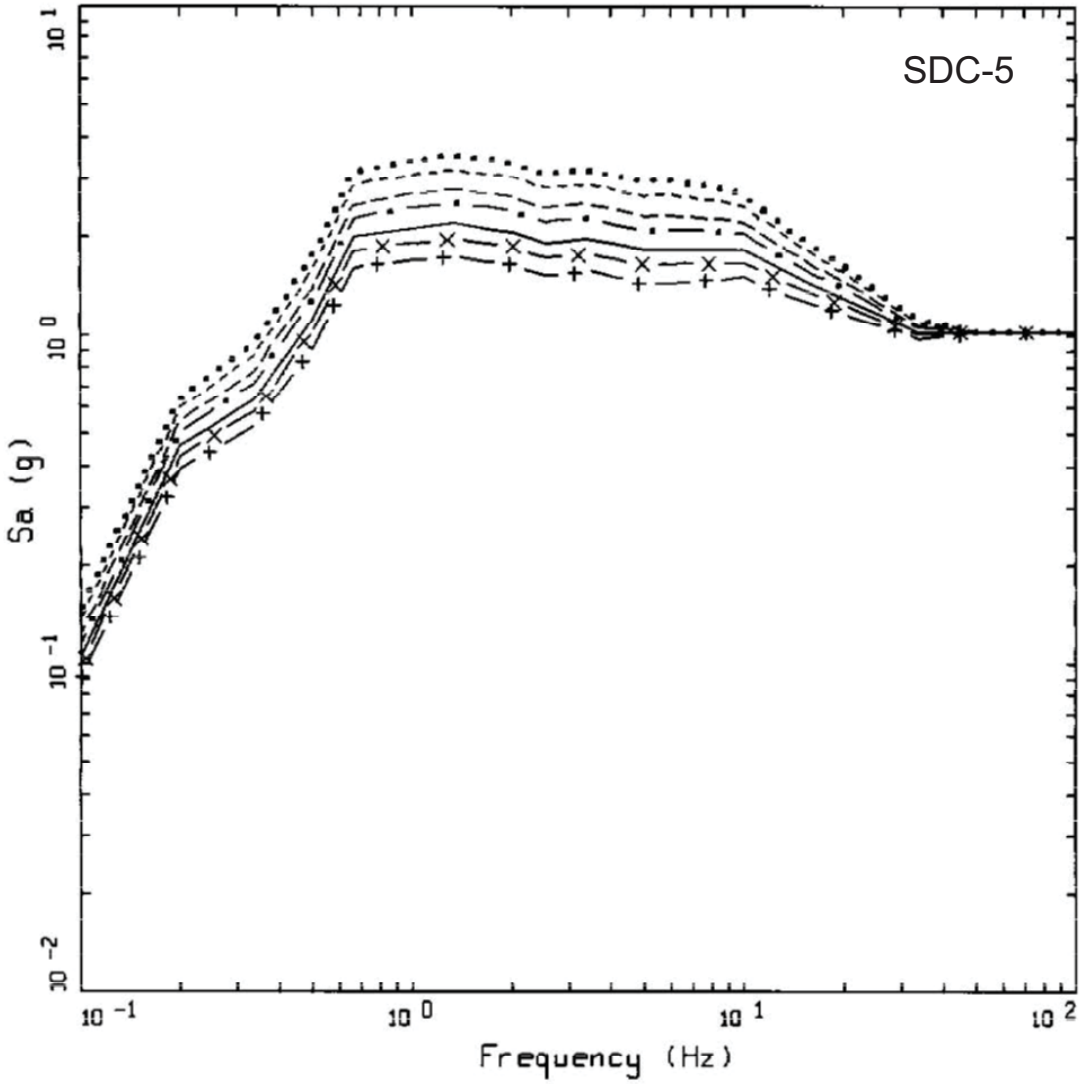


CMRR DRS SPECTRA, HORIZONTAL
SDC 4 (4X10-4), (M6.75)

LEGEND

- 0.5% DAMPING
- 1.0 % DAMPING
- 2.0 % DAMPING
- 3.0 % DAMPING
- 5.0 % DAMPING
- 7.0 % DAMPING
- 10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	HORIZONTAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - CMRR	Figure 86b

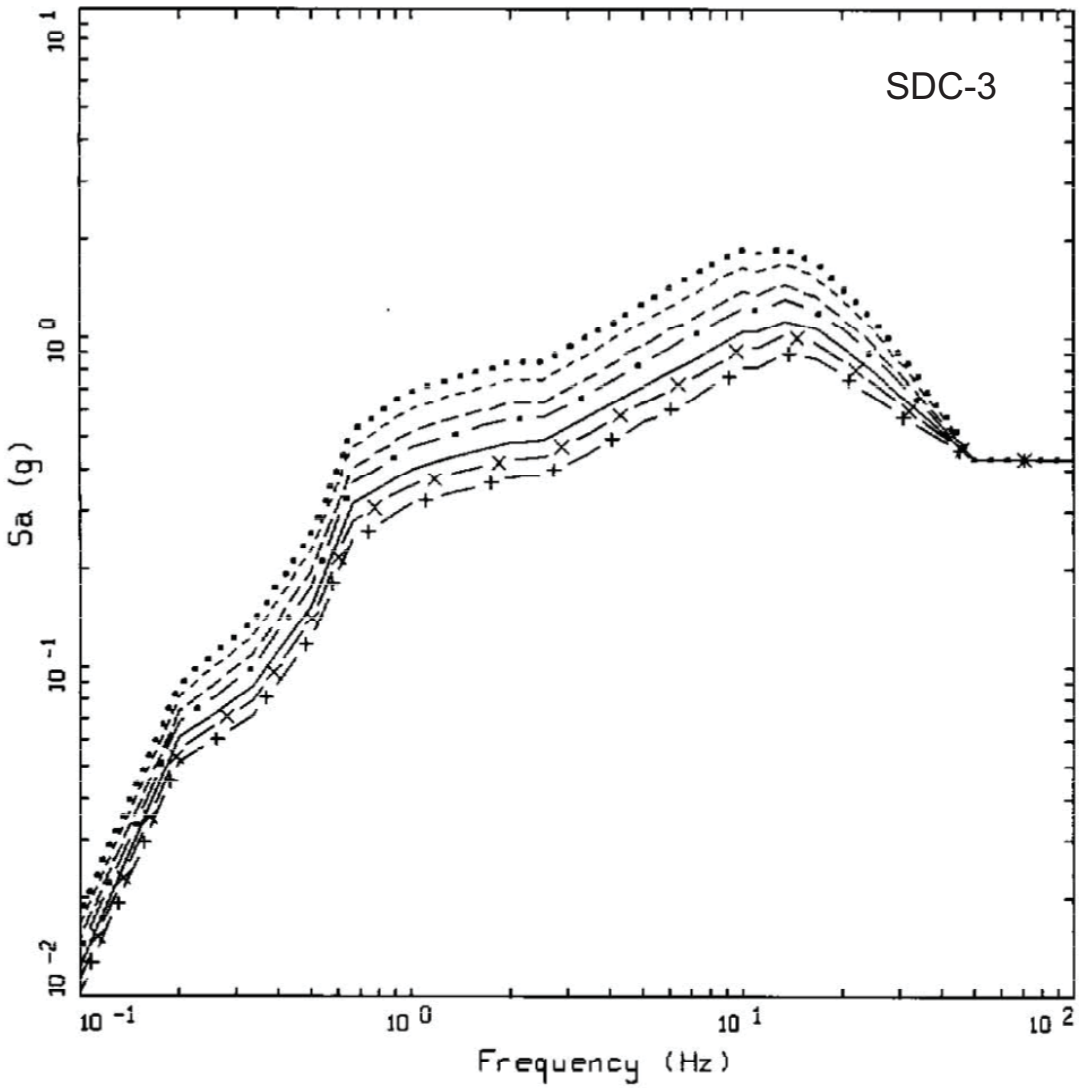


CMRR DRS SPECTRA, HORIZONTAL
SDC 5 (1X10-4), (M6.75)

LEGEND

- 0.5% DAMPING
- 1.0 % DAMPING
- 2.0 % DAMPING
- 3.0 % DAMPING
- 5.0 % DAMPING
- 7.0 % DAMPING
- 10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	HORIZONTAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - CMRR	Figure 86c

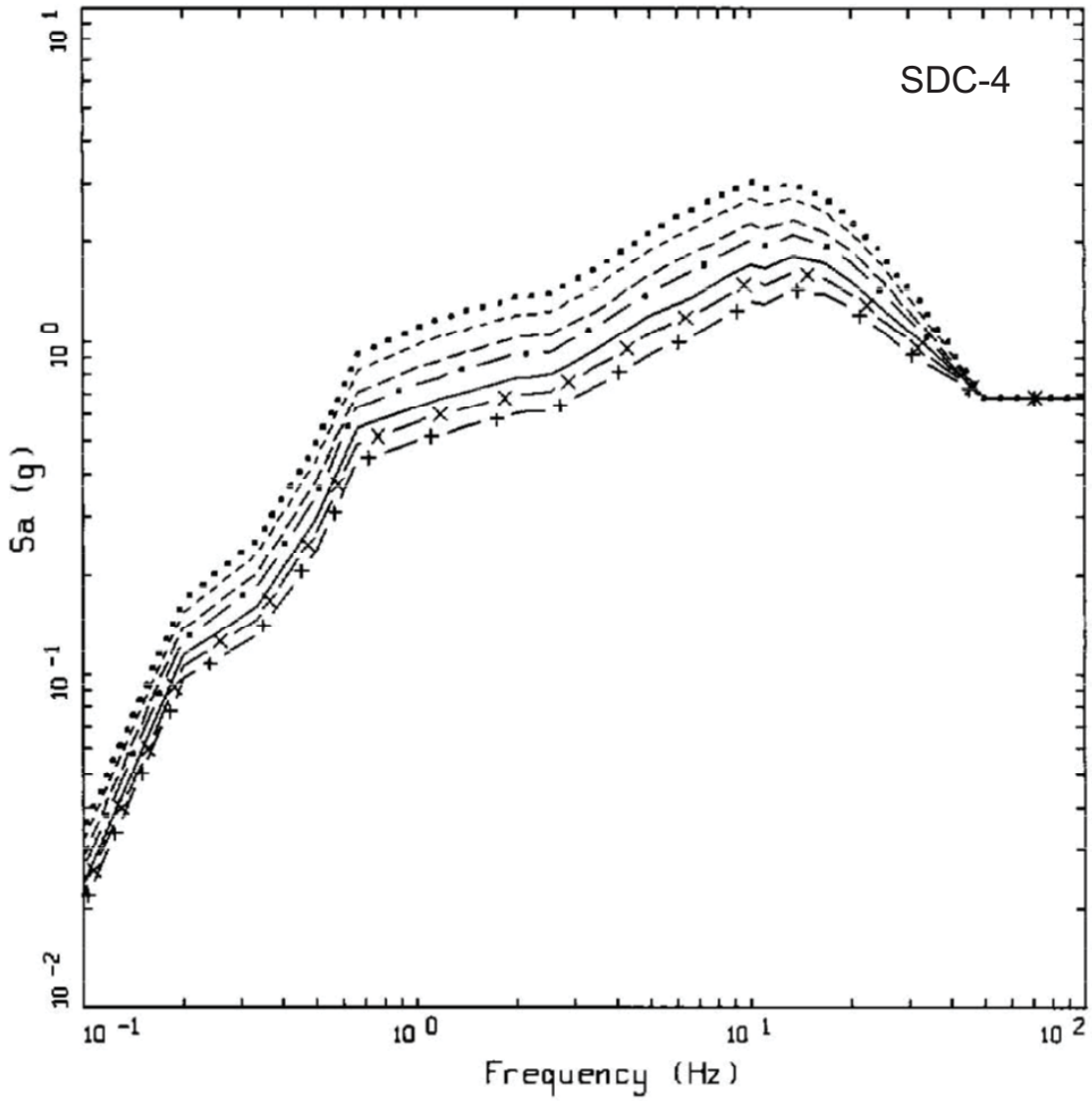


CMRR DRS SPECTRA, VERTICAL
SDC 3 (4X1D-4), (M6.75)

LEGEND

- 0.5% DAMPING
- 1.0 % DAMPING
- 2.0 % DAMPING
- 3.0 % DAMPING
- 5.0 % DAMPING
- 7.0 % DAMPING
- 10.0 % DAMPING

URS	Project No. 26817259	VERTICAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - CMRR	Figure 87a
	Los Alamos National Lab		

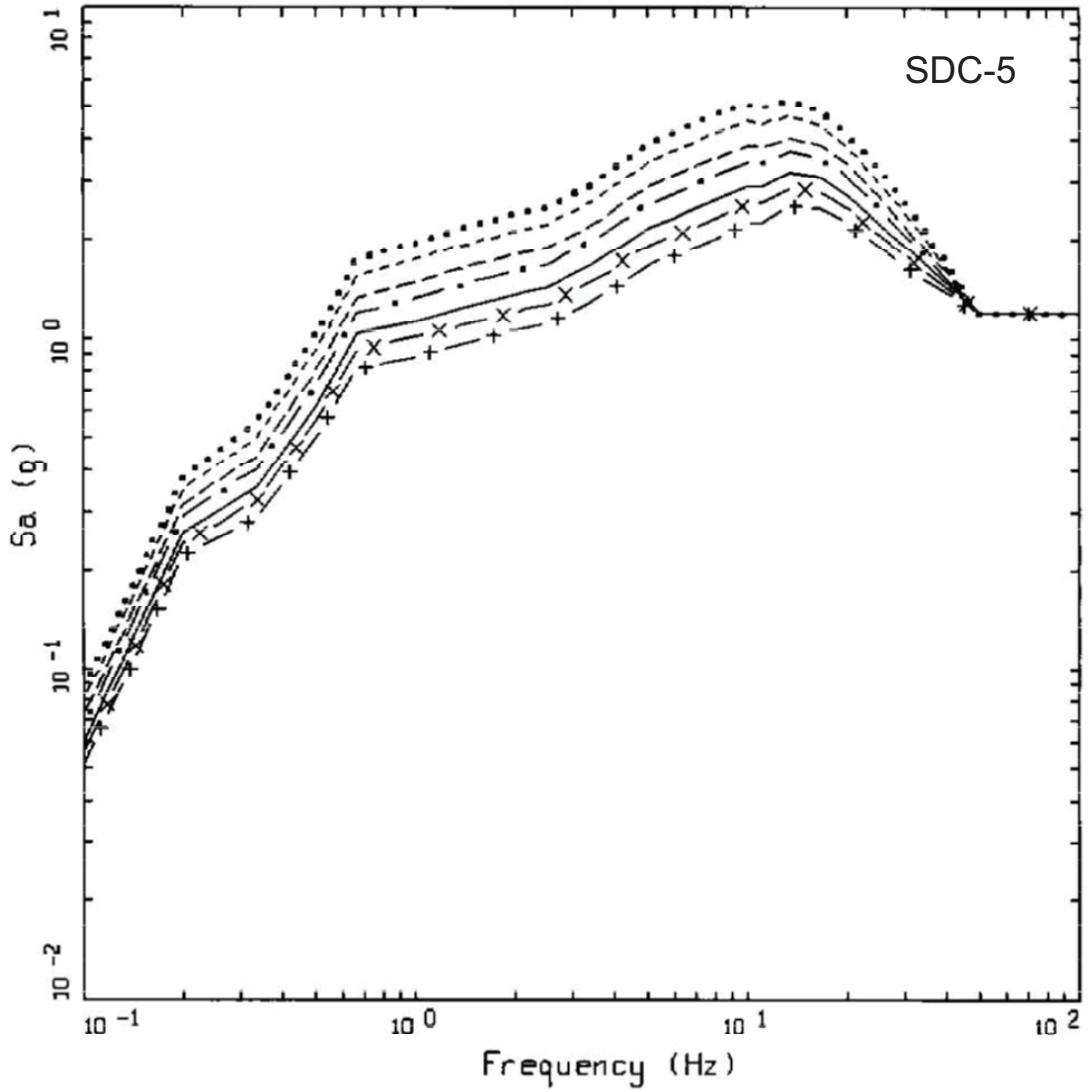


CMRR DRS SPECTRA, VERTICAL
SDC 4 (4X10-4), (M6.75)

LEGEND

••••	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— • —	3.0 % DAMPING
———	5.0 % DAMPING
— × —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - CMRR	Figure 87b

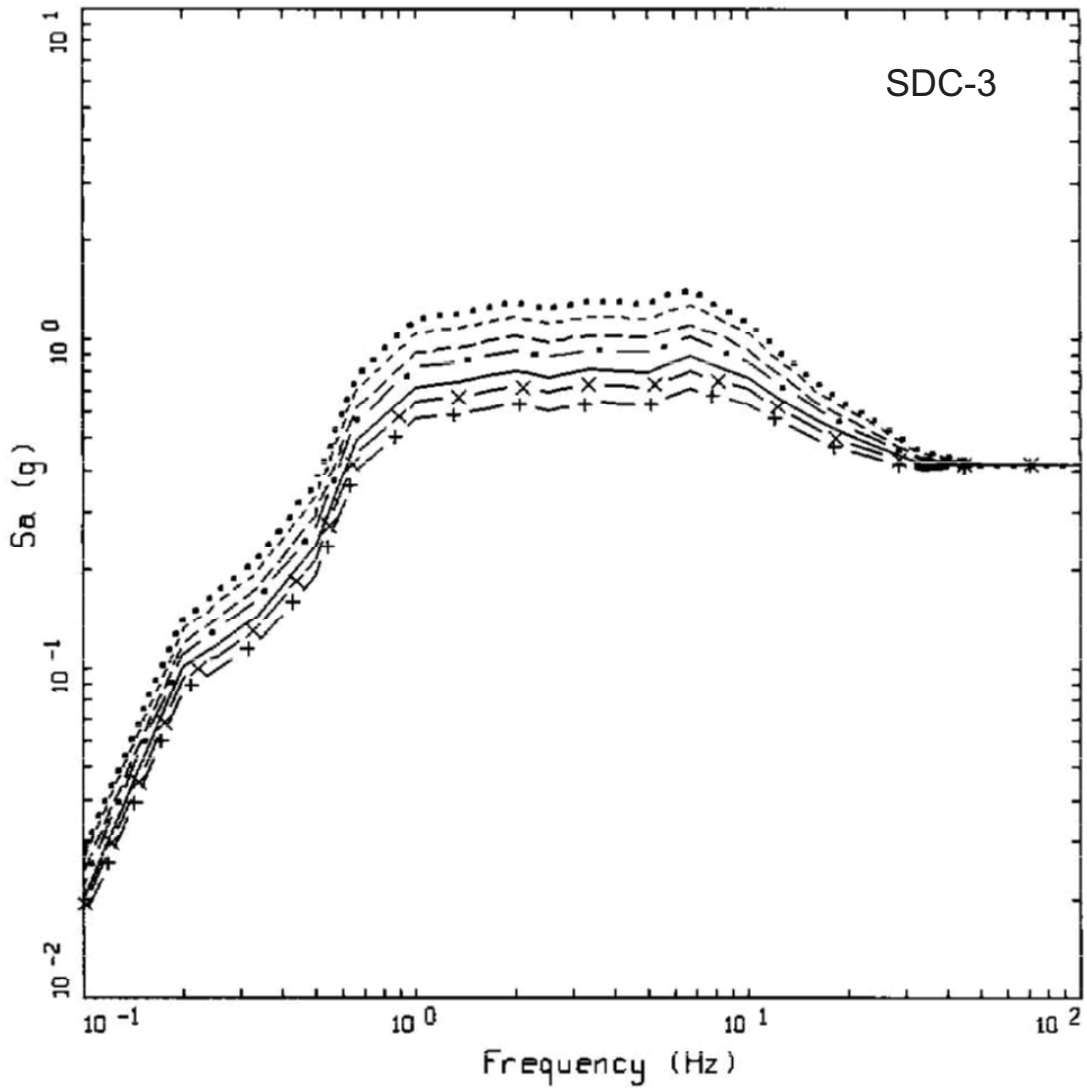


CMRR DRS SPECTRA, VERTICAL
SDC 5 (1X1D-4), (M6.75)

LEGEND

....	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— · —	3.0 % DAMPING
———	5.0 % DAMPING
— × —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - CMRR	Figure 87c

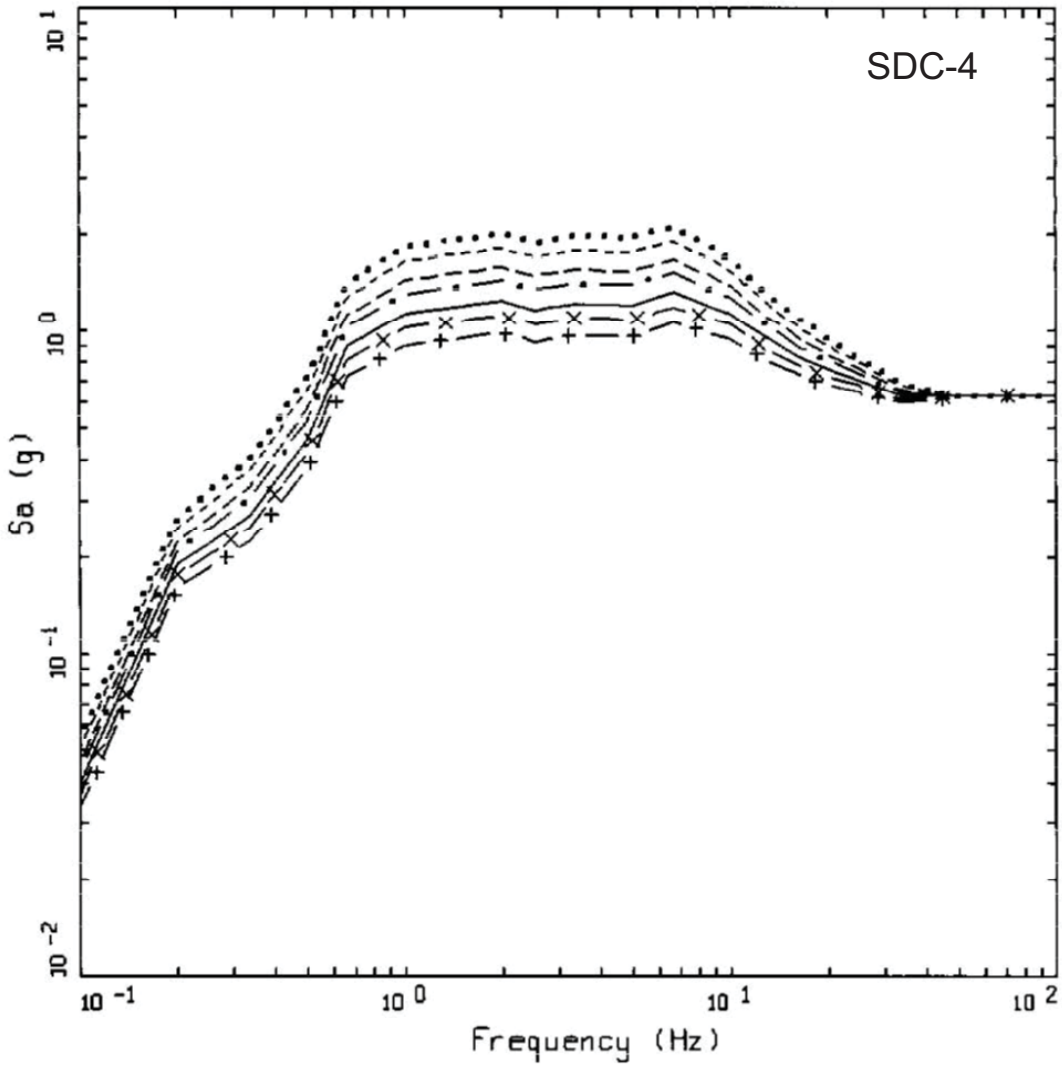


TA55 DRS SPECTRA, HORIZONTAL
SDC 3 (4X1D-4), (M6.75)

LEGEND

....	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— • —	3.0 % DAMPING
———	5.0 % DAMPING
— × —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	HORIZONTAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - TA-55	Figure 88a

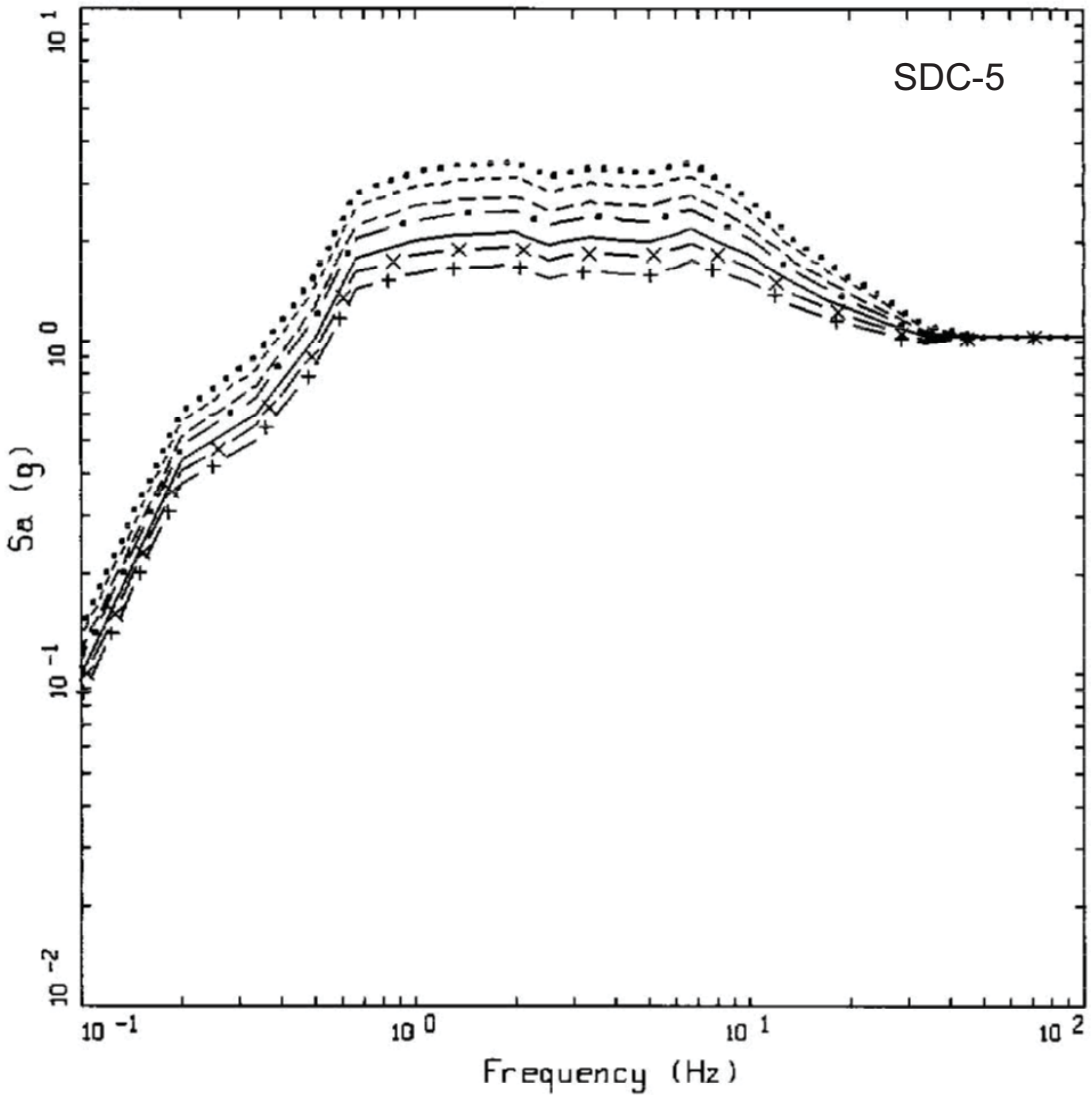


TA55 DRS SPECTRA, HORIZONTAL
SDC 4 (4X1D-4), (M6.75)

LEGEND

• • • •	0.5% DAMPING
- - - - -	1.0 % DAMPING
— — — —	2.0 % DAMPING
— • —	3.0 % DAMPING
———	5.0 % DAMPING
— × —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	HORIZONTAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - TA-55	Figure 88b

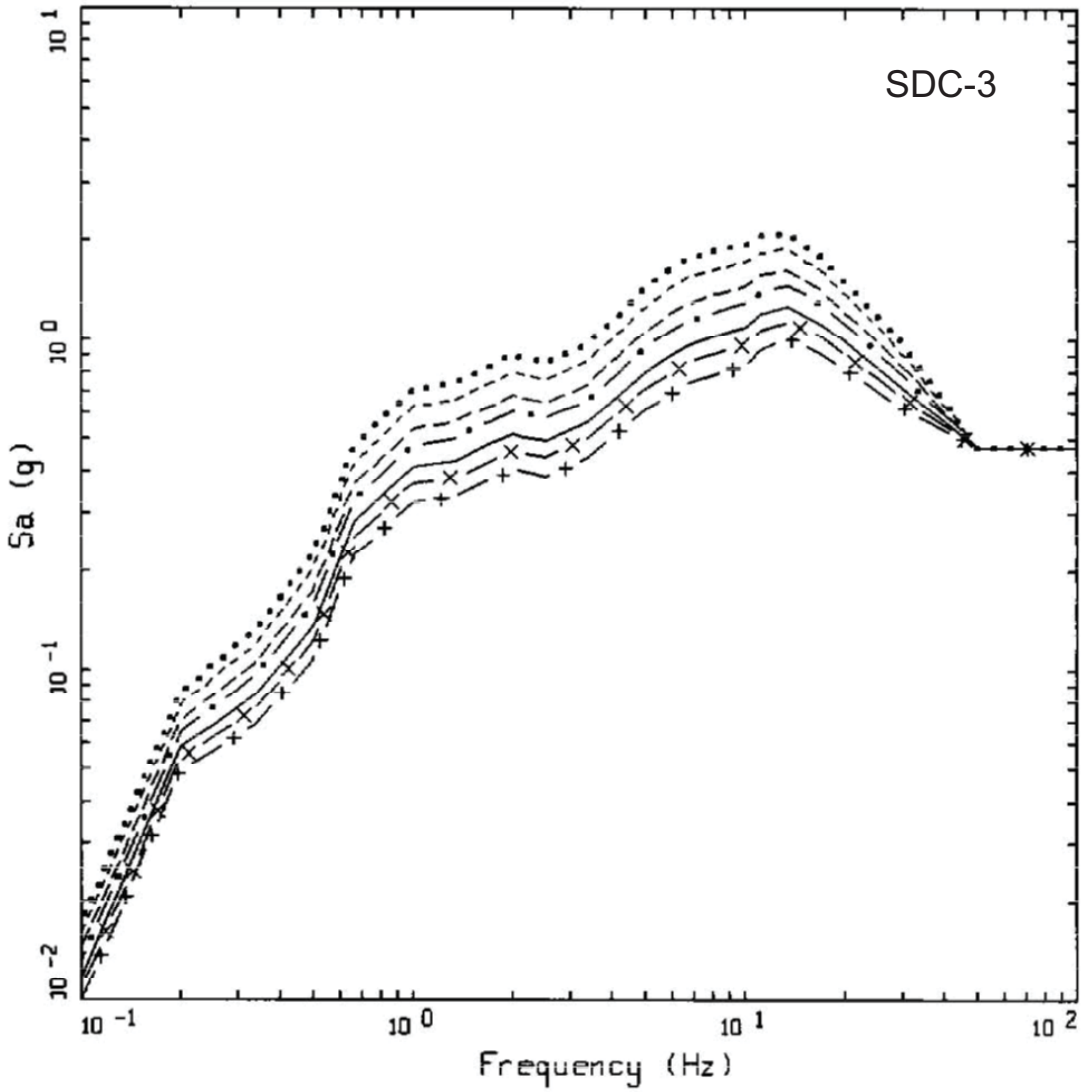


TA55 DRS SPECTRA, HORIZONTAL
SDC 5 (1X10-4), (M6.75)

LEGEND

••••	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— · —	3.0 % DAMPING
———	5.0 % DAMPING
— × —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	HORIZONTAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - TA-55	Figure 88c

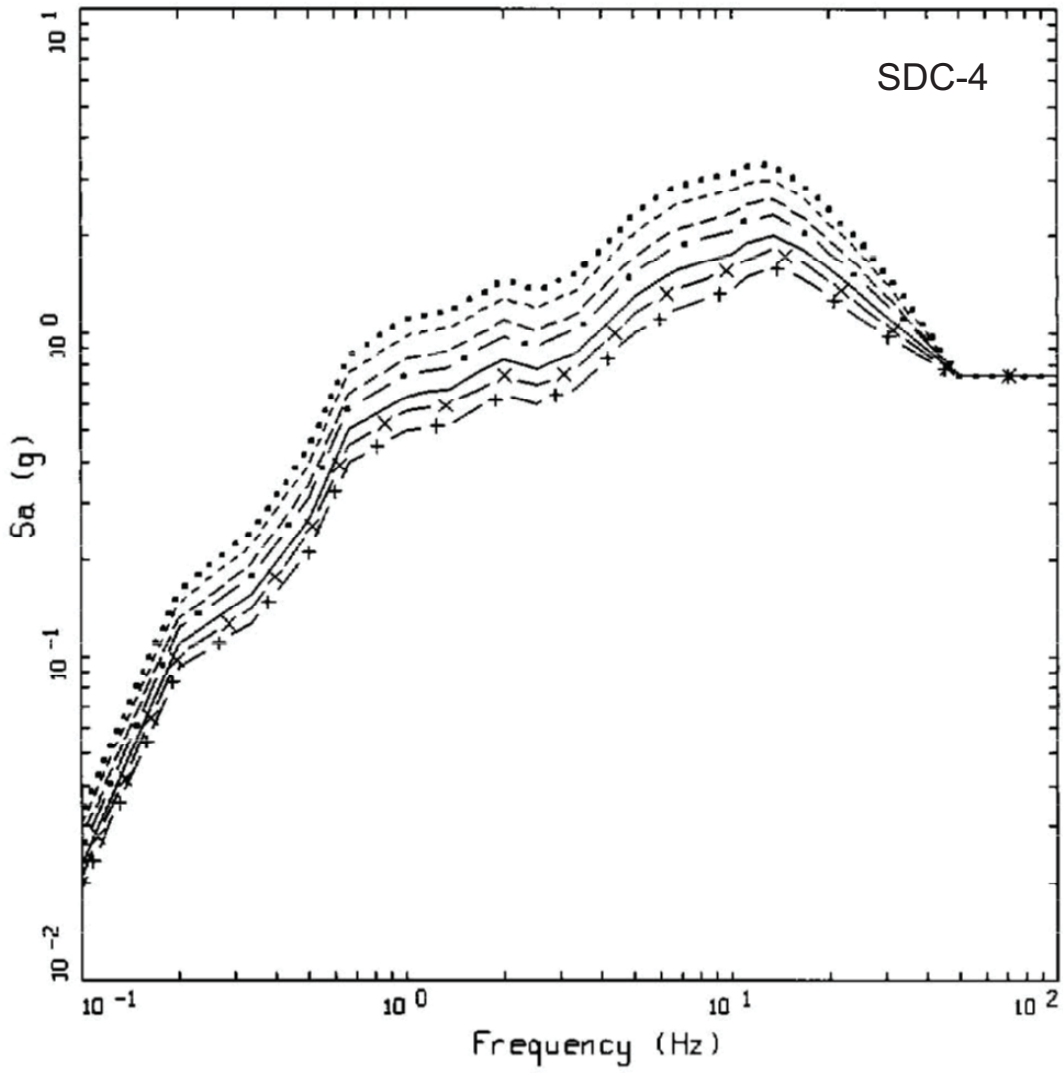


TA55 DRS SPECTRA, VERTICAL
SDC 3 (4X10-4), (M6.75)

LEGEND

....	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— · —	3.0 % DAMPING
———	5.0 % DAMPING
— × —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - TA-55	Figure 89a

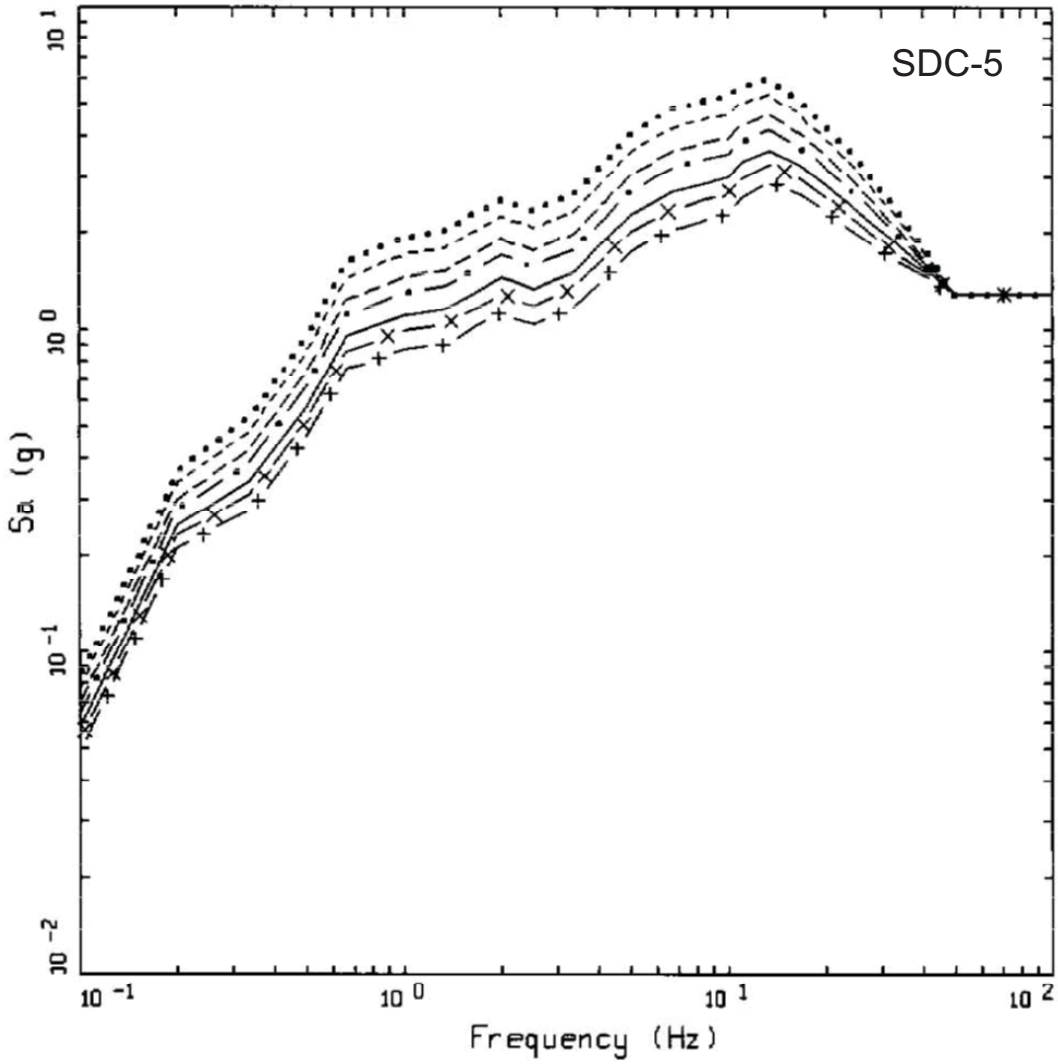


TA55 DRS SPECTRA, VERTICAL
SDC 4 (4X10-4), (M6.75)

LEGEND

••••	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— · —	3.0 % DAMPING
———	5.0 % DAMPING
— × —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - TA-55	Figure 89b

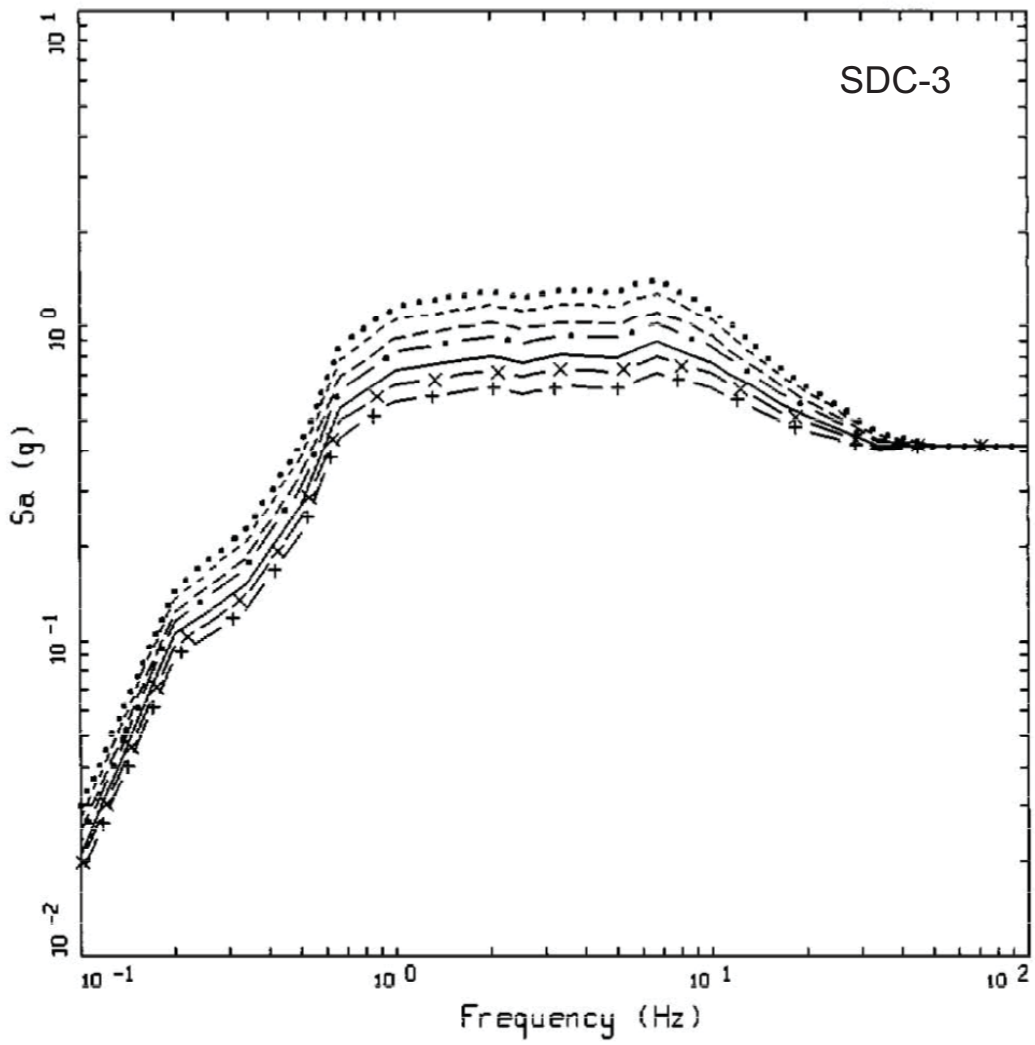


TA55 DRS SPECTRA, VERTICAL
SDC 5 (1X10-4), (M6.75)

LEGEND

• • • •	0.5% DAMPING
- - - - -	1.0 % DAMPING
— — — —	2.0 % DAMPING
— • —	3.0 % DAMPING
———	5.0 % DAMPING
— X —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - TA-55	Figure 89c

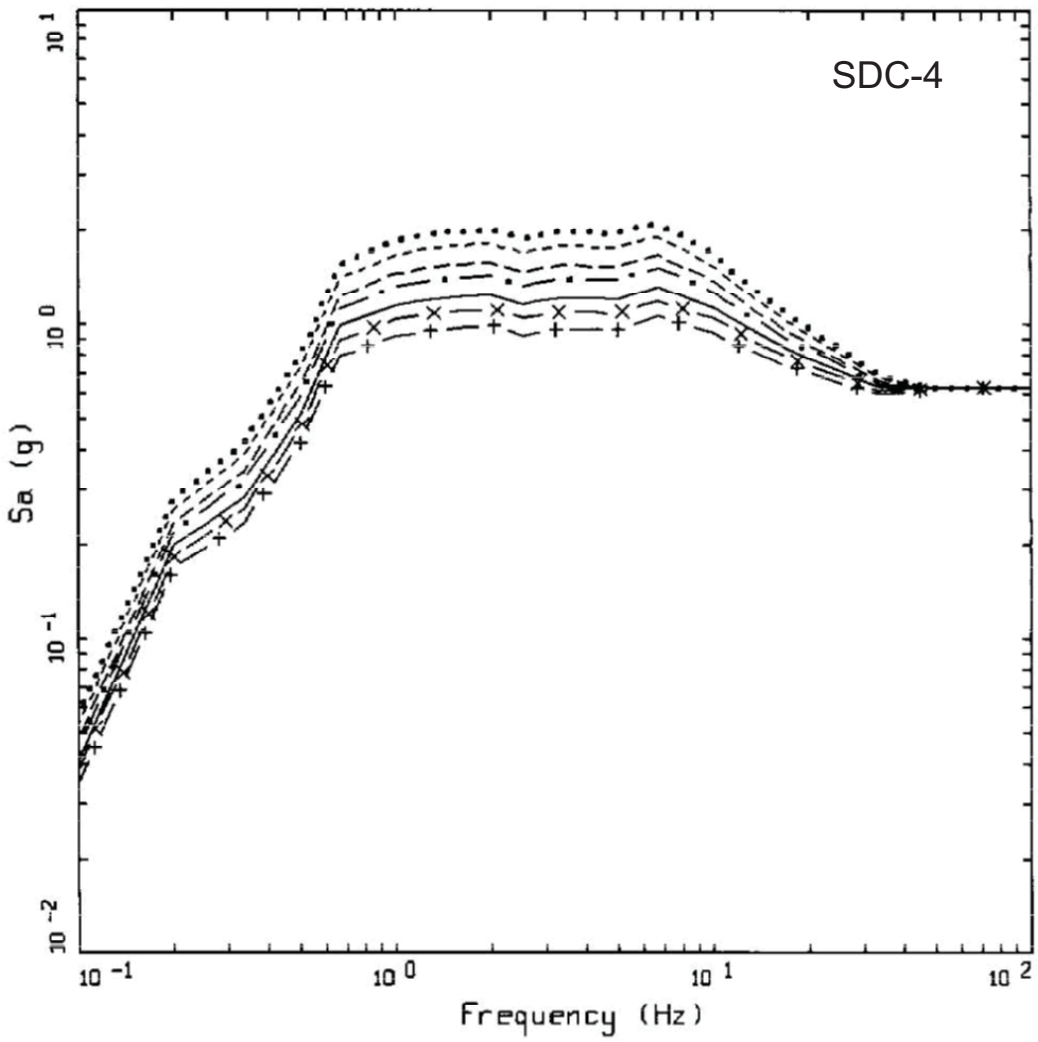


CMRR&TA55 ENVELOPE DRS SPECTRA, HORIZONTAL
SDC 3 (4X10-4), (M6.75)

LEGEND

- 0.5% DAMPING
- 1.0 % DAMPING
- 2.0 % DAMPING
- 3.0 % DAMPING
- 5.0 % DAMPING
- 7.0 % DAMPING
- 10.0 % DAMPING

URS	Project No. 26817259	HORIZONTAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - CMRR AND TA-55 ENVELOPE	Figure 90a
	Los Alamos National Lab		

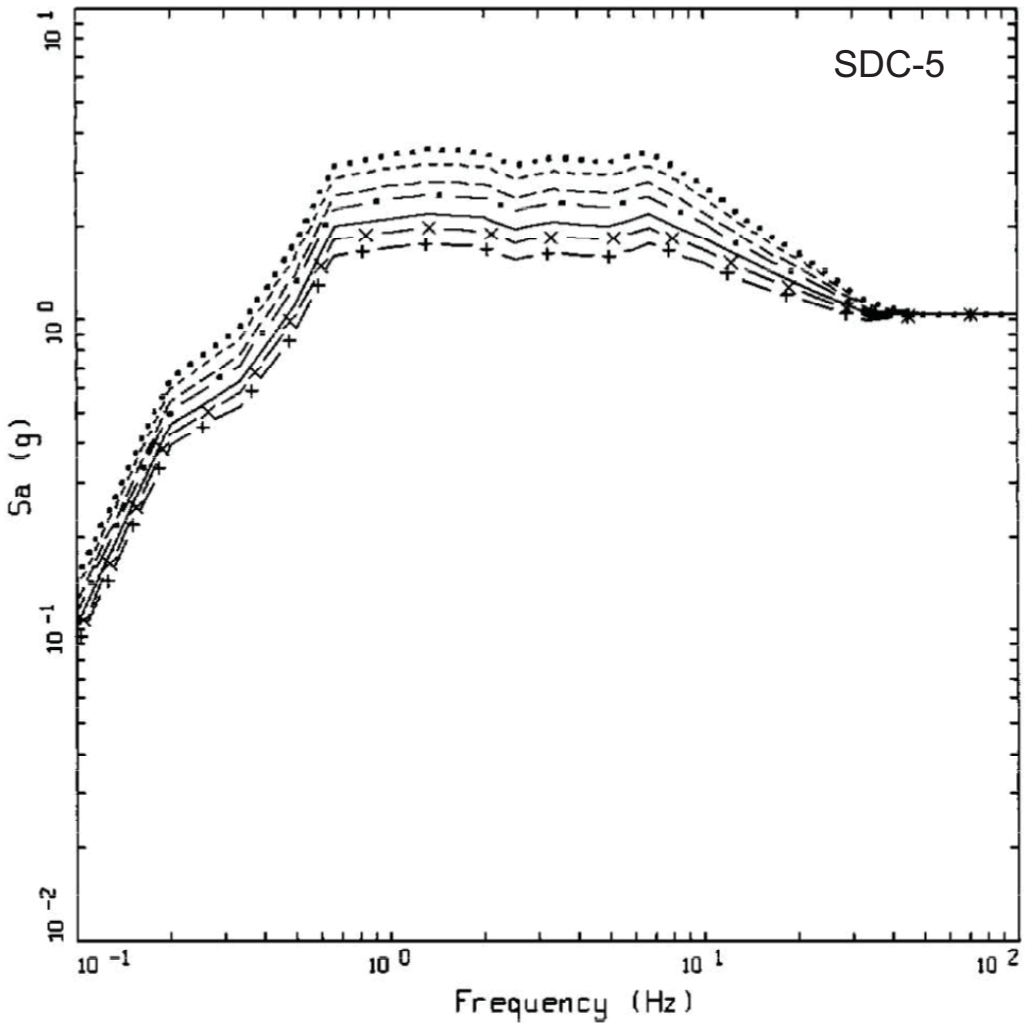


CMRR&TA55 ENVELOPE DRS SPECTRA, HORIZONTAL
SDC 4 (4X1D-4), (M6.75)

LEGEND

••••	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— · —	3.0 % DAMPING
———	5.0 % DAMPING
— × —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259	HORIZONTAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - CMRR AND TA-55 ENVELOPE	Figure 90b
	Los Alamos National Lab		

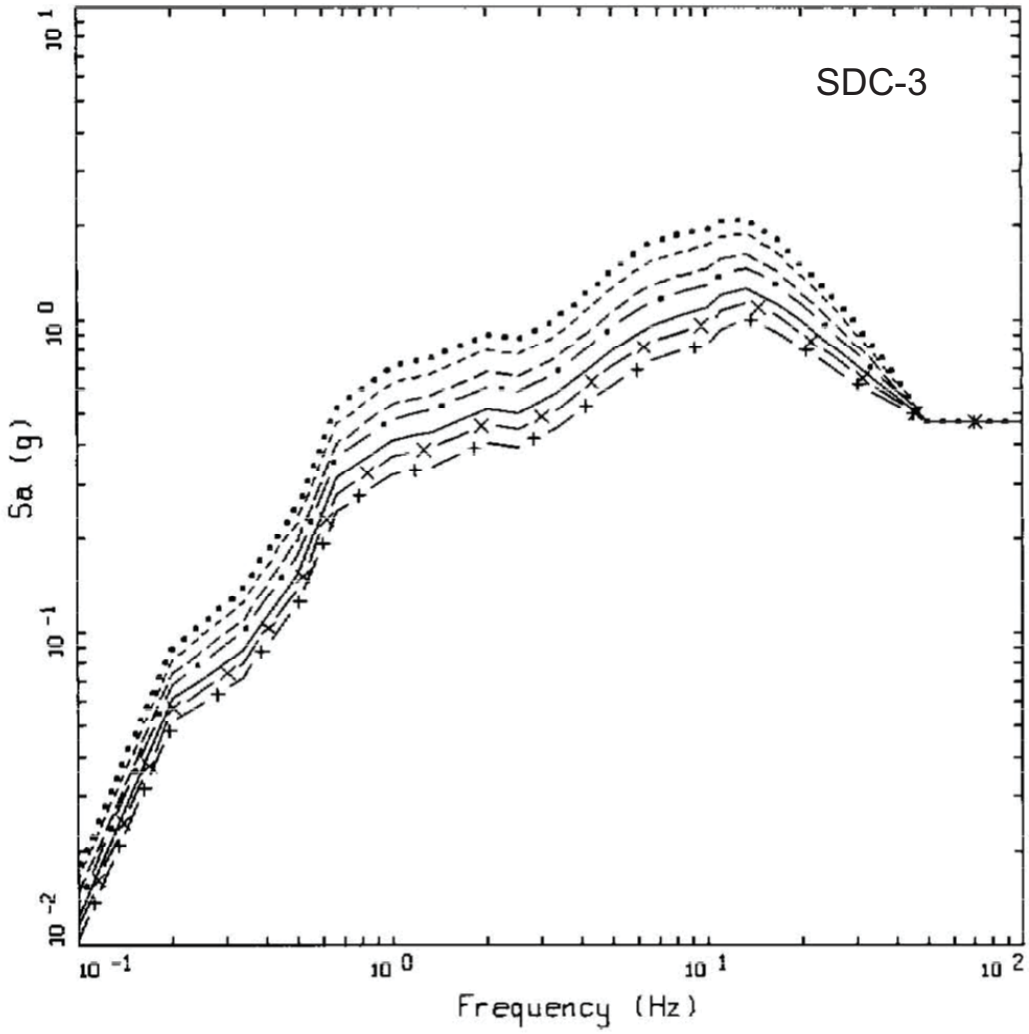


CMRR&TA55 ENVELOPE DRS SPECTRA, HORIZONTAL
SDC 5 (1X10-4), (M6.75)

LEGEND

....	0.5% DAMPING
-----	1.0 % DAMPING
----	2.0 % DAMPING
—·—	3.0 % DAMPING
———	5.0 % DAMPING
—×—	7.0 % DAMPING
—+—	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	HORIZONTAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - CMRR AND TA-55 ENVELOPE	Figure 90c

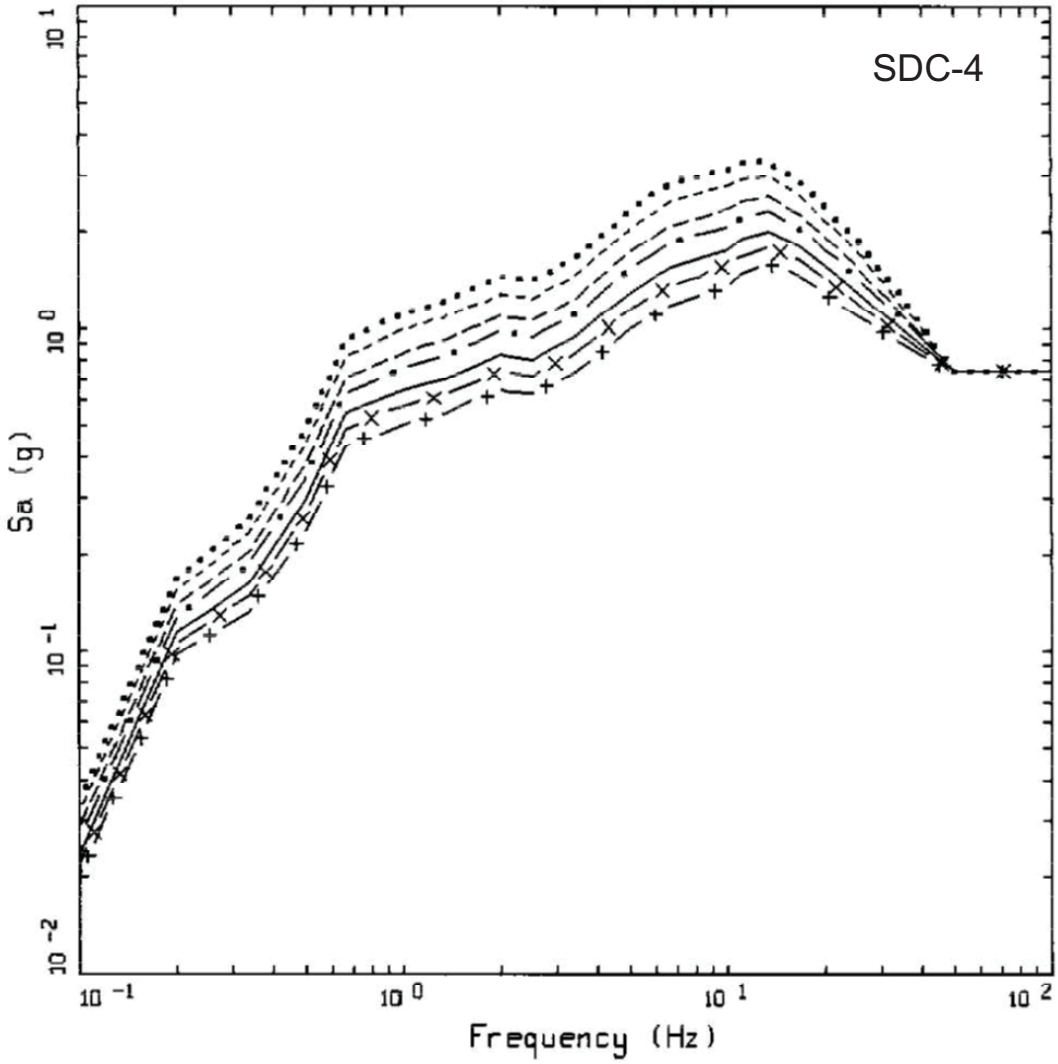


CMRR&TA55 ENVELOPE DRS SPECTRA, VERTICAL
SDC 3 (4X1D-4), (M6.75)

LEGEND

••••	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— • —	3.0 % DAMPING
———	5.0 % DAMPING
—×—	7.0 % DAMPING
—+—	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - CMRR AND TA-55 ENVELOPE	Figure 91a

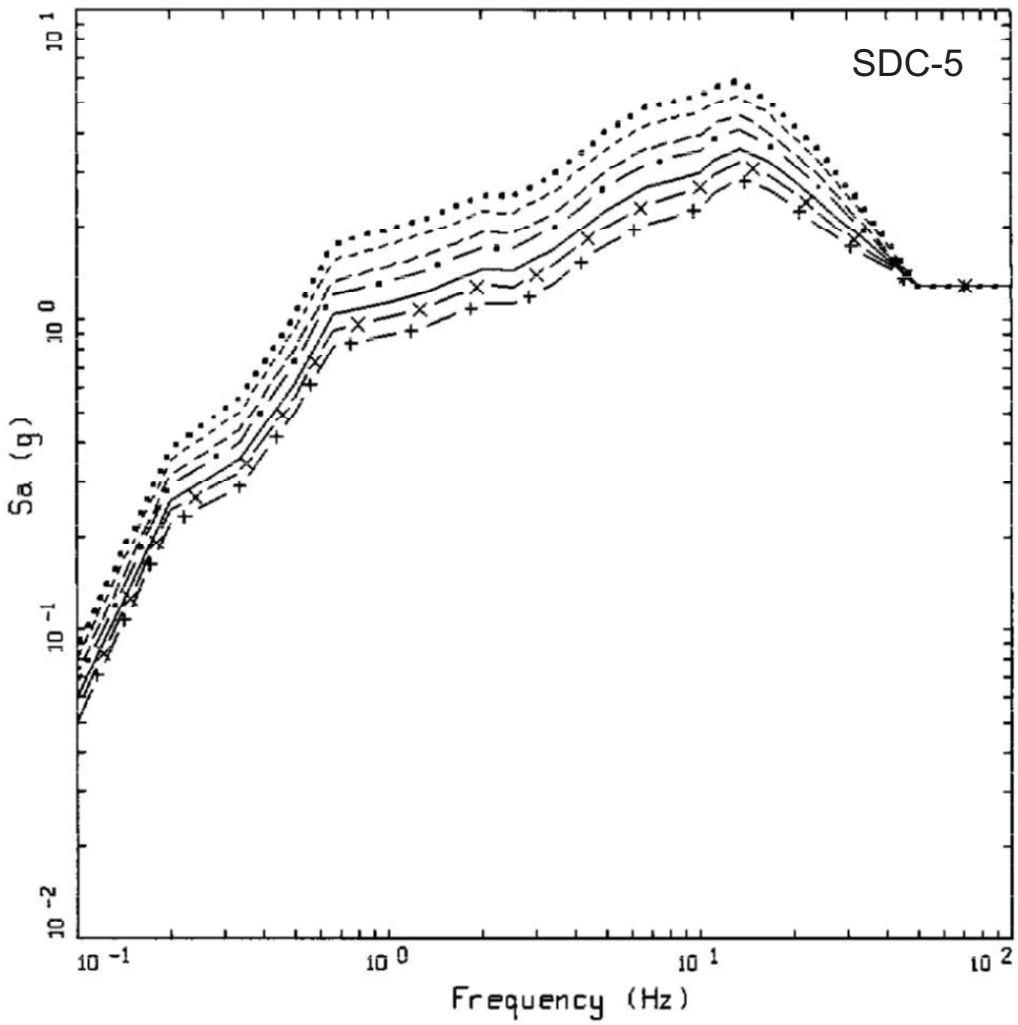


CMRR&TA55 ENVELOPE DRS SPECTRA, VERTICAL
SDC 4 (4X10-4), (M6.75)

LEGEND

• • • •	0.5% DAMPING
- - - - -	1.0 % DAMPING
— — — -	2.0 % DAMPING
— • —	3.0 % DAMPING
———	5.0 % DAMPING
— × —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - CMRR AND TA-55 ENVELOPE	Figure 91b

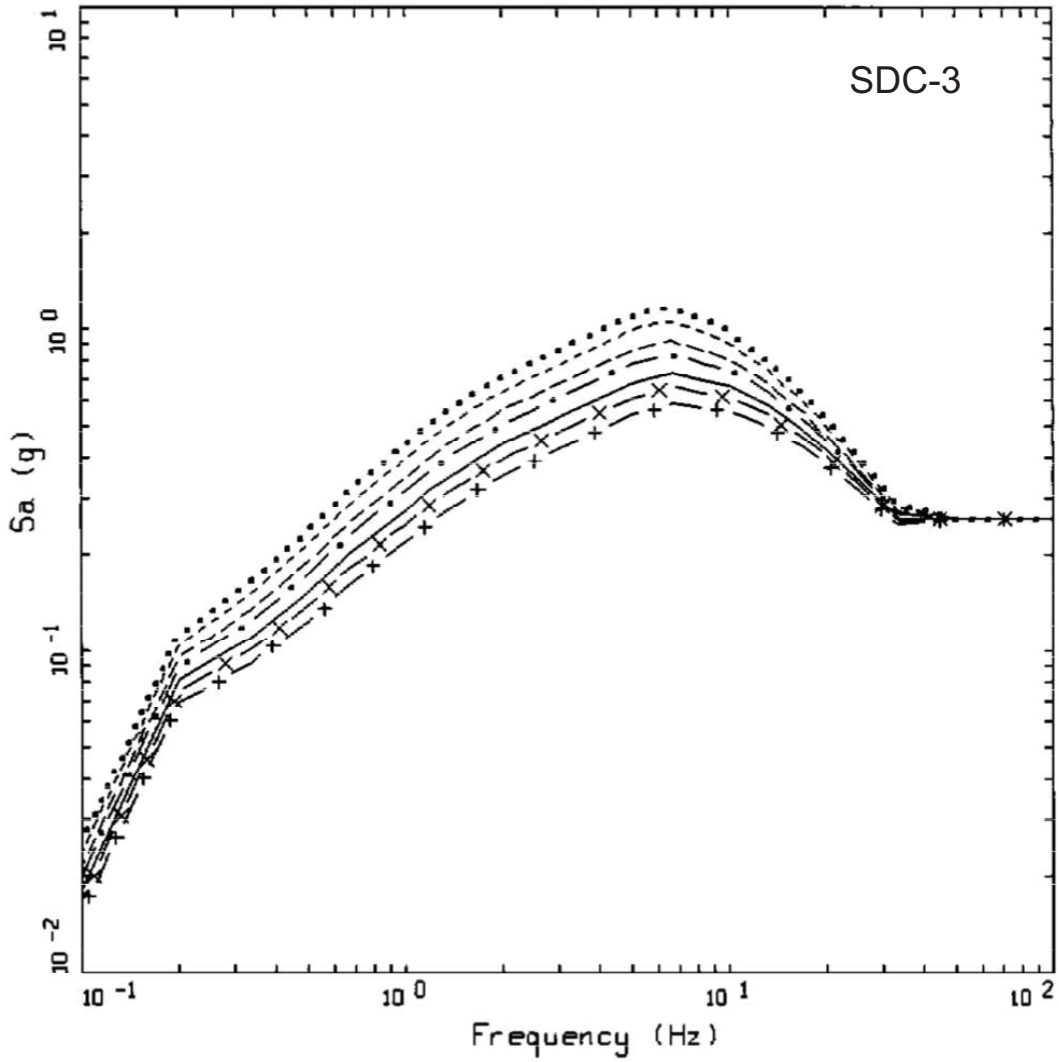


CMRR&TA55 ENVELOPE DRS SPECTRA, VERTICAL
SDC 5 (1X1D-4), (M6.75)

LEGEND

....	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— · —	3.0 % DAMPING
———	5.0 % DAMPING
—×—	7.0 % DAMPING
—+—	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - CMRR AND TA-55 ENVELOPE	Figure 91c

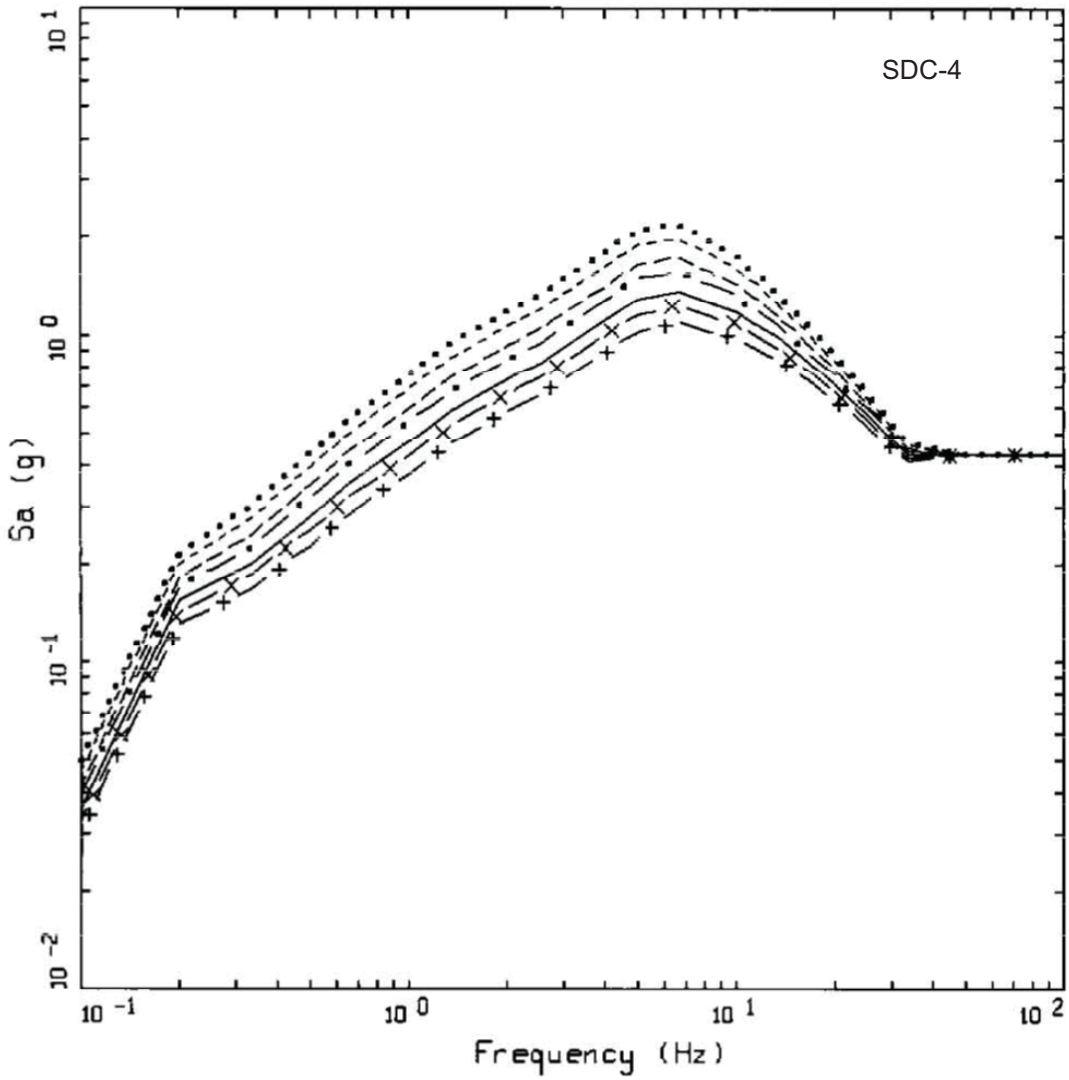


DACITE DRS SPECTRA, HORIZONTAL
SDC 3 (4X10-4), (M6.75)

LEGEND

• • • •	0.5% DAMPING
- - - - -	1.0 % DAMPING
— — — -	2.0 % DAMPING
— • —	3.0 % DAMPING
———	5.0 % DAMPING
— × —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	HORIZONTAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - DACITE WITH TOPOGRAPHIC AMPLIFICATION	Figure 92a

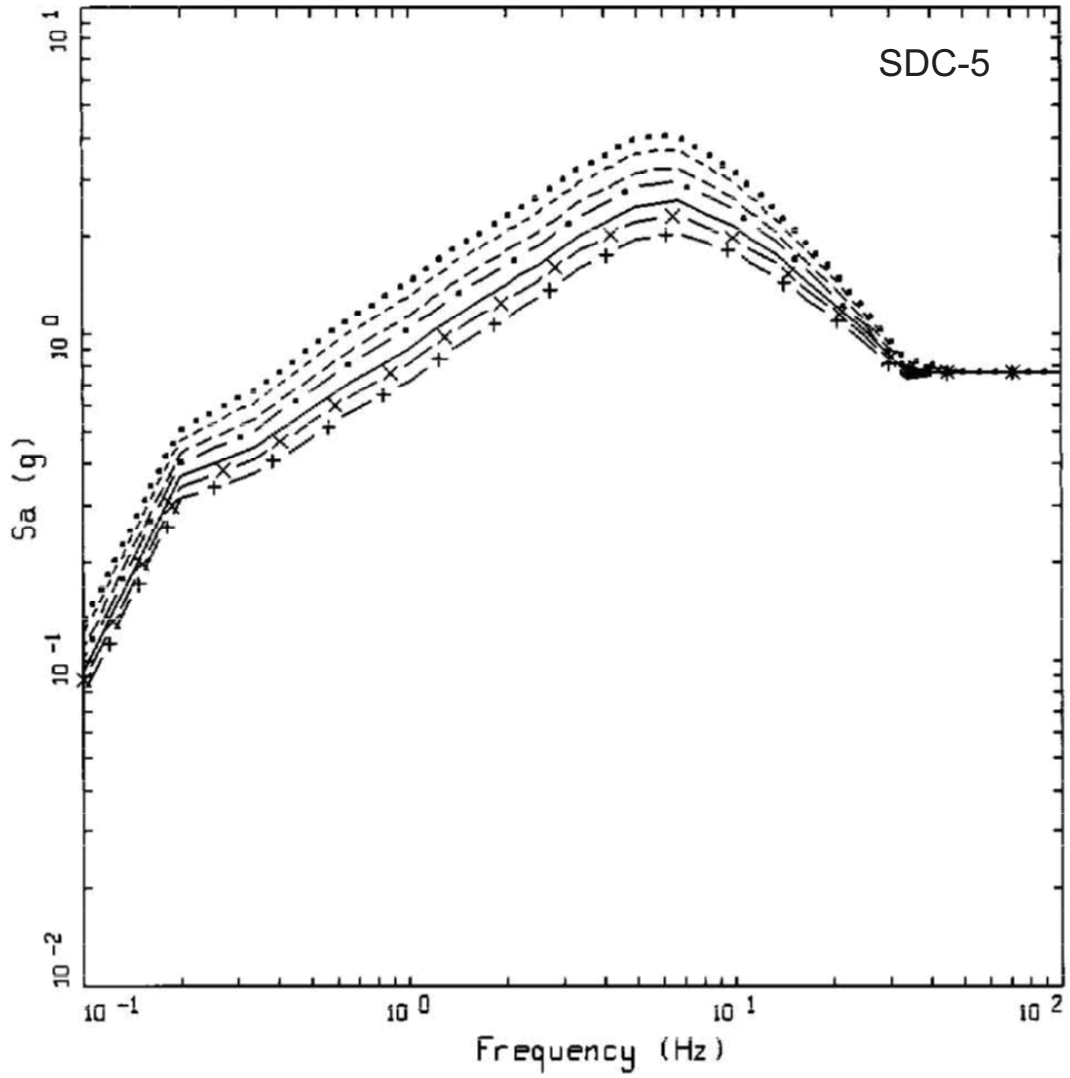


DACITE DRS SPECTRA, HORIZONTAL
SDC 4 (4X10-4), (M6.75)

LEGEND

- 0.5% DAMPING
- 1.0 % DAMPING
- 2.0 % DAMPING
- 3.0 % DAMPING
- 5.0 % DAMPING
- 7.0 % DAMPING
- 10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	HORIZONTAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - DACITE WITH TOPOGRAPHIC AMPLIFICATION	Figure 92b

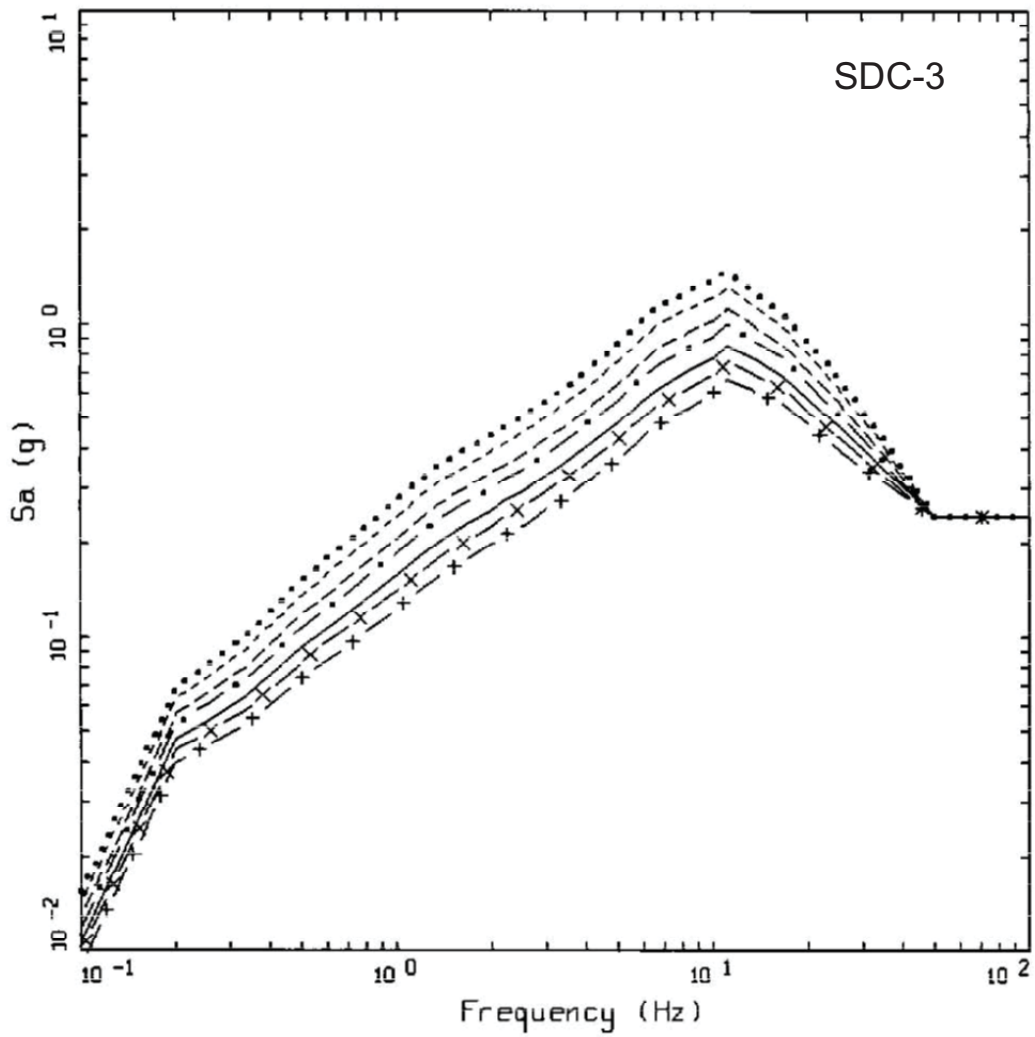


DACITE DRS SPECTRA, HORIZONTAL
SDC 5 (1X1D-4), (M6.75)

LEGEND

....	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— · —	3.0 % DAMPING
———	5.0 % DAMPING
— X —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	HORIZONTAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - DACITE WITH TOPOGRAPHIC AMPLIFICATION	Figure 92c

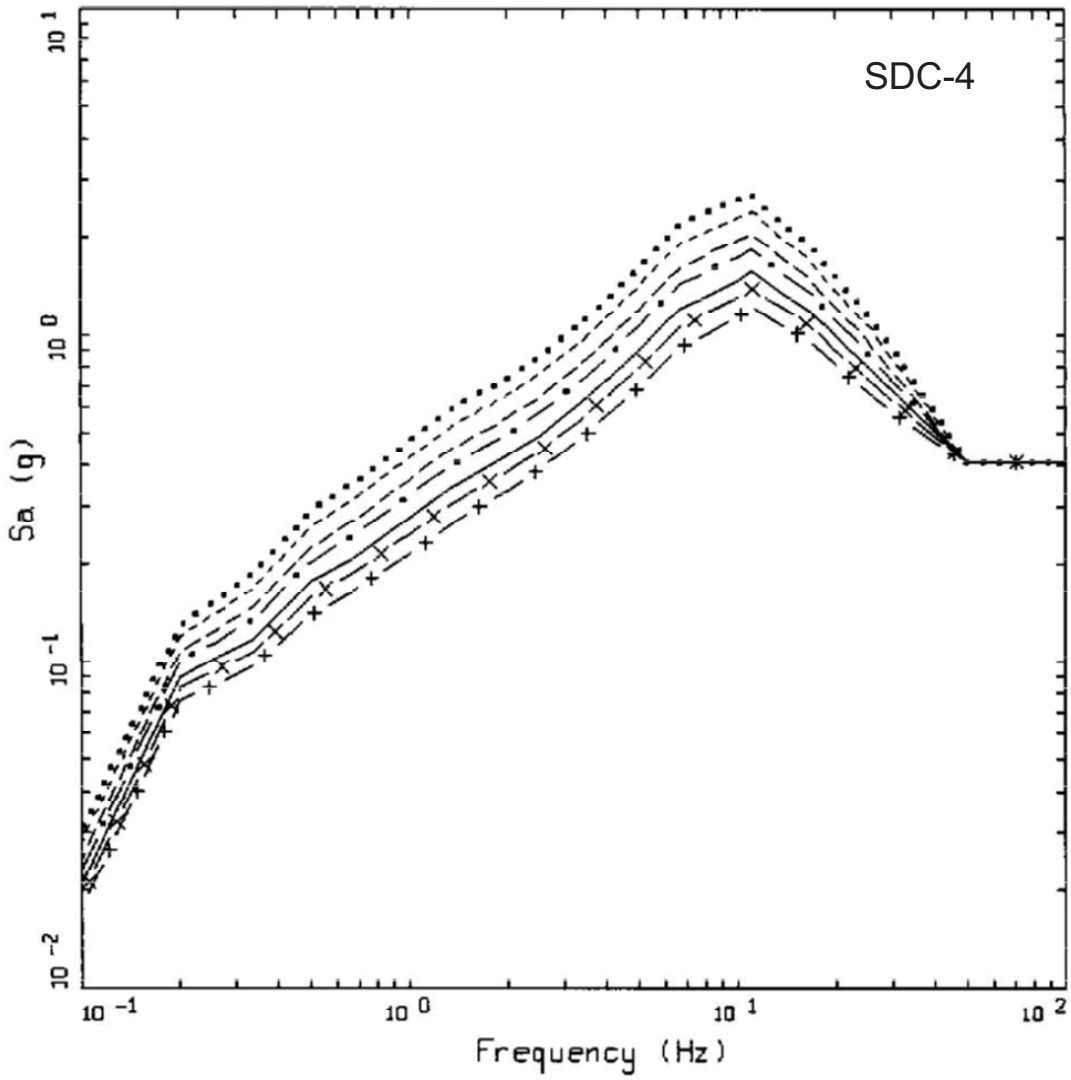


DACITE DRS SPECTRA, VERTICAL
SDC 3 (4X10-4), (M6.75)

LEGEND

....	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— · —	3.0 % DAMPING
———	5.0 % DAMPING
— X —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - DACITE WITH TOPOGRAPHIC AMPLIFICATION	Figure 93a

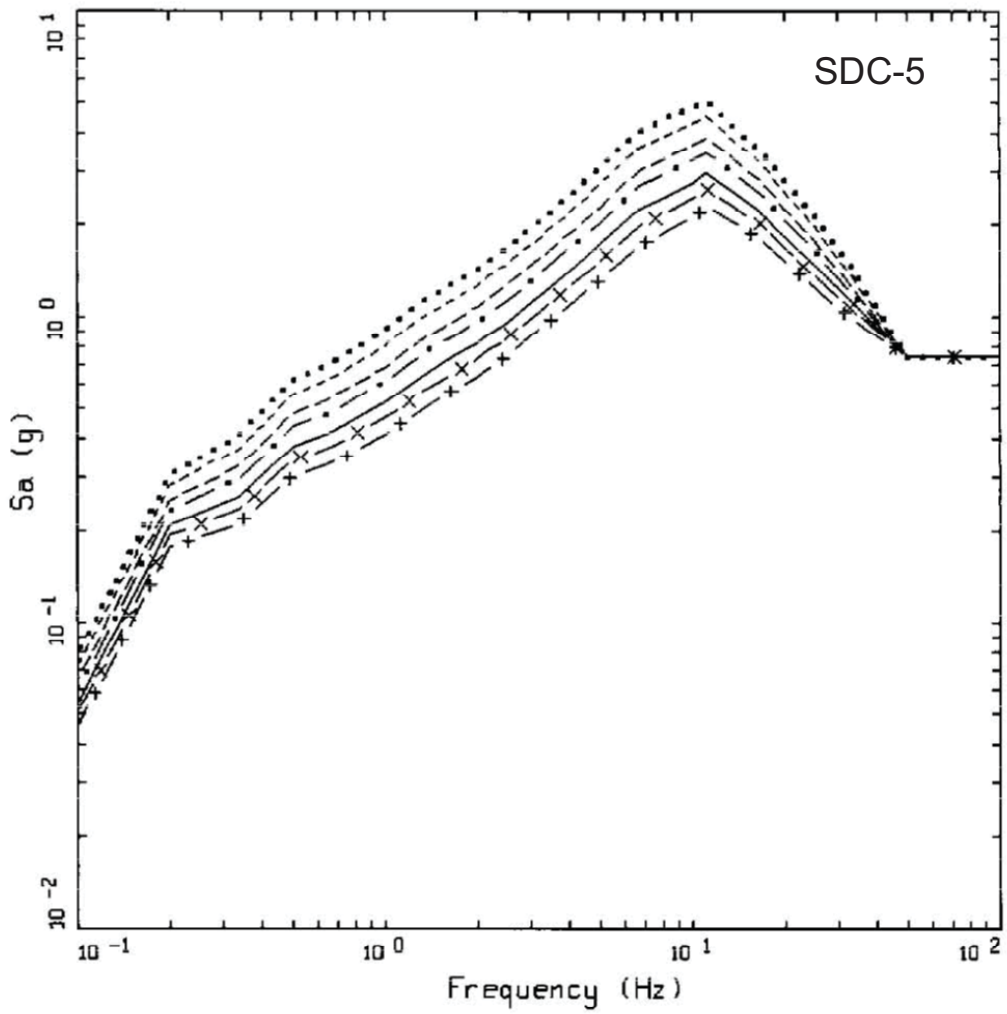


DACITE DRS SPECTRA, VERTICAL
SDC 4 (4X1D-4), (M6.75)

LEGEND

- 0.5% DAMPING
- 1.0 % DAMPING
- 2.0 % DAMPING
- 3.0 % DAMPING
- 5.0 % DAMPING
- 7.0 % DAMPING
- 10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - DACITE WITH TOPOGRAPHIC AMPLIFICATION	Figure 93b

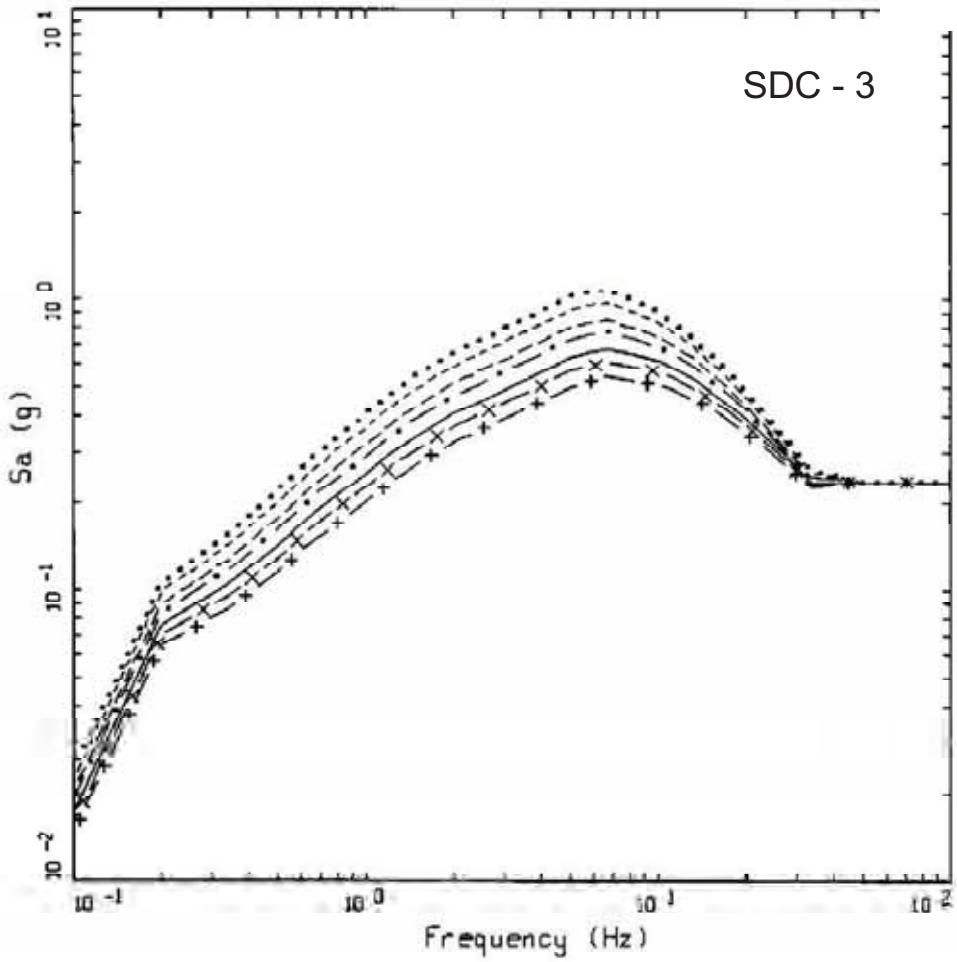


DACITE DRS SPECTRA, VERTICAL
SDC 5 (1X10-4), (M6.75)

LEGEND

- 0.5% DAMPING
- 1.0 % DAMPING
- 2.0 % DAMPING
- 3.0 % DAMPING
- 5.0 % DAMPING
- 7.0 % DAMPING
- 10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC- 3, 4, AND 5 AT MULTIPLE DAMPINGS - DACITE WITH TOPOGRAPHIC AMPLIFICATION	Figure 93c

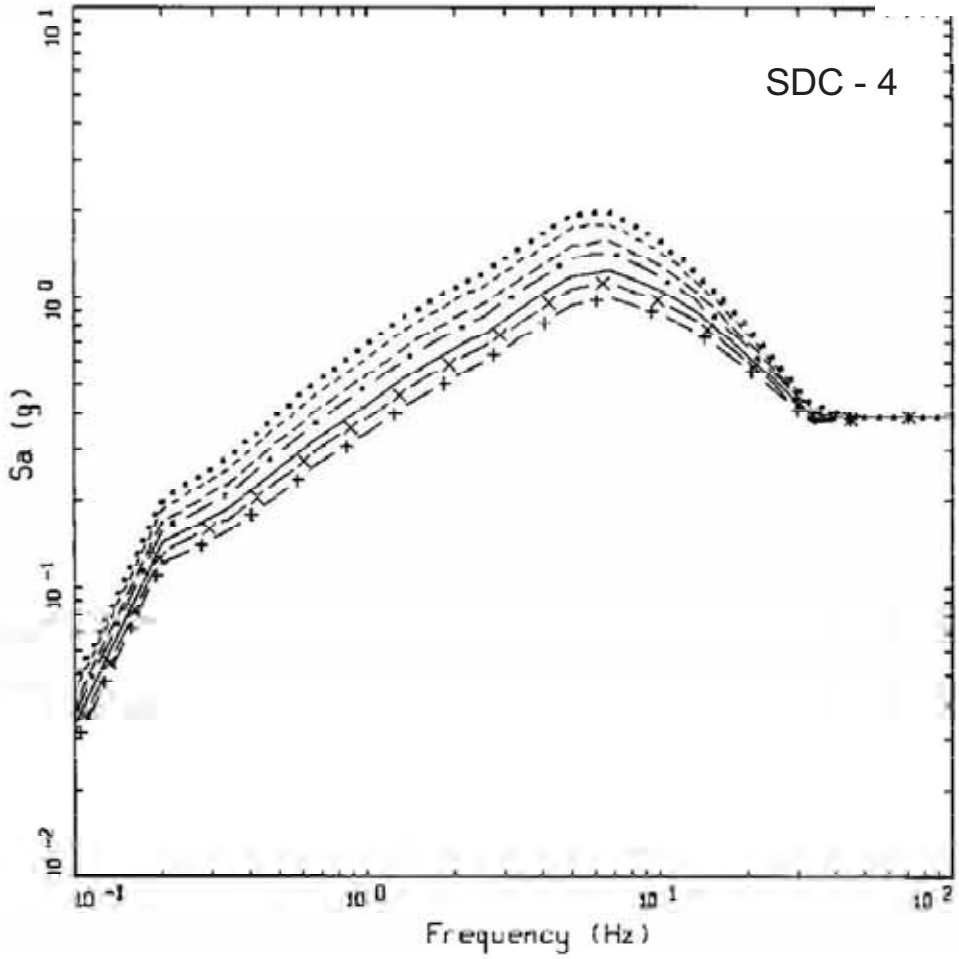


DACITE DRS SPECTRA, HORIZONTAL (NO TOPO)
SDC 3 (4X1D-4), (M6.75)

LEGEND

- 0.5% DAMPING
- 1.0 % DAMPING
- 2.0 % DAMPING
- 3.0 % DAMPING
- 5.0 % DAMPING
- 7.0 % DAMPING
- 10.0 % DAMPING

URS	Project No. 26817259	HORIZONTAL DRS FOR SDC - 3, 4, AND 5 AT MULTIPLE DAMPINGS - DACITE WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 94a
	Los Alamos National Lab		

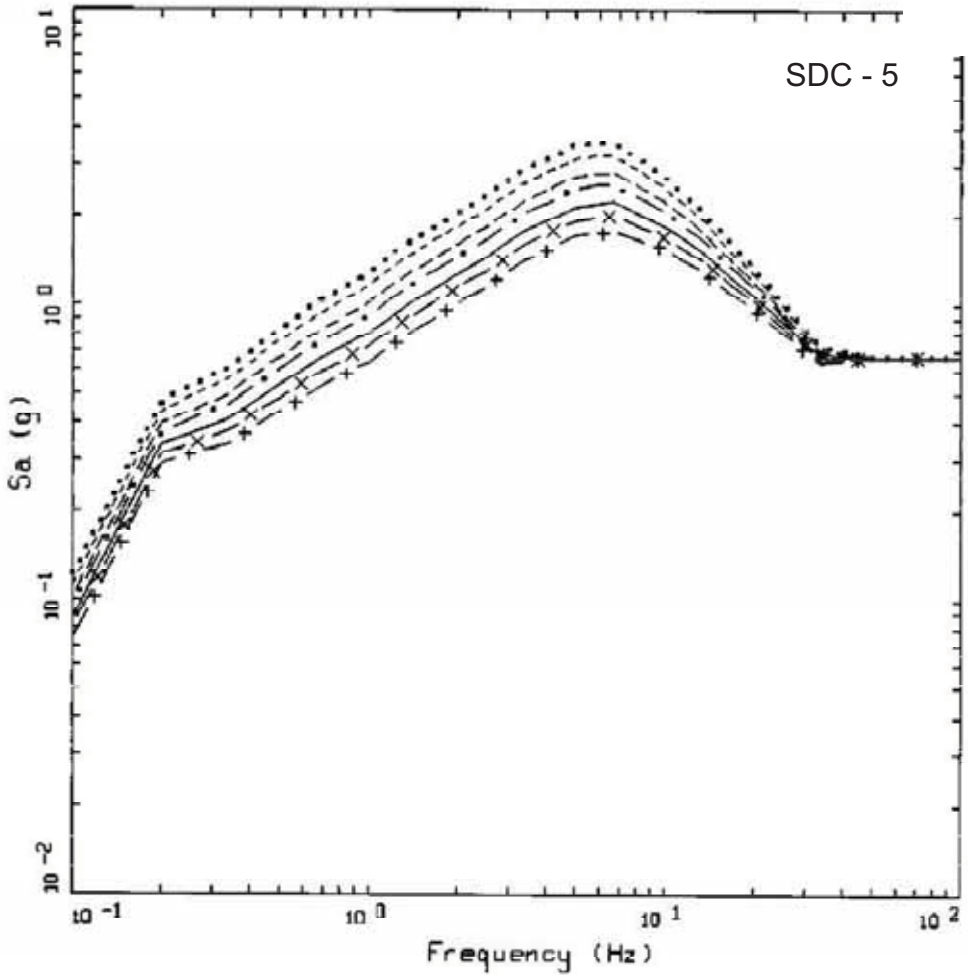


DACITE DRS SPECTRA, HORIZONTAL (NO TOPO)
SDC 4 (4X10-4), (M6.75)

LEGEND

....	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— • —	3.0 % DAMPING
———	5.0 % DAMPING
—×—	7.0 % DAMPING
—+—	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	HORIZONTAL DRS FOR SDC - 3, 4, AND 5 AT MULTIPLE DAMPINGS - DACITE WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 94b

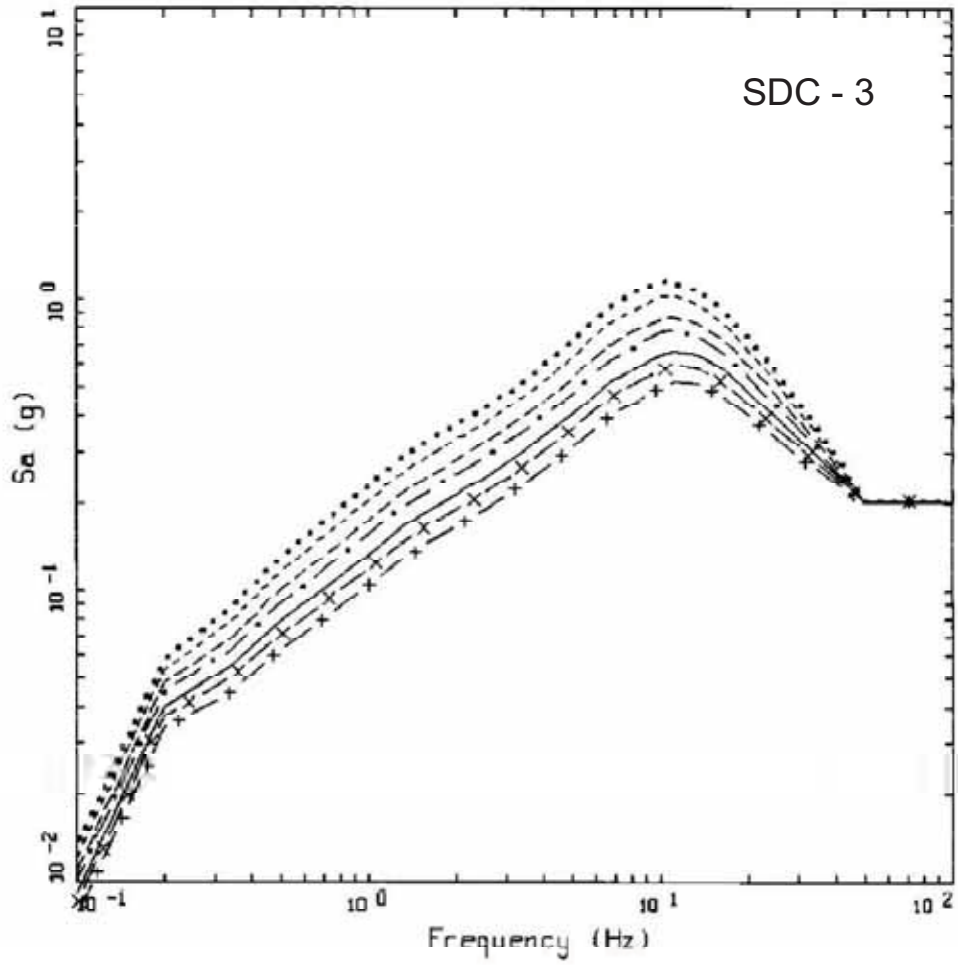


DACITE DRS SPECTRA, HORIZONTAL (NO TOPO)
SDC 5 (1X1D-4), (M6.75)

LEGEND

....	0.5% DAMPING
-----	1.0 % DAMPING
— — — —	2.0 % DAMPING
— · —	3.0 % DAMPING
———	5.0 % DAMPING
— × —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	HORIZONTAL DRS FOR SDC - 3, 4, AND 5 AT MULTIPLE DAMPINGS - DACITE WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 94c

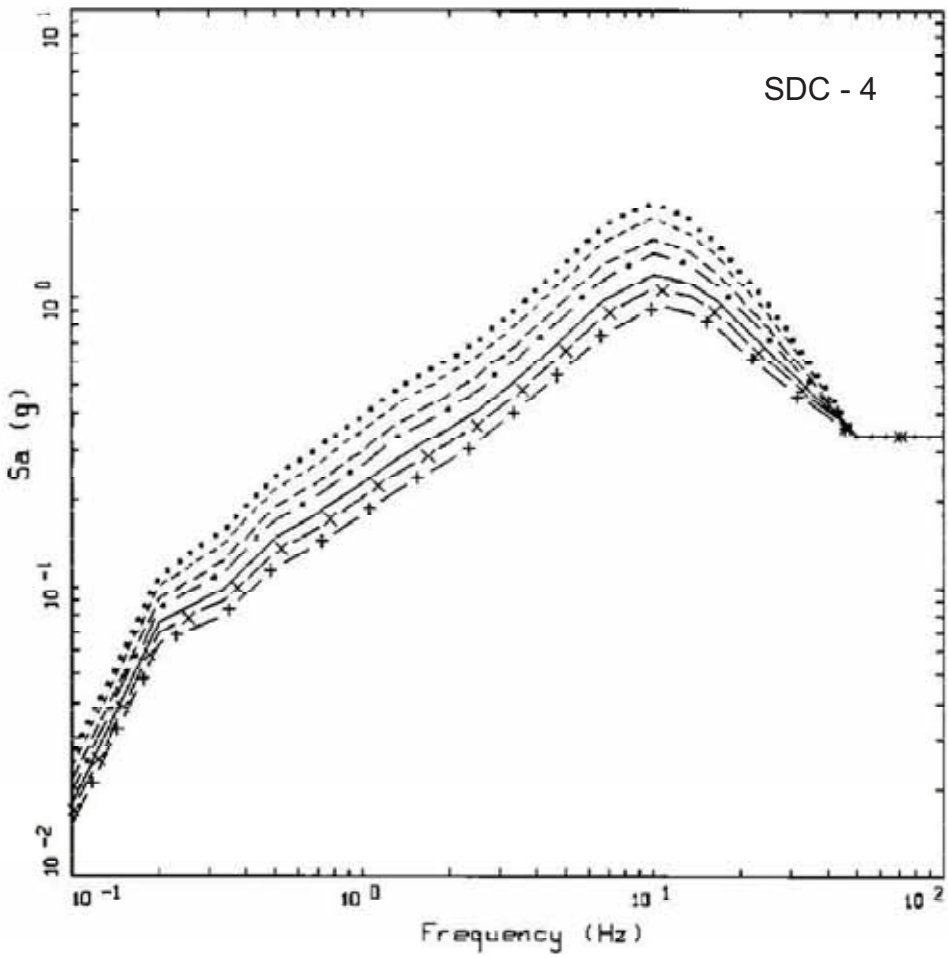


DACITE DRS SPECTRA, VERTICAL (NO TOPO)
SDC 3 (4X10-4), (M6.75)

LEGEND

- 0.5% DAMPING
- 1.0 % DAMPING
- 2.0 % DAMPING
- 3.0 % DAMPING
- 5.0 % DAMPING
- 7.0 % DAMPING
- 10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC - 3, 4, AND 5 AT MULTIPLE DAMPINGS - DACITE WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 95a

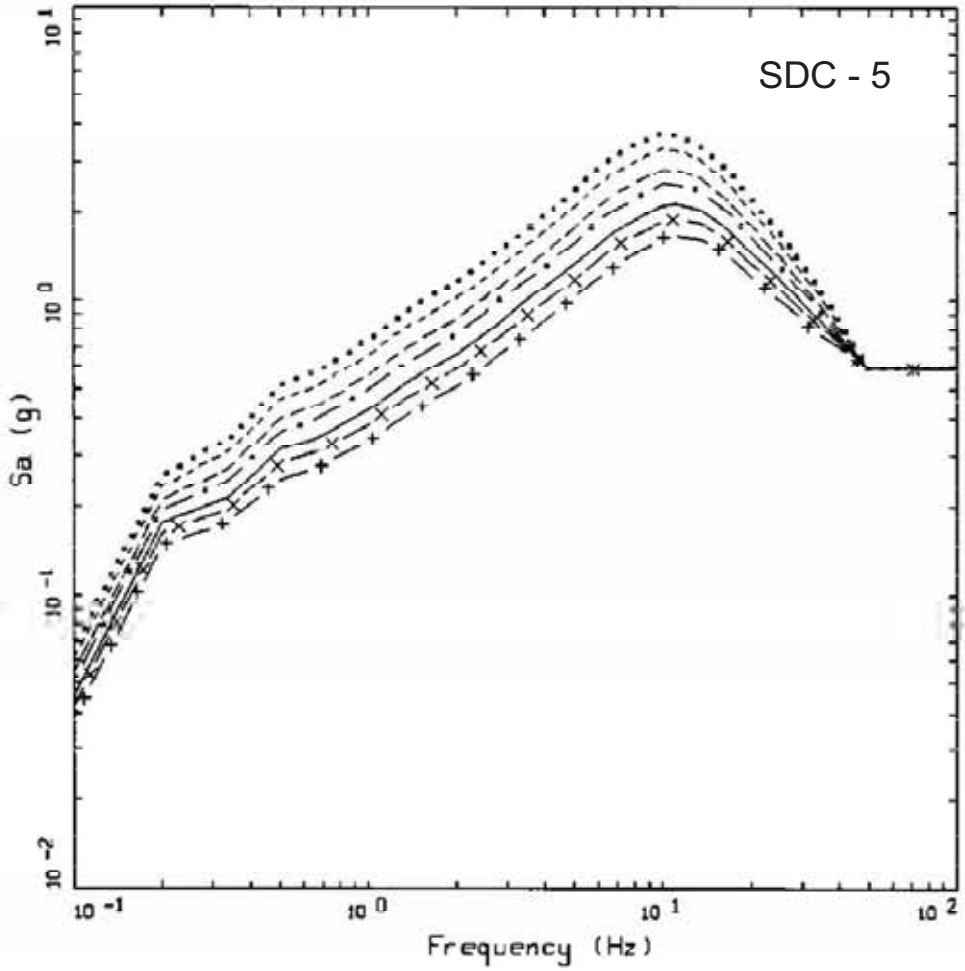


DACITE DRS SPECTRA, VERTICAL (NO TOPO)
SDC 4 (4X10-4), (M6.75)

LEGEND

- 0.5% DAMPING
- 1.0 % DAMPING
- 2.0 % DAMPING
- 3.0 % DAMPING
- 5.0 % DAMPING
- 7.0 % DAMPING
- 10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC - 3, 4, AND 5 AT MULTIPLE DAMPINGS - DACITE WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 95b



DACITE DRS SPECTRA, VERTICAL (NO TOPO)
SDC 5 (1X1D-4), (M6.75)

LEGEND

• • • •	0.5% DAMPING
- - - - -	1.0 % DAMPING
— — — —	2.0 % DAMPING
— • —	3.0 % DAMPING
———	5.0 % DAMPING
— x —	7.0 % DAMPING
— + —	10.0 % DAMPING

URS	Project No. 26817259 Los Alamos National Lab	VERTICAL DRS FOR SDC - 3, 4, AND 5 AT MULTIPLE DAMPINGS - DACITE WITHOUT TOPOGRAPHIC AMPLIFICATION	Figure 95c